BRIDGE CONDITION INDICATORS

Volume 1

Commission Report

CSS Bridges

ROADS Service
An Agency within the Department for Regional Development

LoBEG

British Waterways

ENG 1/02

BRIDGE CONDITIONS INDICATORS

Volume 1
Commission Report

Published by CSS

July 2002

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WSA CJ0089-Vol. 1/Issue 3

BRIDGE CONDITION INDICATORS
Volume 1

COMMISSION REPORT

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Issue No.: 3
Issue Date: April 2002

ISSUE RECORD

Issue	Date	Page	Para	Comments
1	February 2002			Draft report issued to CSS Steering Group for Comments
2	March 2002			Draft report issued to CSS Steering Group for Comments
3	April 2002			Final Report issued for publication

Note

This document has been specifically produced by WS Atkins Consultants Ltd for the CSS Bridges Group solely for the purposes of deriving Bridge Condition Indicators from inspection data and is only suitable for use in connection therewith.

EXECUTIVE SUMMARY

This document has been prepared by WS Atkins Consultants Limited on behalf of the CSS Bridges Group as part of the commission for developing bridge condition indicators. The bridge condition indicators serve as part of a suite of Performance Indicators under the Governments Best Value initiative.

CSS reviews have identified significant under funding for bridge maintenance in recent years, resulting in an increasing backlog of bridge maintenance work. The CSS concluded that in order to maintain and manage a stock of bridges it is essential to have a Condition Indicator which can be used to determine whether the overall stock condition is deteriorating. This commission was set up to develop bridge Condition Indicators for this purpose.

The main objective of the commission is to develop robust procedures for the consistent measurement and monitoring of the condition of a bridge/bridge stock to demonstrate the need for, and effectiveness of, bridge maintenance expenditure.

A survey of current bridge inspection reporting systems used in the UK was performed. The survey identified a wide diversity of condition marking schemes and terminology that exist. To provide reliable and comparable bridge Condition Indicators it was therefore essential to establish a consistent inspection reporting system.

A new inspection reporting system has been developed for adoption by Local Authorities. However, it was also recognised that (1) many Authorities would not be able to immediately implement the new system, and (2) there is benefit to be gained from analysing historical bridge condition data. A harmonisation table is proposed that translates current/historical condition scores to the new system.

Bridge Condition Indicator algorithms have been developed which evaluate a Bridge Condition Index (BCI) for an individual bridge or a stock of bridges using the element condition data collected during inspections. The algorithms have been extensively trialled with real and synthetic data and found to be robust while being sensitive to appropriate factors.

The commission has culminated in the production of two Guidance Notes:

1. Guidance Note on Bridge Inspection Reporting
2. Guidance Note on the Evaluation of Bridge Condition Indicators.

The above Guidance Notes constitute Volumes 2 and 3 respectively of the Bridge Condition Indicators Commission Report. Each Guidance Note describes, and provides assistance on, how to implement and interpret the new procedures.

This document presents the background work (reasoning, decisions made, calculations etc.) to the Guidance Notes, while the guidance on the use of the procedures is detailed in the Guidance Notes.

ACKNOWLEDGEMENTS

WS Atkins would like to acknowledge the financial support from the CSS Bridges Group for this research and development project. In particular, the immense support and guidance provided by the members of the CSS Steering Group throughout the project is acknowledged. The Steering Group comprised:

Dr Roger Cole – Lancashire County Council
Mr Steve Pearson – Derbyshire County Council
Mr Greg Perks – Northumberland County Council
Mr John Powell – British Waterways Board
Mr Steve Tart – Manchester City Council
Mr Mark Wyatt – Cheshire County Council
Mr David Yeoell – London Bridges Engineering Group

The Author would also like to acknowledge the contribution of Mr Mike Chubb, Dr Navil Shetty and Mr Steve Harris of WS Atkins Consultants Limited to this report.

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GLOSSARY

Authorities – includes Local Authority bridge owners in England, Scotland and Wales as well as the Northern Ireland Office and British Waterways, and other bridge owners/managers that may wish to adopt the procedures described in this report.

Bridge – all Local Authority owned bridges on the adopted road network. A bridge is defined in a previous CSS Report (Ref. 1) as a structure with a span of 1.5m or more and includes subways, culverts, footbridges, tunnels and underpasses.

Bridge Condition Index (BCI) – the numerical value of a bridge condition evaluated using the BCS on a scale of 100 (best condition) to 0 (worst condition).

Bridge Condition Score (BCS) - the numerical value of a bridge condition on a scale of 1 (best condition) to 5 (worst condition).

Bridge Stock Condition Index (BSCI) – the numerical value of a bridge stock condition evaluated as an average of the BCI values weighted by the deck area (m^2) of each bridge.

Deck Area – (overall width) × (distance from centreline to centreline of end supports) or (distance between face of end supports + 0.6m)

BCS_{Av} and BCI_{Av} – the average BCS or BCI for a bridge evaluated taking into account the condition of all structural elements in a bridge.

BCS_{Crit} and BCI_{Crit} – the critical BCS or BCI for a bridge evaluated taking into account the condition of those elements deemed to be of very high importance to the bridge.

$BSCI_{Av}$ – the average condition index for a bridge stock evaluated using the BCI_{Av} values.

$BSCI_{Crit}$ – the critical condition index for a bridge stock evaluated using the BCI_{Crit} values.

Element Condition Index (ECI) – the weighted element condition taking into account of ECS and ECF.

Element Condition Score (ECS) – the numerical value of the condition of an element evaluated using inspection data on a scale of 1 (best condition) to 5 (worst condition).

Element Importance – this takes account of importance of an element to the overall bridge in terms of load carrying capacity, durability and public safety and is designated as Low, Medium, High or Very High. The Element Importance classification is used to identify two factors, namely:

> **Element Condition Factor (ECF)** – used to weight the ECS to obtain the ECI, this enables direct comparison of element conditions in terms of the overall bridge condition.
>
> **Element Importance Factor (EIF)** – used to weight individual ECI scores when evaluating the BCS_{Av}.

Severity and Extent – procedure used in some inspection reporting systems to assess and report the condition of bridge elements. The severity/extent inspection reporting system developed in tandem with these Condition Indicators is presented in Vol. 2.

General Inspection – visual inspection, possibly with some hands-on and basic assessment e.g. hammer tapping and measurements.

Principal Inspection – visual inspection with hands-on assessment of most/all elements plus detailed assessment e.g. hammer tapping, half-cell, chloride measurements etc. Detailed data can then be used to assist the inspector in assigning element condition scores.

Retaining Wall – all walls irrespective of height whose dominant function is to act as a retaining structure (Ref. 1).

1. INTRODUCTION

1.1 GENERAL

This document has been prepared by WS Atkins Consultants Limited on behalf of the CSS Bridges Group as part of the commission for developing bridge condition indicators.

The report is organised into the following sections:

Section 1 discusses the background and objectives of study.

Section 2 presents details of the survey of existing inspection reporting systems and identifies differences and common features between systems.

Section 3 provides background to the development of the Guidance Note on Bridge Inspection Reporting.

Section 4 discusses in detail the selection and development of the Bridge Condition Index (BCI) and Bridge Stock Condition Index (BSCI) algorithms, presenting the strengths and weaknesses of different approaches and how these were overcome.

Section 5 presents the sensitivity trials and illustrates the robustness and sensitivity of the developed algorithms.

Section 6 discusses the interpretation and use of the BCI/BSCI values.

1.2 BACKGROUND

Reviews carried out by the CSS Bridges Group on levels of funding provided for bridge maintenance (Ref. 1 and 2) highlighted significant under-funding in recent years, resulting in an increasing backlog of bridge maintenance work. A study of bridges in Lancashire indicates that the average condition of bridges has deteriorated over the period from 1991-2000. The situation appears to be worse for retaining walls which have received a much smaller proportion of maintenance funding, in relation to average replacement cost, than bridges (Ref. 1).

The CSS Review concluded that in order to maintain and manage a stock of bridges and retaining walls, it is essential to have a "Condition Indicator" which can be used to determine whether the overall condition of highway structures is deteriorating or not, and use this as a means for monitoring whether adequate funding is being provided for structures maintenance work.

1.3 THE NEED FOR PERFORMANCE INDICATORS

Performance measurement is an integral and important component of a good asset management system. Performance measurement plays a major role in influencing human behaviour, as 'what gets measured, gets done', and therefore is seen as a key to achieving significant improvements in performance. Performance measurement is a mechanism by which audit, review and improvement are achieved. These are important elements of asset management and also of the Government's "Best Value" initiative which seeks to achieve continuous improvement in performance through measurement, target setting and benchmarking. By comparing indicator values against identified targets and goals, strengths and weaknesses in performance can be identified. By monitoring the indicator values over time early warnings, if any, of progressive degradation in performance can be identified so that corrective action can be taken at an early stage. Thus performance indicators provide important inputs for the decision-making processes relating to management of existing assets.

Experience of using performance measurement in different sectors has shown that, to be successful, the performance indicators should be clearly linked to the strategic objectives of an organisation. This ensures that the effort is focussed on what really matters and allows the organisation to demonstrate how well it is meeting its objectives. At the same time it is important to ensure that the chosen performance indicators form a "balanced set" covering all the different dimensions of an organisation's function. Otherwise, all the effort will be focussed on those aspects that are being measured and there is a danger that the remaining functions will be overlooked. In this context, the National Audit Commission's Best Value Performance Indicator framework recommends measuring five dimensions of performance as summarised below.

Dimension	Description
Strategic Objectives	Why the service exists and what it seeks to achieve?
Cost/Efficiency	The resources committed to the service and the efficiency with which they are turned into outputs.
Service Delivery Outcomes	How well the service is being operated in order to achieve the strategic objectives?
Quality	The quality of the service delivered, explicitly reflecting users' experience of service.
Fair Access	Ease and equality of access to services.

Performance indicators can also be distinguished into 'Strategic' and 'Operational' indicators depending on their use as below:

Strategic	These would be used by a Local Authority for external reporting to the DTLR and the public and for this reason need to be simple and few in number. These should relate to the strategic objectives of bridge maintenance, for example *Safety, Availability, Asset Preservation, Sustainability, etc.*
Operational	These indicators are required for the day-to-day operational management of structures, for example deciding on the need and timing of interventions and for business planning purposes, for example allocation of funding to different functions or bridge types. These indicators should aim to measure the *efficiency* and *effectiveness* of bridge maintenance.

1.4 DUTIES, DELIVERABLES AND CONSIDERATIONS OF COMMISSION

1.4.1 Duties and Deliverables

The duties under the commission were:

i. Review types of bridges to be covered by the Indicator.

ii. Survey inspection reporting systems used by bridge owners.

iii. Develop a Bridge Condition Indicator (BCI) based on minimum alteration to current inspection reporting procedures, taking into account existing national and international developments in this field.

iv. Carry out sensitivity studies based on field tests by selected highway authorities.

v. Refine Indicator in light of trials.

vi. Prepare Guidance Note for consistent levels of inspection reporting.

vii. Prepare Guidance Note on the derivation of Bridge Condition Indicator.

viii. Prepare final report on commission.

1.4.2 Considerations

Particular considerations to be reported on were:

i. Severity, extent of faults and importance of element.

ii. Scoring range to be sufficiently sensitive to detect change whilst still being broad enough to be easily defined at inspection stage.

iii. Should be based on visual condition assessments but capable of accommodating any test results that may be available.

iv. Should take account of size of bridge.

v. Should be applicable to a single bridge or to a group of bridges.

1.5 OBJECTIVES

The objectives of the procedures developed under this commission are:

1. To produce a tool that is easy to use and provides beneficial and meaningful information to bridge owners.
2. To measure and monitor the condition of an individual bridge or stock of bridges to demonstrate the need for and effectiveness of bridge maintenance expenditure.
3. To be used as one of the Best Value Performance Indicators being considered by DTLR.
4. To develop procedures for consistent and harmonised inspection reporting.
5. To provide assistance to bridge inspectors on the implementation of the new inspection reporting system.
6. To provide base data for the evaluation of Bridge and Bridge Stock Condition Indicators.
7. To provide algorithms for the evaluation of Condition Indicators.
8. To provide guidance on the interpretation and application of condition indicators.

The two Guidance Notes developed under this commission, Bridge Inspection Reporting and Evaluation of Bridge Condition Indicators, are presented in Volumes 2 and 3 respectively (Ref. 3 and 4). The Guidance Notes are stand alone documents that only deal with the application of the developed procedures, while the background to the work performed to develop the procedures is described in the current Volume 1.

In the context of performance measurement discussed in section 1.3, Bridge Condition Indicators developed in this project should be seen as one of a suite of performance indicators that may be required for performance measurement. The condition indicators can be seen as Strategic performance indicators to demonstrate how a Local Authority is achieving the objective of *Asset Preservation*. They also serve to demonstrate the *effectiveness* of bridge maintenance work carried out in previous years. Other indicators which make use of 'asset value', 'safety', 'availability' and cost of maintenance can complement these indicators in demonstrating *efficiency* of maintenance and for demonstrating the effect of under-funding in maintenance on the asset value and functionality of the structure stock.

Furthermore, it should be noted that performance measurement and hence the Bridge Condition Indicators are complementary tools to other essential bridge management functions such as inspection, assessment, maintenance planning, management of abnormal loads, etc.

1.6 SCOPE

1. The procedures developed should be applicable to the majority of bridge and bridge element types found in the UK.
2. The algorithms utilise information collected from General Inspections or a combination of General and Principal Inspections.
3. Bridge Condition Indicator algorithms can also utilise data from historical bridge inspections.

2. REVIEW OF BRIDGE TYPES & INSPECTION PROCEDURES

All Authorities within the UK regularly report on the condition of their bridges using General Inspections or a combination of General and Principal Inspections. Inspections are largely carried out using visual methods and the condition of various bridge elements is described using predefined *condition descriptors*. The inspection results are summarised on an *Inspection Pro Forma*.

The inspection reporting systems used by different Authorities vary significantly, particularly in terms of the condition descriptors used and the bridge elements reported upon. Therefore a review of a wide range of reporting systems was essential.

Within and between Authorities there is a large diversity of bridge types. The Bridge Condition Index (BCI) and the new inspection reporting system must be capable of dealing with as wide a variety of bridge/element types as possible. Thus a review of bridge types commonly found in the UK was also carried out.

2.1 DATA COLLECTION

Preliminary investigations identified a wide variety of inspection reporting procedures that are currently used by different Authorities. It was decided that a large data sample was required in order to obtain a representative picture of the reporting systems used in the UK.

A request was circulated by the CSS Bridge Maintenance Working Group to Bridge Managers/Authorities to provide details of bridge types, inspection reporting format and medium of data storage i.e. paper or electronic.

A total of 76 Authorities supplied details of their inspection reporting procedures and data storage format. A number of these Authorities also supplied typical examples of completed bridge inspection forms.

The Ordnance Survey map in APPENDIX A illustrates the distribution of Authorities that contributed data for the review.

2.2 REVIEW OF INSPECTION REPORTING SYSTEMS

The spreadsheet in APPENDIX A indicates that in general the elements reported on the inspection forms are reasonably consistent e.g. see element numbers 1 to 40 in APPENDIX A. In the main they tend to follow the list from the Highways Agency BE11 Form amended in some cases by the TRL Bridge Management System. The aforementioned bridge inspection reports historically lacked elements relating to masonry arch structures. Bridge managers have therefore added additional elements to cover arches.

Condition reporting was found to fall into three main systems.

i. Good, Fair, Poor.

ii. Extent (A to D) and Severity (1 to 4)

iii. Condition Factor (with varying scales e.g. 1 to 5, 0.1 to 1.0, etc.)

A number of Authorities have modified these basic criteria, sometimes combining condition factors with either i) or ii). However, in general, the above three systems cover the majority of inspection reports reviewed.

From the data available it was apparent that a number of Authorities have adopted a condition factor which also incorporates element importance. This system is common among the Scottish Authorities and is also used by Northamptonshire. The system has evolved from an original IHT paper prepared by Peter Andrews, formerly Bridge Engineer at Northamptonshire [Ref. 5]. This is similar to the British Railway Bridge Marking System [Ref. 6].

2.3 SELECTION OF REPRESENTATIVE DATA SETS

In order to test the flexibility and consistency of the BCI it was considered essential that each of the three main types of inspection reporting be represented. Three Authorities were selected for trialling the BCI:

1. Plymouth City – Good/Fair/Poor system
2. Manchester City – Extent/Severity system
3. Lancashire County – Condition/Location factor system.

The above cover a range of bridges stocks:

- Large and small quantities (ranging from 150 to over 1400)
- Urban and rural environments; and
- Northern and Southern counties.

It was felt that these three bridge stocks would provide a balanced view of UK Authorities. Two of these Authorities (Lancashire and Manchester) provided data in computerised format which greatly simplified usage and manipulation. Additional data for sensitivity analysis was made available by Hertfordshire and Cambridgeshire.

2.4 REVIEW OF BRIDGE TYPES

Data returned regarding bridge types were limited. However, it was recognised that highway structures have often had a varied history and that any particular bridge may have been modified, strengthened or extended resulting in a variety of construction types in one bridge.

A review was carried out with the aim of identifying the range of bridge forms that exist. The review material included:

- Corporate knowledge and experience
- Bridge data from Lancashire, Manchester, Plymouth, Hertfordshire and Cambridgeshire
- 1997 to 1999 bridge census
- Local Authority bridge inspection reports
- Highways Agency Bridge Inspection Manual
- Railtrack SCMI (Structures Condition Marking Index) Handbook; and
- LoBEG Bridge Prioritisation System.

An extensive list of bridge types was compiled. It was established that the majority of bridge types could be uniquely described in terms of the structural form of primary and secondary deck elements and their material. A procedure for uniquely defining bridge type based on these criteria is proposed in Section 3.1.1 and the Inspection Reporting Guidance Note (Ref. 3).

2.5 SURVEY CONCLUSIONS

The survey illustrated the diversity of inspection reporting systems that exist among Authorities in the UK and hence the need for:

i. a consistent inspection reporting system; and

ii. a methodology for converting historical/current bridge inspection data to the new inspection reporting system.

3. DEVELOPMENT OF A HARMONISED INSPECTION REPORTING SYSTEM

Detailed guidance on the implementation of the new bridge inspection reporting system is provided in Volume 2 (Ref. 3) and hence is not repeated here. Instead this section provides the background information (qualitative and quantitative) on the development of the new system.

3.1 NEW INSPECTION PRO FORMA

The review of inspection reporting systems (Section 2) highlighted a wide variety of inspection terminology used between Authorities, but the pro forma layout was found to be similar. It was therefore decided, at an early stage of the commission, that a simple and effective way of creating a consistent inspection reporting system would be to tie it in with a new inspection reporting pro forma. This allows the new inspection pro forma to act as the starting point for the introduction of the new system to bridge managers and inspectors.

The new pro forma developed in this commission collects two types of information:

1. Information <u>essential</u> to the evaluation of Bridge Condition Indicators i.e. Bridge Type Code, element type, defect severity and extent; and

2. Information that is necessary for bridge management but not required for the evaluation of Bridge Condition Indicators e.g. bridge name, O.S ref, work requirements etc.

It is not intended that Authorities should adhere to the exact layout and contents of the proposed pro forma. Authorities can alter the inspection pro forma to suit their specific needs provided they still collect information essential to the Bridge Condition Indicators as specified above. The following sections describe in more detail the fields essential to effective use and evaluation of Bridge Condition Indciators.

3.1.1 Essential fields for the BCI

<u>Element Descriptions</u>

The element list provided on the pro forma identifies the bridge elements for which condition data must be collected, if the element is on the bridge. The condition data is the raw data used to evaluate the BCIs and therefore must remain consistent between Authorities. Authorities can extend the list to incorporate other elements they wish to report on, but the condition data from these elements will not be used in the BCI algorithms.

The survey identified more than 100 terms (see APPENDIX A) used to describe bridge elements. Investigation of the terms showed that frequently two or more terms were being used to describe the same bridge element, and almost all inspection forms attempted to describe different types of primary, secondary and tertiary deck elements.

In order to avoid duplication of terms a table of equivalent elements was created. The table, shown in Appendix B of Volume 2 (Ref. 3), relates the pro forma list of element descriptions to the terms currently used by different Authorities.

Bridge Type Code

The survey of inspection reporting systems found that more than 25 element descriptions are used for bridge deck elements. Primary and secondary deck elements were found to constitute 19 and 7 common deck element descriptions respectively. The primary/secondary deck element groups could be further subdivided by material type. It was therefore decided to develop a Bridge Type Code (BTC) that would not only conserve space on the pro forma but would also provide a code that could be used to filter different bridge sub-groups in a BCI database. This will provide information to bridge managers when deciding where maintenance work is most necessary, or where historically there has not been adequate maintenance work.

Severity and Extent Columns

The Severity and Extent codes (discussed in Section 3.2.1) are essential to the evaluation of the BCI/BSCI. Only the condition scores (combined Severity/Extent) for elements 1 to 34 are used to evaluate the BCI. It was decided that numbers 35 to 38 were not sufficiently important to the load carrying capacity, durability and public safety of the bridge to merit inclusion in the BCI score. Any additional elements added to the pro forma and reported on must not be used in the BCI evaluation. (The exception being bridges with more than one primary and/or secondary deck element type in one span that is not due to modification/widening. Guidance is provided on how to deal with this in Ref. 3 and 4).

Construction Types

Many bridges consist of more than one construction type, most commonly due to past road widening schemes. Different construction types/material in one bridge/span are most likely to be in different conditions, as such reporting the condition of elements in different construction types together will not be accurate. It was therefore decided that, when more than one construction type is present, the Guidance Note (Ref. 3) should recommend the use of one pro forma for each structural type.

It is recommended that the BCI is evaluated initially for each completed pro forma, even if this only constitutes a small number of elements evident from a bridge modification. A pro forma reporting a modification should include all elements relevant to it that have not already been reported on in the main bridge pro forma. For example, if the modified section uses the same abutments/foundations as the original pro forma then these will be covered by the main bridge pro forma, however, if new abutments/foundations were constructed for the modification then the inspector should report their condition on the appropriate pro forma. Evaluation of the BSCI should use the deck area relevant to the section (span and/or modification) reported on. If necessary, the BCI evaluated from different pro forma for one bridge can be combined together to produce an overall BCI for the bridge as explained in Ref. 4.

All above ground elements

This information is useful for establishing the number of bridges that were not fully inspected. It may prove beneficial to establish this simple statistic as a local Performance Indicator (PI).

3.2 Element Condition Reporting

The review of Local Authority, Highways Agency and Railtrack inspection reporting pro forma illustrated that three main types of system are in use: Good/Fair/Poor, Condition Factor and Severity/Extent (see Section 2.2). The general trend being for the recent systems to adopt the Severity/Extent approach.

The inspection system must be sensitive enough to pick up changes in condition but also avoid becoming overly sensitive and thus difficult for inspectors to implement effectively during a visual survey. An effective, and widely used, procedure that is sensitive to condition change is assessing the severity and extent of the defect. This is clearly the basis of the Severity/Extent approach, but it is also apparent within many of the condition descriptions used by some Local Authorities e.g. Hertfordshire, Lancashire. The Highways Agency and Railtrack also use a Severity/Extent approach.

It was decided to adopt a Severity/Extent approach for the new system. This in some cases can cause confusion for inspectors using a different system at present, especially the mixing of extent with severity, particularly in the case of masonry/brick arch structures. This placed substantial emphasis on the clear definition of Severity/Extent codes and the provision of guidance (via written and photographic examples) wherever possible.

3.2.1 Severity and Extent

Sensitivity

The sensitivity of the Severity/Extent scale was determined by considering the level of detail on which an inspector can realistically report during a General Inspection. It was recognised that inspection resources are stretched in many Authorities and therefore it is simply unrealistic to suggest Extent categories that change by a few % of length/area/number, or severity categories for example that change in corrosion depth by a few mm. The categories do need to be sensitive to change in condition but they still need to retain the simplicity for practical implementation.

Existing condition scales were found to normally have between 3 and 7 categories, with 5 being the most common. The five category scale has remarkably similar severity descriptions between different Authorities even though the codes/score for each category are different e.g. Clackmannanshire, Lancashire, Hertfordshire, Moray etc. Also, the Highways Agency BE11 severity scale is very similar to the 5 category scale, it is only missing the most severe category (5) which refers to failed/lost functionality. It appears logical to maintain such a widely recognised scale.

For consistency the extent is also described on a five category scale. This was based on Local Authority, HA and Railtrack condition and extent descriptions.

Codes

Table 1 and 2 present the agreed severity and extent categories. The categories are relatively self explanatory but there are some combinations that are not permissible, these are shown in Table 3.

Table 1 Severity Codes

Code	Description
1	As new condition or defect has no significant effect on the element (visually or functionally).
2	Early signs of deterioration, minor defect/damage, no reduction in functionality of element.
3	Moderate defect/damage, some loss of functionality could be expected
4	Severe defect/damage, significant loss of functionality and/or is close to failure/collapse
5	The element is non-functional/failed

Table 2 Extent Codes

Code	Description
A	No significant defect
B	Slight, not more than 5% of surface area/length/number
C	Moderate, 5% - 20% of surface area/length/number
D	Wide: 20% - 50% of surface area/length/number
E	Extensive, more than 50% of surface area/length/number

The approach attempts to make a clear distinction between severity and extent. Extent is a measure of the severity observed, hence extent does not enable a severity to increase to the next level.

Table 3 Permissible Combinations

Extent	**Severity**				
	1	**2**	**3**	**4**	**5**
A	1A				
B	1B	2B	3B	4B	5B
C	1C	2C	3C	4C	5C
D	1D	2D	3D	4D	5D
E	1E	2E	3E	4E	5E

The combinations blanked out in Table 3 are not permissible, namely 2A, 3A, 4A and 5A. These combinations are not permitted because it is not feasible to have a Severity condition greater than 1 with an Extent description of "no significant defect".

Queries were raised about the use of extent codes with a severity rating of 5, meaning that only a score of 5E is necessary because failure affects the whole element. However, it must be remembered that the element descriptions frequently cover elements that do not fail as a whole e.g. footway surfacing and a series of transverse beams. Thus if one of six transverse beams fails a rating of 5C is given, this can be beneficial when determining work requirements. However the BCI evaluation treats 5B, 5C, 5D and 5E all equally, see section 4.3.

Detailed Severity Descriptions

Example severity descriptions are provided in Ref. 3. The descriptions are not comprehensive but are intended to act as guidance for bridge inspectors. Over time additional descriptions can be added to this table to produce a more comprehensive guidance. The descriptions in the table were obtained from the review of current inspection procedures, bridge inspector opinion and consensus opinion of the CSS Steering Group and WS Atkins Consultants Ltd.

It is recognised that the table may prove confusing and difficult to use at first, but the introduction of any new system requires a "bedding in" period. It is felt that the provision of this table will greatly help the creation of consistent inspection reporting between Authorities.

3.2.2 Multiple Defects

The inspection pro forma allows one condition entry per element description. This is ideal for reporting the condition of the element when it only suffers from one defect type, which is frequently the case. When this is not the case, and an element is affected by two or more defect types, it is more difficult to report the condition using one score.

When an element is affected by multiple defect/damage types the following two points were considered:

i. Are the defects all at the same level of severity?; and

ii. Do the defects interact to increase the severity?

Based on these two considerations the descriptions for "Dominant" and "Interacting Defects" were established (see Ref. 3). Clearly the determination of the condition score in the case of Interacting Defects is very subjective; some guidance on the interpretation of interacting defects is provided in Ref. 3. This issue also needs to be addressed by bridge inspector training.

3.3 DEFECT CODE

The detailed severity table in Ref. 3 provides an opportunity to reference defect types. A column was therefore added to the inspection pro forma for recording a defect type. Knowledge of the defect type can prove very beneficial to the bridge engineer when assessing the priority, type and cost of maintenance work required.

The reporting of defect codes can also be used to establish local and national databases. Linking defect type with the maintenance type and cost, and eventually the actual service life of any maintenance, will enable trends and best practice to be identified. This data is essential if accurate and robust Life Cycle Costing models are to be created for all bridge and defect types in the future, thus providing improved justification for using preventative maintenance activities that have high initial costs but are able to provide long term cost savings when compared with maintenance options that have low initial costs.

3.4 FIELD TRIALS

Three Local Authorities (Cheshire, Lancashire and Manchester) trialled the new inspection reporting procedures. A summary of the comments received from the trials are shown in APPENDIX B. Many comments were concerned with how to report different deck element types.

The trial highlighted the need to report on an additional secondary deck element for one bridge/span (Manchester had bridges with jack arches and flat metal plates on the same span) and more explanation on Dominant and Interacting Defects. Additional guidance was subsequently added to Ref. 3 for both of the highlighted problems.

Comparison with the current inspection procedures indicated that the new pro forma covered the necessary element types in all areas except for masonry/brick arch bridges. The new system includes arch barrel and face in the primary element description and arch springing in the abutments description. It was felt this would make the inspection reporting of arch bridges more consistent with other bridge types.

3.5 CONCLUSIONS

A new inspection reporting procedure has been developed to ensure consistency in condition reporting between Authorities and to provide consistent base data for the evaluation of bridge Condition Indicators. Realistic severity and extent categories are proposed that are sufficiently sensitive to pick up changes that can be identified by visual surveys.

4. DEVELOPMENT OF CONDITION INDICATOR ALGORITHMS

4.1 TRADITIONAL/EXISTING INDICATORS

The UK is currently leading the field in the development of Condition Indicators for bridges. Including the indicators presented herein, there are also condition indicators under development by the Highways Agency and Railtrack. In addition, a number of Local Authorities in the UK have already developed and implemented procedures for evaluating inspection scores and prioritising repair e.g. Clackmannanshire, Hertfordshire, Kent, Moray, Northamptonshire, Lancashire and LoBEG.

4.2 OVERVIEW OF THE PROCEDURE

The overall procedure for producing the Condition Indicators is shown in Figure 1 of Ref. 4 and summarised below.

i. Each element within a bridge is selected in turn and its condition data is used to produce an Element Condition Score (ECS) for the element.

ii. Next, the Element Importance is identified, this accounts for the importance of the element to the overall condition and functionality of the bridge. Then the Element Condition Factor (ECF) is evaluated by taking into consideration the Element Importance and the ECS.

iii. The ECS and ECF values are combined to produce the Element Condition Index (ECI) which represents the condition of the element on a scale of 1 (Best) to 5 (Worst). Steps (i) to (iii) are repeated for all elements in a bridge.

iv. Next, two different Bridge Condition Scores are evaluated: BCS_{Av} is an average of ECI values of all the elements in a bridge (weighted by the Element Importance Factor, EIF), and BCS_{Crit} is the maximum of ECI values of those elements which are considered "critical" to the integrity of the bridge. BCS values therefore have the same 1 to 5 scale as ECI.

v. The BCS values are then converted to the corresponding Bridge Condition Indices BCI_{Av} and BCI_{Crit} on a scale of 100 (Best) and 0 (Worst) condition. Steps (i) to (v) are repeated for all bridges in the stock.

vi. Finally, the BCI values for all bridges in the stock are weighted by their respective deck areas and the average values for the stock are evaluated. Thus the Bridge Stock Condition Index $BSCI_{Av}$ is a weighted average of BCI_{Av} values, while the $BSCI_{Crit}$ is a weighted average of BCI_{Crit} values for all bridges in the stock. BSCI values have the same 100 (Best) to 0 (Worst) scale as BCI.

4.3 ELEMENT CONDITION SCORE (ECS)

The first step in deriving bridge condition indicators is to determine the Element Condition Score (ECS) for each bridge element based on the condition information obtained from inspections.

The indicator algorithms presented herein are primarily intended for use with the inspection results reported using the new inspection reporting system (Ref. 3). Guidance is also provided in Ref. 3 for translating element condition data collected using other inspection reporting systems to a consistent harmonised condition scale.

The new inspection reporting system (Ref. 3) uses a Severity scale of 1 (Best) to 5 (Worst) and an Extent scale of A (non significant) to E (>50% area/length/number affected). The severity and extent values for an element are combined to produce Element Condition Scores (ECS) as specified in Table 4. The scoring reflects the view that the extent of damage is less critical than the severity of damage. The detailed severity descriptions provided in Ref. 3 reflect this.

Table 4 Element Condition Score (ECS)

Extent	Severity				
	1	**2**	**3**	**4**	**5**
A	1.0				
B	1.0	2.0	3.0	4.0	5.0
C	1.1	2.1	3.1	4.1	
D	1.3	2.3	3.3	4.3	
E	1.7	2.7	3.7	4.7	

When condition data is obtained from different inspection reporting systems a harmonisation matrix is used to translate the condition data to a common scale as suggested in Table 5.

The translations shown in Table 5 were created by comparing the condition descriptions of the new system with the existing systems. In general it was found that translations become more difficult, and inaccurate, as the coarseness of the existing system increased. As a result there is low confidence in the translation suggested for the coarsest systems e.g. Good/Fair/Poor.

Appropriate guidance is provided in Table 5 but Authorities should seek agreement with the CSS Bridges Group before finalising a translation for their particular inspection system. The translations provided in Table 5 may need to be refined on the basis of further trials by the appropriate Authorities.

Table 5 Harmonisation Matrix for a common condition scale

	Element Condition Score (ECS)																
Condition Reporting System	**1**	**1.1**	**1.3**	**1.7**	**2**	**2.1**	**2.3**	**2.7**	**3**	**3.1**	**3.3**	**3.7**	**4**	**4.1**	**4.3**	**4.7**	**5**
New Inspection System (Ref. 3)	1A, 1B	1C	1D	1E	2B	2C	2D	2E	3B	3C	3D	3E	4B	4C	4D	4E	5
HA BE11 Extent & Severity	1A, 1B	1C	1D	1E	2B	2C	2D		3B	3C	3D		4B	4C	4D		
Lancashire Condition Factor	5					4				3					2		1
PJ Andrews (Ref. 5) Condition Factor						0.9				0.7			0.5		0.3		0.1
Good, Fair, Poor (e.g. Cheshire)	G									F				P			
Condition Factor (e.g. Northumberland)	*					3				2				1			

4.4 ELEMENT IMPORTANCE

Influence on the overall bridge condition and functionality is not the same for all elements. Ideally element function, size, material, redundancy, consequence of failure, maintenance/replacement costs etc. should be included when determining the importance of each element on a particular bridge. Clearly this would be a huge exercise requiring substantial data collection and considerable subjective input.

The BCI, as conceived in this commission, is not intended to be a measurement that includes all the factors mentioned above because of the difficult in obtaining the necessary data. The BCI is intended to provide a robust, consistent and reasonably accurate measure of the individual or stock condition that assists bridge owners/managers to make high level management decisions and also demonstrates the need for and effectiveness of maintenance expenditure.

At present it is therefore not possible to incorporate all of the influencing factors mentioned above, however some account needs to be taken of element importance in order to:

i. provide realistic descriptions of Severity of deterioration/damage to the overall bridge as this is dependent on the condition of the constituent elements, more important elements therefore have a greater influence on condition; and

ii. enable direct comparison between the condition of different element types in terms of their influence on the overall bridge condition.

A questionnaire survey was carried out involving the CSS Bridges Group members and engineers from WS Atkins Consultants Ltd to gain a consensus view on element importance. The document circulated to gather opinions on element importance is shown in APPENDIX C.

The engineers were requested to classify elements as having Low, Medium, High or Very High importance to the bridge in terms of (i) load carrying capacity, (ii) durability, and (iii) public safety. The survey results are summarised in APPENDIX C. They show that for some element types good agreement was achieved while others showed considerable scatter e.g. Primary deck element and expansion joint respectively. It is suggested the spread of data for some element types is due to:

i. **Local factors**: the commonality of bridge type/material changes from the north to the south of the country thus influencing the importance of different element types to different Authorities e.g. expansion joints are very important to a stock primarily comprising reinforced/pre-stressed concrete beam and slab bridges, while it has much less significance to a stock primarily comprising brick/masonry arch bridges.

ii. **Inspecting/Engineering experience**: similar to the first point, in that the inspector/engineer is influenced by the environment they work in. This can be further influenced by specific opinions on safety and durability that they have formed.

iii. **Maintenance Expenditure**: again similar to the first point but looking from a financial perspective. Engineers would like higher importance given to elements common to their bridge stock in order to indicate a greater need for funds, even when they realise other element types, that are not common to their stock, may be equally or more important.

The survey resulted in the element importance classifications shown in Table 6.

The next step in the development of the condition indicator was to determine what factors are assigned to the element importance classifications and how these are used to weight the Element Condition Score (ECS).

4.5 INVESTIGATION OF OPTIONS FOR WEIGHTING THE ECS

All available systems for condition scoring or prioritisation based on inspection data typically use some kind of weighting factors to alter the influence of an element's condition on the work priority/overall condition score. There are two practical ways of altering the condition score:

1. multiplication factor; or
2. additive/subtractive factor.

Table 6 Element importance for different bridge elements

<table>
<tr><th>SET</th><th>ITEM No.</th><th colspan="2">ELEMENT DESCRIPTION</th><th>ELEMENT IMPORTANCE</th></tr>
<tr><td rowspan="7">Deck Elements</td><td>1</td><td colspan="2">Primary deck element</td><td>Very High</td></tr>
<tr><td>2</td><td rowspan="2">Secondary deck element/s</td><td>Transverse Beams</td><td>Very High</td></tr>
<tr><td>3</td><td>Element from Table 2 of Ref. 3</td><td>Very High</td></tr>
<tr><td>4</td><td colspan="2">Half joints</td><td>Very High</td></tr>
<tr><td>5</td><td colspan="2">Tie beam/rod</td><td>Very High</td></tr>
<tr><td>6</td><td colspan="2">Parapet beam or cantilever</td><td>Very High</td></tr>
<tr><td>7</td><td colspan="2">Deck bracing</td><td>High</td></tr>
<tr><td rowspan="7">Load-Bearing Substructure</td><td>8</td><td colspan="2">Foundations</td><td>High</td></tr>
<tr><td>9</td><td colspan="2">Abutments (incl. arch springing)</td><td>High</td></tr>
<tr><td>10</td><td colspan="2">Spandrel wall/head wall</td><td>High</td></tr>
<tr><td>11</td><td colspan="2">Pier/column</td><td>Very High</td></tr>
<tr><td>12</td><td colspan="2">Cross-head/capping beam</td><td>Very High</td></tr>
<tr><td>13</td><td colspan="2">Bearings</td><td>High</td></tr>
<tr><td>14</td><td colspan="2">Bearing plinth/shelf</td><td>Medium</td></tr>
<tr><td rowspan="7">Durability Elements</td><td>15</td><td colspan="2">Superstructure drainage</td><td>Medium</td></tr>
<tr><td>16</td><td colspan="2">Substructure drainage</td><td>Medium</td></tr>
<tr><td>17</td><td colspan="2">Water proofing</td><td>Medium</td></tr>
<tr><td>18</td><td colspan="2">Movement/expansion joints</td><td>High</td></tr>
<tr><td>19</td><td colspan="2">Painting: deck elements</td><td>Medium</td></tr>
<tr><td>20</td><td colspan="2">Painting: substructure elements</td><td>Medium</td></tr>
<tr><td>21</td><td colspan="2">Painting: parapets/safety fences</td><td>Medium</td></tr>
<tr><td rowspan="4">Safety Elements</td><td>22</td><td colspan="2">Access/walkways/gantries</td><td>Medium</td></tr>
<tr><td>23</td><td colspan="2">Handrail/parapets/safety fences</td><td>High</td></tr>
<tr><td>24</td><td colspan="2">Carriageway surfacing</td><td>Medium</td></tr>
<tr><td>25</td><td colspan="2">Footway/verge/footbridge surfacing</td><td>Low</td></tr>
<tr><td rowspan="9">Other Bridge Elements</td><td>26</td><td colspan="2">Invert/river bed</td><td>Medium</td></tr>
<tr><td>27</td><td colspan="2">Aprons</td><td>Medium</td></tr>
<tr><td>28</td><td colspan="2">Fenders/cutwaters/collision protection</td><td>Medium</td></tr>
<tr><td>29</td><td colspan="2">River training works</td><td>Medium</td></tr>
<tr><td>30</td><td colspan="2">Revetment/batter paving</td><td>Low</td></tr>
<tr><td>31</td><td colspan="2">Wing walls</td><td>High</td></tr>
<tr><td>32</td><td colspan="2">Retaining walls</td><td>Medium</td></tr>
<tr><td>33</td><td colspan="2">Embankments</td><td>Low</td></tr>
<tr><td>34</td><td colspan="2">Machinery</td><td>Medium</td></tr>
<tr><td rowspan="4">Ancillary Elements</td><td>35</td><td colspan="2">Approach rails/barriers/walls</td><td rowspan="8">Elements not used in BCI evaluation, thus importance not required</td></tr>
<tr><td>36</td><td colspan="2">Signs</td></tr>
<tr><td>37</td><td colspan="2">Lighting</td></tr>
<tr><td>38</td><td colspan="2">Services</td></tr>
<tr><td rowspan="4">Blank spaces provided on pro forma</td><td>39</td><td colspan="2"></td></tr>
<tr><td>40</td><td colspan="2"></td></tr>
<tr><td>41</td><td colspan="2"></td></tr>
<tr><td>42</td><td colspan="2"></td></tr>
</table>

Multiplication Factor

The most commonly used approach is to use a multiplication factor that increases the influence of bridge elements deemed to have greater importance. In this case the Bridge Condition Score (BCS) could be evaluated as:

$$BCS = \frac{\sum_{i=1}^{N}\left(ECS_i \times W_{f\,i}\right)}{\sum_{i=1}^{N} W_{f\,i}}$$

Where ECS = Element Condition Score
W_f = element importance weighting factor
N = number of elements in a bridge

The weighting factor normally takes a value of ≥ 1.0 depending on the importance of the element, the least important element having a weighting of 1.0. Dividing through by the sum of the weightings allows the BCS to remain on the same scale as the ECS.

The main drawback of this approach is illustrated by the following hypothetical example.

Table 7 Example 1

Element Condition	Element Condition Score (ECS)	Element Importance	Importance Factor	Weighted Condition
3B	3.0	Very High	2	6
3B	3.0	Very High	2	6
3B	3.0	Very High	2	6
3B	3.0	Very High	2	6
3B	3.0	Very High	2	6
3B	3.0	Low	1	3
			Σ = 11	**Σ = 33**
			BCS =	**33/11 = 3.0**

Table 8 Example 2

Element Condition	Element Condition Score (ECS)	Element Importance	Importance Factor	Weighted Condition
3B	3.0	Very High	2	6
3B	3.0	High	1.5	4.5
3B	3.0	Medium	1.2	3.6
3B	3.0	Medium	1.2	3.6
3B	3.0	Low	1	3
3B	3.0	Low	1	3
			Σ = 7.9	**Σ = 23.7**
			BCS =	**23.7/7.9 = 3.0**

This hypothetical example illustrates the lack of sensitivity of the weighted average method to element importance in certain scenarios. The objective of applying element weightings is to alter the influence of different elements on the final score. In the above, Example 1 is in a worse overall condition because it has a large number of Very High importance elements in a fair to poor condition, therefore when evaluating a BCS we would wish this structure to be ranked higher than Example 2.

Subtractive Factor

An alternative option is to use a subtractive factor that weights the element condition on its perceived influence on the overall bridge condition. In this case the BCS could be evaluated as:

$$BCS = \frac{\sum_{i=1}^{N}(ECS_i - ECF_i)}{N}$$

Where ECF = Element Condition Factor

A subtractive factor overcomes the insensitivity to spread evident in the weighted average (Table 7 and Table 8), however, it is seen to be overly sensitive to lower importance elements when averaging for the BCS, for example:

Table 9 Example 3

Element Condition	Element Condition Score (ECS)	Element Importance	Subtractive Factor	Weighted Condition
4B	4.0	Very High	0.0	4
4B	4.0	Very High	0.0	4
4B	4.0	Very High	0.0	4
2B	2.0	Low	0.9	1.1
2B	2.0	Low	0.9	1.1
2B	2.0	Low	0.9	1.1
			6 elements	**Σ = 15.3**
			BCS =	**15.3/6 = 2.55**

Table 10 Example 4

Element Condition	Element Importance Score (ECS)	Element Importance	Subtractive Factor	Weighted Condition
2B	2.0	Very High	0.0	2
2B	2.0	Very High	0.0	2
2B	2.0	Very High	0.0	2
4B	4.0	Low	0.3	3.7
4B	4.0	Low	0.3	3.7
4B	4.0	Low	0.3	3.7
			6 elements	**Σ = 17.1**
			BCS =	**17.1/6 = 2.85**

Example 3 should provide a worse BCS score than Example 4, but the subtractive factor produces an incorrect evaluation.

Combined Approach

A combined element condition and importance weighting is therefore proposed to overcome the problems with the above two approaches when used individually. The BCS in the combined approach is evaluated as:

$$BCS = \frac{\sum_{i=1}^{N}\left(\left(ECS_i - ECF_i\right)\times W_{fi}\right)}{\sum_{i=1}^{N} W_{fi}}$$

Redoing the hypothetical examples above using this approach gives:

Table 11 Influence of Combined Weighting

Hypothetical Example	Single Factor	Combined Factors	Comment
1: Table 7	3.0	2.95	The condition of the lower importance elements is deemed less influential on the overall bridge condition, this is reflected in the combined approach.
2: Table 8	3.0	2.73	
3: Table 9	2.55	3.03	Spurious results are not caused by the subtractive factor when it is balanced by the multiplication factor.
4: Table 10	2.85	2.56	

The combined approach is more robust than the subtractive or the weighted average approach. Detailed sensitivity studies are presented in Section 5.

4.6 CONSTRAINTS OF A SINGLE INDICATOR

The previous section illustrated how the combined approach is more robust than the other approaches considered. However, because an average condition is evaluated none of the approaches identify cases when a single bridge element is in a poor condition while all other elements are in a better condition. The element with the worst condition will influence the BCS, but the influence decreases as the total number of bridge elements increases, for example:

Table 12 Loss of Information in BCS

Element Importance				Total No. of Elements	BCS
Low		Very High			
No. of Elements	Condition of Element	No. of Elements	Condition of Element		
1	1	1	4	2	3.0
3	1	1	4	4	2.2
7	1	1	4	8	1.7

Table 12 illustrates that the overall bridge condition, as represented by the BCS, decreases as the number of elements in a good condition increases, one would expect the BCS to reflect this. However, what is lost is an indication of the condition of the Very High importance element. Therefore, while a series of BCS values may appear satisfactory they may actually be concealing very high importance elements in a poor condition.

A second condition indicator which reflects the condition of the most important bridge elements i.e. those that directly influence the functionality, load carrying capacity, durability and public safety of the structure, is needed to complement the average BCS and provide a more complete picture of the "health" of the bridge.

