Transport Wales Framework Lot 5

Task Order 5/2
BD 63/07 Risk Based Inspections

User Manual

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Plan Design Enable

Plan Design Enable

Welsh Assembly Government
Risk-based Principal Inspections

User Manual

Notice

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1. Introduction

Managing highways structures requires considerable resource. Balancing the need to minimise the risk to public safety (and maintaining sufficient data on structures) whilst also ensuring the effective and efficient use of resource is often a difficult task. Historically, despite allowance in BD 63/07 (Clauses 3.34 to 3.38), and past incarnations of it, to risk assess structures and flexibly inspect them, the arbitrary Principal Inspection interval of six-years has consistently been kept to. In doing so, it may be argued that the finite resources available to public bodies are not effectively used. Acknowledging this, the Welsh Assembly Government and Atkins have developed a simple risk assessment tool to inform engineering judgment and assist the on-going management of structures.

The risk assessment, developed by Atkins for the Welsh Assembly Government, is a simple, quick and accessible programme. The user requires little engineering knowledge to complete the assessment data, but does need basic structural information, from the BE 11/94 and the Roads 277 Form. The objective has been to create a 'fit-for-*purpose'* programme, able to assist and inform, but not replace engineering judgement.

This User Manual explains where all information relevant to each question can be found. This covers simplistic illustrations of how the BE 11/94 and Roads 277 Form can be used to inform the risk assessment, as well as further advice on other select questions. This User Manual does not seek to explain the answers, or point-scoring methodology for each question, but simply looks to advise the user on where answers can be found. Additionally, the User Manual explains the importance of information gathering before embarking on the risk assessment process.

Finally, the simplicity of the User Manual reflects the approach undertaken during the production of the risk assessment tool. Easy to use and to understand, it is not a theoretical justification of how the certain conclusions have been reached. It merely serves to inform and advise anyone that uses the risk assessment tool on how it should be completed.

2. Document Navigation

To directly find advice on a specific question contained within the risk assessments, please follow the hyperlinks contained in Sections 2.1 to 2.6 below:

For advice on the scoring system applied by the risk assessment, follow the hyperlinks below:

Scoring Risk

Weighting Scores

Scoring Guideline

[NOTE: in electronic format, to return the original page following selection of a hyperlink, press CTRL and LEFT ARROW together.]

2.1 A - Culverts

	Risk Assessment Question	Hyperlink for guidance
A.1	A.1.1 What is the structural form?	Using the Roads 277 – Culverts
	A.1.2 What are the constituent materials?	Using the Roads 277 – Culverts
A.2	A.2.1 What is the surrounding environment?	Using the Roads 277 – Culverts
	A.2.2 What was access for the GI like?	Using the Roads 277 – Culverts
A.3	A.3.1 What is the culvert's condition?	Using the BE 11/94 – Culverts
	A.3.2 Is the culvert susceptible to scour?	Using the Roads 277 – Culverts
	A.3.3 Has the culvert been assessed?	Using the Structural Assessment Report – Culverts
	A.3.4 What condition factor was used?	Using the Structural Assessment Report – Culverts
	A.3.5 What is the age, relative to Design Life?	Using the Roads 277 – Culverts Risk assessing Age
A.4	A.4.1 What is the approximate cover?	Using the Roads 277 – Culverts
	A.4.2 What loading is applied to the culvert?	Using the Roads 277 – Culverts
	A.4.3 What is the AAH HGV Flow?	Using the Structural Assessment Report – Culverts Using the Roads 277 – Culverts
	A.4.4 What is the Road Surface Category?	Using the Structural Assessment Report – Culverts Using the Roads 277 – Culverts

2.2 B - Single-span Bridges

	Risk Assessment Question	Hyperlink for guidance
B.1	B.1.1 What is the structural form?	Using the Roads 277 – Single-span Bridges Risk assessing Structural Form – Single-span Bridges
	B.1.2 What are the constituent materials?	Risk assessing Constituent Materials Using the Roads 277 – Single-span Bridges
B.2	B.2.1 What does the bridge span?	Using the Roads 277 – Single-span Bridges
	B.2.2 Is the bridge post-tensioned?	Using a Post-Tensioned Special Investigation (PTSI) Report Using the Roads 277 – Single-span Bridges
	B.2.3 What was accessibility for GI?	Using the Roads 277 – Single-span Bridges
	B.2.4 What is height under bridge?	Using the Roads 277 – Single-span Bridges
	B.2.5 What is the bridge span?	Using the Roads 277 – Single-span Bridges
B.3	B.3.1 What is the bridge's condition?	Using the BE 11/94 – Single-span Bridges
	B.3.2 Is it susceptible to concrete attack?	Using the BE 11/94 – Single-span Bridges
	B.3.3 Is it susceptible to scour?	Using the Roads 277 – Single-span Bridges
	B.3.4 Has the bridge been assessed?	Using the Structural Assessment Report – Culverts
	B.3.5 What was the Condition Factor?	Using the Structural Assessment Report – Culverts
	B.3.6 What is its age, relative to Design Life?	Using the Roads 277 – Single-span Bridges
B.4	B.4.1 What loading is applied to the bridge?	Using the Roads 277 – Single-span Bridges
	B.4.2 What is the AAH HGV Flow?	Using the Roads 277 – Single-span Bridges Using the Structural Assessment Report – Culverts
	B.4.3 What is the Road Surface category?	Using the BE 11/94 – Single-span Bridges

2.3 C - Multi-span Bridges

	Risk Assessment Question	Hyperlink for guidance
C.1	C.1.1 What is the structural form?	Using the Roads 277 – Multi-span Bridges
	C.1.2 What are the constituent materials?	Using the Roads 277 – Multi-span Bridges Risk assessing Constituent Materials
	C.1.3 What is the bridge articulation?	Using the Roads 277 – Multi-span Bridges Risk assessing Bridge Articulation
C.2	C.2.1 What does the bridge span?	Using the Roads 277 – Multi-span Bridges
	C.2.2 Is the bridge post-tensioned?	Using the Roads 277 – Multi-span Bridges Using a Post-Tensioned Special Investigation (PTSI) Report
	C.2.3 What was accessibility for GI?	Using the Roads 277 – Multi-span Bridges
	C.2.4 What is height under bridge?	Using the Roads 277 – Multi-span Bridges
	C.2.5 What access is there to the bridge spans?	Using the Roads 277 – Multi-span Bridges
C.3	C.3.1 What is the bridge's condition?	Using the BE 11/94 – Multi-span Bridges
	C.3.2 Is it susceptible to concrete attack?	Using the BE 11/94 – Multi-span Bridges
	C.3.3 Is it susceptible to scour?	Using the Roads 277 – Multi-span Bridges
	C.3.4 Has the bridge been assessed?	Using the Structural Assessment Report – Culverts
	C.3.5 What was the Condition Factor?	Using the Structural Assessment Report – Culverts
	C.3.6 What is its age, relative to Design Life?	Risk assessing Age Using the Roads 277 – Multi-span Bridges
C.4	C.4.1 What loading is applied to the bridge?	Using the Roads 277 – Multi-span Bridges
	C.4.2 What is the AAH HGV Flow?	Using the Roads 277 – Multi-span Bridges
	C.4.3 What is the Road Surface category?	Using the BE 11/94 – Multi-span Bridges

2.4 D - Footbridges / Gantries

	Risk Assessment Question	Hyperlink for guidance
D.1	D.1.1 What is the structural form?	Using the Roads 277 – Footbridges / Gantries
	D.1.2 What are the constituent materials?	Using the Roads 277 – Footbridges / Gantries
D.2	D.2.1 What does the bridge span?	Using the Roads 277 – Footbridges / Gantries
	D.2.2 Is the bridge post-tensioned?	Using the Roads 277 – Footbridges / Gantries Using a Post-Tensioned Special Investigation (PTSI) Report
	D.2.3 What was accessibility for GI?	Using the Roads 277 – Footbridges / Gantries
	D.2.4 What is height under bridge?	Using the Roads 277 – Footbridges / Gantries
	D.2.5 What access is there to the bridge spans?	Using the Roads 277 – Footbridges / Gantries
D.3	D.3.1 What is the bridge's condition?	Using the BE 11/94 – Footbridges / Gantries
	D.3.2 Is it susceptible to concrete attack?	Using the BE 11/94 – Footbridges / Gantries
	D.3.3 Is it susceptible to scour?	Using the Roads 277 – Footbridges / Gantries
	D.3.4 Has the bridge been assessed?	Using the Structural Assessment Report – Culverts
	D.3.5 What was the Condition Factor?	Using the Structural Assessment Report – Culverts
	D.3.6 What is its age, relative to Design Life?	Using the Roads 277 – Footbridges / Gantries Risk assessing Age
D.4	D.4.1 What kind of loading is typically applied to the bridge?	Using the Roads 277 – Footbridges / Gantries

2.5 E - Retaining Walls

	Risk Assessment Question	Hyperlink for guidance
E.1	E.1.1 What is the structural form?	Using the Roads 277 – Retaining Walls
	E.1.2 What are the constituent materials?	Using the Roads 277 – Retaining Walls
E.2	E.2.1 What is the wall adjacent to?	Risk assessing Adjacent Land Properties Using the Roads 277 – Retaining Walls
	E.2.2 What was accessibility for GI?	Using the Roads 277 – Retaining Walls
	E.2.3 What is the retained height?	Using the Roads 277 – Retaining Walls
E.3	E.3.1 What is the wall's condition?	Using the BE 11/94 – Retaining Walls
	E.3.2 Is it susceptible to concrete attack?	Using the BE 11/94 – Retaining Walls
	E.3.3 What is the environment surrounding the wall?	Using the Roads 277 – Retaining Walls
	E.3.4 Is it susceptible to scour?	Using the Roads 277 – Retaining Walls
	E.3.5 Has the wall been assessed?	Using the Structural Assessment Report – Retaining Walls
	E.3.6 What was the Condition Factor?	Using the Structural Assessment Report – Retaining Walls
	E.3.7 What is its age, relative to Design Life?	Risk assessing Age Using the Roads 277 – Retaining Walls
E.4	E.4.1 What loading is applied around the wall?	Risk assessing Live Loading Conditions Using the Roads 277 – Retaining Walls
	E.4.2 What is the AAH HGV Flow on any roads affecting the wall?	Using the Roads 277 – Retaining Walls
	E.4.3 What is the Road Surface category on roads near the wall?	Using the BE 11/94 – Retaining Walls

2.6 F – Technology Structures

	Risk Assessment Question	Hyperlink for guidance
F.1	F.1.1 Is the structure a standard design?	Using the Roads 277 Form – Technology Structures
	F.1.2 What is the foundation type?	Risk assessing Technology Structures Using the Roads 277 Form – Technology Structures
F.2	F.2.1 Is the majority of the structure accessible and accessed during the last GI?	Using the Roads 277 Form – Technology Structures
F.3	F.3.1 What is the condition of the structure?	Using the BE 11/94 Form – Technology Structures
	F.3.2 What is its age, relative to Design Life?	Using the Roads 277 Form – Technology Structures
F.4	F.4.1 Does the structure have fixed ADS or Electronic signs?	Using the Roads 277 Form – Technology Structures

3. Information gathering for desk study

The first part of completing the risk assessment is to gather the relevant background information relating to the structure. This is, however, not an exhaustive process where box upon box of archive information needs to be located. The only documents required are:

- The **Roads 277** form (*required*);
- The most recent **BE 11/94 General Inspection** form (*required*);
- The most recent **Principal Inspection** (*optional*);
- The most recent **Structural Assessment Report** (*optional*);
- Any associated material (e.g. a Post-Tensioned Special Investigation) (*optional*).

The bulk of the risk assessment can be completed using the Roads 277 and BE 11/94. Having additional information, however, will help the risk assessment process.

3.1 Roads 277 Form

This form gives basic facts about the structure, ranging from form of structure, year of construction, design loading and surrounding environment. Advice on using the 277 Form for each of the structure risk assessments can be found using the following links:

Using the Roads 277 – Culverts

Using the Roads 277 – Single-span bridges

Using the Roads 277 – Multi-span bridges

Using the Roads 277 – Footbridges / gantries

Using the Roads 277 – Retaining walls

3.2 BE 11/94 Form

This document details the findings of the biennial General Inspection, giving recent condition 'data' on the structure being risk assessed. Advice on how to best use the BE 11/94 Form for each of the structure risk assessments can be found using the following links:

Using the BE 11/94 – Culverts

Using the BE 11/94 – Single-span bridges

Using the BE 11/94 – Multi-span Bridges

Using the BE 11/94 – Footbridges / gantries

Using the BE 11/94 – Retaining walls

3.3 Principal Inspection Report

This provides a much more detailed insight into the structure's condition than that provided in the BE 11/94 as it documents a physical inspection of all visible elements of the structure. If available, this should be used to reinforce the condition information seen on the BE 11/94.

3.4 Structural Assessment Report

A Structural Assessment will contain the assessed load capacity of the structure, as well as the condition factor. Bridge assessment programmes, carried out in accordance with DMRB Volume 3 (see BD 21/01, BD 44/95, BD 56/96 etc) have been undertaken for a variety of reasons, particularly over the last 20 years or so. These have predominantly been done to take into account changes in concrete, steel and design standards, as well as complex loading conditions, caused by the advent of heavier vehicles. These assessments, however, did not cover all structures on the road network. For structures that were assessed, detailed reports were produced, specifying their load capacities. These Structural Assessment Reports, if available, can be used to inform the risk assessment process.

When completing a risk assessment, questions may refer to what the 'status' of the structure is with respect to this retrospective assessment. Advice on how to approach these questions can be found using the following links:

Using the Structural Assessment Report – Culvert example

Using the Structural Assessment Report - Retaining wall example

3.5 Additional Reports

3.5.1 Post-Tensioned Special Investigation

If the constituent material of a bridge is post-tensioned concrete, it is highly probable that it will have undergone some kind of further investigation, possibly a Post-Tensioned Special Investigation (PTSI). This should have determined the current status of the structure.

Post-tensioned concrete bridges are particularly vulnerable to corrosion and severe deterioration where internal grouting of tendon ducts is incomplete and moist air, water or de-icing salts can attack the post-tensioning tendons. The ingress of water and salts into tendon ducts is most likely at joints in segmental construction, other construction joints and anchorages at the ends of members.

Existing post-tensioned concrete bridges with grouted tendon ducts may need to be examined in a Special Inspection Programme over a 5-year period. Advice on undertaking this programme is given in BA 50/93: Post-Tensioned Bridges – *Planning, Organisation and Methods for Carrying-Out Special Investigations*.

When completing a risk assessment, questions may refer to what the 'status' of the structure is with respect to any additional assessment, particularly a PTSI. Advice on how to approach these questions can be found using the following link:

Using a Post-Tensioned Special Investigation (PTSI) Report

3.5.2 Concrete Deterioration Special Investigation

Alternative additional investigations may have been undertaken to identify the presence of serious concrete deterioration. The visible symptoms should have been recognised at either General or Principal Inspection stage, but findings at those stages would not have been in-depth enough to enable an accurate analysis of the problem.

The reasons that concrete deteriorates can be attributed to either design and construction errors and / or environmental effects. Correct diagnoses of the problem are essential before engineers can confidently go-ahead and restore defective concrete. In addition, a systematic analysis must be undertaken to determine the causes and extent of the damage. The source of the problems can range from an excessively slender design to poor workmanship; to shrinkage or insufficient contraction / expansion tolerances.

Risk assessment needs to consider whether environmental effects are known to be a major contributor to concrete deterioration. These environmental problems can often take the form of alkali-silica reaction (ASR), alkali-carbonate reaction (ACR) and thaumasite sulphate attack (TSA). All three can be very damaging to concrete and if present, will require investigation. When assessing the risks associated to any concrete structure, a history of concrete attack must be carefully considered. Knowledge of the geology of an area and typical aggregates used in concrete will be of benefit.

When completing a risk assessment, questions may refer to what the 'status' of the structure is with respect to any history of ASR, ACR or TSA. Advice on how to approach these questions can be found using the following link:

Using Concrete Deterioration Investigation Report

4. Culverts

Having gathered all available information about a culvert, completing the risk assessment should be simple. In all cases, the BE 11/94 and Roads 277 Form are a necessary part of the information required.

4.1 Culverts Questionnaire

All questions capable of being answered by directly taking information from a BE 11/94 or Roads 277 Form are illustrated in Figures 4.5 - 4.8. Other questions, which may not have direct answers in either of these forms, are described in Sections 4.1.1. and 4.1.2 below. The advice given on these subjects is helpful for all other structural types and not just for culverts.

4.1.1 Using the *Structural Assessment Report* – Culverts

How does having, or not having, a Structural Assessment Report affect the risk assessment?

