STUDY ON DAMAGE FACTOR FOR BRIDGE MANAGEMENT SYSTEM IN LAOS BASED ON THE GOOD PRACTICES OF JAPANESE TECHNOLOGY

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1. INTRODUCTION

Lao People`s Democratic Republic (Lao PDR) has total road network of length 56,000 km with 3,580 bridges of all types. Bridges are an integral and important part of the road network, and thus proper maintenance and performance assurance of these road and bridge infrastructures are indispensable for realizing the balanced industrial and economic development across the country as stipulated in the five-year National Socio-economic Development Plan (2016-2020). Few attempts have been made in systemizing the bridge maintenance planning but due to lack of proper damage evaluation and diagnosis, it could not be taken place yet. Realizing this fact, Japan International Cooperation Agency (JICA) has been providing support in development of a new Bridge Management System (BMS) under the Project for Capacity Development on Bridge Maintenance and Management (JICA-BMM) to establish bridge maintenance cycles and contributes to the improvement of bridge maintenance capabilities in Lao PDR. In BMS, detailed damage evaluation and diagnosis are incorporated at bridge element (bridge member) level. Since this is the first time that Lao PDR is evaluating and diagnosing the bridge at element level considering various factors, the good practices of Japanese technology in collaboration of Public-Private-Academia participated from both Japan and Lao PDR is incorporated in BMS. Nagasaki University, Japan and National University of Laos are supporting in customizing damage evaluation and diagnosis of Lao Bridges.

2. BRIDGE DAMAGE EVALUATION AND DIAGNOSIS

The Manual for Bridge Element Inspection (MBEI) published by the American Association of State Highway and Transportation Officials (AASHTO) categorize the bridge element into nine (9), Johnson et al. (2019). The Bridge Inspection Manual published by Road Maintenance Division of Nagasaki Prefecture, Japan (BIM-Nagasaki) categorizes the bridge elements into eighteen (18) categories, Road Maintenance Division, (2015). In Lao PDR, the same bridge elements as used in BIM-Nagasaki is used in Bridge Inspection Manual of Lao PDR (BIM-Lao). The details of bridge elements practiced in United States, Japan (Nagasaki Prefecture) and Lao PDR are shown in Table 1.

Table 1 Bridge Elements in United States, Japan (Nagasaki Prefecture) and Lao PDR

Bridge Elements in MBEI (AASHTO)	Bridge Elements in BIM-Nagasaki and BIM-Lao	
1. Deck and Slabs	1. Deck	10. Noise Barrier
2. Railings	2. Main Structure (Girder, Beam)	11. Lights, Traffic Signs
3. Superstructure	3. Other than Deck and Main Structure	12. Wheel Guard
4. Bearing	4. Body	13. Pavement
5. Substructure	5. Foundation	14. Expansion Joint
6. Culverts	6. Bearing Body	15. Drainage Facility
7. Joint	7. Shoe Seat	16. Inspection Facility
8. Approach Slabs	8. Bearing Fall Prevention Device	17. Accessories
9. Wearing Surface, Protecting Coating, Concrete Reinforcement Steel Protective System	9. Railing, Guard Fence	18. Wing Wall

Bridge inspection in Lao PDR has been carried out very roughly and maintenance plans have been prepared without any systematic assessment of bridge structural conditions including deterioration forecasting. In BMS, computation of bridge element Health Index (HI) is introduced. Damage types depends on material of bridge element. Therefore, the damage types, damage patterns and severity in concrete and steel are different. Eight (8) types of damages are considered in BIM-Lao, Department of Roads et al. (2023) as shown in Table 2. The structural condition (soundness) of bridge elements is evaluated in different damage level, their extent of damages in the element as percentage and eventually bridge element HI is calculated using Eq. 1 and Eq. 2, Department of Roads et al. (2023).

$$Health\ Index\ (HI) = (100 - Damage\ Grade\ (DG)) \quad (1)$$

$$DG = CF_D \times \sum_{Level}(Damage\ Level\ \times Extent\ of\ Damage) \quad (2)$$

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Where, CF_D is the damage factor and it indicates the magnitude of the effect of each damage for each structural element.

