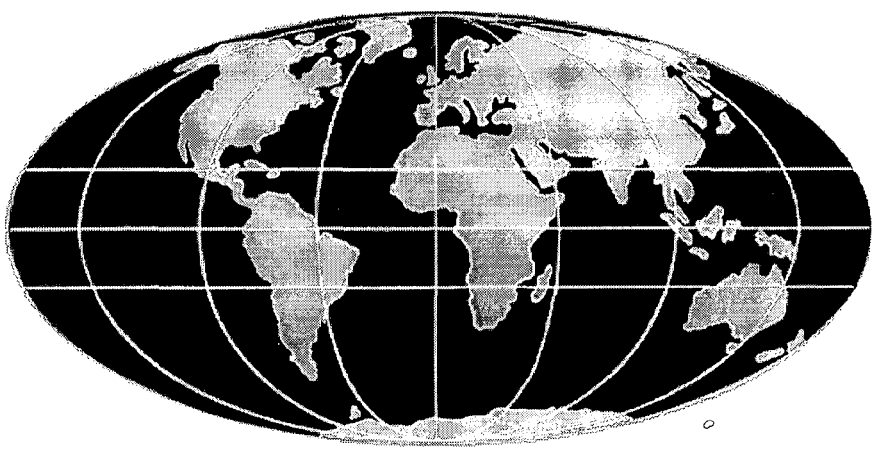
TRANSPORT RESEARCH LABORATORY

DFID Department For International Development

TITLE: A system of bridge inspection and data management in developing countries

by: J Parry



Overseas Centre
Transport Research Laboratory
Crowthorne
Berkshire RG45 6AU
United Kingdom

PA1222/90

Parry, J D, 1990. A system of bridge inspection and data management in developing countries. In: REAAA. Proceedings of the 6th Conference of REAAA. Kuala Lumpur 4 - 10 march 1990.

A SYSTEM OF BRIDGE INSPECTION AND DATA MANAGEMENT IN DEVELOPING COUNTRIES

BY

J D PARRY, Overseas Unit, TRRL

ABSTRACT

This paper describes a system of bridge inspection designed to assist a District Engineer, who may not be a bridge specialist but nevertheless has a number of structures in his charge. This situation has been shown to exist in developing and industrialised countries. Overseas Road Note 7, Volumes 1 and 2 (1988) describe the system and give guidance on the management of bridge inspection procedures, reports and other bridge data in the forms of the bridge inventory and drawings.

The main features of this publication are:

i. A manual for the engineer in charge,
ii. An instruction and reference book for technician inspectors and
iii. A comprehensive check-list to be used as the inspection report form.

The system was given field trials in several countries before publication, the most extensive being in Malaysia with the co-operation of Jabatan Kerja Raya.

INTRODUCTION

1 In most countries it is now well recognised by those involved with highways that timely, appropriate maintenance is cost effective, from the point of view of the maintenance organisation as well as that of the road user and the national economy. It is also clear that the maintenance problem is larger now than ever before, because of the large increase in the size of national networks over recent decades and because of deterioration due to age and wear. Good maintenance management is the aim of all highway departments but highway maintenance is universally under-financed and under-staffed.

2 In order to meet the demand for efficient use of maintenance resources, highway departments are now employing maintenance management systems of varying complexity, all claiming to improve the efficiency of the maintenance process, and all based on detailed inspection of the road network. However, these systems tend to concentrate on the road carriageway and give little or no attention to the structures, which form a small but none-the-less essential part of the network.

3 When road structures deteriorate, extensive sections of the road network may be affected by weight, height or width restrictions on vehicles, and road closure in cases of bridge failure. The result is a large and often

preventable expense to the road users and the highway department. The problem is extensive in both developing and industrialised countries.

4 It its fifth annual report to the US Congress, the Federal Highway Administration (1984) rated about 45 percent of the existing bridges in the United States as either functionally or structurally deficient.