4.6.1 Second Indicator

A BCS to monitor the condition of critical (very high importance) elements is proposed. On the 1 (best) to 5 (worst) condition scale this is the BCS_{Crit}. It is defined as:

$$BCS_{Crit} = \max\left\{\begin{array}{l}\text{ECI for primary deck elements}\\ \text{ECI for secondary deck elements}\\ \text{ECI for half joints}\\ \text{ECI for tie beam/rod}\\ \text{ECI for parapet beam or cantilever}\\ \text{ECI for pier/column}\\ \text{ECI for cross - head/capping beam}\end{array}\right\}$$

4.7 SELECTED CONDITION INDICATORS

The algorithms presented in this section are the finalised versions. Throughout the development stage and sensitivity studies the algorithms were modified in light of any weaknesses observed.

The combined approach was selected as the most sensitive and robust procedure for evaluating the BCS.

4.8 ELEMENT IMPORTANCE

Element importance is accounted for by two factors:

1. **Element Condition Factor (ECF)** which represents the influence of the individual element on the overall bridge condition.
2. **Element Importance Factor (EIF)** which represents the importance of the element to the overall functionality of the bridge in terms of (i) load carrying capacity (ii) durability, and (iii) public safety.

4.8.1 Element Condition Factor (ECF)

The ECF is subtracted from the ECS to give the Element Condition Index (ECI) i.e.

$$\mathbf{ECI = ECS - ECF} \qquad \mathbf{but} \geq \mathbf{1.0}$$

The ECI allows direct comparison of the influence of the condition of different element types on the overall bridge condition. The ECF varies with element condition as described in Table 13, the ECF alters the ECS as shown in Figure 1.

Table 13 Expressions for Element Importance Factor (ECF)

Element Importance	Element Importance Factor (ECF)
Very High	ECF = 0.0
High	$ECF = 0.3 - [(ECS - 1) \times 0.3/4]$
Medium	$ECF = 0.6 - [(ECS - 1) \times 0.6/4]$
Low	$ECF = 1.2 - [(ECS - 1) \times 1.2/4]$

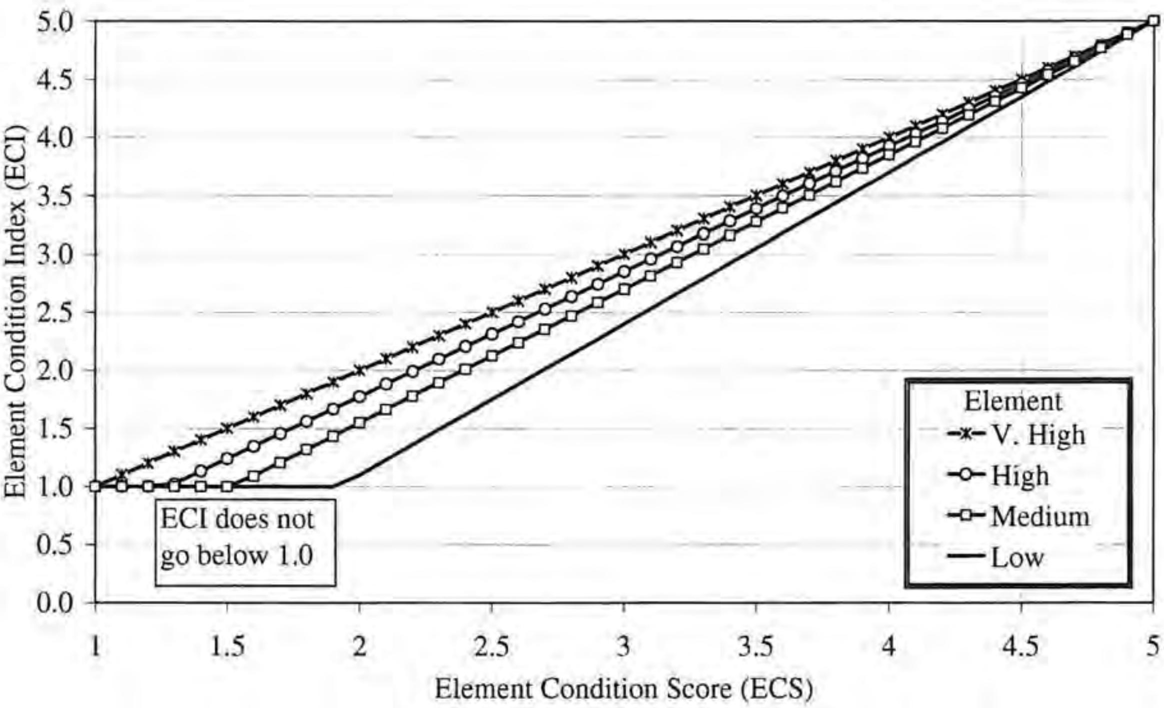


Figure 1 Influence of ECF on the Element Condition Index (ECI)

Defining all element conditions on the ECI scale means their individual influence on the whole bridge condition can be directly compared. On a bridge stock level the average ECI (ECI_{Av}) for each element type can be directly compared as shown in Figure 2.

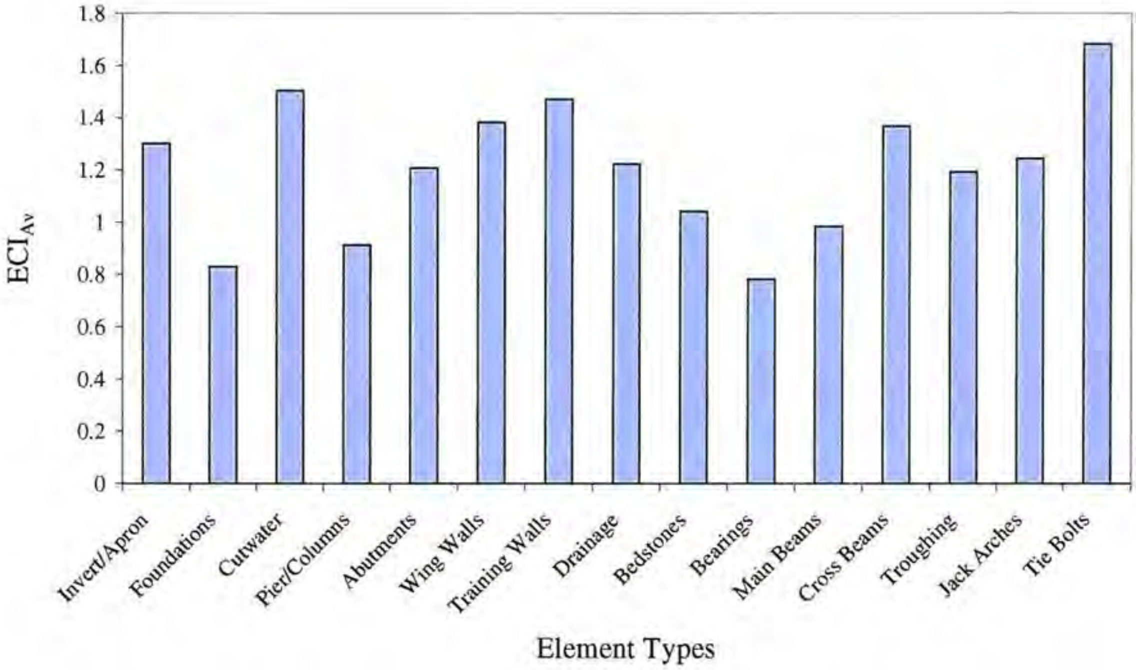


Figure 2 Comparison of ECI_{Av} for different Element Types

Figure 2 allows bridge owners/managers to easily identify which elements are in a generally worse condition. This could be used to provide additional information for decision making, along with the BCI/BSCI scores, and identify the areas of a bridge stock that require more maintenance work, for example it is highly likely that more maintenance work is required to improve the ECI_{Av} from 5 to 1 for Main Beams than for Drainage due to the larger quantities and greater costs involved.

4.8.2 Element Importance Factor (EIF)

The ECI is weighted by the EIF to give the Bridge Condition Score (BCS):

$$BCS_{Av} = \frac{\sum_{i=1}^{N} (ECI_i \times EIF_i)}{\sum_{i=1}^{N} EIF_i}$$

The EIF values used in this equation are shown in Table 14.

Table 14 Element Importance Factor (EIF)

Element Importance	EIF
Very High	2.0
High	1.5
Medium	1.2
Low	1.0

The result is called the BCS_{Av} and is on a scale of 1 (best) to 5 (worst).

4.9 BRIDGE CONDITION INDEX (BCI)

The Bridge Condition Score (BCS) has the same scale as the Element Condition Score (ECS), i.e. 1 (Best) to 5 (Worst), and can in general be interpreted in an analogous way to ECS. However, this scale is considered to be somewhat difficult to understand and confusing for those outside the bridge engineering community. A Bridge Condition Index (BCI) is introduced which is defined on a linear 100 (Best) to 0 (Worst) condition scale. Guidance on the interpretation and use of BCS and BCI values is given in Section 6.

The BCS_{Av} and BCS_{Crit} are converted to the corresponding BCI_{Av} and BCI_{Crit} as below. The relationship is also shown in Figure 3. The non-linear relationship reflects the fact that as the BCS value increases from 1 to 5, the bridge condition deteriorates gradually in the beginning but progressively more rapidly thereafter.

$$BCI_{Av} = 100 - 2\left[(BCS_{Av})^2 + (6.5 \times BCS_{Av}) - 7.5\right]$$

$$BCI_{Crit} = 100 - 2\left[(BCS_{Crit})^2 + (6.5 \times BCS_{Crit}) - 7.5\right]$$

4.10 BRIDGE STOCK CONDITION INDEX (BSCI)

In addition to the operational need for monitoring the condition of individual bridges using the BCI values, there is also a need for monitoring the condition of the overall bridge stock at a strategic level. The Bridge Stock Condition Index (BSCI) was developed to serve this purpose.

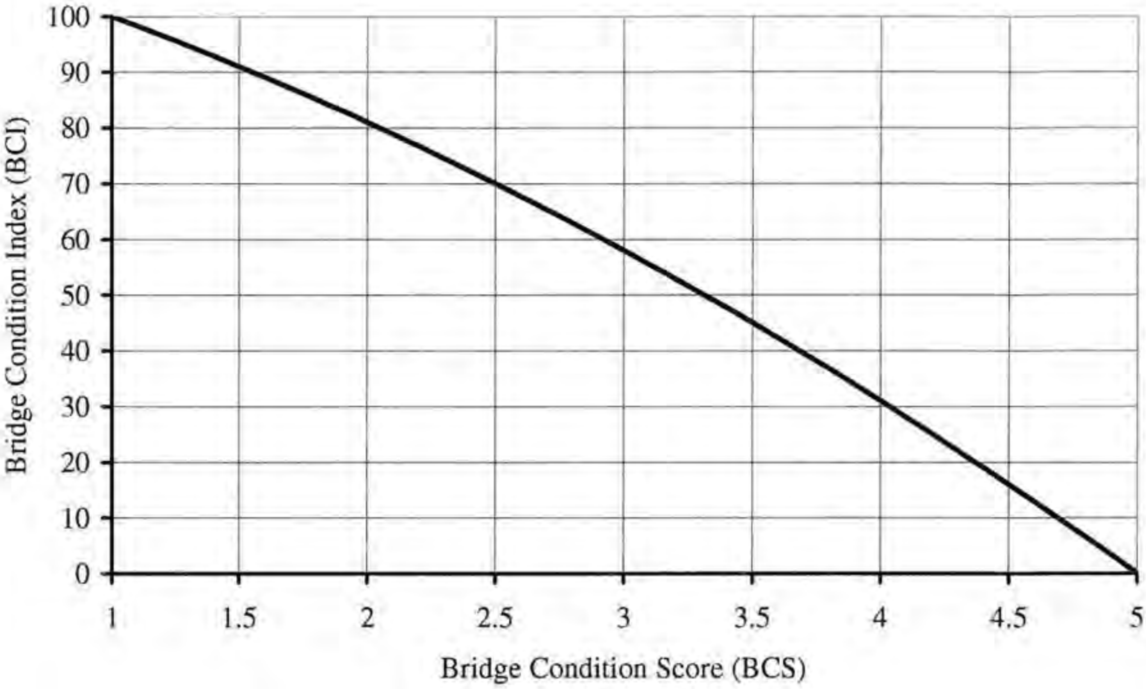


Figure 3 Relationship between BCS and BCI values

In aggregating the BCI values for the whole stock it was recognised that the differences in their size should be considered. Otherwise, large multi-span bridges carrying four or more traffic lanes which require higher maintenance funding would be unfairly treated compared to small single span bridges carrying one or two lanes of traffic. Furthermore, the inspection reporting system (Ref. 3) allows the reporting of element conditions either on individual spans or for all the spans together; and in this case it is necessary that the resulting BSCI is the same for both the options.

It was initially proposed to use a Bridge Importance Factor considering traffic flow rates on the road carried, type of obstacle crossed and deck area to weight the individual BCI. The Bridge Stock Condition Index (BSCI) is then evaluated as:

$$BSCI = \frac{\sum (BCI \times BIF)}{\sum BIF}$$

It was decided that this approach to BSCI evaluation would not be adopted under this commission, because it did not fit in with an indicator measuring condition alone. It was therefore decided to use "deck area" as the most appropriate weighting factor for calculating BSCI. An asset (replacement) value factor would have been preferable but this would create considerable workload and thus delay the implementation of the BCIs as information is not readily available. It is also highly likely that an asset (replacement) value factor would require additional calculations of a more complex nature than those presented herein.

Analogous to the BCI two different BSCIs, average and critical, are calculated using the expressions given below. $BSCI_{Av}$ and $BSCI_{Crit}$ similarly have a scale of 100 (Best) to 0 (Worst).

$$BSCI_{Av} = \frac{\sum_{i=1}^{M} (BCI_{Av} \times \text{Deck Area})_i}{\sum_{i=1}^{M} \text{Deck Area}_i}$$

$$BSCI_{Crit} = \frac{\sum_{i=1}^{M} (BCI_{Crit} \times \text{Deck Area})_i}{\sum_{i=1}^{M} \text{Deck Area}_i}$$

where *M* is the total number of bridges (or spans) in the stock.

Where the element conditions are reported on an individual span basis, the deck area in the above should correspond to each span. On the other hand, if the element conditions are reported for all the spans taken together, the deck area should correspond to the entire bridge. Similarly, where different construction forms in the modified parts of a bridge are reported on separately, these should be treated as separate bridges for the calculation of BCI and BSCI values.

The deck area should be evaluated as:

$$Deck\ Area\ (m^2) = Overall\ \ width \times bridge\ (or\ span)\ length$$

Where *bridge/span length* is defined as the distance between the centre line of supports, or if this is not available, the distance between abutment/column faces plus 0.6m. If bridge modifications have been reported on separate pro forma then the appropriate width/length should be used. Guidance is also provided in Ref. 4 on converting BCI scores for spans to a BCI score for the whole bridge, and the same approach can also be used when converting original construction type/modified type BCIs to a BCI for the whole bridge.

5. SENSITIVITY TRIALS

The aim of the sensitivity study was to test and demonstrate that the algorithms are robust, consistent and sensitive to appropriate factors such as:

- element importance
- element condition
- number of elements
- element deterioration/maintenance
- number of bridges
- deck area.

The sensitivity trials concentrated on BCS_{Av} and $BSCI_{Av}$ because these are primarily influenced by the factors listed above. Trialling on the BCS_{Crit}, BCI and $BSCI_{Crit}$ was limited because their evaluation is straightforward and/or indirectly covered by the aforementioned trials.

5.1 BCS_{Av} TRIALS

A large number of trials based on real and hypothetical data were performed. It is difficult to separate the trials into distinct groups, where each group trials one specific aspect, because trialling of one factor frequently involves trialling of others. Because of this some repetition of results is unavoidable in the following sections.

5.1.1 Element Importance

For the purpose of this trial all the bridge elements are assumed to be in the same condition i.e. 3C. This means the influence of the spread of element importance on the BCS_{Av} can be compared between examples.

5.1.1.1 Real Bridges

Eight different bridge types were selected from the Cambridgeshire stock. Table 15 presents the spread of element importance classifications for each bridge type considered. Trends are more easily identified using the percentage values because the total number of elements changes between bridges. There is a reasonably high spread of percentage values within each importance classification, however a general trend is identifiable.

The majority of elements are classified as having medium importance (38%) and a significant proportion are classified as having high importance (29%). Low and very high importance element classification make up a significantly lower proportion, 14%

and 19% respectively. The spread of classifications appears to be reasonable as one would expect to have fewer elements of low and very high importance, with the majority of elements having medium to high importance.

Table 15 Spread of Element Importance for different bridge types

	Bridge Type	Total No. of Elements	Number and percentage of elements with given importance							
			Low		Medium		High		Very High	
1	Bulldog Bridge: RC beam and slab	12	1	8%	6	50%	2	17%	3	25%
2	Sandhill Bridge: RC slab	14	2	14%	5	36%	5	36%	2	14%
3	Gravel Bridge: Precast Prestressed beam and slab	8	2	25%	3	38%	2	25%	1	12%
4	Brick End Wimpole Bridge: Brick Arch	5	1	20%	2	40%	1	20%	1	20%
5	Spaldwick Bridge: stone arch	12	2	17%	5	41%	3	25%	2	17%
6	Dexters Bridge: steel and wrought iron with concrete slab	13	1	8%	4	31%	6	46%	2	15%
7	White Bridge: steel with wrought iron jack arch	10	2	20%	4	40%	2	20%	2	20%
8	New Road Rail Bridge: Cast iron and jack arch	7	0	0%	2	29%	3	42%	2	29%
		Average =		**14%**		**38%**		**29%**		**19%**

Figure 4 shows the spread of BCS_{Av} values for all bridges when the elements are assumed to be all in condition 3C (corresponding to an ECS of 3.1). As expected there is very little variation in the BCS_{Av} because all the bridges have a reasonably consistent spread of element importance classifications (Table 15). However, it is worth noting that Bridge 8 has the highest BCS, this is attributed to the absence of low importance elements on this bridge.

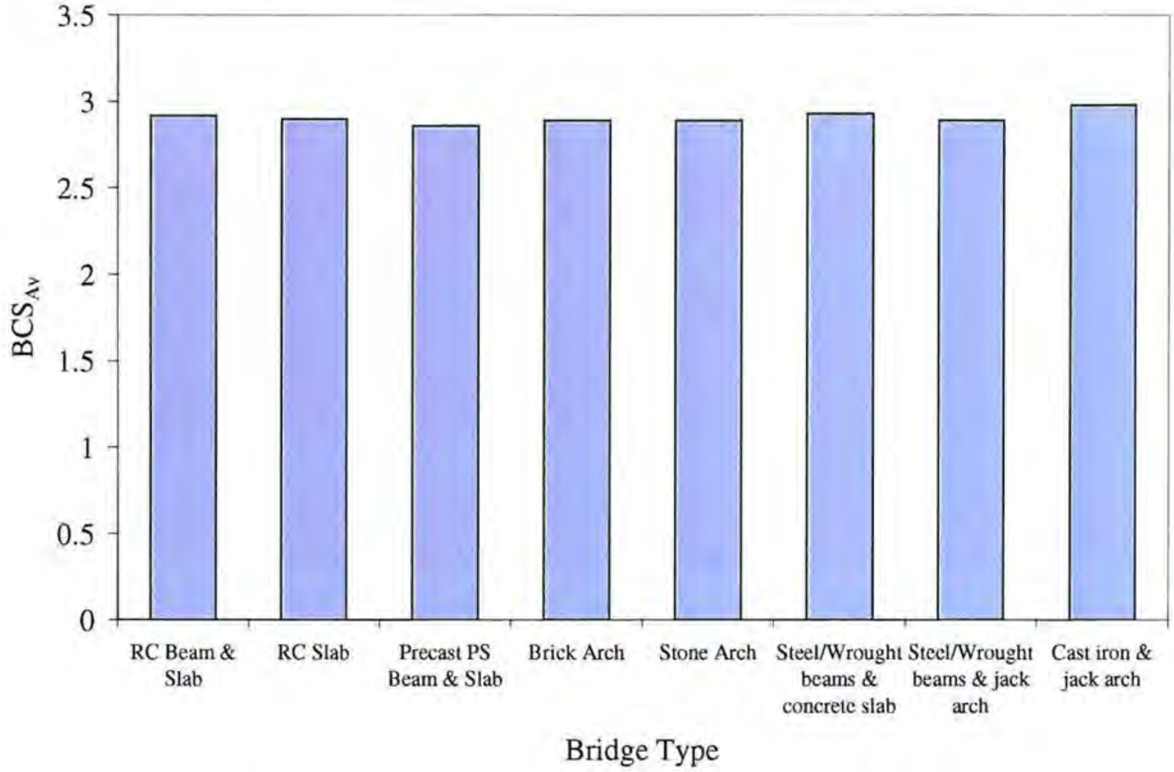


Figure 4 Influence of Bridge Type on BCS

The selected element importance classifications (Table 6) were trialled for real bridges and appear to be reasonably consistent across bridge types i.e. the proportion of elements having a given importance classification remains relatively constant. Therefore the BCS_{Av} of different bridge types is not adversely influenced by the element importance classification adopted.

5.1.1.2 Hypothetical Bridges

The previous section trialled the BCS_{Av} algorithm for real bridges and the element importance classifications were found to be robust. However, extreme element importance mixes may exist for some bridge types and these cannot be easily identified by a small sample trial of real bridges. Therefore this section aims to trial the importance classifications for hypothetical bridges that have extreme (possibly unrealistic) mixes of element importance.

Table 16 summarises the trials performed with hypothetical bridges. The trials were performed for all element conditions and no spurious results were observed, only a sample of these are presented in Table 16 i.e. 2B, 3C and 4D.

Table 16 Summary of hypothetical bridge trials

Group	Trial	No. of Elements with Importance of				Total No of	BCS_{Av}		
		Low	Medium	High	Very High	Elements	2B	3C	4D
1	a	1	2	2	1	6	**1.68**	**2.90**	**4.23**
	b	2	4	4	2	12	**1.68**	**2.90**	**4.23**
	c	3	6	6	3	18	**1.68**	**2.90**	**4.23**
2	a	7	0	0	1	8	**1.30**	**2.66**	**4.14**
	b	6	0	0	2	8	**1.46**	**2.76**	**4.17**
	c	5	0	0	3	8	**1.59**	**2.84**	**4.20**
	d	4	0	0	4	8	**1.70**	**2.91**	**4.23**
	e	3	0	0	5	8	**1.79**	**2.97**	**4.25**
	f	2	0	0	6	8	**1.87**	**3.02**	**4.27**
	g	1	0	0	7	8	**1.94**	**3.06**	**4.29**
3	a	4	4	2	2	12	**1.59**	**2.84**	**4.20**
	d	4	2	4	2	12	**1.63**	**2.87**	**4.21**
	c	4	2	2	4	12	**1.69**	**2.91**	**4.23**
	d	2	4	4	2	12	**1.68**	**2.90**	**4.23**
	e	2	4	2	4	12	**1.74**	**2.94**	**4.24**
	f	2	2	4	4	12	**1.77**	**2.95**	**4.25**
4	a	1	6	6	1	14	**1.68**	**2.90**	**4.23**
	b	2	6	6	1	15	**1.65**	**2.88**	**4.22**
	c	1	6	6	2	15	**1.71**	**2.92**	**4.23**
5	a	1	1	1	1	4	**1.69**	**2.90**	**4.23**
	b	2	1	1	1	5	**1.60**	**2.85**	**4.21**
	c	1	1	1	2	5	**1.77**	**2.95**	**4.25**

Group 1

These trials show that the overall bridge condition score, BCS_{Av}, remains constant if the proportion of elements in different importance classifications remains constant. Since each element classification represents the same proportion of the total bridge in trials a, b & c one would expect the BCS_{Av} scores to remain constant.

Group 2

Illustrates that as the proportion of higher importance elements increases, and the proportion of lower importance elements decreases, the overall BCS_{Av} increases. The BCS_{Av} increases from 1.30 to 1.94 for trials 2(a) through 2(g) when all elements are in condition 2B. If all elements are in condition 4D the increase is from 4.14 to 4.29. The magnitude of the difference has greatly decreased. This reflects the increased influence of lower importance elements on the overall bridge condition when they are in a very poor condition. This feature is included in the algorithm through the Element Condition Factor (ECF) to increase the maintenance necessity of low importance elements when they are in a very poor condition.

Group 3

Illustrates that as the spread of element importance classification changes the BCS_{Av} changes. Again larger changes are apparent when elements are in a better condition i.e. 2B. As expected, as the proportion of elements is increased from lower to higher importance the BCS_{Av} increases. It also illustrates that Low Importance combined with Very High Importance is almost identical to Medium Importance combined with High Importance, trials 3(c) and 3(d), this appears to be a reasonable approximation and a desirable feature.

Group 4 & 5

Group 4 has bridges with an above average number of elements, while Group 5 has bridges with a below average number of elements. The Group 4 trials show that having two or only one Low/Very High importance elements has very little influence on the BCS_{Av}. The influence increases in Group 5 because they constitute a greater proportion of the bridge.

The above trials show that the BCS_{Av} algorithm provides logical scores even in extreme scenarios. In conclusion the BCS_{Av} algorithm produces no spurious results due to the element importance classifications assigned, and a logical spread of importance classifications appears to have been found.

5.1.2 Element Condition

The aim of these trials was to ensure that the condition of elements, with different importance classifications, have the appropriate influence on the BCS_{Av}. It is recognised that there in a loss of information when averaging the ECI scores to obtain the BCS_{Av}, this is why the BCS_{Crit} is also used. Therefore, the following trials will not illustrate that the BCS_{Av} is unable to adequately indicate when a critical member is in a poor/very poor condition because this fact has already been recognised and accounted for by the BCS_{Crit}.

The examples presented in Table 17 illustrate that the higher importance elements have a greater influence on the BCS_{Av} score, as expected. In Table 18 the difference between the condition of the higher and lower importance elements is increased. This reduces the overall BCS_{Av} compared with Table 17 but also results in a greater difference between the two BCS_{Av} shown in Table 18, illustrating the increased influence of the higher importance elements when the difference between individual element conditions increases. These are both desirable features for the algorithm.

The influence of element condition (irrespective of importance) varies with the total number of elements in that condition in the bridge. All trials on element condition showed the BCS_{Av} to alter in the correct direction i.e. either up or down depending on the condition change. However, the exercise did emphasise that the BCS_{Av} is not enough to provide a clear picture of the bridge health. Table 18 has a BCS_{Av} of 2.95 in the right hand table, this does not alert the bridge engineer to the fact that two very high importance elements are in a very severe condition. This illustrates the need for the BCS_{Crit}.

Table 17 Influence of ECS on BCS_{Av}: Comparison 1

Element Condition	Element Importance	Weighted ECS
2.3	V. High	4.60
2.3	V. High	4.60
2.3	High	3.15
2.3	High	3.15
2.3	High	3.15
2.3	High	3.15
4.3	Medium	5.03
4.3	Medium	5.03
4.3	Medium	5.03
4.3	Medium	5.03
4.3	Low	4.09
4.3	Low	4.09
	BCS_{Av} =	**2.98**

Element Condition	Element Importance	Weighted ECS
4.3	V. High	8.60
4.3	V. High	8.60
4.3	High	6.37
4.3	High	6.37
4.3	High	6.37
4.3	High	6.37
2.3	Medium	2.27
2.3	Medium	2.27
2.3	Medium	2.27
2.3	Medium	2.27
2.3	Low	1.49
2.3	Low	1.49
	BCS_{Av} =	**3.26**

Table 18 Influence of ECS_{Av} on BCS: Comparison 2

Element Condition	Element Importance	Weighted ECS
1	V. High	2.00
1	V. High	2.00
1	High	1.50
1	High	1.50
1	High	1.50
1	High	1.50
4.3	Medium	5.03
4.3	Medium	5.03
4.3	Medium	5.03
4.3	Medium	5.03
4.3	Low	4.09
4.3	Low	4.09
	BCS_{Av} =	**2.28**

Element Condition	Element Importance	Weighted ECS
4.3	V. High	8.60
4.3	V. High	8.60
4.3	High	6.37
4.3	High	6.37
4.3	High	6.37
4.3	High	6.37
1	Medium	1.20
1	Medium	1.20
1	Medium	1.20
1	Medium	1.20
1	Low	1.00
1	Low	1.00
	BCS_{Av} =	**2.95**

5.1.3 Variation of BCS_{Av} with Time

A sample of 39 bridges grouped into eight different types were selected from the Cambridgeshire bridge stock to analyse the change in BCS_{Av} over time. Bridge inspection data was compiled for three separate time periods:

- Inspections performed in the period 1991 to 1994
- Inspections performed in the period 1995 to 1998
- Inspections performed in the period 1999 to 2001

The results of the analysis are shown in Figure 5.

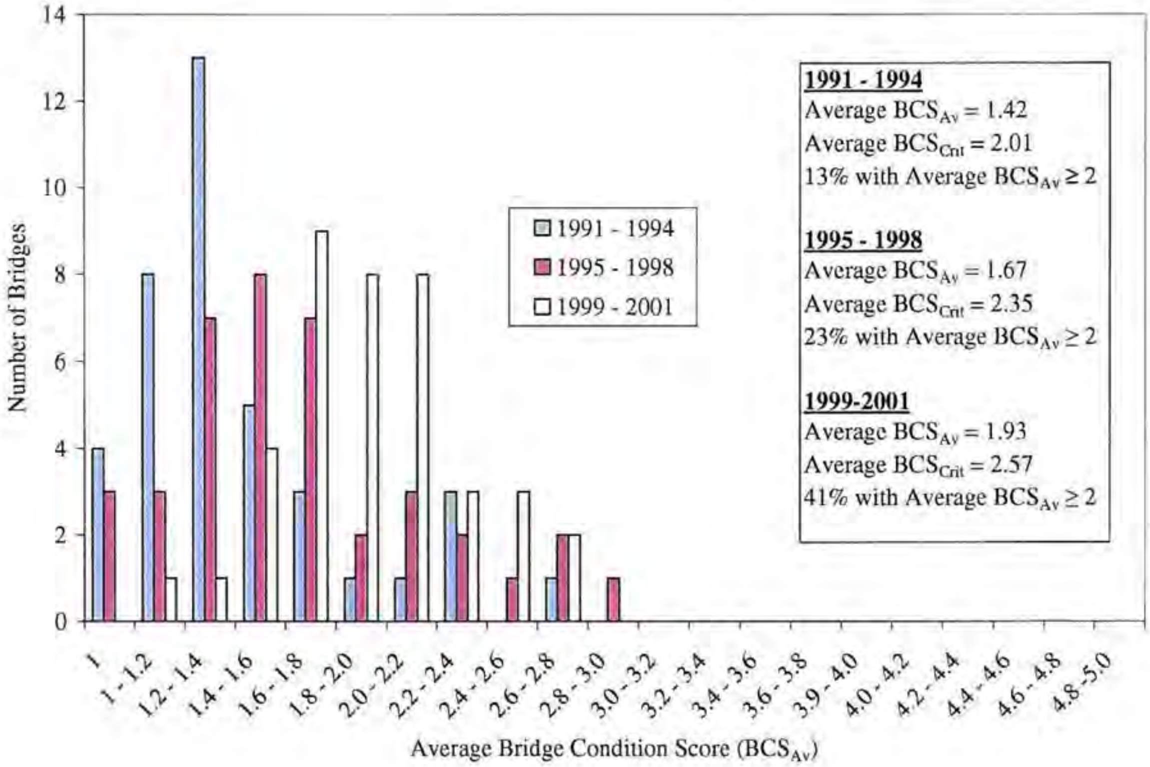


Figure 5 Change of Cambridgeshire BCS_{Av} over 11 years

Figure 5 clearly illustrates the change in condition of the overall bridge stock and provides a great deal more information than simply tracking the change in Bridge Stock Condition Index.

Assuming Figure 5 is a representative sample of the Cambridgeshire bridge stock then it is fair to say that either maintenance has been under funded or insufficient maintenance work has been performed for the past 11 years.

5.1.4 Maintenance Work

It is essential that the BCS_{Av} is sensitive to maintenance work i.e. when resources are used to improve the condition of a bridge element. This section aims to illustrate that the BCS_{Av} is sensitive to elements repaired and relatively insensitive to the bridge type the maintenance is performed on.

The overall impact of maintenance on the BCS_{Av} is illustrated in Figure 6 which shows how it would change if all the maintenance work recommended by the 1999-2001 Cambridgeshire inspections was performed.

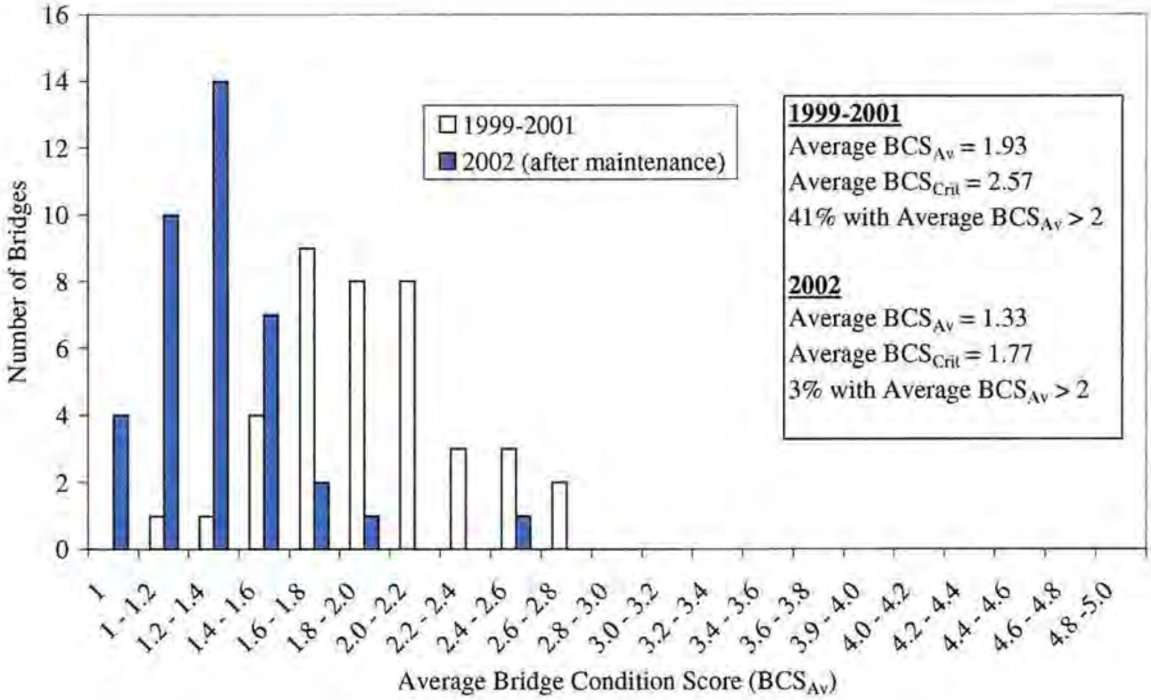


Figure 6 Improvement in BCS_{Av} for Cambridgeshire sample

Carrying out the recommended maintenance work results in a significant improvement in the BCS_{Av} histogram. The maintenance work carried out on two of the bridges, Sandhill bridge and Lock Farm bridge, which showed respectively the highest and lowest change in BCS are detailed in Table 19.

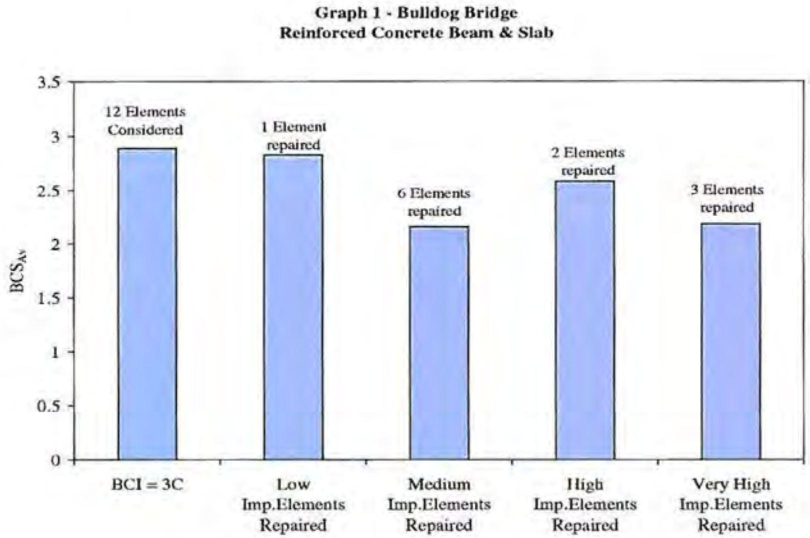
The Sandhill Bridge is in a poor condition overall and a complete maintenance programme was suggested. For the Lock Farm Bridge the maintenance work was focused on specific elements. The primary deck elements and handrails have been identified (very high and high importance respectively). Two medium importance elements (drainage and carriageway surfacing) have also been identified for repair even though they are in a good/fair condition.

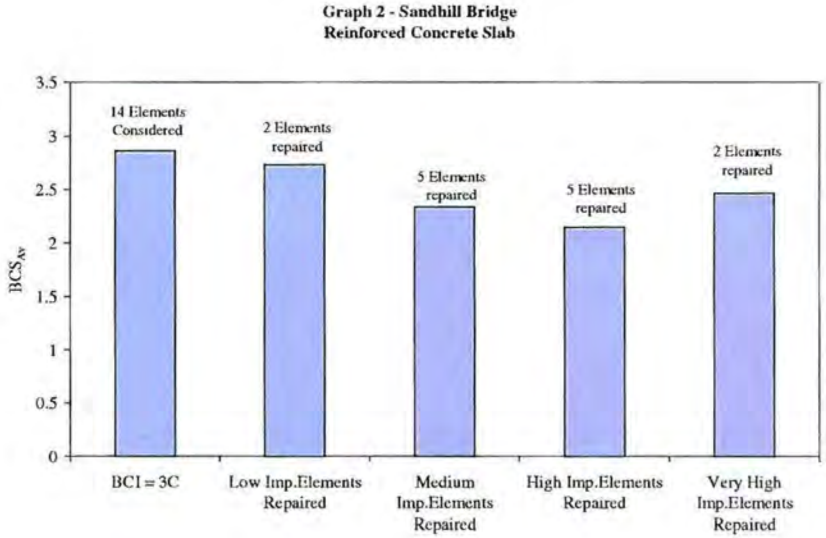
Table 19 Maintenance work carried out on two bridges

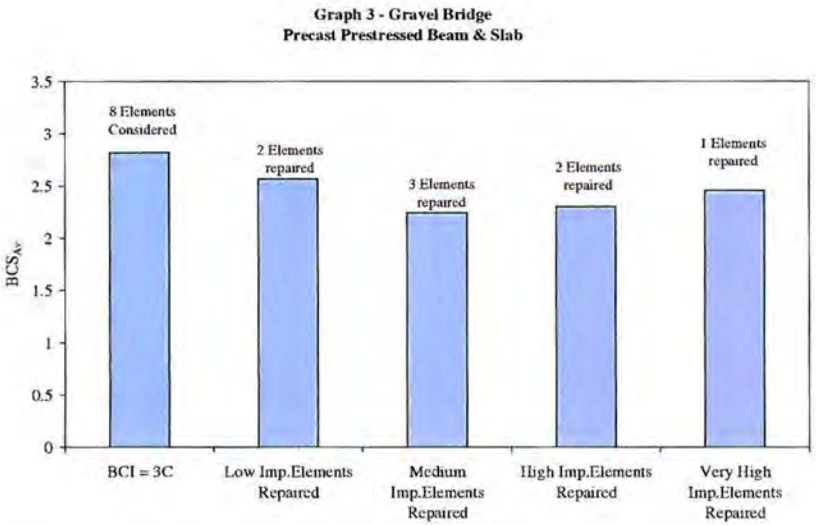
			Element Condition			
			Sandhill		Lock Farm	
	Element Descriptions	Importance	1999-2001	2001	1999-2001	2001
1	Primary Deck Element	Very High	3.10	1.00	2.30	1.00
2	Transverse Beams	Very High				
3	Secondary Deck Element	Very High			2.00	2.00
4	RC Half Joints	Very High				
5	Tie beam/rod	High				
6	Parapet beam or cantilever	High				
7	Deck Bracing	High				
8	Foundations	High	1.00	1.00		
9	Abutments (inc. arch springing)	High	3.17	1.00	1.78	1.78
10	Spandrel Wall/head wall	High				
11	Pier/Column	Very High	2.10	1.00		
12	Cross-head/capping beam	Very High				
13	Bearings	High	1.78	1.00		
14	Bearing Plinth/shelf	Medium				
15	Superstructure Drainage	Medium	1.55	1.00	1.55	1.00
16	Substructure Drainage	Medium	2.70	1.00		
17	Waterproofing	Medium	2.70	1.00		
18	Movement/expansion joints	High	3.17	1.00		
19	Painting: deck elements	Medium				
20	Painting: substructure elements	Medium				
21	Painting: parapets/safety fences	Medium				
22	Access/walkways/gantries	Medium				
23	Parapets/handrails/safety fences	High	1.78	1.00	2.96	1.00
24	Carriageway surfacing	Medium	2.82	1.00	1.55	1.00
25	Footway/verge/footbridge surfacing	Low	1.10	1.00		
26	Invert/river bed	Medium			1.90	1.90
27	Aprons	Medium				
28	Fenders/cutwaters/collosion prot.	Medium				
29	River training works	Medium				
30	Revetment/batter paving	Low				
31	Wing walls	Medium	1.55	1.00		
32	Retaining Walls	Medium			1.55	1.55
33	Embankments	Low	1.49	1.00	1.00	1.00
34	Machinery	Medium				
		BCS_{Av} =	**2.20**	**1.00**	**1.92**	**1.38**

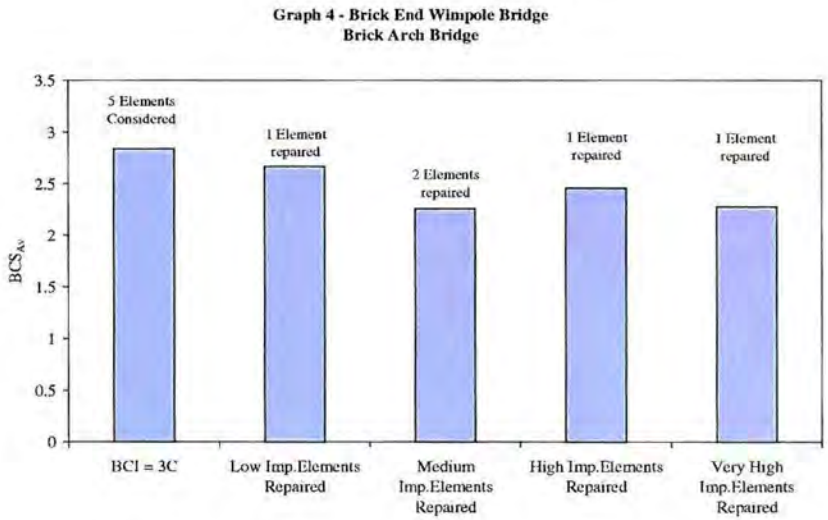
The eight bridge types shown in Table 15 were also used to investigate the influence of element maintenance on the BCS_{Av}. The trials were performed assuming that all elements on each bridge were in condition 3C. Then each group of element importance classifications were assumed to be improved to condition 1A in turn. Graphs 1 to 8 show the influence of maintenance on each bridge type.

All the graphs show that the maintenance of higher importance elements has a greater influence on the BCS_{Av}. The maintenance of one Very High importance element offers equivalent improvement to the maintenance of two Medium importance elements, see Graphs 1, 4, 6 and 7.

