

TRANSPORT SCOTLAND

TRBO: BRIDGES

TS INTERIM AMENDMENT 20 – CONCRETE HALF-JOINT DECK STRUCTURES INTERIM MANAGEMENT STRATEGY

1 INTRODUCTION

- 1.1 This Interim Amendment (IA) implements an Interim Management Strategy for reinforced concrete and steel/concrete composite half-joint deck detailing in suspended span and propped-cantilever bridges. (It does not include steel to steel half-joint deck details). Operating Companies (OCs) are requested to check their stock of bridges to determine if this IA applies, then consult with Transport Scotland (TS) Unit Bridge Managers (UBM) to implement the guidance. The risk based strategy is necessary to ensure that all structures of this type, which are particularly vulnerable to deterioration and difficult to inspect, are recorded, specially inspected, remedial works planned, and to allow the future maintenance funding requirements to be identified.
- 1.2 This is a framework document, offering advice to OCs on the performance and management of bridges with half-joints. OCs are responsible for the appraisal of the bridges with half-joints within the scope of this framework, until such a time that the Future Management Strategy is implemented.
- 1.3 This guidance is also being provided for DBFO Companies..

2 BACKGROUND

- 2.1 Half-joints were introduced into bridge decks as a means of simplifying design and construction operations. This form of joint is vulnerable to deterioration in the event of deck expansion joint failure, where chloride rich seepage through the joint can cause concrete deterioration and corrosion of the reinforcement. Loss of reinforcement section through corrosion, or associated concrete spalling can induce higher stresses and significantly reduce the safety margins expected of serviceable structures. Half-joints are a particular concern because they are not easily accessible for inspection or maintenance and they are mostly located over or under live traffic lanes.
- 2.2 Trunk Road Bridges owned by the Scottish Ministers incorporating half-joints are mainly distributed in the South West Unit. Many have already been subject to visual inspection, and may have been prioritised for maintenance on the basis of their external condition. Some may already have been repaired and/or strengthened. This IA sets out an Interim Management Strategy (IMS) for all structures of this type, the actions are indicated in flow chart format in ANNEX A, and described below.

3 INTERIM MANAGEMENT STRATEGY

3.1 Data validation check

- 3.1.1. A preliminary data collection exercise has already been undertaken by TS utilising the information in the Structures Management System (SMS) to identify all Trunk Road and Motorway bridges with half-joints – the results are contained in ANNEX C.

As a priority OCs shall confirm the identity of all Trunk Road bridges with half-joints, for which they are currently responsible, to the UBM.

3.2 Initial Special Inspection

- 3.2.1 Bridges with half-joints which have not had a special inspection of the half-joints, **shall be inspected within the next six months**. Where special inspections have been carried out within the last 3 years (or principal inspections have examined the half-joint and its internal surfaces closely), OCs shall consider if the requirements in paragraph 3.3 are met and, if necessary, undertake further inspection within the next six months.
- 3.2.2 Initial special inspections, by endoscopic inspection where practicable (ISI) shall determine whether there is evidence of failure of the expansion joint over the half-joint and consequent leakage of water and chlorides onto the bearing shelf of the half-joint. It shall also determine whether there is cracking at the re-entrant corners of the half-joint (shown at ANNEX B) and, if present and possible, the width of the crack. The measurements shall be averaged to ensure that a true value for the crack width is reported. Care shall be taken in the measurement of cracks to avoid overestimation by recording surface effects such as fretting of the concrete surface adjacent to the crack. Bridge temperature shall also be recorded since crack width may be influenced by seasonal temperature variation. The severity and location of any other defects such as leaching or corrosion products shall also be recorded and any relevant concrete delamination and spalling in the vicinity of the half-joint. Whilst carrying out the ISI, consideration shall be given to install monitoring across the re-entrant corner cracking where there is evidence of significant cracking, to enable periodic monitoring of future changes to crack width. Consideration of remote monitoring shall be given and discussed with the relevant UBM.
- 3.2.3 Where there is no indication of significant cracking of the half-joints, seepage or other defects observed, no immediate action is required, pending further advice that may be issued in due course. However, normal inspection and maintenance arrangements shall apply and OCs should ensure that information relating to the half-joints is reported.

3.3 Further Special Inspection

- 3.3.1 The approval of the UBM shall be required before a Further Special Inspection (FSI) is undertaken.
- 3.3.2 Where the half-joints have significantly cracked (defined as crack widths >2mm) or where there is evidence of current or past significant seepage or serious delamination of concrete in the vicinity of the joint, the opportunity shall be taken to determine the condition of the reinforcement (if practical). One method of doing this without significant intrusion is to carefully drill small holes to the reinforcement and inspect bars using a borescope. However, this will only produce limited information. At the same time if there is significant seepage, limited concrete condition testing (chloride content, cement content, half-cell measurement etc) shall be carried out at the half-joint to supplement existing data already available from earlier principal or special inspections.
- 3.3.3 OCs should report this inspection information as soon as possible to the UBM, with recommendations for further investigation work if necessary.

3.4 Monitoring and Inspection

3.4.1 Where significant cracks have been observed, and there may be other deterioration, a regime of periodic monitoring and inspection shall be instigated. This shall generally be based on a visual approach that will target the key factors affecting half-joint performance such as changing condition, material deterioration or bridge movements. In some cases it may be appropriate to utilise monitoring using strain or other movement gauges. The intervals for monitoring shall be appropriate for the structure (eg. 3 months to 1 year), depending on the nature and severity of the deterioration, and the potential risk to the network. The objective of the monitoring is to determine if there is any:

- i) progressive horizontal and vertical movement at the joint,
- ii) movement due to traffic loading and,
- iii) ongoing material deterioration.

3.4.2 Depending on the ease of access, monitoring of cracks at the re-entrant corner of half-joints can be undertaken on site using a demountable strain gauge to measure manually between demec pips bonded either side of the crack. Manual monitoring is perhaps best used as part of an initial investigation into structural performance. To enable prior warning of structural problems, or remote monitoring using vibrating wire strain gauges is also possible. Embedded silver/silver chloride/potassium chloride half-cells may be used to monitor for potential corrosion risk of reinforced concrete elements.

3.4.3 OCs shall discuss and agree proposals for monitoring with their respective UBM.

3.5 Invasive Inspection and Non-destructive Testing

3.5.1 Detailed structural assessment requires accurate information on the condition and geometry of half-joints. This can only be obtained by detailed measurements, invasive inspection, testing and non-destructive methods. Full advantage shall be taken of NDT techniques, although most are still in development (refer to paragraph 3.14 below). If it is considered that there is still insufficient information about the condition of the half-joint and its reinforcement for assessment purposes, further invasive testing to expose the reinforcement may be necessary. Such investigations will be subject to technical approval procedures and must be supported by a full technical appraisal, to safeguard the structure during the course of the work, and to set down the type of investigation proposed and details of the expected outputs.