5 It is a false economy to assume that bridges are in good condition until faults become apparent to the road user, because by then the damage may be extensive and difficult to repair. One of the main purposes of a regular bridge inspection system is to detect faults when they are still minor and relatively cheap to rectify.

6 This paper describes a system of bridge inspection and management of bridge data, which can be incorporated into a road maintenance management system, or operated by a highway department independently of any such system.

7 The efficient maintenance of roads and bridges alike is dependent on frequent inspections of the stock, and then interpretation of inspection data, followed by appropriate remedial treatment. In industrialised as well as developing countries there are rarely enough engineers to perform the first stage, i.e. bridge inspection. In practice the bridge engineers at highway department headquarters show little interest in maintenance and are too few to take on the task of regular inspection nationwide. The engineers responsible for highways in the separate districts are rarely experienced in bridges and either reluctant, or too busy, to inspect personally all the bridges in their charge.

8 There is, therefore, in many countries, a requirement that bridges should be inspected more frequently than at present.

TRRL OVERSEAS ROAD NOTE 7 (1988)

9 This is a further publication in the series of practical guides published by the Overseas Unit at the Transport and Road Research Laboratory in the UK, primarily for developing countries. It is entitled, "A Guide to Bridge Inspection and Data Systems for District Engineers." In this subject as in many others, there is no simple division between industrialised and developing countries, and although this guide was written primarily for the latter, it has been well received in the United States as well as in countries of varying development in Asia and Africa.

10 There are two fundamental problems addressed by ORN 7. The first is the organisation and use of the various bridge records and the second is the management of bridge inspection. This corresponds with the basic requirements for the maintenance management of any commodity, i.e. (1) a complete record of the stock and (2) regular bulletins of current condition.

Bridge Records

11 These are divided into four categories:

i. The bridge inventory.
ii. Drawings and calculations.
iii. Inspection reports.
iv. Maintenance records.

12 The guide recommends that the *Bridge Inventory* should take the form of one A3 size card for each bridge. A sample layout is shown in Figures 1 and 2.

13 As well as showing all the basic information about each bridge or culvert, the cards contain information used in the inspection process.

14 Two sides of an A3 size card provide sufficient space for photographs, location sketch, plan, elevation, and cross-section of the structure, construction drawing and calculation references and notes, as well as use restrictions which may be in force. It is recognised that such detailed information may not be available in all cases but the engineer is encouraged to obtain as much data as possible to enable him to assess the importance of faults subsequently recorded.

15 The guide contains a detailed description of each item of data on the bridge record card with recommendations for a bridge numbering system, based on route number and distance to the bridge from the road origin. Advice is given on methods which may be used to establish a new inventory.

16 It is rare that a full set of *Drawings and Calculations* is available for bridges more than a few years old. The types of drawings and calculations commonly found are described as:

i. Standard – drawings that may be suitable for a number of sites, without specific site details.

ii. Original design drawings not marked "as built." These will not include changes made during construction.

iii. As-built drawings. These will not record modifications made since construction, such as widening, strengthening, etc.

iv. As-built with all modifications shown and dated, with any calculations made in connection with the passage of unusual loads.

17 It is important that *Inspection Reports* should be clearly understood by all who refer to them. ORN 7 includes a standard format for an inspection form that covers all common types of bridge design and commonly used materials. It is simple to complete and to read, and allows for more detailed reporting in the form of further notes or sketches.

18 One advantage of using a standard format is that consecutive reports may be easily compared to detect small, progressive deterioration which can

N 3 / 125·3

BRIDGE NUMBER

BRIDGE NAME CLEANWATER CREEK

MAINTENANCE AUTHORITY P.W.D.