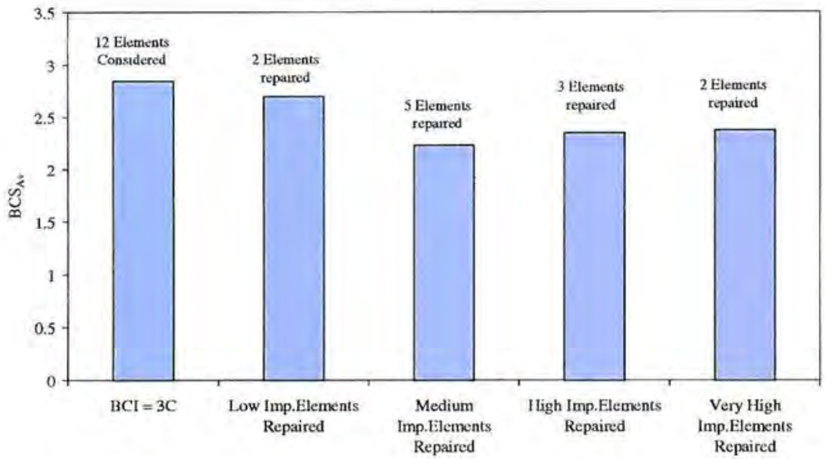

Graph 1 - Bulldog Bridge
Reinforced Concrete Beam & Slab
12 Elements Considered
1 Element repaired
6 Elements repaired
2 Elements repaired
3 Elements repaired
BCI = 3C
Low Imp.Elements Repaired
Medium Imp.Elements Repaired
High Imp.Elements Repaired
Very High Imp.Elements Repaired
BCS_Av


Graph 2 - Sandhill Bridge
Reinforced Concrete Slab
14 Elements Considered
2 Elements repaired
5 Elements repaired
5 Elements repaired
2 Elements repaired
BCI = 3C
Low Imp.Elements Repaired
Medium Imp.Elements Repaired
High Imp.Elements Repaired
Very High Imp.Elements Repaired
BCS_Av

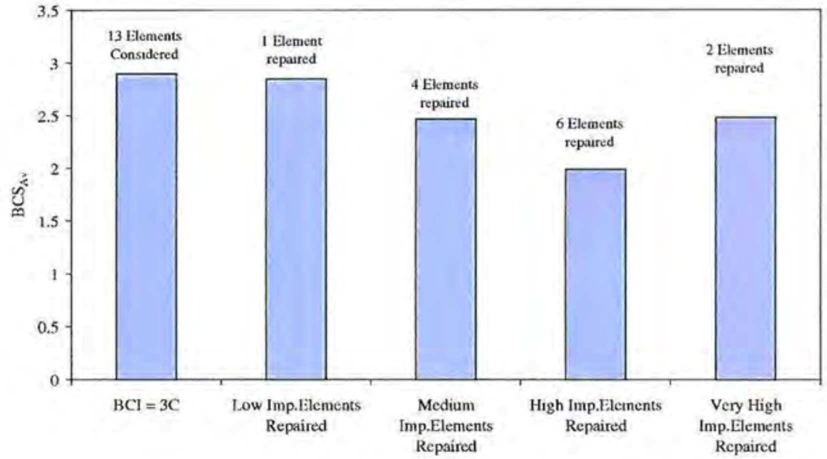

Graph 3 - Gravel Bridge
Precast Prestressed Beam & Slab
8 Elements Considered
2 Elements repaired
3 Elements repaired
2 Elements repaired
1 Elements repaired
BCI = 3C
Low Imp.Elements Repaired
Medium Imp.Elements Repaired
High Imp.Elements Repaired
Very High Imp.Elements Repaired
BCS_Av


Graph 4 - Brick End Wimpole Bridge
Brick Arch Bridge
5 Elements Considered
1 Element repaired
2 Elements repaired
1 Element repaired
1 Element repaired
BCI = 3C
Low Imp.Elements Repaired
Medium Imp.Elements Repaired
High Imp.Elements Repaired
Very High Imp.Elements Repaired
BCS_Av

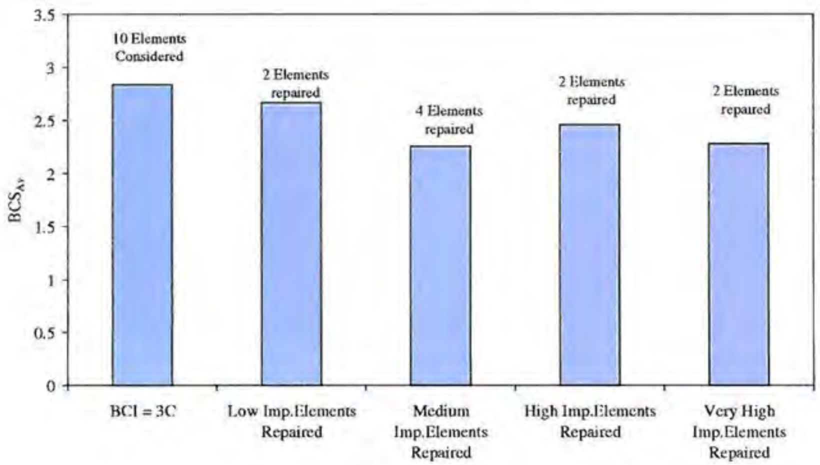
Graph 5 - Spaldwick Bridge
Stone Arch Bridge



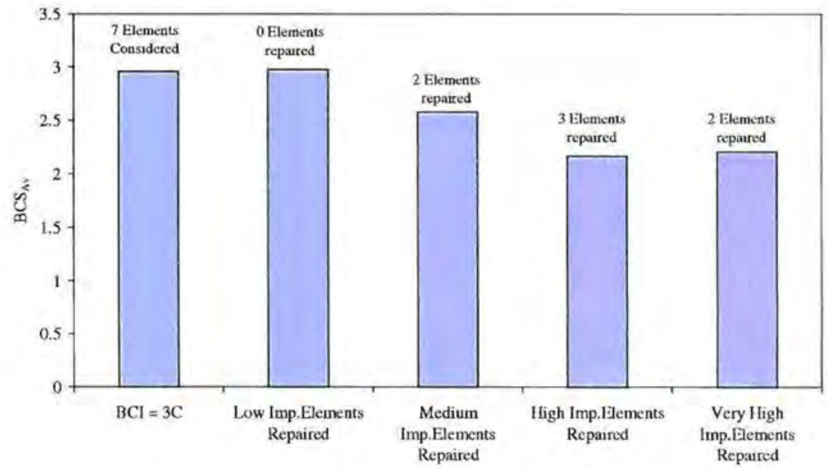
Graph 6 - Dexters Bridge
Steel / Wrought & Concrete Slab



Graph 7 - White Bridge
Steel / Wrought & Jack Arch Bridge



Graph 8 - New Road Rail Bridge (Disused)
Cast Iron & Jack Arch Bridge



5.2 BRIDGE STOCK CONDITION INDEX (BSCI) TRIALS

5.2.1 Deck Area

Four hypothetical bridges are shown in Table 20, two of the bridges have a small deck area while the other two have considerably larger deck areas. Assuming this represents a stock of four bridges it can be observed how the $BSCI_{Av}$ is influenced by the deck area, and thus provides a better representation of the condition of the bridge stock.

Table 20 $BSCI_{Av}$ Comparisons for four Hypothetical Bridges

Hypothetical Bridge	Deck Area (m^2)	BCI_{Av} Score		
		Trial 1	Trial 2	Trial 3
1	10	65	95	35
2	20	65	95	35
3	90	65	35	95
4	100	65	35	95
	$BSCI_{Av}$ =	**65**	**43**	**87**
	Average BCI_{Av} =	**65**	**65**	**65**

The average BCI_{Av} is 65 for all three trials because it is independent of deck area. Thus for Trial 1, where all the bridges are assumed to be in the same condition, the average BCI_{Av} and $BSCI_{Av}$ agree well. Trials 2 and 3 illustrate how using only the average BCI_{Av} value can be misleading and provide an incorrect picture of the bridge stock condition.

The influence of the deck area was then trialled on a larger stock of 50 bridges, selected from the Hertfordshire database. Details of the trials performed are presented in Table 21.

Table 21 BSCI trials on a stock of 50 bridges from Hertfordshire

Trial		Average Deck Area (m^2)	BSCI		Average BCI_{Av}
No.	Description		Av	Crit	
1	Control (actual data set)	50.2	84	78	Independent of deck area ∴ remains constant for all trials: Av. BCI_{Av} = 84 Av. BCI_{Crit} = 77
2	Deck area of 3 bridges with worst BCI altered to 500m^2	78.4	79	69	
3	Deck area of 3 bridges with worst BCI altered to 10m^2	49.0	85	78	
4	Deck area of 3 bridges with best BCI altered to 500m^2	77.2	89	86	
5	Deck area of 3 bridges with best BCI altered to 10m^2	47.8	83	77	

The BSCI values from the control analysis (all bridges using their actual deck area) agrees well with the BCI values, thus indicating a low variability of bridge deck areas, see Figure 7.

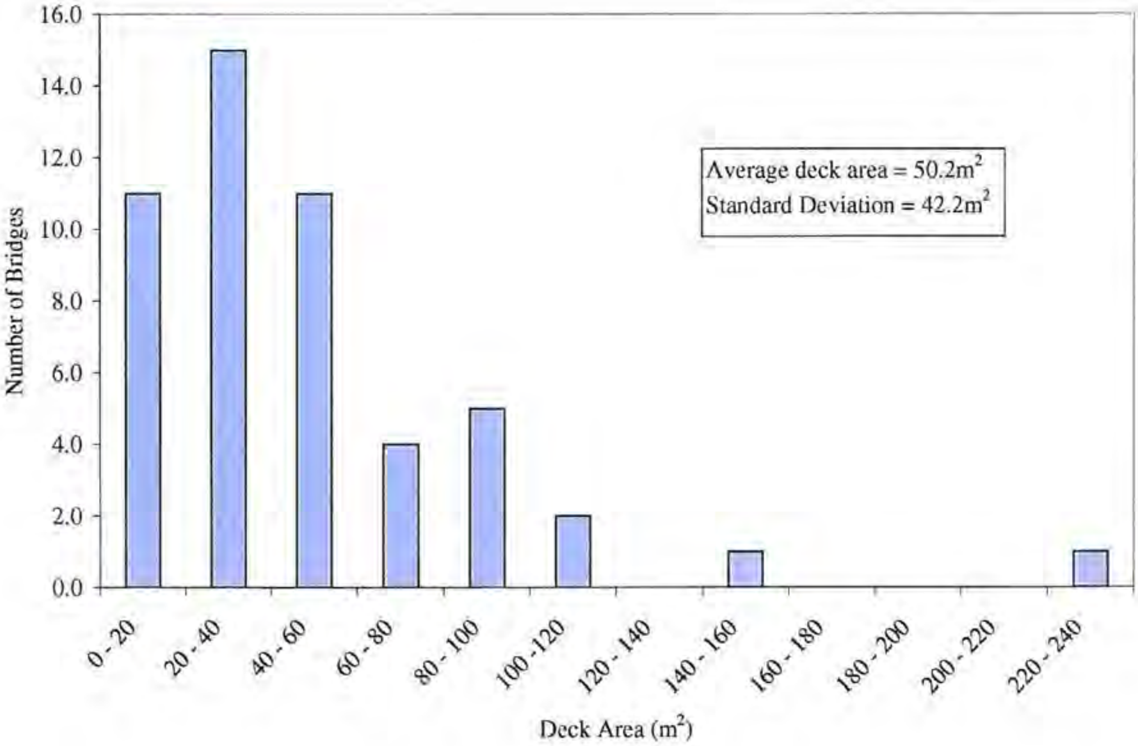


Figure 7 Histogram of bridge deck area for sample of 50 Hertfordshire bridges

The BSCI scores in Table 21 deviate from the BCI values when large bridges are entered into the stock, small bridges have a much lesser impact. From Figure 7 it can be seen that the deck area of $500m^2$ lies well outside the sample bridge stock range, whereas the stock contains many bridges with small deck areas similar to the $10m^2$ example in Table 21. Therefore, for cases 3 and 5 the BSCI does not change appreciably from the control value because the average deck area is not greatly altered, while for cases 2 and 4 the BSCI changes markedly due to a significant increase in the average bridge deck area.

5.2.2 Inspection Reporting System

The following example illustrates how coarse inspection reporting systems e.g. Good/Fair/Poor, do not provide a good conversion to the BCI. Figure 8 shows the BCI_{Av} histogram for a sample bridge stock (Manchester) inspected using the BE11 system, Figure 9 shows the histogram for a sample stock (Lancashire) inspected using a Condition Factor system and Figure 10 shows the histogram for a sample stock (Plymouth) inspected using the Good/Fair/Poor system.

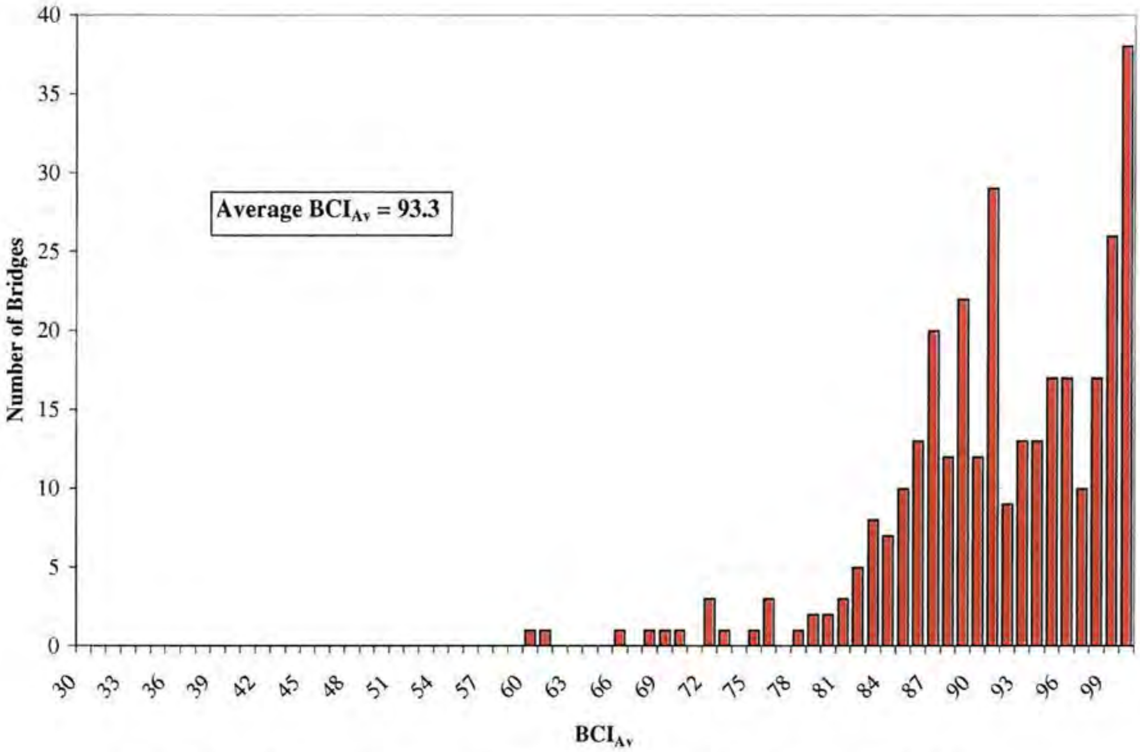


Figure 8 Good Conversion to BCI for BE11 inspection data

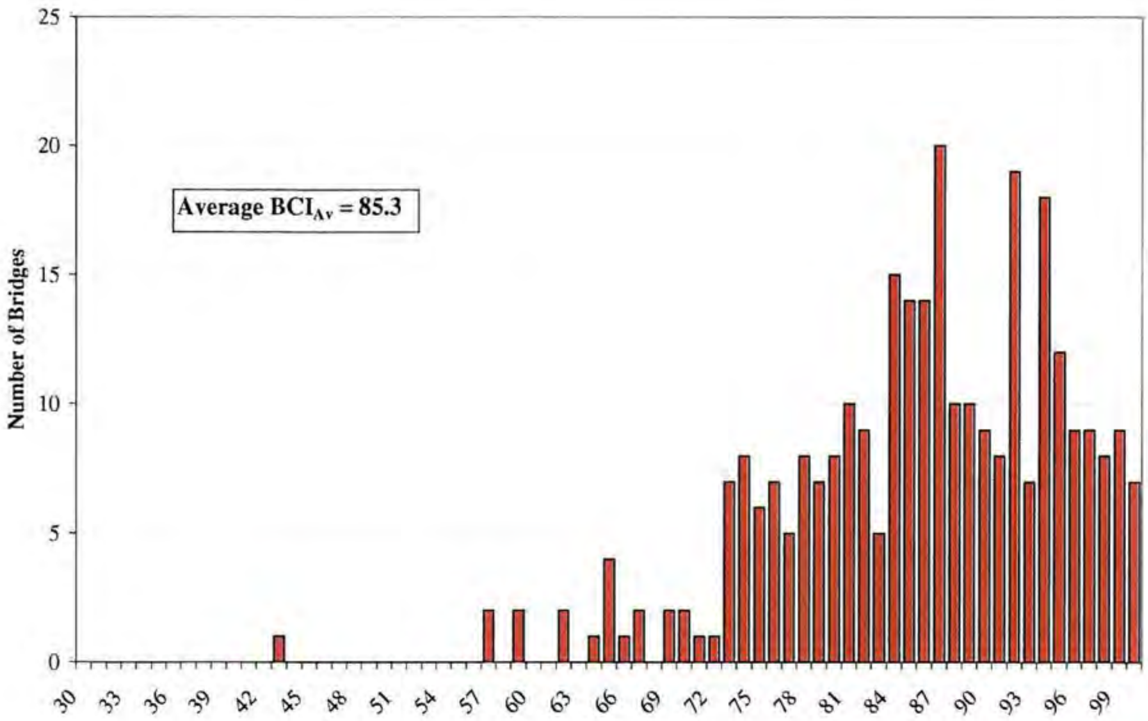


Figure 9 Good Conversion to BCI for Condition inspections data

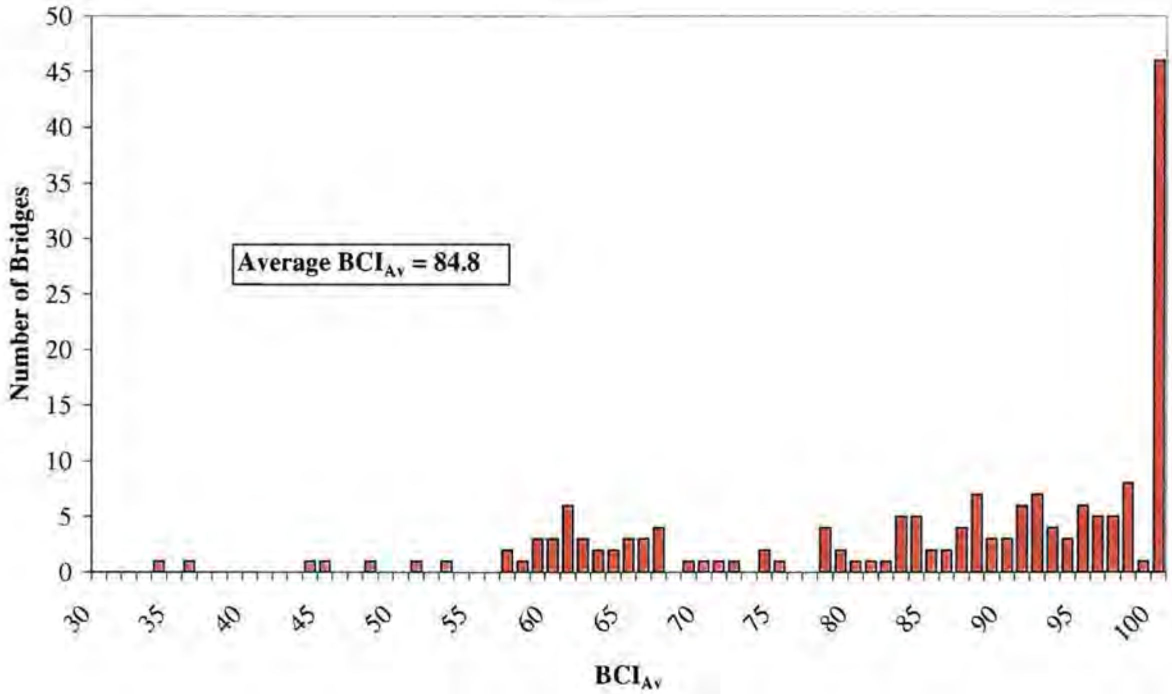


Figure 10 Poor conversion to BCI for coarse inspection procedures

Figure 8 and Figure 9 show a good conversion with no pronounced peaks. Figure 10, however, has a large peak at 100 because it was assumed an element condition report of Good corresponds to 1A (see Table 5). There is a reasonable spread of BCI_{Av} values if 100 is ignored, however the main problem is the large shift in ECS for 1A (Good) to 3C (Fair) to 4D (Poor). It is postulated that these large divisions would result in erratic jumps in the BSCI scores from one inspection period to the next. Unfortunately no Good/Fair/Poor data collected over a number of years was available to test this. However, it is reasonable to say that the more fine the condition scoring system the more effective it will be at picking up small changes via the BSCI scores.

It is therefore recommended that authorities who use a reporting system with less than 5 condition states should transfer to the new inspection reporting system as soon as possible. The more condition categories a system has (no systems were found that have more than the 17 categories suggested in Ref. 3) the more sensitive the BCI and BSCI will be to changes in element condition.

5.3 CONCLUSIONS FROM TRIALS

The trialling has shown the developed algorithms to be robust and consistent but also sensitive to the appropriate stimuli, namely element importance, condition and maintenance. The main conclusions drawn from the trials are:

- A good balance of element importance classifications has been achieved which remains relatively consistent between different bridge types.
- As element importance increases the influence of the element condition on the overall bridge condition increases.
- The maintenance of one very high importance element has a similar influence on the BCS to the maintenance of two medium importance elements.
- When possible the BSCI should be weighted by deck area to produce a more representative score.
- BCI histograms provide a great deal more information that simply tracking change via the BSCI values.
- Coarse inspections systems are less sensitive to change in element condition, this is reflected in the BSCI scores and BCI histograms.

6. INTERPRETATION OF INDICATOR VALUES

6.1 SINGLE CONDITION INDICATOR VALUES

A number of tables have been developed to aid the interpretation of BCS_{Av}, BCS_{Crit}, $BSCI_{Av}$ and $BSCI_{Crit}$. The tables are presented Ref. 4, additional discussion is presented below.

6.1.1 BCS Values

The BCS values are evaluated on the 1 (best) to 5 (worst) condition scale, their interpretation is as suggested in Table 6 of Ref. 4.

The BCS_{Av} value is the average of the ECS, therefore the descriptions attempt to interpret the most likely condition of elements. As the sensitivity trials have shown it is not possible for the BCS_{Av} to reflect the spread of ECS thus BCS_{Crit} is also utilised. The BCS_{Crit} interpretations concentrate on the influence the condition of the critical elements have on the load carrying capacity of the structure because they relate to the condition of high importance elements e.g. primary members, secondary members etc.

The BCS_{Av} is unable to convey the spread of element conditions to anyone viewing such numbers, however this is not its purpose. It is designed to take all elements on the bridge into account and present a representative score, the sensitivity trials have shown it achieves this. The BCS are only meant as a high level management tool, existing procedures should continue to be used to determine what maintenance work is actually required on a specific bridge.

6.1.2 BSCI Values

The BSCI values are evaluated on the 100 (best) to 0 (worst) condition scale, their interpretation is as suggested in Table 9 of Ref. 4.

Interpreting the underlying stock condition through a single BSCI value is somewhat difficult because information is lost in the averaging. The BSCI values do not reflect the actual spread of BCI scores, for example:

Consider two bridge stocks with 10 bridges in each, all with the same deck area of $50m^2$. The BCI_{Av} scores are as shown in Table 22.

Table 22 illustrates how averaging results in a loss of information. It may be that similar maintenance expenditure is required to bring both stocks up to an appropriate level and therefore the figures are useful as a high level management tool. This is not very informative to the bridge engineer/manager who wants a clearer picture of the bridge stock health. It is therefore recommended that the BCI_{Av} data is used to create histograms of stock condition.

Table 22 Loss of Information in $BSCI_{Av}$

Bridge	Stock 1 BCI_{Av}	Stock 2 BCI_{Av}	Deck Area (m^2)
1	75	75	50
2	75	55	50
3	75	85	50
4	75	95	50
5	75	90	50
6	75	85	50
7	75	40	50
8	75	85	50
9	75	90	50
10	75	50	50
$BSCI_{Av}$ =	**75**	**75**	

6.2 HISTOGRAMS

The BCS and BCI values can be used to create histograms that illustrate the spread of bridge conditions within a stock. The procedure for creating these histograms is described in Ref. 4.

Figure 11 illustrates the spread of bridge condition within two sample stocks. *Number of Bridges* is plotted against BCI_{Av}, however, if bridge deck area data are available then *Proportion of Stock* can be plotted against BCI_{Av}. The histograms and associated simple statistics (e.g. % with $BCI_{Av} < 85$) clearly illustrate that Bridge Stock 2 is in a better overall condition than Bridge Stock 1. A BCI_{Av} value of 85 was chosen because it corresponds with the Good/Fair boundary which is a good comparator for these two bridge stocks. Equally other BCI_{Av} values may be used when comparing within or between stocks.

The bridge inspection data used in Figure 11 originated from two different inspection procedures, the HA BE11 form was used for Bridge Stock 2 while a condition factor on a 1 to 5 scale was used for Bridge Stock 1. Both systems had sufficient levels of fineness to provide a reasonable conversion to the BCI (Table 5).

Figure 12 illustrates that the shape of the graph can change depending on the stock measurement property used. For example, 4% of the bridges have a BCI_{Av} of < 78, but these bridges actually represent 10% of the total deck area. It is advisable to produce both graphs to give a better indication of the spread of bridge conditions.

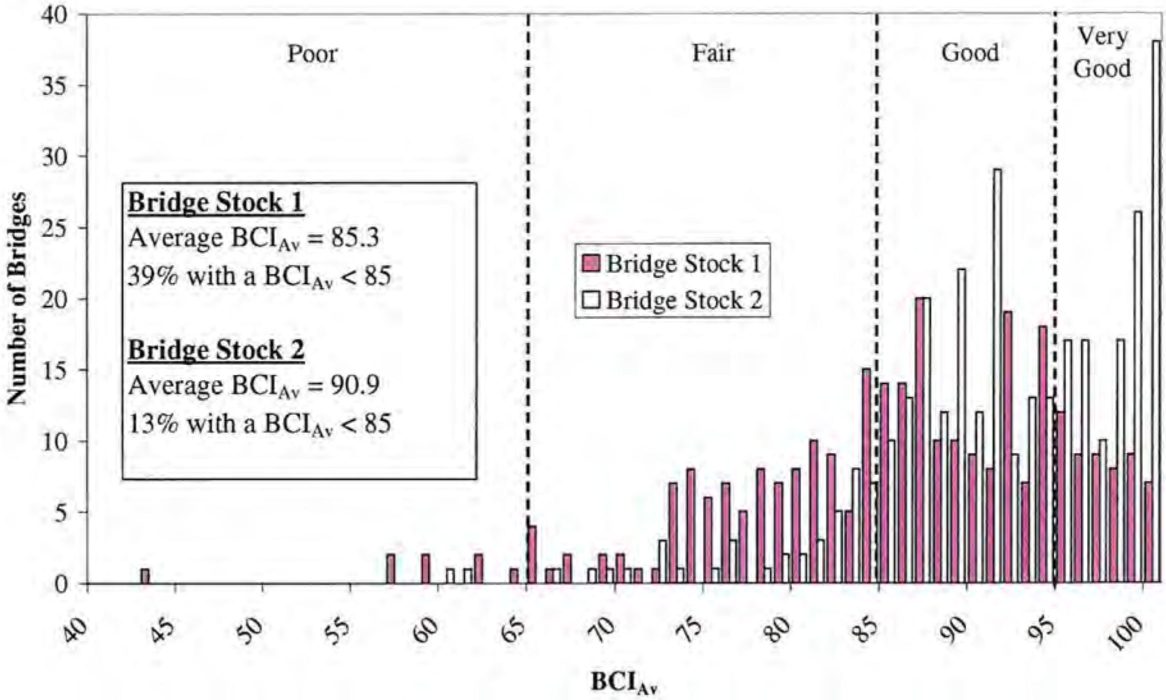


Figure 11 Histogram of BCI_{Av} values.

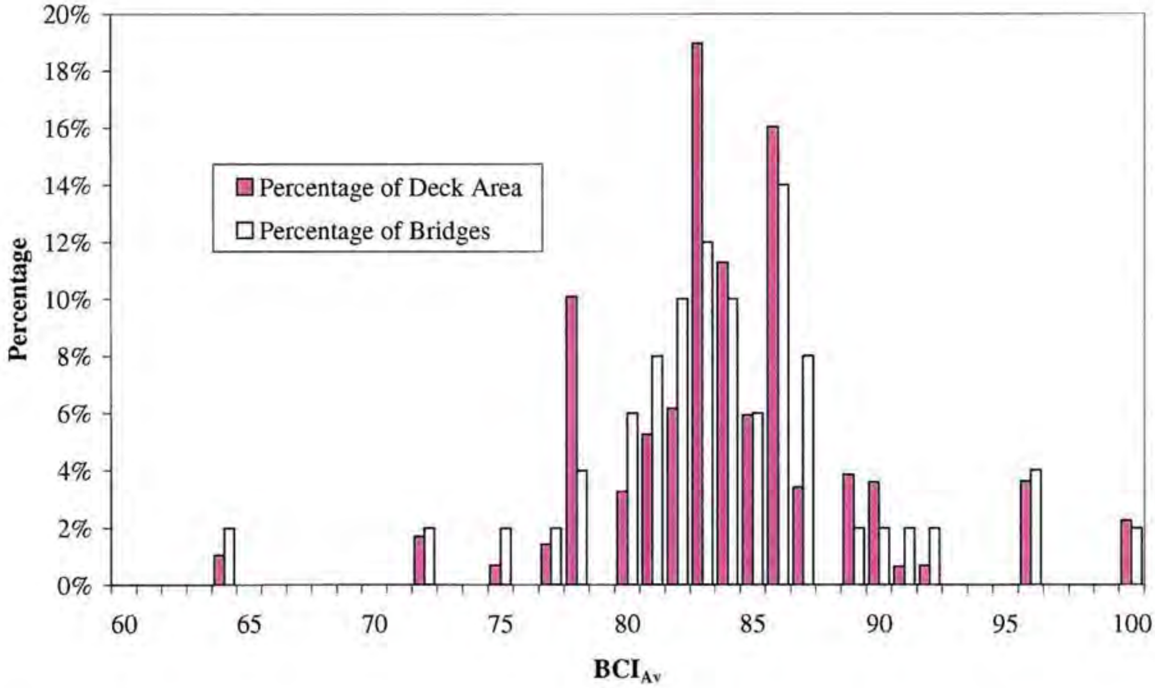


Figure 12 Comparison of Deck Area and Bridge Number Percentages

6.3 TARGET VALUE OF CONDITION INDICATORS

Target values for condition indicators need to be established and the actual indicator values should be monitored against these targets. The objectives of monitoring are to identify areas for improvement, and opportunities and constraints for achieving this. The results should feed into the development of Action Plans, and a Local Authority's Annual Business Plan.

The targets should be achievable and should be set by each Local Authority based on the current condition of its bridge stock and the resources available for the achievement of the targets. The target values should be reviewed and possibly revised annually in the light of current performance and change in circumstances. The targets can be revised upwards each year to demonstrate continuous improvement.

In addition to setting annual targets, it is desirable to have a long-term 'goal' that all Local Authorities in the country should aspire to achieve. The following values are proposed as a long-term goal:

Table 23 Target Values

Indicator	Average Value	Spread
$BSCI_{Av}$	90	Not more than 10% of bridges have $BCI_{Av} < 70$ No bridge has a $BCI_{Av} < 60$
$BSCI_{Crit}$	95	Not more than 10% of bridges have $BCI_{Av} < 75$ No bridge has a $BCI_{Av} < 65$

7. CONCLUSIONS

The following main conclusions can be drawn from the work performed under this commission:

i. Procedures have been developed for consistent inspection reporting.

ii. A severity/extent condition reporting system was developed which provides a good degree of fineness for identifying change in condition.

iii. One condition indicator is not adequate to provide a sufficient indication of the overall heath of a bridge or bridge stock. Hence two indicators, $BSCI_{Av}$ and $BSCI_{Crit}$, have been developed.

iv. Algorithms have been developed that can be applied to an individual bridge, a group of bridges and the complete bridge stock.

v. Robust algorithms have been developed for the evaluation of BCI and BSCI.

vi. The BCI/BSCI algorithms are sensitive to appropriate factors e.g. element importance, element condition, maintenance, number of elements etc. but are relatively insensitive to bridge type and number of elements reported upon.

vii. To overcome the loss of information in the BCI/BSCI averaging, it is recommended that histograms are used to provide a more complete picture of bridge stock condition.

8. REFERENCES

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2. The CSS Review, ICE Seminar on Bridge Rehabilitation in the UK, October 2000.

3. Bridge Condition Indicators Volume 2: Guidance Note on Bridge Inspection Reporting, CSS Bridges Group, April 2002.

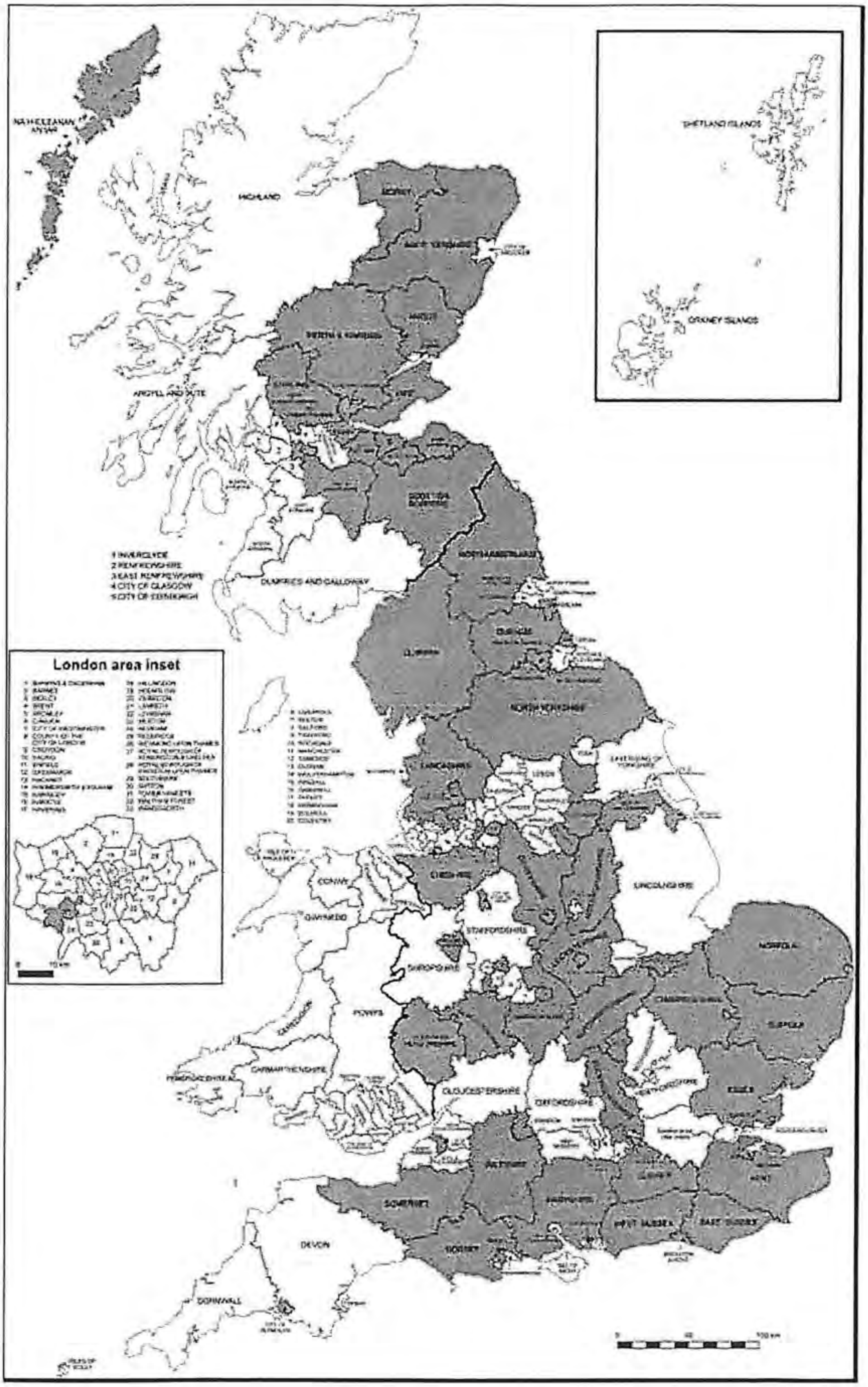
4. Bridge Condition Indicators Volume 3: Guidance Note on the Evaluation of Bridge Condition Indicators, CSS Bridges Group, April 2002

5. P.J. Andrews, "Objectivity in Bridge Maintenance", IHT April 1984.

6. British Railways, BRB Handbook No. 26, 1964.

APPENDIX A

INSPECTION REPORTING SURVEY RESULTS


HIGHLAND
MORAY
ARGYLL AND BUTE
1 INVERCLYDE
2 RENFREWSHIRE
3 EAST RENFREWSHIRE
4 CITY OF GLASGOW
5 CITY OF EDINBURGH
DUMFRIES AND GALLOWAY
SHETLAND ISLANDS
ORKNEY ISLANDS
NORTHUMBERLAND
CUMBRIA
DURHAM
NORTH YORKSHIRE
LANCASHIRE
LEEDS
CHESHIRE
LINCOLNSHIRE
CONWY
GWYNEDD
STAFFORDSHIRE
SHROPSHIRE
NORFOLK
POWYS
SUFFOLK
CARMARTHENSHIRE
ESSEX
GLOUCESTERSHIRE
OXFORDSHIRE
KENT
SOMERSET
HAMPSHIRE
WEST SUSSEX
EAST SUSSEX
DEVON
DORSET
CORNWALL
London area inset

[illegible]						✓									
Bedstones						✓									
Armco/Concrete Pipe						✓			✓ ✓						
Subway Lighting						✓									
Tunnel Portals						✓				✓					
Mast						✓				✓					
Panel						✓									
Prestressing						✓									
Tunnel Linings						✓									
Corrugated Metal						✓					✓		✓		
Cassion						✓									
Primary Lighting						✓									
Secondary Lighting						✓									
Portal						✓									
Stone Slab							✓								
Counterfort/Buttresses							✓								
Runway Beams							✓								
Abutment Slope							✓								
Bankseal							✓								
Miscellaneous Items							✓								
Leakage								✓							
Parapet Beam									✓ ✓		✓				
Troughing Infill									✓ ✓		✓				
Buckle Plates									✓ ✓		✓				
Rivits and Bolts									✓ ✓		✓				
Welds									✓ ✓		✓				
Arch Soffit									✓ ✓		✓ ✓				
Wall									✓						
Gabions									✓						
Sleeper Bridge										✓					
Piles											✓				
Road Approaches												✓			
Arch Mortar													✓		
Arch Cracks													✓		
Arch Deformation													✓		
Fillets And Haunching									✓						
Condition Rating															
(Excelent) Good Fair Poor (Dire)	✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓		✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓
State	✓														
Condition Factor	✓		✓		✓ ✓ ✓	✓	✓	✓	✓	✓	✓	✓			
Other Data															
Extent	✓	✓ ✓	✓ ✓	✓ ✓ ✓ ✓	✓	✓ ✓	✓	✓ ✓ ✓ ✓		✓ ✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓
Severity		✓ ✓	✓ ✓	✓ ✓		✓ ✓	✓	✓ ✓ ✓		✓ ✓ ✓	✓ ✓ ✓	✓	✓ ✓	✓ ✓	✓ ✓
Priority	✓	✓ ✓ ✓	✓ ✓	✓	✓	✓ ✓		✓ ✓ ✓	✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓
Location Factor	✓		✓		✓	✓		✓		✓	✓				
Route Factor					✓										
Priority made up from Factors					✓		✓				✓	✓			
Action			✓ ✓			✓ ✓					✓				
Urgency	✓	✓						✓		✓					
Maintenance Scoring								✓	✓						
Item Factor												✓			
Remedial Works Factor															
Defect Category								✓							
Importance Factor							✓								
Stored Electronicaly															
Yes	✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓ ✓ ✓	✓ ✓	✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓ ✓	✓		✓
No	✓ ✓	✓	✓ ✓ ✓		✓	✓ ✓	✓ ✓ ✓	✓ ✓	✓	✓	✓	✓	✓		✓ ✓
Unknown or (Unknown Type)	✓ ✓		✓	✓ ✓ ✓	✓ ✓	✓		✓	✓	✓ ✓ ✓	✓ ✓ ✓ ✓	✓ ✓ ✓	✓ ✓	✓ ✓ ✓ ✓	
Word or Excel		✓			✓	✓		✓	✓					✓	
Database															
Bridgeman	✓			✓	✓						✓	✓			
COSMOS															
Access or Equivilent		✓ ✓		✓		✓	✓ ✓	✓	✓ ✓				✓		✓
HISMIS			✓												
Exor										✓		✓			

Summary of General Inspection Reporting Survey

APPENDIX B

COMMENTS FROM INSPECTION REPORTING TRIALS

Summary of Comments Received from Trials of Inspection Reporting System

1. There is frequently more than one primary/secondary element type in one bridge/span. How is this recorded on the pro forma if only one row is provided for information?

2. The Bridge Type Code does not take into account different types of construction in one bridge e.g. as frequently occur with widenings.

3. More guidance is required on interacting and dominant defect condition classification.

4. Guidance is required on how retaining walls should be inspected.

5. More guidance required on delamination severities.

6. Clearer explanation of how to record the defect type code required.

7. Provide blank spaces on the pro forma.

A large number of comments related to the provision of additional fields on the pro forma. The pro forma is not a standard form and can be amended to include any addition fields required by specific Authorities, however the element list must remain consist.

All comments were reviewed, discussed and appropriately addressed before the BCI Guidance Notes were finalised.

APPENDIX C

ELEMENT IMPORTANCE SURVEY

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Primary deck element	Very High	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	24
	High																									0
	Medium																									0
	Low																									0
Secondary deck element	Very High	1	1		1	1	1	1		1		1	1		1	1				1					1	13
	High			1					1		1			1			1	1	1		1	1	1	1		11
	Medium																									0
	Low																									0
RC half joints	Very High	1	1	1	1	1	1		1	1		1	1	1	1	1		1	1	1	1	1	1	1	1	21
	High							1			1															2
	Medium																									0
	Low																1									1
Tie beam/rod	Very High	1				1									1			1	1							5
	High		1	1	1		1	1	1			1		1							1	1				10
	Medium									1	1		1							1			1	1	1	7
	Low															1	1									2
Transverse beams	Very High	1	1		1		1									1		1								6
	High			1		1		1	1	1	1	1	1	1	1		1		1	1	1	1	1		1	17
	Medium																							1		1
	Low																									0
Parapet/edge beam or cantilever	Very High			1		1			1	1			1	1				1								7
	High	1	1		1		1	1			1				1	1			1		1	1				11
	Medium											1					1			1			1	1	1	6
	Low																									0
Deck bracing	Very High				1														1					1		3
	High	1	1	1		1	1	1		1	1		1	1								1	1			12
	Medium								1			1			1	1	1	1		1	1				1	9
	Low																									0
Pier/column	Very High	1			1			1	1	1		1		1	1	1	1	1			1		1		1	14
	High		1	1		1	1				1		1						1	1		1		1		10
	Medium																									0
	Low																									0
Cross-head/capping beam	Very High				1				1	1		1					1									5
	High	1	1			1	1	1			1		1	1	1	1		1	1		1	1				14
	Medium			1																1			1	1	1	5
	Low																									0
Abutments (incl. arch springing)	Very High			1	1					1		1				1	1				1					7
	High	1	1				1	1			1			1	1			1	1							9
	Medium					1			1				1							1		1	1	1	1	8
	Low																									0
Bearings	Very High	1				1			1	1												1				5
	High		1		1							1						1	1		1		1			7
	Medium			1			1	1			1		1	1	1	1	1							1	1	11
	Low																			1						1
Bearing plinth/shelf	Very High									1																1
	High	1	1		1							1							1							5
	Medium			1		1	1	1							1	1		1			1	1	1	1		11
	Low								1		1		1	1			1			1					1	7
Spandrel wall/head wall	Very High																									0
	High	1	1		1	1		1		1		1	1		1	1			1	1					1	13
	Medium			1			1		1		1			1			1	1			1		1	1		10
	Low																					1				1
Foundations	Very High			1	1					1		1		1	1	1										7
	High		1			1	1	1			1							1	1		1		1		1	10
	Medium	1															1			1		1		1		5
	Low								1				1													2
Superstructure drainage	Very High																									0
	High				1																1	1	1			4
	Medium	1	1			1	1	1		1		1	1											1	1	10
	Low			1					1		1			1	1	1	1	1	1	1						10
Substructure drainage	Very High																									0
	High				1														1							2
	Medium	1	1	1		1		1		1		1			1	1					1	1	1	1		13
	Low						1		1		1		1	1			1	1		1					1	9
Water proofing	Very High		1							1																2
	High	1			1				1					1							1		1	1		7
	Medium			1		1	1	1			1	1	1		1	1		1	1	1		1			1	14
	Low																1									1
Movement/expansion joints	Very High	1	1			1				1																4
	High			1	1				1			1		1						1		1				7
	Medium						1	1			1		1		1	1			1		1		1	1	1	11
	Low																1	1								2

Access/walkways/gantries	Very High		1			1																				2
	High				1							1		1		1						1				5
	Medium									1	1										1				1	4
	Low	1		1			1	1	1				1		1		1	1	1	1			1	1		13
Handrail/parapets/safety fences	Very High	1								1									1							3
	High				1	1		1	1		1	1		1	1		1	1		1	1	1	1		1	15
	Medium		1	1			1						1			1								1		6
	Low																									0
Deck surfacing	Very High																									0
	High																									0
	Medium	1		1	1	1	1	1				1		1				1		1	1	1	1	1	1	15
	Low		1						1	1	1		1		1	1	1		1							9
Footway surfacing	Very High																									0
	High																									0
	Medium	1			1	1		1				1												1		6
	Low		1	1			1		1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	18
Invert/river bed	Very High					1			1	1						1			1							5
	High		1																				1			2
	Medium				1			1			1	1	1	1	1					1	1	1			1	11
	Low	1		1			1										1	1						1		6
Aprons	Very High									1						1			1							3
	High		1										1		1					1					1	5
	Medium			1	1	1		1			1	1		1				1			1		1			10
	Low	1					1		1								1					1		1		6
Fenders/cutwaters/collision prot.	Very High																		1							1
	High			1	1						1		1	1						1			1		1	8
	Medium		1			1	1			1		1			1	1		1			1	1				10
	Low	1						1	1								1							1		5
River training works	Very High																									0
	High																		1							1
	Medium		1	1	1	1				1	1	1	1	1	1					1	1	1		1	1	15
	Low	1					1	1	1							1	1	1					1			8
Revetment/batter paving	Very High																									0
	High																									0
	Medium				1	1				1		1		1					1				1		1	8
	Low	1	1	1			1	1	1		1		1		1	1	1	1		1	1	1		1		16
Wing walls	Very High																									0
	High			1	1					1		1							1							5
	Medium	1	1			1	1	1	1		1			1	1	1	1	1		1	1	1	1		1	17
	Low												1											1		2
Retaining walls	Very High				1					1																2
	High			1		1		1				1						1	1		1					7
	Medium		1				1		1		1		1	1		1				1			1	1	1	11
	Low	1													1		1					1				4
Embankments	Very High																									0
	High					1													1							2
	Medium			1	1			1			1	1		1						1	1				1	9
	Low	1	1				1		1	1			1		1	1	1	1				1	1	1		13
Painting – deck elements	Very High		1																							1
	High								1	1	1													1		4
	Medium	1		1	1	1	1	1				1			1	1	1		1	1	1	1			1	15
	Low												1	1				1					1			4
Painting – substructure elements	Very High																									0
	High								1	1																2
	Medium	1	1		1	1	1	1			1	1					1		1		1	1		1		13
	Low			1									1	1	1	1		1		1			1		1	9
Painting – parapets/safety fences	Very High																									0
	High								1																	1
	Medium	1			1	1		1		1		1				1	1		1		1	1				11
	Low		1	1			1				1		1	1	1			1		1			1	1	1	12
Machinery	Very High	1	1									1														3
	High																		1		1					2
	Medium				1	1		1			1			1			1	1		1		1	1		1	11
	Low			1			1		1	1			1		1	1								1		8

Summary of Element Importance Classification Survey

BRIDGE CONDITION INDICATORS

Volume 2

Guidance Note on Bridge Inspection Reporting

CSS Bridges

ROADS Service
An Agency within the Department for Regional Development

LoBEG

British Waterways

BRIDGE CONDITIONS INDICATORS

Volume 2
Guidance Notes on Bridge Inspection Reporting

Published by CSS

July 2002

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WSA CJ0089-Vol. 2/Issue 4

BRIDGE CONDITION INDICATORS
Volume 2

GUIDANCE NOTE ON BRIDGE INSPECTION REPORTING

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Issue No.: 4
Issue Date: April 2002

ISSUE RECORD

Issue	Date	Page	Para	Comments
1	January 2002			Draft Guidance Note for comments by the Steering Group
2	January 2002			Issued to CSS Bridges Group
3	March 2002			Issued to CSS Steering Group for final comments
4	April 2002			Final Report issued for publication

<u>Note</u>
This document has been specifically produced by WS Atkins Consultants Ltd for the CSS solely for the purposes of developing a Bridge Condition Indicator (BCI) and is only suitable for use in connection therewith.

PREFACE

This document has been prepared by WS Atkins Consultants Limited on behalf of the CSS Bridges Group as part of the commission for developing bridge condition indicators.