3.5.2 Consideration shall be given to selecting the most appropriate bridges for invasive testing and the most suitable test location(s) on the bridge. Where invasive testing involves de-stressing the half-joint reinforcement, the additional loading carried by the adjacent bar sets shall be assessed and the necessity and effects of propping the bridge during the work considered. In determining testing locations, concentration of half-joint loading, drainage paths and the severity of defects shall be considered together with safety, access and traffic management issues.

3.5.3 OCs shall submit detailed proposals for invasive testing to their respective UBM for discussion and agreement including the method, timescale, cost, materials tests and inspection, reinstatement procedures, traffic management, noise control and

contingency measures etc. Particular attention shall be given to planning reinstatement of test areas and the selection of materials, method of reinstatement, given the time constraints, weather and engineering requirements. Contingency measures shall be planned to take into account difficulties encountered during the invasive testing process, including the condition of the exposed half-joint reinforcement, unexpected delays and weather conditions.

- 3.5.4 Non-destructive testing methods such as impact echo, radiography, acoustic emission, and thermography etc. may be considered to minimise the need for invasive inspection of half-joints. Whilst NDT methods alone are unlikely to give definitive indications of defects and overall condition, they can be used to assist determination of the variations in condition along joints and may also allow coverage of large areas in a relatively short time. The results, properly interpreted and compared to known conditions at one or more locations derived by invasive inspection, should give a good indication of the relative condition elsewhere, or point to where further invasive inspection may be necessary. However some care is required in selection of the NDT technique as the difficulty in access, health and safety issues, and unsuitability of application to half-joints may prevent their widespread adoption and the production of meaningful data.

3.6 Structural Assessment

- 3.6.1 For those bridges which have already been identified as substandard through the Assessment Programme, strengthening schemes should be either completed or well advanced. However, for some structures with half-joints, which have previously passed the 40 tonne assessment and are now exhibiting significant deterioration (refer to paragraph 3.4), it is possible that their capacity may have been further reduced. Where half-joint structures are exhibiting significant deterioration, OCs shall review existing structural assessment reports and carry out new assessments as appropriate.
- 3.6.2 Particular attention shall be paid to the method of analysis previously adopted and whether it is still considered appropriate. Any assumptions made about the condition of the half-joint in the assessment and the continued appropriateness of any departures from standards previously granted. It is recognised that previous assessments concentrated on the effects of the 40 tonne assessment live load, and it may be necessary to reassess the structure in its present (i.e. deteriorated and cracked) condition, taking account of construction defects such as poor concrete compaction, curing and reinforcement misalignment, where known, and particularly the condition of the half-joint.
- 3.6.3 Assessment should be carried out in two parts:
- i) To determine the range of load effects on the half-joint;
 - ii) To calculate the capacity of the joint in its deteriorated condition, OCs shall use their judgement as to the deteriorated condition of the joint taking account of the likely loss of reinforcement section and the effects of delamination of cover concrete. Reference shall be made to BA39/93 'Assessment of reinforced concrete half-joints' as necessary to assist. In due course it is expected that this document will be updated.
- 3.6.4 One of the objectives of the assessment shall be to identify a deterioration trigger point to feed into a monitoring and inspection regime and to assist in determining when interim safeguarding measures are required. To facilitate this, a 'sensitivity'

analysis shall be carried out to determine the influence of variations in the condition of the structure. Defects can be categorised under reinforcement yielding, concrete debonding, and loss of link reinforcement. A range of severity of each defect (and any other factors) shall be considered and the position of the structure within this range determined. For the sake of consistency of reporting, sensitivity shall be expressed in terms of 'usage factor': the ratio of load effect to assessed joint capacity. Technical Approval procedures in accordance with BD 2 will apply to this assessment work.

- 3.6.5 OCs shall discuss and agree proposals for structural assessment with their respective UBM.

3.7 Risk Management

- 3.7.1 In order to develop a strategy for the repair and maintenance of bridges with half-joints, a method of prioritisation is required to focus resources appropriately. Initial prioritisation shall be on the basis of external condition only, in terms of the need for further detailed investigations. A method of prioritisation is set out in the Priority Scoring Flowchart in ANNEX E.

- 3.7.2 A more detailed qualitative assessment produced by the former Highways Agency has also been appended to Annex D to assess the likelihood of a structure with half-joints becoming substandard in the future. This can be used to establish a priority ranking once more detailed information about the condition and assessed capacity of the half-joint is known. The likelihood factor ranges from 1 to 9, where 5 is considered to be the median likelihood. Example and blank proformas for the qualitative risk assessment are given in ANNEX D, together with detailed guidance on the methodology adopted.

3.8 Interim Measures

- 3.8.1 Risks shall be assessed considering joint configuration and access, current usage factor, current condition, rate of deterioration and network factors such as traffic volume and HGV loading over the bridge. If the results of the investigations indicate a potentially unacceptable level of risk to the integrity of the structure, interim measures shall be implemented to safeguard the road network such as temporary propping and/or load reduction, or permanent repair/renewal. Structures with half-joints with a likelihood factor of 6 or higher are likely to require management effort in the near future to ensure they will not become substandard. The higher the likelihood factor

the more urgent the need for remedial action is likely to be. The procedures outlined in BD 79 'Management of Sub-standard Highway Structures' shall be instigated and Technical Approval procedures for the temporary / permanent works will apply.

3.9 Maintenance

- 3.9.1 For all half-joint bridges, high priority shall be given to preventing further deterioration of half-joints by maintaining drainage in working order, the integrity of deck waterproofing and expansion joints, including pipe bays where appropriate. Bids for remedial works shall be prioritised and submitted as part of the normal bidding arrangements. Advantage shall also be taken during any planned re-waterproofing or resurfacing work to undertake inspection and concrete condition testing of half-joints and reinforcement inspection from above.

3.9.2 Expansion joint replacement and renewal of waterproofing, where they have shown to have failed, are the most important preventative remedial actions to safeguard against further deterioration of a half-joint.

3.10 Repair

3.10.1 The repair of half-joints is made particularly difficult due to poor access, generally congested reinforcement and traffic management issues. Advice is given below on possible repair methods and further guidance will be provided in the Future Management Strategy.

