Bridge Inspection in Developing Countries

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The United Kingdom Transport and Road Research Laboratory is publishing a two-part guide to bridge inspections. The guide is intended for use in developing countries and provides advice to a district engineer on organizing bridge inspection and record systems, and detailed technical advice to an inspector on the defects he may find while inspecting bridges. A description is provided of the development of the two-part guide, with particular emphasis on the care taken with the communication aspects of the guides. The problems of bridge inspection in developing countries are discussed. The particular need to overcome the shortage of trained engineers is considered and a solution is proposed in which road foremen and other personnel can be trained to perform the majority of inspection work, which would allow the engineers to concentrate on those bridges that require inspection by a specialist. Part One, "A Guide to Bridge Inspection for District Engineers," provides guidance not only on bridge inspection but on record systems; the use of inspection reports in organizing maintenance, rehabilitation, and reconstruction programs; and the preparation and use of a bridge inventory. Part Two, the "Bridge Inspector's Handbook," is a pocket-sized book designed to provide detailed defect-by-defect advice to a bridge inspector. It is presented in such a manner that a road foreman or technician in a developing country who is able to read some basic English should be able to understand.

Large and small bridges form a vital part of a nation's road network. Few people would argue against the need for adequate maintenance, yet bridge maintenance rarely receives the attention it deserves. A system of inspection is needed to organize maintenance. Without regular inspections, it is likely that defects that could be rectified readily and cheaply if caught in time will develop into major problems.

Most developed countries now have formal bridge inspection systems, although in many cases these have only been established on a national basis during the last 20 years. Details of many of these systems can be found in the OECD's *Bridge Inspection 1976* (*1*). However, even in the developed world, many bridge maintenance authorities find it difficult to provide the resources necessary to perform an adequate bridge inspection program, despite the fact that bridge inspection is acknowledged to be cost-effective. In developing countries in which both financial resources and experienced engineers may be in short supply, the difficulties of carrying out a bridge inspection program are often multiplied.

A considerable number of English language publications on the subject of bridge inspection already exist. However, a review of such publications showed that most were written for the specific circumstances of a particular developed country and are therefore unsuitable for use in developing countries in two major respects. First, these books are generally intended for use either by qualified engineers or by personnel who have undergone at least some formal technical education. Thus, the level of technical knowledge assumed may be beyond that which could reasonably be expected of many potential bridge inspectors in a developing country. Second, because most of these publications assume that their audience is capable of reading complex technical English with relative ease, they are often too difficult for people with poor English to understand.

In an attempt to provide suitable guidance on bridge inspection, the UK Transport and Road Research Laboratory (TRRL) is currently completing a two-part bridge inspection guide for use in developing countries. The guide is intended to cover all common small to medium bridges. Large or unusual bridges are excluded, because these need to be inspected by specialist engineers. Part One of this guide is entitled "A Guide to Bridge Inspection for District Engineers." It covers inspection and record or inventory systems appropriate to bridges on low-cost roads, and takes into account the limited resources usually available to manage them. Part Two is the "Bridge Inspector's Handbook," which explains bridge inspection and gives a comprehensive step-by-step guide to inspection, following a set procedure. The handbook contains more detailed but straightforward technical advice on bridge defects than is provided by existing publications. The TRRL has already published a guide for district engineers on road maintenance, the *Overseas Road Note 1: Maintenance Management for District Engineers,* but it deals with bridges in only a very general manner (*2*).

David Brooks and John Parry of TRRL's Overseas Unit were responsible for the guide. This unit has experience in the engineering and operational aspects of transportation in developing countries through its research activities performed on behalf of the British government. The authors of the draft of the guide were from London consulting engineers Rendel, Palmer & Tritton, and from the School of Language Studies at Ealing College of Higher Education. Rendel, Palmer & Tritton is an international consulting firm, founded in 1838, with substantial experience in the design, construction supervision, and inspection of bridges in many developing countries. A language consultant from Ealing College with experience in teaching English to engineers and technicians from developing countries advised on the communication aspects of the guide. Those involved in the production of the guide were therefore able to draw upon a wide range of relevant experience of the developing world.

The basic premise of the new guide is that, in some countries, inspection and maintenance are sadly inadequate, partly because the few trained staff available rarely make visits to their bridges. If trained engineers are unavailable, or unwilling, to inspect the bridge stock, it must be done by others under the supervision of a district engineer. The district engineer, therefore, needs to know not only how to set up and administer a system, but also how to select and train suitable bridge inspectors. Assistance in this task can be found in Part One of the guide.

