Journal of Engineering and Applied Sciences 12 (4): 787-791, 2017
ISSN: 1816-949X

Condition Rating System of Bridges in Malaysia: A Case Study

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Abstract: Bridge Unit Department of Jabatan Kerja Raya (JKR) Malaysia was using Bridge Maintenance System (BMS) to evaluate the condition of bridge. Introducing of condition rating method implemented in United Kingdom to determine the level of Maintenance Priority Number (MPN) in order to sustain the bridge in good condition. It is logical, relatively simple to use in practice and readily understood by the inspector. This research is to determine the level of MPN and to predict the bridge performance and predict the lifespan of bridge. The data of bridges which is called as routine condition inspection form consist of the year built, type of maintenance, condition of bridge, capacity and road type were getting from Petaling District of Jabatan Kerja Raya (JKR). Through determination of MPN can analysed the condition of bridge structure. Moreover, MPN can outline the scheme of maintenance. The results show that the value of all elements for Jambatan near to Penjara Sungai Buloh is below 50 and the most critical is beam element which is 7.86. From the result, it is expected the bridge can sustain >44 years by introducing maintenance of beam element which is 6 years (minor maintenance) and 10 years (major maintenance) and giving.

Key words: Bridge maintenance system, condition rating, maintenance, MPN, JKR

INTRODUCTION

Bridge structures are facing to several of defects which can deteriorate their performance such as cracking, honeycomb, reinforcing steel corrosion and scaling. In order to maintain the structures, a practical tool is needed to manage their maintenance, inspection and repairing. This tool is very important to evaluate the condition of bridge during their service lives.

The condition rating system of bridge is applied when the bridge in circumstances of good or critical situation. The rating is in numerical value which indicates the level of bridge damaging. The bridge will start to deteriorate when age of bridge become increase year by year and because of that, the strength of bridge will decrease (Fu, 2005). Maintenance is an activity should be carried out during the bridge was serving to the public, in order to ensure the bridge functioning purposely without jeopardize the structural safety. Therefore, the development of structural evaluation methods for existing bridges is of considerable interest. Qiao (2012) stated that the choice of evaluation method is affected by a few factors of the nature of the bridge and the amount of the information available about its existing. Finally, Qiao (2012) develops the evaluation procedure for concrete bridges based on the load rating. Furthermore, developing countries were already applied rating systems which provide an effective framework for assessing structural performance (Sarachaga *et al*., 2016).

This research is to adopt Maintenance Priority Number (MPN) methods to be applied to these problems and analyses the bridges in Malaysia. It is based on the comparison of Condition Rating System (CRS) from two countries which is Thailand and Australia. In Thailand, the process on how to determine the distress type for each element of bridge and the determination of severity level but this method did not cover the type of road which supported by bridge (Suksuwan and Hadikusumo, 2010). In United Kingdom (UK) the road type is an important where it will affect the capacity of load on the bridge. The outcomes from the Thailand findings, it only derived from the proposed method which is reflects a bridge's levels of deterioration, performance and no prediction on lifespan of bridge as compared to UK method.

Condition Rating System (CSR) in Australia used rating 1-4 which are not compatible with JKR rating (rating 1-5) (Rashidi and Gibson, 2011). Furthermore, it is only focused the result for the whole bridge and not analyses for each element since this study will discovered about beam element in the bridge. There is no prediction of lifespan of bridge by using Australia method.

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Objectives: The aim of this study is to evaluate the result of method condition rating that has been practiced in UK for Highway Bridge in Malaysia to determine the level of Maintenance Priority (MPN) and predict the bridge performance of beam element after major or minor maintenance. The results can expect the lifespan of bridges.