3.10.2 Concrete replacement is an option for repairing deteriorated concrete. Information on concrete replacement is provided in BD27 'The repair of concrete highway structures'. The HA/CSS/TRL publication, 'Repair of Concrete in Highway Bridges – A Practical Guide (AG43)' details current thinking on best practice to be adopted for concrete repair. Unless such practices are adopted, it is likely that concrete repairs will be only partially effective in minimising future corrosion of reinforced concrete.

3.10.3 Information on cathodic protection (CP) is available as an Advice Note BA83 'Cathodic protection for use in reinforced concrete highway structures'. This can be an effective technique for minimising future corrosion in reinforced concrete, usually in combination with some concrete repair work. However it is essential that specialist advice is sought if cathodic protection is to be considered. It is also important that the condition of the half-joint and in particular the reinforcement is known with certainty. CP is an active corrosion control method but it must be managed and monitored to ensure continued effective operation. If it is, then there should be no further deterioration to affect the load capacity of the half-joint.

3.10.4 Where half-joints have deteriorated so badly that it is practically or economically beyond repair, such as the reinforcement is so badly corroded that it cannot be satisfactorily reinstated, then replacement of a whole element may be a cost effective option.

3.10.5 There are a number of alternative commercial repair systems available to manage deteriorating reinforced concrete such as chloride extraction, galvanic protection and active moisture reduction systems. The effectiveness of these particular remedial methods for use on half-joints is not yet proven and, as such, they are not considered appropriate at this time.

3.11 Data management

3.11.1 The OC is required to input any changes to the structure due to maintenance or repairs carried out to SMS.

4 ENQUIRIES

4.1 If you have any questions on this document please

contact: Jim Brown,
E-mail: jim.brown@transport.gov.scot

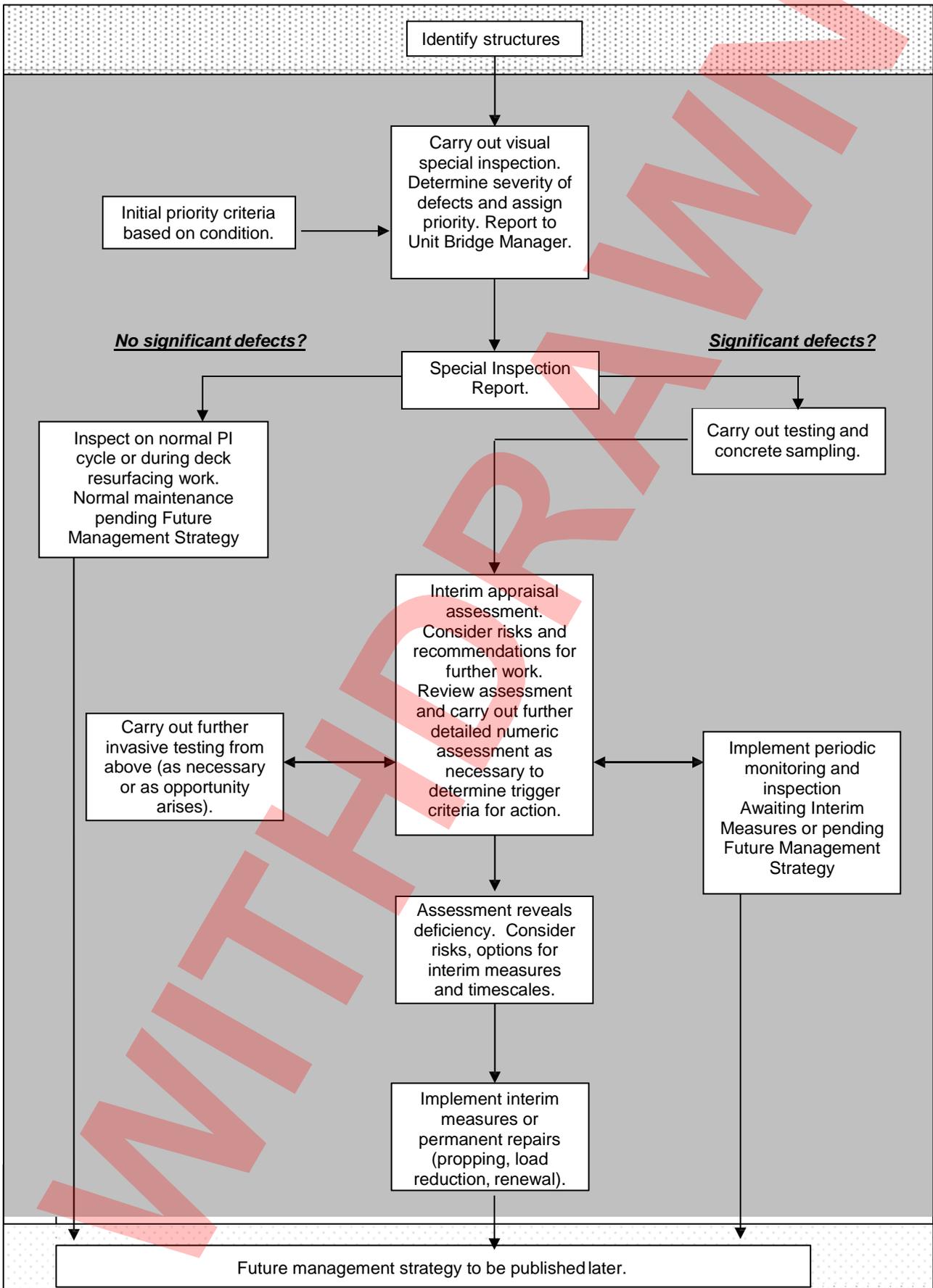
- 4.2 If you have any queries about individual structures with half-joints, please contact the relevant TS Unit Bridge Manager.