Two Guidance Notes have been developed as part of the commission:

1. Guidance Note on Bridge Inspection Reporting
2. Guidance Note on the Evaluation of Bridge Condition Indicators.

This document contains the first of these Guidance Notes. The document provides guidance to bridge inspectors for reporting the condition of bridge elements observed during General and Principal Inspections. Detailed guidance is provided on the use of the inspection pro forma, classification of elements, defect type, severity and extent of damage. The indicators can also be applied to highway retaining walls.

The background work carried out for developing the Guidance Documents, sensitivity analysis and field trials is presented in Bridge Condition Indicators Volume 1.

The scope and content of the Guidance Documents is influenced by three essential requirements specified by the CSS:

1. The developed indicator must be able to operate effectively from information gathered as part of the General and Principal bridge inspections, with very minimal change required for the current inspection systems.
2. The indicator is intended for use by Local Authority bridge owners in England, Scotland and Wales as well as by the Northern Ireland Office and British Waterways. Therefore, the indicator must be sufficiently versatile to cater for the diverse cross-section of bridge types owned by these authorities.
3. The indicator should be applicable to a single bridge or to a stock of bridges.

The Bridge Inspection Reporting system presented in this document is an outcome of the harmonisation of various systems currently used by Local Authorities. It is intended that the Authorities will implement the new system at their earliest convenience. However, the Bridge Condition Indicators can be derived using data from existing inspection systems. Broad comparisons can be made between Condition Indicators based on different inspection systems however the comparisons will not be as accurate or meaningful as those made using the new system.

The scope and periodicity of inspections is outside the remit of this Guidance Note, however, it is strongly recommended that a consistent standard of inspection is adopted by all Authorities. To closely monitor the change in the condition of the bridge stock and identify the build-up of maintenance backlog, a frequency of 2-yearly General Inspections is considered desirable.

CSS GUIDANCE NOTE

BRIDGE CONDITION INDICATORS
Volume 2

BRIDGE INSPECTION REPORTING

Prepared by:
WS Atkins Consultants Limited

CSS GUIDANCE NOTE

BRIDGE INSPECTION REPORTING

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1. INTRODUCTION

GENERAL

1.1 This is Volume 2 of the CSS Bridge Condition Indicators suite (Ref. 1 and 2). Its purpose is to provide guidance to bridge inspectors on reporting the condition of bridge elements observed during General and Principal Inspections. This Guidance Note is intended to harmonise inspection reporting across all Local Authorities in the UK to provide consistent base data for the evaluation of the CSS Bridge Condition Indicators (Ref. 2).

1.2 The inspection reporting system is intended for use by highway authorities for all Local Authority owned bridges on the adopted road network. A bridge is defined in a previous CSS Report (Ref. 3) as a structure with a span of 1.5m or more and includes subways, culverts, footbridges, tunnels and underpasses.

1.3 Guidance is also provided on applying the inspection reporting system to retaining walls, which are defined in Ref. 3 as all walls irrespective of height whose dominant function is to act as a retaining structure. Retaining walls should be inspected in a similar manner to bridges except that only the elements listed in Section 4.17 are relevant.

BACKGROUND

1.4 Bridges are essential components of the UK transport infrastructure and their safety and serviceability is therefore vital to the smooth functioning of the transport network. Society expects and perceives bridges to be safe, and the fact that there have been no cases of catastrophic bridge failures in recent years owes largely to the skill and ability of professional bridge engineers and managers. However, to maintain the continuing safety and serviceability of bridges, adequate funding needs to be made available for maintenance (i.e. inspection, testing, repair and replacement work).

1.5 Reviews by the CSS (Ref. 3 and 4) identified:

- A significant backlog of bridge maintenance in the UK.
- Inadequate current levels of expenditure on bridge maintenance.

- The condition of bridges will continue to deteriorate unless funding is significantly increased in the future to clear the backlog of works.

1.6 The CSS review concluded that in order to effectively maintain and manage the stock of bridges it is essential to have a "Condition Indicator" which can be used to determine whether the overall condition of highway bridges is deteriorating or not, and use this as a means for monitoring whether adequate funding is being provided for bridge maintenance.

1.7 There are a wide variety of inspection reporting systems used in the UK e.g. severity/extent (BE11), Good/Fair/Poor and condition scales specific to Authorities. To aid, and ease, the implementation of Bridge Condition Indicators a consistent inspection reporting system is needed.

OBJECTIVES

1.8 This Guidance Note recommends a common procedure for reporting bridge inspection results. This is not a guide for performing bridge inspections nor does it offer guidance on the scope and periodicity of inspections. Standardisation of bridge inspection reporting will, in general, provide a higher degree of accuracy and consistency between inspectors and Authorities.

1.9 This Guidance Note presents a new inspection pro forma and assists the inspector in completing it. Guidance is provided on the classification of bridge elements, defect type and reporting of severity and extent of damage. (The new inspection pro forma is not a standard form, Authorities may alter/adopt it to suit their particular needs provided they continue to collect the data identified as essential to the evaluation of BCIs, see Ref. 2).

1.10 This inspection reporting system will provide the base data for the evaluation of Bridge/Stock Condition Indicators intended for monitoring the change in condition over time.

SCOPE

1.11 This Guidance Note covers the majority of bridge types found in the UK.

1.12 The bridge elements selected for condition reporting should cover the majority of elements currently used by Authorities in their inspection reporting systems. Additional guidance is provided where "equivalent" terms are used by some Authorities instead of the element descriptions given herein.

1.13 Detailed guidance is provided for the classification of severity, extent and defect type, while the classification for "work required", "work priority" and "estimated cost of work" is left for the individual Authorities to define.

1.14 The inspection pro forma is intended for use with General and Principal Inspections. When test data, for example half-cell values, chloride levels, etc. are available, they should be used by the inspectors to aid the identification of appropriate severity and extent levels for the bridge elements.

GENERAL AND PRINCIPAL INSPECTIONS

1.15 The inspection pro forma should be completed during General and Principal Inspections.

General Inspection: visual inspection, possibly with some hands-on and basic assessment e.g. hammer tapping and measurements.

Principal Inspection: visual inspection with hands-on assessment of most/all elements plus detailed assessment e.g. hammer tapping, half-cell, chloride measurements etc. Detailed data can then be used to assist the inspector in assigning element Severity and Extent levels.

1.16 After a General Inspection it is normal that only the pro forma is completed. After a Principal inspection a detailed report is normally compiled, however the pro forma should still be completed to evaluate the Condition Indicators (Ref. 2).

2. INSPECTION PRO FORMA

2.1 The inspection pro forma is shown in Appendix A. The pro forma covers both sides of an A4 page and should be used thus. The pro forma may also be used for retaining walls, see Section 4.17.

2.2 The pro forma can be used to report element conditions separately for each span or for all the spans of a bridge taken together. Although the former approach is to be preferred, the choice is left to the individual Authorities. A combination of span by span reporting and overall bridge reporting may be used within the same bridge stock. Guidance on reporting for a bridge that has been widened using a different construction type to the original bridge is provided in Section 3.

2.3 The following sections introduce the various fields and terminology used in the inspection pro forma. Definition of the terms used for the following fields on the pro forma is left to individual Authorities.

- 'W' (work) column
- 'P' (priority) column
- 'Cost' column; and
- 'Work required' table.

These items are included so the pro forma covers all the requirements of inspectors and maintenance engineers.

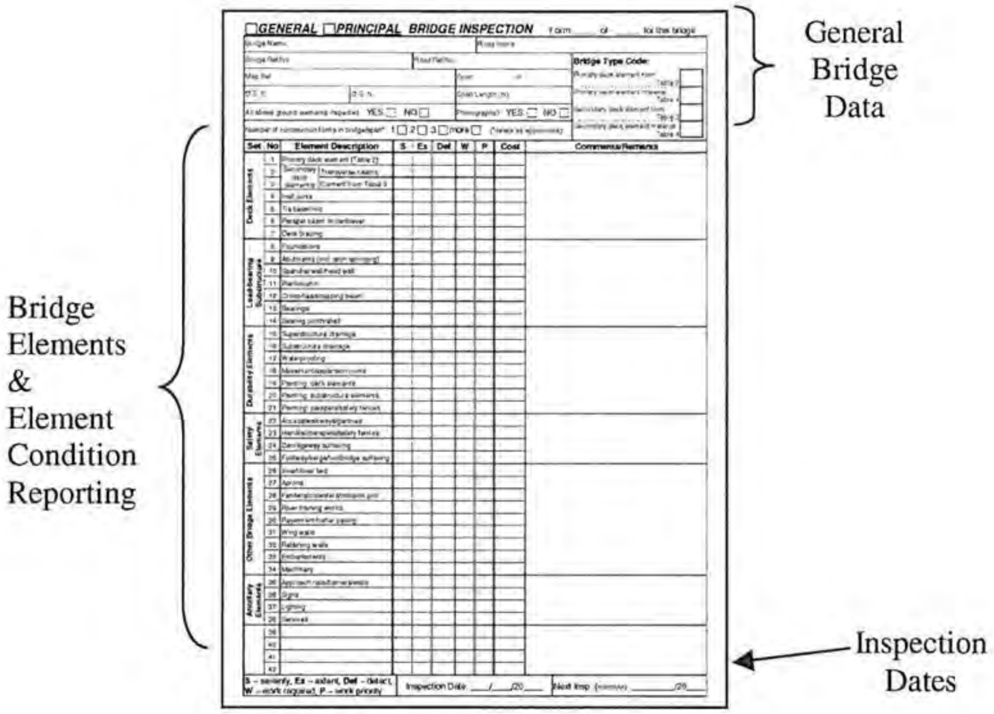
LAYOUT OF THE INSPECTION PRO FORMA

2.4 The layout of the inspection pro forma is shown in Figure 1. The inspection pro forma is divided into the following areas:

1. General Bridge Data (Section 3). This area of the pro forma is for recording general information about a bridge such as bridge name, road name, O.S. grid reference, number of spans, span length, Bridge Type Code, etc.
2. Bridge Elements (Section 4). This area of the pro forma lists all the bridge elements for which a condition score needs to be recorded.

3. Element Condition Reporting (Section 5). This information is recorded on the pro forma for each bridge element, with separate columns for 'Severity', 'Extent' and 'Defect Type'.
4. The 'Work Required', 'Work Priority' and 'Cost of Work' may also be recorded against each element.
5. Inspection Dates.
6. Comments (Section 6). Space is provided on the pro forma for the Inspector and Engineer to record their comments.
7. Work Required and Signing Off (Section 6).

2.5 The pro forma presented herein identifies data fields that enable the creation of a comprehensive bridge database; however, as stated in Section 1.9, the pro forma is not a standard form and may be altered to the needs of individual Authorities. The data fields that are mandatory and must not be altered are the Bridge Type Code (from No. 1 above), the element list (No. 2) and the element condition (Severity and Extent from No. 3). The other data fields may be altered to suit individual Authority needs but it is recommended they form the minimum data collection requirements.



Front Page

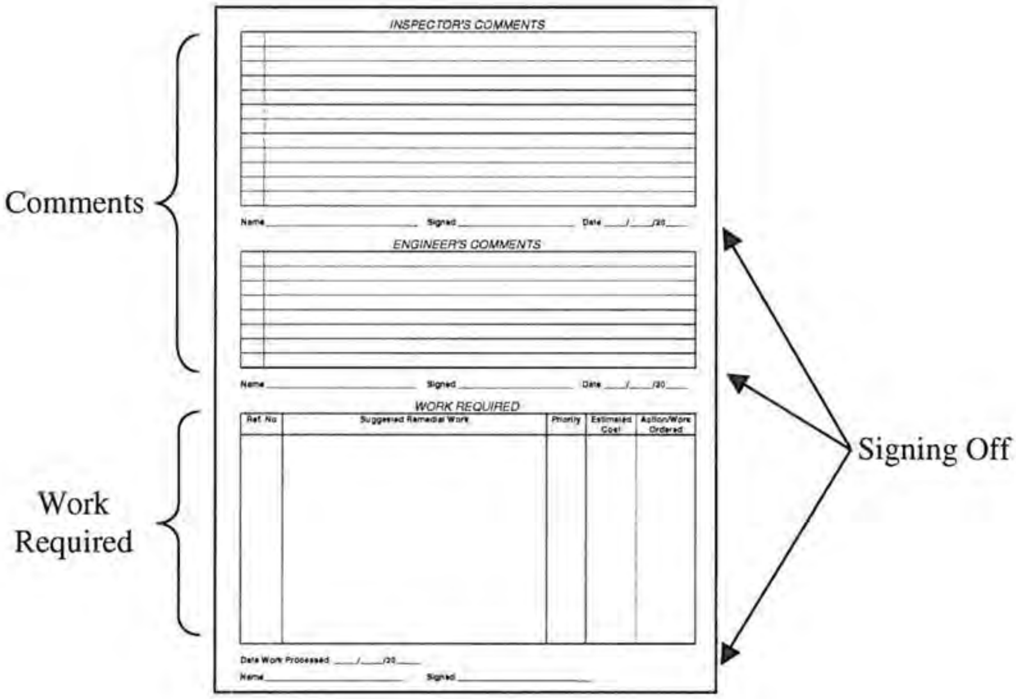


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Figure 1 Inspection pro forma layout

3. GENERAL BRIDGE DATA

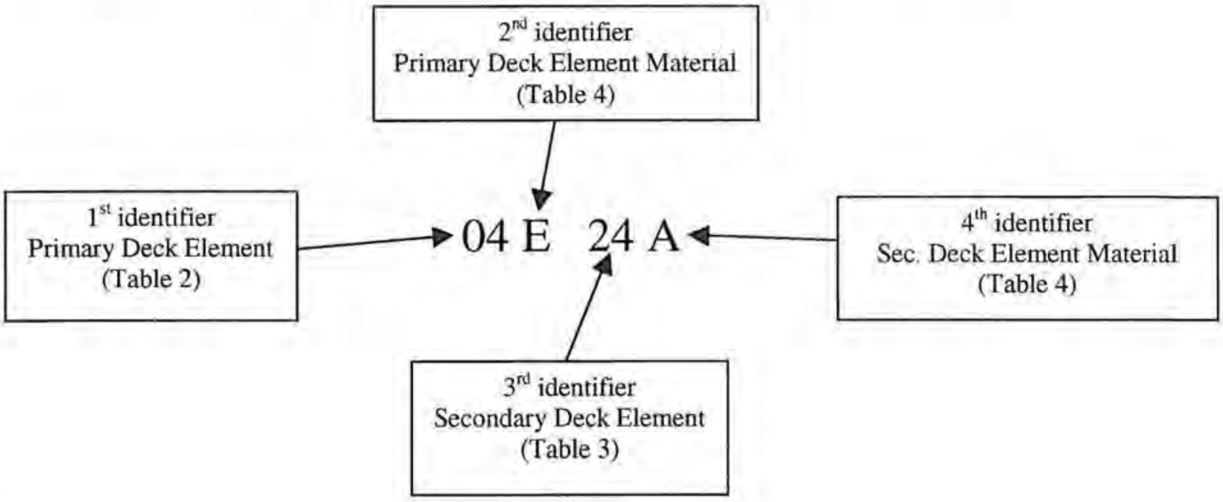
3.1 The data required in this area of the pro forma are described in Table 1.

FIELD	DECRIPTION OF DATA REQUIRED
Form *x* of *n* for this bridge	Used to keep account of the number of inspection pro forma used for a bridge i.e. separate pro forma may be completed for different spans and/or different construction types within a span. *x* refers to this pro forma and *n* to the total number of pro forma used for this bridge.
Bridge Name	The name used for the bridge in the Authority's records.
Road Name	The name used for the road in the Authority's records.
Bridge Ref/No	Bridge reference used in the Authority's records.
Road Ref/No	Road reference used in the Authority's records.
Map Ref	Reference of map that O.S. readings are taken from.
O.S. E	Ordnance Survey grid reference, Easting.
O.S. N	Ordnance Survey grid reference, Northing.
Span *x* of *n*	Only needs to be filled in when individual spans are reported on separate pro forma. When spans are reported separately *n* represents the total number of spans for the bridge and *x* represents which span the form relates to e.g. *Span 2 of 4* refers to the second span of a four span bridge.
Span Length (m)	Used to report span length when one pro forma is used per span of a multi span bridge, otherwise may be ignored. Some Authorities may wish to collect bridge span data for all their structures if this does not exist in their records.
All above ground elements inspected	Used to determine if the inspection covered all above ground bridge elements. The inspectors should tick the "NO" box if they are unable to survey all above ground elements due to difficulty access, obstruction by vegetation etc. An appropriate comment must be made on the pro forma when an element cannot be inspected and NI (Not Inspected) recorded in the Severity or Extent column. Guidance is provided in Ref. 2 as to how this information may be used.
Photographs?	Questioning if photographs were taken during the inspection. The inspector's comments must describe which elements/bridge views were photographed.
Number of construction…	Many bridges have different construction types within, or between spans. See section on **Multiple Construction Types** (3.4 to 3.8)
Bridge Type Code	Describes the structural form of the bridge, see section on **Bridge Type Code** (3.2 and 3.3)

Table 1 Definition of General Bridge Data Fields

BRIDGE TYPE CODE

3.2 There are a wide variety of bridge types in the UK, the major differences typically being between deck forms. The bridge type here is defined using a 4-key code combining the primary and secondary deck elements and their material as illustrated below (see Sections 4.5 to 4.13 for element type and material lists).



Examples

3.3 Examples of Bridge Type Code are shown below:

04E 24A - a bridge composed of a reinforced concrete deck slab supported by longitudinal steel beams.

01K 20P - solid spandrel brick arch.

10E 32E – full through steel truss with a flat steel plate deck and transverse beams.

MULTIPLE CONSTRUCTION TYPES

3.4 Some bridges can have more than one construction type, normally due to road widening, but also due to different construction types used on different spans of a multi-span bridge or within a span. When a bridge has more than one construction type a separate inspection form should preferably be used for each type if merited by the total number of elements related to it, see Section 3.7 and 3.8.

3.5 The inspector must tick the relevant box in the "Number of Construction Forms" field to indicate how many are on the bridge. The inspector must clearly state on the pro forma (e.g. in Bridge Name field and Comments field) which construction type, and part of the bridge/span, the pro forma relates to e.g. original bridge, road widening, footpath widening etc.

3.6 When more than one construction type exists it is the responsibility of the inspector to decide which elements should be recorded on each pro forma. The following recommendations are made:

- The first pro forma for a bridge/span should be for the original construction type and include all substructure, durability, safety etc., elements relevant to it.
- Each additional pro forma should report on one other construction type. The inspector should also attempt to distinguish which other bridge elements belong to the modification/widening e.g. abutments, drainage etc., and report these on the same pro forma.

3.7 When the construction type of a bridge changes from one span to the next separate pro forma are preferable and merited because it is relatively easy to distinguish which elements correspond to which construction type. When there is more than one construction type within a span it is generally more difficult to distinguish which elements correspond to each type.

3.8 When there is more than one construction type in a single span a separate pro forma is preferable if five or more elements can be distinguished for each type. Otherwise the inspector should record a combined element condition on one pro forma for an element present on more than one construction type in the span. Additional guidance on recording a combined primary or secondary deck element condition when they are present in more than one construction type is provided in Sections 4.6 and 4.11 respectively.

4. BRIDGE ELEMENTS

GENERAL

4.1 The pro forma contains 38 pre defined bridge elements (see Appendix A) categorised into: Deck Elements, Load-bearing Sub-Structure Elements, Durability Elements, Safety Elements, Other Bridge Elements and Ancillary Elements.

4.2 The form of the primary and secondary deck elements are defined using codes to minimise the number of elements listed on the inspection pro forma. These codes, along with the primary and secondary deck element material type codes, are used to define the Bridge Type Code (see Section 3.2 on Bridge Type Code).

4.3 The primary deck elements are denoted using the codes defined in Table 2, while the secondary deck elements are denoted using the codes defined in Table 3. Material type codes are defined in Table 4.

4.4 The element list shown on the pro forma does not cover all the terms, or element types, currently used by Authorities. Appendix B provides tables of "equivalent elements" that relate other element types/terms to those used on the pro forma.

PRIMARY DECK ELEMENTS (OR SPAN PRIMARY STRUCTURAL FORM)

4.5 The Primary Deck Element is No. 1 on the inspection pro forma (see Appendix A) and is denoted using the codes defined in Table 2. This identifies the form of the structural elements spanning in the longitudinal direction. Figure 2 illustrates <u>some</u> of the bridge types and primary elements covered in Table 2. A "00" code denotes a retaining wall.

4.6 Some bridges contain more than one of the primary deck element types shown in Table 2 on an individual span. Section 3.8 recommends a separate pro forma for a construction type if five or more elements can be distinguished for it. When there are less than five elements for a construction type, or if the Authority does not wish to report construction types separately, the condition score of the different primary deck element types should be recorded separately on the same pro forma (i.e. utilising the blank rows, 39 to 42, on the pro forma).

4.7 The dominant (by area, length or number, which ever is most appropriate) primary deck element should be used in the BTC and its condition recorded in row No. 1 of the pro forma. The blank rows, 39 to 42, on the pro forma should be used to report the condition of the other primary deck elements. The inspectors comments must clearly state if an element is a primary deck element so it can be appropriately included in the Condition Indicator calculations (guidance on this is provided in Ref. 2). The inspector should also record the approximate deck area (or proportion of deck area) served by each different primary deck element type (the proportion may be based on length or number as appropriate).

Table 2 Primary Deck Element Codes

Span Structural Form (Primary Deck Element)		Code
Retaining Wall	All types	00
Arch	solid spandrel	01
	open/braced spandrel	02
	tied (including hangers)	03
Beam/Girder	at/below deck surface	04
	box beams (exterior & interior)	05
	half through	06
	filler beam	07
Truss	at/below deck surface (underslung)	08
	half through	09
	full through	10
Slab	solid	11
	voided	12
Culvert/pipe/subway	circular/oval	13
	box	14
	portal/U-shape	15
Troughing		16
Cable stayed/suspension		17
Tunnel		18
Other		19
Multiple Construction Types		MC

Multiple Construction Types: may be used where there is more than one primary structural form within a bridge/span, see Section 3 on Multiple Construction Types for further guidance. However, it is recommended that a separate pro forma is used for each construction type.

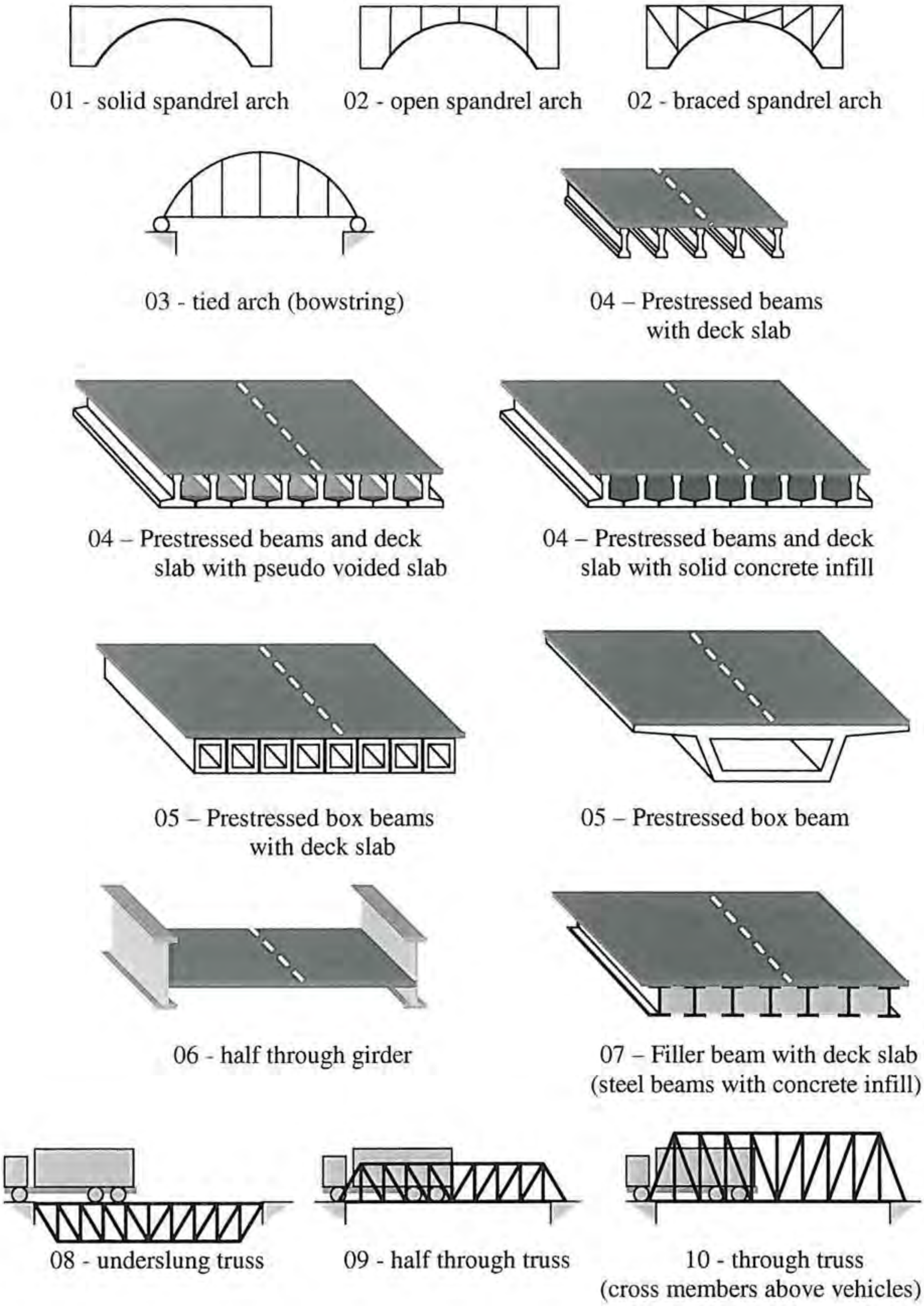


Figure 2 Schematic of Bridge Types and Primary Deck Elements

SECONDARY DECK ELEMENT

4.8 Secondary Deck Elements are recorded in row No.'s 2 and 3 on the inspection pro forma (Appendix A). These are denoted using codes defined in Table 3 which identifies the form of the structural elements spanning transversely between primary elements. On some bridges secondary deck elements may not be present, e.g. arch bridges, a code of "20" or "30" signifies "no secondary deck element", the code used depends on whether or not transverse beams are present. No secondary deck element code is required for retaining walls.

Table 3 Secondary Deck Element Codes

Secondary Deck Element	Code	
	No Transverse Beams	Transverse Beams
No secondary deck element	20	30
Buckle Plates	21	31
Flat Plate	22	32
Jack Arch	23	33
Slab	24	34
Troughing	25	35
Other	26	36

4.9 Transverse beams are a very common type of secondary deck element and have been assigned their own row on the inspection pro forma (row No. 2 on the pro forma in Appendix A). If transverse beams are not present codes 20 to 26 are used in the Bridge Type Code, when transverse beams are present codes 30 to 36 are used in the Bridge Type Code.

4.10 When transverse beams are present the elements given in Table 3 are sometimes called "tertiary" deck elements; if transverse beams are not present they are called "secondary" deck elements. For simplicity, and consistency, they are called "secondary" deck elements throughout this document whether transverse beams are present or not.

4.11 Some bridges contain more than one of the secondary deck element types shown in Table 3 on an individual span. Section 3.8 recommends a separate pro forma for a construction type if five or more elements can be distinguished for it. When there are less than five elements to a construction type, or if the Authority does not wish to report them separately, the condition score of the different secondary deck element types should be recorded separately on the same pro forma (i.e. utilising the blank rows, 39 to 42, on the pro forma).

4.12 The dominant (by area, length or number, which ever is most appropriate) secondary deck element should be used in the BTC and its condition recorded in row No. 3 of the pro forma. The blank rows, 39 to 42, on the pro forma should be used to report the condition of the other secondary deck elements. The inspectors comments must clearly state if an element is a secondary deck element so it can be appropriately included in the Condition Indicator calculations (guidance on this is provided in Ref. 2). The inspector should also record the approximate deck area (or proportion of deck area) served by each different secondary deck element type (the proportion may be based on length or number as appropriate).

MATERIAL TYPE

4.13 The material type code of the primary and secondary deck elements is also used in defining the Bridge Type Code. The Material Type codes are given in Table 4.

Table 4 Material Type Code

Material		Code
Concrete	reinforced	A
	plain/mass	B
	post-tensioned	C
	pre-tensioned	D
Metal	steel	E
	cast iron	F
	wrought iron	G
	aluminium	H
	corrugated steel	I
	corrugated aluminium	J
Masonry	brick	K
	stone	L
FRP/GRP/Composite		M
Timber		N
No secondary element → no material		P
Other		Q

*Letter O not used, avoids confusion with zero "element type" codes

MULTIPLE ELEMENTS

4.14 If one element description on the pro forma covers several equivalent elements (Appendix B) then the condition reporting should take the condition of all of these into account.

4.15 The following situations are covered by one element description and one condition score on the pro forma:

- Multiple elements of one type e.g. longitudinal beams, transverse beams, pier/column etc.
- Elements repeated over several spans if the whole bridge is reported on one pro forma e.g. primary deck elements, abutments, invert/river bed etc.
- Element descriptions on the pro forma that cover several element types e.g. the primary deck element description on the pro forma covers arch barrel and voussoirs for a masonry arch bridge.
- "Elements" that were previously treated as separate items by some Authorities e.g. pointing is now included in masonry severity description, vegetation is covered by severity descriptions, welds are covered by metalwork severity descriptions etc. Severity descriptions are covered in Section 5.

BLANK ROWS

4.16 Four blank rows, 39 to 42, are provided on the pro forma. These may be used for any elements that are not covered by the pro forma if the inspector regards it as important to report the condition of these elements, e.g. third party elements, fire equipment, telecommunications, smoke detectors, one-off element types, decorative elements, etc. However, it is recommended that every effort is made to report the complete bridge condition using the element descriptions already provided on the pro forma. Any additional elements added to the pro forma will not be included in the evaluation of the Condition Indicators (Ref. 2) unless as specified in Section 4.6 and 4.11.

RETAINING WALLS

4.17 The elements that should be reported on when inspecting a retaining wall are shown in Table 5. A code is provided in Table 2 to identify a structure as a retaining wall and Table 4 is used to identify the material type, thus the Bridge Type Code (BTC) box on the pro forma is also used for retaining walls.

Table 5 Retaining Wall Elements

Pro Forma No.	Element Description	Comment
8	Foundations	-
16	Substructure drainage	Covers all wall drainage
18	Movement/Expansion joints	-
20	Painting – substructure elements	Covers all painting
23	Parapets	
24	Carriageway surfacing	Supported by wall
25	Footway/verge surfacing	Supported by wall
26	Invert/river bed	If watercourse alongside wall
27	Aprons	If watercourse alongside wall
32	Retaining wall	Table 3 used to define material
35	Approach rails/barriers/walls	-
36	Signs	-
37	Lighting	-
38	Services	-

5. ELEMENT CONDITION REPORTING

SEVERITY AND EXTENT CODES

5.1 The condition of a bridge element is recorded in terms of the Severity of damage/defect and the spatial Extent of the damage/defect. The codes used to describe the Extent and Severity levels are shown in Table 6 and Table 7, respectively, where:

Extent:	The area, length or number (as appropriate) of the bridge element affected by the defect/damage.
Severity:	The degree to which the defect/damage affects the function of the element or other elements on the bridge.

Table 6 Extent Codes

Code	Description
A	No significant defect
B	Slight, not more than 5% of surface area/length/number
C	Moderate, 5% - 20% of surface area/length/number
D	Wide: 20% - 50% of surface area/length/number
E	Extensive, more than 50% of surface area/length/number

Table 7 Generic Severity Descriptions

Code	Description
1	As new condition or defect has no significant effect on the element (visually or functionally).
2	Early signs of deterioration, minor defect/damage, no reduction in functionality of element.
3	Moderate defect/damage, some loss of functionality could be expected
4	Severe defect/damage, significant loss of functionality and/or element is close to failure/collapse
5	The element is non-functional/failed

5.2 Permissible combinations of Severity and Extent are shown in Table 8. This shows that some severity/extent combinations are not permissible, namely 2A, 3A, 4A and 5A. These combinations are not permitted because it is not feasible to have a Severity condition greater than 1 with an Extent description of "no significant defect".

Table 8 Permissible combinations of Severity and Extent

Extent	Severity				
	1	**2**	**3**	**4**	**5**
A	1A				
B	1B	2B	3B	4B	5B
C	1C	2C	3C	4C	5C
D	1D	2D	3D	4D	5D
E	1E	2E	3E	4E	5E

5.3 More detailed guidance on severity descriptions for different construction material and defect types is presented in Appendix C. These descriptions do not cover all element or defect types but provide general guidance on the identification of severity states. Many of the severity states in Appendix C contain a number of descriptions for each item e.g. metalwork has five possibilities in severity state 3. The element condition only needs to satisfy one of these possibilities to be categorised as severity state 3.

5.4 Appendix D provides photographic examples of some of the defects described in Appendix C.

Multiple Defects on an Element

5.5 When an element has more than one type of defect/damage, the following guidelines should be used to assess its condition.

1. Dominant Defect is Present:

Severity	When the severity of one defect is adjudged to be at least one severity category higher (Appendix C) than any other defect on the element, the Severity for the element is defined based on this dominant defect, **AND** Other defects do not reduce the functionality of the element beyond that caused by the dominant defect.
Extent	The extent code in this case should correspond to the area affected by the dominant defect alone.

2. Interacting Defects, or No Dominant Defect Present:

Severity	Where the cumulative effect of several defects is adjudged to be the same as, or worse than, the effect of the dominant defect then the severity code should be reported based on the cumulative effect of all the defects on the element, **OR** Where no dominant defect is evident, the severity should be based on the cumulative effect of the defects the inspector feels are relevant.
Extent	The extent code in this case should correspond to the area affected by all defects considered in assessing the severity.

5.6 The inspector should record the worst condition for the element at all times from either dominant or interacting defects.

5.7 The dominant and interacting defects are described in terms of the damage to a single element. The same guidelines also apply when assessing the condition of multiple elements. For example, if one primary beam, out of a total of 10, has a severity of 4 and all the others are 2 then the severity recorded is 4 and the extent recorded is C (i.e. 10% of elements), giving a condition of 4C. However, if all the beams were in condition 2 then the extent category would be E, giving a condition of 2E.

5.8 Some examples of interacting defects are shown in Table 9.

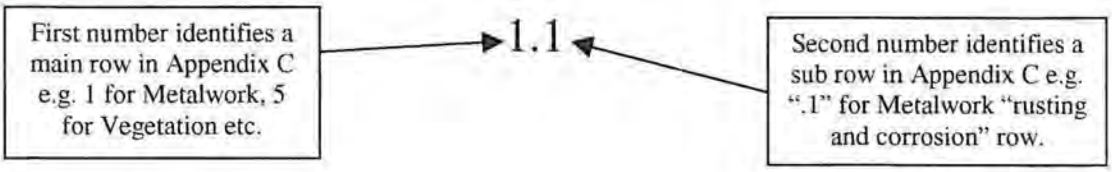
Table 9 Examples of Interacting Defects

	Element	Individual Defects	S/Ex	Interacting Effect	S/Ex
1	RC Abutment	10% of concrete spalled, general corrosion of steel	3C	Extent increases; Severity does not increase, abutment is generally in compression therefore anchorage of steel not critical	3D
		15% delaminated (signifies corrosion of underlying steel)	3C		
2	RC Beam	10% of concrete spalled, general corrosion of main tensile steel	3C	Extent increases; Severity also increases because anchorage of the tensile steel is critical to the functionality of the element.	4D
		15% of main tensile steel cover delaminated	3C		
		Cracking parallel to tensile reinforcement	3B		
3	Masonry Arch	Arch ring separation (<25mm)	3E	Extent already maximum of E; Severity increases because all defects interrupt the load path and together have a significant influence on functionality.	4E
		10 to 25mm of pointing lost	3E		
		Pockets of bricks missing and loose	3C		
4	Masonry Retaining Wall	Few bricks missing at base of retaining wall	3B	Extent is low due to small area of wall damaged; Severity increased because stability of bulge is directly influenced by missing bricks	4B
		Moderate bulging above missing bricks	3B		
5	Metal beam	Slight corrosion of girder weld run between web and bottom flange at mid span	2B	Extent stays the same; Severity increases because the corrosion is concentrated at the critical section of the member	3B
		Minor section loss of flange and web cross section at mid span	2B		

DEFECT CODE

5.9 The Defect code helps in the identification of Work Required, Priority and Cost. This also provides valuable information about defect types, their frequency of occurrence and cost of repairs. The defect type is not used for the evaluation of Bridge Condition Indicators.

5.10 When the observed defect relates to a defect described in Appendix C the appropriate reference should be recorded in the defect column of the pro forma. The defect code is recorded as:



5.11 The severity code is not used in the defect code because it is reported for the elements in the severity column on the pro forma. If the defect is not covered by the codes in Appendix C then a description should be entered in the comment box.

5.12 The inspector should record the most relevant or dominant defect. If other defects are also felt to be appropriate to work requirements (type, priority and cost) then their code/description should be entered in the comments column.

6. OTHER AREAS OF THE INSPECTION PRO FORMA

COMMENTS

6.1 Space for comments is provided on the front and back of the pro forma. Comments should be used by the inspector to provide additional information that will be beneficial to the engineer and for the development of a computer database e.g.

- Clearly define if the bridge has several construction types.
- Descriptions of defects not covered in Appendix C or D, these can be used to update and improve future Guidance Notes.

6.2 Space is also provided for the engineer to add his/her comments to the pro forma. This may include an assessment of the overall condition of the bridge.

WORK REQUIRED

6.3 Space is provided for identifying work required. The details of the information to be recorded in this area are not covered in this document and should be defined by individual Authorities.

SIGNING OFF

6.4 The inspector, engineer and data processing personnel must print their name, sign and date the pro forma in the appropriate sections.

6.5 The signing of the pro forma is essential for future reference and traceability.

7. BRIDGE SPECIFIC PRO FORMA

7.1 The electronic version of the bridge inspection pro forma is available from the CSS (contact details provided in Section 8) and can therefore be tailored to produce a bridge specific inspection pro forma. Bridge specific pro forma will improve the overall accuracy, consistency and speed of bridge inspection reporting.

7.2 It is recommended that the generic pro forma (Appendix A) is used to perform the first inspection on all bridges. After the inspection, the data collected should be used to create a bridge specific pro forma comprising:

- All the general bridge data and bridge type code.
- Actual names of primary and secondary element types on the bridge (No's 1 and 3 on the pro forma) taken from Table 2 and Table 3.
- Only element types relevant to that bridge, with the rest deleted or their fields blanked-out.

7.3 For future inspections the inspector will also be able to take the previous inspection report, thus enabling comparison with the previous element conditions.

8. ENQUIRIES

An Microsoft Word version of the inspection reporting pro forma is available from:

Mr Greg Perks
Principal Transport Policy Officer
Northumberland County Council
Environment Directorate
County Hall
Morpeth
NE61 2EF

Telephone: 01670 533973
Fax: 01670 533086
E-mail: GPerks@northumberland.gov.uk

9. REFERENCES

1. Bridge Condition Indicators Volume 1: Commission Report, CSS Bridges Group, April 2002.

2. Bridge Condition Indicators Volume 3: Guidance Note on the Evaluation of Bridge Condition Indicators, CSS Bridges Group, April 2002.

3. Funding for Bridge Maintenance, CSS Bridges Group, February 2000.

4. The CSS Review, ICE Seminar on Bridge Rehabilitation in the UK, October 2000.

APPENDIX A

INSPECTION PRO FORMA

☐GENERAL ☐PRINCIPAL BRIDGE INSPECTION Form _____ of _____ for this bridge

Bridge Name:		Road Name:	
Bridge Ref/No:	Road Ref/No:		**Bridge Type Code:**
Map Ref:		Span of	Primary deck element form Table 2 ☐
O.S. E	O.S. N	Span Length (m):	Primary deck element material Table 4 ☐
All above ground elements inspected: YES ☐ NO ☐		Photographs? YES ☐ NO ☐	Secondary deck element form Table 3 ☐
Number of construction forms in bridge/span*: 1 ☐ 2 ☐ 3 ☐ more ☐ (*delete as appropriate)			Secondary deck element material Table 4 ☐

Set	No	Element Description	S	Ex	Def	W	P	Cost	Comments/Remarks
Deck Elements	1	Primary deck element (Table 2)							
	2	Secondary deck element/s: Transverse beams							
	3	Secondary deck element/s: Element from Table 3							
	4	Half joints							
	5	Tie beam/rod							
	6	Parapet beam or cantilever							
	7	Deck bracing							
Load-bearing Substructure	8	Foundations							
	9	Abutments (incl. arch springing)							
	10	Spandrel wall/head wall							
	11	Pier/column							
	12	Cross-head/capping beam							
	13	Bearings							
	14	Bearing plinth/shelf							
Durability Elements	15	Superstructure drainage							
	16	Substructure drainage							
	17	Water proofing							
	18	Movement/expansion joints							
	19	Painting: deck elements							
	20	Painting: substructure elements							
	21	Painting: parapets/safety fences							
Safety Elements	22	Access/walkways/gantries							
	23	Handrail/parapets/safety fences							
	24	Carriageway surfacing							
	25	Footway/verge/footbridge surfacing							
Other Bridge Elements	26	Invert/river bed							
	27	Aprons							
	28	Fenders/cutwaters/collision prot.							
	29	River training works							
	30	Revetment/batter paving							
	31	Wing walls							
	32	Retaining walls							
	33	Embankments							
	34	Machinery							
Ancillary Elements	35	Approach rails/barriers/walls							
	36	Signs							
	37	Lighting							
	38	Services							
	39								
	40								
	41								
	42								

S – severity, **Ex** – extent, **Def** – defect, **W** – work required, **P** – work priority	Inspection Date: ___/___/20___	Next Insp. (month/yr) ________/20___

INSPECTOR'S COMMENTS

Name______________________________ **Signed** _______________________ **Date** ____/____/20____

ENGINEER'S COMMENTS

Name______________________________ **Signed** _______________________ **Date** ____/____/20____

WORK REQUIRED

Ref. No	Suggested Remedial Work	Priority	Estimated Cost	Action/Work Ordered

Date Work Processed ____/____/20____

Name______________________________ **Signed** __________________________

APPENDIX B

EQUIVALENT ELEMENTS

Table B1 Equivalent Elements

No.	ELEMENT DESCRIPTION	EQUIVALENT ELEMENTS
1	Primary deck element	Main Beams
		Truss members
		culvert
		Arch Arch Ring Vousoirs/Arch Face Arch Barrel/Soffit
		Encased Beams
		Subway
		Box beam interiors
		Armco/Concrete pipe
		Pottal/Tunnel portals
		Prestressing
		Sleeper bridge
		Tunnel Linings
2	Transverse Beams	
3	Secondary deck element	Concrete deck slab
		Timber deck
		steel deck plates
		Jack Arch
		Troughing
		Stone slab (or primary member)
		Troughing Infill
		Buckle plates
4	Half joints	
5	Tie beam/rod	
6	Parapet beam or cantilever	Edge Beams
7	Deck bracing	Diaphragms
8	Foundations	Piles
9	Abutments (incl. arch springing)	Arch Springing
		Abutment slope
		Bank seat
		Counterfort/Buttresses
10	Spandrel wall/head wall	Stringcourse
		Coping
11	Pier/column	
12	Cross-head/capping beam	
13	Bearings	
14	Bearing plinth/shelf	
15	Superstructure drainage	
16	Substructure drainage	Subway drainage
		Retaining wall drainage
17	Water proofing	
18	Movement/expansion joints	Sealants
19	Painting: deck elements	Sealants
		Decorative Appearance
20	Painting: substructure elements	Sealants
		Decorative Appearance

Table B1 Equivalent Elements (cont.)

