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A National Guide For Bridge Inspection

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Abstract

Bridge inspection, which involves a systematic check on the physical condition of a bridge, is effective in preventing bridge failures by early detection and arrest of any problems. Also, bridge inspection collects data as the inputs to a bridge management system (BMS). In Malaysia, majority of the bridges are operated and managed by the Public Works Department or Jabatan Kerja Raya (JKR). Other bridge authorities include private concessionaire companies of tolled highways, Keretapi Tanah Melayu Berhad (KTMB) and the Municipalities.

It is important that a national guide is available for bridge agencies in Malaysia to have a standard set of procedures for bridge inspection. This important responsibility is undertaken by REAM "Working Committee on A Guide to Bridge Inspection." The purpose of this paper is to discuss the concepts adopted in the drafting of this Guide. The paper also highlights the importance of having an overall bridge management program involving different types/levels of bridge inspections.

INTRODUCTION

The Need for Bridge Inspection

Bridges are key elements in the road network and constitute a major capital investment of a nation's resources. Bridge failure, either involving a catastrophic collapse or simply the loss of a few critical components, for example, the bridge railings may endanger the lives of public members. Also, because bridges are meant to provide passage over obstacles, a bridge failure may limit or severely disrupt the traffic flow, with consequent inconvenience and economic losses to the community. Bridge inspection, which involves a systematic check on the physical condition of a bridge, is effective in preventing these incidents from happening by early detection and arrest of any problems that may otherwise propagate to a critical state.

Another motivation for bridge inspection is in the preservation of capital investment. Due to limited funds there is a need to optimize use of available resources. OECD (1992) reports that bridge owners around the world are devoting much effort in optimizing the scarce resources. To this end, it has become mandatory in some countries, for example, the U. S. A. for bridge agencies to operate a computerized bridge management system (BMS). A BMS keeps data of all the bridges in a database; and provides supports for informed decisions to be made regarding the management of these bridges. Common bridge management decisions are bridge maintenance and repair, weight restriction, rehabilitation and replacement. Bridge inspection provides the necessary inputs for the BMS.

The Need for a National Guide on Bridge Inspection

In Malaysia, the Public Works Department or Jabatan Kerja Raya (JKR) is the custodian of over 6,640 highway bridges* along the Federal Roads in the Peninsula (Ng 1999). The inventory of state bridges has not been completed yet. It is estimated that there are at least as many bridges along the State Roads as that along the Federal Roads. Although it has been a traditional practice for JKR to conduct different levels and types of bridge inspections from time to time, it was not until 1995 that bridge inspection on Federal bridges was made mandatory to all the districts (Yusof 1996).

In the past, almost all the bridges in Malaysia belong to JKR. With the privatization of road projects starting 1984 many bridges are now also operated and managed by private concession companies of tolled highways. Although majority of the privately managed bridges is new the need for a systematic bridge inspection program of these bridges cannot be over-emphasized. Indeed, Malaysian Highway Authority or Lembaga Lebuhraya Malaysia (LLM) has required that all privatized road concessionaires conduct regular bridge inspection (Md. Salleh 1997). Trains are also a major mode of transportation in Malaysia. It is a routine exercise for Keretapi Tanah Melayu Berhad (KTMB) to inspect its bridges regularly. Another major bridge owner is Dewan Bandaraya Kuala Lumpur (DBKL), which has over 155 bridges to inspect and manage (Low 1997).

It is important that a uniform set of procedures and standards on bridge inspection is available for all the various bridge agencies in the country. This will help to ensure a uniform level of service for all the bridges in the nation regardless of who their owners are. Besides this, sharing of information and resources among these authorities could be more easily achieved when there is a uniform standard of practice. A working committee under the Committee of Road Structures of Road Engineering Association of Malaysia (REAM) has thus been set up to undertake the task of preparing a national guide for bridge inspection. Pertinent engineers or managers from JKR, LLM, KTMB, DBKL and Penang Bridge Sdn Bhd. and the academicians are members of this committee. The content of the guide is mainly based on JKR's current practices in bridge inspection (JKR 1995). It is hoped that the guide will help ensure the safety of the nation's bridges. However, like the other REAM documents, use of this Guide is not mandatory unless required by relevant authority.