J Wayne Hindshaw

Chief Bridge Engineer
March 2018

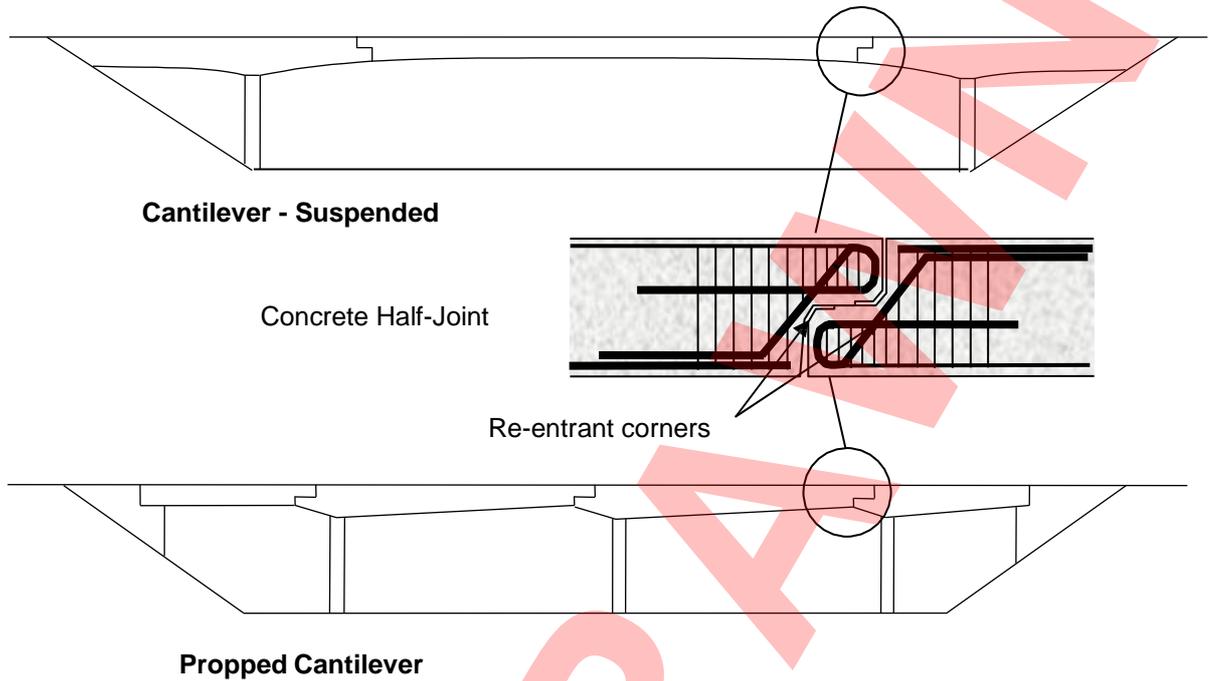
INTERIM MANAGEMENT STRATEGY

ANNEX A

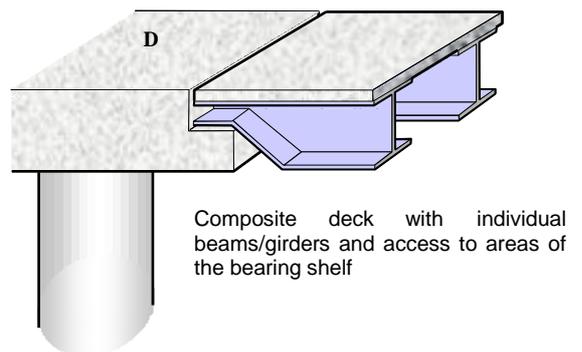
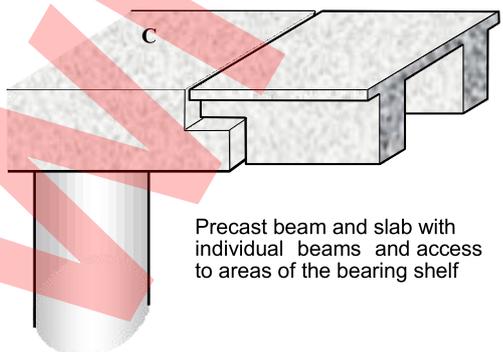
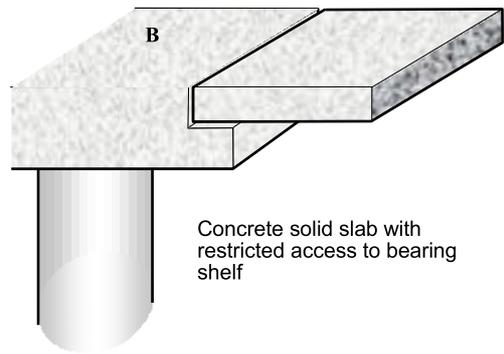
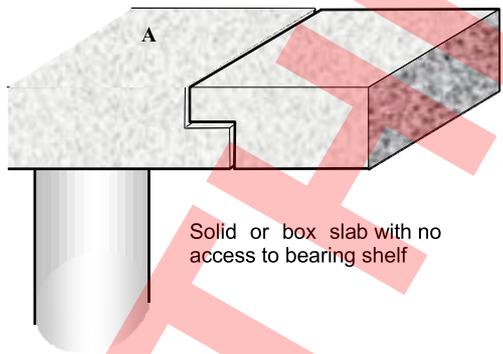


TYPICAL HALF-JOINT DETAIL

ANNEX B



TYPES OF HALF-JOINT CATEGORISED BY ACCESS TO BEARING SHELF



STRUCTURES WITH HALF-JOINTS

ANNEX C

South West

| Structure Ref No | Structure Name |
|------------------|-------------------------------------|
| M74 3-2 80 | M74 RAIL |
| A76 310 | HOWFORD |
| A77 370 | SPITTALHILL |
| A78 470 | RIVER IRVINE (IBP) |
| M74 6-6 10 | M74 OVER A723 |
| M74S 6-6 20 | A723 SB - M74 NB SR |
| M74S 6-6 30 | M74 NB - A723 NB SR |
| M74S 6-6 40 | M74 SB - A723 SB SR |
| M74 7-6 90 | AVON |
| M74 8-7 50 | BURNHEAD ROAD O/B |
| M8 27-28 55 | WHITE CART VIADUCT |
| M8 20-20 10 | M8 MAIN APP SOUTH EB |
| M8 20-20 20 | M8 MAIN APP SOUTH WB |
| M8S 20-20 30 | WEST STREET OFF RAMP |
| M8S 20-20 40 | WEST STREET ON RAMP |
| M8 21-21 10 | SCOT ST VIA OFF RAMP |
| M8 19-19 10 | M8 MAIN APP NORTH EB |
| M8 19-19 20 | M8 MAIN APP NORTH WB |
| M8S 19-19 50 | WATERLOO ST ON RAMP |
| M8S 19-19 60 | BOTHWELL ST OFF RAMP |
| M8S 17-17 20 | GT. WESTERN OFF RAMP |
| M8 25-26 55 | KGV DOCK ACCESS (a.k.a. SHIELDHALL) |
| M8 16-17 70 | WOODSIDE VDUCT EB 11 |
| M8 16-17 75 | WOODSIDE VDUCT WB 12 |
| M8 13-13 30 | PROVAN VIADUCT EB |
| A78 1 | HIGH STREET GREENOCK |
| M8S 17-17 50 | W GRAHAM ST OFF RAMP |
| M8 13-13 31 | PROVAN VIADUCT WB |
| M8 21-21 11 | SCOT ST VDUCT EB SEC |
| M8 21-21 12 | SCOT ST VDCT EB MAIN |
| M8 21-21 13 | SCOT ST VIA WB MAIN |
| M8 21-21 14 | SCOT ST VIA WB SEC |
| M8S 19-19 70 | NORTH ST OFF RAMP |
| M8S 19-19 80 | NEWTON ST ON RAMP |
| M74S 6-6 F70 | NW M74 SLIP F/B |
| M74S 6-6 F80 | SW M74 SLIP F/B |
| M74S 6-6 F90 | SE M74 SLIP F/B |
| M74S 6-6 F100 | NE M74 SLIP F/B |
| M8 21-22 F50 | CORNWALL STREET F/B |
| M8 22-22 F90 | PERCY STREET F/B |
| M8 22-22 F40 | KIRKWOOD STREET F/B |
| A726 170 | COLLEGE MILTON |

