THE NEED FOR BRIDGE INSPECTION AND STRENGTH ASSESSMENT

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1. Synopsis

In Malaysia a survey of all existing highway bridges on main roads is being carried out. This paper discusses the need to evaluate the strength of existing bridges and cover the methods of inspection and the likely range of bridges which are commonly found in Malaysia. The objective of the study is to plan a renewal policy giving priority to structurally weak bridges and those on roads which are likely to experience considerable growth in heavy traffic. The results will also provide basic data for assessing the cost involved in allowing heavier vehicles to use designated routes.

2. Introduction

In many ways bridge inspection and evaluation is much more difficult than the design or construction of new bridges. It requires a keen eye to notice faults and sound engineering judgement to assess the importance of those faults to the life or safety of that structure. Then calculations need to be done making allowance for existing faults, corroded sections of steel etc. Many old bridges have been designed to earlier codes of practice or loadings – fortunately often high factors of safety were incorporated in these codes. It is quite logical to 'use up' some of this factor of safety and relate the bridge to modern loading standards, and to reassess its strength and suitablity for existing and future traffic.

New bridge design is essentially the application of fixed standards or codes. Bridge inspection and evaluation seeks to answer the following basic questions:

(i) Is the bridge in sound overall condition?

(ii) Is it behaving structprally in the way that the designer intended?

(iii) What is the maximum load that can be carried safely by this bridge without causing it to weaken?

(iv) Is the strength of the existing foundations, piers, abutments compatible with that of the deck?

(v) What strengthening programme is needed to allow the bridge to carry present and future traffic loadings?

(vi) Is this strengthening programme economic or should the bridge be replaced in the near future?

(vii) What simple maintenance is required for the bridge now to reduce its rate of deterioration?

(viii) What simple improvements are required for the safe movement of traffic; e.g. widening, sign posts, improvement to old surfacing, handrail/crash barrier, signalling for single line working?

Since almost all bridges in Malaysia and most developing countries have road over water, the inspecting engineer must also make a judgement on the adequacy of the opening, and the possibility of flood damage to the road or scour to the foundations. The most common cause of bridge failure is flood and scour damage.

Once all those factors have been considered a programme of repair works and planned reconstruction can be carried out for each road or traffic route.

3. The need for inspection

An inventory of all bridges in Malaysia was carried out in 1973/74. There are approximately 1600 bridges on main (Federal) roads and 2500 on state roads. Of the total, some 14 per cent are of timber construction. The design life of bridges is often taken as being 50 years, in which case some 80 bridges ought to be replaced each year. With a substantial construction programme of new roads this level of renewal is unlikely to be realised and hence all existing bridges may have to last 100 to 300 years.

Inevitably, with increasing traffic and lorry weights, in particular, these existing bridges must carry greater loads and function at higher stress levels. Fortunately, many of the bridges were designed for low stress levels and can accommodate this traffic, if they are maintained in good condition.

An assessemnt of their condition is therefore a prerequisite to the continuing safe use of these structures. Any, which are overstressed, will deteriorate very quickly and may fail suddenly causing at the least substantial inconvenience and at the worst fatal accidents.

4. The methodology of inspection

The inspection is done by engineers who are familiar with bridge design or construction and entails, in the first instance, a visual inspection along with measurement of the important features of the bridges. Bridges that are in very poor condition may then be seen by a more senior engineer. On some bridges, load testing and strain gauge measurements may be done to assertain their behaviour under load.

The survey form is shown in figure 1. It has been kept as simple as possible in order to reduce the time of survey and to allow for the essentials to be recorded accurately. Items 1 to 19 cover basic information in the location and type of bridge. Items 20 to 29 detail the main bridge components and their condition. Most bridges are either a slab or I beam and deck construction. The surveyor must fill in all the dimensions given on the form. For condition rating, a simple system of good, fair, poor and dangerous is used. It has been stressed to all surveyors that dangerous means that the bridge is in a near state of collapse. All dangerous bridges will be inspected again by a more senior engineer, who will also be in the position to decide whether to repair or renew. At the top of the form 'Rating' refers to the strength rating, eg. full HA; or 15 Ton ect; condition refers to the overall condition.

Item 31 allows the surveyor to recommend immediate maintenance activity; and if a bridge is showing signs of considerable weakness then it may be necesary to reinspect it every 3 months or so, in which case the information is given in Item 32.