THE CONCEPTS AND ORGANIZATION OF THE GUIDE

The Concepts

Many guidelines or manuals on bridge inspection exist from the U.S., Canada, the U. K. and Japan. The need for a national standard, which focus more on common types of bridges in Malaysia and damages commonly found in this country, has often been felt. Although existing guidelines from around the world have been referenced and parts thereof adopted for the development of this Guide, care was taken to exclude portions that are not relevant to the Malaysian situation.

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* Bridges include box and pipe culverts of span over 0.5 m.

Also, although JKR practice has been the basis used in this document, objectives and needs of other bridge agencies are also considered. The proposed Guide is not intended as an inspection handbook or manual but can be used to formulate ones pertaining to the needs of individual bridge agencies. The emphasis of the Guide, indeed, is on providing guidelines to the organization of a bridge inspection program. A major chapter of the Guide also provides guidelines on assessing bridge damages and defects. These guidelines can be included in the respective bridge agencies' own inspection manuals.

Organization of the Guide

The Guide consists of four chapters and a few appendices. First chapter gives the introduction to bridge inspection. Various types of inspections are discussed. Important part of the chapter is the organization for bridge inspection team, the equipment needed and the procedures involved.

Chapter 2 deals with the common types of damages and defects found on Malaysian bridges. Brief description of each type of damages is made in order that bridge inspectors can understand the causes of the damage and the impact it may bring to a structure. Chapter 3 deals with the procedures of conducting and reporting a bridge inspection. Chapter 4 discusses how severity and extent of each damage can be assessed and used in condition rating.

Appendix A gives some statistics of the number of bridges owned by each bridge agency in Malaysia. Appendix B gives an introduction to common bridge structural systems in Malaysia. Appendix C summarizes the forms and checklists to be used in a bridge inspection.

TYPES OF BRIDGE INSPECTION

OECD Classification of Bridge Inspection

OECD (1976) classifies bridge inspection in terms of the scale or intensity, and/or its frequency. Based on this classification, three types of bridge inspection have been identified:

A *superficial inspection* would be carried out by highway maintenance personnel who have a good practical knowledge of road structures, but may not necessarily been trained in bridge inspection. These inspections may or may not be made regularly and will usually occur as the opportunity arises, perhaps during cleaning or routine road or bridge maintenance.

A trained inspector under the supervision of a bridge engineer would usually make a *principal inspection*. This type of inspection falls into two categories referred as *general* and *major* distinguished by their frequency and intensity. The *general* principal inspection would be made at intervals of one to two years. The *major* principal inspection, on the other hand, would be more intensive and the interval between major inspections would vary between three to five years and may be as long as ten years.

A *special inspection* would usually be made in connection with unusual circumstances, such as exceptional loading, with occurrence of major weaknesses or with reassessment of the

structure against revised specifications and regulations. Such inspections may require a good deal of supplementary testing and structural analysis and will invariably require detailed involvement of a bridge engineer.

Different Purposes of Bridge Inspections

In a broader sense, bridge inspection is the *data collection* stage of the so-called "scientific approach" of problem solving, which encompasses *problem identification, data collection, comparing alternatives* and *selection of the best alternative*. It is easy to see the rationale of collecting data prior to comparing the alternatives and selecting the best one among them. In the context of an overall bridge management strategy, bridge inspection involves taking measurements, assessing bridge performance, investigating possible and probable causes of defects, studying feasible courses of remedial actions; etc., in summary, collecting all the necessary data needed for making an informed bridge management decision. Ng (1999a) classifies bridge inspection in terms of the main purpose of the inspection as follows:

Inventory Inspection

An *inventory inspection* is the first inspection carried out on a particular bridge to collect data for the bridge inventory. This type of inspection is done visually and systematically on every bridge in the network. It involves taking dimensional measurements, sketches and photographs of the bridges. It may be very helpful if the design or tender drawings are available. However, because the as-built dimensions of the bridges may sometimes differ much from that in the design or tender drawings it is imperative that the dimensions in the drawings are verified at sites.

Since the data would be the basis of decision-making in the BMS and sometimes be used for structural analysis, it is important that the data are free from errors and are as precise as possible. The bridge inspector must thus have proper knowledge of taking precise measurements.

Some of the information needed for the bridge inventory, for example, the year of construction or design loads may be may be obtained from the plaque or imprints on the bridge parapets. Otherwise the needed information have to be inferred or assumed based on whatever information that could be found at the site. For example, the year of construction and thus the probable design standards used could be inferred from an old newspaper stuck to the underside of the bridge deck.