Number of structures 42

STRUCTURES WITH HALF-JOINTS

ANNEX C

South East

| Structure Ref No | Structure Name |
|------------------|---------------------|
| A985 1 | KINCARDINE |
| M876 0-1 20 | DENNYLOANHEAD |
| A985 20 | BLUTHER BURN |
| M8 3-4 40 | DEANS ROAD O/B |
| M8 3-4 60 | STARLAW ROAD O/B |
| M8 4-4 10 | EAST WHITBURN EAST |
| M8 4-4 20 | EAST WHITBURN WEST |
| M8 4-5 22 | A706 U/B |
| M8 5-6 20 | DEWSHILL O/B |
| M8S 3-3 F60 | KNIGHTSRIDGE F/B |
| M8 3-4 F25 | DECHMOUNT HOUSE F/B |
| M8 3-4 F70 | SOUTH INCH F/B |
| M8 3-4 F85 | RIDDOCHILL F/B |
| M8 3-4 F26 | DECHMOUNT HOUSE F/B |
| M8 3-4 F86 | RIDDOCHILL F/B |
| M8 3-4 F71 | SOUTH INCH F/B |

Number of structures 16

North East

| Structure Ref No | Structure Name |
|------------------|---------------------|
| A985 20 | BLUTHERBURN |
| M90 10-11 55 | FRIARTON BRIDGE |
| A92 110 F | JOHN MARSH LOAN F/B |

Number of structures 3

M8 DBFO

| Structure Ref No | Structure Name |
|------------------|----------------------|
| M80 2-3 75 | WHITEHILL ROAD |
| M80 6-7 70 | SEABEGS OB |
| A8 60 | SHAWHEAD |
| M73 2-2 30 | M73 OVER M8 |
| M73 2-3 80 | DRUMCAVIL |
| M73S 1-1 10 | M73 SB - M74 WB SLIP |
| M74S 4-4 10 | M74 WB - M73 NB SLIP |
| M80S 5-5 5 | LOW WOOD BRIDGE |
| M8 9-10 F75 | HALLIBURTON CRES |

Number of structures 9

Autolink

| Structure Ref No | Structure Name |
|------------------|----------------|
| M74 13-12 12 | DUNEATON WATER |
| M74 14-14 10 | A702 APR U/B |

Number of structures 2

STRUCTURES WITH HALF-JOINTS

ANNEX C

FBOC

Structure Ref No
M823 0-0 50

Structure Name
ACCOMMODATION OB

WITHHOLD DRAWM

QUALITATIVE RISK ASSESSMENT

ANNEX D

This Annex D has been produced by the former Highways Agency using one of their own bridges as the Example Proforma on page 20.

In Scotland, based on the initial data collection exercise (refer paragraph 3.1) there are 68 trunk road bridges with half-joints, of varying forms of construction and usage. When considering risks, clearly those associated with a substandard footbridge spanning a single carriageway road in a rural location are likely to be significantly easier to manage than that of a road bridge carrying a dual carriageway over a 3 lane motorway in an urban setting. In order to develop a strategy for the repair and maintenance of such a significant number of bridges, a methodology is required to rationally assess the comparative risks that may arise from the deterioration process.

Although there is no single set methodology for qualitative risk assessment, the practice is well established in a number of industries. Qualitative risk assessment is being used increasingly by managers of infrastructure assets and some published guidelines are available. The guidance within CIRIA Report SP125 'Control of risk: a guide to the systematic management of risk from construction' has generally been adopted in this particular methodology. It should be noted that there are no right or wrong answers in qualitative assessment only relative opinion. The principal value of qualitative risk assessment is not necessarily in the final ranking outcome but in the process of risk identification. It is a formalised process enabling work to be reported objectively and open to scrutiny.

The definition of risk is widely accepted as being the product of the probability or likelihood of an event occurring and the consequences arising from the event.

$$\text{Risk} = \text{Likelihood of occurrence} \times \text{Consequence}$$

In the method adopted in this study, a simple numerical scale is used for the likelihood and consequence. It is important to stress that the indicator may have no numerical significance, other than to show qualitatively that one asset is likely to require more management effort than another.

1.1 OUTLINE METHODOLOGY

A number of factors have been identified which may increase or decrease the likelihood of a bridge with half-joints becoming substandard, as follows:-

- (P1) Configuration and Access;
- (P2) Current Capacity;
- (P3) Current Condition;
- (P4) Rate of Deterioration;
- (P5) Future Loading.

It is important to establish a numerical scale that may be used objectively. The scale adopted for the likelihood is based on CIRIA SP125 five point scale:

| | |
|-----------|---|
| Very Low | 1 |
| Low | 3 |
| Medium | 5 |
| High | 7 |
| Very High | 9 |

Not all factors should be given equal weighting, therefore a significance factor has been applied to further enhance the assessment. A distorted numerical scale has been adopted to take account of the potential difference between very high and very low significance as follows:

| | |
|-----------|-----|
| Very Low | 0.5 |
| Low | 1 |
| Medium | 2 |
| High | 4 |
| Very High | 8 |

The significance factors are used to weight the relative likelihood factors.

The consequences arising from a bridge collapse due to the failure of a half-joint, in terms of potential loss of life and/or confidence in this form of bridge construction, would be so great as to totally dominate any qualitative risk assessment. The safety of the road user is paramount and it is a primary objective that all bridges with half-joints be managed so that safety is assured. Given this policy statement, consequences in this study have been considered solely in terms of the financial costs of investigation, assessment, repair and traffic delay costs.