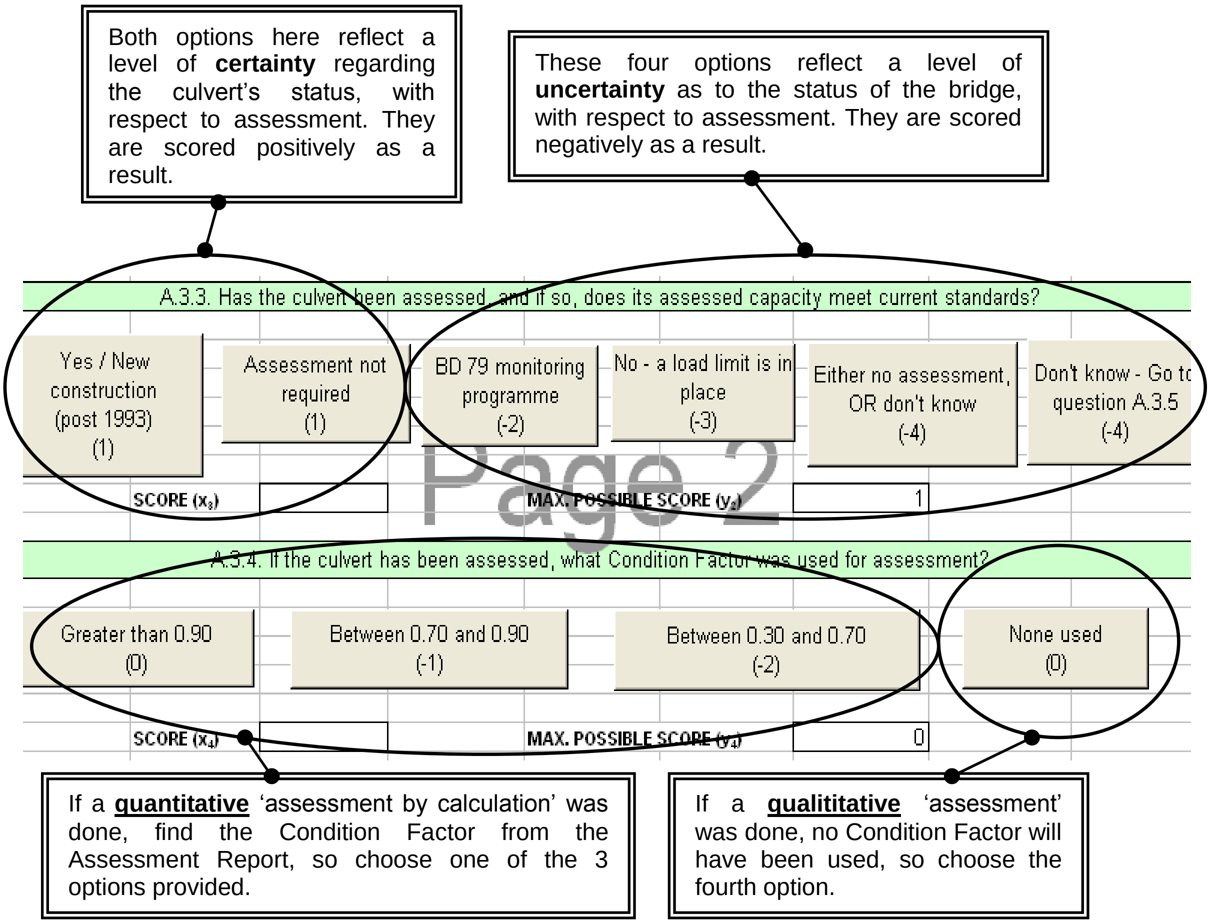


Figure 4.1 Risk assessing a Structural Assessment Report - Culverts

4.1.2 Risk assessing *Age*

How does the age of a structure affect the risk assessment? The Design Life for a structure can vary from 30 up to 120 years, depending on the type of structure. On occasions, a bridge owner may also have stipulated a different design life from what would normally be expected. Consequently, it is important to validate the value for each structure. A structure which is less than 70% of its Design Life, but not new, is expected to be at lowest risk of deteriorating. Whereas a new bridge is yet to be ‘proven’, an old bridge is approaching the end of its Design Life and may be expected to deteriorate.

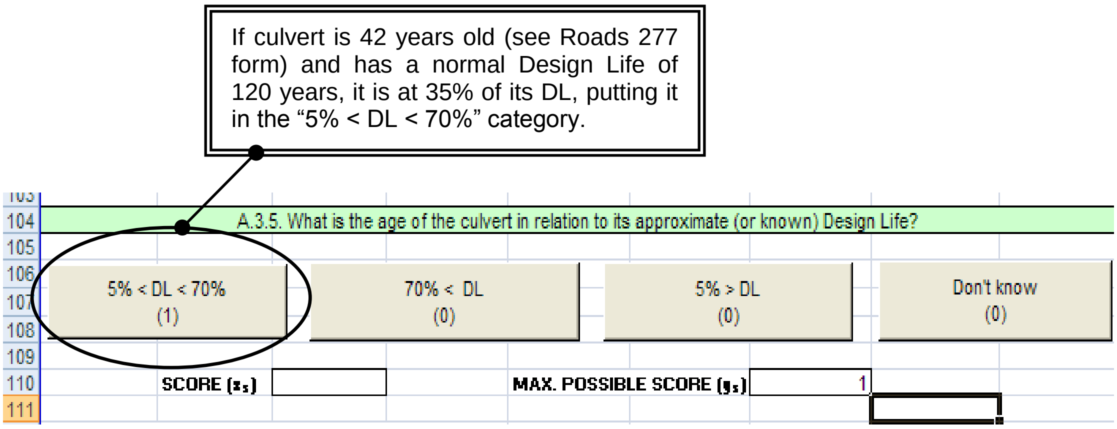
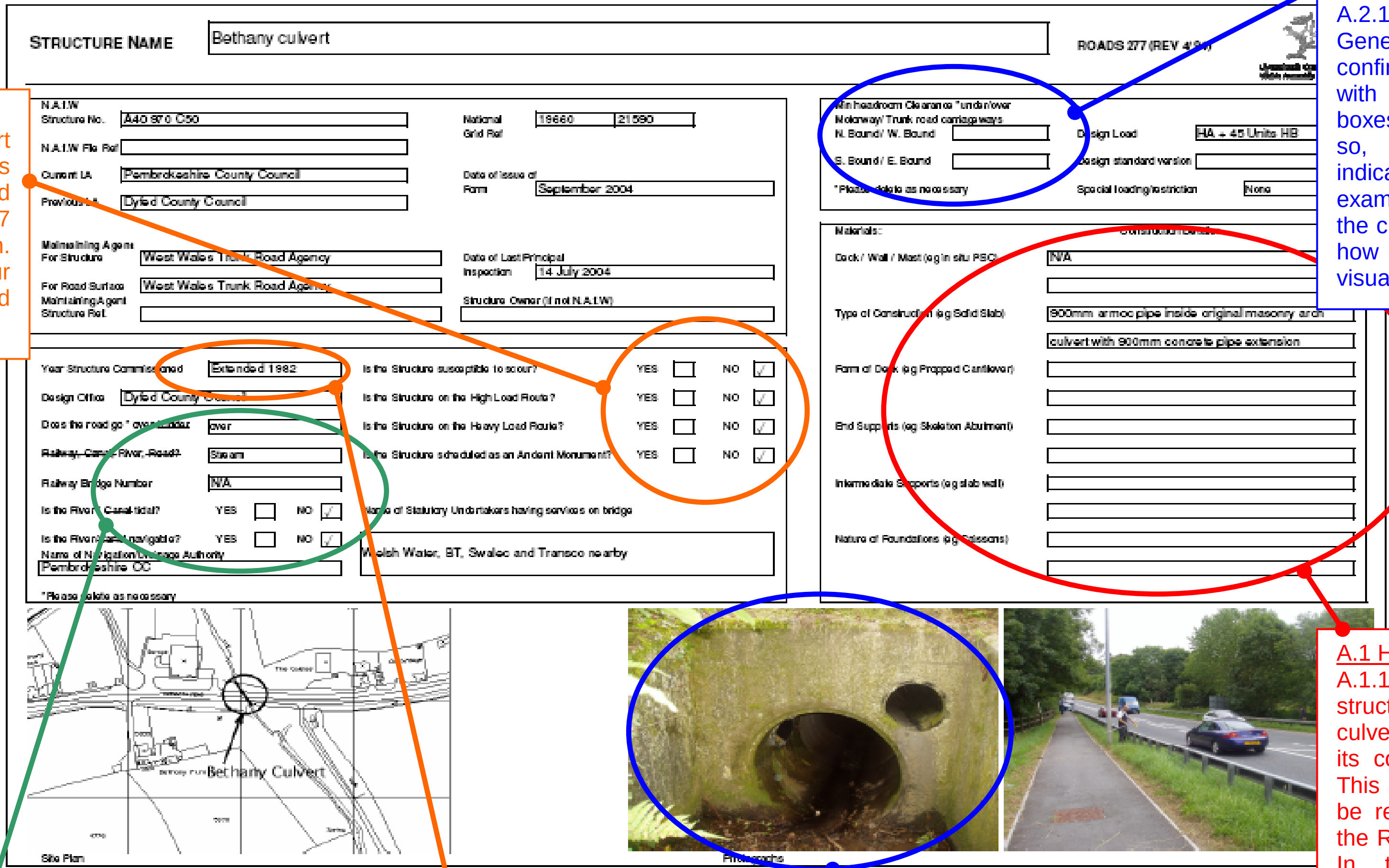


Figure 4.2 Risk assessing age relative to Design Life

4.2 Using the Roads 277 – Culverts



A.2 INSPECTION DATA
A.2.1-Was access for the General Inspection confined or difficult? As with this example, these boxes may be left blank. If so, move on to other indicative evidence. For example, a photograph of the culvert will often show how easy access and visual inspection was.

A.3 CONDITION DATA
A.3.2-Is the culvert susceptible to scour? This question is answered directly by the Roads 277 form in this section. Further advice on scour assessment can be found in BA 74/06

A.1 HISTORICAL DATA
A.1.1-What is the structural form of the culvert? A.1.2-What are its constituent materials? This information should be readily available from the Roads 277 form here. In this example, the culvert is an ARMCO steel pipe inside a concrete surround.

A.4 USAGE DATA
A.4.2-What loading is typically applied to the culvert? This gives details of what goes over the culvert. Whether it takes highway live loads is then self-explanatory.

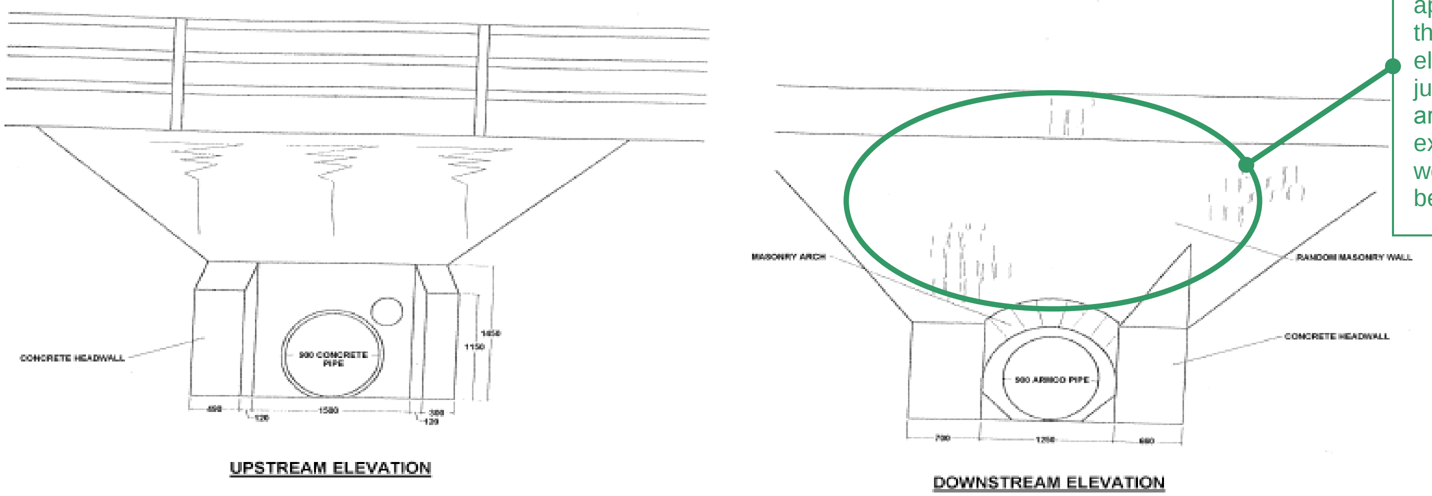
A.3 CONDITION DATA
A.3.5-What is the age of the culvert in relation to its design life? One can easily work out the age as it is given here. But how can we know what the culvert's Design Life would be? See Section 4.1.2

A.2 INSPECTION DATA
A.2.1-What is the environment in and around the culvert? Look at the photograph-it is often obvious as to whether you have a predominantly dry culvert or wet culvert. Again local knowledge will be of use.

Figure 4.3 - Using the Roads 277 to risk assess culverts (Page 1 of 2)

Dimensional Elevation, Cross Section and Components of Structure.
Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road.

ROADS 277(REV 4/94)



A.4 USAGE DATA
A.4.1-What is the approximate cover above the culvert? Use the elevation to inform your judgement if dimensions aren't available. For example, this culvert would have a cover of between 0.6m and 3m.

	Manufacturer	Type
Prestressing System		
Paint System: Parapet		
Internal		
External		

	Manufacturer	Type	Position
Bearings*	None		
Joints*	None		
Parapets	Not Known	Open box beam safety fencing	Both sides of carriageway
Waterproofing	None		

*Indicate on sketch above

Figure 4.4 - Using the Roads 277 to risk assess culverts (Page 2 of 2)

4.3 Using the BE 11/94 – Culverts

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

BE 11/94

TRUNK ROAD / MOTORWAY STRUCTURE INSPECTION REPORT

Structure No. A 4 0 9 7 0 C 5 0 — Agent Code 0 0 1 1

Agent Name South Wales Trunk Road Agency — Grid Ref 1 9 6 6 0 2 1 5 9 0

Structure Name Bethany Culvert — From Span 0 1 — To span 0 1

Date of Inspection 1 2 Jun 2 0 0 8 — Type of Inspection* G √ P S — Inspected by N.Morgan / M.Hughes

Overall Assessment G F P √ *Please Tick

Defect Assessment	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
1.Foundations				B			No evidence of settlement
2.Inverts or Aprons		A	1				
3.Fenders							
4.Piers or columns							
5.Abutments							
6.Wing Walls		A	1				
7.Retaining Walls or Revetments	1 0 0 0 0	D	3	R	M		Downstream retaining wall in poor condition
8.Approach Embankments		A	1				
9.Bearings							
10.Main Beams / Tunnel Portals / Mast							
11. Transverse Beams / Catenary Cables							
12. Diaphragms or Bracings							
13.Concrete Slab							
14.Metal Deck Plates / Tunnel Linings							

Please turn over

A.3 CONDITION DATA
A.3.1-What is the condition of the structure, as noted by the General Inspection?
Using a combination of the Engineer's overall assessment (Good, Fair or Poor) and other comments in the BE 11/94, a valuable picture of the culvert's condition can be formed.-and allow the questions posed by the Risk Assessment to be answered.

Figure 4.5 - Using the BE 11/94 to risk assess culverts (Page 1 of 2)

BE 11/94

Defect Assessment (cont)	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
15. Jack Arches							
16. Arch Ring / Corrugated Metal	50000	D	3	R	L		Corrugated steel pipe corroded.
17. Spandrels		A	1				
18. Tie Rods							
19. Drainage Systems		B	2	N			Poor pipe outlet connections into culvert
20. Waterproofing							
21. Surfacing		A	1				
22. Service Ducts							
23. Expansion Joints							
24. Parapets / Handrails	3000	D	3	C	M		Downstream blockwork parapet in poor condition
25. Access Gantries or Walkways							
26. Machinery							
32. Dry Stone Walls							
33. Troughing							

Reasons for Priority Allocation

7. Masonry retaining wall in unsafe condition and requires repair - M.

16. Pipe inspected from inlet and outlet. Invert of pipe badly corroded. Access difficult due to size of pipe - confined space. Remedial works required, not urgent - L.

24. Concrete blocks forming downstream parapet are of poor quality and are badly weathered. Sections of parapet can be removed as pedestrian containment is provided by existing timber fence - M.

Signed: Neil Morgan

Name: Neil Morgan

Date: 12. 6. 2008

A.4. USAGE DATA

A.4.4-What is the Road Surface Category? As a formal structural Assessment Report may not be available for a culvert, looking at this section of the BE 11/94 can give good guidance as to what the recent condition status of the road surfacing is. Is it good, or has it deteriorated?

Figure 4.6 - Using the BE 11/94 to risk assess culverts (Page 2 of 2)

5. Single-span Bridges

Having gathered all available information about a single-span bridge, completing the risk assessment should be straightforward. In all cases, the BE 11/94 and Roads 277 Form should be a necessary part of the information required.

5.1 Single-Span Bridges Questionnaire

All questions capable of being answered by directly taking information from a BE 11/94 or Roads 277 Form are illustrated in Figures 5.6 - 5.9. Other questions, which may not have direct answers in either of these forms, are described in Sections 5.1.1 - 5.1.3 below. The advice given on these subjects is helpful for all other structural types and not just for bridges.