CF_D depends on various factors such as construction quality of bridge element itself, meteorological conditions, environmental conditions and type of traffics and their loading conditions in general. Therefore, this study aims at customizing the damage factor in Lao context taking good practices of Japan for short-term (provisional) and long-term.

3. METHODOLOGY

Two methods are used to determine the suitable value of damage factor for short and long term as described below.

3.1 Experts' Judgement

Empirical studies employed a number of methodologies to estimate optimum value of damage factors: Regression analysis, AHP (Analytic Hierarchy Process) and Fuzzy analysis. Since the bridge soundness evaluation was newly introduced in Laos under the support by JICA-BMM and local experts do not have sufficient experiences to determine the level of damage of each bridge element and hence overall bridge soundness, this Study applied AHP by simply comparing the importance between paired damages. An AHP questionnaire survey was conducted to collect the experts' opinion on damage factor that will be suitable for Lao context. Bridge experts working as professional as well as academia in Laos were requested to provide damage factors for bridge elements by material types. The experts' opinions were analyzed and final damage factors were determined as provisional.

3.2 Trend Analysis of Actual Inspection Data and Deterioration Curve Calibration

Trend analysis of actual annual inspection data of several years of sample bridges is to be analyzed and compare with the deterioration curve drawn through the adaptation of arbitrary number of damage factor in BMS. The predicted deterioration curve will be adjusted (i.e., by changing CF_D in trial-and-error method) with the actual deterioration trend as recorded through the annual actual inspection data of sample bridges. When the predicted deterioration curve nearly aligns with the actual trend of damage progression, the final damage factor is to be determined and set in BMS for all bridges.

4. RESULTS ANALYSIS AND CALIBRATING THE DAMAGE FACTOR TO LAO CONTEXT

4.1 Results of Experts' Opinion Survey

Relevant experts were participated in opinion survey. Based on the analysis of the opinion survey results, CF_D is determined as shown in Table 2. Considering the severity of damages in steel elements especially cracks and fracture, 100% weightage has been given. Similarly, the scouring of foundation is considered to be very critical from the view point of collapse of bridge pier or abutment, 100% weightage has been given by the experts.

Table 2 Damage Factor thru Opinion Survey

Element material	Damage type	Damage Factor	
		Japan	Lao
Steel	Corrosion	0.25-0.6	0.43
	Cracks	1.0	0.84
	Fracture	1.0	1.00
Concrete	Cracks	0.33-0.75	0.48
	Peeling, Exposure of Rebar	0.13-0.67	0.60
	Leaching, Free Lime	0.13-0.4	0.40

4.2 Trend Analysis and Curve Calibration

The required data for trend analysis and deterioration curve calibration is to be carried out when historical date of bridge element inspection is available. However, the conceptual image of calibration is shown in Fig. 1. The annual bridge element inspection data shall be recorded and compared with the predicted deterioration curve accordingly.

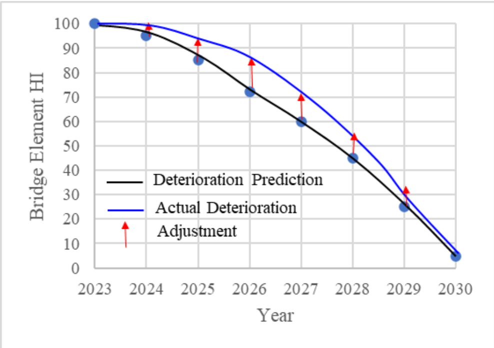

Fig. 1 Calibration of Deterioration Curve

5. CONCLUSIONS

Damage factor is one of the important parameters in quantitative assessment of bridge elements. However, newly introduced BMS in Laos has no sufficient data in determining the accurate damage factor. Therefore, two approaches of customizing damage factor in Lao context are considered for short and long-term purpose. The experts' opinion which is also solely depends on individual's judgement, thus an average damage factor is taken as provisional. As for long term, the inspection data of several years shall analyze and use accordingly in curve calibration.

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