To enable the future management effort to be identified and readily grouped, a continuous numerical scale of 1 to 9 has been established for the cost consequence. Unlike the likelihood of failure, the indicator for consequence does have a meaningful relationship to actual cost.

| Consequence Factor | | Cost | |
|--------------------|---|------------|-----|
| Very Low | 1 | £25,000 | 1 |
| | 2 | £50,000 | 2 |
| Low | 3 | £100,000 | 4 |
| | 4 | £200,000 | 8 |
| Medium | 5 | £400,000 | 16 |
| | 6 | £800,000 | 32 |
| High | 7 | £1,600,000 | 64 |
| | 8 | £3,200,000 | 128 |
| Very High | 9 | £6,400,000 | 256 |

A distorted scale of costs has been adopted with each increase in consequence of 1 unit representing a doubling of cost. The consequence factor may be determined directly from the cost by the equation:

$$(\text{Log}_n (\text{Cost} / \text{£}25,000) / \text{Log}_n 2) + 1$$

Or the cost may be determined from the consequence factor by the equation:

$$\text{£}25,000 \times 2^{(\text{Consequence factor} - 1)}$$

For example, a cost of £235,700 would have a consequence factor of:

$$(\text{Log}_n (\text{£}235,700/\text{£}25,000) / 0.301) + 1 = 4.2$$

Values up to £25,000 will have a consequence score of less than 1.

1.2 LIKELIHOOD OF OCCURRENCE

The qualitative assessment of the likelihood of the half-joints becoming substandard is determined by considering the five factors P1 to P5.

1.2.1 (P1) Joint Configuration

The four generic arrangements of half-joint identified during the initial data collection process are illustrated in Annex B. Ease of access to the bearing shelf for inspection is influenced by the joint arrangement. Joint type A is the most difficult to inspect due to the half-joint spanning the full width of the deck and therefore no access to the bearing shelf. Joint type B is easier to inspect than type A with limited access to the bearing shelf. Joint types C and D have some access to the bearing shelf. The values were assigned as follows:

| | | | |
|--------|------------|--------|---|
| Type A | or unknown | High | 7 |
| Type B | | Medium | 5 |
| Type C | | Low | 3 |
| Type D | | Low | 2 |

Where physical access to the joints from below is particularly difficult factor P1 may be increased by up to two units. The adjustments to be applied for ease of access are as follows:

| | |
|---|----|
| Difficult access to more than one joint | +2 |
| Difficult access to one joint | +1 |
| Moderate | 0 |

1.2.2 (P2) Current Capacity

Structural assessment results are generally reported for the bridge as a whole and do not necessarily relate to the capacity of the joint. Nevertheless, a comparison of the current assessed capacity with the original design capacity would indicate whether the overall design was more or less robust.

A median value of 5 is initially assigned to P2. It is reasonable to assume that where the current capacity is less than the design capacity, loading restrictions will be in place. However, the probability of failure is increased by 4 units for structures with current capacity less than 50% of the original design capacity. The adjustments to be applied for assessed capacity are as follows:

| | |
|--|----|
| Current capacity < 1/2 design capacity | +4 |
| Current capacity < design capacity | +2 |
| Current capacity is not known | 0 |
| Current capacity = design capacity | -2 |
| Current capacity > design capacity | -4 |

Where comparisons are borderline, i.e. current capacity is just less than or just greater than the design capacity, the age of the assessment and the availability of calculations should be considered. Assessments that are recent and available should be considered more accurate and reliable than older calculations.

1.2.3 (P3) Current Condition

Information of current condition should be based on the latest inspection report (or special inspection report carried out as part of this strategy) and where possible in relation to the Stage II Assessment condition factor. For half-joints in a fair condition a median value of 5 is assumed with the following adjustment made for good and poor condition:

| | |
|------|----|
| Poor | +2 |
| Fair | 0 |
| Good | -2 |

If particular concerns or defects have been identified which may affect the performance of the joints a further +2 adjustment may be warranted. If repairs have been undertaken a negative adjustment may be appropriate to reflect the long-term improvement in condition. If repairs are only cosmetic then no adjustment is warranted.

| | |
|------------------------|----|
| Specific defects | +2 |
| Cosmetic or no repairs | 0 |
| Structural repair | -2 |

1.2.4 (P4) Rate of Deterioration

Direct measurements of concrete properties such as concrete permeability, chloride contamination, cover etc are not currently widely available for the majority of half-joints. However, there are other indicators which can give an insight as to whether the likely rate of deterioration will be greater or lesser than the average half-joint to which a median value of 5 is assigned.

The type and condition of the road joint above the half-joint will influence how much salt is likely to penetrate through to the half-joint. The service life of elastomeric joints is of the order of 20 years. The expected service life of modern buried joints is 10 years and 5 years for asphaltic plug type joints.

Due to poor maintenance in the past, joints with a shorter service life are more likely to result in contamination of the half-joint. For half-joints with asphaltic plug joints in a fair condition on an average salted road a median value of 5 is assumed.

The following adjustments have been adopted:

| | |
|--|----|
| Open joint (irrespective of condition) | +3 |
| All other joints | 0 |
| Buried joints | -1 |
| Elastomeric | -2 |

A road joint in a poor condition is likely to allow chloride contamination of the half-joint. Depending on road joint condition the following adjustments are appropriate:

| | |
|------|----|
| Poor | +1 |
| Fair | 0 |
| Good | -1 |

The level of salt use on a route is an important consideration as this is a major contributor for the deterioration of reinforced concrete structures. The following adjustments are adopted depending on the salt usage:

| | |
|--------|----|
| High | +1 |
| Medium | 0 |
| Low | -1 |

1.2.5 (P5) Future Loading

Increased usage and congestion on a route will increase the probability of a joint becoming substandard and so increase the rate of deterioration of road joints. Routes which are likely to experience unchanged and average traffic growth are assigned a median value of 5. Urban and strategic routes, which are being carried by the structure, are likely to see greater increases in future loading and traffic volume than rural routes. Access roads are less likely to see any increase in loading. As a guide the following factors are appropriate, however, local knowledge should prevail.

| | |
|-------------------------------|----|
| Motorway | +2 |
| Dual A P Trunk Road | +1 |
| Single Carriageway Trunk Road | 0 |
| Lane / Local Road | -2 |
| Access Road / Footway | -4 |

1.2.6 Significance Factors

Not all contributing factors should be given equal weighting. The significance factor applies a weighting to the likelihood. The relative significance given to each factor is as follows:

| | |
|-------------------------------|---|
| (P1) Configuration and Access | 2 |
| (P2) Current Capacity | 4 |
| (P3) Current Condition | 4 |
| (P4) Rate of Deterioration | 2 |
| (P5) Future Loading | 1 |

Management effort will be greatest for those bridges deemed to be imminently substandard. The current capacity (P2) and current condition (P3) of a joint will be the primary factors affecting whether or not a joint is likely to be substandard at the present time and are given a "high" significance score of 4. For those bridges deemed to be of adequate capacity but actively deteriorating, management effort will be required to prevent further deterioration but this may be spread over a number of years. Factors (P1) joint configuration and access, and (P4) rate of deterioration, are factors which generally indicate the potential for a half-joint to become substandard in the future and are assigned a significance factor of 2. Future loading (P5) is considered to be of low significance as future increases in loading can be planned for well in advance of any potential problems arising and is assigned a significance score of 1.