21	Painting: parapets/safety fences	Sealants
		Decorative Appearance
22	Access/walkways/gantries	Steps
23	Handrail/parapets/safety fences	Balustrade
		Barrier
24	Carriageway surfacing	Ramp Surface
		Approaches
25	Footway/verge/footbridge surfacing	
26	Invert/river bed	Channel bedstones
27	Aprons	
28	Fenders/cutwaters/collision prot.	Flood Barrier
29	River training works	
30	Revetment/batter paving	
31	Wing walls	Newel
32	Retaining walls	Counterfort/Buttresses
		Gabions
		Wall
33	Embankments	Approach Embankments
		Side slopes
34	Machinery	
35	Approach rails/barriers/walls	Posts
		Remote approach walls
36	Signs	
37	Lighting	Subway Lighting
		Primary Lighting
		Secondary Lighting
38	Services	Manholes
		Pipes
		Mast

Table B2 Other Element Relationships

OTHER ELEMENTS	COVERED BY
Pointing/Arch mortar	severity description No. 3
Condition of Masonry/Brickwork	severity description No. 3
Masonry/Brickwork	severity description No. 3
Vegetation	severity description No. 5
Decorative Appearance	severity description No. 4
Cleanliness	Various severity descriptions
Dry Stone Wall & other walls	Corresponds to 9, 10, 11, 23, 31, 32 or 35 on the pro forma, depending on function and location
Scour	severity description No. 6 & 7
Finishings	Various severity descriptions
Corrugated metal	material codes
Leakage	severity descriptions No. 8, 10 and 14
Rivets and bolts	severity descriptions No. 1
Welds	severity descriptions No. 1
Arch cracks and deformation	severity descriptions No. 3
Fillets and Haunching	Reported with element they are part of

APPENDIX C

SEVERITY DESCRIPTIONS

No	Item		Severity				
			1	2	3	4	5
1	Metalwork	.1	No signs of rusting or damage	Minor rusting (surface/general corrosion)	Rusting and pitting (localised corrosion)	Deep pits and perforations (localised sever corrosion)	Disintegrated by corrosion mechanisms
		.2	No loss of section thickness	Minor section loss (penetration less than 5% of section)	Moderate section loss causing some reduction in functionality (penetration 5 to 20% of section thickness)	Major section loss causing significant reduction in functionality (penetration more than 20% of section)	Collapsed or collapsing
		.3	No signs of rusting or damage to bolts, nuts and rivets	Non structural bolts loose, minor corrosion of nuts and washers	Non structural bolts missing, moderate corrosion of rivet heads, nuts and washers	Structural bolts missing, rivets loose or missing, crack through bolt repair	Failure of element due to missed/failed bolts/rivets
		.4	No corrosion or damage of weld runs	Slight corrosion of weld run	Crack at toe of weld, reduction in size of weld, corrosion of weld run	Longitudinally cracked weld and possibility of internal weld corrosion	Weld connection failure (longitudinal crack)
		.5	Slight weathering	No pitting or perforation, surface impact damage	No perforations, moderate deformation due to impact	Major corrosion or impact deformation of metalwork	Failure due to excessive weathering and/or impact
2	Reinforced Concrete, Prestressed Concrete & Filler Joist	.1	Minor surface weathering and staining	Major surface weathering and weather staining	Leaching, rust and soil staining	Heavy leaching, rust staining from expansion/half joints	Disintegrated
		.2	No spalls	Minor localised spalls exposing shear links	Major localised spalls exposing shear links and main bars with general corrosion	Joined up, deep spalls exposing shear links and main bars with general and pitting corrosion	Collapsed
		.3	Hairline cracks, difficult to detect visually	Shrinkage cracks, thermal cracks and crazing in areas of low flexural behaviour (cracks less than 0.3mm)	Shrinkage/thermal cracks and crazing in areas of high flexure. Cracks approx. 1mm and easily visible	Wide/deep cracks (more than 2mm). Shear cracks.	Element unable to function due to structural cracks
		.4	No signs of damage to prestressing	Substandard grouting of ducts (may not be visible)	Cracks along line of prestressing duct	Exposed prestressing cables	Failed prestressing cables
		.5	No signs of delamination	Early signs of delamination e.g. cracks with rust staining	Delamination in areas of low flexural and/or shear action	Delamination in areas of high flexural and/or shear action	Failure due to delaminated bars
		.6	No signs of thaumasite or freeze-thaw attack	Slight cracking caused by thaumasite or freeze-thaw	Localised thaumasite or freeze-thaw attack	Extreme thaumasite or freeze-thaw attack	Failure due to thaumasite or freeze-thaw attack

No	Item		Severity 1	2	3	4	5
3	Masonry, Brickwork & Mass Concrete	.1	Minor surface weathering	Major surface weathering	Minor deformation	Moderate deformation	Major deformation
		.2	Pointing sound	Minor depth of pointing deteriorated	Moderate to significant depth of pointing lost, but does not appear to be rapidly disintegrating or crumbling, bricks not easily loosened	Pointing in very poor condition, severely weathered, crumbling to touch and/or significant depth loss, bricks easily loosened.	Collapsed
		.3	No arch ring cracking or separation	Arch ring cracks difficult to see	Arch ring separation (gap less than 25mm)	Arch ring separation (gap greater than 25mm)	Disintegrated
		.4	No arch barrel cracks	No diagonal cracks, longitudinal cracks less than 3mm wide, lateral cracks	Diagonal cracks, longitudinal cracks greater than 3mm wide	Diagonal cracks, longitudinal cracks breaking barrel into 1m sections or less	Arch barrel failure
		.5	No cracks	Minor hairline cracks and shallow spalls	Moderate cracks (easily visible, crazing) and deep localised spalls	Major cracks and spalling	Failure due to structural cracks
		.6	No bricks/masonry blocks missing	Few bricks/stones missing (no adjacent ones missing)	Moderate loss of bricks/stones	Sever loss of bricks/stones	Failure due to missing bricks/stones
		.7	No bulging, leaning or displacement	Minor bulging, leaning or displacement	Moderate bulging, leaning or displacement	Severe bulging, leaning or displacement	Collapsed or non functional
4	Paintwork and Protective Coatings	.1	Finishing coat sound, slight weathering	Normal weathering of finishing coat	Spot chips and cracks of finishing coat	Failure of finishing coat	All coats failed
		.2	Finishing coat sound, slight weathering	Normal weathering of finishing coat	Undercoat/substrate exposed but sound	Spot chips and cracks to undercoat/substrate	Protective coating not functioning
		.3	No material exposed	Not used: Material exposure is always Severity of 5			Material exposed
5	Vegetation	.1	Slight to no vegetation	Minor vegetation causing no structural damage (surface mosses, small grass and weeds)	Vegetation growth on or near bridge causing structural damage and/or deformation e.g. roots and branches of nearby trees, small tree/plants growing on structure	Vegetation growth on or near bridge causing major structural damage and/or deformation e.g. roots and branches of nearby trees, large tree growing on structure	Failure caused by vegetation growth or a tree collapsing on the structure
		.2	Slight to no vegetation	Low depth/density of vegetation cover, easily removed e.g. moss	Significant depth/density of vegetation, obscuring inspection e.g. ivy	Inspection of critical structural elements not possible due to density of vegetation e.g. ivy and root systems likely to be causing structural damage	Inspection impossible due to vegetation growth

No	Item		Severity				
			1	2	3	4	5
6	Foundations	.1	No visible settlement of structure	No visible settlement, but cracks that may be due to it	Minor settlement of structure	Major settlement of structure	Collapsed due to settlement
		.2	No visible differential movement of structure	No visible movement, but cracks that may be due to it	Minor differential movement of structure	Major differential movement of structure	Collapsed due to differential movement
		.3	No visible sliding of structure	No visible sliding, but cracks that may be due to it	Minor sliding of structure	Major sliding of structure	Collapsed due to sliding
		.4	No visible rotation of structure	No visible rotation, but cracks that may be due to it	Minor rotation of structure	Major rotation of structure	Collapsed due to rotation
		.5	No scour	Minor scour	Moderate scour	Major scour	Dangerous scour or failure
		.6	Substructure appears unaffected by foundation faults (assume no foundation faults)	Foundation faults causing minor cracks in substructure	Foundation faults causing moderate cracks in substructure	Foundation faults causing major cracks and deformation in substructure	Failure due to foundation faults
7	Invert, apron & river bed (also see 2 and 3)	.1	No scour	Minor scour	Moderate scour	Major scour	Dangerous scour or failure
		.2	No vegetation growth or silting	Vegetation growth, trapped debris and silting causing slight disruption to flow	Vegetation growth, trapped debris and silting significant disruption to flow causing faster flow in areas of the river	Vegetation growth, trapped debris and silting severe disruption to flow causing much faster flow in areas of the river	Failure caused by vegetation growth, trapped debris and silting
8	Drainage	.1	In sound condition and fully functional	Mostly functional (less than 25% of cross section blocked)	Part functional (25 to 50% of cross section blocked)	Mostly non-functional (more than 50% of cross section blocked)	Totally blocked/non-functional/broken
		.2	Causing no staining	Causing minor staining	Cleaning of staining required	Urgent cleaning required	Urgent & frequent cleaning
		.3	No structural damage	Causing minor structural damage	Causing structural damage	Causing major structural damage	Causing severe damage to adjacent elements
		.4	No blockage of weep holes, outlets	Minor blockage of weep holes, outlets	Moderate blockage of weep holes, outlets	Major blockage of weep holes, outlets	Non function weep holes (e.g. evident by spider's web at outlet)
9	Surfacing	.1	Little to no wear and weathering	Minor wear/weathering	Moderate wear/weathering	Major wear/weathering	Dangerous
		.2	No crazing, tracking or fretting	Minor crazing, tracking and/or fretting	Moderate crazing, tracking and/or fretting	Major cracks, tracking and/or fretting	Complete break up
		.3	Dense	Poor texture	Open texture	Very open texture	Dangerous
		.4	Sound	Cracks in top layer	Top layer breached	Deep cracks and potholes	Top layer completely missing

No	Item			Severity				
				1	2	3	4	5
10	Expansion Joints	Buried Joint	.0	Reasonably sound	Minor surfacing cracking	Moderate surfacing cracking	Major surfacing cracking	Failure
		Asphaltic plug	.1	Sound	Minor debonding between plug and road	Moderate debonding between plug and road	Major debonding between plug and road	Dangerous
			.2	Sound	Slight loss of surface binder and aggregate	Loss of aggregate (surface penetration 20 to 50mm)	Loss of material from joint (causing holes > 50mm deep)	Missing
			.3	Sound	Minor tracking and flow of binder	Moderate tracking and flow of binder	Major tracking and flow of binder	Disintegrated
		Nosing Defects	.4	Sound	Minor cracking along nosing	Moderate cracking along nosing, some break-up	Break-up of nosing material	Disintegrated
		Elastomeric and others	.5	Minor signs of wear	One bolt missing at cross section	Numerous bolts missing at cross section	Majority of bolts missing at a cross section	Failure due to missing bolts
			.6	Strip sealant sound	Strip sealant loose/poor, compression seal dropped and/or worn	Sealant breached, strip sealant breached	Sealant missing, strip sealant missing/out	Failure
			.7	Sound road surface adjacent to joint	Minor break up of road surface adjacent to joint	Moderate break up of road surface adjacent to joint, some debris in joint seal	Major break up of road surface adjacent to joint, significant debris in joint seal	Joint failure due to deteriorated condition of adjacent road surface
			.8	Sound fixings	Bolt sealer missing	Fixings loose	Fixings missing, plates and angles loose	Failure due to missing fixtures
			.9	Sealant for induced crack is sound	Minor cracking or break up of sealant for induced crack	Moderate cracking or break up of sealant for induced crack	Major cracking or break up of sealant for induced crack	Disintegrated or missing sealant for induced crack
11	Embankments		.1	Sound No deformation	Minor subsidence Minor deformation	Minor slip/settlement causing slight cracking of carriageway	Major slip/settlement causing major cracking of carriageway	Critical slip/settlement
12	Bearings (also see 1)		.1	Negligible rusting, minor Weathering	Minor Rusting, moderate weathering	Moderate rusting	Major rusting	Failed or seized due to rusting
			.2	Correct position	Minor offset	Moderate offset/tilt	Dislodged	Off bearing/missing
			.3	Sliding bearing in correct position	Sliding bearing in slightly skewed (off centre) position at normal temp	Sliding bearing at end of travel in normal temperatures	Sliding bearing beyond designed extent of travel at normal temperatures	Sliding bearing failed
			.4	No crazing	External crazing	External breakdown	Major breakdown (PTFE, laminations, rubber etc.)	Complete breakdown
			.5	Sliding plate sound	Minor deformation of sliding plate	Moderate deformation of sliding plate	Major deformation of sliding plate	Bearings seized by sliding plate deformations
			.6	Bearings sound	Minor cracks	Moderate cracks or loose	Splitting and deformation	Disintegrated

No	Item		Severity				
			1	2	3	4	5
13	Impact Damage	.1	No damage	Slight surface scoring, minor displacement of element e.g. marking and chipping of beam faces, several bricks across arch barrel width	Moderate displacement of element e.g. beam slightly offset on bearings, significant number of bricks knocked out across arch barrel width,	Severe displacement of element e.g. beam dislodged off bearings, many bricks knocked out across arch barrel width	Knocked down Broken
14	Waterproofing (try to exclude leaks through joints)	.1	No visible sign of seepage	Minor seepage through deck/arch etc. (slow dripping)	Moderate seepage through deck/arch etc. (some resistance to seepage)	Major seepage (little resistance) through deck/arch etc. causing structural damage	Non-functional Causing critical structural damage
		.2	No visible sign of seepage	Damp surface, slight water stains on soffit	Wet surface, drops of water falling and significant staining	Very wet surface and stalactites causing structural damage	Major structural damage caused by waterproofing not functioning properly
15	Stone slab bridges	.1	Sound, no defects or damage	Minor cracking	Moderate cracking but no visible displacement	Major cracking and/or displacement	Collapsed

APPENDIX D

SEVERITY EXAMPLE PHOTOGRAPHS

Note: the severity number identifies which column in Appendix C the photo refers to. The number in brackets after the severity number identifies which row in Appendix C the photo relates to. The column and row information therefore identifies the specific description the photo relates to.

EXAMPLE SEVERITY CODES
1. METALWORK

SEVERITY CODE 2 (1.1 and 1.3)

SEVERITY CODE 3 (1.1)

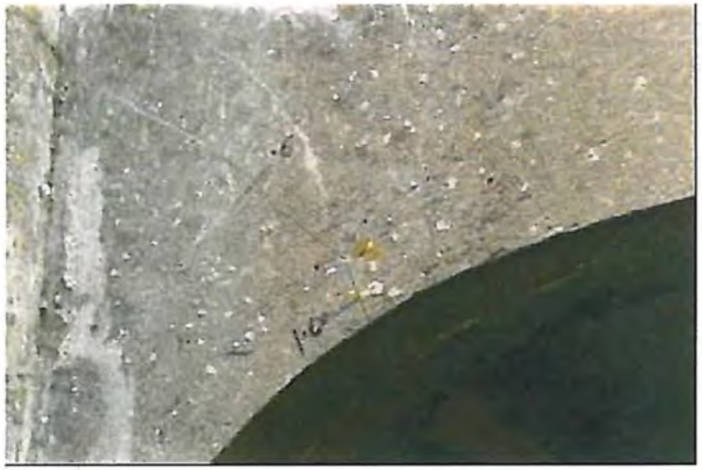
SEVERITY CODE 4 (1.1)

SEVERITY CODE 4 (1.4)

EXAMPLE SEVERITY CODES
2. REINFORCED CONCRETE & PRESTRESSED CONCRETE & FILLER JOIST

SEVERITY CODE 2 (2.2)

SEVERITY CODE 2 (2.2)



SEVERITY CODE 3 (2.3)

SEVERITY CODE 3 (2.2)

EXAMPLE SEVERITY CODES
2 REINFORCED CONCRETE & PRESTRESSED CONCRETE & FILLER JOIST

SEVERITY CODE 3 (2.2)

SEVERITY CODE 4 (2.3)

SEVERITY CODE 4 (2.3)

SEVERITY CODE 5 (2.1)

EXAMPLE SEVERITY CODES
3. MASONRY, BRICKWORK & MASS CONCRETE

SEVERITY CODE 2 (3.1)

SEVERITY CODE 3 (3.2 and 3.3)

SEVERITY CODE 4 (3.6)

SEVERITY CODE 4 (3.3 and 3.6)

EXAMPLE SEVERITY CODES
4. PAINTWORK & PROTECTIVE COATINGS

SEVERITY CODE 3 (4.2)

SEVERITY CODE 4 (4.2)

SEVERITY CODE 5 (4.3)

EXAMPLE SEVERITY CODES
5. VEGETATION

SEVERITY CODE 2 (5.1)

SEVERITY CODE 3 (5.1)

EXAMPLE SEVERITY CODES
8. DRAINAGE

SEVERITY CODE 2(8.2)

SEVERITY CODE 2 (8.2)

SEVERITY CODE 3 (8.2)

SEVERITY CODE 3 (8.2)

EXAMPLE SEVERITY CODES
9. SURFACING

SEVERITY CODE 2 (9.2)

SEVERITY CODE 3 (9.2)

SEVERITY CODE 4 (9.4)

EXAMPLE SEVERITY CODES
10. EXPANSION JOINTS

SEVERITY CODE 2 (10.7)

SEVERITY CODE 3 (10.1)

EXAMPLE SEVERITY CODES
12. BEARINGS

SEVERITY CODE 2 (12.1)

SEVERITY CODE 3 (12.1)

SEVERITY CODE 2 (bearing plinth/shelf – 2.2)

SEVERITY CODE 3 (bearing plinth/shelf – 2.2)

EXAMPLE SEVERITY CODES
16. RETAINING WALLS

SEVERITY CODE 4 (3.5 and 3.7)

SEVERITY CODE 5 (3.7)

SEVERITY CODE 5 (3.7)

County Surveyors' Society

ADDENDUM TO

CSS GUIDANCE NOTE ON

BRIDGE CONDITION INDICATORS

Volume 2: Bridge Inspection Reporting

August 2004

ENG-1/2004

Prepared by:

CSS Bridges Group &

ATKINS

Published by CSS

August 2004

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Members: £10 per volume
£15 for both volumes

Non-Member: £15 per volume
£25 for both volumes

(Including post and packaging)

Contents

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1. Introduction

This addendum has been produced by the CSS Bridges Group and Atkins Highways & Transportation to supplement the original CSS BCI document suite (Refs. 1 to 3).

1.1 Background to Addendum

The CSS published three documents on Bridge Condition Indicators in April 2002:

1. Volume 1: Commission Report (Ref. 1).
2. Volume 2: Guidance Note on Bridge Inspection Reporting (Ref. 2).
3. Volume 3: Guidance Note on Evaluation of Bridge Condition Indicators (Ref. 3).

The BCI procedures are recommended as Good Practice by the CSS Bridges Group and the Code of Practice for Highway Structure Management (Ref. 4). The BCI procedures have been adopted by the majority of highway authorities in the UK and it is likely that the BCI will be used as a Best Value Performance Indicator (BVPI) by the Office of the Deputy Prime Minister (ODPM).

All authorities that adopted the BCI procedures were encouraged to provide feedback on the guidance documents to the CSS Bridges Group, in particular:

- Any errors or inconsistencies.
- Areas where the guidance is unclear or where additional guidance is required.
- Concerns/disagreements with the guidance provided.

Feedback was collated between April 2002 and December 2003, the feedback was summarised and circulated for further comment and discussion. The discussion period was closed at the end January 2004. Based on the comments/discussion it was decided that the BCI documents did not require a full revision, instead an addendum to supplement each of the Guidance documents (Ref. 2 & 3) was deemed sufficient.

1.2 Objectives of Addendum

The objectives of this addendum are:

1. To provide additional guidance on those areas of Volume 2 (Ref. 2) where the existing guidance was deemed unclear or insufficient.
2. To provide guidance on inspection reporting for retaining walls, sign/signal gantries and other structure types.

1.3 Scope of Addendum

This addendum is only intended for use with *Volume 2: Guidance Note on Bridge Inspection Reporting* (Ref. 2). In particular the addendum is intended to compliment Volume 2 and enable consistent and meaningful Condition Indicators to be produced for the following structure types:

- **Bridges** – structures with a span of 1.5 metres or above. This category includes subways, culverts, footbridges, tunnels and underpasses (Ref. 2 & 5). Structures with spans less than 1.5m are considered part of road maintenance because they are maintained using techniques developed by drainage engineers.
- **Retaining Walls** – all retaining walls associated with the highway, irrespective of height, are included provided their dominant function is to act as a retaining structure (Ref. 2 & 5).
- **Sign/Signal Gantries** – a structure spanning or adjacent to the highway, the primary function of which is to support traffic signs and signalling equipment.
- **Other Structure Types** - structure types associated with the highway that are not covered by the aforementioned categories.

1.4 Contents of Addendum

The contents of this addendum are:

1. Clarification of paragraph 1.16 in Volume 2 (Section 2.1).
2. Re-production of Figure 2 to provide improved guidance on construction forms and primary and secondary deck elements (Section 2.2).
3. Half-joint defect reporting (Section 2.3).
4. Surface finish defect reporting (Section 2.4).
5. Multiple defect reporting (Section 2.5).
6. Revision of Appendix C Severity Descriptions (Section 2.6).
7. Guidance on retaining wall inspection reporting (Section 3).
8. Guidance on sign/signal gantry inspection reporting (Section 4).
9. Guidance on inspection reporting for other structure types (Section 5).

2. Addendum Guidance to Volume 2

2.1 Paragraph 1.16

Paragraph 1.16 of Volume 2 (Ref. 2) states that:

> *After a General Inspection it is normal that only the pro forma is completed. After a Principal Inspection a detailed report is normally compiled, however the pro forma should still be completed to evaluate the Condition Indicators.*

Paragraph 1.16 has been interpreted in a number of different ways, the correct interpretation is:

> *The inspection pro forma (Appendix A of Volume 2, Ref. 2) must be completed during <u>General and Principal Inspections</u>. The condition data from <u>General and Principal Inspections</u> is used to evaluate the Condition Indicators.*
>
> *A detailed report is normally compiled after a <u>Principal Inspection</u>; however the inspection pro forma must still be complete during the <u>Principal Inspection</u>.*

When General and Principal Inspections are performed it is normal practice to replace a General with a Principal Inspection when the years coincide. It is therefore important that the inspection pro forma is complete during both GIs and PIs to ensure up-to-date and regular condition data is supplied for structures management and the Condition Indicator calculation.

2.2 Figure 2

Figure 2, page 12 of Volume 2 (Ref. 2), shows simple schematic diagrams for ten of the structural forms described in Table 2, page 11 of Volume 2 (Ref. 2). Figure 2 has been revised to show the structural forms more clearly along with typical element types. The revised Figure 2 is shown in Appendix A of this addendum.

2.3 Half-joints

Half-joints, although not distinct elements, receive a separate entry on the inspection pro forma due to their structural criticality and inherent maintenance problems. However, given that half-joints are an integral part of the primary deck element there is the possibility that defects may be double counted during the inspection. Additional inspection guidance is therefore provided on reporting the condition of half-joints.

The pro forma will retain half-joints as a separate element and their condition should be reported as:

- Defects on the primary element, in the immediate vicinity of the half-joint, likely to have been caused by the presence of the half-joint e.g. defects in a region D (beam or slab depth) either side of the joint, see Figure 1; and
- Defects to the half-joint e.g. dowel/bearing plate, filler etc.

Defects used to assess the condition of the half-joint should not be included in the condition assessment of the primary deck element. A typical section through a half joint is shown in Figure 1.

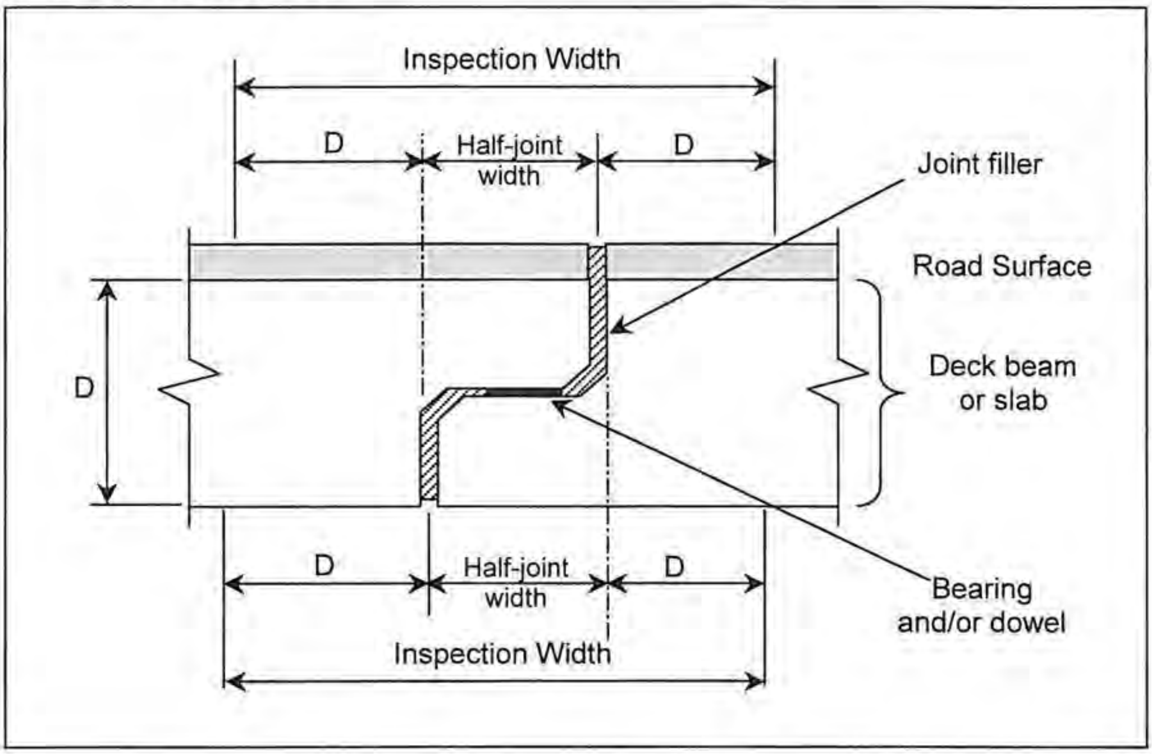


Figure 1 Half-joint Cross Section

2.4 Surface Finish Defect Reporting

The inspection pro forma provided in Volume 2 (Ref. 2) had three rows dedicated to painting:

- Row 19 - Painting: deck elements
- Row 20 - Painting: substructure elements
- Row 21 - Painting: parapets/safety fences.

Painting is a common type of surface finish used on highway structures, but it is not the only type, others include masonry cladding, tiles, paving etc. Therefore elements 19, 20 and 21 on the pro forma (see Appendix B) have been amended to:

- Row 19 - Finishes: deck elements
- Row 20 - Finishes: substructure elements
- Row 21 - Finishes: parapets/safety fences.

The same approach to surface finishes is used by the Retaining Wall and Sign/Signal Gantry inspection pro forma, these are shown in Sections 3 and 4 respectively.

2.5 Multiple Defect Reporting

The inspection pro forma was designed to collect condition data in an appropriate format for:

1. Assisting structures management; and
2. Evaluating the Condition Indicator.

To meet the requirements of the latter, i.e. one condition entry per element, Volume 2 (Ref. 2) provides guidance on recording one Condition Score against an element even when it has more than one defect type present (see paragraphs 5.5 to 5.8 of Volume 2 (Ref. 2) on Dominant and Interacting defects). Although this approach meets the requirements of Condition Indicator evaluation it may not always provide the best data for structures management. If there are several defect types on the element (i.e. multiple defects) then recording the severity/extent of each may improve the structures management process when the inspection pro forma is assessed in the office.

To assist structures management a new section has been added to the pro forma that allows the severity/extent of up to three defects on one element to be recorded. The format of the new section is shown in Table 1; Appendix B shows the revised pro forma layout with the section for recording *Multiple Defects*.

Table 1 New Pro Forma Section for Recording Multiple Defects

MULTIPLE DEFECTS										
Element No.	**Defect 1**			**Defect 2**			**Defect 3**			**Comments**
	S	**Ex**	**Def**	**S**	**Ex**	**Def**	**S**	**Ex**	**Def**	

The new pro forma section (shown in Table 1 above and on the pro forma in Appendix B) should be used in accordance with the following guidance:

1. The Dominant and Interacting defect rules (paragraphs 5.5 to 5.8 in Ref. 2) are still used for the severity/extent codes entered on the front page of the inspection pro forma.
2. If the inspector feels that one condition entry is not sufficient for maintenance management then they can provide additional severity/extent codes, for up to three defects per element, in the new section:

a. Enter an "M" in the Defect column (*Def*) on the front page of the pro forma to indicate that Multiple defects have been recorded for this element on the reverse of the pro forma.

b. The element number, from the front page of the pro forma, is entered in the first column (*Element No.*) of the *Multiple Defects* section.

c. The severity, extent and defect code for the most severe defect on the element are entered in the *Defect 1* columns.

d. The severity, extent and defect code for the defect with the next highest severity are entered in the *Defect 2* columns.

e. The severity, extent and defect code for the defect with the next highest severity are entered in the *Defect 3* columns.

f. Addition notes can be added into the *Comments* column.

The severity/extent codes entered in the *Multiple Defects* table are not used in the Condition Indicator calculation. Only the severity/extent code entered on the front page of the pro forma is used in the Condition Indicator calculation and therefore the Dominant/Interacting rules apply for these entries.

2.6 Revision of Appendix C Severity Descriptions

Appendix C in Volume 2 (Ref. 2) provides guidance on how to classify the severity of defects for different material and element types. The guidance provided on defect classification is not comprehensive; it is unlikely that comprehensive guidance can be produced and attempting to do so may create a defect table that is unwieldy and less user friendly.

Table 7 in Volume 2 (Ref. 2) gives the generic severity descriptions and must be used as the primary source for defining severity. Table 7 should be used to assess those materials, elements and defect types not covered by Appendix C. It is considered that if Appendix C is used in conjunction with Table 7 a more consistent approach to inspection reporting will be achieved by authorities.

Based on feedback received some minor amendments have been made to Appendix C, in particular to avoid confusion in some areas. As timber is a common material used for footbridges it has been added to the defect table.

The revised defect table is presented in Appendix C of this Addendum; the areas changed or added are shaded in grey.

3. Inspection Reporting for Retaining Walls

3.1 General

Volume 2 (Ref. 2) provides limited guidance on the inspection of retaining walls. The following sections replace the guidance provided on retaining walls in Section 4.17 of Vol. 2 (Ref. 2). Where a retaining wall is defined as *any wall, irrespective of height, where the dominant function is to act as a retaining structure* (Ref. 2 & 5).

Retaining walls represent a significant proportion of the highway structure asset for many authorities and should therefore feed into the Structures Condition Indicator. The guidance provided for retaining walls aims to promote a consistent approach and covers the following topics:

1. Structural forms (Section 3.2)
2. Material types (Section 3.3)
3. Inspection elements (Section 3.4); and
4. Retaining Wall inspection pro forma (Section 3.5).

3.2 Structural Forms

The structural forms for retaining walls are show in Table 2 along with the associated retaining wall code. These codes replace the "00" code provided in Table 2 of Volume 2 (Ref. 2) for Retaining Walls.

Table 2 Retaining Wall Structural Form Code

Structural Form	Code
Gravity	R1
Cantilever on foundation	R2
Embedded	R3
Reinforced soil	R4
Gabions	R5
Cribwork	R6
Other	R7

Schematics of different retaining wall structural forms, along with typical elements, are shown in Figure 2. The schematics do not provide comprehensive coverage of retaining wall arrangements; they should be used as a general guide along with local knowledge to ensure the appropriate elements are recorded for each wall.

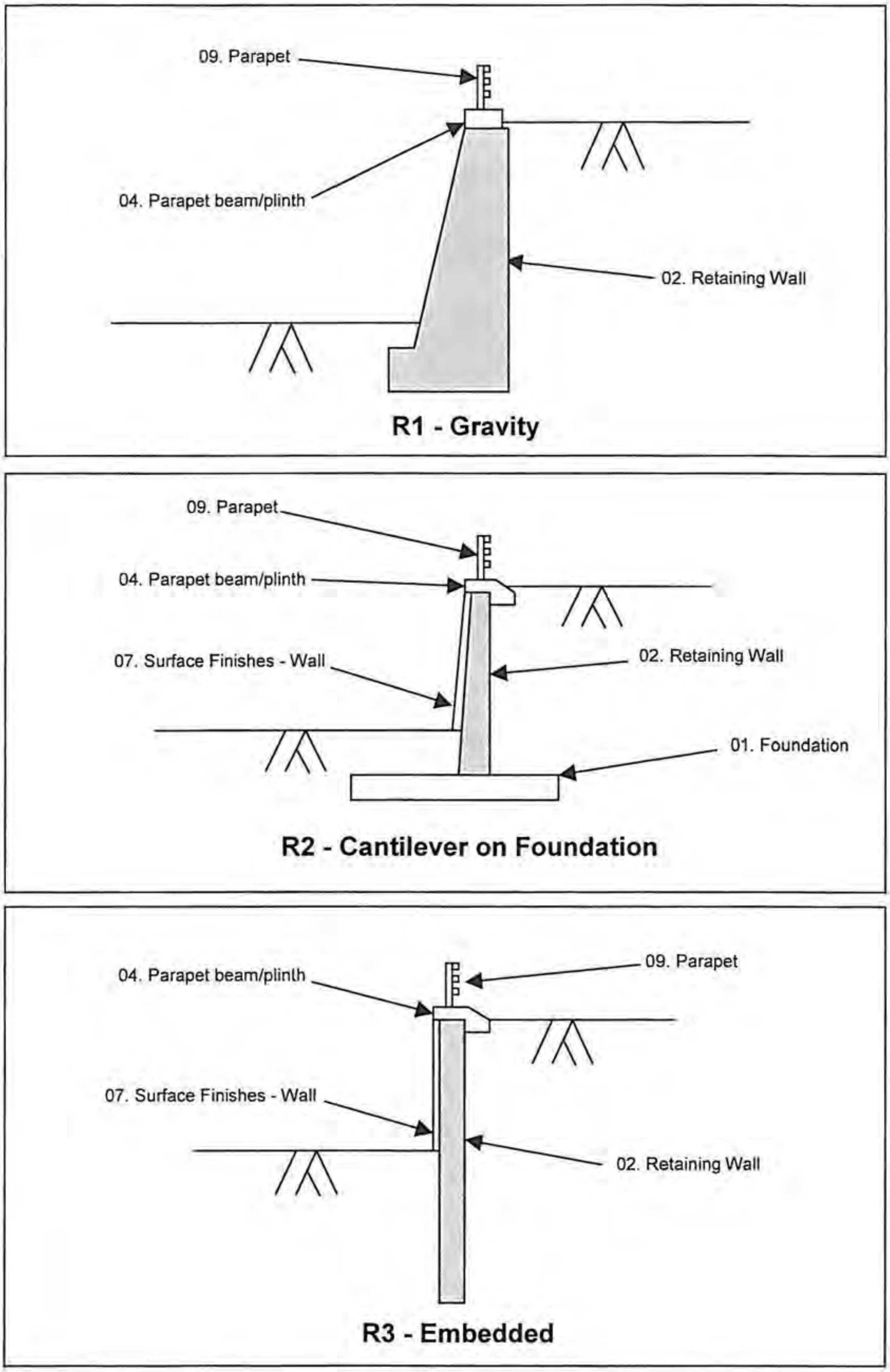
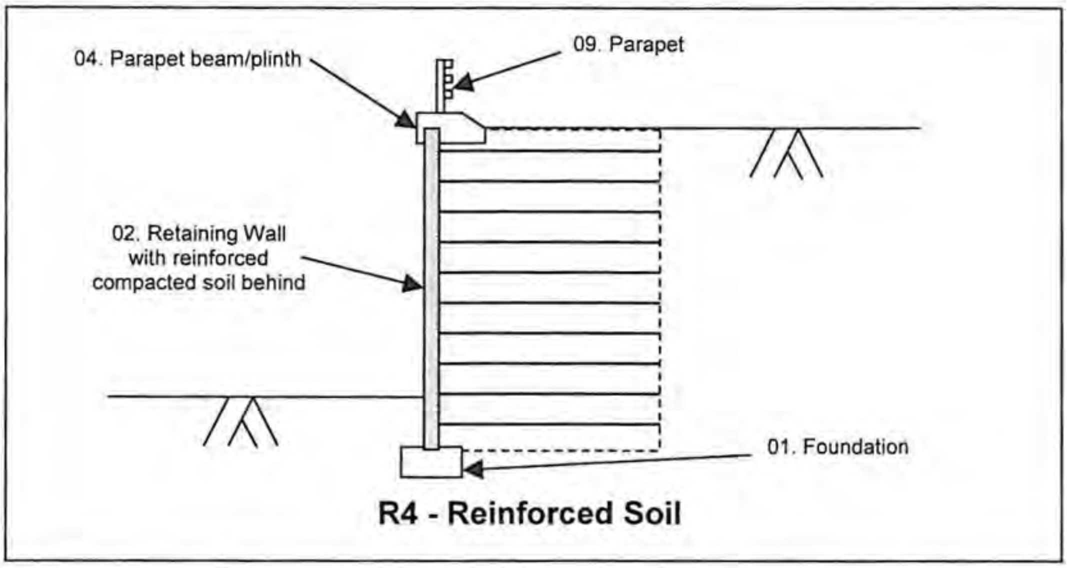
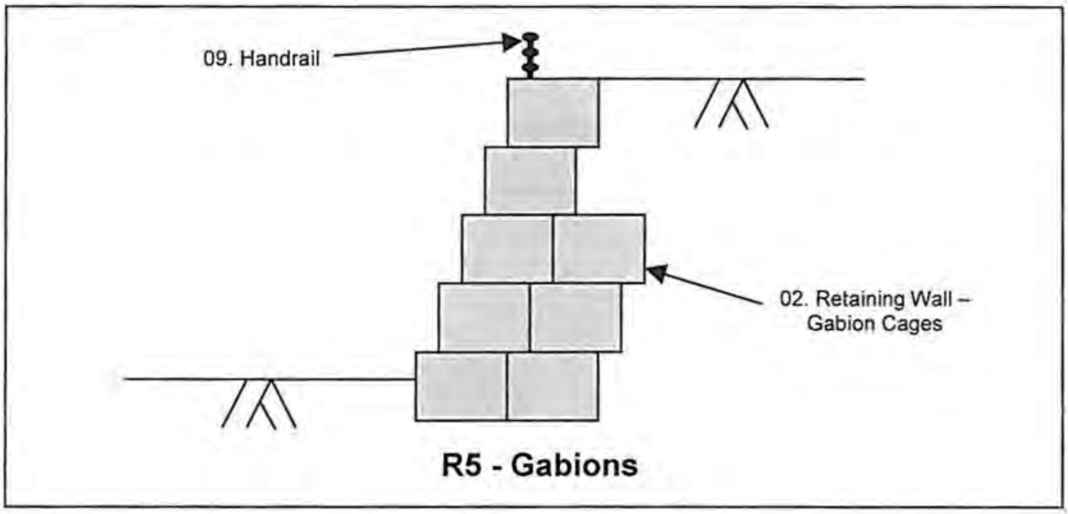


Figure 2 Schematic of Retaining Wall Structural Forms





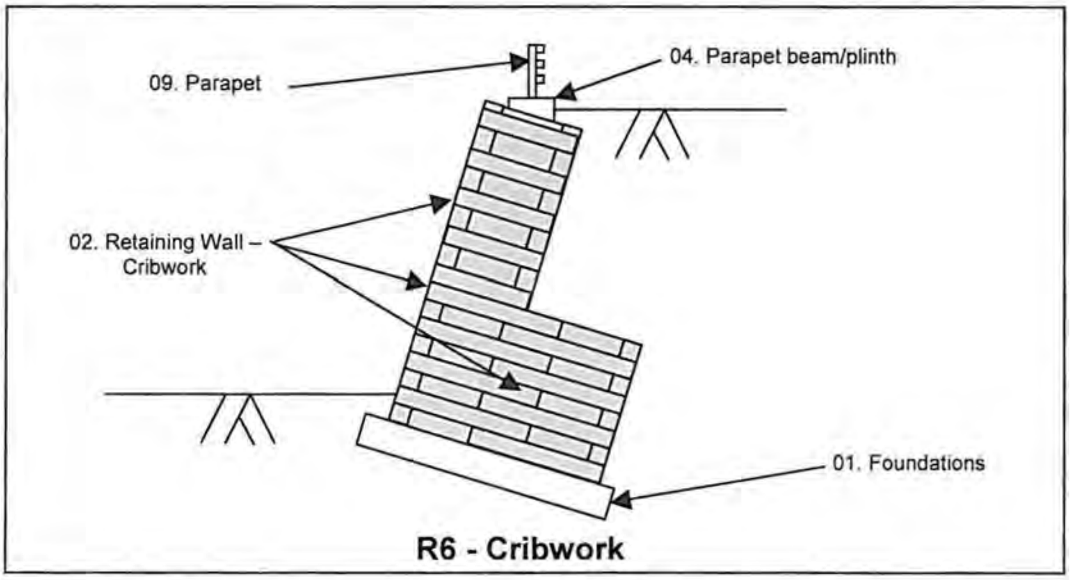


Figure 2 Schematic of Retaining Wall Structural Forms

3.3 Material Types

The material type code for a retaining wall is based on the material of the main structural element (element number 2 in Table 4) and selected from Table 3. When a retaining wall has a composite construction e.g. soldier piles with lagging, then the primary structural form is used to define the element type, see Figure 3.

Table 3 Retaining Wall Material Type Code

Material Type	Code
Mass concrete	RA
Reinforced concrete	RB
Masonry	RC
Steel	RD
Timber	RE
FRP/Plastic	RF
Other	RO

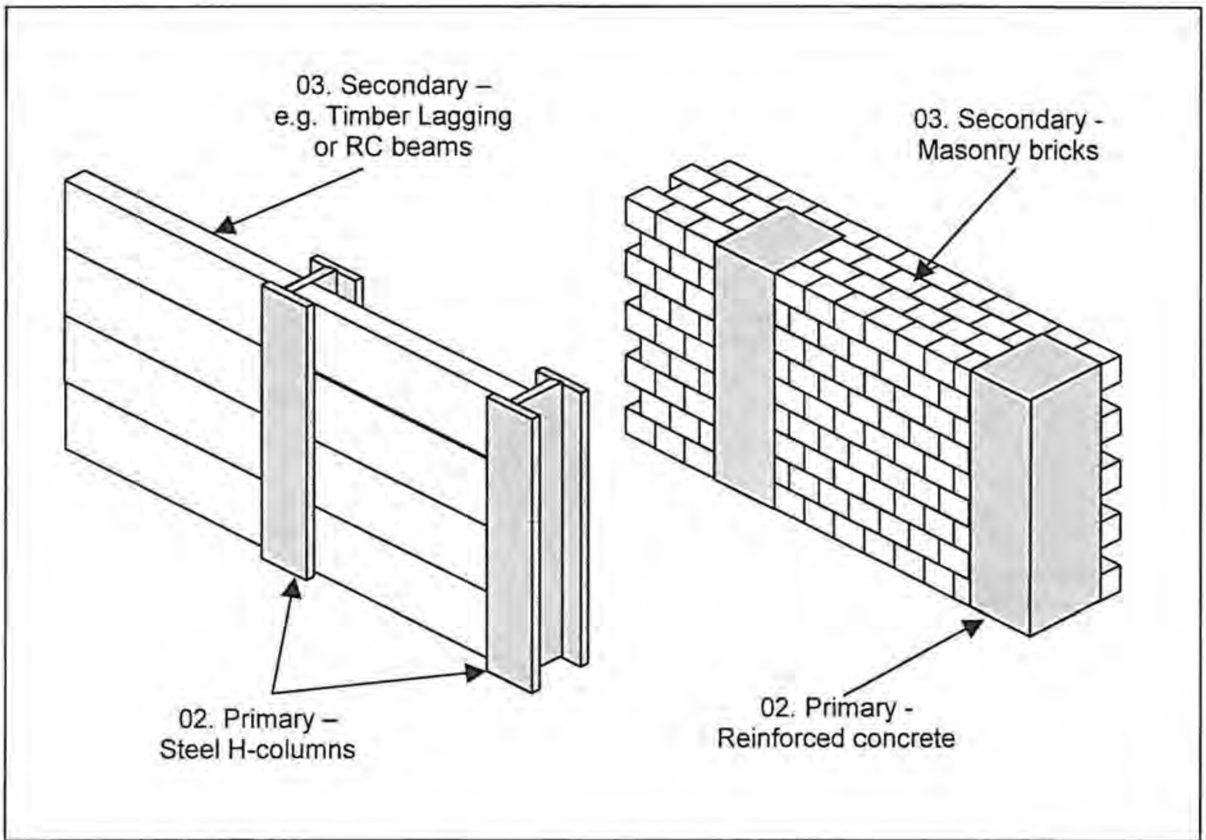


Figure 3 Retaining Walls with Primary and Secondary Elements

3.4 Inspection Elements

The inspection elements on a retaining wall are shown in Table 4.

Table 4 Retaining Wall Inspection Elements

No.	Element		Comment
1	Foundations		Assessed by signs of distress on retaining wall
2	Retaining wall	Primary	See Figure 2 and Figure 3
3		Secondary	See Figure 3
4	Parapet beam/plinth		Longitudinal beam/plinth on top of wall to support parapet/handrail
5	Drainage		Weep holes, back of wall drainage, drainage of supported material
6	Movement/expansion joints		Normally non critical for retaining walls
7	Surface finishes: wall		e.g. painting, cladding, tiles
8	Surface finishes: handrail/parapet		e.g. painting, cladding, tiles
9	Handrail/parapets/safety fences		Along top of retaining wall (not foot of wall)
10	Carriageway	Top of wall	Defects may indicate movement or instability
11		Foot of wall	Defects may indicate movement or instability
12	Footway/verge	Top of wall	Defects may indicate movement or instability
13		Foot of wall	Defects may indicate movement or instability
14	Embankment	Top of wall	Defects may indicate movement or instability
15		Foot of wall	Defects may indicate movement or instability
16	Invert/river bed		If watercourse is alongside the wall
17	Aprons		If watercourse is alongside the wall
18	Signs		Attached to the retaining wall
19	Lighting		Attached to the retaining wall
20	Services		Attached to the retaining wall

3.5 Retaining Wall Inspection Pro Forma

The retaining wall inspection pro forma retains the general layout of the bridge inspection pro forma. The retaining wall inspection pro forma is shown in Appendix D of this addendum.

Note: The Retaining Wall length and retained height (average and maximum) are required.

4. Inspection Reporting for Sign/Signal Gantries

4.1 General

The BCI documents (Ref. 2 & 3) do not provide guidance on the inspection of sign/signal gantries. A sign/signal gantry is defined as *a structure above or adjacent to the highway, the primary function of which is to support traffic signs and signalling equipment.*

Sign/signal gantries do not represent a significant proportion of the highway structure asset; however they are sufficiently common and unique to merit separate inspection guidance from bridges and retaining walls. The guidance provided for sign/signal gantries aims to promote a consistent approach and covers the following topics:

1. Structural forms (Section 4.2)
2. Material types (Section 4.3)
3. Inspection elements (Section 4.4); and
4. Signal Gantry inspection pro forma (Section 4.5).

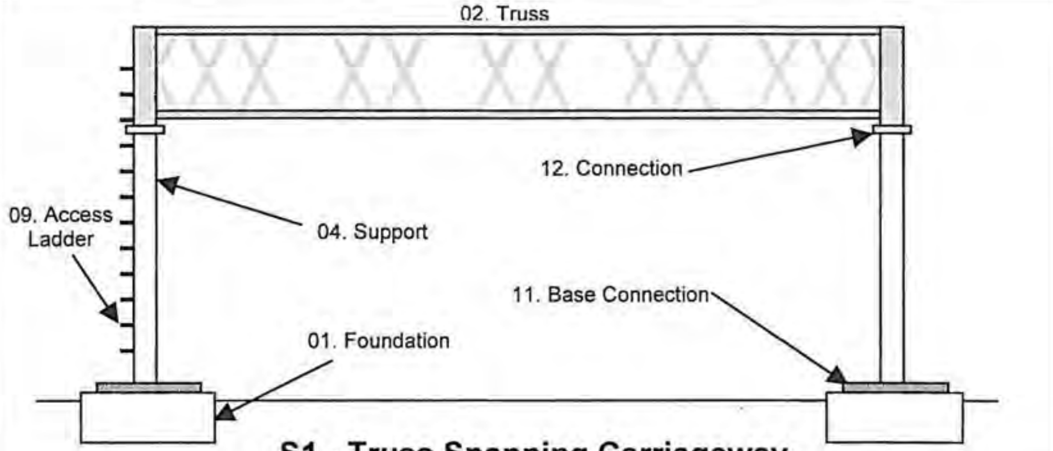
4.2 Structural Forms

The structural forms for sign/signal gantries are show in Table 5 along with the associated code.