Scopes: A total of three bridges were selected in this study to examine the condition rating of bridges in Malaysia and further to predict the lifespan of those bridges. The chosen bridges were from Petaling district which are Jambatan near to Penjara Sungai Buloh, Jambatan Masjid Sungai Plong and Jambatan P1 Kuala Selangor which already existed for 32, 25 and 14 years, respectively. The data of bridges which is called as Routine Condition Inspection Form consist of the year built, type of maintenance, condition of bridge, capacity and road type were getting from Petaling District of Jabatan Kerja Raya (JKR) at Persiaran Atmosfera, Seksyen U5, Shah Alam Selangor. The rating from each bridge is required to find value of Maintenance Priority Number (MPN). In this study, beam element for each bridge is used as to predict the lifespan of bridge trough minor or major maintenance. The deck type for three bridges are using precast R.C beam. It is expected, the application of condition rating in Malaysian bridge can improve the maintenance systems. The bridges located along Kuala Selangor old road was the most important with frequent vehicles including heavy vehicles (Tham *et al*., 1991).

MATERIALS AND METHODS

In Malaysia, bridge performance evaluation was performed by using BMS. In order to enhance the assessment method, condition rating as practicing in UK was adopted to analyse the existing data of selected bridges in Malaysia. The data received from JKR Petaling consist of three bridges which is Jambatan near to Penjara Sungai Buloh, Jambatan Masjid Sungai Plong and Jambatan P1 Kuala Selangor. CSR requires data of of bridges from JKR for determination of MPN. MPN is calculated based on calculation involving Condition Factor (CF), Road Type (RT) and Location Factor (LF) (Manfield and Ng, 1991).

Procedure of condition rating system of UK for highway bridge

Step 1: Initially following a principal inspection, each element of the bridge is awarded a condition value of between 1 and 5. Table 1 shows the conversion from CV to CF.

Step 2: Describes the method here takes into account the importance of the road supported by the bridge and the importance different elements with regard to safety and overall performance. Table 2 shows the road type using in calculation of MPN. For other types of structure, the relative importance of the facility that the structure supports can be rated using a similar system. The importance of each element is addressed by giving each element a Location Factor (LF) using the guidelines given in Table 3.

Table 1: Condition Value (CV)

Condition Value (CV)	5 (Critical)	4	3	2	1 (Good)
Condition Factor (CF)	1	2	4	7	10

Table 2: Road type

Road type	Road Factor (RF)
Motorway (i.e., the most important road)	9
Trunk road	10
"A"class roads (Regional principal highways)	11
"B" and "C" class roads (Regional non-principal highways)	12
Unclassified (minor) roads	13
Public right of way (probably serving a few small private properties)-considered to be the least important	14

Table 3: Location Factor (LF)

Element of bridge	Location Factor (LF)	Remarks
Main beams, transverse and pier	5	These are main structural beam components. Deterioration is likely to lead to a reduction in the load carrying capacity of the bridge
Concrete slab, metal deck plate, bearings	6	As above but deterioration is ikely to have lesser impact on performance of bridge
Abutments, wingwalls and approach embankments	7	As above but deterioration is and likely to have lesser impact on performance of bridge
Foundation	8	As above but deterioration is likely to have lesser impact on performance of bridge
Waterproofing, surfacing,	9	These elements do not contribute to the strength of the bridge deck but parapet and pedestrian handrails provide containment of traffic (safety) durability, articulation and ride expansion joint quality
Drainage system, inverts, aprons	10	

Step 3: The Maintenance Priority Number (MPN) is then calculated using the following relationship:

$$MPN = CF \times LF \times RF/14 \quad (1)$$

RESULTS AND DISCUSSION

Rating from JKR inspection: CSR requires data from JKR which is the data routine condition inspection in order to determine the value of MPN. Table 4 shows data routine condition inspection from JKR. Data was based from three

Table 4: Data routine condition inspection from JKR

JKR Rating	Element	Jambatan near to Penjara Sg Buloh (32 years)	Jambatan Masjid Sungai Plong (25 years)	Jambatan P1 Kuala Selangor (14 years)
Rating (1-5)	Beam	4	1	1
	Deck slab	4	1	1
	Abutment	3	1	1
	Bearing	3	3	1
	Drainpipe	3	3	1
	Parapet	2	3	2
	Surfacing	2	3	2
	Expansion joint	4	1	1