5.1.1 Risk assessing *Structural Form* – Single-span Bridges

How does the structural form of a single-span bridge affect the likelihood of deterioration? The main things to look at are, unsurprisingly, historical performance (e.g. any known problems with durability or robustness) and the degree of redundancy associated with a specific form of construction. The rationale behind many of the structural forms chosen is illustrated in Figure 5.1:

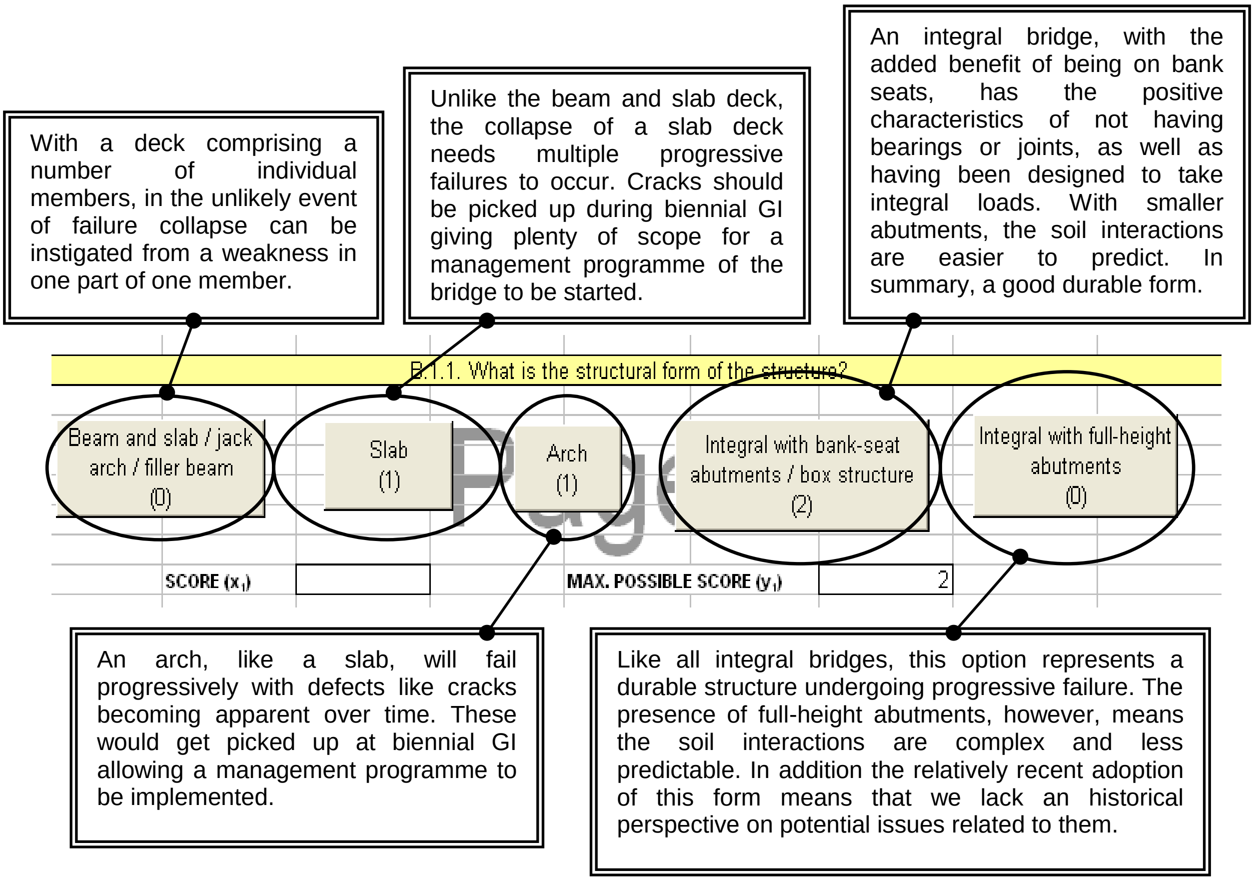


Figure 5.1 - Risk assessing Structural Form of single-span bridges

5.1.2 Risk assessing Constituent Materials

How does the constituent material of a single-span bridge affect the likelihood of deterioration? Similarly to structural form, the main factor to consider is historical performance. The rationale behind each of the constituent materials chosen is illustrated in Figure 5.2 below:

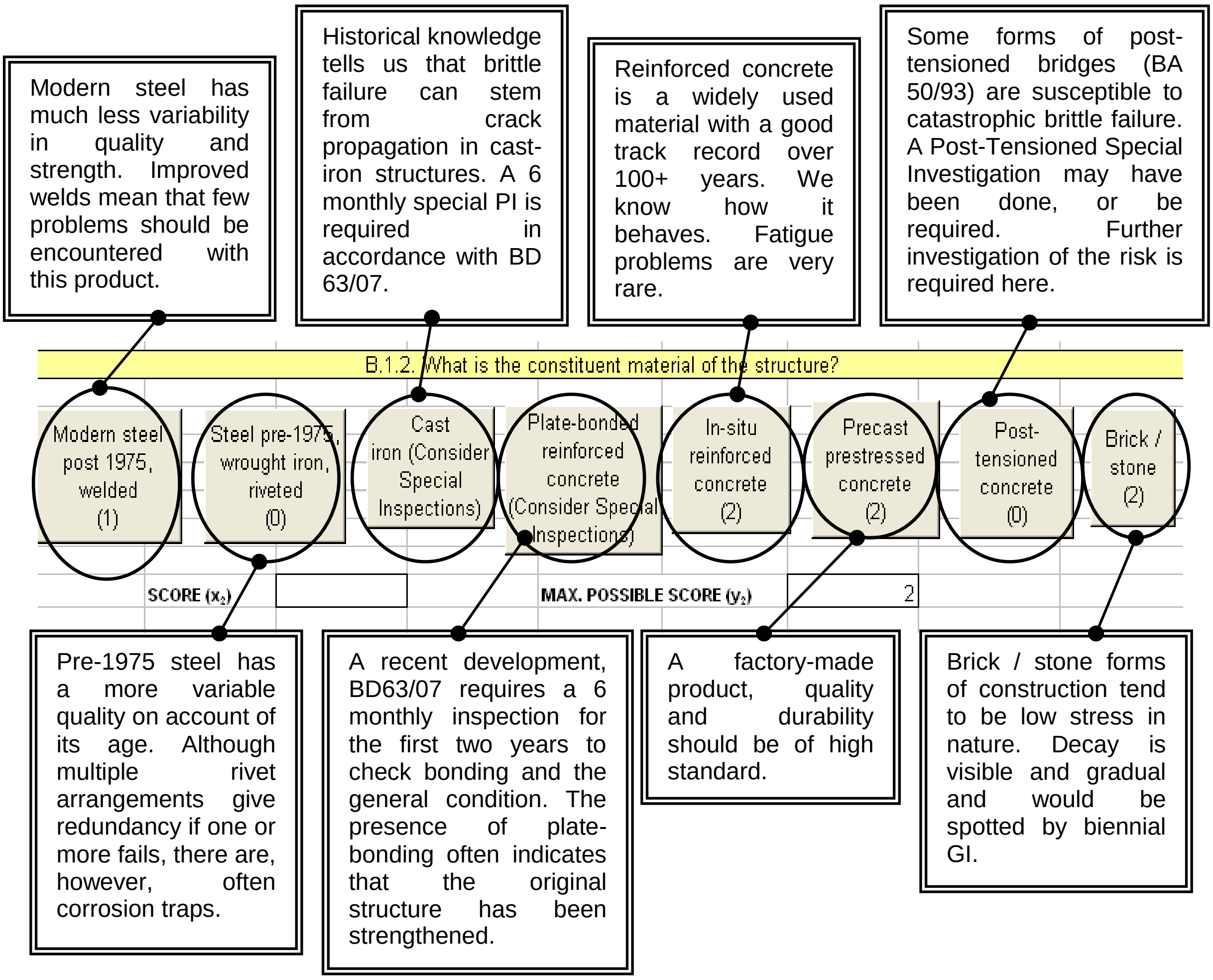


Figure 5.2 Risk assessing constituent materials of single-span bridges

5.1.3 Using a Post-Tensioned Special Investigation (PTSI) Report

If the constituent material in 5.1.2 is post-tensioned concrete, it is highly probable that the structure will have undergone some kind of further investigation, possibly a Post-Tensioned Special Investigation (PTSI).

Post-tensioned concrete bridges are particularly vulnerable to corrosion and severe deterioration where internal grouting of tendon ducts is incomplete and moist air, water or de-icing salts can enter the ducting system. The ingress of water and salts into tendon ducts is most likely at joints in segmental construction, other construction joints and anchorages at the ends of members.

Existing post-tensioned concrete bridges with grouted tendon ducts are required to be examined as part of a Special Inspection Programme over a 5-year period. Advice on undertaking this programme is given in BA 50/93: Post-Tensioned Bridges – *Planning, Organisation and Methods for Carrying Out Special Investigations*.

This advice note states: '*Most forms of in-situ post-tensioned monolithic construction carry little risk of sudden structural collapse. Solid slabs and voided slab decks represent the safest form of construction. Monolithic beams with or without composite slabs and monolithic forms of box construction are all unlikely to collapse without prior warning. Providing there are no built-in planes of weakness arising from construction joints, there is a low probability of all the prestressing tendons across a deck failing at specific transverse sections*.

'In comparison with monolithic construction, all types of segmental bridge decks have a higher probability of a sudden mode of collapse. Many forms of segmental construction have been used for both simply supported and continuous bridge decks. The basic distinctions that can be made between them relate to the direction of the joint, the joint material and the width of the joint[1].

The need to maintain an appropriate level of public safety leads to a system of classification for segmental post-tensioned bridge decks. The broad categories of segmental decks (see Figure 5.3) are intended to illustrate the degree of risk of a brittle mode of failure associated with various types of post-tensioned structure. Where the risk is high, special monitoring and testing procedures should be considered for the site investigation. Sudden failure is more likely where there is no secondary reinforcement across the joints.

A variety of segmental bridge decks have been constructed without any form of composite action. In the extreme case of simply supported segmental beams, it is necessary to consider monitoring methods to provide a reliable warning of imminent failure. A combination of specialist techniques can be applied, but the technical approach needs very careful planning and considerable experience. Longitudinal cracks may indicate that tendons have severed and re-anchored, and these cracks should be investigated and monitored with suitable instrumentation.

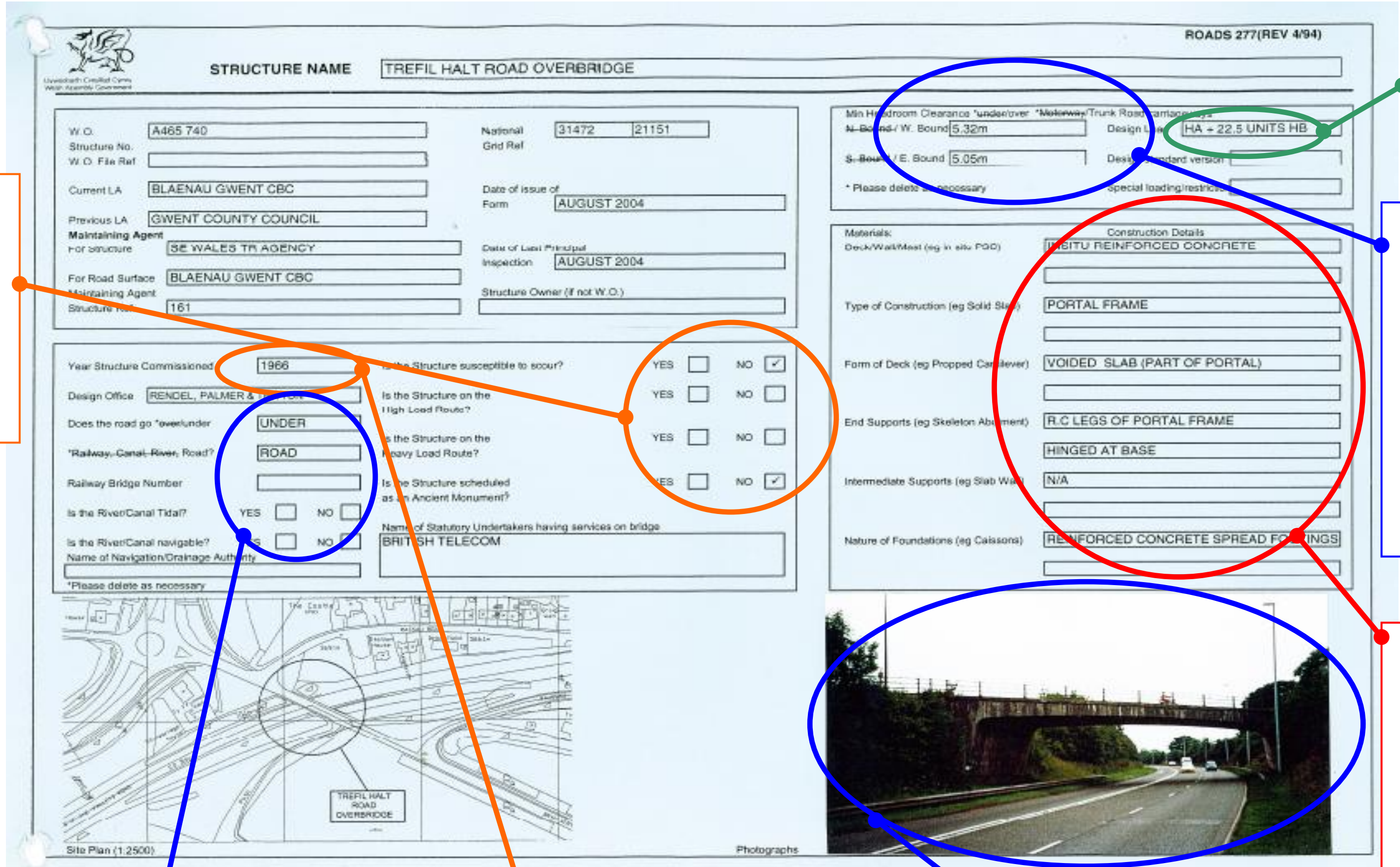
The probability of a sudden mode of collapse is reduced when simply supported segmental beams are transversely connected to form a grillage.

DECK TYPE	JOINT DIRECTION	ELEMENT TYPE	RISK OF BRITTLE MODE OF FAILURE
Simply supported (non-composite)	Transverse	Beams	Very high
	Longitudinal and transverse	Beam grillage	High
	Transverse	Box girders	High
	Longitudinal	Monolithic beams with transverse prestressing	Very low
Simply supported (composite)	Transverse	Composite beams with in-situ top slab	Medium
	Transverse	Composite beams with in-situ top and bottom slabs	Low
Continuous	Transverse	Composite beam and slab, and box girders	Low

Figure 5.3 Risk classifications of post-tensioned bridges in accordance with BA 50/93

[1] DMRB BA 50/93: Post-Tensioned Bridges – *Planning, Organisation and Methods for Carrying Out Special Investigations*

5.2 Using the Roads 277 – Single-span Bridges



B.3 CONDITION DATA
B.3.3-Is the bridge susceptible to scour? This question is answered directly by the Roads 277 form in this section. Further advice on scour assessment can be found in BA 74/06

B.4 USAGE DATA
B.4.1-What loading is typically applied to the bridge? The loading that the bridge has been designed for is shown here.

B.2 INSPECTION DATA
B.2.3-Was access for the General Inspection confined or difficult? B.2.4- What is the height beneath the bridge? Judgements concerning questions of how well a visual inspection could have been carried out can be made by looking at these details.

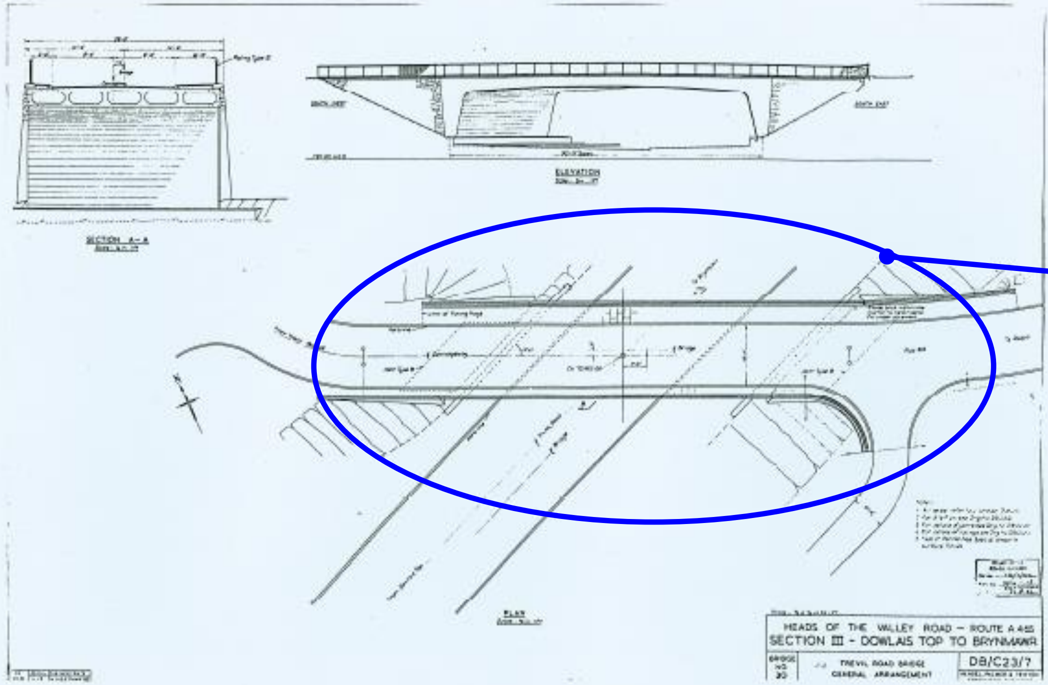
B.1 HISTORICAL DATA
B.1.1-What is the structural form of the bridge? B.1.2-What are its constituent materials? All of the answers to these questions posed by the risk assessment should be readily available here.