Condition Inspection

Condition inspection aims to assess the performance level of a bridge structure and its components. Generally, two types of performance measures have been used: condition rating and load rating. Condition rating assesses the performance level based on physical condition of the bridge whilst load rating evaluates the theoretical safe load-carrying capacity of the bridge. Very often, condition rating is used in a routine bridge inspection while load rating is determined separately in a bridge assessment exercise involving detailed bridge inspections (see Assessment Inspection below).

Condition rating are numerical values from 1 to 5 assigned to each component of the structure based upon observed material defects and the resulting effect on the ability of the

component to perform its function in the structure. Sometimes, an overall system rating is obtained either directly by the bridge inspectors or by aggregating the ratings for each individual bridge components and taking into consideration their respective importance. Table 1 gives the rating system for Malaysia as presented in JKR Bridge Inspection Manual (JKR 1995).

Table 1 Malaysian Rating System (JKR 1995)

Rating	General Definition
0	Bridge part cannot be fully inspected because of access problem, such as submerged structures. Re-inspection necessary whenever possible.
1	No damage found and no maintenance required as a result of the inspection.
2	Damage detected and it is necessary to record the condition for observation purposes.
3	Damage detected is slightly critical and thus it is necessary to implement routine maintenance work.
4	Damage detected is critical and thus it is necessary to implement repair work or to carry out a detailed inspection to determine whether any rehabilitation works are required not.
5	Being heavily and critically damaged and possibly affecting the safety of traffic, it is necessary to implement emergency temporary repair work immediately or rehabilitation work without delay after the provision of a load limitation traffic sign.

Despite the fact that each category of rating in Table 1 has been defined as precise as possible, it may be better to regard the rating system as an ordinal scale from 1 to 5, with 1 represents the 'best' condition and 5 the 'worst'. Condition rating is a function of the extent and severity of the damages/defects found on the components. The REAM Guide provides recommendations on how a bridge component should be rated based on the damages/defects that are present.

Condition inspection can be carried out annually by an inspection team led by a technician, who has undergone formal bridge inspection training. Every 3-5 years depending on the conditions of the bridges, a bridge engineer should participate in the *condition inspection*. This arrangement would ensure that a bridge engineer inspects every bridge at least once every few years.

Maintenance Inspection

Maintenance has been defined as the work needed to preserve the intended performance level of the bridge and to ensure the continued safety of road users. OECD (1981) classifies maintenance operations as *Ordinary maintenance* and *Specialized maintenance* operations. *Ordinary maintenance* operations are operations of a repetitive nature and in general, technically rather simple. The intervention level for an ordinary maintenance operation is often already established. *Specialised maintenance* operations are essentially repair work triggered by the results of a bridge inspection.

A *maintenance inspection* aims to come up with a program for maintenance and repair. During a *maintenance inspection*, the damages that are present in a bridge must first be identified. The inspector would appraise the severity and extent of these damages. She

would analyze the situation, based on whatever tell tales she observes at site; or her previous experience on similar types of bridges, or the fundamental theory of bridge engineering, to determine the probable causes of the problem(s). She would then evaluate the risk of further deterioration. Finally, she would decide on the maintenance operations needed to overcome the problems.

It is evident that a *maintenance inspection* has to be carried out by a bridge engineer who has sufficient knowledge and experience in bridge design and construction; as well as bridge repair techniques and materials.

Rehabilitation/Replacement Inspection

Rehabilitation involves an extensive repair work that may either restore or improve a bridge. A *Rehabilitation/Replacement inspection* is indeed a detailed inspection to study the feasibility of rehabilitating the bridge rather than replacing it.

In this case, information for both rehabilitation and replacement alternatives are to be collected in the inspection exercise so that a comparison could be made between the two options. These information include the practical aspects of various rehabilitation and replacement options, their cost implications; etc.

Assessment Inspection

This type of inspection involves a very detailed inspection to collect data for the purpose of computing the theoretical safe load-carrying capacity of the bridge. This is a very specialized job and it often requires use of nondestructive testing equipment in the inspection exercise. The inspector must have access to the structure to enable him to do measurements and to appraise the defects from close range. It is best that the person doing the evaluation would also perform the bridge inspection.