ROAD N3 (MALAN - GOROKAN SECTION)

KILOMETRE 31·7

MAP GOROKAN	REFERENCE 655470/139419
ROAD CLASSIFICATION NATIONAL HIGHWAY	OVER/UNDER CLEANWATER CREEK
LENGTH 28·7 m	NAVIGATION RESTRICTIONS NOT NAVIGABLE
WIDTH OF CARRIAGEWAY 7.5m	HEIGHT RESTRICTION NONE
LOAD RESTRICTION NONE	ABNORMAL VEHICLE A3 LOW LOADER + 60 TONNE

CONSTRUCTION DETAILS

SPAN(S)	14·0m, 14·0m
RUNNING SURFACE	CONCRETE
SUPERSTRUCTURE	COMPOSITE STEEL CONCRETE
PIER(S)	STEEL PILE, CONCRETE CAP
ABUTMENTS	CONCRETE BANK SEAT
FOUNDATION TYPE	PILED (PIER & ABUTMENTS)
MOVEMENT	FIXED AT ABUTMENTS, FREE AT PIER
SERVICES CARRIED	1 TELEPHONE CABLE
ROAD SIGNS	3 50 kph SIGNS

DESIGNED BY

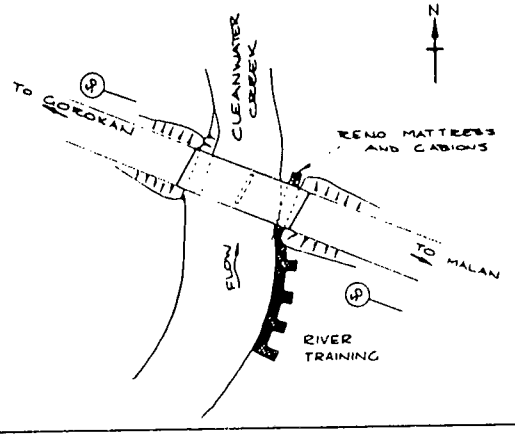
P.W.D.