B.2 INSPECTION DATA
B.2.1-What does the bridge span? This gives details of what goes over or under the bridge.

B.3 CONDITION DATA
B.3.6-What is the age of the bridge in relation to its design life? One can easily work out the age as it is given here. Design Life is typically 120 years, but check with bridge owner.

B.2 INSPECTION DATA
B.2.5-What was visual accessibility to the bridge like? Look at the photograph-it is often obvious from this as to whether GI would have been difficult or straightforward.

Figure 5.4 - Using the Roads 277 to risk assess single-span bridges (Page 1 of 2)



Dimensional Elevation, Cross Section and Components of Structure. ROADS 277(REV 4/94)

Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road and also of the crossing road where appropriate (include spans)
Indicate type and position of bearings and joints.

		Manufacturer	Type
Prestressing System			
Paint System	Parapet	CROWN	5 COAT MIO SYSTEM
	Internal		
	External		

	Manufacturer	Type	Position
Bearings*	N/A	NONE	
Joints*	UNKNOWN	BURIED RADFLEX	
Parapets	UNKNOWN	P2 -80kph MESH INFILL	
Waterproofing	UNKNOWN	12mm MASTIC ASPHALT	

*Indicate on sketch above

B.2 INSPECTION DATA
B.2.5-What is the span of the bridge? Is it less than 10m, between 10 and 25m or greater than 25m? All major dimensional requirements can be obtained from drawing on Page 2 of the Roads 277.

Figure 5.5 - Using the Roads 277 to risk assess single-span bridges (Page 2 of 2)

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5.3 Using the BE 11/94 – Single-span Bridges

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Trunk Road / Motorway Structure Inspection Report **BE 11/94**

Structure No. A 4 6 5 7 4 0 Agent Code 0 0 1 1

Agent Name SOUTH WALES TRUNK ROAD AGENCY Grid Ref 3 1 4 7 2 2 1 1 5 1

Structure Name TREVIL HALT ROAD OVERBRIDGE From Span 0 1 To Span 0 1
(161)

Date of 0 3 J U L 2 0 0 8 Type of Inspection* G ✓ P S Inspected by R Poulton
(eg 0 1 J U N 1 9 9 4)

Overall Assessment* G F ✓ P *Please tick

Defect Assessment	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
1. Foundation				B			
2. Inverts or Aprons							
3. Fenders / Safety Barriers	8,000	D	3	C	M		Replace low TCB's
4. Piers or Columns							
5. Abutments		D	2	N			Large repaired sections, new cracking with staining/leachates.
6. Wing Walls	1500	C	2	R	L		Some repointing of masonry required. Loose block at top of NW wingwall. Coping spalled on SE wingwall.
7. Retaining Walls or Revetments							
8. Approach Embankments		B	2	N			Overgrown
9. Bearings							
10. Main Beams / Tunnel Portals / Mast							
11. Transverse Beams / Catenary Cables							
12. Diaphragms or Bracings							
13. Concrete Slab		D	2	N			Multiple concrete repairs with poor compaction, leachates and co staining. Heavy leachate staining to east fascia
14. Metal Deck Plates / Tunnel Linings							

Please turn over

<u>B.3 CONDITION DATA</u>
B.3.1-What is the condition of the bridge, as noted by the General Inspection? Using a combination of the Engineer's overall assessment (Good, Fair or Poor) and other comments in the BE 11/94, a valuable picture of the bridge's condition can be formed.- and allow the questions posed by the Risk Assessment to be answered.

<u>B.3 CONDITION DATA</u>
B.3.2-Is the bridge undergoing suspected concrete attack? If it is, the evidence should be recorded on the BE 11/94. A competent Inspecting Engineer would certainly comment on the kind of damage caused by ASR or ACR if seen during the GI.

Figure 5.6 - Using the BE 11/94 to risk assess single-span bridges (Page 1 of 2)

BE 11/94

Defect Assessment (cont)	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
15. Jack Arches							
16. Arch Ring / Corrugated Metal							
17. Spandrels							
18. Tie Rods							
19. Drainage Systems				B			
20. Waterproofing				B			(No evidence of problems)
21. Surfacing	5000	D	2	C	L		Worn with patches/trial pit reinstatement..
22. Service Ducts				B			
23. Expansion Joints							
24. Parapets / Handrails	10,000	D	4	R	H		Bottom rail corroded away on west, generally poor elsewhere
25. Access gantries or walkways							
26. Machinery							
32. Dry Stone Walls							
33. Troughing							

B.4. USAGE DATA
B.4.3-What is the Road Surface Category? Again, a competent Inspecting Engineer would certainly comment on any deterioration or sub-standard surfacing on the bridge, and would note it in this section if it was seen during GI.

Reasons for priority allocation

3: Vehicle safety – M

6: Early action will reduce life-time cost – L

21: General maintenance – L

24: Vehicle safety - H

Signed	R. Poulton	Name	R Poulton
		Date	03/07/08

Figure 5.7 - Using the BE 11/94 to risk assess single-span bridges (Page 2 of 2)

6. Multi-span Bridges

Having gathered all available information for a multi-span bridge, completing the risk assessment should be straightforward. In all cases, the BE 11/94 and Roads 277 Form should be a necessary part of the information required.

Multi-span bridges will often be the largest of the five structural types being risk assessed. These bridges are multi-span because they need to cross large obstacles such as rivers and motorways. The main difference, therefore, between the multi-span bridge risk assessment and the single-span bridge risk assessment is accounting for differences in articulation and overcoming difficulties in getting a good visual inspection.

6.1 Multi-Span Bridge Questionnaire

All questions capable of being answered by directly taking information from a BE 11/94 or Roads 277 Form are illustrated in Figures 6.4 – 6.7. Other questions, which may not have direct answers in either of these forms, are described in Section 6.1.1 below. The advice given on these subjects is helpful for all other structural types and not just for bridges.

6.1.1 Risk assessing Bridge Articulation

How do different bridge articulations affect the risk of deterioration? As with single-span bridges the main thing to consider is historical performance. Secondly, the degree of redundancy associated with various bridge articulations is also worth consideration. The rationale behind each of the various bridge articulations chosen is illustrated in Figure 6.1 below:

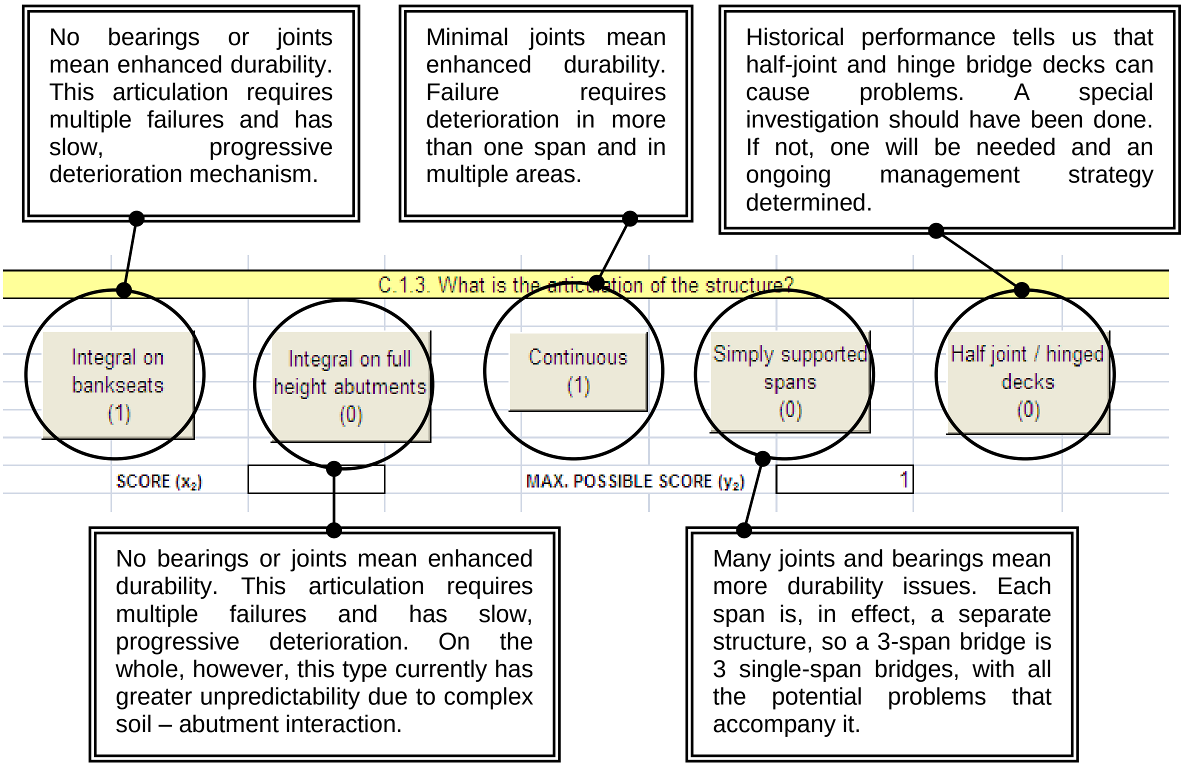
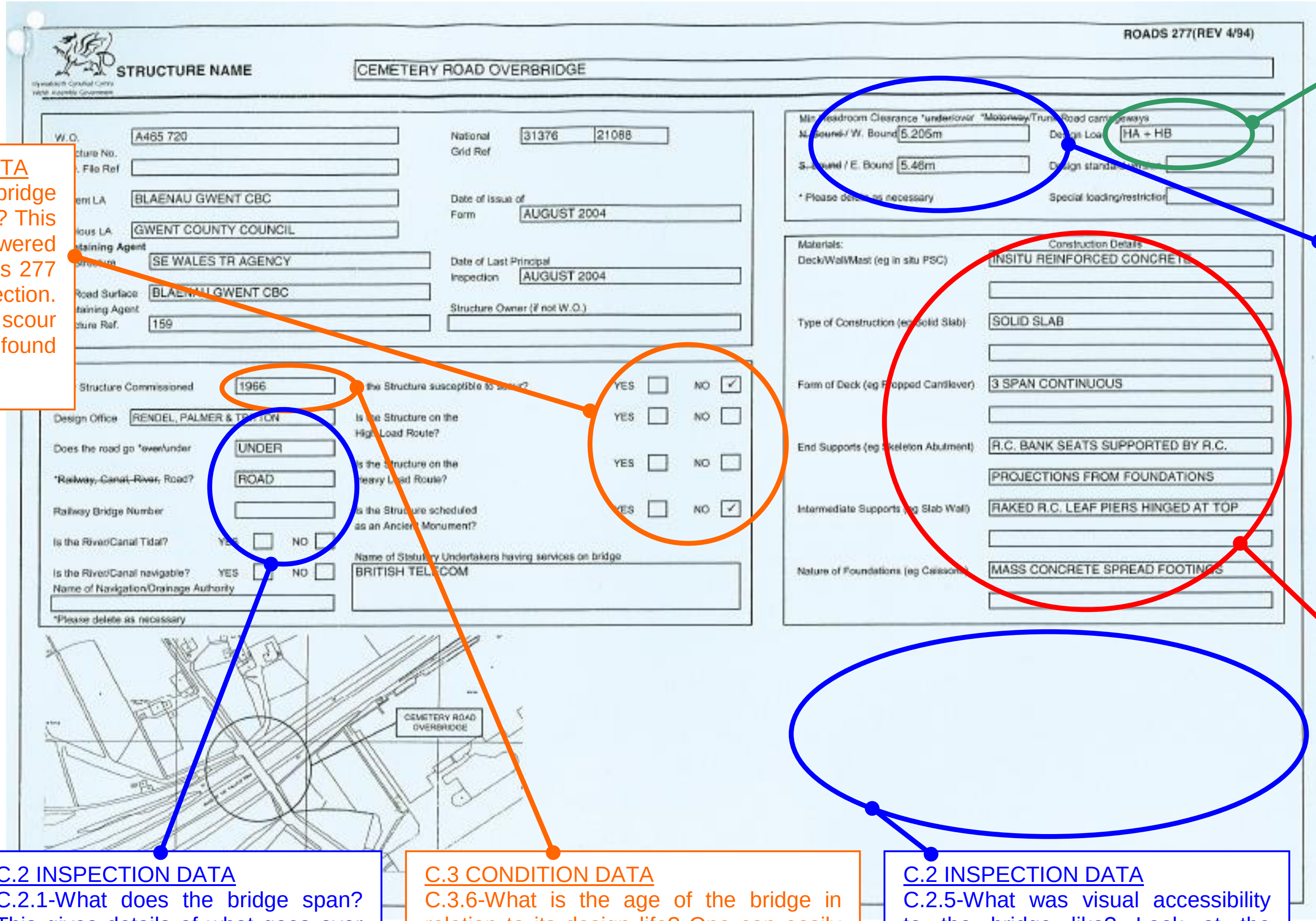


Figure 6.1 – Risk assessing bridge articulation - Multi-span bridges

6.2 Using the Roads 277 – Multi-span Bridges



C.4 USAGE DATA
C.4.1-What loading is typically applied to the bridge? The loading that the bridge has been designed for is shown here.

C.3 CONDITION DATA
C.3.3-Is the bridge susceptible to scour? This question is answered directly by the Roads 277 form in this section. Further advice on scour assessment can be found in BA 74/06

C.2 INSPECTION DATA
C.2.3-Was access for the General Inspection confined or difficult? C.2.4- What is the height beneath the bridge? Judgements concerning questions of how well a visual inspection could have been carried out can be made by looking at these details.

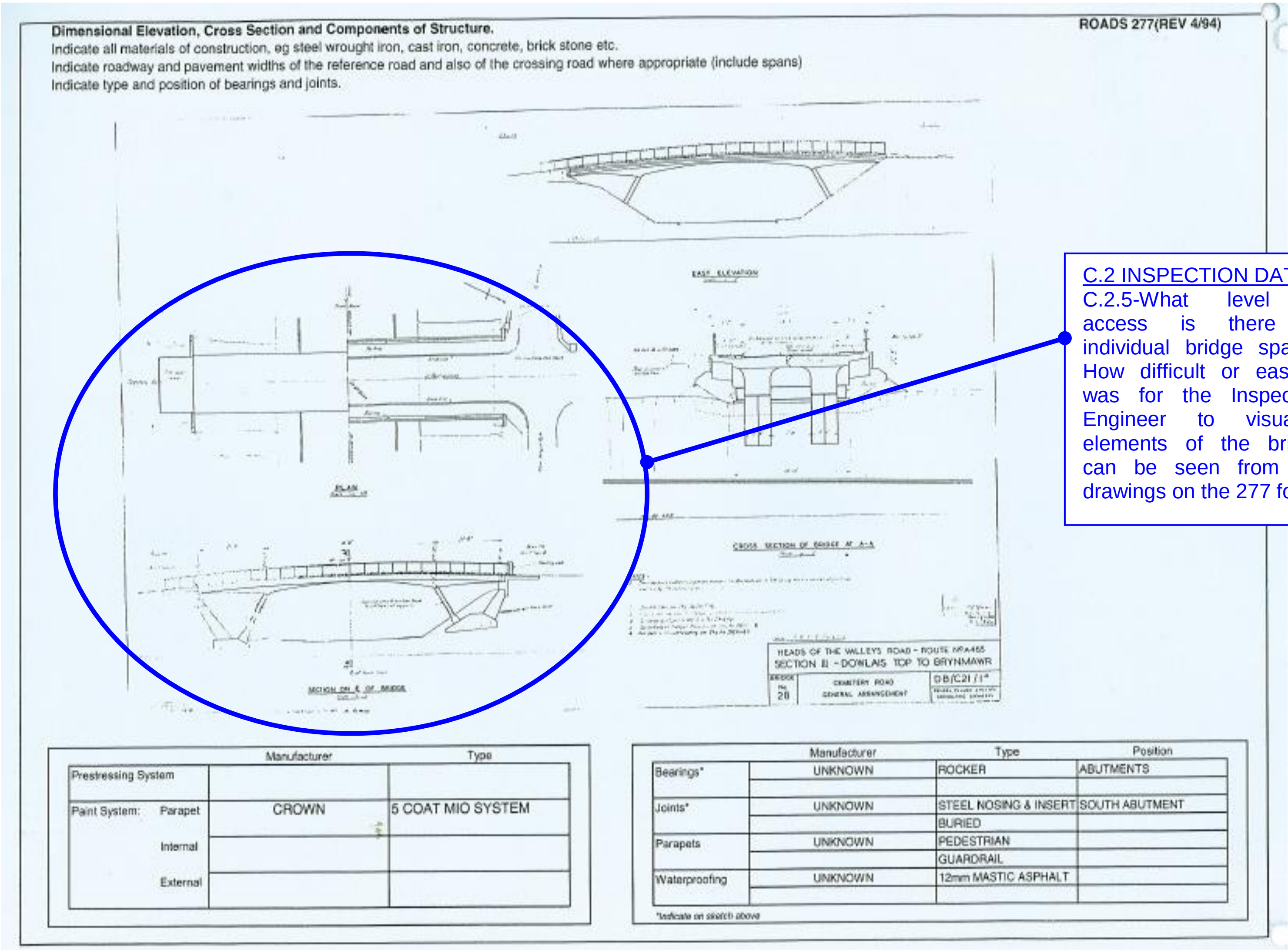
C.1 HISTORICAL DATA
C.1.1-What is the structural form of the bridge? C.1.2-What are its constituent materials? C.1.3-What is the bridge articulation? All of the answers to these questions posed by the risk assessment should be readily available here.