Determination of Maintenance Priority (MPN)

Table 5: Data routine condition inspection from JKR

JKR Rating	Element	Jambatan near to Penjara Sg Buloh (32 years)		Jambatan Masjid Sungai Plong (25 years)		Jambatan P1 Kuala Selangor (14 years)	
Rating (1-5)/MPN	Beam	4	7.86	1	39.30	1	39.30
	Deck slab	4	9.43	1	47.14	1	47.14
	Abutment	3	22.00	1	55.00	1	55.00
	Bearing	3	18.86	3	18.86	1	47.14
	Drainpipe	3	31.40	3	31.40	1	78.57
	Parapet	2	49.50	3	28.29	2	49.50
	Surfacing	2	49.50	3	28.29	2	49.50
	Expansion joint	4	14.10	1	70.70	1	70.71

Prediction of bridge lifespan based on beam element value of MPN

Table 6: Result of beam element Jambatan near to Penjara Sungai Buloh

Age of beam	10	12	14	16	18	20	22	24	26	28	30	32
CV	1	1	1	2	2	2	2	3	3	3	3	4
CF	10	10	10	7	7	7	7	4	4	4	4	2
LF	5	5	5	5	5	5	5	5	5	5	5	5
RF	11	11	11	11	11	11	11	11	11	11	11	11
MPN (current)	39.29	39.29	39.29	27.50	27.050	27.050	27.50	15.71	15.71	15.71	15.71	7.86

Table 7: Minnor maintenance (6 years)

Age of beam	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
CV	1.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00
CF	10.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00
LF	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
RF	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
MPN (minor maintenance)	39.29	39.29	39.29	27.50	39.29	39.29	27.50	39.29	39.29	27.50	39.29	39.29	27.50	39.29	39.29	27.50	39.29	39.29

different location of bridge which is Jambatan near to Penjara Sungai Buloh, Jambatan Masjid Sungai Plong and Jambatan P1 Kuala Selangor. The data routine condition inspection was using 1 until 5 which indicates normal to critical condition of damage.

Table 5 shows the result of MPN from three bridges. Details calculation of MPN can be seen in appendix section. In the CRS, the greater value of MPN represents the least priority of maintenance while the least value of MPN represents the most priority of maintenance and need quick action.

The result from Jambatan Masjid Sungai Plong shows all element of bridge was <50 of MPN except for expansion joint were 70.7 of MPN. While of third bridge, Jambatan P1 Kuala Selangor shows only element of drainpipe and expansion joint above 50 of MPN. Table 6 shows the result of beam element from the Jambatan near to Penjara Sungai Buloh. The value of MPN decreased year by year because of none of minor maintenance to be taken until it was reached rating of 4 at bridge age of 32 years. At this stage, the beam was totally damaged and dangerous to the public user.

From this observation, the first option is to do minor maintenance of beam every 6 years do the where Table 7 which improvise the rating from 2-1. Each time the rating reached 2, minor maintenance needs to be applied as soon as possible to prevent the value of MPN achieved <50 which is in critical condition. The highlighted years show the year of maintenance to be taken which improved the rating.