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Engineering technicians, junior engineers, and road maintenance foremen could be trained to perform bridge inspections. Some road foremen, who are unlikely to have much technical background, are nevertheless felt to be suited to the task because of the practical experience they have gained in their work, and because they are accustomed to working on site, rather than in an office. Part Two of the guide has been prepared so that it can be understood by potential bridge inspectors who have little formal technical training and whose knowledge of written English is basic.

COMMUNICATION

It can be assumed that users of the engineer's guide are relatively sophisticated readers with a reasonable command of technical English. The engineer's guide therefore uses the sort of English one might expect to find in a textbook on the subject, although extra care has been taken to ensure that the language used is clear and unambiguous and that the organization of the whole text is suited to the needs of its users.

In contrast, users of the inspector's handbook are unlikely to be fluent readers of English. Some older inspectors may have attended an English-medium school in which they were able to develop competency in reading and writing English. However, the trend in many developing countries is away from English-medium schools and toward the use of a local language in government schools. This means that many younger inspectors are less likely to have learned to read fluently in English, because their exposure to English will have been more limited. It was therefore assumed that users of the handbook would, in many cases, be slow readers of English texts and would be unlikely to have developed reference skills. The handbook is designed to account for these limitations.

As far as the ability to write is concerned, the Bridge Inspection Report Form has been designed so that the inspector only needs to have a basic writing ability in a language, not necessarily English, that the engineer responsible is willing to accept. In fact, the engineer responsible may prefer his inspectors to write their comments in a common local language, if it exists in written form, rather than attempt to decipher comments written in poor English. However, the amount of writing the inspector will need to do is minimal, because most of the inspection report is completed by placing ticks in the appropriate columns of the preprinted report form.

When the handbook was designed, much thought was given to the ways in which the language could be adjusted to encourage better understanding by the inspector. The approach taken focuses on the likely interests, experience, knowledge, and skills of the target reader, the trainee inspector. For instance, it was assumed that most trainee inspectors would be unaccustomed to learning independently from textbooks, especially ones written in English. It was therefore decided to make the language in the handbook "user-friendly." The text addresses the inspector directly, as would be the case in face-to-face interaction. For example, the handbook does not contain the more standard impersonal forms such as, the fixings must always be checked for looseness and damage." It instead uses the more direct "check to see if the fixings are loose or damaged." Care was taken to ensure that sentences are simple, and that more complex grammatical structures, such as "the scour the river causes can be serious," were avoided. The range of vocabulary has been kept to a minimum and many, though not all, potentially problematic words have also been avoided. Two steps have been taken to cope with vital words that may cause problems. First, the word is introduced in a context that helps to explain the meaning. To this end, much use has been made of labelled diagrams. Second, the handbook contains a glossary that explains those words that may cause a problem. The glossary only gives the meaning each item has in the text. For instance, the entry for the word "fill" only covers the noun form: "FILL (FILL IN FRONT OF THE ABUTMENT)—Soil."

Sometimes areas of conflict naturally arose between the engineers and the language consultant when the text was being prepared. These were eventually all resolved and it is believed that the final text does indeed display the clarity known to be necessary.

Another vital aspect of communication in the handbook concerns visual aspects such as layout and illustration. These are discussed in a later section.

THE ENGINEER'S GUIDE (PART ONE)

Effective bridge management requires that comprehensive records be regularly updated. Advice is given in the engineer's guide on establishing and updating bridge record systems, and a method of inspection is presented that could be undertaken by nonspecialist personnel. Guidance is also given on the use of these data in the planning of bridge maintenance, bridge replacement, and feedback to bridge designers.

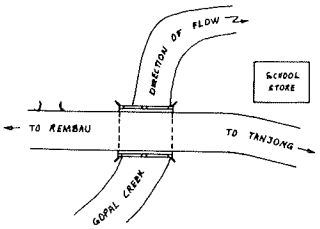
Bridge records fall into two categories: unchanging data, such as location and structural details, and changing data , such as inspection reports. The guide recommends a single card record system to record the unchanging data. The recommended card is shown in Figure 1 (front) and Figure 2 (back). The guide contains a detailed description of each data item 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 that could be used to establish a new inventory. The use of computers in handling bridge records is also discussed and advice is given on the possible advantages and disadvantages of computer-based systems to supplement the card system.