C.2 INSPECTION DATA
C.2.1-What does the bridge span? This gives details of what goes over or under the bridge.

C.3 CONDITION DATA
C.3.6-What is the age of the bridge in relation to its design life? One can easily work out the age as it is given here. Design Life should be 120 years, but always check with bridge owner.

C.2 INSPECTION DATA
C.2.5-What was visual accessibility to the bridge like? Look at the photograph-it is often obvious from this as to whether GI would have been difficult or straightforward.

Figure 6.2 - Using the Roads 277 to risk assess multi-span bridges (Page 1 of 2)


ROADS 277(REV 4/94)

Dimensional Elevation, Cross Section and Components of Structure.
Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road and also of the crossing road where appropriate (include spans)
Indicate type and position of bearings and joints.

	Manufacturer	Type
Prestressing System		
Paint System: Parapet	CROWN	5 COAT MIO SYSTEM
Internal		
External		

	Manufacturer	Type	Position
Bearings*	UNKNOWN	ROCKER	ABUTMENTS
Joints*	UNKNOWN	STEEL NOSING & INSERT	SOUTH ABUTMENT
		BURIED	
Parapets	UNKNOWN	PEDESTRIAN	
		GUARDRAIL	
Waterproofing	UNKNOWN	12mm MASTIC ASPHALT	

*indicate on sketch above

C.2 INSPECTION DATA
C.2.5-What level of access is there to individual bridge spans? How difficult or easy it was for the Inspecting Engineer to visualise elements of the bridge can be seen from the drawings on the 277 form.

Figure 6.3 - Using the Roads 277 to risk assess multi-span bridges (Page 2 of 2)

6.3 Using the BE 11/94 – Multi-span Bridges

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Trunk Road / Motorway Structure Inspection Report **BE 11/94**

Structure No.	A 4 6 5 7 2 0	Agent Code	0 0 1 1
Agent Name	SOUTH WALES TRUNK ROAD AGENCY	Grid Ref	3 1 3 7 6 2 1 0 8 8
Structure Name (159)	CEMETERY ROAD OVERBRIDGE	From Span	0 1 To Span 0 3
Date of	0 3 J U L 2 0 0 8 (eg 0 1 J U N 1 9 9 4)	Type of Inspection*	G ✓ P S Inspected by R Poulton
		Overall Assessment*	G ✓ F ✓ P *Please tick

Defect Assessment	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
1. Foundation				B			
2. Inverts or Aprons							
3. Fenders / Safety Barriers							
4. Piers or Columns		B	2	N			Minor defects only
5. Abutments		B	2	N			Minor defects only
6. Wing Walls							
7. Retaining Walls or Revetments		B	2	N			Loose shall/marl
8. Approach Embankments		B	2	N			Overgrown
9. Bearings							
10. Main Beams / Tunnel Portals / Mast							
11. Transverse Beams / Catenary Cables							
12. Diaphragms or Bracings							
13. Concrete Slab	3000	C	2	R	L		Several transverse cracks in both cantilevers with leachates/stalac new concrete repairs/skim material and in original concrete
14. Metal Deck Plates / Tunnel Linings							

Please turn over

<u>C.3 CONDITION DATA</u>
C.3.1-What is the condition of the bridge, as noted by the General Inspection? Using a combination of the Engineer's overall assessment (Good, Fair or Poor) and other comments in the BE 11/94, a valuable picture of the bridge's condition can be formed.- and allow the questions posed by the Risk Assessment to be answered.

<u>C.3 CONDITION DATA</u>
C.3.2-Is the bridge undergoing suspected concrete attack? If it is, the evidence should be recorded on the BE 11/94. A competent Inspecting Engineer would certainly comment on the kind of damage caused by ASR or ACR if seen during the GI.

Figure 6.4 - Using the BE 11/94 to risk assess multi-span bridges (Page 1 of 2)

BE 11/94

Defect Assessment (cont)	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
15. Jack Arches							
16. Arch Ring / Corrugated Metal							
17. Spandrels							
18. Tie Rods							
19. Drainage Systems							
20. Waterproofing				B			See '13'
21. Surfacing		D	2	N			Worn with significant craze cracking
22. Service Ducts				B			
23. Expansion Joints		B	2	N			Worn with minor corrosion
24. Parapets / Handrails	2000	D	2	P	L		Corrosion at joints and general paint system failure.
25. Access gantries or walkways							
26. Machinery							
32. Dry Stone Walls							
33. Troughing							

Reasons for priority allocation

13, 24: Early action will reduce life time costs – L

Signed: *R. Poulton*

Name: R Poulton

Date: 03/07/08

<u>C.4. USAGE DATA</u>
C.4.3-What is the Road Surface Category? Again, a competent Inspecting Engineer would certainly comment on any deterioration or sub-standard surfacing on the bridge, and would note it in this section if it was seen during GI.

Figure 6.5 - Using the BE 11/94 to risk assess multi-span bridges (Page 2 of 2)

7. Footbridges / Gantries

7.1 Footbridge / Gantries Questionnaire

Having gathered all available information for a footbridge or gantry, completing the risk assessment should be straightforward. In all cases, the BE 11/94 and Roads 277 Form should be a necessary part of the information required.

7.1.1 Using Concrete Deterioration Investigation Report

How does a history of concrete deterioration affect the risk assessment for any given structure? This risk assessment asks the user to consider whether environmental effects are known to be a major contributor to any concrete deterioration. These environmental problems can often take the form of *alkali-silica reaction* (ASR), *alkali-carbonate reaction* (ACR) and *thaumasite sulphate attack* (TSA). All three are very damaging to concrete and, if present will need investigation.

1. **Alkali-Silica Reaction (ASR)** - Certain types of aggregate with poor alkali resistance interact with alkaline fluids in the pores of the concrete to form a silica gel around the surface. This gel absorbs moisture, causing it to expand, and ultimately leads to cracking and further deterioration of the concrete.
2. **Alkali-Carbonate Reaction (ACR)** - Similar to ASR in that the alkaline environment of concrete attacks the aggregate that includes reactive particles. In ACR, the alkaline reacts with dolomite limestone, replacing it with less stable and expansive products. This reaction usually occurs early and structures may show cracking within five years after construction. Over time, the ACR products create a ‘rim’ around the aggregate, weakening the bond and creating micro-cracks and voids. Cracks allow ingress of water, sulphates and chlorides to the interior of the concrete, leading to durability issues such as freeze / thaw damage, sulphate attack or steel corrosion.
3. **Thaumasite Sulphate Attack (TSA)** - The thaumasite form of sulphate attack (often abbreviated to TSA) requires a source of sulphate and also of carbonate. Thaumasite can occur rarely as a natural mineral as an alteration product of limestone. Thaumasite can form in concrete and in mortar. The cement hydration products normally present, mainly calcium silicate hydrate and calcium hydroxide, are decomposed as a result of both sulphate attack and of carbonation. Since it is the calcium silicate hydrate in concrete that provides most of the strength, thaumasite formation results in severe weakening.

An illustration of how risk assessment approaches the presence of concrete deterioration / attack is shown in Figure 7.1 below.

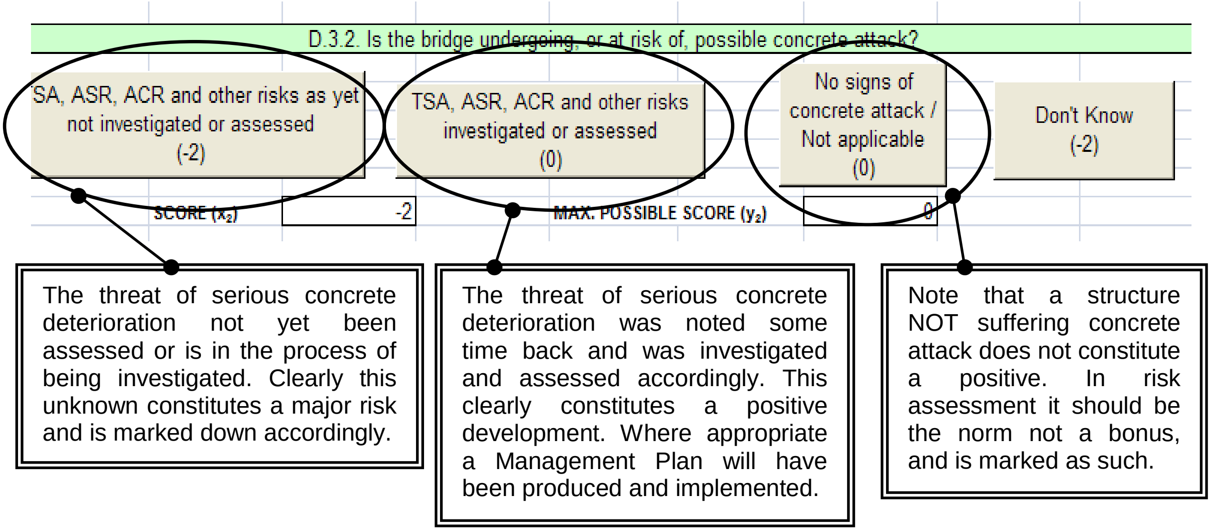


Figure 7.1 – Risk assessing concrete deterioration or attack

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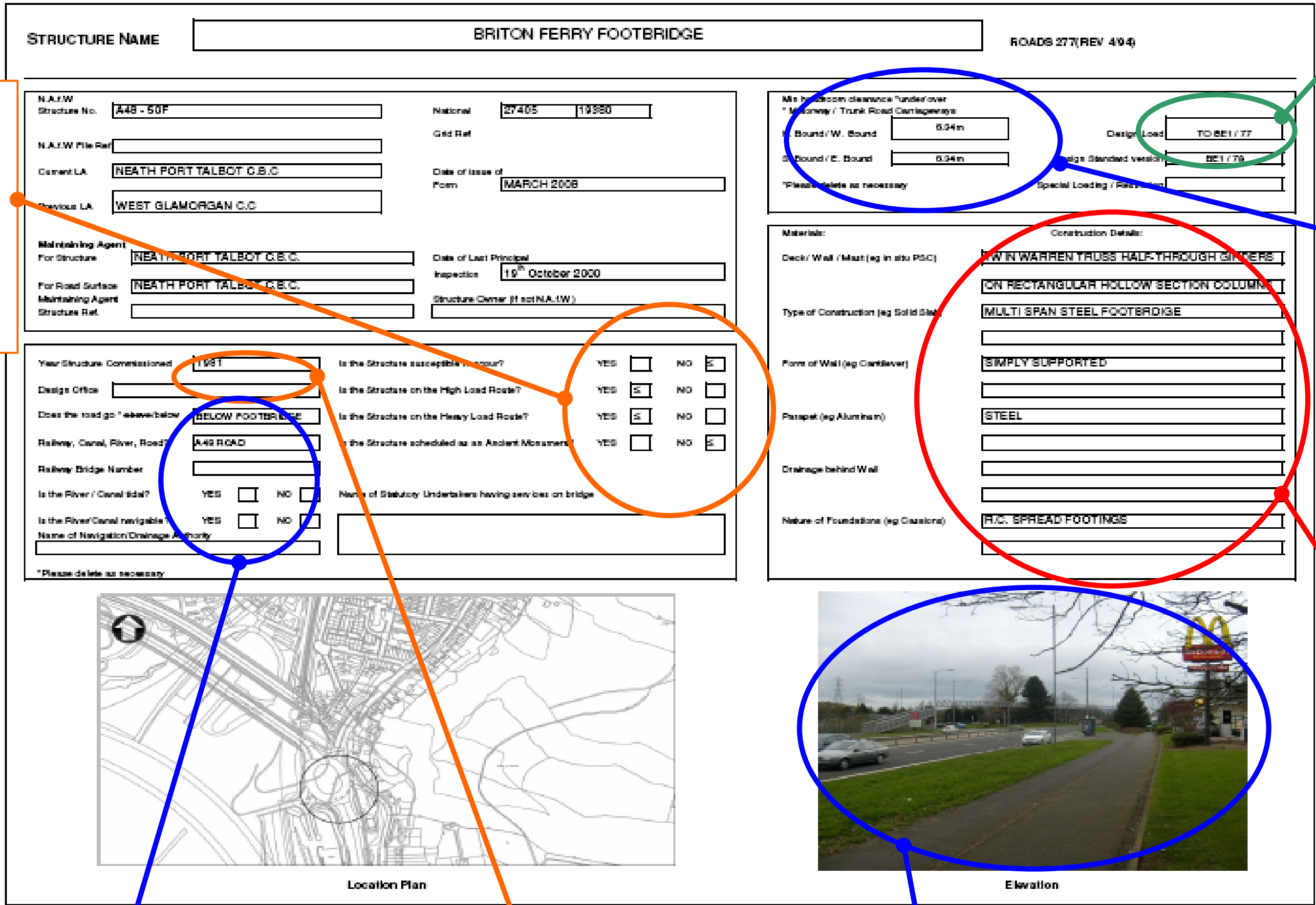
7.2 Using the Roads 277 – Footbridges / Gantries

D.4 USAGE DATA
D.4.1-What loading is typically applied to the bridge? The loading that the bridge has been designed for is shown here.

D.3 CONDITION DATA
D.3.3-Is the bridge susceptible to scour? This question is answered directly by the Roads 277 form in this section. Further advice on scour assessment can be found in BA 74/06



D.2 INSPECTION DATA
D.2.3-Was access for the General Inspection confined or difficult? D.2.4- What is the height beneath the bridge? Judgements concerning questions of how well a visual inspection could have been carried out can be made by looking at these details.

D.1 HISTORICAL DATA
D.1.1-What is the structural form of the bridge? D.1.2-What are its constituent materials? All of the answers to these questions posed by the risk assessment should be readily available here.

D.2 INSPECTION DATA
D.2.1-What does the bridge span? This gives details of what goes over or under the bridge.

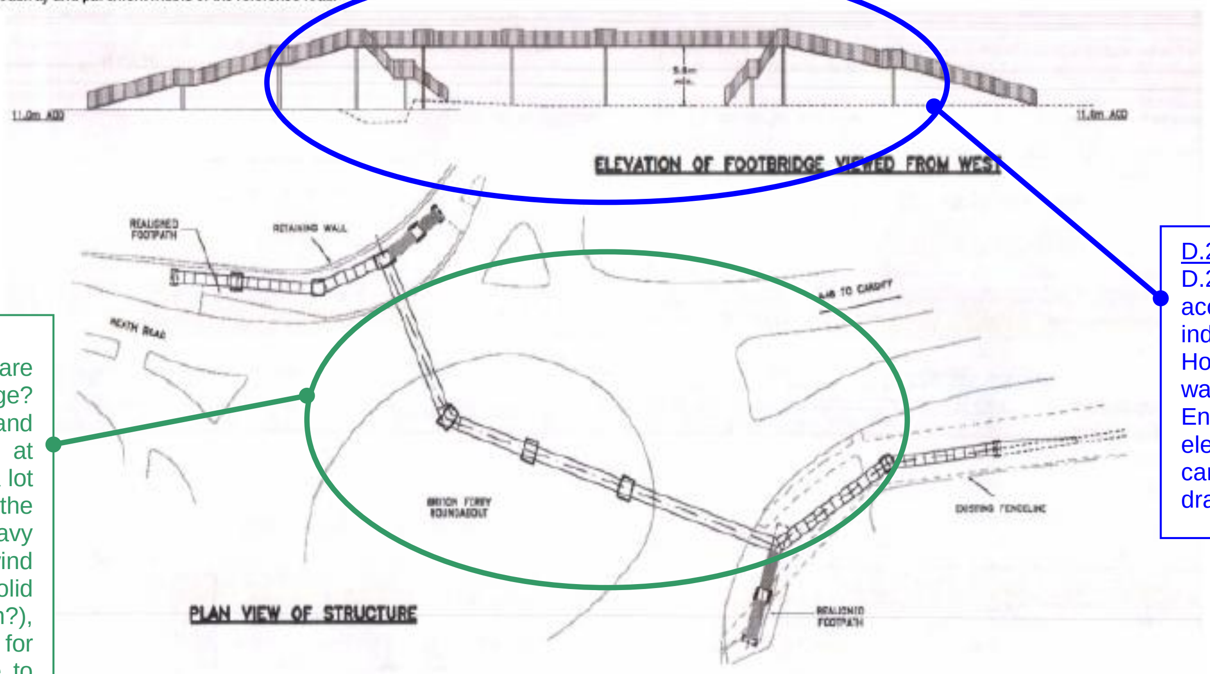
D.3 CONDITION DATA
D.3.6-What is the age of the bridge in relation to its design life? One can easily work out the age as it is given here. Design Life can vary but for a footbridge is typically 120 years.