CONSTRUCTED BY

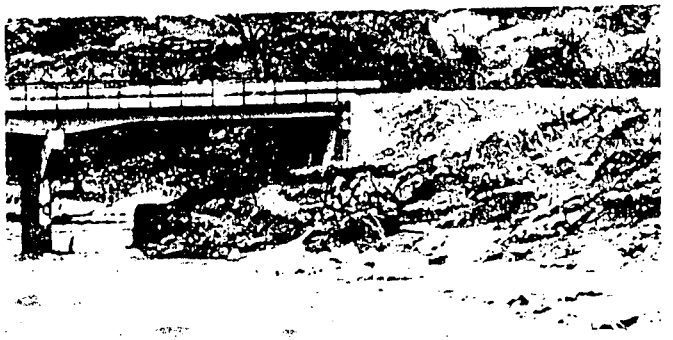
BAKER CONSTRUCTION

YEAR OF COMPLETION 1976

LOCATION PLAN



PHOTOGRAPHS



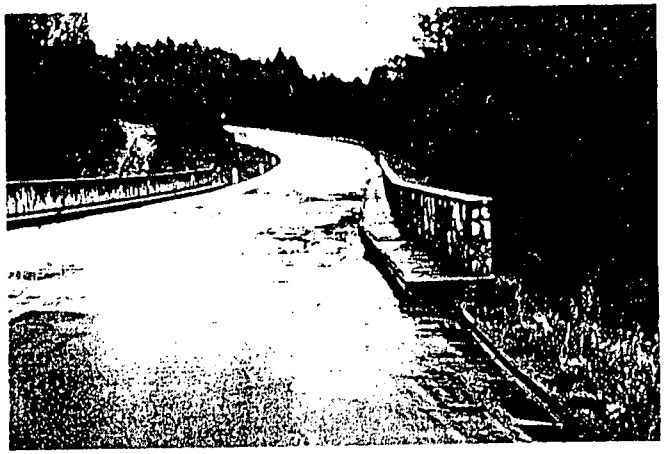


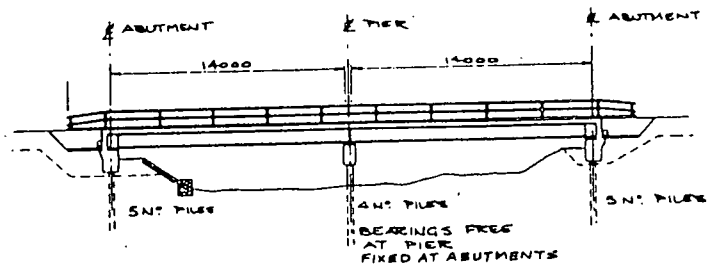
Fig.1 Bridge record card (side 1)

DRAWING NUMBERS AND CALCULATION REFERENCES	
CALCULATION FILE BE 45/74	
GENERAL ARRANGEMENT	DRG. No. B1/80712
ABUTMENT DETAILS Sheet 1	B1/80713
ABUTMENT DETAILS Sheet 2	B1/80714
PIER DETAILS	B1/80715
STEELWORK DETAILS	B1/80716
DECK DETAILS	B1/80717
WING WALL DETAILS	B1/80718
MISCELLANEOUS DETAILS	B1/80719

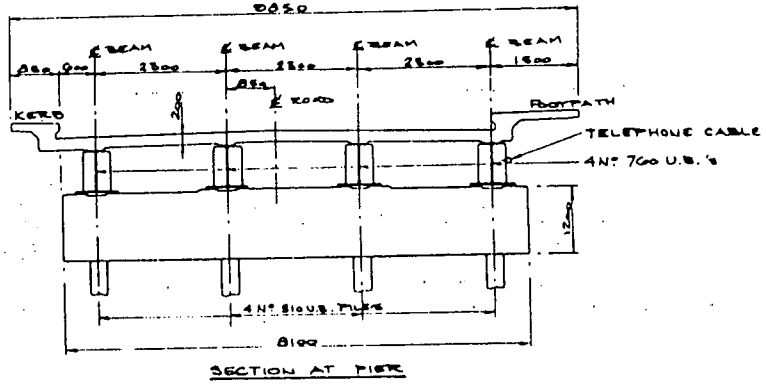
NOTES

INSPECTION REPORT PAGES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
NUMBER OF PAGES	1	1	1	1	1	1	2	0	2	2	0	0	2	0	2	1	1	1	0	

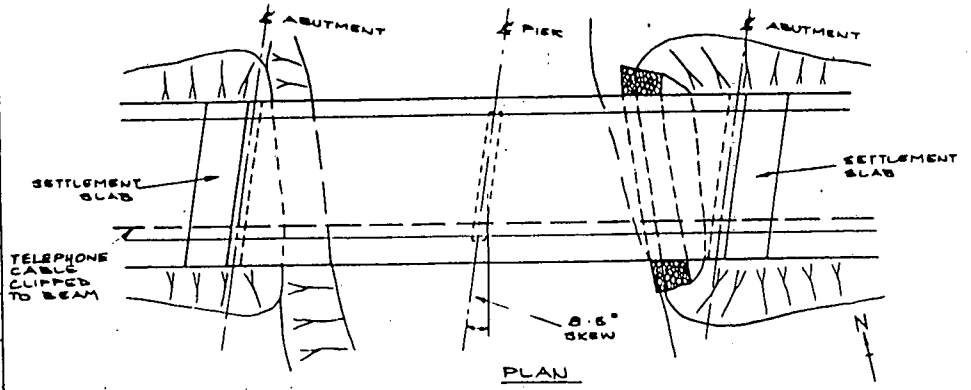
PLAN, ELEVATION AND CROSS SECTION



NORTH ELEVATION



SECTION AT PIER



PLAN

Fig.2 Bridge record card (side 2)

lead to serious problems if not remedied at an early stage. Maintenance may be commissioned using these reports and they are also consulted when preparing maintenance budgets for future years.