1.3 COST CONSEQUENCE

The overall costs of repair comprise the design costs, the actual costs of undertaking repairs and the cost to the road user in terms of traffic delays. Traffic delay costs are often many times greater than the actual cost of repair and should be taken into consideration when considering the impact of a structure becoming substandard. For structures with a calculated likelihood factor of 6 or greater, the Agent is required to estimate the costs of undertaking repairs to the half-joints. These estimates may initially be based on the provision of discrete anode cathodic protection. However, if the Agent already has a clear understanding of the remedial measures to be adopted a detailed estimate of repair is available (inclusive of user delay costs) these costs shall be reported.

1.3.1 Repair Costs

The total works costs includes an allowance for access and traffic management costs. If a half-joint requires repair then replacement of the deck expansion joint above will also be required. The repair techniques which are suitable for half-joints are limited. The most promising technique is likely to be discrete anode cathodic protection for those joints which require long-term repair. The cost estimate may assume the implementation of this particular repair technique to assess the relative consequences of a structure becoming substandard. It is important to note that this is a comparative exercise using limited data. Should repair be required for an individual structure, the Maintenance Agent will be responsible for determining the actual scope of repair and a more thorough budget estimate for submittal through the annual bidding process.

For bridges crossing a river or other watercourse access for repair by scaffolding off the deck may be assumed. For bridges over roads, access may be assumed to be via scaffolding from the road below.

Generally traffic management will be required for repair from both above and below deck. The nature of repairs is such that 2 running lanes are likely to be closed with contraflow running. The length of traffic management for contraflow may be assumed to be 5km for motorways and dual all purpose trunk roads, to accommodate cross-over points at an assumed distance of 3km. For single carriageway roads, traffic signalling with shuttle flow may be assumed. The time to undertake repairs is likely to be split say 75% from below deck and 25% from above deck and this would be reflected in the relative access and traffic delay costs incurred from above and below deck working.

For underbridges over rail, access may be assumed to be by scaffold access tower and additional rail protection staff will also be required. Gaining access to a railway is always difficult and requires careful planning and liaison with the rail authorities to obtain track possessions. This will limit the time available to undertake repairs and every opportunity should be made to limit the works duration undertaken from below deck. In this case the time to undertake repairs is more likely to be split 25% from below deck and 75% from above deck.

For specialist repair techniques the ratio of design and contract preparation costs to works costs will be relatively high and may be assumed to be as high as 50% of the contract value for each bridge (which includes traffic management and access costs).

1.3.2 Traffic Delay Costs

Traffic user delay costs can be calculated using the computer program QUADRO (QUEues And Delays at ROadworks). Tables contained in the Trunk Road Maintenance Manual (TRMM) - Volume 1 have been derived from QUADRO to estimate traffic delay costs for different scenarios of traffic management restriction. These tables have been used as the basis for deriving the traffic delay costs per day.

The traffic delay costs are related to the type of road, the degree of the restriction, the daily traffic flow, the percentage of Heavy Goods Vehicles (HGV) and the physical length of the works on site.

The duration of the works above and below deck needs to be considered to obtain the total traffic delay costs. To evaluate traffic delay costs it is generally necessary to obtain the following information:

- Road classification;
- The likely lane restriction;
- Annual average daily traffic (AADT) flows;
- Percentage of HGVs using the structure;
- Alternative routes for diversion if appropriate;
- Whether or not works are undertaken off-peak.

Road classification codes have been assigned to each bridge with half-joints for the carriageway carried and carriageway or obstacle crossed in Annex C (although these should be confirmed by the Agent). The type of repair or investigation will dictate the nature of the lane restrictions for each road classification.

In the absence of more local knowledge Table 4 presents typical traffic delay costs per 8 hour working day for repair. The percentage of HGVs which use the road influence the traffic user delay costs. Motorways are assumed to have 30% HGVs, dual all purpose trunk roads 20% HGVs and single carriageway roads are assumed to have 10% HGVs. Motorway slip roads are classified as wide single carriageways and particularly where two motorways join, the percentage HGVs is more likely to be 30%. However, there is only a few £100 per day

between 10% and 30% HGVs and therefore the assumption of 10% for all situations is considered acceptable for the level of accuracy required.

For minor roads with 2 marked lanes of 5.5m width up to 7.3m width the maximum traffic flow is assumed to be 5,000 AADT. For access roads the costs are assumed to be half those given for single carriage ways.

For repairs 2 running lanes are assumed to be closed with contraflow running. The length of traffic management for contraflow is assumed to be 5km. For single carriageway roads, traffic signalling with shuttle flow is assumed. The traffic management proposed is such that traffic is unlikely to divert on to alternative roads and therefore no additional factors have been applied to the TRMM tables.

Off-peak or night working is considered practical for most short duration repair work. The traffic delay costs presented in the Table may be factored by 0.25 if off-peak working is a practical option to reflect the reduced volume of traffic.

1.3.3 Cost Consequence Factor

The estimated costs shall be identified as:

- design costs;
- works costs including access and traffic management;
- traffic delay costs.