D.2 INSPECTION DATA
D.2.3-What was visual accessibility to the bridge like? Look at the photograph-it is often obvious from this as to whether GI would have been difficult or straightforward.

Figure 7.2 - Using the Roads 277 to risk assess footbridges or gantries (Page 1 of 2)

Dimensional Elevation, Cross Section and Components of Structure.
Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road.

ROADS 277(REV 4/94)



D.2 INSPECTION DATA
D.2.5-What level of access is there to individual bridge spans? How difficult or easy it was for the Inspecting Engineer to view elements of the bridge can be seen from the drawings on the 277 form.

D.4 USAGE DATA
D.4.1-What loadings are put on the footbridge? Looking at the plan and elevation, looking at location etc can tell us a lot about whether the footbridge has heavy usage, is affected by wind (e.g. does it have solid elements in elevation?), was designed for equestrian us, or prone to vandalism?

BRIDGE No. A48 - 50F

	Manufacturer	Type
Prestressing System		
Paint System: Parapet		
External		

	Manufacturer	Type	Position
Joints*			
Parapets			
Waterproofing			

*Indicate on sketch above

Figure 7.3 - Using the Roads 277 to risk assess footbridges or gantries (Page 2 of 2)

7.3 Using the BE 11/94 – Footbridges / Gantries

BE 11/94

TRUNK ROAD / MOTORWAY STRUCTURE INSPECTION REPORT

Structure No.	A 4 8 - 5 0 F	Agent Code	0 0 1 1
Agent Name	South Wales Trunk Road Agency	Grid Ref	2 7 4 0 5 1 9 3 8 0
Structure Name	Briton Ferry Footbridge	From Span	-
		To span	-
Date of Inspection	13th February 2006	Type of Inspection*	G [ ] P [√] S [ ]
Inspected by	Mott MacDonald	Overall Assessment*	G [√] F [ ] P [ ]

*Please Tick

Defect Assessment	Estimated Cost(£)	Extent	Severity	Work	Priority	PD	Comments
1.Foundations		A	1	-	-		Small area of spalling
2.Inverts or Aprons	-	-	-	-	-		
3.Fenders	-	-	-	-	-		
4.Piers or columns	150	B	2	P	L		Areas of paint loss, corroded bolts
5.Abutments	-	-	-	-	-		
6.Wing Walls	-	-	-	-	-		
7.Retaining Walls or Revetments	-			-	-		
8.Approach Embankments	-	-	-	-	-		
9.Bearings	-	-	-	-	-		
10.Main Beams / Tunnel Portals / Mast	-	-	-	-	-		
11. Transverse Beams / Catenary Cables	-	-	-	-	-		
12. Diaphragms or Bracings	250	B	2	P	L		Minor paint loss
13.Concrete Slab	-	-	-	-	-		
14.Metal Deck Plates / Tunnel Linings	-	A	1	-	-		

Please turn over

D.3 CONDITION DATA
D.3.1-What is the condition of the bridge, as noted by the General Inspection? Using a combination of the Engineer's overall assessment (Good, Fair or Poor) and other comments in the BE 11/94, a valuable picture of the bridge's condition can be formed and allow the questions posed by the Risk Assessment to be answered.

D.3 CONDITION DATA
D.3.2-Is the bridge undergoing suspected concrete attack? If it is, the evidence should be recorded on the BE 11/94. A competent Inspecting Engineer would certainly comment on the kind of damage caused by ASR or ACR if seen during the GI.

Figure 7.4 - Using the BE11 /94 to risk assess footbridges or gantries (Page 1 of 2)

BE 11/94

Defect Assessment (cont)	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
15. Jack Arches	-	-	-	-	-		
16. Arch Ring / Corrugated Metal	-	-	-	-	-		
17. Spandrels/Headwalls	-	-	-	-	-		
18. Tie Rods	-	-	-	-	-		
19. Drainage Systems	-	-	-	-	-		
20. Waterproofing	-	-	-	-	-		
21. Surfacing	100	B	2	R	L		Beginning to wear in places. Two instances of surface break down. Remove vegetatin
22. Service Ducts	-	-	-	-	-		
23. Expansion Joints	-	-	-	-	-		
24. Parapets / Handrails	550	B	3	R	M		Deformation of infill bar. minor paint loss
25. Access Gantries or Walkways	-	-	-	-	-		
26. Machinery	-	-	-	-	-		
32. Dry Stone Walls	-	-	-	-	-		
33. Troughing	-	-	-	-	-		

Reasons for Priority Allocation

24 - Re-alignment of deformed vertical infill bar will ensure safety of footbridge users - M
4, 12, 24 - Reapplication of protective paintwork will prolong life of structure - L
21 - Removal of vegetation will improve appearance of structure - L

Signed: S. Russell

Name: Stuart W Russell

Date: 13th February 2008

D.3 CONDITION DATA
D.3.1-What is the condition of the bridge, as noted by the General Inspection? Additional information on the general condition of the footbridge can be found here.

Figure 7.5 - Using the BE11 /94 to risk assess footbridges or gantries (Page 2 of 2)

8. Retaining walls

8.1 Retaining Walls Questionnaire

Having gathered all available information for a retaining wall, completing the risk assessment should be straightforward. In all cases, the BE 11/94 and Roads 277 Form should be a necessary part of the information requested.

8.1.1 Using the *Structural Assessment Report* – Retaining Walls

Structural assessments of retaining walls will often be qualititative, due to much of the structure being buried and a lack of as-built information. Figure 8.1 explains the risk assessment options.

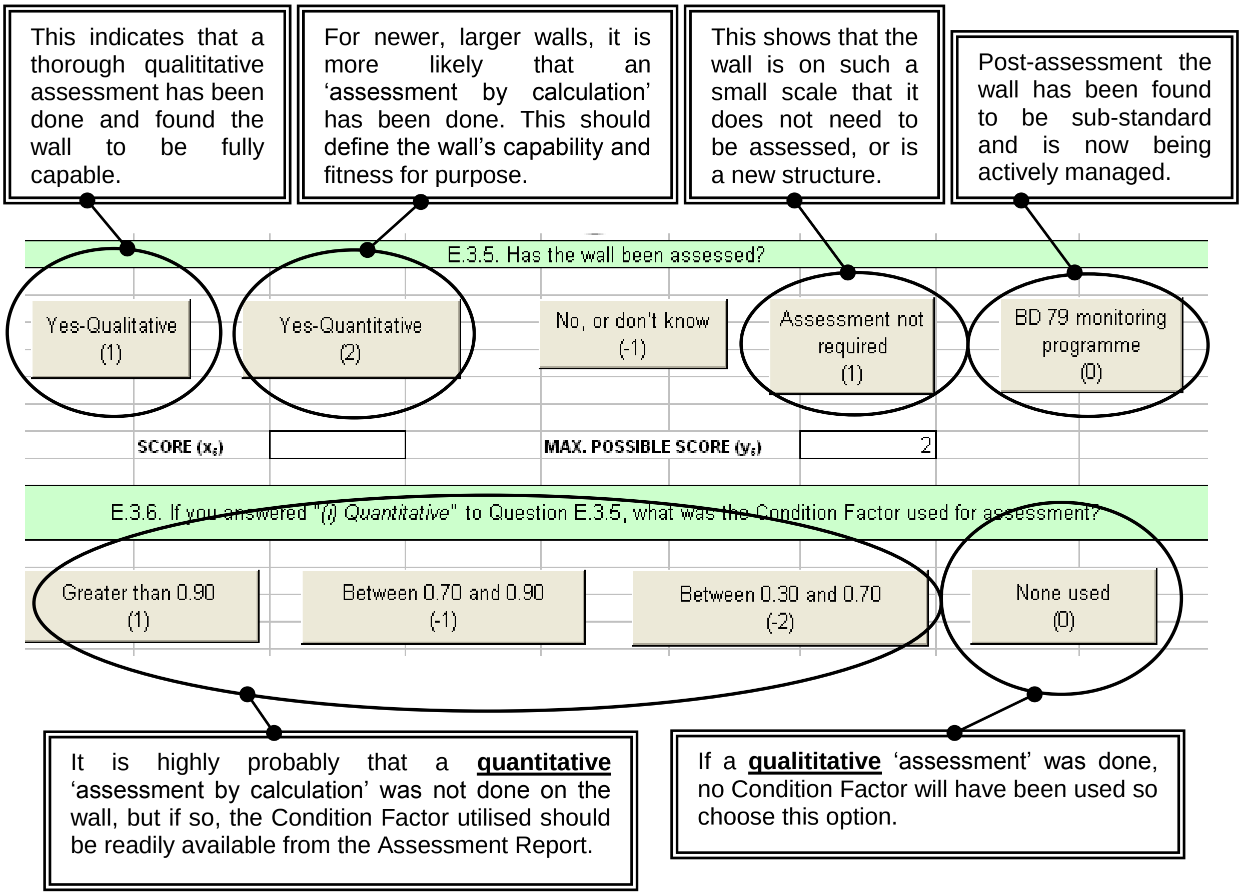


Figure 8.1 Risk assessing a Structural Assessment Report - Retaining wall

8.1.2 Risk assessing *Live Loading Conditions*

Transient live loads can affect retaining walls in different ways. The most obvious way is from HA live load surcharge transferring vertical and horizontal loads against the back of the wall through the retained soil. In the context of risk, however, there are other considerations, such as vehicular impact which need to be considered. When assessing this risk, a distinction is made as to what constitutes ‘close proximity’, a dimension relative to the size of structure. For the purposes of this risk assessment, a dimension of H/2 was chosen, where H is the total height of the wall being assessed (see Figure 8.2).

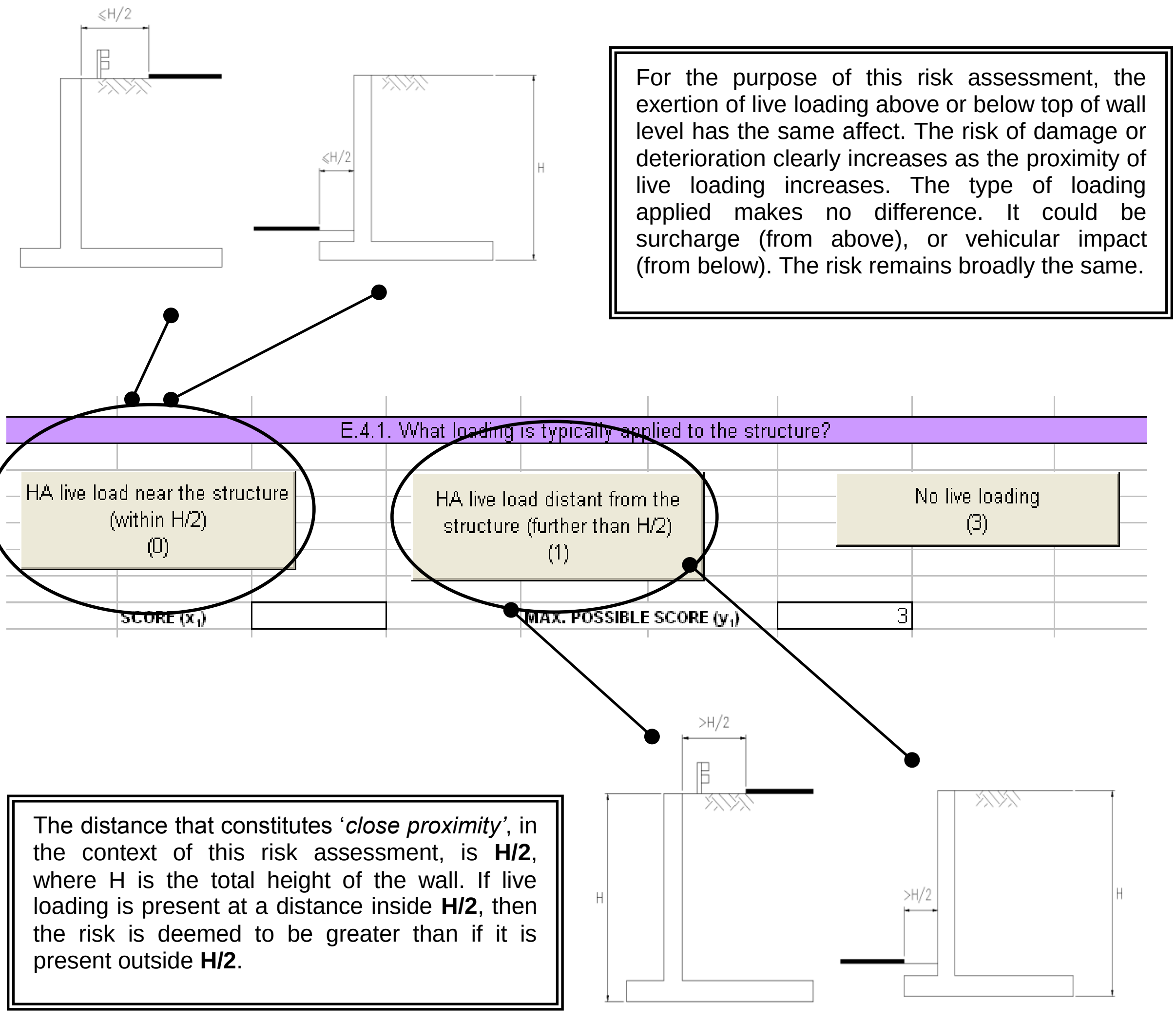


Figure 8.2 Risk assessing live loading affects - Retaining wall

8.1.3 Risk assessing Adjacent Land Properties

Adjacent land properties can be hugely influential in both the *likelihood* of deterioration and the *consequence* of failure. They affect risk both directly and indirectly. Indirectly, they can limit access and make it difficult to view the structure. This can compromise the quality of the inspection data obtained, and therefore the validity of the information being fed into the risk assessment. Directly, they influence risk by bringing *consequence* into the equation. The adjacent land property, to a large extent, determines what the consequence of failure is. Adding further to the equation is the ability of the adjacent land property to affect the *likelihood* of the structure deteriorating. The rationale behind the risk assessment, based on these influencing factors, is given below in Figure 8.3:

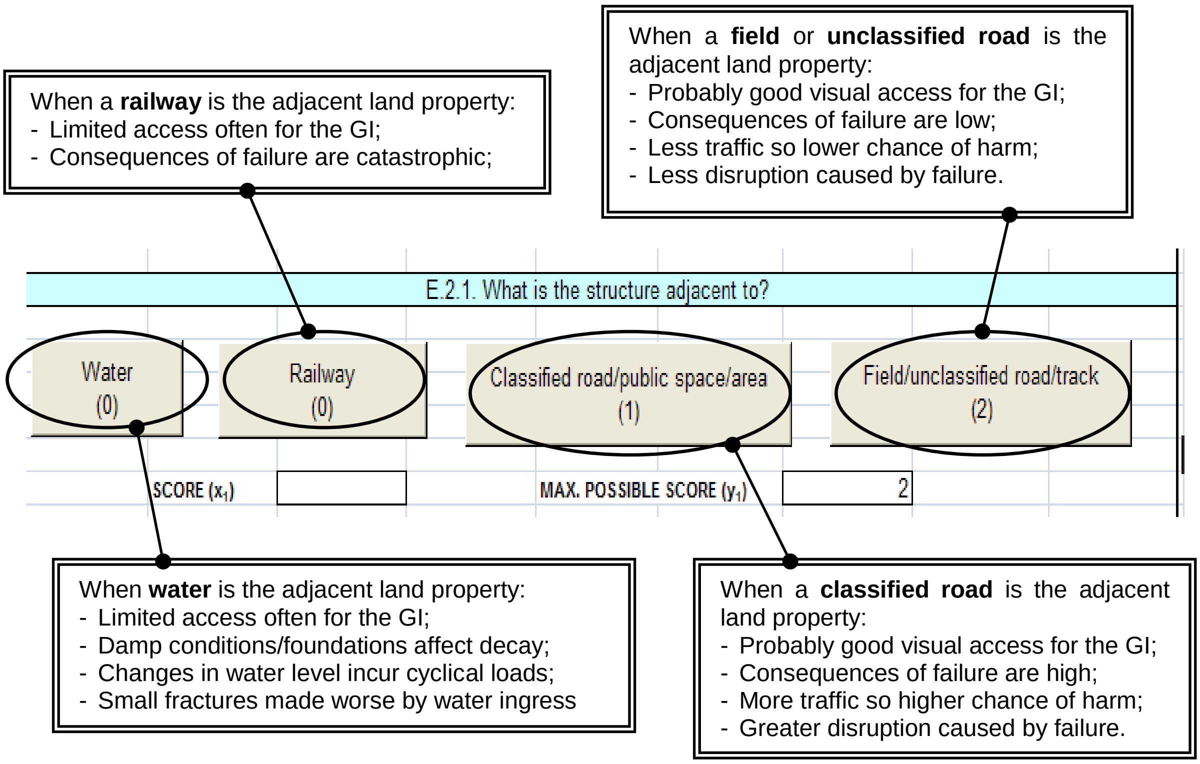
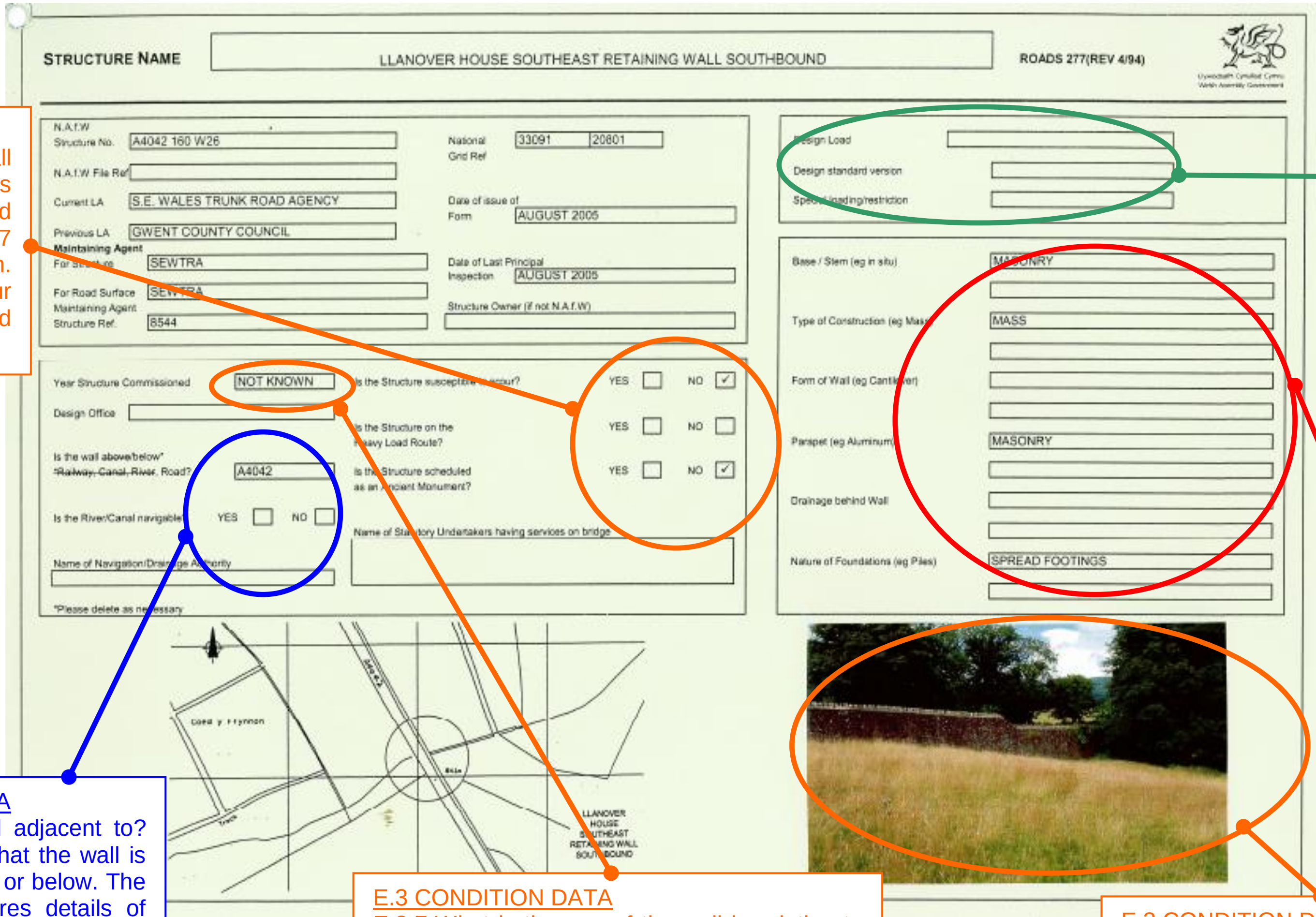


Figure 8.3 Risk assessing adjacent land properties - Retaining wall

8.2 Using the Roads 277 – Retaining Walls



STRUCTURE NAME: LLANOVER HOUSE SOUTHEAST RETAINING WALL SOUTHBOUND

ROADS 277(REV 4/94)

N.A.f.W Structure No.: A4042 160 W26
N.A.f.W File Ref:
Current LA: S.E. WALES TRUNK ROAD AGENCY
Previous LA: GWENT COUNTY COUNCIL
Maintaining Agent For Structure: SEWTRA
For Road Surface Maintaining Agent: SEWTRA
Structure Ref: 8544
National Grid Ref: 33091 20801
Date of issue of Form: AUGUST 2005
Date of Last Principal Inspection: AUGUST 2005
Structure Owner (if not N.A.f.W):

Design Load:
Design standard version:
Special loading/restriction:

Base / Stem (eg in situ): MASONRY
Type of Construction (eg Mass): MASS
Form of Wall (eg Cantilever):
Parapet (eg Aluminium): MASONRY
Drainage behind Wall:
Nature of Foundations (eg Piles): SPREAD FOOTINGS

Year Structure Commissioned: NOT KNOWN
Design Office:
Is the wall above/below* *Railway, Canal, River, Road?: A4042
Is the River/Canal navigable? YES ☐ NO ☐
Name of Navigation/Drainage Authority:
*Please delete as necessary
Is the Structure susceptible to scour? YES ☐ NO ☑
Is the Structure on the Heavy Load Route? YES ☐ NO ☐
Is the Structure scheduled as an Ancient Monument? YES ☐ NO ☑
Name of Statutory Undertakers having services on bridge:

E.3 CONDITION DATA
E.3.4-Is the wall susceptible to scour? This question is answered directly by the Roads 277 form in this section. Further advice on scour assessment can be found in BA 74/06

E.4 USAGE DATA
E.4.1-What loading is typically applied to the wall? For example, does HA live loading affect the wall in any way, and if so, is it in close proximity (i.e. within H/2) or is it not (i.e. further than H/2). See Section 7.2 for further details on this question.

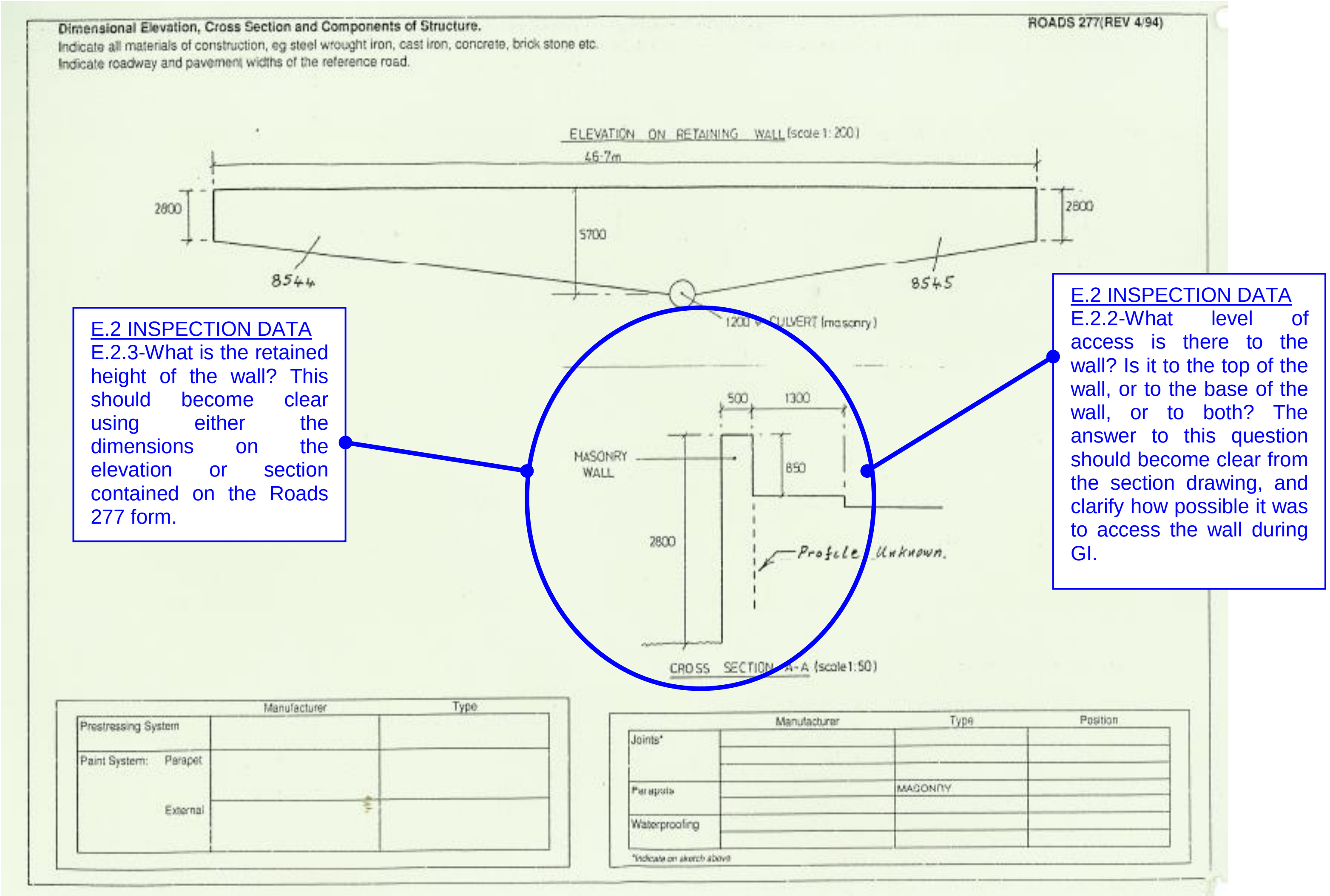
E.1 HISTORICAL DATA
E.1.1-What is the structural form of the wall? E.1.2-What are its constituent materials? All of the answers to these questions posed by the risk assessment should be readily available here.

E.2 INSPECTION DATA
E.2.1-What is the wall adjacent to? This gives details of what the wall is next to, whether above or below. The risk assessment requires details of what is at the base of the wall and whether the wall takes highway loading on top (e.g. water, road, field, and railway).

E.3 CONDITION DATA
E.3.7-What is the age of the wall in relation to its design life? This is often an unknown as walls will often be older than bridges, and have less background information. Choose the "don't know" option if that is the case

E.3 CONDITION DATA
E.3.3-What is the environment around the wall like? Is it wet or is it dry? Look at the photograph and the GI notes. From these a view on whether the wall is in a predominantly wet or dry environment can be taken.

Figure 8.4 - Using the Roads 277 to risk assess retaining walls (Page 1 of 2)



Dimensional Elevation, Cross Section and Components of Structure.
Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road.

ROADS 277(REV 4/94)

		Manufacturer	Type
Prestressing System			
Paint System:	Parapet		
	External		

	Manufacturer	Type	Position
Joints*			
Parapets		MASONRY	
Waterproofing			

*Indicate on sketch above

<u>E.2 INSPECTION DATA</u>
E.2.3-What is the retained height of the wall? This should become clear using either the dimensions on the elevation or section contained on the Roads 277 form.

<u>E.2 INSPECTION DATA</u>
E.2.2-What level of access is there to the wall? Is it to the top of the wall, or to the base of the wall, or to both? The answer to this question should become clear from the section drawing, and clarify how possible it was to access the wall during GI.

Figure 8.5 - Using the Roads 277 to risk assess retaining walls (Page 2 of 2)

8.3 Using the BE 11/94 – Retaining Walls

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Trunk Road / Motorway Structure Inspection Report **BE 11/94**

Structure No. A 4 0 4 2 1 6 0 W 2 6
Br. 8544
Agent Code
Agent Name SOUTH WALES TRUNK ROAD AGENCY
Grid Ref 3 3 0 9 1 2 0 8 6 1
Structure Name LLANOVER HOUSE RETAINING WALL SE SB
From Span
To Span
Date of Inspection 1 9 O C T 2 0 0 7
(eg 0 1 J U N 1 9 9 4)
Type of Inspection* G ✓ P S
Inspected By L Hiles
Overall Assessment* G ✓ F ✓ P
*Please tick

Defect Assessment	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
1. Foundation				B			
2. Inverts or Aprons		A	1				
3. Fenders / Safety Barriers							
4. Piers or Columns							
5. Abutments / Intermediate wall							
6. Wing Walls / Training walls							
7. Retaining Walls or Revetments	7500	C	3	R	M		Vegetation and small trees growing out of mortar joints. Loss of mortar to joints to top of wall. Displaced stone work. Cracking to concrete haunching.
8. Approach Embankments							
9. Bearings							
10. Main Beams / Tunnel Portals / Mast							
11. Transverse Beams / Catenary Cables							
12. Diaphragms or Bracings							
13. Concrete Slab							
14. Metal Deck Plates / Tunnel Linings							

E.3 CONDITION DATA
E.3.1-What is the condition of the wall, as noted by the General Inspection? Using a combination of the Engineer's overall assessment (Good, Fair or Poor) and other comments in the BE 11/94, a valuable picture of the wall's condition can be formed.- and allow the questions posed by the Risk Assessment to be answered.

E.3 CONDITION DATA
E.3.2-Is the wall undergoing suspected concrete attack? If it is, the evidence should be recorded on the BE 11/94. A competent Inspecting Engineer would certainly comment on the kind of damage caused by ASR or ACR if seen during the GI.

Figure 8.6 - Using the BE 11/94 to risk assess retaining walls (Page 1 of 2)

Defect Assessment (cont) **BE 11/94**

	Estimated Cost (£)	Extent	Severity	Work	Priority	PD	Comments
15. Jack arches							
16. Arch Ring / Corrugated Metal							
17. Spandrels							
18. Tie Rods							
19. Drainage Systems							
20. Waterproofing				B			
21. Surfacing		A	1				
22. Service Ducts							
23. Expansion Joints							
24. Parapets/Handrails/Timber fences	5000	C	3	R	M		West face: Loss of mortar to joints, hairline cracking. Parapet height at northern end of the wall is less than the standard minimum height (0.85 < 1m)
25. Access gantries or walkways							
26. Machinery							
32. Dry Stone Walls							
33. Troughing							

Reasons for priority allocation

7: Vegetation clearance, Concrete repairs, Re-pointing of masonry wall – Medium
24: Re-pointing of masonry wall, Safety of road users – Medium

Signed

Name L Hiles
Date 31/10/07

E.4. USAGE DATA
E.4.3-What is the Road Surface Category? If the wall could be affected by live loading being transferred through road surfacing (particularly if the wall is below road level and in close proximity to it) then the condition of the road needs to be considered for the risk assessment. The condition can also indicate settlement of the retaining wall backfill, indicating wash out or wall movement.

Figure 8.7 - Using the BE 11/94 to risk assess retaining walls (Page 2 of 2)

9. Technology Structures

Technology structures are primarily large independent variable message signs but would also include larger high mast lighting columns. Variable Message Signs (VMS) display information about traffic and accidents to road users on major road networks. Typically, they are modern structures located at key locations, such as major junctions and are used to help manage the network by providing information or advanced warning to drivers of emergencies and incidents. VMS have been an essential requirement to allow effective management and operation of the network. VMS make new initiatives such as Managed Motorways possible.

9.1 Risk assessing *Technology Structures*

Technology structures typically have little or no redundancy and little variation in structural form, constituent materials or consequence of failure means that the *Technology Structures* risk assessment has fewer factors than others with only six questions being used to gauge risk. Most of these answers should be available from the Roads 277 form, and the recent condition of the structure from the latest BE11/94 form.

The structural designs are often standardised with only occasional bespoke designs. Foundations can vary for a given superstructure. Foundations comprising traditional reinforced concrete piles or reinforced concrete spread footings have a proven track record. Other, newer foundation types have yet to be shown to be as robust. This is likely to change as more data becomes known.

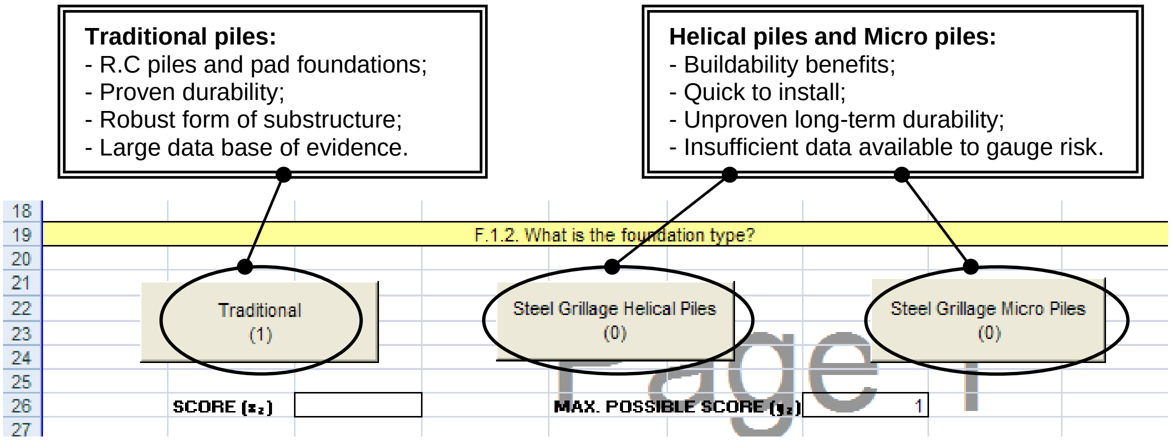


Figure 9.1 – Risk assessing various foundation types for Technology Structures

Unlike the other major structural types, technology structures have a shorter design life, often sixty years, or thirty. As a consequence, sections are often thinner. Loading on Technology Structures is primarily dead load and wind load. Large fluctuations of stress can be caused by wind from alternating directions. In addition to this, vibration of the structure can amplify the damage caused.