19 It is recommended that individual *Maintenance Records* are kept for each bridge. When repair works affect the structure significantly, these should be recorded on the bridge inventory card and also be copied to the headquarters bridge division.

Use of Computers

20 Bridge records are only partially suitable for recording on computer. Data most suitably recorded in the pictorial form are usually more efficiently stored as hard copy drawings or on micro-fiche. However, much of the information is in the numerical form and this is often useful to retrieve or process using a micro computer.

21 A bridge inventory may contain a large amount of data, and a variety of organisations may need information derived from it. Computers are a powerful tool for assisting in the handling of data. Proprietary database systems exist for most modern computers. Such a system could form the basis of a bridge record system but would still require additional software development. It must be stressed that all software development is both expensive and difficult.

22 The costs and benefits of implementing a computer-based system should be evaluated before its introduction. Proprietary systems, if available, are likely to provide the cheapest solution, but the assistance and advice of professional consultants should always be sought at a very early stage.

23 In planning such a bridge record system, it is necessary to decide which bridge data are to be included. Possible alternatives are:

i. The inventory only (bridge record cards).
ii. The inventory and inspection reports.
iii. The inventory, inspection reports and maintenance records.

24 The ultimate file sizes and software required should be estimated initially, to enable decisions concerning appropriate development and/or equipment to be made.

25 Two principal systems exist for computer equipment:

i. A central computer with links to district offices.
ii. A microcomputer at headquarters and in each district office.

26 A central computer is the best option in terms of general access to one central file. It resolves the problem of ensuring that all users are dealing with current and consistent data. Microcomputers, however, may be cheaper, and are less vulnerable to unreliable electricity supplies, telecommunications problems, and hardware failure.

The Inventory (Bridge Record Cards)

27 This is the simplest and possibly the most useful element of the bridge records to record on computer. An inventory data base has a wide variety of potential users with widely different requirements. Some examples of queries received from users might be:

i. 'List all bridges with load limits less than 10T.'

ii. 'List all bridges on the N23 road which are too narrow for a 4.5 metre wide load.'

iii. 'List all bridges in the National Park.'

iv. 'List all bridges under the control of the 'Ilam' maintenance authority.'

v. 'List all bridges built by 'Barton Construction' between 1970 and 1976.'

vi. 'List all bridges in an area bounded by the following map references.'

Inspection Reports and Maintenance Records

28 If inspection and maintenance data are computerised, it will still be necessary to keep copies of inspection and maintenance reports. Some of the data on these reports cannot readily be computerised (sketch maps, references etc.) These systems have a narrower application than the basic bridge record system, as the data are concerned mostly with maintenance. The system could provide the basis for a series of regularly updated reports, which would be a valuable management tool for the district engineer. Reports could include:

i. Regular summaries of urgent work highlighted by inspections.

ii. Summaries, defect by defect, which may highlight incorrect mainten-ance techniques, inappropriate materials, etc.

iii. A maintenance diary of work needed and work carried out, listing for example, bridges inspected this month, bridges to be inspected next month, etc.

iv. Work schedules for different gangs, provided either on an area by area basis, or a work type by work type basis.

29 The inspection report form, shown as Appendix C in Overseas Road Note 7 Part 1 (1988) was designed so that the inspection data may be easily transfered onto a computer disc.