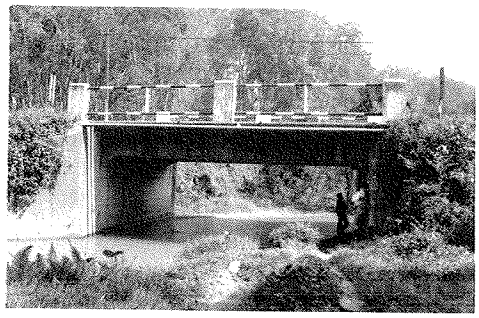
In order to collect changing data, recommendations are made on the management of an inspection program, including frequency of inspection, selection, briefing and equipping of inspectors, and record-keeping. A standard inspection form is used to record this data.

Special attention has been paid to problems that can arise from the use of unqualified staff to perform routine inspections. For instance, because the inspector is likely to have little formal technical education, it is important that the limitations of his role and responsibilities are clearly understood. The engineer's guide describes the inspector as the "eyes of the District Engineer" but cautions:

> "It should be clear to both the District Engineer and his Inspector that inspecting a bridge is a highly responsible job which ideally should be carried out by an Engineer. It should also be clear that it is the District Engineer, not his Inspector, who bears the ultimate responsibility for the inspection. The Inspector should not in general have to make decisions beyond giving his view of the severity and extent of problems he finds".

N 305/2 BRIDGE NUMBER	BRIDGE NAME GOPAL CREEK	MAINTENANCE AUTHORITY REMBAU DISTRICT - P.W.D.
	ROAD REMBAU - TANJONG	KILOMETRE 33.6
MAP 1/100,000 - REMBAU	REF 81,536 / 15,036	
ROAD CLASSIFICATION TRUNK	OVER / ~~UNDER~~ GOPAL CREEK	
LENGTH 9.81 m	NAVIGATION RESTRICTIONS —	
WIDTH RESTRICTION —	HEIGHT RESTRICTION —	
LOAD RESTRICTION —	ABNORMAL VEHICLE —	
CONSTRUCTION DETAILS		
SPAN(S) 9.5 m		
RUNNING SURFACE		
SUPERSTRUCTURE R.C. BEAM SLAB		
PIER(S) —		
ABUTMENTS R.C. WALL		
FOUNDATION TYPE SPREAD FOOTING ON ROCK		
ARTICULATION SIMPLY SUPPORTED		
SERVICES CARRIED NONE		
DESIGNED BY	LOCATION PLAN	PHOTOGRAPHS
WILLCOX & PARTNERS		
CONSTRUCTED BY		
P.W.D. - REMBAU		
DISTRICT		
YEAR OF COMPLETION 1965		





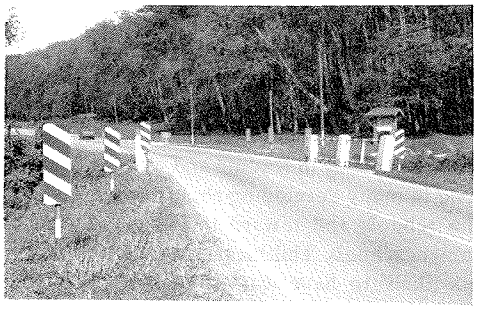


FIGURE 1 Front of proposed bridge record card (A3 size).

Thus, the Inspector reports what he finds but is not expected to make judgments about the implications of what he records as defects. For instance, an inspector may notice and report both that the road surface is cracking just behind the abutment and that the bridge has no room to move on its bearings. However, it is the district engineer who must decide whether these are unconnected events or whether these are signs of forward movement of the abutment. The principle behind this system is that if the engineer does not perform the inspection himself, he must study each of the inspection reports and determine whether a further inspection by an engineer is required.

It is recommended that an engineer perform the first inspection for each bridge. This will not only produce a starting list of defects that require maintenance, but will also ensure that the inspector, on subsequent inspections, will be given the appropriate inspection form with notes covering any aspects specific to the bridge in question.

An appendix to the engineer's guide contains supplementary notes on technical details. These notes expand the basic information presented in the inspector's handbook by more thoroughly treating such topics as cracking in concrete, corrosion bulking of steel, and the special problems of Bailey bridges which receive only a simplified explanation in the handbook.

A further reading list is provided to assist those district engineers who wish to study specific problems or techniques.