For a repeated standardised design, the lessons learnt from inspections can be applied to all similar structures. Areas where cracking has been found should be checked on all similar structures. On other structures, Principal Inspections should look at those areas where fatigue effects are more likely.

9.2 Using the Roads 277 Form – Technology Structures

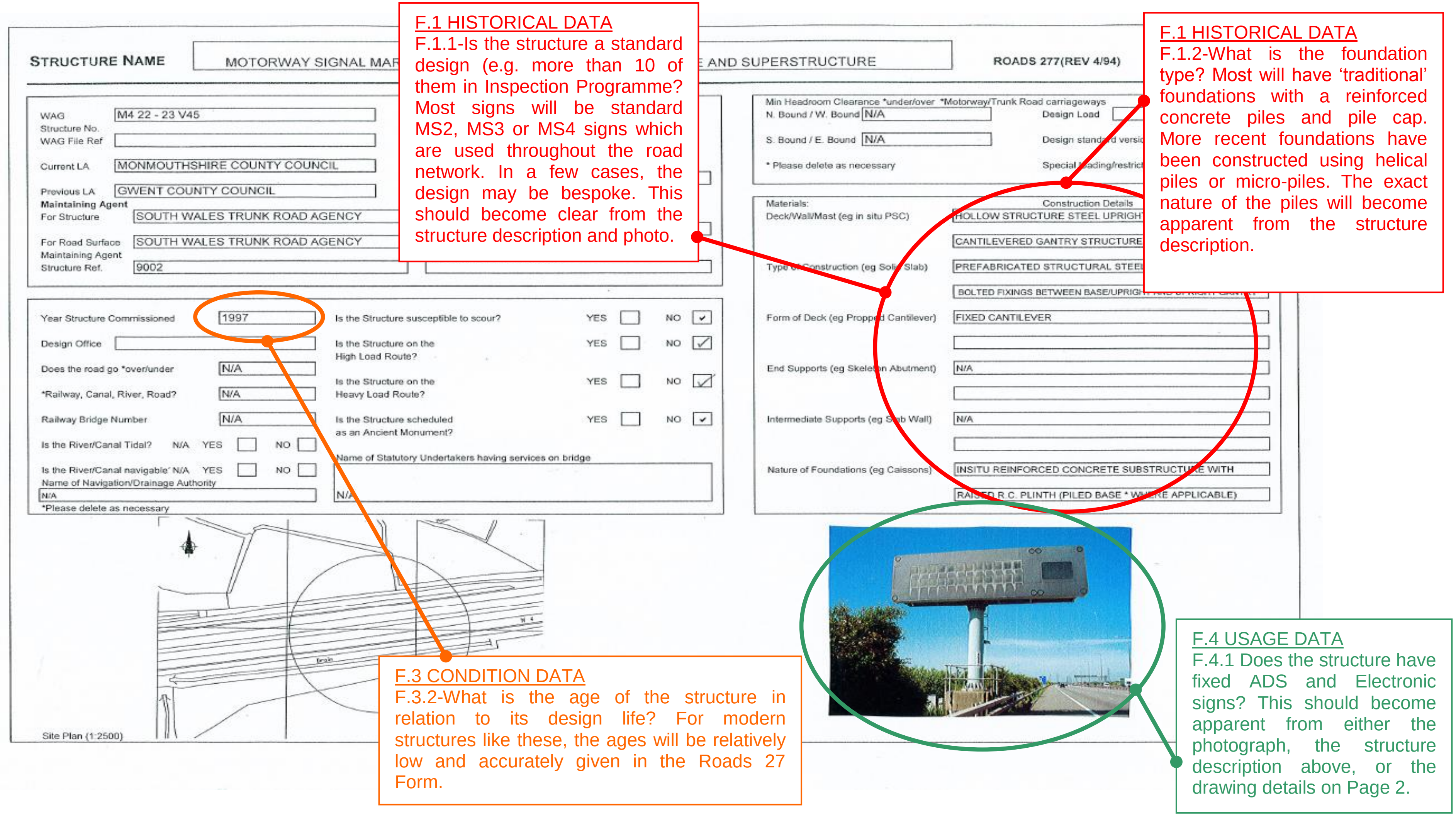


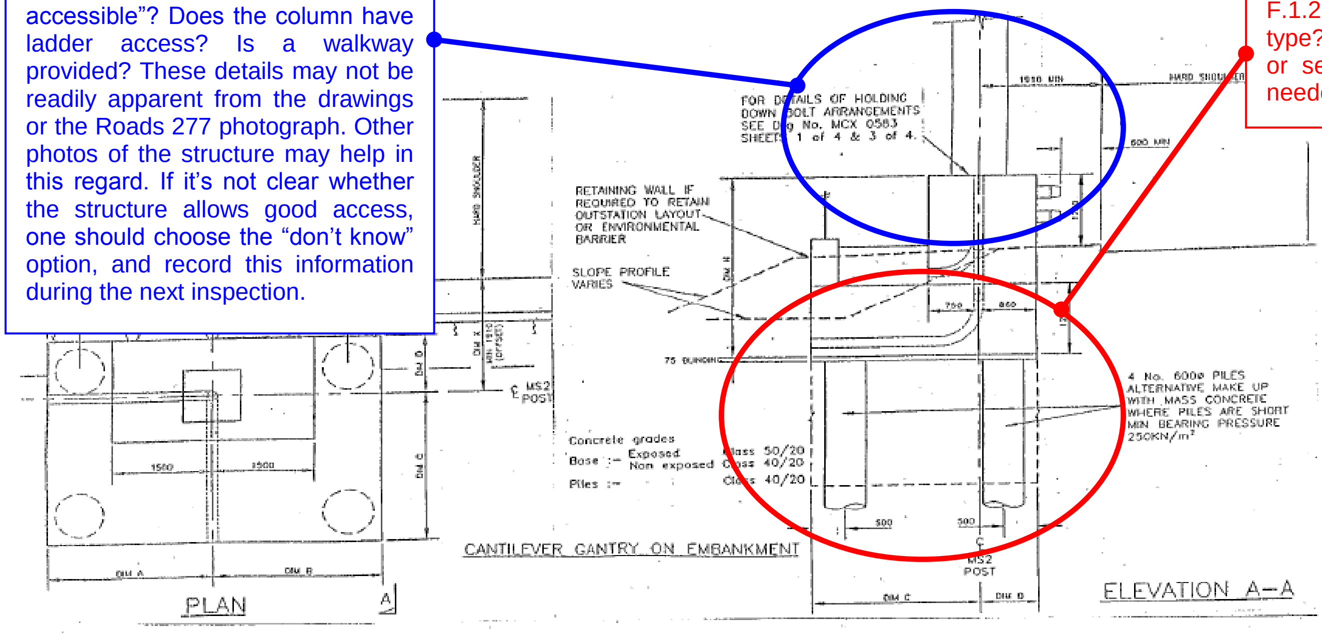
Figure 9.2 - Using the Roads 277 to risk assess technology structures (Page 1 of 2)

Dimensional Elevation, Cross Section and Components of Structure. ROADS 277(REV 4/94)

Indicate all materials of construction, eg steel wrought iron, cast iron, concrete, brick stone etc.
Indicate roadway and pavement widths of the reference road and also of the crossing road where appropriate (include spans)
Indicate type and position of bearings and joints.

F.2 INSPECTION DATA
F.2.1-Is the structure "man-accessible"? Does the column have ladder access? Is a walkway provided? These details may not be readily apparent from the drawings or the Roads 277 photograph. Other photos of the structure may help in this regard. If it's not clear whether the structure allows good access, one should choose the "don't know" option, and record this information during the next inspection.

F.1 HISTORICAL DATA
F.1.2-What is the foundation type? See the drawing elevation or section for further details if needed.



	Manufacturer	Type
Prestressing System		
Paint System: Parapet		
Internal		
External		

	Manufacturer	Type	Position
Bearings*			
Joints*			
Parapets			
Waterproofing			

*Indicate on sketch above

Figure 9.3 - Using the Roads 277 to risk assess technology structures (Page 2 of 2)

ATKINS

9.3 Using the BE 11/94 Form – Technology Structures

Llywodraeth Cynulliad Cymru
Welsh Assembly Government

Trunk Road / Motorway Structure Inspection Report **BE 11/94**

F.3 CONDITION DATA
F.3.1-What is the condition of the structure, as noted by the last General Inspection? Using a combination of the Engineer's overall assessment (Good, Fair or Poor) and other comments in the BE 11/94, a valuable picture of the structure condition can be formed.-and allow the questions posed by the Risk Assessment to be answered.

Structure No. 2 6 — Agent Code
Br. 8544
Agent Name NCY — Grid Ref 3 3 0 9 1 2 0 8 6 1
Structure Nam SE SB — From Span — To Span
Date of Inspe — Type of Inspection* G ✓ P S — Inspected By L Hiles
Overall Assessment* G ✓ F ✓ P — *Please tick

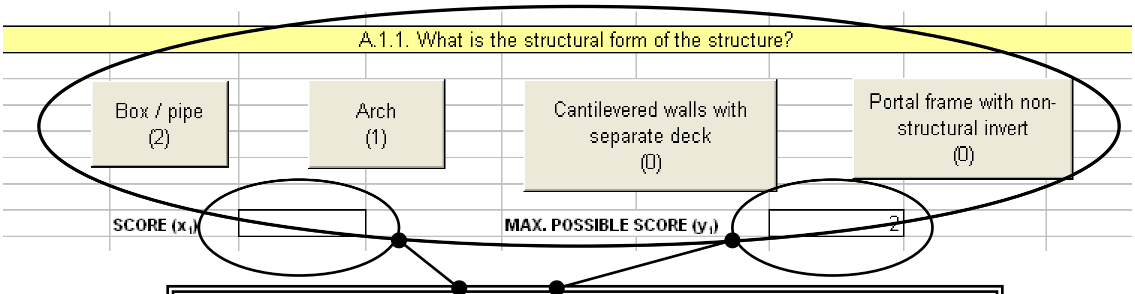
Defect Asses	ated (£)	Extent	Severity	Work	Priority	PD	Comments
1. Founda				B			
2. Inverts or Aprons		A	1				
3. Fenders / Safety Barriers							
4. Piers or Columns							
5. Abutments / Intermediate wall							
6. Wing Walls / Training walls							
7. Retaining Walls or Revetments	7500	C	3	R	M		Vegetation and small trees growing out of mortar joints. Loss of mortar to joints to top of wall. Displaced stone work. Cracking to concrete haunching.
8. Approach Embankments							
9. Bearings							
10. Main Beams / Tunnel Portals / Mast							
11. Transverse Beams / Catenary Cables							
12. Diaphragms or Bracings							
13. Concrete Slab							
14. Metal Deck Plates / Tunnel Linings							

Please turn over

Figure 9.4 - Using the BE 11/94 to risk assess technology structures

10. Scoring Risk

How does the scoring system work? Having chosen the appropriate solution for the structure a certain number of points will be scored, based on how positively, or negatively, that attribute influences the risk associated to the structure.



<u>EXAMPLE SCORING – Culvert</u>

If the culvert is a box, or pipe, it will score 2 points;
If the culvert is an arch, it will score 1 point;
If the culvert is any other form, it will score 0 points.

The % score taken forward measures the culvert score in comparison to the maximum available.

So, a box or pipe culvert will be given a 100% (i.e. 2 out of 2) mark
An arch will be given a 50% (i.e.1 out of 2) mark
Any other structural form will be given a 0% (i.e. 0 out of 2) mark.

HIGH % MARKS POSITIVELY INFLUENCE THE ASSESSMENT

Figure 10.1 –Risk assessment point-scoring methodology

11. Weighting Scores

Each risk assessment / questionnaire is divided into four main categories of question. These cover the four main categories of structural attributes which most heavily influence the likelihood for deterioration, and the consequence of failure. There are **Historical** questions, **Inspection** questions, **Condition** questions and **Usage** questions.

Each set of questions has different levels of importance. Accordingly, they are weighted in order of importance. The greater the influence the 'set' has on the risk assessment, the greater the weighting it is given. The weightings of all four 'sets' add up to 100 (i.e. the percentage total). For example, a culvert being risk assessed will be weighed as follows:

- **Historical** score – W = 25%
- **Inspection** score – W = 25%
- **Condition** score – W = 30%
- **Usage** score – W = 20%

The other structural types will have variations on these weightings, appropriate to them. In this case, points accumulated under **Condition** questions are given greater influence in the overall risk assessment than those accumulated for **Historical, Inspection data** and **Usage** questions.

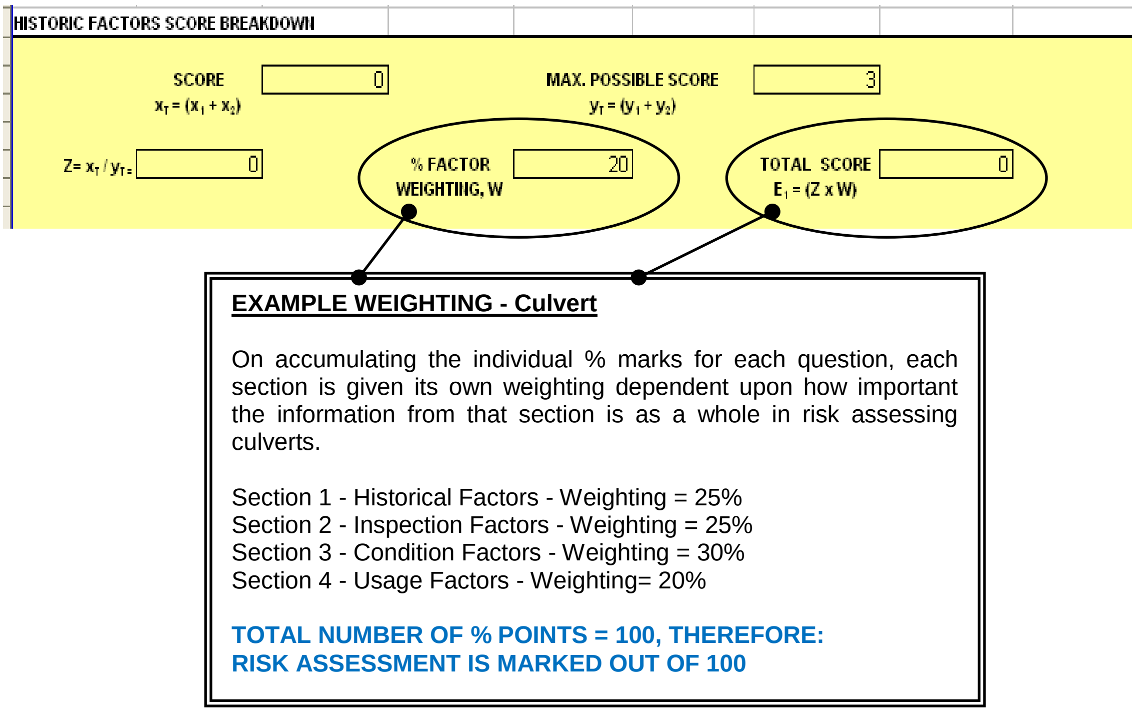


Figure 11.1 - Weighting the points accumulated in each category

12. Scoring Guideline

What do the scores mean in practical terms? Benchmarking undertaken by Atkins on a group of 75 structures in South Wales found that the aggregate scores from risk assessment could be categorised as shown in Figure 12.1 below. Structures on the M4, A470 and A465 were assessed independently by two different teams in Atkins and the results compared. These results were analysed by Atkins' engineers with over 50 years' experience of inspections. Cross-referencing risk assessment and engineering experience and knowledge, resulted in the classifications as detailed below in Figure 12.1.

Any structure scoring 20 or less should have its Principal Inspection interval kept at six years. Any structure scoring between 20 and 40 should be considered for an interval of eight years. Any structures scoring between 40 and 60 or 60 and above should be considered for an interval of 10 years and the maximum 12 years respectively.

Final Score	Recommended Principal Inspection Time Interval
< 20 %	**Maintain** at 6 years
20% < x > 40%	**Consider** increasing to 8 years
40% < x > 60%	**Consider** increasing to 10 years
> 60%	**Consider** increasing to 12 years

Figure 12.1 - Recommended Principal Inspection time interval guidelines

When completing the risk assessment, the scoring guidelines given in Figure 12.1 should be acknowledged as being just that: a *guideline*. These results are to guide and inform the engineer's judgement, not replace it.

info@atkinsglobal.com
www.atkinsglobal.com