On the back of the form, the surveyor is encouraged to sketch or explains anything which is wrong about the bridge. For instance cracks in a wing may be old and not moving, or may be serious. Assessing the strength of concrete bridges is more difficult than for steel since the material is very variable. The use of a Schmidt rebound hammer will give an indication of concrete strength, and only where there is doubt will concrete cores be taken.

The measurement of the structural details of the bridge will allow calculations to be made of the total load in terms of Bending Moment and End Shear Force that can be carried by that structure. From this the bridge can then be rated for Standard loadings such as BS 153 : HA or the total truck weight allowed. In Malaysia, calculations will be done in terms of load limit as a proportion of HA, but this is only understandable to a bridge engineer. Later this figure will be related to the axle load, axle configuration and spacings of typical trucks which travel. The bridge can than be classified in terms of 16 ton, 20 ton, 24 ton, 30 ton, 35 ton and so on. Using a computer system for storing this information, senior management can then make quick assessments of the number of bridges that must be replaced on a route, in allow say 32 ton lorries to operate on it.

5. The different types of bridge in Malaysia

Before setting out on any inspection, the engineer must have a feel for the types of bridge that he will be surveying and the common faults and problems that are associated with each type. It will be very helpful to know the date of road construction and the date of each structure. In many cases the actual drawings have been lost or destroyed so structural details of each bridge will be hard or impossible to find. Often, a road has a series of bridges of the same type on it – this may mean that structural details can be obtained at one site and used for other bridges as well. But more importantly an old bridge may have been replaced. If so, why it was replaced (structural failure, river problems, widening) – will give useful information for other bridges.

5.1 Concrete bridges.

Almost all new bridges are of concrete construction. There are several standard JKR designs for prestressed or post tensioned beams. As well as these, many bridges have been designed by Consultants or 'Turnkey Contractors'. Some of these may be built to a different loading than BS 153: HA, plus 45 units of HB. If the drawings are available then checking the existing bridge with the drawing is quite easy. Unfortunately even many of these relatively new structures are without "as built" drawings. There is then a problem of deciding how much reinforcement and how much prestress has been used. In general the JKR standard prestressed beams are standard inverted T beams with known prestress and position of the strand. With post tension beams, i.e. in situ or on site construction and the simple Reinforced Concrete (RC) beam, it is difficult to decide how much and where the reinforcement is. Most RC designs are 'balanced' in that the amount of steel in the tension zone would give the same yield force as the concrete in the compression zone. When no other information is available this can be used as well as the assumption that the steel is Mild Steel and the Concrete a 1: 2: 4 mix with 28 day cube strength of 25 N/mm2. Other values for limiting steel or concrete stress may be used depending on the quality of the concrete as seen or tested using a Schmidt hammer. The inspecting engineer must therefore judge the quality of the concrete. If he sees any of the following, they are automatic indicators of "trouble".

(i) Cracking at position of max. BM or Shear Cracks at end of beam.

(ii) Spalling of concrete – corrosion of reinforcement OR stress?

(iii) Segregation of concrete – poor construction standards.

(iv) Blistering of concrete – steel corrosion or poor construction standards.

(v) Looseness of the exposed surface-poor construction or carbonation of the concrete.

(vi) Members out of alignment.

(vii) Anything else which looks wrong.

5.2 Steel Bridges.

There are many designs of steel bridge in use in Malaysia. Most of them seem to be quite short span (5-8m) "steel buckle plate". It is probable that most of these were constructed in the period 1920-1940 using steel imported from the United Kingdom. The abutments are usually brick (perhaps with a concrete rendering). The design is a series of parallel I beams with an arched plate riveted to the top flange. Above this is fill material – which in some cases will be concrete and on top of that comes the road surfacing. There are seldom any bearings as such or any method to accommodate temperature movements. The design has many similarities with a much earlier design used in the UK known as the cast iron jack arch.

Problems with bridges of this type are:–

(i) Cracking of the abutment under the girder(s)

(ii) Movement of the abutments.

(iii) Bouncing of the bridge deck on the abutment.

(iv) Alignment out of vertical for the I beam.

(v) Flattening of the buckle plate.

(vi) Corrosion of the buckle plate, usually seen at the rivets caused by water penetration through the road surface.

(vii) Corrosion of the I beam. Often worst for the edge members where vegetation is an added problem.

(viii) Because the abutments are gravity only and not piled these bridges often suffer from scour under the abutment (see Scour Section).

(ix) A number of these bridges have been widened (when?). Check that this is compatible with the existing structure and if cracked between old and new, is the crack new and a sign of movement, or just poor workmanship when the widening was done?