Handbook page (2)	ABUTMENT, WING WALLS AND RETAINING WALLS ABUTMENT NAME: Malan POSSIBLE PROBLEM	Problem: No	Problem: Yes	How bad ?: Not very bad	How bad ?: Bad	How bad ?: Very serious	How much ?: Not much	How much ?: Some	How much ?: A lot	Note or sketch reference
	82 ABUTMENT, WING WALLS AND RETAINING WALLS									
	82 GENERAL									
	Erosion or scour near abutment ?		✓			✓			✓	See note 1
	Damage to caissons or piles ?	✓								
	Movement of abutment ?	✓								
	Debris against abutment ?	✓								
	Vegetation growing on or in abutment ?	✓								
	Scour near to retaining walls ?									
	Movement of retaining walls ?									
	Water leaking down through the expansion joint ?	✓								
	87 DRAINAGE SYSTEM									
	Not enough weepholes ?	✓								
	Weepholes not working ?		✓	✓			✓			Only downriver weepholes working.
	Water leaking through the abutment ?	✓								
	89 CONCRETE ABUTMENTS, WING WALLS AND RETAINING WALLS									
	Cracking ?	✓								
	Spalling ?	✓								
	Corrosion of reinforcement ?	✓								
	Poor concrete ?	✓								

All checked: Yes ✓ No

Fig.3 Inspection report form, Page 13

Computer Field Recording

30 Microcomputer-based data loggers are not recommended for bridge inspection. When an inventory is very well established and all inspectors are very familiar with its operation, it is possible that such a system could be considered, provided suitable training is available and equipment can be maintained. Even then, such a system could not fully replace the manual one recommended here.

BRIDGE INSPECTION

31 There are may text books and manuals available written for bridge engineers, that give excellent guidance on bridge inspection. This guide, although it contains parts that will be of interest to bridge specialists, is written specifically for highway engineers who are not bridge specialists, but nevertheless have responsibility for a number of road structures.

32 Four types of inspection are identified:

i. Informal
ii. General
iii. Major
iv. Special

33 The *Informal inspections* are performed when highways staff cross a bridge and take a cursory look at the structure. No expense is involved, but defects may be detected long before a general inspection becomes due. Road foremen etc. should be encouraged to make brief examinations of bridges they cross, particularly the more remote ones that the district engineer is unlikely to see.

34 The *General inspection* should take place regularly and at least once a year on every bridge. It should include the structure, road approaches and river bed, and is demanding in inspection time.

35 The *Major inspection* takes place every five to ten years according to type of structure, and concerns a detailed examination by a bridge specialist.

36 *Special inspections* are commissioned because of unusual circumstances, such as a recent overload or a flood-damaged bridge carrying restricted traffic. The frequency and extent of these inspections vary greatly according to the need.

37 The check list is intended to ease the task of bridge inspection for the engineer responsible, and it is recommended that the general inspection should be performed by an engineer whenever possible, but there are not always enough engineers for this work. Where this situation exists, the engineer in charge has two alternatives open:

i. his bridges are inspected only infrequently or
ii. the bridges are inspected by inspectors who are not engineers.

38 The requirement for engineers to inspect bridges regularly can be re-written in two parts:

i. The requirement for regular, frequent inspections.
ii. An engineer's assessment of bridge defects.

39 By careful reading of inspection reports prepared by others and comparing them with previous ones, a district engineer should be able to decide which bridges require his personal attention and *visit only those*. Further, he will be *motivated to leave his office* and go to such bridges, when he sees a report that suggests that they have problems. The advantages of this system are clear:

i. A saving of engineering time.

ii. Motivation for an engineer to examine damaged bridges that he might otherwise neglect.

40 Should this alternative system of inspection be adopted, it is important that the following restrictions be observed:

i. The engineer must remain in control and retain responsibility, as before.

ii. He must select suitable inspectors from among his staff.

iii. He must train these inspectors or arrange training for them at a ministry school.

iv. Routine annual inspections may be carried out in this way – not major or special inspections.

v. Only small and medium size bridges of common construction should be inspected by non-engineers. This will, however, include most or all the bridges that are the responsibility of a district engineer.

vi. The engineer must examine and retain all the reports submitted to him and act upon any suggestion of structural defect in a report. Routine or minor works may be commissioned without his personal attendance, such as clearing debris, parapet repairs, etc.

vii. It is helpful if the first report on each bridge is completed by the engineer and his inspectors together, so that the inspectors can learn how the engineer classes the defects and the engineer has personal experience of each bridge that will be reported on.