THE BRIDGE INSPECTION REPORT FORM

Both the guide and the handbook are based on the Bridge Inspection Report Form, which covers all aspects of bridge inspection for routine small- and medium-sized bridges. Although the form will undoubtedly be of use to a qualified engineer performing inspections, it has been written specifically to be suitable for use by technicians, road foremen, or junior engineers inspecting bridges.

The title page of the Bridge Inspection Report Form (Figure 3) contains all data required to make a positive identification of the structure to be inspected. The need for a clear reference system to elements of the bridge (pier 1, pier 2, etc.) is stressed both in the engineer's guide and the handbook. A sketch plan is provided for this purpose on the title page. Special instructions from the engineer to the inspector appear on this page and there is also space for the inspector to write any urgent notes for the engineer's immediate attention.

The main body of the form is arranged in such a manner that an inexperienced inspector following the order of the form will be led into a logical inspection sequence. This sequence starts with the road approaches and peripheral items that might easily be neglected, such as a missing load limit sign. It then progresses to an examination of the deck surface, the main superstructure elements, and the underside of the deck, including such items as drainage, expansion joints, and bearings. Then the sub-

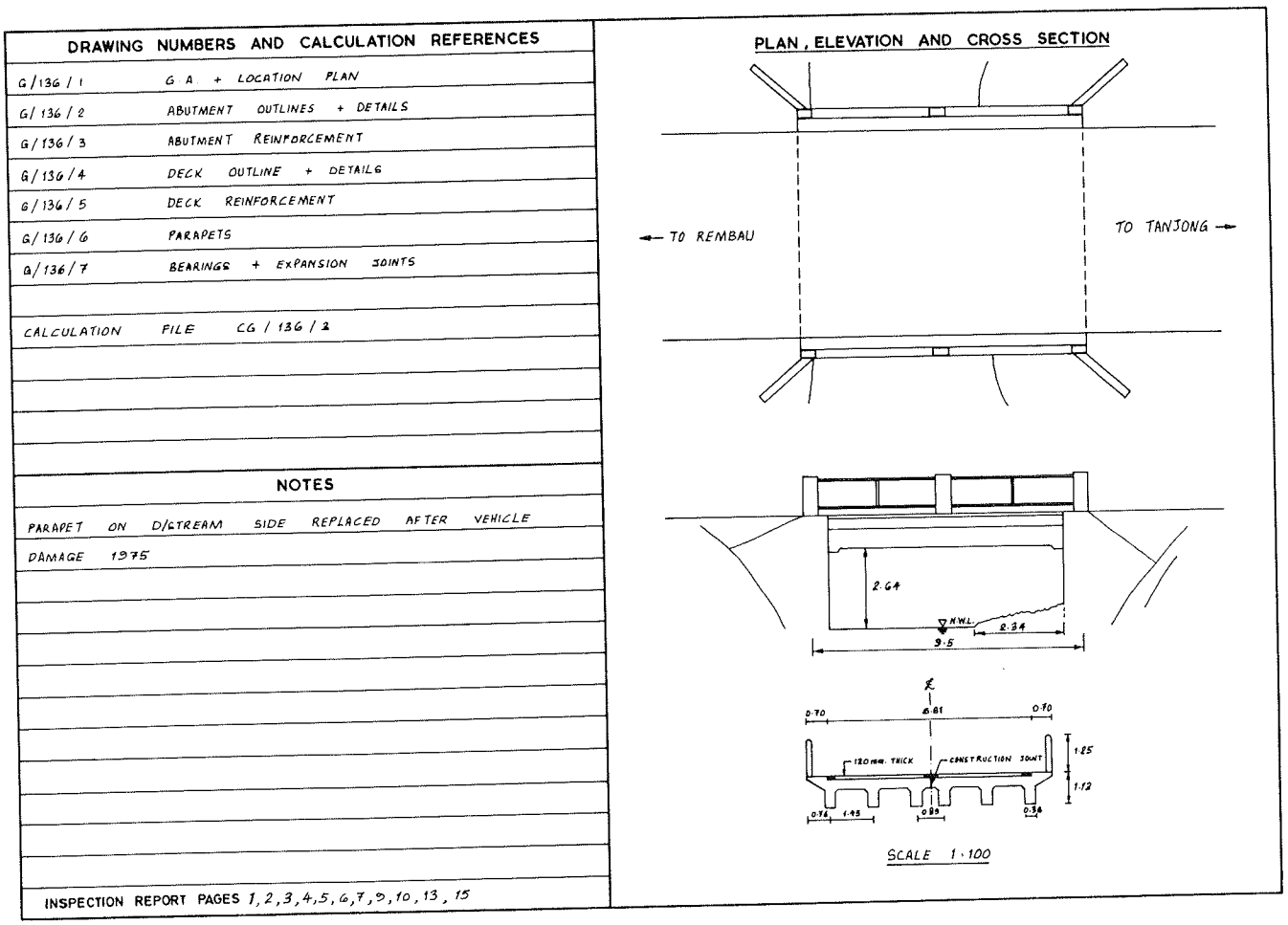


FIGURE 2 Back of proposed bridge record card.