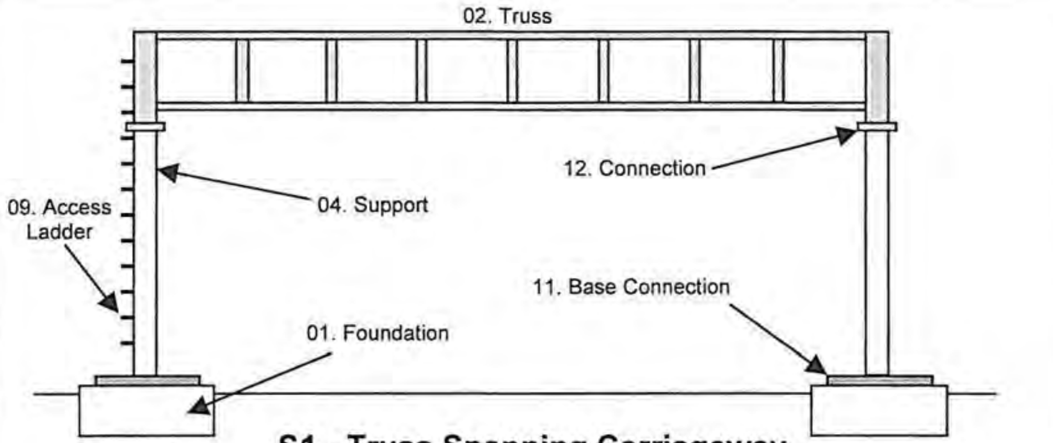
Table 5 Sign/Signal Gantry Structural Form Code

Structural Form		Code
Spanning carriageway	Truss	S1
	Beam	S2
Cantilever	Truss	S3
	Beam	S4
Other		S5

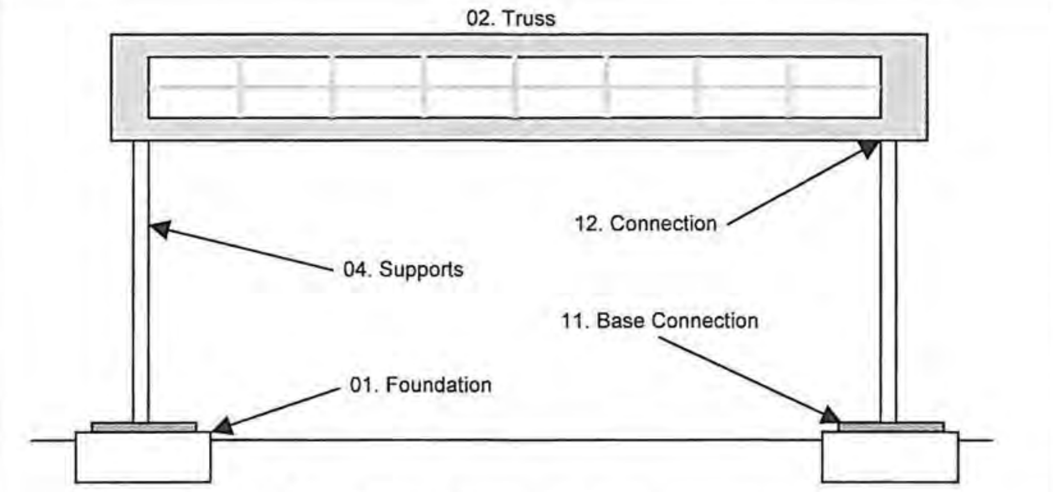
Schematics of the different sign/signal gantry structural forms are shown in Figure 4; also Figure 5 shows schematics of sign/signal gantry side elevations. The schematics do not provide comprehensive coverage of sign/signal gantry arrangements; they should be used as a general guide along with local knowledge to ensure the appropriate elements are recorded for each gantry.



S1 - Truss Spanning Carriageway



S1 - Truss Spanning Carriageway



S1 - Truss Spanning Carriageway

Figure 4 Schematic of Sign/Signal Gantry Structural Forms

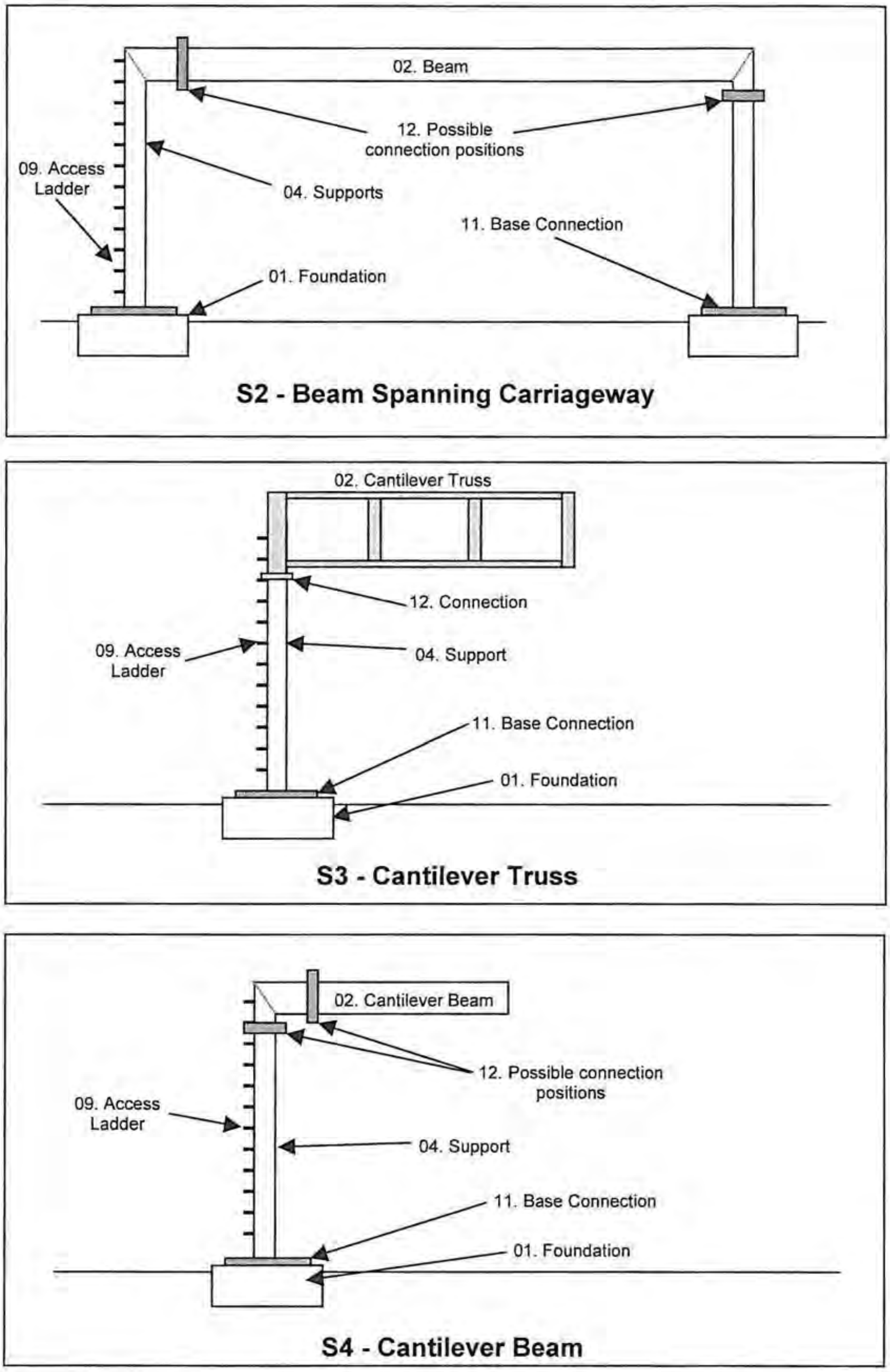


Figure 3 Schematic of Sign/Signal Gantry Structural Forms

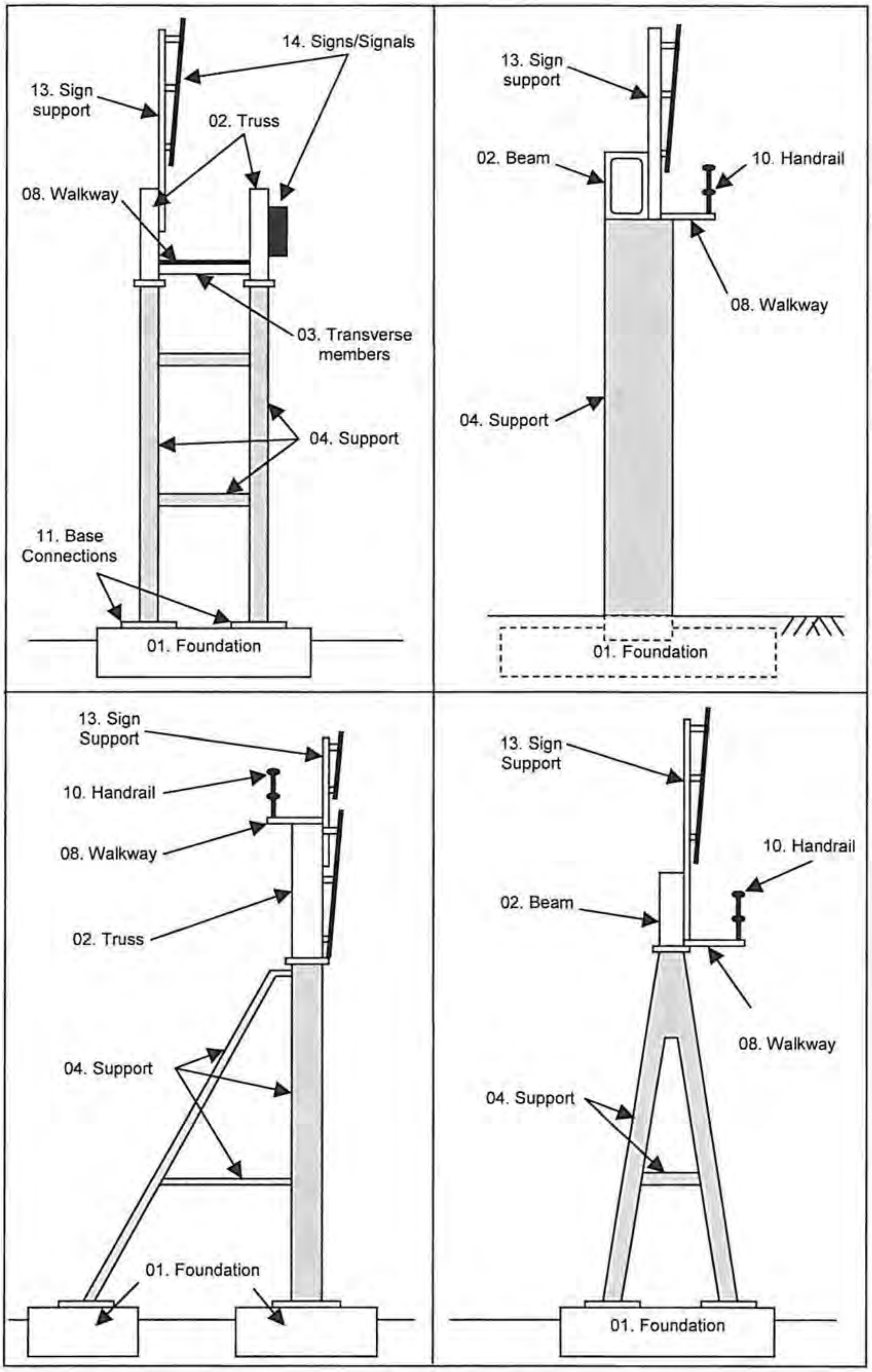


Figure 5 Schematic of Sign/Signal Gantry Side Elevations

4.3 Material Types

The material type code for a sign/signal gantry is based on the main structural elements (element number 2 from Table 7) and selected from Table 3.

Table 6 Sign/Signal Gantry Material Type Code

Material Type	Code
Steel	SA
Aluminium	SB
Reinforced concrete	SC
Prestressed concrete	SD
FRP/Plastic	SE
Other	SF

4.4 Inspection Elements

The inspection elements on a sign/signal gantry are shown in Table 4.

Table 7 Sign/Signal Gantry Inspection Elements

No.	Element	Comment
1	Foundations	Assessed by signs of distress on superstructure
2	Truss/beams/cantilever	See Figure 4
3	Transverse members	See Figure 5
4	Columns/supports/legs	See Figure 4 and Figure 5
5	Surface finishes: truss/beam/cant.	e.g. painting, cladding, tiles
6	Surface finishes: column/support	e.g. painting, cladding, tiles
7	Surface finishes: other elements	For example elements 8, 9, 10 and 13
8	Access walkway/deck	The elements that support personnel on the gantry
9	Access ladder	-
10	Handrails	Handrail on walkway
11	Base connections	Connection between the leg and the foundations, see Figure 4
12	Support to longitudinal connection	The connection between the support and the longitudinal element, see Figure 4
13	Sign and signal supports	The structural components that support the signs and signals, see Figure 5
14	Signs/Signals	Attached to the gantry
15	Lighting	Attached to the gantry
16	Services	Attached to the gantry

4.5 Sign/Signal Gantry Inspection Pro Forma

The sign/signal gantry inspection pro forma retains the general layout of the bridge inspection pro forma. The sign/signal gantry inspection pro forma is shown in Appendix E of this addendum.

Where length and height are defined as:

- Length = distance from centreline to centreline of supports (m).
- Height = minimum distance from road surface to underside of gantry (m).

5. Inspection Reporting for Other Structure Types

Local Authorities own and manage many other structures associated with the highway e.g. vaults, cellars, historical monuments, high masts etc. In general these structure types are less common that bridges, retaining walls and sign/signal gantries and therefore specific inspection procedures have not been created.

It is recommended that authorities develop their own procedures for the inspection and condition reporting of these other structure types. The procedures developed can then closely reflect the local reporting/management requirements.

The following recommendations are made for inspection reporting on other structure types:

1. Where possible align with the CSS Condition Inspection Reporting System.

2. Ensure the inspection procedure covers all structures, and elements on the structures, that the authority is responsible for maintaining.

3. Ensure that the inspection procedures are applied consistently (an in-house procedural document will ensure consistent practice as personnel change).

6. References

1. CSS Bridge Condition Indicator, Volume 1: Commission Report, April 2002.

2. CSS Bridge Condition Indicator, Volume 2: Guidance Note on Bridge Inspection Reporting, April 2002.

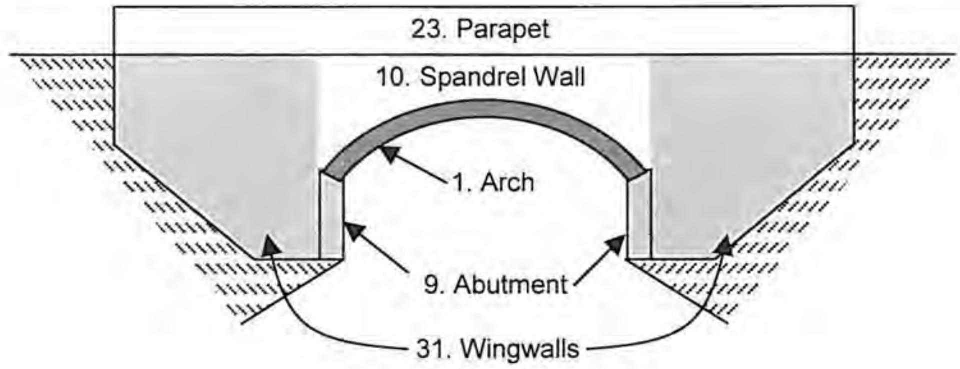
3. CSS Bridge Condition Indicator, Volume 3: Guidance Note on Evaluation of Bridge Condition Indicators, April 2002.

4. Code of Practice for the Management of Highway Structures, DfT and Bridges Board, under development, to be published in 2005.

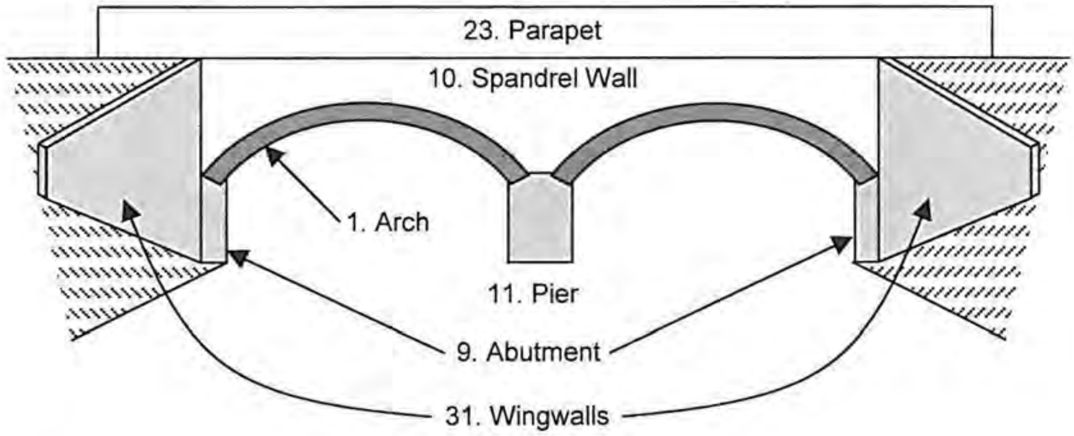
5. Funding for Bridge Maintenance, Report by CSS Bridges Group, February 2000.

6. Addendum to CSS Bridge Condition Indicator, Volume 3: Guidance Note on Evaluation of Bridge Condition Indicators, August 2004.

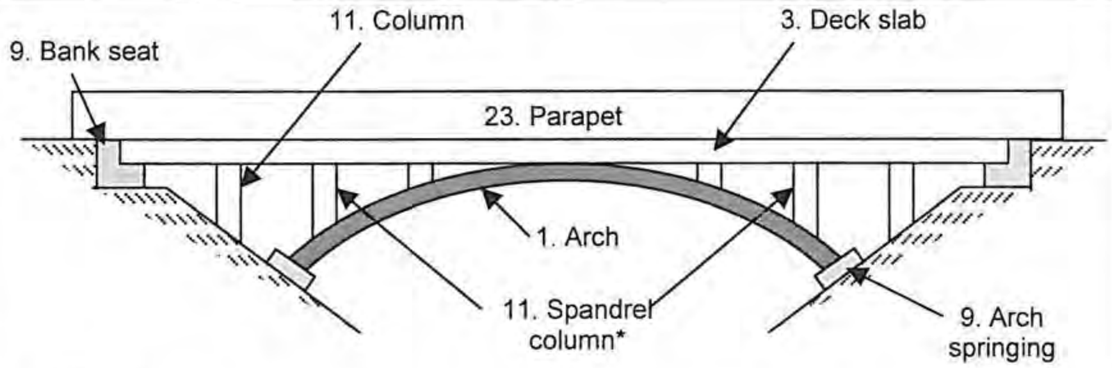
APPENDIX A
Revision of Figure 2



01 - Solid Spandrel Arch

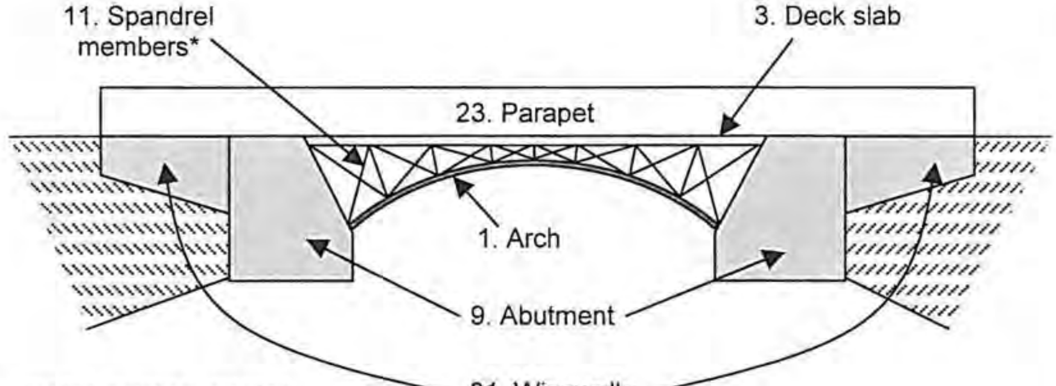


01 - Solid Spandrel Arch



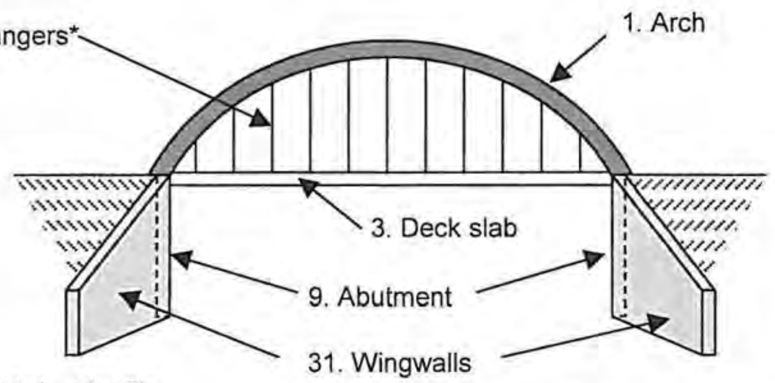
* spandrel columns also reported under Column (No. 11 on the pro forma)

02 - Open Spandrel Arch



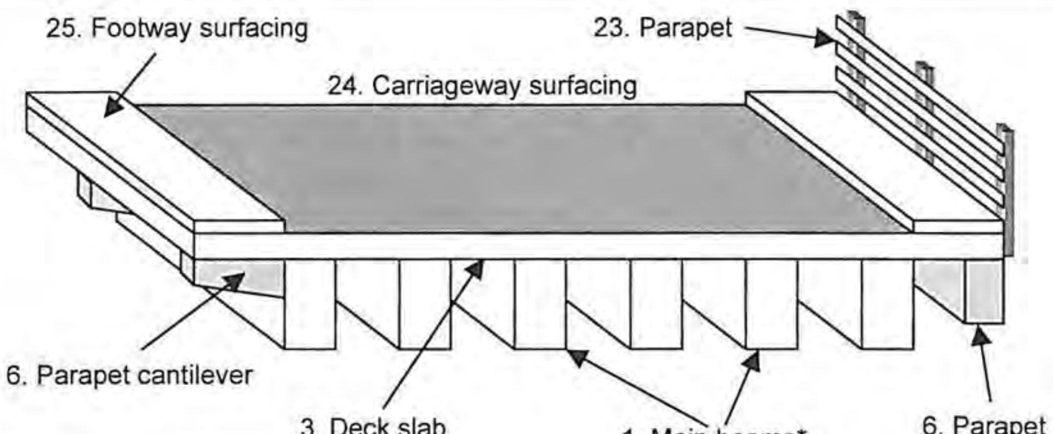
* spandrel members reported under Column (No. 11 on the pro forma)

02 - Open Spandrel Arch



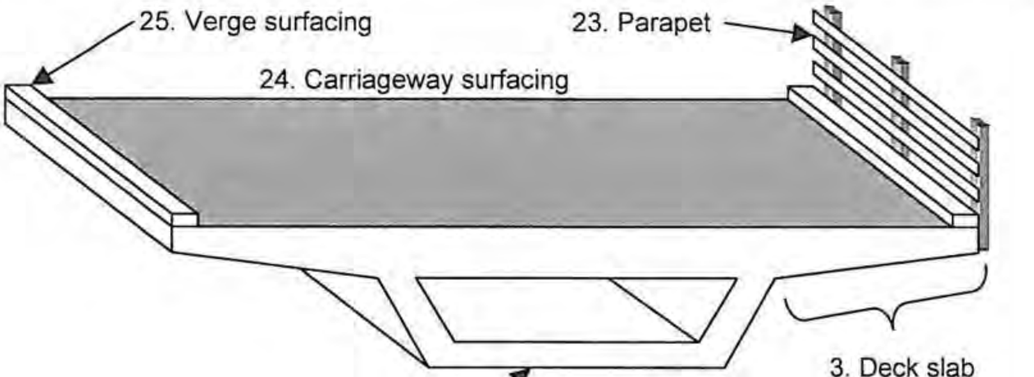
* hangers reported under Tie beam/rod (No. 5 on the pro forma)

03 - Tied Arch (Bowstring)



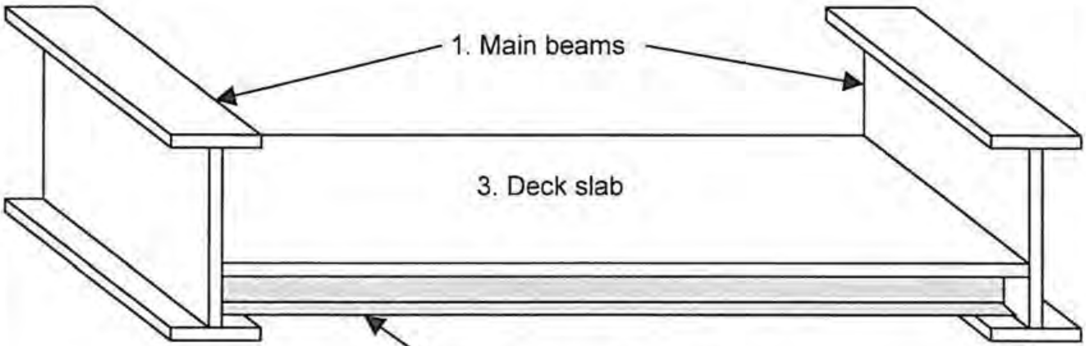
* main beams come in a range of cross section shapes e.g. I, Y, M, rectangular etc.

04 - Beam and Slab

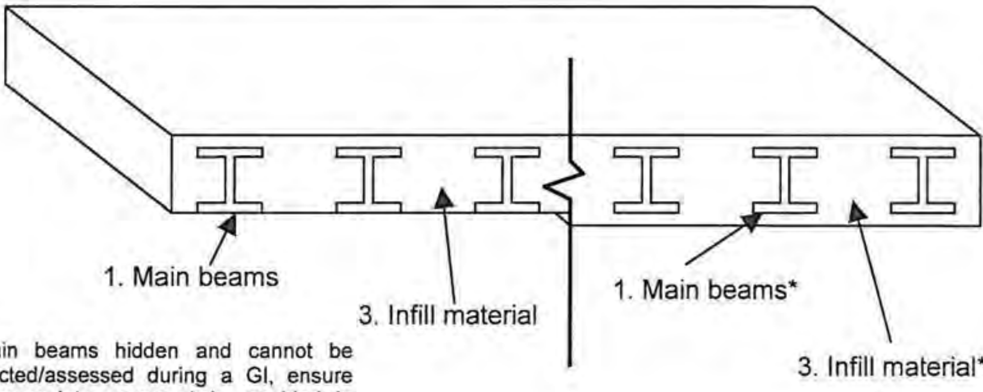


* condition may be reported as deck slab or parapet cantilever, both have the same influence on the Condition Indicator calculation

05 - Box Beam

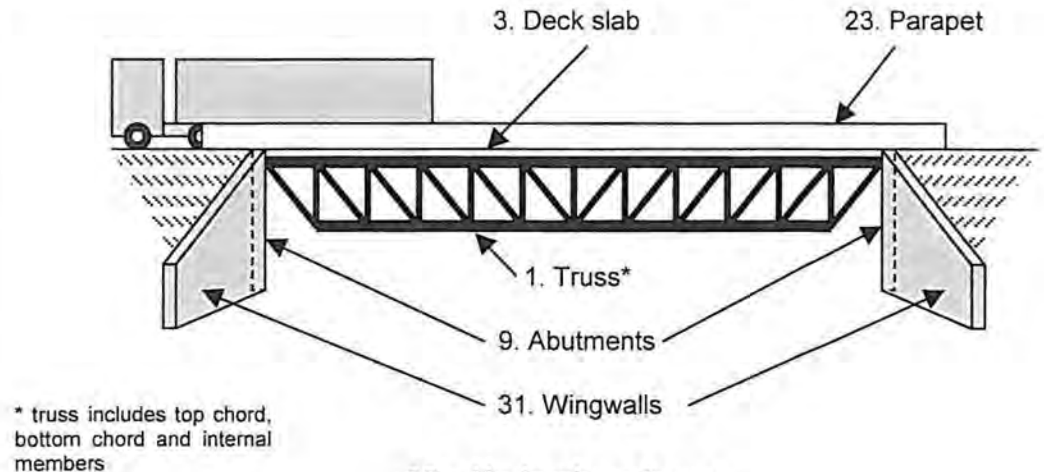


06 - Half through girder

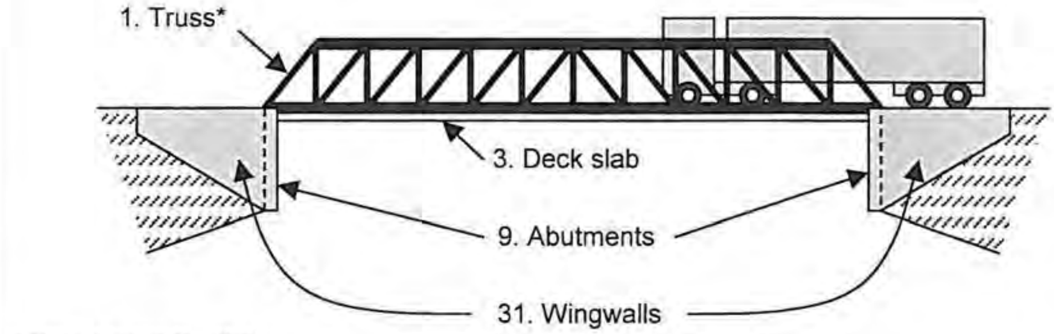


* main beams hidden and cannot be inspected/assessed during a GI, ensure an appropriate comment is provided in inventory/inspection pro forma
** report condition of infill as secondary, not primary, deck element

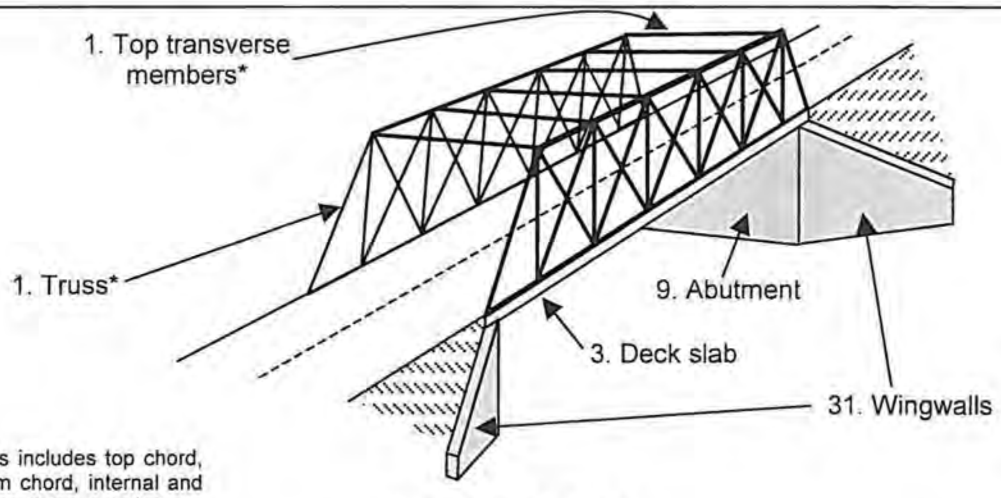
07 - Filler Beam



08 – Underslung truss



09 – Half through truss



10 – Through Truss

APPENDIX B
Bridge Inspection Pro Forma

Bridge Inspection Pro Forma

Version: July 2004

☐ Superficial	☐ General	☐ Principal	☐ Special	**Form _____ of _____ for this bridge**

Inspector:	Date:	Next Inspection Type/Date:

Bridge Name:		Bridge Ref/No:	Road Ref/No:	
Map Ref:	O.S.E	O.S.N	**Bridge Code** Primary deck form Table 2	
Span of	Span Width (m):	Span Length (m):	Primary deck material Table 4	
All above ground elements inspected: YES ☐ NO ☐		Photographs? YES ☐ NO ☐	Secondary deck form Table 3	
Number of construction forms in bridge/span*: 1 ☐ 2 ☐ 3 ☐ more ☐ (*delete as appropriate)			Secondary deck material Table 4	

Set	No	Element Description		S	Ex	Def	W	P	Cost	Comments/Remarks
Deck Elements	1	Primary deck element (Table 2)								
	2	Secondary deck element/s	Transverse beams							
	3		Element from Table 3							
	4	Half joints								
	5	Tie beam/rod								
	6	Parapet beam or cantilever								
	7	Deck bracing								
Load-bearing Substructure	8	Foundations								
	9	Abutments (incl. arch springing)								
	10	Spandrel wall/head wall								
	11	Pier/column								
	12	Cross-head/capping beam								
	13	Bearings								
	14	Bearing plinth/shelf								
Durability Elements	15	Superstructure drainage								
	16	Substructure drainage								
	17	Waterproofing								
	18	Movement/expansion joints								
	19	Finishes: deck elements								
	20	Finishes: substructure elements								
	21	Finishes: parapets/safety fences								
Safety Elements	22	Access/walkways/gantries								
	23	Handrail/parapets/safety fences								
	24	Carriageway surfacing								
	25	Footway/verge/footbridge surfacing								
Other Bridge Elements	26	Invert/river bed								
	27	Aprons								
	28	Fenders/cutwaters/collision prot.								
	29	River training works								
	30	Revetment/batter paving								
	31	Wing walls								
	32	Retaining walls								
	33	Embankments								
	34	Machinery								
Ancillary Elements	35	Approach rails/barriers/walls								
	36	Signs								
	37	Lighting								
	38	Services								
	39									
	40									
	41									
	42									

S – severity, **Ex** – extent, **Def** – defect, **W** – work required, **P** – work priority, **Cost** – Cost of work

MULTIPLE DEFECTS

Element No.	Defect 1			Defect 2			Defect 3			Comments
	S	Ex	Def	S	Ex	Def	S	Ex	Def	

INSPECTOR'S COMMENTS

Name:	Signed:	Date:

ENGINEER'S COMMENTS

Name:	Signed:	Date:

WORK REQUIRED

Ref. No	Suggested Remedial Work	Priority	Estimated Cost	Action/Work Ordered?

Name:	Signed:	Date:

APPENDIX C
Revision of Severity Descriptions

No	Item		Severity				
			1	2	3	4	5
1	Metalwork	.1	No signs of rusting or damage	Minor surface rusting	Moderate pitting	Deep pits and perforations (localised sever corrosion)	Disintegrated by corrosion mechanisms
		.2	No loss of section thickness	Minor section loss (penetration less than 5% of section)	Moderate section loss causing some reduction in functionality (penetration 5 to 20% of section thickness)	Major section loss causing significant reduction in functionality (penetration more than 20% of section)	Collapsed or collapsing
		.3	No signs of rusting or damage to bolts, nuts and rivets	Non structural bolts loose, minor corrosion of nuts and washers	Non structural bolts missing, moderate corrosion of rivet heads, nuts and washers	Structural bolts missing, rivets loose or missing, crack through bolt	Failure of element due to missed/failed bolts/rivets
		.4	No corrosion or damage of weld runs	Slight corrosion of weld run	Crack at toe of weld, moderate reduction in size of weld due to corrosion	Longitudinally cracked weld, major reduction in size of weld due to corrosion	Weld connection failure (longitudinal crack)
		5	**Defect category Removed**				
2	Reinforced Concrete, Prestressed Concrete & Filler Joist	1	**Defect Category Removed**				
		.2	No spalls	Minor localised spalls exposing shear links	Major localised spalls exposing shear links and main bars with general corrosion	Joined up, deep spalls exposing shear links and main bars with general and pitting corrosion	Collapsed
		.3	Hairline cracks, difficult to detect visually	Cracks and crazing in areas of low flexural behaviour (cracks less than 0.3mm)	Cracks and crazing in areas of high flexure. Cracks approx. 1mm and easily visible	Wide/deep cracks (more than 2mm). Shear cracks.	Element unable to function due to structural cracks
		.4	No signs of damage to prestressing	Substandard grouting of ducts (may not be visible)	Cracks along line of prestressing duct	Exposed prestressing cables	Failed prestressing cables
		.5	No signs of delamination	Early signs of delamination e.g. cracks with rust staining	Delamination in areas of low flexural and/or shear action	Delamination in areas of high flexural and/or shear action	Failure due to delaminated bars
		.6	No signs of thaumasite or freeze-thaw attack	Slight cracking caused by thaumasite or freeze-thaw	Moderate thaumasite or freeze-thaw attack	Major thaumasite or freeze-thaw attack	Failure due to thaumasite or freeze-thaw attack

No	Item		Severity 1	2	3	4	5
3	Masonry, Brickwork & Mass Concrete	.1	No evidence of deformation	Minor deformation	Moderate deformation	Major deformation	Collapsed
		.2	Pointing sound	Minor depth of pointing deteriorated	Moderate to significant depth of pointing lost, but does not appear to be rapidly disintegrating or crumbling, bricks not easily loosened	Pointing in very poor condition, severely weathered, crumbling to touch and/or significant depth loss, bricks easily loosened.	Collapsed
		.3	No arch ring cracking or separation	Arch ring cracks difficult to see	Arch ring separation (gap less than 25mm)	Arch ring separation (gap greater than 25mm)	Disintegrated
		.4	No arch barrel cracks	No diagonal cracks, longitudinal cracks less than 3mm wide, lateral cracks	Diagonal cracks, longitudinal cracks greater than 3mm wide	Diagonal cracks, longitudinal cracks breaking barrel into 1m sections or less	Arch barrel failure
		.5	No cracks	Minor hairline cracks and shallow spalls	Moderate cracks (easily visible, crazing) and deep localised spalls	Major cracks and spalling	Failure due to structural cracks
		.6	No bricks/masonry blocks missing, minor surface weathering	Few bricks/stones missing (no adjacent ones missing), major surface weathering	Moderate loss of bricks/stones	Sever loss of bricks/stones	Failure due to missing bricks/stones
		.7	No bulging, leaning or displacement	Minor bulging, leaning or displacement	Moderate bulging, leaning or displacement	Severe bulging, leaning or displacement	Collapsed or non functional
4	Paintwork and Protective Coatings	.1	Finishing coat sound, slight weathering	Normal weathering of finishing coat	Spot, chips and cracks of finishing coat, undercoat exposed but sound	Failure of finishing coat and spots, chips and cracks to undercoat/ substrate	All coats failed
		.2	**Defect category Removed**				
		.3	**Defect Category Removed**				

No	Item		Severity				
			1	2	3	4	5
5	Vegetation	.1	Slight to no vegetation	Minor vegetation causing no structural damage (surface mosses, small grass and weeds)	Vegetation growth on or near bridge causing structural damage and/or deformation e.g. roots and branches of nearby trees, small tree/plants growing on structure	Vegetation growth on or near bridge causing major structural damage and/or deformation e.g. roots and branches of nearby trees, large tree growing on structure	Failure caused by vegetation growth or a tree collapsing on the structure
		.2	Slight to no vegetation	Low depth/density of vegetation cover, easily removed e.g. moss	Significant depth/density of vegetation, obscuring inspection e.g. ivy	Inspection impossible due to vegetation growth but structural damage due to vegetation unlikely	Inspection of critical structural elements not possible due to density of vegetation and root systems likely to be causing structural damage
6	Foundations	.1	No visible settlement of structure	No visible settlement, but cracks that may be due to it	Minor settlement of structure	Major settlement of structure	Collapsed due to settlement
		.2	No visible differential movement of structure	No visible movement, but cracks that may be due to it	Minor differential movement of structure	Major differential movement of structure	Collapsed due to differential movement
		.3	No visible sliding of structure	No visible sliding, but cracks that may be due to it	Minor sliding of structure	Major sliding of structure	Collapsed due to sliding
		.4	No visible rotation of structure	No visible rotation, but cracks that may be due to it	Minor rotation of structure	Major rotation of structure	Collapsed due to rotation
		.5	No scour	Minor scour	Moderate scour	Major scour	Dangerous scour or failure
		.6	Substructure appears unaffected by foundation faults (assume no foundation faults)	Foundation faults causing minor cracks in substructure	Foundation faults causing moderate cracks in substructure	Foundation faults causing major cracks and deformation in substructure	Failure due to foundation faults

No	Item		Severity				
			1	2	3	4	5
7	Invert, apron & river bed (also see 2 and 3)	.1	No scour	Minor scour	Moderate scour	Major scour	Dangerous scour or failure
		.2	No vegetation growth or silting	Vegetation growth, trapped debris and silting causing slight disruption to flow	Vegetation growth, trapped debris and silting significant disruption to flow causing faster flow in areas of the river	Vegetation growth, trapped debris and silting severe disruption to flow causing much faster flow in areas of the river	Failure caused by vegetation growth, trapped debris and silting
8	Drainage	.1	In sound condition and fully functional	Mostly functional (less than 25% of cross section blocked)	Part functional (25 to 50% of cross section blocked)	Mostly non-functional (more than 50% of cross section blocked)	Totally blocked/non-functional/broken
		.2	Causing no staining	Causing minor staining	Cleaning of staining required	Urgent cleaning required	Urgent & frequent cleaning
		.3	No structural damage	Causing minor structural damage	Causing structural damage	Causing major structural damage	Causing severe damage to adjacent elements
		.4	No blockage of weep holes, outlets	Minor blockage of weep holes, outlets	Moderate blockage of weep holes, outlets	Major blockage of weep holes, outlets	Non functioning weep holes
9	Surfacing	.1	Little to no wear and weathering	Minor wear/weathering	Moderate wear/weathering	Major wear/weathering	Dangerous
		.2	No crazing, tracking or fretting	Minor crazing, tracking and/or fretting	Moderate crazing, tracking and/or fretting	Major cracks, tracking and/or fretting	Complete break up
		.3	Dense	Poor texture	Open texture	Very open texture	Dangerous
		.4	Sound	Cracks in top layer	Top layer breached	Deep cracks and potholes	Top layer completely missing
		.5	Not slippery	Starting to become slippery	Definitely becoming slippery	Slippery	Dangerous
	Flagged surfacing	.6	No defects	Trips < 5mm	Cracked flags Trips >5mm and < 10mm	Trips >10mm and <20mm	Trips > 20mm

No	Item		Severity					
				1	2	3	4	5
10	Expansion Joints	Asphaltic plug	.1	Sound	Minor debonding between plug and road	Moderate debonding between plug and road	Major debonding between plug and road	Dangerous
			.2	Sound	Slight loss of surface binder and aggregate	Loss of aggregate (surface penetration 20 to 50mm)	Loss of material from joint (causing holes > 50mm deep)	Missing
			.3	Sound	Minor tracking and flow of binder	Moderate tracking and flow of binder	Major tracking and flow of binder	Disintegrated
		Nosing Defects	.4	Sound	Minor cracking along nosing	Moderate cracking along nosing, some break-up	Break-up of nosing material	Disintegrated
		Elastomeric and others	.5	Minor signs of wear	One bolt missing at cross section	Numerous bolts missing at cross section	Majority of bolts missing at a cross section	Failure due to missing bolts
			.6	Strip sealant sound	Strip sealant loose/poor, compression seal dropped and/or worn	Sealant breached, strip sealant breached	Sealant missing, strip sealant missing/out	Failure
			.7	Sound road surface adjacent to joint	Minor break up of road surface adjacent to joint	Moderate break up of road surface adjacent to joint, some debris in joint seal	Major break up of road surface adjacent to joint, significant debris in joint seal	Joint failure due to deteriorated condition of adjacent road surface
			.8	Sound fixings	Bolt sealer missing	Fixings loose	Fixings missing, plates and angles loose	Failure due to missing fixtures
			.9	Sound components	Initiation of cracking or tearing of components	Crack/tear < 20% of width of component	Crack/tear > 20% but <50% of width of component	Failure of expansion joint components
		Buried Joint (formerly "0" in this list)	.10	Reasonably sound	Minor surfacing cracking	Moderate surfacing cracking	Major surfacing cracking	Failure
			.11	Sealant for induced crack is sound	Minor cracking or break up of sealant for induced crack	Moderate cracking or breal up of sealant for induced crack	Major cracking or break up of sealant for induced crack	Disintegrated or missing sealant for induced crack
		Joint leakage	.12	No visible signs of leakage	Minor leakage through joint	Moderate leakage through joint	Major leakage through joinl causing structural damage	Open joint causing major structural damage

APPENDIX D
Retaining Wall Inspection Pro Forma

Retaining Wall Inspection Pro Forma

Version: July 2004

☐ Superficial	☐ General	☐ Principal	☐ Special	**Form _____ of _____ for this wall**

Inspector:	Date:	Next Inspection Type/Date:
Wall Name:	Wall Ref/No:	Road Ref/No:

District:	Map Ref:	O.S.E	O.S.N
Panel of / Retained Height (m): Max: Ave:		Wall/Panel Length (m):	**Retaining Wall Code**
All above ground elements inspected: YES ☐ NO ☐		Photographs? YES ☐ NO ☐	Structural form Table 2 in Vol. 2 Addendum
Number of construction forms in wall/panel* length: 1 ☐ 2 ☐ 3 ☐ more ☐ (*delete as appropriate)			Material Table 3 in Vol. 2 Addendum

Set	No	Element Description		S	Ex	Def	W	P	Cost	Comments/Remarks
Main Elements	1	Foundations								
	2	Retaining Wall	Primary							
	3		Secondary							
	4	Parapet beam/plinth								
Durability Elements	5	Drainage								
	6	Movement/Expansion Joints								
	7	Surface finishes: wall								
	8	Surface finishes: handrail/parapet								
Safety Elements	9	Handrail/parapets/safety fences								
	10	Carriageway	Top of Wall							
	11		Foot of Wall							
	12	Footway/verge	Top of Wall							
	13		Foot of Wall							
Other Elements	14	Embankment	Top of Wall							
	15		Foot of Wall							
	16	Invert/river bed								
	17	Aprons								
Ancillary Elements	18	Signs								
	19	Lighting								
	20	Services								
	21									
	22									
	23									
	24									

Defect sketches:

S – severity, **Ex** – extent, **Def** – defect, **W** – work required, **P** – work priority, **Cost** – Cost of work

MULTIPLE DEFECTS

Element No.	Defect 1			Defect 2			Defect 3			Comments
	S	Ex	Def	S	Ex	Def	S	Ex	Def	

INSPECTOR'S COMMENTS

Name:	Signed:	Date:

ENGINEER'S COMMENTS

Name:	Signed:	Date:

WORK REQUIRED

Ref. No	Suggested Remedial Work	Priority	Estimated Cost	Action/Work Ordered?

Name:	Signed:	Date:

APPENDIX E
Sign/Signal Gantry Inspection Pro Forma

Sign/Signal Gantry Inspection Pro Forma

Version: July 2004

☐ Superficial	☐ General	☐ Principal	☐ Special	**Form _____ of _____ for this gantry**

Inspector:	Date:	Next Inspection Type/Date:
Gantry Name:	Gantry Ref/No:	Road Ref/No:

District:	Map Ref:	O.S.E	O.S.N
Span of	Height (m):	Length (m):	**Sign/Signal Gantry Code**
All above ground elements inspected: YES ☐ NO ☐		Photographs? YES ☐ NO ☐	Structural form Table 5 in Vol. 2 Addendum
Access Information:	Access Ladder/s YES ☐ NO ☐	Machine Aided Access YES ☐ NO ☐	Material Table 6 in Vol. 2 Addendum

Set	No	Element Description	S	Ex	Def	W	P	Cost	Comments/Remarks
Load Bearing Elements	1	Foundations							
	2	Truss/beams/cantilever							
	3	Transverse members							
	4	Columns/supports/legs							
Durability Elements	5	Surface finishes: truss/beams/cant.							
	6	Surface finishes: columns/supports							
	7	Surface finishes: other elements							
Access	8	Access walkway/deck							
	9	Access ladder							
	10	Handrails							
Other	11	Base connections							
	12	Support to longitudinal connection							
	13	Sign and signal supports							
Ancillary	14	Signs/Signals							
	15	Lighting							
	16	Services							
	17								
	18								
	19								
	20								

Defect Sketches:

S – severity, **Ex** – extent, **Def** – defect, **W** – work required, **P** – work priority, **Cost** – Cost of work

MULTIPLE DEFECTS

Element No.	Defect 1			Defect 2			Defect 3			Comments
	S	Ex	Def	S	Ex	Def	S	Ex	Def	

INSPECTOR'S COMMENTS

Name:	Signed:	Date:

ENGINEER'S COMMENTS

Name:	Signed:	Date:

WORK REQUIRED

Ref. No	Suggested Remedial Work	Priority	Estimated Cost	Action/Work Ordered?