The second option is to do the major maintenance of beam every 10 years as shown in Table 8. However, after 10 years, the rating will increase from 2-3 and need major maintenance in order to keep the bridge is sustainable and safe to be used. By conducting the maintenance activity, it will improved the value of MPN from least to greater value. Figure 1 shows the correlation between the

Table 8: Major maintenance (10 years)

Age of beam	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
CV	1.00	1.00	1.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00
CF	10.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00	7.00	10.00	10.00
LF	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
RF	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
MPN (mjor maintenance)	39.29	39.29	39.29	27.50	27.50	27.50	27.50	15.71	27.50	27.50	27.50	27.50	15.71	39.29	39.29	27.50	39.29	15.71

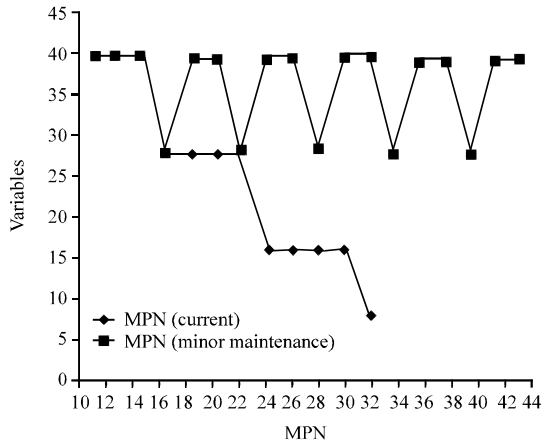

Fig. 1: Correlation of MPN (6 years)

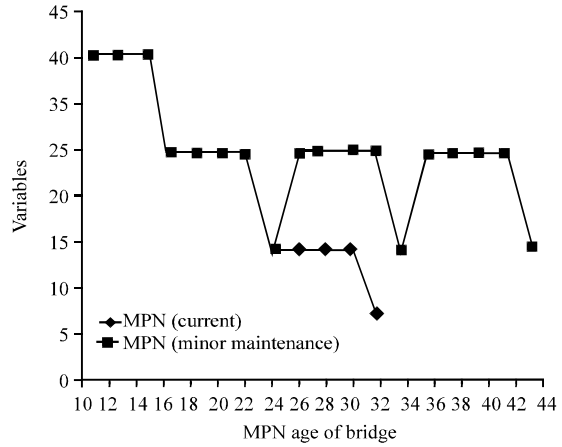

Fig. 2: Correlation of MPN (10 years)

values of MPN current and after analysis of 6 years minor maintenance of beam. The correlation between two MPN which is MPN current and MPN for minor maintenance shows the value improves for condition rating if early maintenance to be adopted. According to analysis, the bridge can sustain >44 years if this method adopted early of existence.

This option is much easier because less of maintenance to be taken compare to first option but the disadvantages is the budget of maintenance will be high because of the rate of repairing the damage is expansive and maybe need to close the road for major maintenance.

The analysis of second option can be seen in Fig. 2 where there is only 3 major maintenance within 20 years and the bridge also can be last <44 years.

From the analysis of 6 and 10 years of maintenance, it is shows that there are choices of how the maintenance scheme can be taken. The minor maintenance consists of regular maintenance activity compare to major maintenance. However, minor is more appropriate compare to major due to constraint in cost, expertise, time and difficulty to user for closing the main road for major maintenance.

CONCLUSION

The result of MPN for Jambatan near to Penjara Sungai Buloh <50 for all elements and the most critical is beam element which is 7.86. The Jambatan Masjid Sungai Plong is critical at abutment and expansion joint with >50 and all element of Jambatan P1 Kuala Selangor below than 50 except abutment and expansion joint. The results of MPN can outline type of maintenance.

The study shows, priority of maintenance is not only depending on visual condition rating but the type of road need to take into consideration. For example, the value of MPN for the element of beam and deck slab for Jambatan Masjid Sungai Plong and Jambatan P1 Kuala Selangor is 39.3 and 47.14, respectively which is <50 of MPN. It shows that the road was major road and long distance; moreover, a lot of heavy vehicles were using this road. If the structure of bridge is small but the load capacity is greater, the bridge cannot cater excessive loads and starts to damage.

The recommendation of this method to be applied in Malaysia is very desirable in order to keep safe and maintain the bridge structures regularly. The analyzing of condition rating into MPN can create scheme of maintenance, therefore it will affect the budget of maintenance itself since maintenance activity requires huge amount of money.

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