structures, including wingwalls and retaining walls, and approach embankments are reported on. The form includes sections that cover river attack, river training works and inverts, and bed protection. Special sections are included on masonry arches and Bailey bridges.

Different structural types and possible materials are covered in each section of the form through the provision of lists of possible defects, as shown in Figure 4. The inspector is required to consider each possible defect and either cross out the section if it does not apply, or tick either the "No" column if there are no problems, or the "Yes" column if there is a problem. Where a defect is noted, the inspector assesses the severity ("How bad?") and the extent ("How much?") and ticks the appropriate column. The frequently used concept of a condition rating was considered to be beyond the capabilities of most of the inspectors likely to use this report form. Where necessary, the inspector is encouraged to write a note, draw a sketch of the defect, and reference these in the final column of the report form. If the inspector is unclear about how to report a particular defect, column one of the form refers him to the page in the second part of the handbook that deals with that particular defect.

One advantage of using a standard format is that it provides a brief but explicit means of communication between the inspector and the engineer, and therefore reduces the likelihood of confusion. Another advantage is that by requiring the inspector to respond to all the defects listed by placing a tick in one of the two columns, the engineer can be reasonably confident that no defects were inadvertently overlooked. Repeated use of a standard form also enables successive inspection reports to be easily compared, a procedure by which any slow deterioration of elements of the bridge will be made apparent. Finally, the design of the form, in which defects are arranged by material type, simplifies the task of collating the information collected for later use in planning maintenance activities, especially those of a repetitive nature.

It is not intended that the inspector should be given an entire blank report form. Given his limited skills with paperwork, it was believed advisable to provide him with only those parts of the form that are appropriate to the bridge he is going to inspect. It is suggested, therefore, that each bridge record card should list the page numbers of relevance to that bridge so that the blank forms may be prepared in advance by clerical staff (see Figure 1).

THE BRIDGE INSPECTOR'S HANDBOOK (PART TWO)

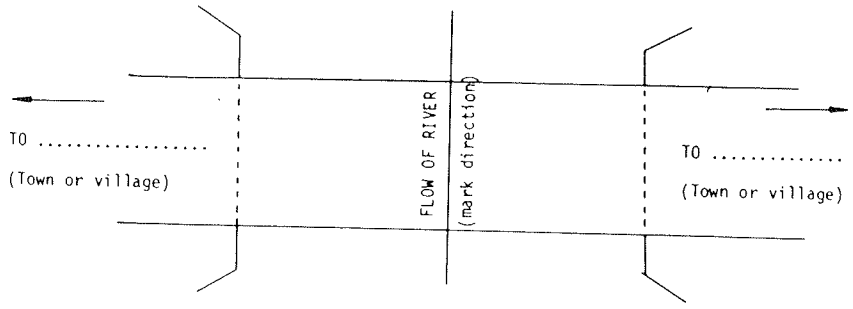
The second part of the guide is intended for use as a reference during inspections, but it is arranged in such a way that it can be used as a training manual. In order to make the book easier to use on site, it was believed that it should be pocket-sized, like the

BRIDGE NUMBER ..... NAME .....

CROSSING .....

KILOMETRE ..... ON THE ..... TO ..... ROAD

VIEW OF BRIDGE LOOKING FROM ABOVE



SPECIAL INSTRUCTIONS FROM THE ENGINEER TO THE INSPECTOR

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.....

SPECIAL NOTES BY THE INSPECTOR

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.....

.....

.....

DATE OF INSPECTION ..... DATE OF LAST

INSPECTED BY ..... INSPECTION .....

NUMBER OF PAGES IN REPORT .....
(includes sketches, notes, photos etc)

REPORT ACCEPTED ..... ENGINEER

..... DATE

FIGURE 3 Title page of Bridge Inspection Report Form.

