A Proposed Framework for Risk-Based Integrity Management System (BIMs) of Highway Bridge in Malaysia

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Abstract—There are more than 10,000 bridges all around Malaysia manage by JKR, KTMB, DBKL and LLM. There are a great number of bridges to monitor which will contribute to the issue on the cost of maintenance which must be given priorities in the maintenance process. Hence, it is significant to have a comprehensive system in bridge performance assessment by proposing the framework of structural integrity management system for concrete highway bridge in Malaysia using risk-based approach which may be emulated from SIMS of offshore platform structure. Generally, the objectives of this study are to identify the bridge performance indicator in order to develop the framework of proposed system and to create the risk matrix for prioritizing the inspection. This paper present the framework of BIMs which shows the main steps of the management process starting from data inventory, evaluation, planning and finally the execution of the inspection and maintenance.

Keywords—Bridge assessment, risk assessment, risk-based inspection, structural integrity.

I. INTRODUCTION

BRIDGE is one of the important parts of road network, which enable a vehicle or a pedestrian to get across a river, a road or any other obstacles. The existing bridges which are either old or new carry the possibility of failure. Early sign of deterioration that occurred on the bridges could help engineers to take an action to prevent them from a serious failure in the future because once there is a fault it could lead to structural failure or even collapse and cause a lot of loss in terms of humanity and economic. Therefore, it is essential to have a continuous bridge performance assessment with a comprehensive method and management system to detect the early stage of failure or damage to ensure that it is in safe condition for use and to prevent any possible collapse event in the future over the lifespan of the bridge.

In Malaysia, there are about more than 10,000 bridges under the jurisdiction of Public Work Department (JKR), Malayan Railways (KTMB), Kuala Lumpur City Council (DBKL) and Malaysia Highway Authority (LLM) which consists of various types of bridge that is concrete bridge, steel bridge, masonry bridge and wooden bridge. These bridges constitute a huge asset to the various agencies as mentioned. These agencies also have an authority to monitor and manage the bridge performance which under their control. With a large number of bridges to be observed and several issue related to the bridge management in Malaysia due to numbers of ageing bridge, the low fund for maintenance and occurrence of catastrophic bridge failure, the comprehensive assessment and management system is essential to develop in order to reduce cost related to bridge performance assessment and which bridge should be given the priorities to be maintained.

Furthermore, in current situation of increasing of traffic demands and ageing bridge, it is significant to have an effective method for deciding which bridges need inspection and maintenance first and which ones can be less observation, thus the need to prioritize.

The purpose of this paper is to develop a system for bridge management by proposing a framework of structural integrity management system for highway bridge in assessing and managing the bridge performance using risk-based approach which is emulated from structural integrity management system (SIMS) of offshore platform structure. The research focused on the concrete bridges since most of the bridges in Malaysia are of concrete types.

A. Objective of Study

The general objective of this research is to obtain a better understanding on the structural integrity management system in order to develop the bridge integrity management system. The overall objectives of the study are including:

1) To identify of the bridge performance indicator in the form of cause-consequence scenario, which most significant to the structural integrity.
2) To proposed framework for Bridge Integrity Management System (BIMs) of concrete highway bridge using risk-based approach in Malaysia.
3) To create risk matrix in prioritizing ranking of bridge...
inspection for future risk mitigation or maintenance action.

B. Problem Statement and Significant of Research

Currently, bridge assessment practice in Malaysia uses a system known as bridge management system (BMS) which is mainly based on condition evaluation and cost optimisation. In addition, the inspection frequencies in the existing system are mainly time-based but some of the bridges may be required less frequency of inspection compare to the bridge with high potential of failure. Furthermore, the present bridge management system is more concern on the prediction of possibility of failure only rather than the consequences if the failure occurred

As repair and maintenance fund is always limited, the new approach of management system is essential to be developed to rank the necessity of inspection for future maintenance by considering both the probability of failure and its consequences during the decision making process. Thus, the cost of inspection of bridges that categorized in a good condition may be reduced by increasing the interval of the next inspection. This approach for the decision making in the asset integrity management system is more recognised as risk-based approach.

Since the risk assessment method has been successfully implemented in structural integrity management of offshore platform structure in order to ensure the fitness of structure for it purpose with long term reduction in operating and assessment cost [6], [19], it is possible to develop the bridge management system using the same approach as implemented for offshore platform structure.

II. LITERATURE REVIEW

This paragraph represents literature review on the areas related to the structural integrity management (SIMS) and risk assessment.

A. Structural Integrity Management System (SIMS)

SIMS is a part of asset integrity management system concept which is specifically formulated for offshore structures and can be defined as an ongoing life-cycle process for ensuring the continued fitness-for-purpose of offshore structures which has four phases of process namely Data, Evaluation, Strategy and Program [10], [19] as illustrated in Fig. 1.

Data at the early phase in SIMS process is essential to be up-to-date in providing necessary information about the installation platform. Data are divided into two categories i.e. characteristic data and condition data. Characteristic data is considered as general information about structure at installation such as age, water depth, design data, fabrication data and installation data while condition data is categorised as data that shows any changes to the characteristic data occurred during the operating life of the platform such as modification, inspection and damage.

Based on data from the first phase the process of SIMS continued to the second stage is to evaluate the data. This evaluation process would determine which strategy and programs for the platform in order to ensure that the platform is fit for purpose. The evaluation of data is undertaken through risk assessment using risk matrix approach.