(x) Hand railings are often in poor condition. They may be set into the road structure or attached to the outer I beam girders.

Of the above, (iv) and (v) indicate possible yield of the steel and must be examined carefully. Corrosion of large section steel is not usually very important. If it occurs in the flange at the position of max Bending Moment or in the web at maximum End Shear then it is structurally important. It must be remembered that when steel corrodes it expands and therefore it is easy to overestimate the loss of section from corrosion. It is probable that not more than 3 or 4 different sections of I beams were imported into Malaysia during the time that these bridges were constructed.

Other steel designs include through trusses with steel girders and timber deck, or plate deck with wearing course of bitumen asphalt. There is also a suspension bridge which has been propped and a large steel truss which has had a road put on top of it. Bailey bridges are frequently used in an emergency and many may be found in long term use as well. Old Bailey bridges need careful examination for cracks in any place where high stress levels may be expected.

5.3 Timber Bridges.

Many of the State and District roads are using timber bridges. Few are now found on the Federal roads. Timber has one great advantage over steel and concrete and that is that it can accommodate movements of the abutments, piers, or deck members without cracking or any residual stresses. It is a flexible and plyable material. Many District road bridges are believed to be more than 50 years old and with some replacement of termite attacked members and general maintenance they should be capable of lasting a long time further.

The principal problems with timber are:–

(i) Short spans and hence often many piers in the water course. Debris can be held in the piers giving high lateral loads in flood times.

(ii) Constant maintenance of the timber running boards – it is preferable to use coach bolts rather than nails.

(iii) Termite attack or water rotting of the main beams, transoms or deck.

(iv) It is difficult to replace main girders without removal of most of the deck. Then there is always the problem in deciding how much replacement to do.

(v) Imprecise strength calculation due to variable nature of the timber itself.

6. Foundations.

The detailed inspection of foundations is not possible without diving equipment or the digging of an inspection pit. However, whether they are adequate or not for existing traffic, can often be judged from a visual inspection. Usually unless there are signs of movement, and especially differential movement, foundations are assumed to be adequate. Piers and abutments can be a major source of problems. Piers are often in the faster stream of water flow and may suffer from considerable scour, damage from debris, damage from boats- tying up or direct impact. Abutments carry not only the traffic loads (bothe vertical and horizontal) but also need to resist the pressure of the soil behind them. If this soil is wet (saturated) then the pressure on the abutment will be much greater – hence the need to allow water to drain from the back of the abutment or through weep holes. Many old abutments are brick and may be quite badly cracked (see also scour).

Indications of trouble are :

(1) Any movement.

(2) New cracks.

(3) Differential settlement.

(4) Abutments or piers out of alignment.

(5) Water seepage through abutments.

(6) Growth of vegetation in the abutments.

From the age of the structure it may, or should be possible to say something about the material of the foundation. Then, it is a question of local knowledge as to which bridges of that foundation have given trouble in the past and making sensible engineering judgements on its strength and suitability. For large bridges, especialy those over coastal rivers, it will be necessary to do an underwater inspection occasionally – intervals of 10 years are suggested.

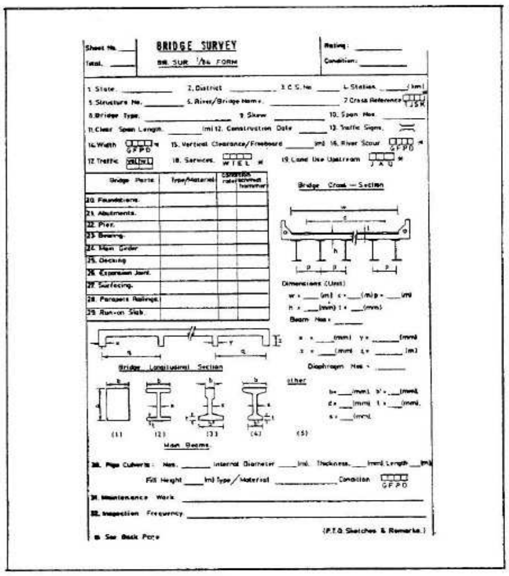
7. Scour.

Seldom do bridges collapse by the simple failure of the deck or main girders. It is much more usual, especially in areas of heavy rainfall, for the bridge to collapse due to scour of the river bed and the bridge foundations. Sometimes this is a result of freak storm and the overtopping of the structure, but also scour may be a continuous process slowly leaching out the particles of soil from under a mass pier or abutment. Regular inspection of the structure should be able to reveal this and set in motion necessary repairs and remedies, such as gabions, river training, repointing of brick work or even underpinning of the structure.