THE BRIDGE INSPECTOR'S HANDBOOK (ORN 7 VOL 2)

41 This 250 page book was written specifically for technician grade inspectors or junior engineers, who may have a limited command of English as a second language. For this reason, vocabulary and sentence construction have been kept as simple as was possible, for a technical subject, and maximum use has been made of photographs, line drawings and water-colours to illustrate the functions of bridge components and defects that should be reported.

42 It was considered that a technician or junior engineer, who has no previous experience of bridge inspection, requires help in three possible ways:

i. Training in bridge materials, basic design and modes of failure,

ii. A simple but comprehensive check list to lead him through the entire inspection process and

iii. A reference book, for help when he is not sure how to report a fault or make a measurement.

43 The handbook is in two Parts. Part 1 acts as a basic text book and may be used for private study or as a classroom aid for more formal tuition. Types and parts of bridges are described and illustrated here, movement and problems at bearings are explained, damage by water below and on the deck is shown with methods of protection, and bridge materials are described with their susceptibilities.

44 The inspection report form which is described in detail below, presents a series of questions and Part 2 of the Bridge Inspector's Handbook follows the sequence of this form, offering guidance and comment on each question with an instruction or illustration of the problem. Because this part of the Handbook follows the report form exactly, a completed report is included in Appendix D as an example to the inspector and to serve as an index. Column 1 of the form contains the relevant page numbers in Part 2 of the book for help in answering each question on the form. Other appendices cover safety during bridge inspections, a list of inspection equipment and a list of technical words used, simply defined.

45 The Bridge Inspector's Handbook is published as Volume 2 of Overseas Road Note 7 (1988).

THE BRIDGE INSPECTION REPORT FORM

46 The purpose of this report from is to lead an inspector through a thorough examination of any small to medium sized bridge of normal construction and to record in a clearly read manner all defects that the inspector may find. It has been designed for use by technician inspectors, with simple three-grade categories of severity and extent of defects, but it can also be used by engineers of experience to record problems in a way that facilitates data retrieval and comparison of reports from previous inspections and from other similar structures.

47 Page 1 of the form contains basic data about the bridge copied from the bridge inventory in order to identify the one to be inspected; a sketch to be completed by the inspector showing any piers, river works, etc; a place for instructions from the engineer in charge to the inspector and space for urgent comments from the inspector to the engineer. Page 2 is concerned with basic dimensions for checking and services carried by the bridge.

48 The main body of the form should contain only those pages appropriate to the structure to be inspected, in terms of materials and design, eg. two concrete piers with steel girder and concrete deck. It is suggested that the page numbers and the number required of each page should be listed on the Bridge Record Card at the bottom of side 2 (Figure 2.) Using these pages, an inspector is led through a logical sequence covering the whole task, starting with the road approaches and signs; the deck surface, drainage; underside of the deck, bearings, abutments, piers, retaining walls; the river bed and river training works. Bailey bridges and masonry arches have separate sections.

49 A typical page from the main part of the report form is shown as Figure 3. On this page the inspector is required to identify the abutment, usually with a name or compass point, and then consider each question in turn. After each question he must tick YES or NO stating if a problem exists, then how bad the problem is and how much there is.

50 The first question on this page is, "Erosion or scour near the abutment?" The inspector has answered with a tick, "Yes, there is a problem." He has decided under the "How bad?" to tick "Very Serious", and under "How much", "A lot." He has also written a note on a separate sheet, which may comment on loss of gabions or include a relevant sketch.

51 Under the heading 'Concrete Abutments' near the bottom of the page, the first question is "Cracking?" If he is not sure how to answer this question the inspector can refer to the relevant page for guidance, which is shown to be page 89 in Part 2 of the Handbook. This is reproduced as Figure 4. Here the inspector can find instructions on what to report and an illustration of a crack in a place considered to be important.