When the evaluation result is available, the inspection strategy plan will be determined. The evaluation result will establish which strategy that should be developed with considers the frequency and scope of inspection and the inspection tools or technique to be used.

Final phase of SIMS process is Program which is to implement the whole scope of work to complete the activities in SIMS. The data collected during program will feed back to the Data in the first stage of SIMS since SIMS is a continued process.

B. Risk Assessment

There are several definition of risk have been defined by many people referring to the risk in various field. Ettouney and Alampalli [15] define the risk as an outcome rating to systems with a degree of uncertainties for an occurrence of uncertain events. Technically, risk is define as a combination of probability (also known as likelihood) and consequence of failure [14], [21], [22] where both failure can be determine through a tool namely risk-based inspection (RBI) and risk can be expressed as:

\[
Risk = \text{Probability of failure } (P) \times \text{consequence of failure } (C)
\]

Risk can also be treated as a performance indicator which includes the requirement to study the occurrence of hazards and the impact due to structure failure. Risk-based approach has been used as a decision making tool in numerous different form in asset management system and applied to various types of structure for many years such as offshore platform structure [26], pipelines [9], [20], chemical plant [12] and recently, transportation [7]. In fact, offshore platform owners had been extensively practicing the risk assessment in their asset management system [13], [17], [19], [26] since a long time ago and this risk-based system are keep improving through research either in terms of proposing a new approach, methodology and technique [3], [18] or development and improvement of recommended practiced [10], [24]. However, this study will focus only on bridge structures concentrating in
structure integrity perspective.

The risk-based approach in the management of bridge integrity is considered new compared to other structure or system in other industries. Since a long time ago, bridge stock were managed through the evaluation of physical performance in term of condition rating and the prediction of remaining life using prediction deterioration model. However, lately, bridge agencies and researchers have started to improve the management system by proposing the use of risk-based approach in measuring the bridge integrity with considering various aspects that may contribute to the safety of structures such as types of hazard and loading that could affect the bridge performance and also in terms of the choices of tools and technique for analysis [2], [4], [5].

1. Risk-Based Inspection (RBI)

RBI is one of a tool that used to analyze risk in risk assessment and management for prioritizing and managing in-service inspection plan and maintenance action. The main objective of using RBI in asset integrity management system is to simplify and standardized the assessment procedures and reduce the managing cost without compromising safety [14]. RBI is more concern on the elements defect rather than the whole system. RBI assessments are divided into three categories i.e. qualitative, quantitative and semi-quantitative assessment. All assessment types can be used to determine the probability and consequence of failure for deciding which structure elements have higher possibility to fail and which one should be given priorities for inspection. The results of risk are appropriate to be presented in the form of risk matrix as shown in TABLE I.

<table>
<thead>
<tr>
<th>Probability</th>
<th>Consequence</th>
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<tr>
<td>A</td>
<td>L</td>
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<tr>
<td>B</td>
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<td>C</td>
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<td>E</td>
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<td>F</td>
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RBI as risk assessment tool has been successfully implemented worldwide in oil and gas industries especially through SIMS in managing the offshore platform structure for prioritizing the inspection plan and helps in reducing the related cost [6], [13], [18], [21] but less recognize in bridge management. However, since a decade ago, a few studies have been reported that researchers and bridge owners have gained interest on using RBI as a decision making tool for bridge assessment in asset management system of bridge structure [1], [8].

III. METHODOLOGY

The general methodology of this study consists of the development of propose framework for the new bridge management system namely BIMs, data collection from one of the main bridge stake holder (JKR) in Malaysia and questionnaire survey. The literature review was initially conducted to identify types and technique used for bridge management that currently practiced in the whole world, generally and specifically practiced in Malaysia and to identify the factors that may affect the performance of bridge. The study is divided into three stages and the overall flow of the process is explained in the Fig. 2. However, this paper focuses only at stage I since the research just started and still ongoing.

![Fig. 2 Research flow](http://dx.doi.org/10.15242/IIE.E0314040)

IV. FRAMEWORK FOR BIMs

The propose framework of BIMs will be emulated from SIM which is consists of four phases namely Data, Evaluation, Strategy and Program. However, this research only focuses on data preparation and evaluation phase only and this paper...
proposed the framework for the whole system of BIMs as illustrated in the Fig. 3.

Since Malaysia is practicing the Bridge Management System (BMS) in the condition assessment and management, most of the needed data are ready for the BIMs Data phase. However, the appropriate data from BMS will be selected and classified into three suggested categories:
1) History data such as age, year of design and construction and drawing.
2) Condition data such as in-service inspection record, maintenance record and ADT (average daily traffic) data.
3) Cost data such as cost of previous and current inspection and maintenance.

B. Evaluation

The Evaluation process will be carried out using risk-based inspection (RBI) approach for future inspection planning which include the determination of both probability and consequence of bridge failure by using combination of fault tree and event tree method. In general, RBI tool will be used in the risk analysis until the risk value is determined and further to develop the risk matrix. Fault tree method is used to identify the causes of bridge failure while event tree method is used to model the consequence of bridge failure. The propose framework for Evaluation phase of BIMs is described in the Fig. 4.

A. Data

By using the same definition for Data in SIMS, Data phase for BIMs will provide basic information about bridge as listed below:
1) Characteristic data such as age, design data, construction data etc.
2) Condition data such as inspection data, maintenance data, damage data etc.
V. FUTURE RESEARCH PLAN

Based on the developed framework, further research work will be carried out to analyze the risk until the risk matrix is developed.

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