The bridge inspection must also note the adequacy of the size of the bridge opening, which is an indication of the risk of damage or over topping. If the bridge is likely to be classified in the 'replace group' then some indication of the type and size of bridge by which it ought to be replaced is useful. Often, old bridges may be economically replaced by pipes or a box culvert; and in some areas the size of opening may be reduced as a result of land drainage programmes, the construction of dams or the changes in agriculturel use. All of these details should be at least thought about when the inspection is done. It is much better for on site engineers to help in deciding the replacement structure rather than just the HQ engineer.

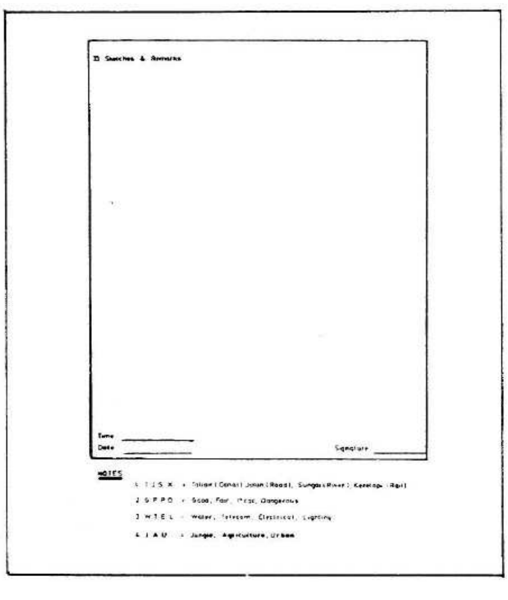
8. Conclusion.

This bridge survey will be done by two teams in the field inspecting 2/3 bridges per day. The system has been designed to be as easy as possible in order to provide quick results for future road planning and upgrading. The basic data about each bridge, its condition and strength rating will be stored with other road data in a computer system. The accuracy of the strength assessment depends much on the actual design of bridge – however a figure of + 15 per cent should be possible. At a later stage, the system will be used on state roads as well and their staff could be trained by the HQ team.


BRIDGE SURVEY
BR. SUR 1/84 FORM
Sheet No. ____ Total ____
Rating: ____ Condition: ____
1. State ____ 2. District ____ 3. C.S. No ____ 4. Station ____ (km)
5. Structure No. ____ 6. River/Bridge Name ____ 7. Cross Reference (T J S K)
8. Bridge Type ____ 9. Skew ____ 10. Span Nos ____
11. Clear Span Length ____ (m) 12. Construction Date ____ 13. Traffic Signs
14. Width (G F P D) 15. Vertical Clearance/Freeboard ____ (m) 16. River Scour (G F P D)
17. Traffic 18. Services (W T E L) 19. Land Use Upstream (J A U)

Bridge Parts	Type/Material	Condition	
20. Foundations.			
21. Abutments.			
22. Pier.			
23. Bearing.			
24. Main Girder			
25. Decking			
26. Expansion Joint.			
27. Surfacing.			
28. Parapets Railings.			
29. Run-on Slab.			

Bridge Cross – Section
Dimensions (Unit)
w = ____ (m) c = ____ (m) p = ____ (m)
h = ____ (mm) t = ____ (mm)
Beam Nos = ____
Bridge Longitudinal Section
x = ____ (mm) y = ____ (mm)
z = ____ (mm) q = ____ (m)
Diaphragm Nos = ____
other
b = ____ (mm) b' = ____ (mm)
d = ____ (mm) t = ____ (mm)
s = ____ (mm)
(1) (2) (3) (4) (5)
Main Beams.
30. Pipe Culverts: Nos. ____ Internal Diameter ____ (m) Thickness ____ (mm) Length ____ (m)
Fill Height ____ (m) Type/Material ____ Condition (G F P D)
31. Maintenance Work ____
32. Inspection Frequency ____
See Back Page
(P.T.O. Sketches & Remarks.)


33. Sketches & Remarks
Time ____
Date ____
Signature ____
NOTES
1. T J S K = Taliar (Canal) Jalan (Road), Sungai (River), Keretapi (Rail)
2. G F P D = Good, Fair, Poor, Dangerous
3. W T E L = Water, Telecom, Electrical, Lighting
4. J A U = Jungle, Agriculture, Urban