The sum of the estimated costs shall be used to calculate the consequence factor, determined directly from the cost by the equation:

$$(\text{Log}_n(\text{Cost} / \text{£}25,000) / \text{Log}_n 2) + 1$$

UNIT RATES FOR COST ESTIMATE

| Activity | Unit rate | Unit | Works Rate |
|--|-----------|--------------------|------------|
| Access costs | | | |
| Scaffolding for repair (<i>for 35m deck width</i>) | £75 | per day | |
| Mobile elevated platform | £300 | per day | |
| Under bridge unit | £750 | per day | |
| Mobile Scaffold + Rail Protection Staff | £1,000 | per day | |
| Traffic Management | | | |
| 2 Lanes closed in contraflow | £1,400 | per day | |
| 1 Lane closed | £300 | per day | |
| Traffic light control | £900 | per day | |
| Joint Replacement | | | |
| Asphaltic | £120 | per m | 14 m/day |
| Buried | £75 | per m | 17 m/day |
| Elastomeric | £575 | per m | 7 m/day |
| Comb | £2,500 | per m | 3 m/day |
| Other or unknown | £200 | per m | 11 m/day |
| Repair | | | |
| Discrete anode CP per m width of joint | £360 | per m | 6 m/day |
| Control & monitoring equipment. | £6,000 | Dual Carriageway | |
| (<i>assumes one control cabinet per 4 joints</i>) | £4,000 | Single Carriageway | |

DAILY TRAFFIC DELAY COSTS FOR HALF-JOINT REPAIR

| AADT (1000) | M4 | M3 | M2 | D2 | SW | SN | SL | SA |
|--------------------|----------|----------|----------|----------|------|--------|------|------|
| TRMM. Table Ref | 5 | 17 | 32 | 38 | 41 | 42 | 42 | 42/2 |
| 2 | | | | | | | | £140 |
| 5 | | | | | | £280 | £280 | |
| 6 | | | | | | £350 | £350 | |
| 7 | | | | | | £430 | £430 | |
| 8 | | | | | | £510 | | |
| 10 | | | | | £250 | £690 | | |
| 12 | | | | | £320 | £1,360 | | |
| 14 | | | | | £390 | | | |
| 16 | | | | | £460 | | | |
| 18 | | | | | £530 | | | |
| 20 | | | £6,100 | £7,200 | £610 | | | |
| 30 | | | £11,000 | £20,000 | | | | |
| 40 | | £9,200 | £36,000 | £62,000 | | | | |
| 50 | | £13,100 | £90,000 | £129,000 | | | | |
| 60 | £13,000 | £17,000 | £112,000 | £148,000 | | | | |
| 80 | £18,000 | £41,000 | £214,000 | £233,000 | | | | |
| 100 | £23,000 | £194,000 | | | | | | |
| 120 | £57,000 | £308,000 | | | | | | |
| 140 | £275,000 | £532,000 | | | | | | |

Note: Costs at 1998 prices

EXAMPLE PROFORMA FOR QUALITATIVE RISK ASSESSMENT

| Structure Key | 555 | Structure Name | Penny Brampton | | | | |
|---|---|--|---|---|----------------|------------------|------------|
| Area Reference | 16 | Maintaining Agent | WSP Group | | | | |
| Ref | Median Factor | Factor Adjustments | | | Likelihood (A) | Significance (B) | AxB |
| PROBABILITY OF FAILURE | | | | | | | |
| P1 | Joint configuration and Access Type A 7 Type B 5 Types C 3 Type D 2 | <u>Access</u> Difficult +2 Difficult & Moderate +1 Moderate 0 | | | 5 | 2 | 10 |
| P2 | Current Capacity at Joint 5 | Current capacity < ½ Design capacity +4 Current capacity < Design capacity +2 Current capacity = Not known 0 Current capacity = Design capacity -2 Current Capacity > Design Capacity -4 | | | 7 | 4 | 28 |
| P3 | Current Condition Poor 7 Fair 5 Good 3 | <u>Particular Defects</u> Yes +2 Yes +1 | <u>Repairs</u> Specific Defects +2 Cosmetic/no repairs 0 Structural repairs -2 | | 3 | 4 | 12 |
| P4 | Rate of Deterioration 5 | <u>Type of road joint</u> Elastomeric -2 Buried joints -1 All other joint 0 Open joint +3 | <u>Condition</u> Poor +1 Fair 0 Good -1 | <u>Salt Use</u> High +1 Med 0 Low -1 | 4 | 2 | 8 |
| P5 | Future Loading 5 | <u>Route Carried</u> Motorway +2 Dual A P Trunk Road +1 Single Carriageway Trunk Road 0 Lane / Local Road -2 Access Road / Footway -4 | | | 9 | 1 | 9 |
| Average Relative Probability of Failure, $P = \sum (A \times B) / 13 = 67/13$ | | | | | | | 5.2 |
| Estimated Works Costs | | Estimated Traffic Delay Costs | | GRAND TOTAL COSTS | | | |
| £65,964 | | £515,014 | | £580,978 | | | |
| Consequence Factor, $C = (\text{Log}_n(\text{Cost} / \text{£}25,000) / \text{Log}_n 2) + 1$ | | | | | | | 5.5 |

PROFORMA FOR QUALITATIVE RISK ASSESSMENT

| Structure Key | | Structure Name | |
|---|---|--|-------------------------------------|
| Area Reference | | Maintaining Agent | |
| Ref | Median Factor | Factor Adjustments | Likelihood (A) Significance (B) AxB |
| PROBABILITY OF FAILURE | | | |
| P1 | Joint configuration and Access Type A 7 Type B 5 Types C 3 Type D 2 | <u>Access</u> Difficult +2 Difficult & Moderate +1 Moderate 0 | |
| P2 | Current Capacity at Joint 5 | Current capacity < 1/2 Design capacity +4 Current capacity < Design capacity +2 Current capacity = Not known 0 Current capacity = Design capacity -2 Current Capacity > Design Capacity -4 | |
| P3 | Current Condition Poor 7 Fair 5 Good 3 | <u>Particular Defects</u> <u>Repairs</u> Yes +2 Specific Defects +2 Yes +1 Cosmetic/no repairs 0 Structural repairs -2 | |
| P4 | Rate of Deterioration 5 | <u>Type of road joint</u> <u>Condition</u> <u>Salt Use</u> Elastomeric -2 Poor +1 High +1 Buried joints -1 Fair 0 Med 0 All other joint 0 Good -1 Low -1 Open joint +3 | |
| P5 | Future Loading 5 | <u>Route Carried</u> Motorway +2 Dual A P Trunk Road +1 Single Carriageway Trunk Road 0 Lane / Local Road -2 Access Road / Footway -4 | |
| Average Relative Probability of Failure, P = $\Sigma (A \times B) / 13 =$ | | | |
| Estimated Works Costs | | Estimated Traffic Delay Costs | GRAND TOTAL COSTS |
| £ | | £ | £ |
| Consequence Factor, C = $(\text{Log}_n(\text{Cost} / \text{£}25,000) / \text{Log}_n 2) + 1$ | | | |

PRIORITISATION

ANNEX E

PRIORITY SCORING FLOWCHART