52 It is essential that the engineer should know that all parts of the bridge have been examined so at the end of each section is the question, "All Checked? YES or NO." If the inspector has been prevented from examining any part of the structure, he is expected to tick the NO box and write a brief note to say why. The engineer can then send him back with appropriate equipment, such as a boat, to complete the inspection.

53 When all the relevant pages have been completed, the inspector should collect them together with any additional notes and sketches, write the number of sheets on page 1, fill in any special remarks, then sign and date the report. It should then be returned to the engineer in charge without delay.

54 If the engineer in charge reads the reports as they come in and demonstrates respect for them, the morale of the inspectors is kept high and the quality of their work benefits accordingly.

CONCRETE ABUTMENTS, WING WALLS AND RETAINING WALLS

CHECK for cracking of the concrete. Make a sketch showing where important cracks are. Show only those cracks which are wider than 1 mm or those where water has come through.
Look carefully for cracks:

- in pilecaps.
- where wing walls connect to the abutment.
- around parapet posts.
- near bearings even thin cracks can be important, so draw all cracks near bearings.

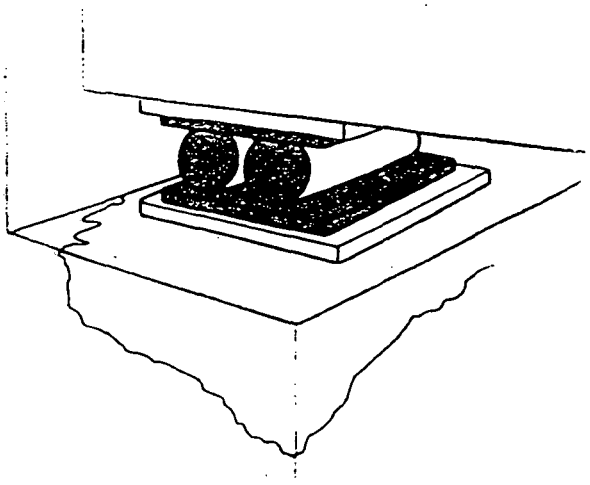


Fig.4 Bridge Inspectors Handbook, Page (2) 89

CONCLUSIONS

55 As with road pavements, the management of road structures requires:

i. A complete record of the stock.
ii. Regularly updated reports on stock condition.

56 The inspection and data management system presented in Overseas Road Note 7 is designed for use by a highway engineer, who has in his charge a number of structures and insufficient specialist engineers to inspect them. It gives guidance on the management of bridge records and practical help with bridge inspection. Volume 1 of the publication is addressed to District Engineers and includes a comprehensive inspection check list. Volume 2 is written for technicians, who have only a limited command of English, the first part being for instruction on bridges and the second part for reference until familiarity is achieved with the inspection process.

57 This system has been adopted in whole or in part by a number of highway authorities and parts are currently being translated into two further languages.

ACKNOWLEDGEMENTS

58 ORN 7 is based on a draft commissioned from Rendell, Palmer and Tritton, consulting engineers in the U.K. The main writer and collaborator during the field trials in Malaysia was Mr R Blakelock.

59 Further tribute must be paid to the late Mr D M Brooks, who as Head of the Overseas Unit's Pavement Management Section, was largely responsible for initiating the work and contributed so much to its successful completion before his untimely death.

60 This paper is published with the permission of the Director of TRRL, Mr D F Cornelius.

REFERENCES

1. FEDERAL HIGHWAY ADMINISTRATION, 1984. Fifth annual report to congress: Highway bridge replacement program. Washington DC: US Department of Transportation.

2. TRRL Overseas Unit, 1988. Vol 1 A Guide to Bridge Inspection and Data Systems for District Engineers, Vol 2 Bridge Inspectors Hand-book. *Overseas Road Note 7*. Crowthorne: Transport and Road Research Laboratory.