UNECA Road Maintenance Handbook, Volume 2, which was prepared by the Overseas Unit of TRRL. In order to make the book as effective as possible, care was taken to ensure that it was attractively presented to encourage trainee inspectors to read it. This was achieved partly through copious use of photographs, color illustrations, and line diagrams. Photographs were used to illustrate particular defects when appropriate, but color illustrations were generally used because they allow some exaggeration, which can be used to focus attention. They also brighten the text and make it appear more attractive, which increases reader motivation. Typical illustrations of the handbook are shown in Figures 5 and 6. Line diagrams were used to illustrate structural actions and typical structural details.

Care was taken to arrange the book in a way that would ease rather than hinder its use by a trainee inspector. Page layout was therefore carefully planned to provide consistency over large parts of the book. Photographs, illustrations, and line diagrams also appear immediately adjacent to the text to which they relate. Because most trainee inspectors are unlikely to have sophisticated reference skills, references to other sections of the book are avoided. The Bridge Inspection Report Form serves as an index to the main text of the handbook. Words used in the form are printed in red in the book to ease cross-reference.

Part One of the handbook begins with a description of the different parts of the bridge, different types of bridges, and different articulation arrangements. Concepts such as movement under temperature change and live load are explained simply. General descriptions of the main causes of damage to bridges are given, followed by an explanation of the defects that beset the different materials used in the bridges. A simple test is described when appropriate. For example, a rivet test is described as follows.

> "You can easily check that rivets are tight and unbroken. Put your finger on one side of the rivet head so that your finger touches both the plate and the rivet head. Then hit the other side of the rivet head firmly with a light hammer. If the rivet is loose or broken your finger will feel the rivet move."

SUPERSTRUCTURE SPAN NO. _____

Handbook Page	SUPERSTRUCTURE SPAN NO. _____ POSSIBLE PROBLEM	NO	YES	HOW BAD? not very bad	bad	very serious	HOW MUCH? not much	some	a lot	Note or Sketch Reference
44	SUPERSTRUCTURE									
45	GENERAL									Not properly checked ☐
	Impact damage to beams, girders, trusses or bracings									
	Debris or vegetation on beams, girders, trusses or bracings or in joints?									
	Water coming through the deck?									
	Water from the deck drainage flowing onto girders, trusses, beams or bracings?									
	Not enough headroom for overbridge?									MIN HEADROOM=.....m
47	MAIN BEAMS, GIRDERS OR TRUSSES									
47	CONCRETE BEAMS OR SLAB									Not properly checked ☐
	Cracking?									
	Spalling?									
	Corrosion of reinforcement?									
	Poor concrete?									
49	STEEL GIRDERS									Not properly checked ☐
	Deterioration of paint or galvanising?									
	Corrosion?									
	Bends in web or flange or stiffeners?									
	Loose bolts or rivets?									
	Cracking?									

FIGURE 4 Sample page of Bridge Inspection Report Form.

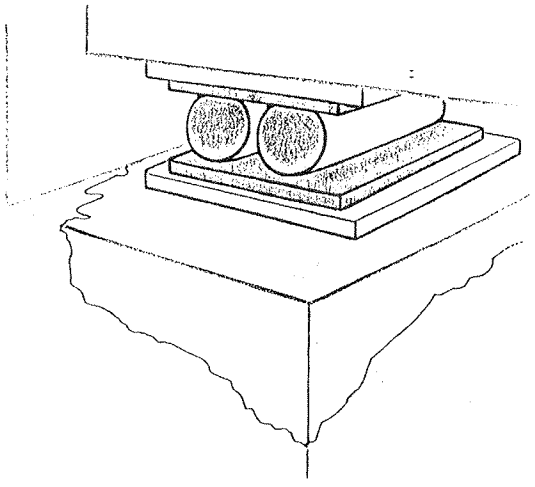

FIGURE 5 Typical handbook illustration: serious cracking near bearing.