Name:	Signed:	Date:

BRIDGE CONDITION INDICATORS

Volume 3

Guidance Note on Evaluation of
Bridge Condition Indicators

CSS Bridges

ROADS Service
An Agency within the Department for
Regional Development

LoBEG

British
Waterways

BRIDGE CONDITIONS INDICATORS

Volume 3
Guidance Notes on Evaluation of Bridge Condition Indicators

Published by CSS

July 2002

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WSA CJ0089-Vol. 3/Issue 4

BRIDGE CONDITION INDICATORS
Volume 3

GUIDANCE NOTE ON EVALUATION OF BRIDGE CONDITION INDICATORS

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Issue No.: 4
Issue Date: April 2002

ISSUE RECORD

Issue	Date	Page	Para	Comments
1	January 2002			Draft Guidance Note for comments by the Steering Group
2	January 2002			Issued to CSS Bridges Group
3	March 2002			Issued to CSS Steering Group for final comments
4	April 2002			Final Report issued for publication

Note
This document has been specifically produced by WS Atkins Consultants Ltd for the CSS solely for the purposes of developing a Bridge Condition Indicator (BCI) and is only suitable for use in connection therewith.

PREFACE

This document has been prepared by WS Atkins Consultants Limited on behalf of the CSS Bridges Group as part of the commission for developing bridge condition indicators.

Two Guidance Notes have been developed as part of the commission:

1. Guidance Note on Bridge Inspection Reporting
2. Guidance Note on the Evaluation of Bridge Condition Indicators.

This document contains the latter of these Guidance Notes. The intention of this document is to provide guidance on the evaluation of Bridge Condition Indices using inspection data. The indicators can also be applied to highway retaining walls.

The background work carried out for developing the Guidance Documents, sensitivity analysis and field trials is presented in Bridge Condition Indicators Volume 1.

The scope and content of the Guidance Documents is influenced by three essential requirements specified by CSS:

1. The developed indicator must be able to operate effectively from information gathered as part of the General and Principal bridge inspections, with very minimal change required for the current inspection systems.
2. The indicator is intended for use by Local Authority bridge owners in England, Scotland and Wales as well as by the Northern Ireland Office and British Waterways. Therefore, the indicator must be sufficiently versatile to cater for the diverse cross-section of bridge types owned by these authorities.
3. The indicator should be applicable to a single bridge or to a stock of bridges.

The Bridge Inspection Reporting system presented in Volume 2 is an outcome of the harmonisation of various systems currently used by Local Authorities. It is intended that the Authorities will implement the new system at their earliest convenience. The Bridge Condition Indicators can be derived using data from existing inspection systems. Broad comparisons can be made between Condition Indicators based on different inspection systems however the comparisons will not be as accurate or meaningful as those made using the new system.

CSS GUIDANCE NOTE

BRIDGE CONDITION INDICATORS
Volume 3

EVALUATION OF BRIDGE CONDITION INDICATORS

Prepared by:
WS Atkins Consultants Limited

CSS GUIDANCE NOTE

EVALUATION OF BRIDGE CONDITION INDICATORS

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1. INTRODUCTION

GENERAL

1.1 This is Volume 3 of the CSS Bridge Condition Indicators suite (Ref. 1 and 2). Its purpose is to provide guidance on the derivation of Bridge Condition Index (BCI) and Bridge Stock Condition Index (BSCI). The indicators allow individual bridge conditions and bridge stock conditions to be monitored over time.

1.2 The Condition Indicator system is intended for use by highway authorities for all Local Authority owned bridges on the adopted road network, and also by the Northern Ireland Office and British Waterways. A bridge is defined in a previous CSS Report (Ref. 3) as a structure with a span of 1.5m or more and includes subways, culverts, footbridges, tunnels and underpasses.

1.3 Guidance is also provided on applying the system to retaining walls, which are defined in Ref. 3 as all walls irrespective of height whose dominant function is to act as a retaining structure. Condition indicators for retaining walls should be derived in a similar manner to bridges except that the element list and importance classifications should be as given in Appendix A.

1.4 Bridges are essential components of the UK transport infrastructure and their safety and serviceability is therefore vital to the smooth functioning of the transport network. Society expects and perceives bridges to be safe, and the fact that there have been no cases of catastrophic bridge failures in recent years owes largely to the skill and ability of professional bridge engineers and managers. However, to maintain the continuing safety and serviceability of bridges, adequate funding needs to be made available for maintenance (i.e. inspection, testing, repair and replacement work).

1.5 Reviews by the CSS (Ref. 3 and 4) identified:

- A significant backlog of bridge maintenance in the UK.
- Inadequate current levels of expenditure on bridge maintenance.
- The condition of bridges will continue to deteriorate unless funding is significantly increased in the future to clear the backlog of works.

1.6 The CSS review concluded that in order to effectively maintain and manage the stock of bridges it is essential to have a "Condition Indicator" which can be used to determine whether the overall condition of highway bridges is deteriorating or not, and use this as a means for monitoring whether adequate funding is being provided for bridge maintenance.

OBJECTIVES

1.7 To provide algorithms for the evaluation of Bridge Condition Index (BCI) and Bridge Stock Condition Index (BSCI), these indicators are used to measure and monitor the condition of bridges and determine the adequacy of maintenance funding.

1.8 To provide guidance on the interpretation and application of Condition Indicators.

SCOPE

1.9 This Guidance Note is intended for application to the majority of Highway Bridge types found in the UK.

1.10 The BCI and BSCI algorithms utilise the condition information on individual bridge elements reported from General Inspections or a combination of General and Principal Inspections.

1.11 To enable a consistent comparison of BCI and BSCI values between Authorities it is important that element conditions are based on a consistent inspection reporting system. The Condition Indicator algorithms presented herein are based on the CSS Inspection Reporting System (Ref. 2), and hence it is preferable that they use inspection data reported in accordance with this system. However, guidance is provided on the translation of element condition data from various existing inspection reporting systems to the CSS Inspection Reporting System.

1.12 The translation adopted is dependent on the interpretation of the existing and CSS condition scales and the coarseness/fineness of the existing inspection system. As a result the comparison of Condition Indicators derived from different inspection systems will not be as accurate or as meaningful as the comparison of Condition Indicators derived from the CSS Inspection Reporting System (Ref. 2).

1.13 The translations also allow Authorities to utilise results of historical inspections and enable existing inspection reporting systems to be used in the interim period until the CSS Inspection Reporting System (Ref. 2) is implemented. The use of historical inspection data enables past trends to be identified, in particular to investigate if the stock condition is improving, constant or deteriorating.

1.14 The bridge Condition Indicators are not intended to be used on their own for prioritising maintenance works as this would need to take account of other factors such as strategic importance of the road, opportunity for network occupancy, etc.

2. DEFINITIONS AND NOTATIONS

Bridge Condition Index (BCI) – the numerical value of a bridge condition evaluated using the BCS on a scale of 100 (best condition) to 0 (worst condition).

Bridge Condition Score (BCS) - the numerical value of a bridge condition on a scale of 1 (best condition) to 5 (worst condition).

Bridge Stock Condition Index (BSCI) – the numerical value of a bridge stock condition evaluated as an average of the BCI values weighted by the deck area (m^2) of each bridge.

Deck Area – (overall width) × (distance from centreline to centreline of end supports) or (distance between face of end supports + 0.6m)

BCS_{Av} and BCI_{Av} – the average BCS or BCI for a bridge evaluated taking into account the condition of all structural elements in a bridge.

BCS_{Crit} and BCI_{Crit} – the critical BCS or BCI for a bridge evaluated taking into account the condition of those elements deemed to be of very high importance to the bridge.

$BSCI_{Av}$ – the average condition index for a bridge stock evaluated using the BCI_{Av} values for all bridges in the stock.

$BSCI_{Crit}$ – the critical condition index for a bridge stock evaluated using the BCI_{Crit} values for all bridges in the stock.

Element Condition Index (ECI) – the weighted element condition taking account of ECS and ECF.

Element Condition Score (ECS) – the numerical value of the condition of an element evaluated using inspection data (e.g. Severity and Extent) on a scale of 1 (best condition) to 5 (worst condition).

Element Importance – this takes account of the importance of an element to the overall bridge in terms of load carrying capacity, durability and public safety, it is designated as Low, Medium, High or Very High. The Element Importance classification is used to identify two factors, namely:

> **Element Condition Factor (ECF)** – used to weight the ECS to obtain the ECI, this enables direct comparison of element conditions in terms of their contribution to the overall bridge condition.
>
> **Element Importance Factor (EIF)** – used to weight individual ECI scores when evaluating the BCS_{Av}.

Severity and Extent – procedure used in some inspection reporting systems to assess and record the condition of individual bridge elements. The CSS severity/extent inspection reporting system developed in tandem with these Condition Indicators is presented in Ref. 2.

3. OVERVIEW OF THE PROCEDURE

3.1 The Condition Indicators for an individual bridge (BCI) or a stock of bridges (BSCI) are evaluated using bridge inspection data collected from General Inspections or a combination of General and Principal Inspections. Bridge inspections typically report the condition of different elements (e.g. main beams, abutments, drainage etc.) according to a predefined condition scale, e.g. CSS Inspection System (Ref. 2), Highways Agency BE11, Good/Fair/Poor, and various other condition scales used by highway authorities in the UK.

3.2 The element conditions reported on the inspection forms are utilised by the mathematical expressions presented herein to produce BCI and BSCI scores. The overall procedure is shown in the flow chart in Figure 1. The steps involved are summarised below:

i. Each element within a bridge is selected in turn and its condition data is used to produce an Element Condition Score (ECS) for the element. Section 4 describes how element condition data from the CSS Inspection Reporting System (Ref. 2) and existing inspection reporting systems are used to produce ECS.

ii. Next, the Element Importance is identified, this accounts for the importance of the element to the overall condition and functionality of the bridge. Then the Element Condition Factor (ECF) is evaluated by taking into consideration the Element Importance and the ECS.

iii. The ECS and ECF values are combined to produce the Element Condition Index (ECI) which represents the condition of the element on a scale of 1 (Best) to 5 (Worst). Steps (i) to (iii) are repeated for all elements in a bridge.

iv. Next, two different Bridge Condition Scores are evaluated: BCS_{Av} is an average of ECI values of all the elements in a bridge (weighted by the Element Importance Factor, EIF), and BCS_{Crit} is the maximum of ECI values of those elements which are considered "critical" to the integrity of the bridge. BCS values therefore have the same 1 to 5 scale as ECI.

v. The BCS values are then converted to the corresponding Bridge Condition Indices BCI_{Av} and BCI_{Crit} on a scale of 100 (Best) and 0 (Worst) condition. Steps (i) to (v) are repeated for all bridges in the stock.

vi. Finally, the BCI values for all bridges in the stock are weighted by their respective deck areas and the average values for the stock are evaluated. Thus the Bridge Stock Condition Index $BSCI_{Av}$ is a weighted average of BCI_{Av} values, while the $BSCI_{Crit}$ is a weighted average of BCI_{Crit} values for all bridges in the stock. BSCI values have the same 100 (Best) to 0 (Worst) scale as BCI.

3.3 The CSS Inspection Reporting System (Ref. 2) provides the option of reporting one span per pro forma or all spans combined together on the same pro forma. In the former case, each span is treated as a separate bridge when calculating the Bridge Condition Index (BCI). The BCI for each span is used with its appropriate deck area when calculating the BSCI. In the latter case the BCI represents the condition of the entire bridge, therefore the whole bridge deck area is used to weight the BCI when calculating the BSCI.

3.4 If necessary the condition of individual spans within a bridge can be combined using deck area for each span to produce a score for the whole bridge. Also, several forms of construction within one bridge can be dealt with in a similar manner to produce an overall BCI score for a bridge.

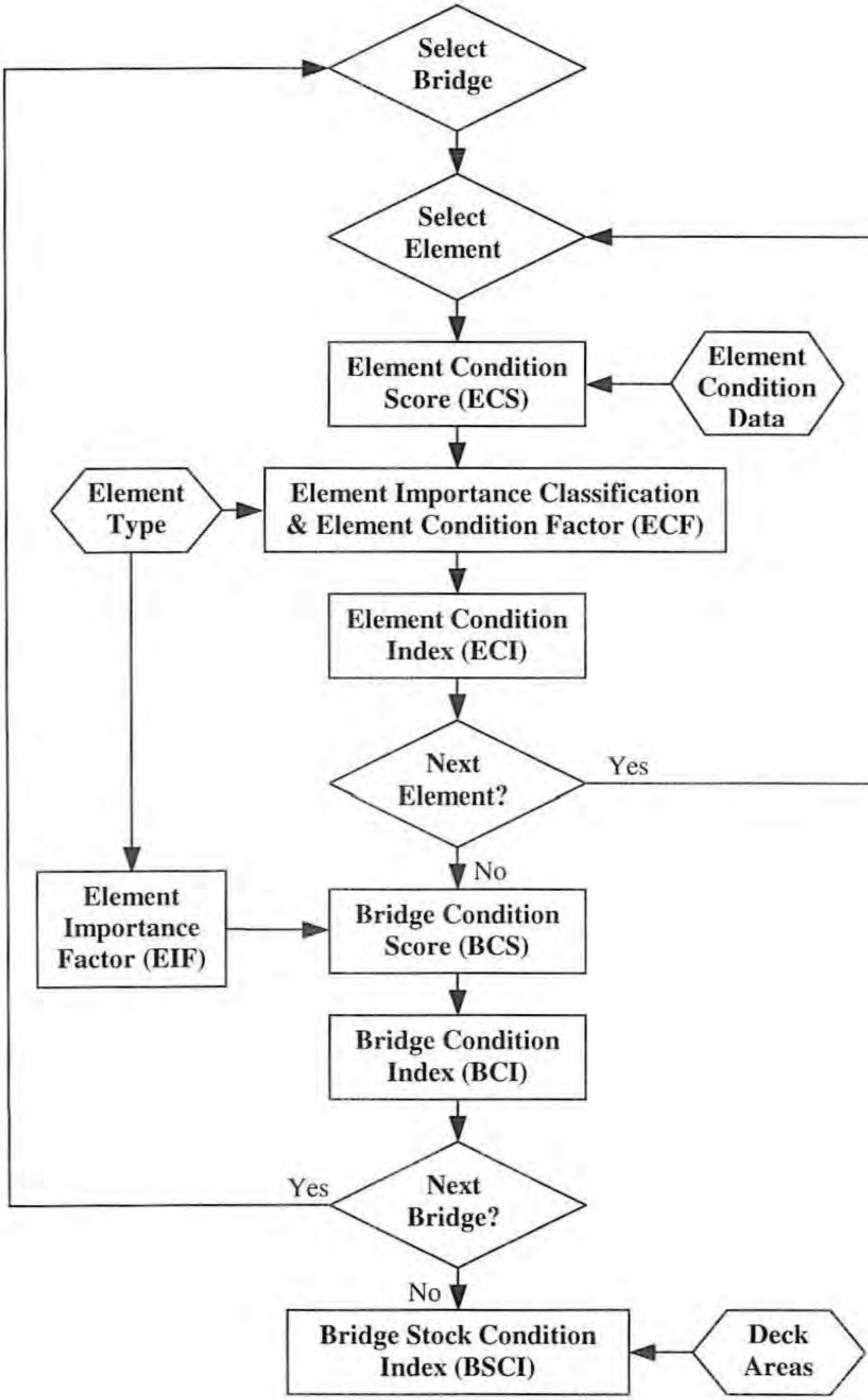

Figure 1 **Flow-chart for the derivation of bridge Condition Indicators**

4. DERIVATION OF CONDITION INDICATORS

4.1 Examples of Condition Indicator derivation are presented in Appendix B.

ELEMENT CONDITION SCORE (ECS)

4.2 The first step in deriving the Condition Indicators is to determine the Element Condition Score (ECS) for each bridge element based on the condition information obtained from inspections.

4.3 The Condition Indicator algorithms presented herein were developed in tandem with the CSS Inspection Reporting System (Ref. 2) thus a simple translation from element condition data to Element Condition Score (ECS) is available. However, the algorithms can be used with data collected by various inspection reporting systems used by Local Authorities. Guidance is provided for translating element condition data collected using other inspection reporting systems to a consistent condition scale.

4.4 The CSS Inspection Reporting System (Ref. 2) uses a Severity scale of 1 (Best) to 5 (Worst) and an Extent scale of A (non significant) to E (>50% area affected). The extent and severity values for an element are combined to produce an Element Condition Score (ECS) as specified in Table 1. The scoring reflects the view that the extent of damage is less critical than the severity of damage.

Table 1 Element Condition Score (ECS)

Extent	Severity				
	1	**2**	**3**	**4**	**5**
A	1.0				
B	1.0	2.0	3.0	4.0	5.0
C	1.1	2.1	3.1	4.1	
D	1.3	2.3	3.3	4.3	
E	1.7	2.7	3.7	4.7	

*Shaded boxes represent non-permissible Severity/Extent combinations, see Ref. 2.

4.5 When the condition data is obtained from different inspection reporting systems a harmonisation matrix is used to translate the condition data to a common scale as given in Table 2.

4.6 Appropriate guidance is provided in Table 2 but Authorities should seek agreement with the CSS Bridges Group before finalising the translation for their particular inspection system. The translations provided in Table 2 may need to be refined on the basis of further trials by the appropriate Authorities.

Table 2 Harmonisation Matrix for a common condition scale

	Element Condition Score (ECS)																
Condition Reporting System	**1**	**1.1**	**1.3**	**1.7**	**2**	**2.1**	**2.3**	**2.7**	**3**	**3.1**	**3.3**	**3.7**	**4**	**4.1**	**4.3**	**4.7**	**5**
CSS Inspection System (Ref. 2)	1A, 1B	1C	1D	1E	2B	2C	2D	2E	3B	3C	3D	3E	4B	4C	4D	4E	5
HA BE11 Extent & Severity	1A, 1B	1C	1D	1E	2B	2C	2D		3B	3C	3D		4B	4C	4D		
Lancashire Condition Factor	5					4				3					2		1
PJ Andrews (Ref. 5) Condition Factor						0.9				0.7			0.5		0.3		0.1
Good, Fair, Poor (e.g. Cheshire)	G									F				P			
Condition Factor (e.g. Northumberland)	*					3				2				1			

ELEMENT IMPORTANCE CLASSIFICATION

4.7 Element importance reflects the importance of an element to the overall bridge in terms of (i) load carrying capacity, (ii) durability, and (iii) public safety. Depending on the function performed by an element and its importance to the overall functioning of a bridge, the importance of an element is designated as "Very High", "High", "Medium" or "Low". The importance assigned to elements in the CSS Inspection Reporting pro forma (Ref. 2) are shown in Table 3. <u>See Appendix A for the EIF to be used with Retaining walls.</u>

4.8 Tables of equivalent element types and terminology to those presented in Table 3 are given in Ref. 2. If the inspection reporting system currently used by an Authority contains elements other than those given in Table 3 then their element importance should be assigned based on the equivalent element tables.

Table 3 Element importance classification for different bridge elements

SET	ITEM No.	ELEMENT DESCRIPTION		ELEMENT IMPORTANCE
Deck Elements	1	Primary deck element		Very High
	2	Secondary deck element/s	Transverse Beams	Very High
	3		Element from Table 2 of Ref. 2	Very High
	4	Half joints		Very High
	5	Tie beam/rod		Very High
	6	Parapet beam or cantilever		Very High
	7	Deck bracing		High
Load-Bearing Substructure	8	Foundations		High
	9	Abutments (incl. arch springing)		High
	10	Spandrel wall/head wall		High
	11	Pier/column		Very High
	12	Cross-head/capping beam		Very High
	13	Bearings		High
	14	Bearing plinth/shelf		Medium
Durability Elements	15	Superstructure drainage		Medium
	16	Substructure drainage		Medium
	17	Water proofing		Medium
	18	Movement/expansion joints		High
	19	Painting: deck elements		Medium
	20	Painting: substructure elements		Medium
	21	Painting: parapets/safety fences		Medium
Safety Elements	22	Access/walkways/gantries		Medium
	23	Handrail/parapets/safety fences		High
	24	Carriageway surfacing		Medium
	25	Footway/verge/footbridge surfacing		Low
Other Bridge Elements	26	Invert/river bed		Medium
	27	Aprons		Medium
	28	Fenders/cutwaters/collision protection		Medium
	29	River training works		Medium
	30	Revetment/batter paving		Low
	31	Wing walls		High
	32	Retaining walls		Medium
	33	Embankments		Low
	34	Machinery		Medium
Ancillary Elements	35	Approach rails/barriers/walls		Elements not used to evaluate Condition Indicators, thus importance not required
	36	Signs		
	37	Lighting		
	38	Services		
Blank spaces provided on pro forma	39			
	40			
	41			
	42			

Note: Some bridges have more than one element type for row No's 1 & 3 (see Ref. 2 on Multiple Construction Forms). If the inspector has additional primary/secondary deck element descriptions and conditions on the pro forma (e.g. rows 39 to 42) they should be used in the BCS calculation as shown in Section 4.15.

ELEMENT CONDITION FACTOR (ECF)

4.9 The Element Condition Factor (ECF) reflects the influence the condition of an element has on the condition of the overall bridge. It is evaluated using the expressions given in Table 4 taking into account the element importance classification from Table 3 and the Element Condition Score (ECS) determined from Table 1 or Table 2.

Table 4 Expressions for Element Condition Factor (ECF)

Element Importance	Element Condition Factor (ECF)
Very High	$ECF = 0.0$
High	$ECF = 0.3 - [(ECS - 1) \times 0.3/4]$
Medium	$ECF = 0.6 - [(ECS - 1) \times 0.6/4]$
Low	$ECF = 1.2 - [(ECS - 1) \times 1.2/4]$

ELEMENT CONDITION INDEX (ECI)

4.10 The Element Condition Index (ECI) indicates the contribution the condition of an element makes to the condition of the bridge as a whole. The ECI is determined by adjusting the Element Condition Score (ECS) to account for the Element Condition Factor (ECF) as shown below.

$$\mathbf{ECI = ECS - ECF} \qquad \text{but is always} \geq 1 \qquad (4.1)$$

4.11 The relationship between the Element Condition Index and the Element Condition Score is shown in Figure 2. This shows that, except for elements of very high importance, the damage is less critical to the overall bridge than it is for that element. For example, a "Low" importance element with an ECS = 4 has an ECI = 3.7, whereas for an ECS = 3 the corresponding ECI is 2.4. On the other hand, for elements of "Very High" importance, the ECI is the same as the ECS, implying that damage on this element is equally critical to the function of the overall bridge.

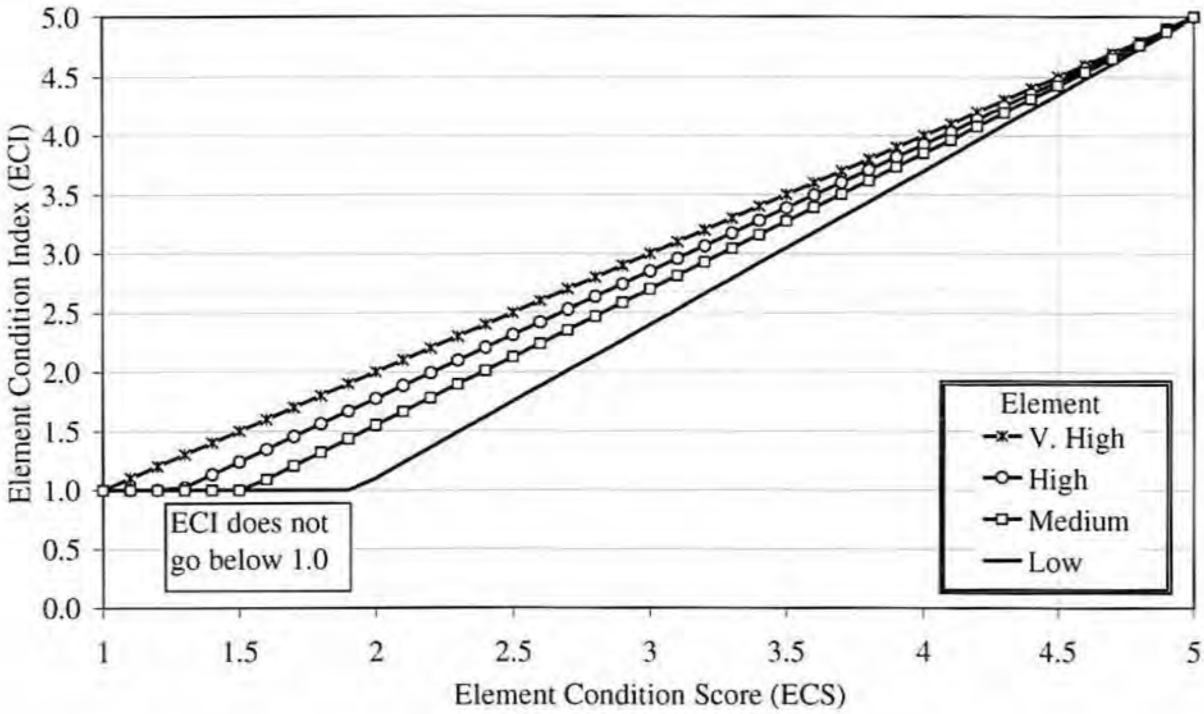

Figure 2 Influence of element importance on the Element Condition Index

ELEMENT IMPORTANCE FACTOR (EIF)

4.12 The Element Importance Factor (EIF) is used to weight the ECI values of different elements for the evaluation of the BCS, see Section 4.13. The EIF represents the importance of the element to the overall functionality of the bridge (load carrying capacity, durability and public safety). The EIFs are shown in Table 5.

Table 5 Element Importance Factor (EIF)

Element Importance	EIF
Very High	2.0
High	1.5
Medium	1.2
Low	1.0

BRIDGE CONDITION SCORE (BCS)

4.13 The Bridge Condition Score (BCS) represents the condition of the bridge as a whole and is evaluated as a function of the ECI values of elements with No.'s 1 to 34 in Table 3. Two different Bridge Condition Scores, BCS_{Av} and BCS_{Crit}, are evaluated as given by the expressions below. BCS_{Av} considers all the elements with No.'s 1 to 34 in Table 3 while the BCS_{Crit} is based on only those elements which are considered as having very high importance to the safety and durability of a bridge.

$$BCS_{Av} = \frac{\sum_{i=1}^{N}(ECI_i \times EIF_i)}{\sum_{i=1}^{N} EIF_i} \tag{4.2}$$

where N is the total number of bridge elements used in the BCS calculation.

$$BCS_{Crit} = \max\begin{Bmatrix} \text{ECI for primary deck elements} \\ \text{ECI for secondary deck elements} \\ \text{ECI for half joints} \\ \text{ECI for tie beam/rod} \\ \text{ECI for parapet beam or cantilever} \\ \text{ECI for pier/column} \\ \text{ECI for cross - head/capping beam} \end{Bmatrix} \tag{4.3}$$

4.14 The BCS_{Av} alone may not give a complete picture of the "health" of a bridge. For example, a bridge may have a low BCI_{Av} score implying it is in a very good condition, however, the bridge may be close to collapse if for instance one of the columns has suffered a severe impact, hence the need for BCI_{Crit}. On the other hand, BCI_{Crit} although giving an indication of the criticality of the bridge, does not provide an indication of how widespread the deterioration is over the bridge. Therefore, both of these indicators should be used to obtain a more complete picture of the health of a bridge.

Additional Considerations when Evaluating the BCS

4.15 When more than one primary/secondary deck element has been reported on a pro forma their ECI scores need to be combined before they are used in the BCS calculation. The combined ECI (ECI_{Comb}) is evaluated as:

$$ECI_{Comb} = \frac{(ECI_1 \times \text{appropriate quantity}) + \text{K} + (ECI_n \times \text{appropriate quantity})}{\text{Sum of appropriate quantity}}$$

where n = number of primary or secondary elements

appropriate quantity = preferable deck area served by the elements but number or length may also be used. The appropriate quantity must be consistent throughout the equation

ECI_{Comb} is then used in Equations 4.2 and 4.3 along with the ECI values for the remaining bridge elements.

4.16 When the inspector has been unable to inspect an element on site the condition is reported as *NI* (not inspected) on the pro forma. This element is not included in the evaluation of the BCS. However this information should be used to:

- indicate which structures received an incomplete inspection and identify what action is required to allow a complete inspection; and
- create an annual Performance Indicator entitled "Percentage of Incomplete Bridge Inspections"

BRIDGE CONDITION INDEX (BCI)

4.17 The Bridge Condition Score (BCS) has the same scale as the Element Condition Score (ECS), i.e. 1 (Best) to 5 (Worst), and can in general be interpreted in an analogous way to ECS. However, this scale is considered to be somewhat difficult to understand and confusing for those outside the bridge engineering community. Therefore, a Bridge Condition Index (BCI) is introduced which is defined on a scale of 100 (Best) to 0 (Worst). Guidance on the interpretation and use of BCS and BCI values is given in Section 5.

4.18 The BCS_{Av} and BCS_{Crit} values are converted to the corresponding BCI_{Av} and BCI_{Crit} values as shown below. The relationship is also shown in Figure 3. The non-linear relationship reflects the fact that as the BCS value increases from 1 to 5, the bridge condition deteriorates progressively more rapidly.

$$BCI_{Av} = 100 - 2\left\{(BCS_{Av})^2 + (6.5 \times BCS_{Av}) - 7.5\right\}$$

$$BCI_{Crit} = 100 - 2\left\{(BCS_{Crit})^2 + (6.5 \times BCS_{Crit}) - 7.5\right\} \quad (4.4)$$

Figure 3 Relationship between BCS and BCI values

Bridge Stock Condition Index (BSCI)

4.19 In addition to the operational need for monitoring the condition of individual bridges using the BCI values, there is also a need for monitoring the condition of the overall bridge stock at a strategic level. The Bridge Stock Condition Index (BSCI) is introduced to serve this purpose.

4.20 In aggregating the BCI values for the whole stock, the differences in the size of bridges should be recognised. If size is not considered then large multi-span bridges carrying four or more traffic lanes which require higher maintenance funding would be unfairly treated compared to small single span bridges carrying one or two lanes of traffic. Furthermore, the CSS Inspection Reporting System (Ref. 2) allows the reporting of element conditions either on individual spans or for all the spans together; and in this case it is necessary that the resulting BSCI is consistent for both the options. For this reason, the BCI values are weighted by their respective deck areas in calculating the average values of BSCI for the stock.

4.21 It is recognised that using deck area to weight the BCI values is a simplification. However, it is sufficient for <u>Condition</u> Indicators and simple for Authorities to determine based on readily available information. Ideally asset or replacement value should be used; these will be addressed by future Performance Indicators.

4.22 Analogous to the BCI two different BSCI, average and critical, are calculated using the expressions given below. $BSCI_{Av}$ and $BSCI_{Crit}$ similarly have a scale of 100 (Best) to 0 (Worst).

$$BSCI_{Av} = \frac{\sum_{i=1}^{M} (BCI_{Av} \times \text{Deck Area})_i}{\sum_{i=1}^{M} \text{Deck Area}_i} \qquad (4.5)$$

$$BSCI_{Crit} = \frac{\sum_{i=1}^{M} (BCI_{Crit} \times \text{Deck Area})_i}{\sum_{i=1}^{M} \text{Deck Area}_i} \qquad (4.6)$$

where M is the total number of bridges (or spans) in the stock; and deck area is defined as:

1. Deck Area = (Overall Width) × (Centreline to Centreline of end supports);

OR

2. Deck Area = (Overall Width) × (distance between faces of end supports + 0.6m)

4.23 Where the element conditions are reported on an individual span basis the deck area in the above should correspond to each span. On the other hand, if the element conditions are reported for all the spans taken together, the deck area should correspond to the entire bridge. Similarly, where different construction types in modified/widened parts of a bridge are reported separately, these should be treated as separate bridges for the calculation of BCI and BSCI values.

SPAN TO BRIDGE BCI CONVERSION FOR MULTI SPAN BRIDGES

4.24 If an overall BCI is required for a multi span bridge that has been inspected per span then the following equations may be used:

$$BCI_{Av} = \frac{\sum_{i=1}^{S}\left(BCI_{Av} \times \text{Span Deck Area}\right)_i}{\text{Whole Bridge Deck Area}} \tag{4.7}$$

$$BCI_{Crit} = \frac{\sum_{i=1}^{S}\left(BCI_{Crit} \times \text{Span Deck Area}\right)_i}{\text{Whole Bridge Deck Area}} \tag{4.8}$$

where S is the total number of spans in the bridge.

This approach still applies when the spans are of different construction forms. It may also be used when separate BCI values have been evaluated for different construction forms within one span.

5. INTERPRETATION AND USE OF CONDITION INDICATOR VALUES

GENERAL

5.1 This Section provides guidance on the interpretation and use of Condition Indicators. The main purpose of the Condition Indicators is to monitor the change in condition of individual bridges and a stock of bridges with time, and determine if the maintenance funding provided has been adequate.

5.2 The Bridge Stock Condition Index (BSCI) provides an overview of the change in condition of a bridge stock and hence can be used as a high level strategic tool. If evaluated on a consistent basis, the BSCI can also be used to compare bridge stocks from different Authorities and benchmark their performance.

5.3 For operational purposes and for use by bridge managers and engineers it is useful to have a detailed break down of the condition of individual bridges and groups of bridges of a similar material, construction, age, etc. This information can be presented in the form of histograms of bridge Condition Indicators as illustrated in the following sections.

5.4 The Bridge Condition Score (BCS) has the same scale as the Element Severity with 1 representing no significant damage to 5 implying failure or loss of serviceability. As the value increases from 1 to 5, the severity of damage increases non-linearly. Bridge engineers have a good intuitive feel for this scale and hence it is suggested that they would primarily use the BCS values for operational purposes.

5.5 The Bridge Condition Index (BCI) on the other hand has a simple linear scale with 100 representing a bridge in a very good condition while 0 implies that a bridge is no longer serviceable. The BCI is therefore useful for communication outside the bridge engineering community.

INTERPRETATION OF BRIDGE CONDITION SCORE (BCS) VALUES

5.6 The Bridge Condition Score values on a scale of 1 to 5 can be interpreted as suggested in Table 6.

Table 6 Interpretation of BCS values

BCS Range	**BCS_{Av}** (All Bridge Elements)	**BCS_{Crit}** (Worst Critical Element)
1.0 → 1.3	No significant defects in any elements; Bridge is in a "**Very Good**" condition overall	Insignificant defects/damage; Capacity unaffected.
1.31 → 1.8	Mostly minor defects/damage; Bridge is in a "**Good**" condition overall;	Superficial defects/damage; Capacity unaffected.
1.81 → 2.7	Minor-to-Moderate defects/damage; Bridge is in a "**Fair**" condition overall; One or more functions of the bridge may be significantly affected.	Minor defects/damage; Capacity may be slightly affected.
2.71 → 3.7	Moderate-to-Severe defects/damage; Bridge is in a "**Poor**" condition overall; One or more functions of the bridge may be severely affected.	Moderate defects/damage; Capacity may be significantly affected.
3.71 → 4.7	Severe defects/damage on a number of elements; One or more elements may have failed; Bridge is in a "**Very Poor**" condition overall;	Possibly element failure; Severe defects/damage; Capacity may be severely affected; Bridge may need to be weight restricted or closed to traffic
4.71 → 5.0	Majority of bridge elements have failed; Bridge is unserviceable.	Failure of critical element; Bridge should be closed.

5.7 The Bridge Stock Condition Index incorporates a large amount of data into one number which inevitably leads to a loss of information. In order to more fully understand the change in the bridge stock condition with time it is beneficial to view the underlying data used to calculate the BSCI. Two histograms are recommended to aid the interpretation of the bridge stock condition: (i) BCS_{Av} and (ii) BCS_{Crit} as illustrated below.

***BCS_{Av}* Histograms**

5.8 The BCS_{Av} scores for a stock of bridges are used to create a histogram based on the intervals shown in Table 7. Smaller intervals may be used if desired but larger intervals should not be used as they result in a significant loss of sensitivity. The "Number of Occurrences" column refers to the number of bridges (or spans), within the stock being analysed, that have BCS_{Av} values within the defined interval. The summation of the Number of Occurrences column should equal the total number of bridges/spans in the stock being analysed.

Table 7 BCS_{Av} Histogram Intervals

Band	BCS_{Av} Interval	Number of Occurrences
1	= 1	F_1
2	> 1 and ≤ 1.2	F_2
3	> 1.2 and ≤ 1.4	F_3
4	> 1.4 and ≤ 1.6	F_4
5	> 1.6 and ≤ 1.8	F_5
6	> 1.8 and ≤ 2.0	F_6
7	> 2.0 and ≤ 2.2	F_7
8	> 2.2 and ≤ 2.4	F_8
9	> 2.4 and ≤ 2.6	F_9
10	> 2.6 and ≤ 2.8	F_{10}
11	> 2.8 and ≤ 3.0	F_{11}
12	> 3.0 and ≤ 3.2	F_{12}
13	> 3.2 and ≤ 3.4	F_{13}
14	> 3.4 and ≤ 3.6	F_{14}
15	> 3.6 and ≤ 3.8	F_{15}
16	> 3.8 and ≤ 4.0	F_{16}
17	> 4.0 and ≤ 4.2	F_{17}
18	> 4.2 and ≤ 4.4	F_{18}
19	> 4.4 and ≤ 4.6	F_{19}
20	> 4.6 and ≤ 4.8	F_{20}
21	> 4.8 and < 5.0	F_{21}
	Total =	$\sum_{i=1}^{M} F_i = M$

Where M = total number of bridges/spans in the stock under consideration.

5.9 An example histogram for a sample stock of bridges is shown in Figure 4. The histogram gives a good indication of the spread of BCS_{Av} values for the bridges in the stock. The average of BCS_{Av} values and percentage of bridges exceeding a specified value (say 2.7) provide useful indicators of bridge condition. Such histograms can be developed for groups of similar bridges, for example by material, construction form, age, etc. which provide an useful insight in understanding which groups of bridges are particularly in a poor or good condition.

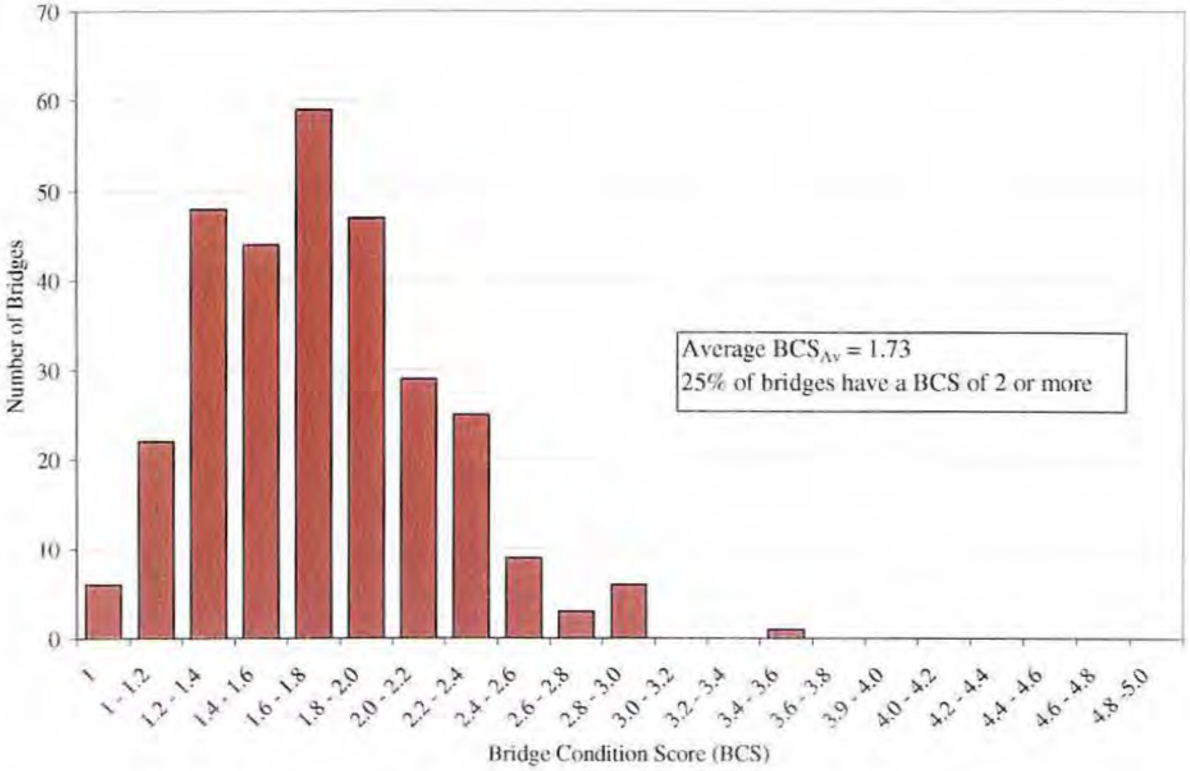

Figure 4 Example BCS_{Av} Histogram

BCS_{Crit} Histograms

5.10 The BCS_{Crit} is based on critical elements that have a "Very High" element importance rating and hence ECI = ECS, see Section 4.9 to 4.11. The BCS_{Crit} therefore takes discrete values and hence the histogram values suggested are as in Table 8.

5.11 An example BCS_{Crit} histogram for a stock of bridges is shown in Figure 5. There are only five bars on the histogram because the bridge data analysed used a different inspection reporting system to that proposed in Ref. 2 i.e. see Table 2 for an indication of the number of bands that will be utilised in Table 8 by different scoring systems.

Table 8 BCS_{Crit} Histogram Intervals

Band	BCS_{Crit} Interval	Number of Occurrences
1	1.0	F_1
2	1.1	F_2
3	1.3	F_3
4	1.7	F_4
5	2.0	F_5
6	2.1	F_6
7	2.3	F_7
8	2.7	F_8
9	3.0	F_9
10	3.1	F_{10}
11	3.3	F_{11}
12	3.7	F_{12}
13	4.0	F_{13}
14	4.1	F_{14}
15	4.3	F_{15}
16	4.7	F_{16}
17	5.0	F_{17}
	Total =	$\sum_{i=1}^{M} F_i = M$

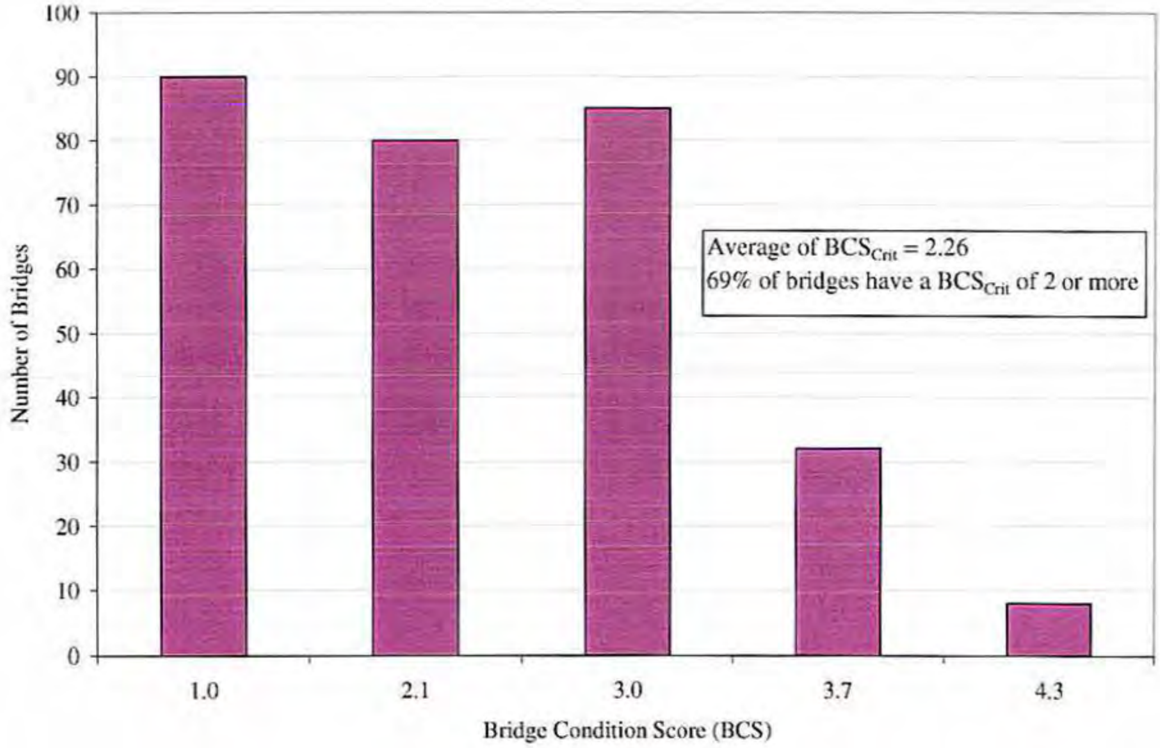

Figure 5 Example BCS_{Crit} Histogram

INTERPRETATION OF BRIDGE CONDITION INDEX VALUES

5.12 The conversion from BCS to BCI maps the values to a linear scale from 0 to 100. The BCI values can be interpreted broadly as the "percentage service potential" of a bridge. Thus, a BCI value of 100 implies that the bridge has retained 100% of its service potential; a value of 60 indicates that the bridge has lost 40% of its service potential; while a value of 0 implies that the bridge is no longer serviceable.

5.13 From Figure 3, it can be seen that when the BCS value is 2 the BCI is 81 implying that the bridge retains 81% of its service potential, while at a BCS value of 4 the bridge is considered to retain only 31% of its service potential.

5.14 It should be recognised that the effort involved, and hence the maintenance funding required, to improve the BCS value of a bridge, for example from 2 → 1 can be significantly different from improving it from 4 → 3. This is reflected in the BCI scale e.g. an improvement in the BCS from 2 → 1 is an improvement of 81 → 100 (19%) on the BCI scale, where as a BCS improvement of 4 → 3 is an improvement of 31 → 58 (27%) on the BCI scale.

INTERPRETATION OF BRIDGE STOCK CONDITION INDEX VALUES

5.15 The interpretation of the $BSCI_{Av}$ and $BSCI_{Crit}$ values in terms of the general condition of the bridge stock is given in Table 9.