In many instances, dimensions of the bridge needed in the analytical calculations would be taken. The loss of member sections and its impact on load-carrying capacity would need to be estimated. Very often, samples are collected to determine the material properties in the laboratory. In some cases, traffic data may also be obtained from conventional traffic survey or by the use of some advanced technique such as the WIM (Weigh-in-motion) (Moses 1979). The REAM National Guide for Bridge Inspection does not cover load rating as a type of inspection. Load rating is considered an assessment exercise and a separate document will be prepared to cover this aspect later.

BRIDGE MANAGEMENT SYSTEM

The different types of inspection as described above are rarely carried out alone. More often than not, to attain a complete surveillance of a bridge calls for a bridge inspection program involving a series of different types of inspections. Even for the same purpose it may sometimes be necessary that the inspectors make a few visits to the bridge site to conduct different levels of inspections.

In particular, a bridge maintenance management procedure must exist in the context of a

BMS, which stipulates how the various levels/types of bridge inspections should be carried out to identify projects for maintenance, rehabilitation and replacement. As an example, in JKR's Annual Mandatory Bridge Inspection (AMBI) Program, four types of bridge inspection are specified (JKR 1995):

a) Inventory Inspection
b) Annual Mandatory Condition Inspection
c) Confirmatory Inspection
d) Detailed Inspection

A flow chart showing the order of these inspections and their outputs are presented in Fig. 1. *Inventory inspection* is necessary for every new bridge or any existing bridge whose inventory has not already been included in the Bridge database. Every year, the JKR district carries out mandatory *Condition inspection* for the purpose of ensuring that the bridges are safe, functional and well maintained. *Confirmatory inspection* follows the annual condition inspection and was carried out by Bridge Unit engineers on selected bridges with poorly rated components (that is, ratings of 4 or 5). This inspection was originally intended more for ensuring that the rating done by the district inspection teams are consistent with the established rating criteria. It has since evolved into an exercise for the Bridge Unit to prepare the annual maintenance programs and schedule for detailed inspection. This is indeed a *maintenance inspection*. For bridges that may require either a rehabilitation or replacement work a *detailed inspection* would subsequently be carried out.

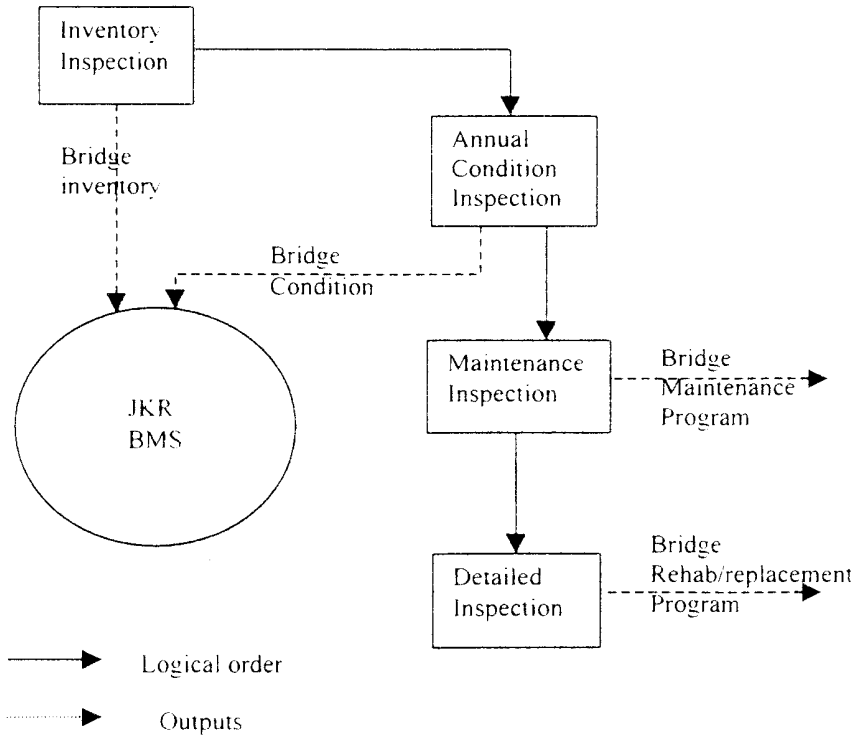

Fig. 1 Flow chart of different levels of inspections

SUMMARY

This paper first presents the needs for regular bridge inspections and a national inspection guide. It furthers explains the concept adopted in the development of the REAM Guide on bridge inspection. It discusses in great length the different types and purposes of bridge inspection. Finally, it highlights the importance of having a certain bridge management procedure, which outlines the flow of different levels of bridge inspection leading to important management decisions.

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