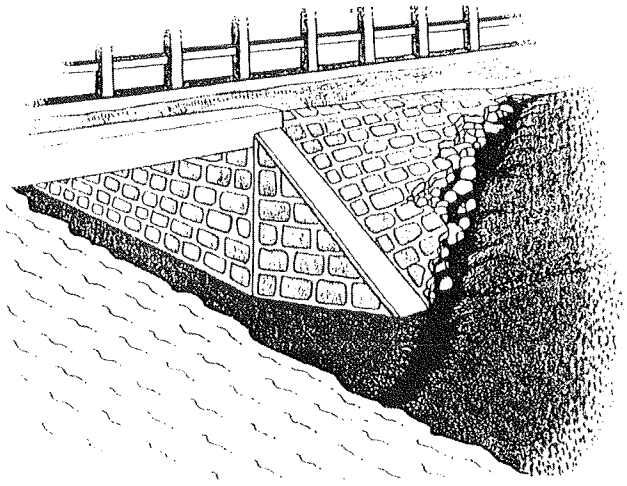

FIGURE 6 Typical handbook illustration: erosion damage to embankment.

Part One thus serves as a basic textbook for all potential inspectors. A road foreman with only a limited knowledge of English may only be able to read one page at a time and it may take a considerable period of time before he can assimilate the information. However, a junior engineer may be able to absorb the contents of Part One in a single sitting. Although the period of time it takes to master the contents of this section is unimportant, it is important that all trainee inspectors understand and learn its contents before they read Part Two.

Part Two precisely follows the order of the Bridge Inspection Report Form and over 200 possible defects are discussed. An explanation is given of what to look for and where to look for it, how to take any necessary measurements, and how to judge such matters as severity and extent. In some cases, only general advice can be given.

> "Brickwork and masonry in a pier may lose some of its motar pointing because of the flow of the river. Later, bricks may be washed out. This can be serious, as the pier is then not so strong. CHECK for poor pointing."

In other cases, the advice is specific. For example a diagram is included that shows where fatigue cracks have been known to occur on Bailey bridges.

Finally, the handbook contains a series of appendices that contain a glossary, a list of recommended equipment, some advice on safety during inspections, an example of a completed Bridge Inspection Report Form, and a blank of the entire form.

TRAINING

It was clear from the beginning that in most cases any training of inspectors necessary would have to be performed by the district engineer. In addition, although guidelines are given in the guide as to the qualities to be expected of an inspector, most district engineers will have a very limited range of possible inspectors to choose from.

The handbook is written to serve the dual purpose of an on-the-job guide and a training manual. Part One in particular is laid out in a manner ideally suited for classroom purposes.

FIELD TRIALS

In order for the guide and handbook to be accepted, it is essential that they are viewed by potential users as practical guides. The authors and the TRRL officers responsible for the guides have been constantly aware of this need. It was therefore decided to subject the guides to field trials before publication. The trials were conducted in Malaysia and Sierra Leone.

The results of the trials might have been considered suspect if a system for the trials was imposed on the responsible engineer. No guidelines other than the guides themselves were therefore issued. In order to ensure some uniformity of response, the responsible engineers were asked to offer opinions on the usefulness and effectiveness of the guides and to answer the following four questions:

1. Are you satisfied that your inspector understands a) the method of inspection, and b) the questionnaire reporting system?
2. Do you have confidence in the data reported in the questionnaire returns?
3. Has the inspection fully revealed the conditions that require attention?
4. Approximately how many hours of instruction were required per inspector before he could be sent out to work alone?

The Malaysian field trials have currently been completed. The results suggest that the guides should indeed be useful and effective. The engineers responsible were satisfied that the inspectors understood both the method of inspection and the questionnaire reporting system.

The inspectors, none of whom had any experience with this type of work, generally had encouragingly few difficulties in understanding and clearly reporting on the defects of the bridge itself. However, real difficulties were encountered in understanding the causes and effects of river damage (scour under structures, aprons, and inverts) and of rainwater run-off (bank erosion and undermining of bankseat abutments). These sections have since been expanded in order to clarify the explanations given. The explanations of one or two technical terms have also been further clarified.

Some minor problems concerning the layout of the report form were revealed. For example, inspectors were unclear about which section to use when reporting on diaphragms and cross-girders. These problems have now been overcome by making small changes to the layout of the form.

As might have been expected, junior engineers took only 1 or 2 days to absorb the contents of the handbook, and technicians took about a week. The trials revealed a tendency for the junior engineers to be a little overconfident. District engineers will also need to ensure that all inspectors follow the guide consistently.

Although it is recognized that other trials may give different results, it was believed that the feedback obtained from Malaysia has been very useful to the authors. It enabled them to redesign or redraft particular points in the guide and report form.

ACKNOWLEDGMENTS

The authors wish to thank Mr. David Brooks and Mr. John Parry of TRRL for their help and cooperation in the preparation of this paper.

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