5.16 In deciding on the level of funding to be allocated to different bridge stocks, it should be recognised that the funding required for a stock which is in a poor condition, e.g. BSCI = 50, can be very high compared to another stock which is in a fair condition with BSCI of say 75 to obtain the same increase in the BSCI value, also see 5.14 above.

5.17 When comparing the condition of different bridge stocks, in addition to their BSCI values, it is more informative to compare the BCI_{Av} and BCI_{Crit} histograms for these bridge stocks.

Table 9 Interpretation of $BSCI_{Av}$ and $BSCI_{Crit}$ values

BSCI Range	BCS Range	Bridge Stock Condition based on $BSCI_{Av}$	Bridge Stock Condition based on $BSCI_{Crit}$
100 → 95 Very Good	1.0 → 1.3	Bridge stock is in a **very good** condition. Very few bridges may be in a moderate to severe condition.	Very few critical load bearing elements may be in a moderate to severe condition. Represents **very low risk** to public safety.
94 → 85 Good	1.31 → 1.8	Bridge stock is in a **good** condition. A few bridges may be in a severe condition.	A few critical load bearing elements may be in a severe condition. Represents a **low risk** to public safety.
84 → 65 Fair	1.81 → 2.7	Bridge stock is in a **fair** condition. Some bridges may be in a severe condition. Potential for rapid decrease in condition if sufficient maintenance funding is not provided. Moderate backlog of maintenance work.	Wide variability of conditions for critical load bearing elements, some may be in a sever condition. Some bridges may represent a **moderate risk** to public safety unless mitigation measures are in place.
64 → 40 Poor	2.71 → 3.7	Bridge stock is in a **poor** condition. A significant number of bridges may be in a severe condition. Maintenance work historically under funded and there is a significant backlog of maintenance work.	A significant number of critical load bearing elements may be in a severe condition. Some bridges may represent a **significant risk** to public safety unless mitigation measures are in place.
39 → 0 Very Poor	3.71 → 5.0	Bridge stock is in a **very poor** condition. Many bridges may be unserviceable or close to it. Maintenance work historically under funded and there is a huge backlog of work.	Many critical load bearing elements may be unserviceable or close to it and are in a dangerous condition. Some bridges may represent a **high risk** to public safety unless mitigation measures are in place.

5.18 Figure 6 presents BCI_{Av} histograms for two sample bridge stocks with approximately 300 bridges in each. The histograms clearly show that Sample Stock 2 is in a better overall condition than Sample Stock 1.

5.19 The histograms illustrate that Sample Stock 1 has some 39% of bridges with BCI_{Av} less than 85, i.e. not in Very Good or Good condition, while Sample Stock 2 has only 13% in a similar state. This simple, yet beneficial, information is not available from the single $BSCI_{Av}$ values, hence the need to supplement BSCI values with histograms.

5.20 It is of benefit to individual Authorities to monitor the change in their own stock on a frequent (say annual) basis. Maintaining annual histograms of the bridge stock, and sub-groups of the bridge stock e.g. similar material, construction, ages etc., allows bridge managers to more readily identify where and when additional funding is required.

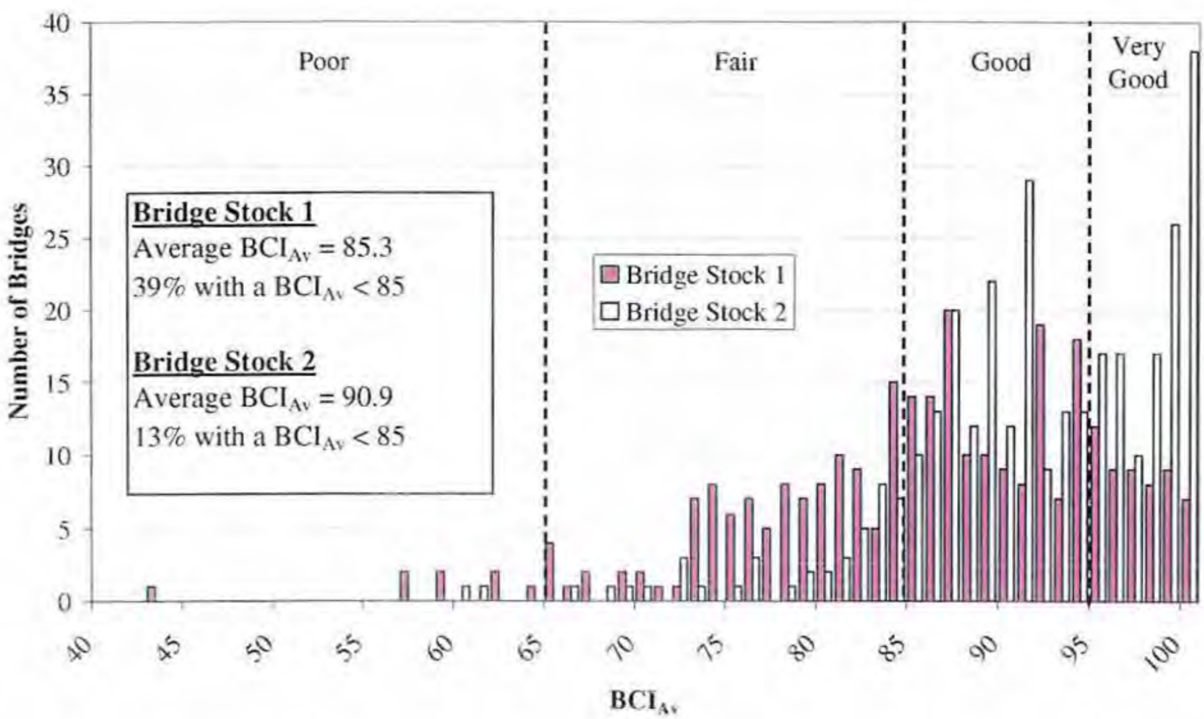

Figure 6 Comparison of BCI_{Av} histograms

6. ENQUIRIES

A Microsoft Excel spreadsheet that calculates the BCI and BSCI values is available from:

Mr Greg Perks
Principal Transport Policy Officer
Northumberland County Council
Environment Directorate
County Hall
Morpeth
NE61 2EF

Telephone: 01670 533973
Fax: 01670 533086
E-mail: GPerks@northumberland.gov.uk

This spreadsheet may be used in the interim period until Authorities have adopted the Condition Indicator algorithms into their bridge management system.

7. REFERENCES

1. Bridge Condition Indicators Volume 1: Commission Report, CSS Bridges Group, April 2002.
2. Bridge Condition Indicators Volume 2: Guidance Note on Bridge Inspection Reporting, CSS Bridges Group, April 2002.
3. Funding for Bridge Maintenance, CSS Bridges Group, February 2000.
4. The CSS Review, ICE Seminar on Bridge Rehabilitation in the UK, October 2000.
5. P.J Andrews, "Objectivity in Bridge Engineering", IHT April 1984.

APPENDIX A

RETAINING WALL IMPORTANCE CLASSIFICATION

Table A1 Retaining Wall Element Importance Classifications

Element Pro Forma No.	Element Description	Element Importance
8	Foundations	High
16	Substructure drainage	Medium
18	Movement/Expansion joints	High
20	Painting – substructure elements	Medium
23	Parapets	High
24	Carriageway surfacing	Medium
25	Footway/verge surfacing	Low
26	Invert/river bed	Medium
27	Aprons	Medium
32	Retaining wall	Medium
35	Approach rails/barriers/walls	Elements not used to calculate Condition Indicators, thus importance not required.
36	Signs	
37	Lighting	
38	Services	

APPENDIX B

WORKED EXAMPLES

Example 1: Steel Beam and Brick Jack Arch Bridge

The steps required to evaluate the BCI are described below:

1. The inspection was performed using the procedure described in Ref. 2. The elements inspected are shown in column 2 of Table B1. The numbers in column 1 relate to the "Item No." in Table 3.

2. The severity/extent scores, described in Ref. 2, are shown in column 3 of Table B1, these are converted to the Element Condition Scores (ECS) using Table 1. The ECS are shown in column 4 of Table B1. ***NI*** is an abbreviation for Not Inspected, which is to be expected for foundations because they are below ground level. Access to the bearings was not possible.

3. The Element Condition Factor (ECF) and Element Condition Score (ECS) are used as shown in Sections 4.9 to 4.11 to calculate the Element Condition Index (ECI) which is shown in column 6 of Table B1. (Note: ECI does not drop below 1.0).

4. Column 6 is weighted by the EIF (column 5) to give the scores in column 7. The summation of column 7 in Table B1, ΣECI_W, divided by the sum of element weightings gives the average Bridge Condition Score (Eq. 4.2, Section 4.13), thus

$$BCS_{Av} = \frac{\sum ECI_W}{\sum EIF} = \frac{35.37}{20.8} = 1.70$$

5. Column 8 of Table B1 shows the ECI for the elements that are considered to be critical as given in Eq. (4.3), Section 4.13. The maximum ECI of this column gives the critical Bridge Condition Score (BCS_{Crit}), thus

$BCS_{Crit} = 2.0$

6. The BCS are converted to the BCI using equation (4.4) given in Section 4.18, thus

$BCI_{Av} = 100 - 2\times(BCS_{Av}^2 + 6.5\times BCS_{Av} - 7.5) = 87.1$

$BCI_{Crit} = 100 - 2\times(BCS_{Crit}^2 + 6.5\times BCS_{Crit} - 7.5) = 81$

Table B1 Evaluation of BCI

1	2	3	4	5	6	7	8
Element No. (Table 3)	**Element Description**	Element Condition (Severity/Extent)	Element Condition Score, ECS (Table 1)	Element Importance Factor, EIF (Table 5)	Element Condition Index, ECI (Section 4.10)	Weighted ECI_W	Critical Elements
1	Steel beams	1A	1.0	2.0	1.0	2.0	1.0
3	Brick jack arch	2B	2.0	2.0	2.0	4.0	2.0
5	Tie beam/rod	2B	2.0	2.0	2.0	4.0	2.0
8	Foundations	***NI***	-	-	-	-	-
9	Abutments	1B	1.0	1.5	1.0	1.5	
10	Spandrel wall/head wall	2C	2.1	1.5	1.883	2.82	
11	Pier/column	1A	1.0	2.0	1.0	2.0	1.0
13	Bearings	***NI***	-	-	-	-	-
14	Bearing plinth/shelf	***NI***	-	-	-	-	-
15	Superstructure drainage	3B	3.0	1.2	2.70	3.24	
17	Waterproofing	4D	4.3	1.2	4.195	5.03	
19	Painting: deck elements	2B	2.0	1.2	1.55	1.86	
23	Handrail/parapets/safety fence	2A	2.0	1.5	1.775	2.66	
24	Carriageway surfacing	2D	2.3	1.2	1.895	2.27	
25	Footway/verge/footbridge surfacing	2D	2.3	1.0	1.49	1.49	
31	Wing walls	1B	1.0	1.5	1.0	1.5	
33	Embankments	1A	1.0	1.0	1.0	1.0	

No. of elements = 17 – 3 = 14 **$\Sigma EIF = 20.8$** **$\Sigma ECI_W = 35.37$** **2.0**

(3 elements not inspected)

Example 2: Arch Bridge

The steps required to evaluate the BCI are described below:

1. The inspection was performed using the Good, Fair, Poor scoring system. The elements inspected are shown in column 2 of Table B2. The numbers in column 1 of Table B2 relate to the "Item No." in Table 3.

2. The Good/Fair/Poor scores are shown in column 3 of Table B2, these are converted to the Element Condition Scores (ECS) using Table 2. The ECS are shown in column 4 of Table B2.

3. The Element Condition Factor (ECF) and Element Condition Score (ECS) are used as shown in Sections 4.9 to 4.11 to calculate the Element Condition Index (ECI) which is shown in column 6 of Table B2.

4. The summation of column 7 in Table B2, ΣECI_W, divided by the sum of element weightings gives the average Bridge Condition Score (Eq. 4.2, Section 4.13), thus

$$BCS_{Av} = \frac{\sum ECI_W}{\sum EIF} = \frac{46.68}{17.2} = 2.71$$

5. Column 8 of Table B2 shows the ECI for the elements that are considered to be critical as given in Eq. (4.3), Section 4.13. The maximum ECI of this column gives the critical Bridge Condition Score (BCS_{Crit}), thus

$BCS_{Crit} = 4.1$

6. The BCS are converted to the BCI using the equation (4.4) given in Section 4.18, thus

$BCI_{Av} = 100 - 2\times(BCS_{Av}^2 + 6.5\times BCS_{Av} - 7.5) = 65.0$

$BCI_{Crit} = 100 - 2\times(BCS_{Crit}^2 + 6.5\times BCS_{Crit} - 7.5) = 28.1$

Table B2 Evaluation of BCI

1	2	3	4	5	6	7	8
Element No. (Table 3)	**Element Description**	**Element Condition (Good, Fair, Poor)**	**Element Condition Score, ECS (Table 2)**	**Element Importance Factor, EIF (Table 5)**	**Element Condition Index, ECI (Section 4.10)**	**Weighted ECI_W**	**Critical Elements**
1	Brick Arch	P	4.1	2.0	4.1	8.2	4.1
8	Foundations	*NI*	-	-	-	-	-
9	Abutments	F	3.1	1.5	2.958	4.44	
10	Spandrel wall/head wall	F	3.1	1.5	2.958	4.44	
15	Superstructure drainage	P	4.1	1.2	3.965	4.76	
17	Waterproofing	F	3.1	1.2	2.815	3.38	
23	Handrail/parapets/safety fence	G	1.0	1.5	1.0	1.5	
24	Carriageway surfacing	F	3.1	1.2	2.815	3.38	
25	Footway/verge/footbridge surfacing	G	1.0	1.0	1.0	1.0	
26	Invert/river bed	F	3.1	1.2	2.815	3.38	
27	Aprons	F	3.1	1.2	2.815	3.38	
29	River training works	F	3.1	1.2	2.815	3.38	
31	Wing walls	F	3.1	1.5	2.958	4.44	
33	Embankments	G	1.0	1.0	1.0	1.0	

No. of elements = 14 – 1 = 13 **ΣEIF = 17.2** **ΣECI_W =46.68** **4.1**

Example 3: Calculation of Bridge Stock Condition Index (BSCI)

A sample of 50 bridges was selected, with known deck areas, to evaluate the BSCI. Figure B1 shows a histogram of the deck areas.

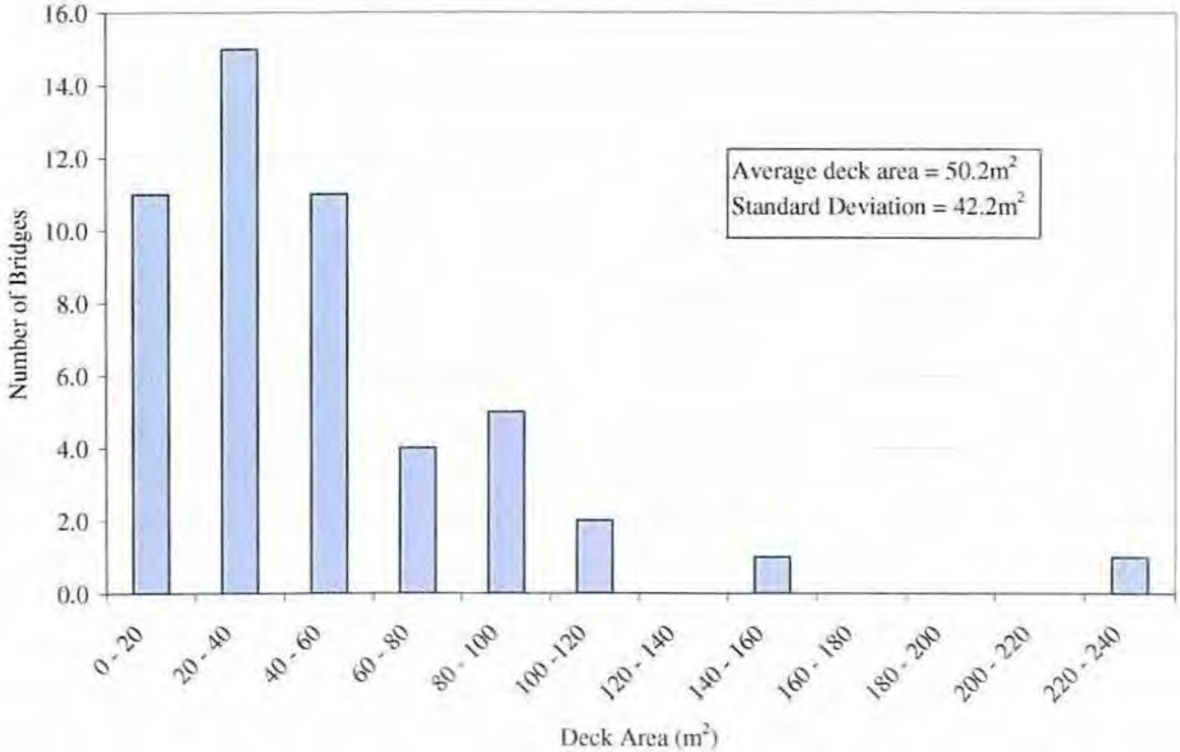

Figure B1 Histogram of deck areas

The $BSCI_{Av}$ and $BSCI_{Crit}$ are evaluated as described in Section 4.22. It is beneficial to set up tables such as that shown in Table B3 to calculate the BSCI. Table B3 contains 10 bridges selected from the 50 shown in Figure B1. The calculation steps to follow are:

1. Evaluate the BCI average and critical values for each bridge as shown in the worked examples.
2. Multiply BCI_{Av} and BCI_{Crit} by the deck area, columns 5 and 7 in Table B3.
3. Sum columns 5 and 7
4. Sum the deck areas for all the bridges in the stock, sum of column 3 in Table B3.

5. Use the summed values to calculate $BSCI_{Av}$ and $BSCI_{Crit}$ (see Section 4.22), thus:

$BSCI_{Av} = 43233/508.7 = 84.9$

$BCSI_{Crit} = 38030/508.7 = 74.8$

Table B3 Evaluation of BSCI

1	2	3	4	5	6	7
Bridge Name	**Bridge Ref**	**Deck Area (m^2)**	**BCI_{Av}**	**Deck Area × BCI_{Av}**	**BCI_{Crit}**	**Deck Area × BCI_{Crit}**
Bayfordbury	2	49.5	81.8	4049	78.9	3906
Bedwell culvert	4	29.6	79.9	2365	78.9	2335
Westmill Trout	22	26.1	63.4	1655	39.5	1031
Roxford	23	42.9	72.0	3089	58.0	2488
Stapleton	47	106.0	85.4	9052	58.0	6148
Cunningham Court	48	42.6	85.4	3638	78.9	3361
Sawbridgeworth	142	56.9	100	5690	100	5690
Beaumont Lane	148	22.6	86.7	1959	78.9	1783
Potterells	180	93.0	85.5	7952	78.9	7338
Durrants Hill Mill	616	39.5	95.8	3784	100	3950
		$\Sigma = 508.7$		$\Sigma = 43233$		$\Sigma = 38030$

County
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ADDENDUM TO

CSS GUIDANCE NOTE ON

BRIDGE CONDITION INDICATORS

Volume 3: Evaluation of Bridge Condition Indicators

August 2004

ENG-2/2004

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Published by CSS

August 2004

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Members: £10 per volume
£15 for both volumes

Non-Member: £15 per volume
£25 for both volumes

(Including post and packaging)

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1. Introduction

This addendum has been produced by the CSS Bridges Group and Atkins Highways & Transportation to supplement the original CSS BCI document suite (Refs. 1 to 3).

1.1 Background to Addendum

The CSS published three documents on Bridge Condition Indicators in April 2002:

1. Volume 1: Commission Report (Ref. 1).
2. Volume 2: Guidance Note on Bridge Inspection Reporting (Ref. 2).
3. Volume 3: Guidance Note on Evaluation of Bridge Condition Indicators (Ref. 3).

The BCI procedures are recommended as Good Practice by the CSS Bridges Group and the Code of Practice for Highway Structure Management (Ref. 4). The BCI procedures have been adopted by the majority of highway authorities in the UK and it is likely that the BCI will be used as a Best Value Performance Indicator (BVPI) by the Office of the Deputy Prime Minster (ODPM).

All authorities that adopted the BCI procedures were encouraged to provide feedback on the guidance documents to the CSS Bridges Group, in particular:

- Any errors or inconsistencies.
- Areas that the guidance is unclear or where additional guidance is required.
- Concerns/disagreements with the guidance provided.

Feedback was collated between April 2002 and December 2003; the feedback was summarised and circulated for further comment and discussion. The discussion period was closed at the end January 2004. Based on the comments/discussion it was decided that the BCI documents did not require a full revision, instead an addendum to supplement each of the Guidance documents (Ref. 2 & 3) was deemed sufficient.

1.2 Objectives of Addendum

The objectives of this addendum are:

1. To provide additional guidance on those areas of Volume 3 where the existing guidance was deemed unclear or insufficient.
2. To provide guidance on the evaluation of Condition Indicators for retaining walls, sign/signal gantries and a stock of mixed structure types.
3. To provide additional guidance on the interpretation and presentation of Condition Indicator data.

1.3 Scope of Addendum

This addendum is only intended for use with *Volume 3: Guidance Note on the Evaluation of Bridge Condition Indicators* (Ref. 3). In particular the addendum is intended to compliment Volume 3 and enable consistent and meaningful Condition Indicators to be produced for the following structure types:

- **Bridges** – structures with a span of 1.5 metres or above. This category includes subways, culverts, footbridges, tunnels and underpasses (Ref. 2 & 5). Structures with spans less than 1.5m are considered part of road maintenance because they are maintained using techniques developed by drainage engineers.
- **Retaining Walls** – all retaining walls associated with the highway, irrespective of height, are included provided their dominant function is to act as a retaining structure (Ref. 2 & 5).
- **Sign/Signal Gantries** – a structure spanning or adjacent to the highway, the primary function of which is to support traffic signs and signalling equipment.
- **Other Structure Types** - structure types associated with the highway that are not covered by the aforementioned categories.

1.4 Contents of Addendum

The contents of this addendum are:

1. Clarification on how to include the condition of half-joints in the Condition Indicator calculation (Section 2.1).
2. Clarification on how to use inspection data collected from General and Principal Inspections for the evaluation of Condition Indicators (Section 2.2).
3. Element importance classifications for retaining walls and sign/signal gantries (Section 2.3).
4. Guidance on how to evaluate the stock Condition Indicator when different structure types are present e.g. bridges, retaining walls and sign/signal gantries (Section 2.4).
5. Revision of the descriptions for the Condition Indicator categories to reflect experience to date (Section 2.5).
6. Guidance on Performance Indicator target setting (Section 2.6).
7. Guidance on the reporting and presentation of Condition Indicator data (Section 2.7).

2. Addendum Guidance to Volume 3

2.1 Half-joints

The condition of half-joints is reported separately on the inspection pro forma even through they are an integral part of the primary deck element. The Condition Indicator calculation (Ref. 3) includes the condition of the primary deck elements and half-joints when present on a structure. The procedure for structures, with half-joints, has subsequently been amended as follows:

1. The bridge inspection pro forma still allows the primary deck element and half-joint condition to be reported separately when present.
2. The calculation of the average Condition Indicator for a bridge, Equation 4.2 in Volume 3 (Ref. 3), should only include the worst of:
    a. The primary deck element condition score; or
    b. The half-joint condition score.
3. The calculation of the critical Condition Indicator for a bridge, Equation 4.3 in Volume 3 (Ref. 3), should still consider both the half-joint and the primary deck element condition ratings.

2.2 Condition Data from General and Principal Inspections

The guidance provided in Volume 2 (Ref. 2) and the Volume 2 Addendum (Ref. 6) recommends that the inspection pro forma is completed during General and Principal Inspections. An inspection pro forma completed during a GI or PI is treated in the same way by the Condition Indicator evaluation procedure i.e. the source of the condition data has no significance to the calculation.

Inspectors may be <u>unable</u> to gain access to all elements on some structures during a General Inspection and therefore cannot provide a complete set of condition ratings. Hands on access to all elements is achieved during a Principal Inspection, therefore it is important that this data is used to supplement the Condition Indicator evaluation when future GIs are incomplete. This is illustrated by the following example:

1. A Principal Inspection records the condition of bridge bearings as 3B in 1998. The rating of 3B is used in the Condition Indicator calculation.
2. During a General Inspection in 2000 the inspector cannot gain access to the bearings and is unable to inspect them, no condition is recorded on the inspection pro forma. The Condition Indicator calculation should use the 3B condition from the 1998 Principal Inspection.
3. During a General Inspection in 2002 the inspector cannot gain access to the bearings and is unable to inspect them, no condition is recorded on the inspection pro forma. The Condition Indicator calculation should again use the 3B condition from the 1998 Principal Inspection.
4. A Principle Inspection records the condition of bridge bearings as 4C in the 2004. The rating of 4C is used in the Condition Indicator calculation and sets a new benchmark condition reference for the future GIs.

5. In 2005 the bridge bearings are replaced. The completion of the maintenance action should trigger the Condition Rating in the database/files to be updated to 1A. Now the condition of 1A is the new benchmark condition reference for future GIs.

This simple example illustrates how Principal Inspection data should be used to fill in the gaps of General Inspection data and the importance of updating condition ratings when maintenance work is carried out.

2.3 Element Importance Classifications

2.3.1 Retaining Walls

Table 1 shows the element importance classifications for retaining wall elements.

Table 1 Element Importance Classifications for Retaining Walls

No.	Element		Element Importance
1	Foundations		High
2	Retaining wall	Primary	Very High
3		Secondary	Very High
4	Parapet beam/plinth		High
5	Drainage		Medium
6	Movement/Expansion joints		Medium
7	Surface finishes: wall		Medium
9	Surfaces finishes: handrail/parapet		Medium
9	Handrail/parapets/safety fences		High
10	Carriageway	Top of wall	Low
11		Foot of wall	Low
12	Footway/verge	Top of wall	Low
13		Foot of wall	Low
14	Embankment	Top of wall	Low
15		Foot of wall	Low
16	Invert/river bed		Medium
17	Aprons		Medium
18	Signs		Not used by Condition Indicator
19	Lighting		Not used by Condition Indicator
20	Services		Not used by Condition Indicator

2.3.2 Sign/Signal Gantries

The element importance classifications for sign/signal gantry elements are shown in Table 2.

Table 2 Element Importance Classifications for Sign/Signal Gantries

No.	Element	Element Importance
1	Foundations	High
2	Truss/beams/cantilever	Very High
3	Transverse members	Very High
4	Columns/supports/legs	Very High
5	Surface finishes: truss/beams/cant.	Medium
6	Surface finishes: columns/supports	Medium
7	Surface finishes: other elements	Low
8	Access/walkway/deck	High
9	Access ladder	High
10	Handrails	High
11	Base connections	Very High
12	Support to longitudinal connection	Very High
13	Sign and signal supports	Medium
14	Signs/Signals	Not used by Condition Indicator
15	Lighting	Not used by Condition Indicator
16	Services	Not used by Condition Indicator

2.4 Condition Indicator Evaluation

The Average and Critical Indicator scores for individual retaining walls and sign/signal gantries are evaluated using the same procedure as described for bridges (see paragraphs 4.10 to 4.14 of Volume 3, Ref. 3). In summary:

1. ***Average Condition Indicator*** = weighted average of all element condition scores that have an associated importance classification (see Table 1 and Table 2).

2. ***Critical Condition Indicator*** = equal to the score of the *Very High* importance element in the worst condition (see Table 1 and Table 2 for elements classified as having Very High importance).

The following sections describe how to evaluate:

- the Condition Indicator for each structure type (bridges, retaining walls and sign/signal gantries); and

- the Condition Indicator for a mixed stock of structure types.

2.4.1 Condition Indicator for Bridges

The Condition Indicator for bridges is evaluated as shown in Equation 1 i.e. Equations 4.5 and 4.6 in Volume 3 (Ref. 3).

Condition Indicator for Bridges

$$\text{Condition Indicator (Bridges)} = CI_B = \frac{\sum_{i=1}^{M}(BCI_i \times \text{Deck Area}_i)}{\sum_{i=1}^{M}\text{Deck Area}_i}$$

Equation 1

Where M = total number of bridges considered

BCI = individual Bridge Condition Indicator scores

The deck area is in m^2 as defined in Section 4.22 of Volume 3 (Ref. 3).

2.4.2 Condition Indicator for Retaining Walls

The Condition Indicator for retaining walls is evaluated as shown in Equation 2.

Condition Indicator for Retaining Walls

$$\text{Condition Indicator (Retaining Walls)} = CI_{RW} = \frac{\sum_{i=1}^{M}(RWCI_i \times \text{Wall Area}_i)}{\sum_{i=1}^{M}\text{Wall Area}_i}$$

Equation 2

Where M = total number of retaining walls considered

$RWCI$ = individual Retaining Wall Condition Indicator scores

The *Wall Area* is measured in m^2 and is the product of the wall length and the average retained height. If the retaining walls are reported per panel then the *Wall Area* should be changed to *Panel Area*.

2.4.3 Condition Indicator for Sign/Signal Gantry

The Condition Indicator for sign/signal gantries is evaluated as shown in Equation 3.

Condition Indicator for Sign/Signal Gantry

$$\text{Condition Indicator (Sign/Signal Gantry)} = CI_{SG} = \frac{\sum_{i=1}^{M}(SGCI_i \times \text{Length}_i)}{\sum_{i=1}^{M}\text{Length}_i}$$

Equation 3

Where M = total number of sign/signal gantries considered

$SGCI$ = individual sign/signal gantry Condition Indicator scores

The length is the span or cantilever length of the gantry.

2.4.4 Condition Indicator for Structure Stock

The Condition Indicator for a stock of structures (bridges, retaining walls, sign/signal gantries) is calculated using Equation 4.

Condition Indicator for Structure Stock

$$CI_{ST} = \frac{(CI_B \times TA_B \times AVF_B) + (CI_{RW} \times TA_{RW} \times AVF_{RW}) + (CI_{SG} \times TL_{SG} \times AVF_{SG})}{(TA_B \times AVF_B) + (TA_{RW} \times AVF_{RW}) + (TL_{SG} \times AVF_{SG})}$$

Equation 4

where CI_{ST} = Condition Indicator score for Structure Stock

CI_B = Condition Indicator score for Bridges, from Equation 1

CI_{RW} = Condition Indicator score for Retaining Walls, from Equation 2

CI_{SG} = Condition Indicator score for Sign/Signal Gantries, from Equation 3

TA_B = Total deck area for Bridges

TA_{RW} = Total wall area for Retaining Walls

TL_{SG} = Total length for Sign/Signal Gantries

AVF_B = Asset Value Factor for Bridges, Table 3

AVF_{RW} = Asset Value Factor for Retaining Walls, Table 3

AVF_{SG} = Asset Value Factor for Sign/Signal Gantries, Table 3

The Asset Value Factor, *AVF*, is used to weight one structure type against another in Equation 4. The *AVF* factors were derived using construction/replacement cost data from a sample of structures. The *AVF* factors for bridges, retaining walls and sign/signal gantries are shown in Table 3.

Table 3 Asset Value Factors, *AVF*

Structure Type	*AVF*		*Units*
	Overseeing Authority	*Local Authority*	
Bridge	0.30	0.20	m^2
Retaining Wall	0.25	0.10	m^2
Sign/Signal Gantry	1.0	1.0	m

Note: the Sign/Signal Gantry factor is per m length while the Bridge and Retaining Walls factors are per m^2; this is accounted for in Equation 4 by the *Total Area* and *Total Length* variables.

2.5 Condition Indicator Interpretations

The descriptions for the average and critical stock condition scores have been amended to reflect lessons learned to date and are shown in Table 4. Additional comments are also provided on funding requirements and Asset Management. It is important to remember that the descriptions shown in Table 4 are generalisations and may not reflect the true nature of your structure stock.

2.6 Condition Indicator Target Setting

The interpretations provided in Table 4 are generalisations. Local Authorities should aim to identify interpretations and Condition Indicator targets specific to their stock characteristics. Two approaches that Local Authorities may consider for target setting are summarised below.

2.6.1 Target Setting using Whole Life Costing

A relatively straightforward way to define a condition target is:

1. Select a representative sample of your structures e.g. type, material, location etc. Five to ten structures should be adequate.
2. Assuming that appropriate funding would be made available, identify a Whole Life Cost (WLC) strategy (in line with Best Value principles) for each structure.
3. Roughly estimated how the condition of the elements will vary over the next 5 to 10 years assuming your preferred WLC solution is adopted.

4. Evaluate the Condition Indicator for the next 5 to 10 years based on your condition projections for the sample structures.

5. Assuming you have projected far enough into the future your maintenance regime should be dominated by preventative activities and a relatively steady state Condition Indicator should emerge.

6. The steady state Condition Indicator value can be assumed to reflect the Best Value target condition for your structure stock.

7. The current condition of the stock can be judged against the Best Value target.

2.6.2 Target Setting using Asset Management

Implement a full Asset Management Regime, Strategy and Plan for highway structures, within the wider context of Highways Asset Management. This will allow the Best Value Condition Indicator score to be evaluated by taking into consideration:

1. Goals, objectives and policies.

2. Demands aspirations.

3. Performance measurement and gaps.

4. Whole Life Costing.

5. Optimisation and budget constraints.

6. Risk Management.

The CSS document *Framework* for *Highway Asset Management* (Ref. 7) provides guidance on developing an Asset Management Plan.

Table 4 Interpretation of Average and Critical Stock Scores

Score	Average Stock Condition	Critical Stock Condition	Addition Comments
100 → 95 **Very Good**	The structure stock is in a **very good** condition. Very few structures may be in a moderate to severe condition.	Very few critical load bearing elements may be in a moderate to severe condition. Represents **very low risk** to public safety.	If it is a relatively new stock of structures then an appropriate maintenance funding level needs to be identified through Asset Management and Best Value. If it is a mature stock then continuing with the same level of funding is likely to sustain a high condition score and an effective preventative maintenance regime.
94 → 90 **Good**	Structure stock is in a **good** condition. A few structures may be in a severe condition.	A few critical load bearing elements may be in a severe condition. Represents a **low risk** to public safety.	Historical maintenance funding levels have been at an appropriate level to maintain a good stock condition. These levels of funding should be continued to ensure condition is maintained and resources are concentrated on preventative maintenance activities.
89 → 80 **Fair**	Structure stock is in a **fair** condition. Some structures may be in a severe condition.	Some critical load bearing elements may be in a severe condition. Some structures may represent a **moderate risk** to public safety unless mitigation measures are in place.	Historical maintenance work may be under funded and structures may not be managed in accordance with Best Value principles, implementation of Asset Management is essential. Potential for rapid decrease in condition if sufficient maintenance funding is not provided. Moderate to significant backlog of maintenance work
79 → 65 **Poor**	Structure stock is in a **poor** condition. A significant number of structures may be in a severe condition.	A significant number of critical load bearing elements may be in a severe condition. Some structures may represent a **significant risk** to public safety unless mitigation measures are in place.	Historical maintenance work under funded and structures not managed in accordance with Best Value principles and Asset management. It is essential to implement Asset Management practices to ensure work is adequately funded and prioritised and risks assessed and managed. Significant to large backlog of maintenance work, essential work dominates spending.
64 → 40 **Very Poor**	Structure stock is in a **very poor** condition. Many structures may be in a severe condition.	Many critical load bearing elements may be unserviceable or close to it and are in a dangerous condition. Some structures may represent a **high risk** to public safety unless mitigation measures are in place.	Historical maintenance work significantly under funded and a large to very large maintenance backlog. An Asset Management regime is essential. Re-active approach to maintenance that has been unable to contain deterioration A significant number of structures likely to be closed, have temporary measures in place or other risk mitigation measures. Essential work dominates spending.
39 → 0 **Severe**	Structure stock is in a **severe** condition. Many structures may be unserviceable or close to it.	Majority of critical load bearing elements unserviceable or close to it and are in a dangerous condition. Some structures may represent a **very high risk** to public safety unless mitigation measures are in place.	Historical maintenance work grossly under funded and a very large maintenance backlog Re-active approach to maintenance that has been unable to prevent deterioration, only essential maintenance work performed, Asset Management is essential. Many structures likely to be closed, have temporary measures in place or other risk mitigation measures. All spend likely to be on essential maintenance.

2.7 Reporting and Presentation of Condition Indicator Data

The following sections suggest reporting and presentation techniques for Condition Indicators. The techniques discussed are:

1. Time dependent plots (Section 2.7.1)
2. Histograms (Section 2.7.2); and
3. Stacked bar graph (Section 2.7.3).

Authorities should considering using these techniques for some or all of the following categories when analysing and presenting results:

1. The whole stock of structures.
2. Comparison of different structure types e.g. bridges, retaining walls, sign/signal gantries etc.
3. Comparison of different material types e.g. reinforced concrete, steel, masonry, timber etc.
4. Comparison of different structure ages e.g. pre 1975 vs. post 1975 etc.
5. Comparison of structures in different areas, districts, parishes, routes etc.

This list is not exhaustive and authorities should consider additional comparators. The Condition Indicators are management tools and should be used to best represent the characteristics of your structure stock and any issues you want to highlight.

All presentations/reporting should be in a clear and easily understood format. If possible establish a fixed format for your annual/periodic reporting so it can be easily compared with historical reports.

2.7.1 Time Dependent Plots

The time dependent plots should include three lines:

1. Average Condition
2. Critical Condition; and
3. Target Condition (could be two lines if different targets are set for the Average and Critical Condition)

An example is shown in Figure 1. The Y-axis is truncated at a Condition Indicator score of 50 in order to place more emphasis on fluctuations in the group score. It is very unlikely that any group of structures will score less than 50, although individual structures do score less than 50.

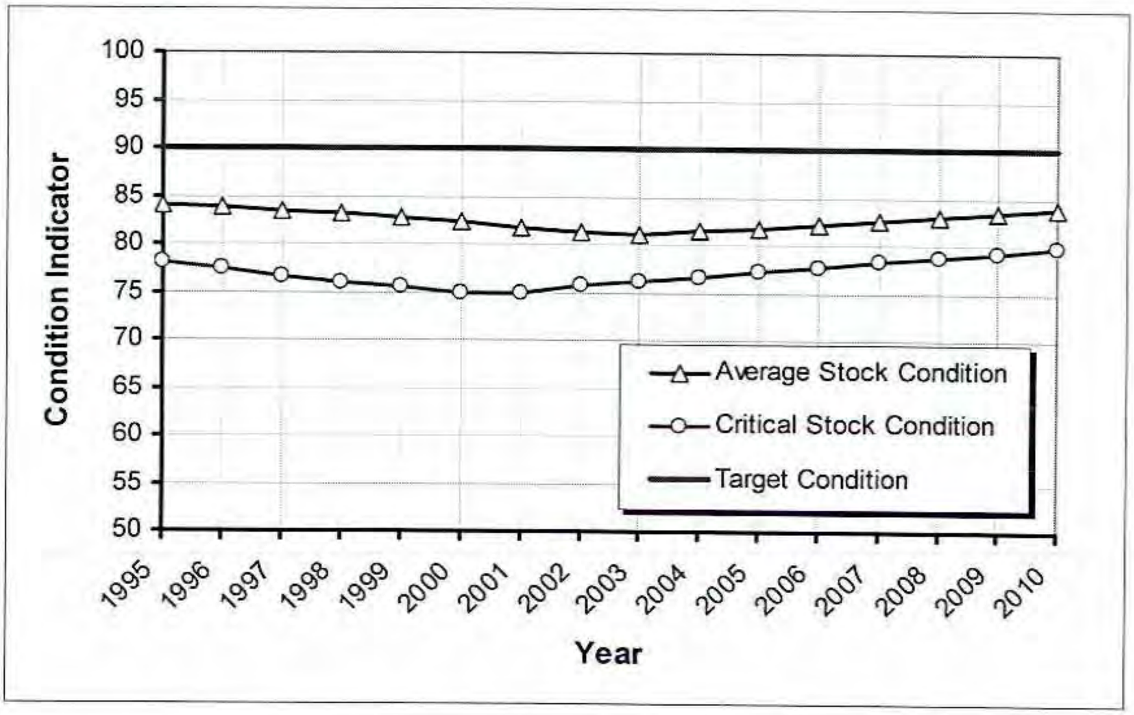

Figure 1 Time Dependent Plot of Condition Indicator

2.7.2 Histograms

The time dependent plot can be supported by histograms that show the spread of structure conditions, an example is shown in Figure 2.

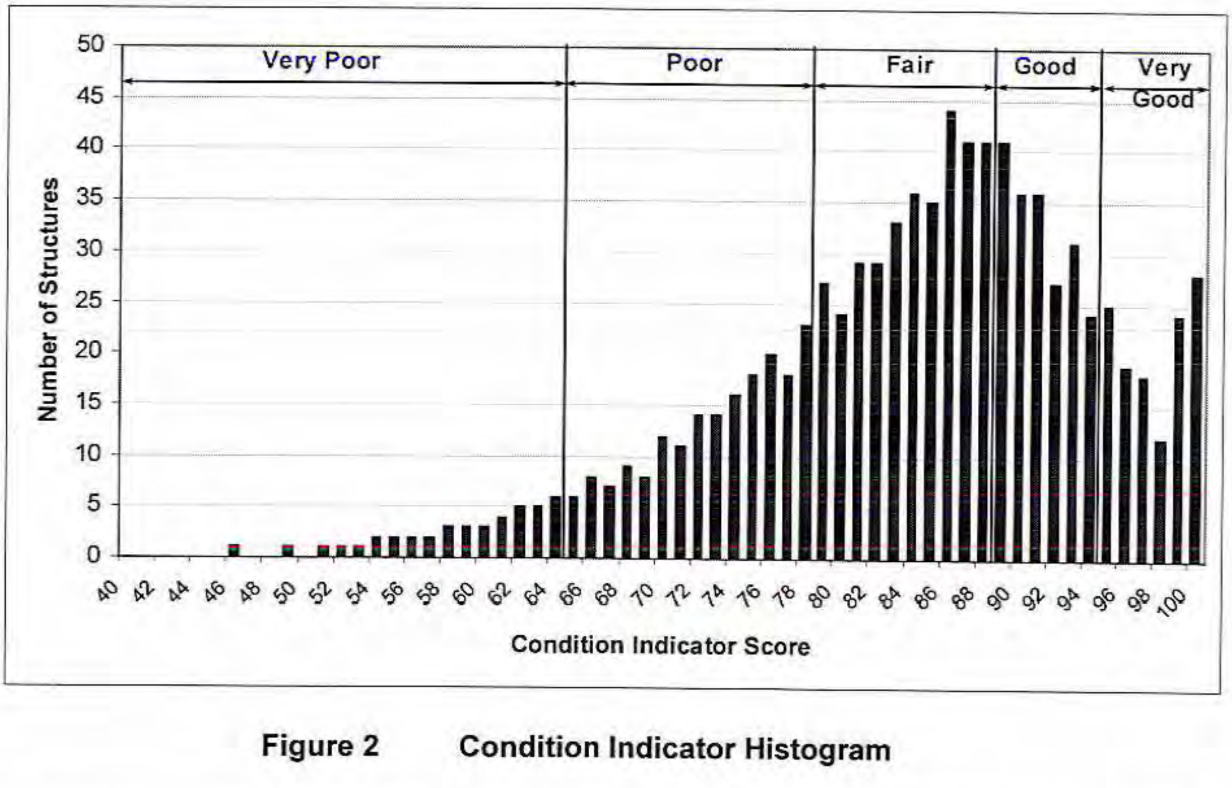

Figure 2 Condition Indicator Histogram

The y-axis can also be described as the proportion or % of structures stock, provided different structure types are weighted by the appropriate *Asset Value Factor* (shown in Table 3) and their dimensional quantity.

2.7.3 Stacked Bar Graph

The spread of condition scores can also be presented in a stacked bar graph as shown in Figure 3, this works best with Average Condition Scores.

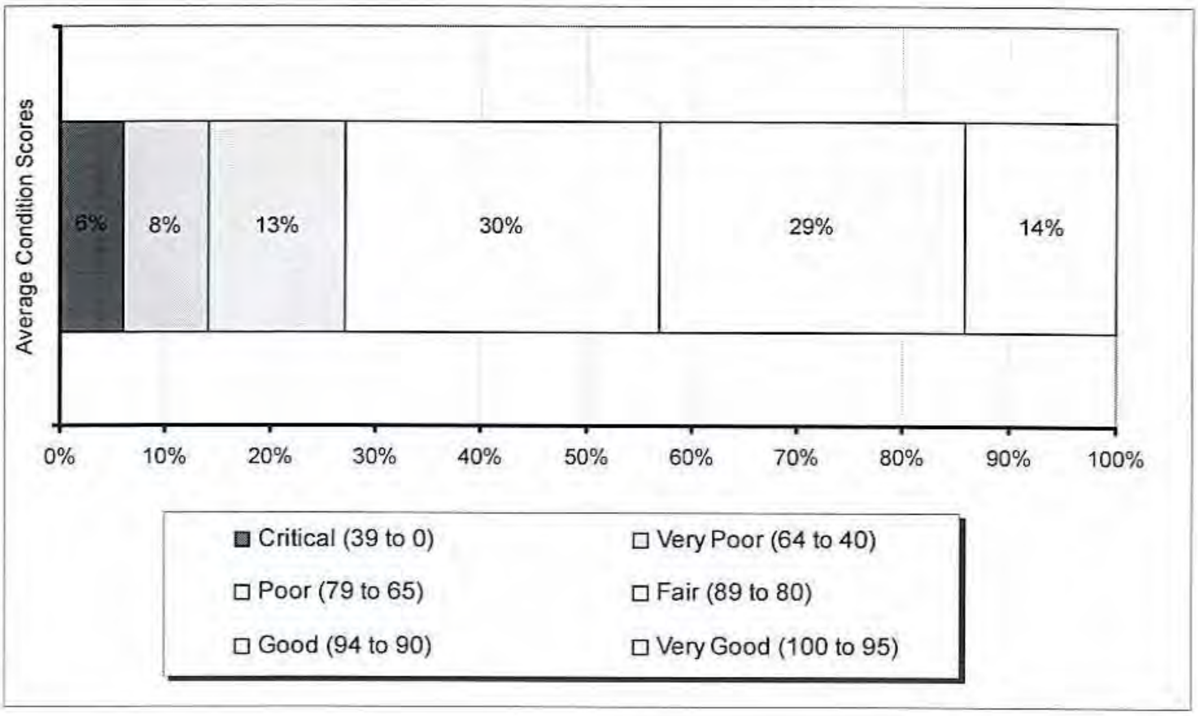

Figure 3 Stacked Bar Graph

3. References

1. CSS Bridge Condition Indicator, Volume 1: Commission Report, April 2002.

2. CSS Bridge Condition Indicator, Volume 2: Guidance Note on Bridge Inspection Reporting, April 2002.

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4. Code of Practice for the Management of Highway Structures, DfT, under development, to be published in 2005.

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7. Framework for Highways Asset Management, CSS, June 2004.