- Technical Paper -

DETERMINATION OF QUALITY DETERIORATION – A CASE STUDY FOR CONCRETE HIGHWAY BRIDGES IN VIETNAM

Ha MINH[*1], Hiroshi MUTSUYOSHI[*2] and Dinh Tuan HAI[*3]

ABSTRACT

Concrete bridges in Vietnam are generally in poor quality. However, this trench is not clearly defined due to lacks of attention. This research is conducted to (1) propose a local method to theoretically estimate physical condition, (2) investigate actual bridge depreciation under influences of external factors, and (3) validate the method to make it appropriate with actual results. Several influence factors will be defined for bridge location, the climate, traffic, society, etc. In addition, a computerized database is constructed to be able to estimate the depreciation, to compare several curves, and to appropriate results.

Keywords: Bridges, Concrete, Maintenance, Management, Physical Condition, Vietnam

1. INTRODUCTION

There has been intense research in recent years related to deterioration of existing concrete bridges. It is recognized that due to uncertainties beyond the control of designers, owners, contractors, public agencies, etc., bridge structures have an inherent risk of quality depreciation and damage. Highway bridges in Vietnam are not in exception for deteriorating physical condition due to adverse impacts of the climate, traffic, premature aging, human invasion and so on. However, the trench of quality depreciation is not clearly defined as there are a few studies conducted by local researchers in this field. Moreover, the evaluation method is currently demanded by local practitioners in order to accurately define for physical condition of existing concrete bridges in Vietnam.

Existing highway networks in Vietnam consist of 4,107 bridges for a total length of 150 km as shown in Fig. 1 (Truong, 2004). An in-deep investigation carried out by Hai (2006) confirms that there is a lack of systematic method in evaluating and predicting physical condition of existing bridges in Vietnam. This prevents highway bridges from reaching optimal levels of serviceability. The research is therefore carried out in order to (1) propose a theoretical method to estimate physical condition of typical concrete bridges, (2) investigate actual bridge deterioration in Vietnam throughout the time, and (3) validate the proposed method for appropriating theoretically assumption with actual depreciation. Upon objectives reached, the result of the paper can be applied for whole bridge population of the country to predict their actual quality deterioration by the time.

2. LITERATURE REVIEW

Methods of assessing and predicting physical condition and actual deterioration of existing concrete bridges have been proposed by many researchers and practitioners in the world. Chase and Gaspar (2000) mentioned the use of the Pontis and the BRIDGIT at US. Federal Highway Administration to provide comprehensive supports for determining the optimum quality required while maintaining a specified level of service for population of bridges. Meanwhile the J-BMS was constructed for Yamaguchi-prefecture government in Japan to evaluate bridge performance, to estimate degrees of deterioration and remains of service life (2000). In Vietnam, even intuitive evaluation is currently used; several simple bridge evaluation systems are however suggested. One of them is developed by Hai (2006) to enable estimating physical condition and load-carrying capacities of bridges at a specific time. However,

*1 Assistant Prof., Dept. of Civil and Env. Engineering, Saitama University, Dr.E., JCI Member
*2 Prof., Dept. of Civil and Env. Engineering, Saitama University, Dr.E., JCI Member
*3 Lecturer, Hanoi University of Civil Engineering, Vietnam, Dr.E.

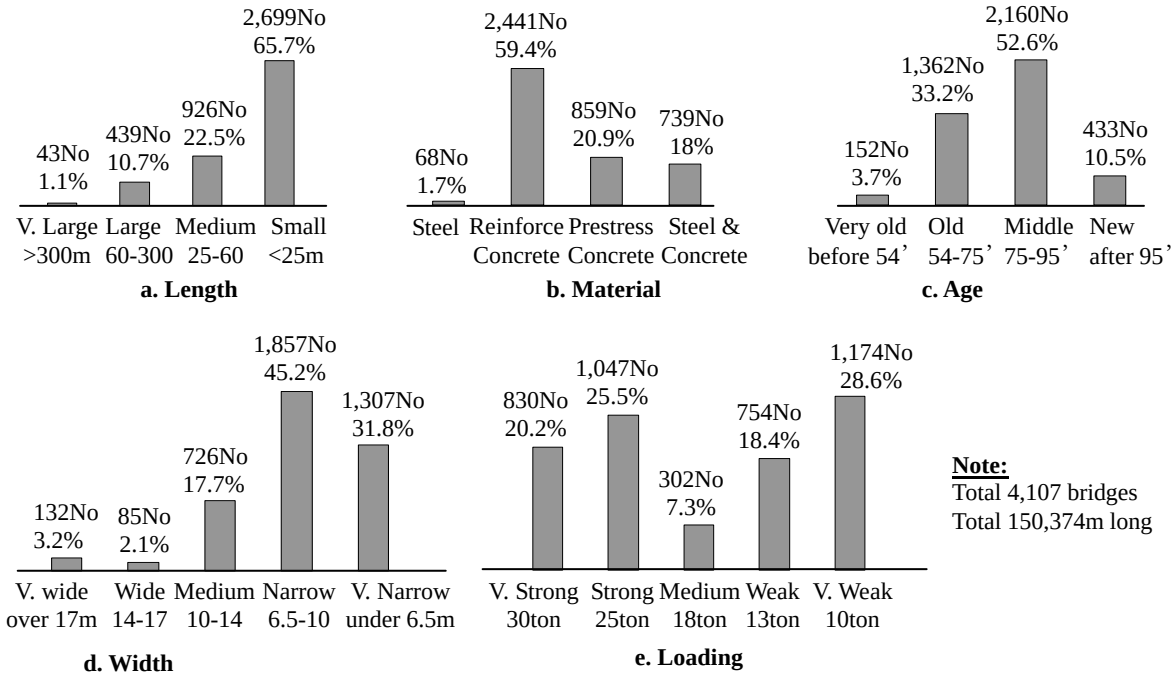


Fig. 1 Classification of existing highway bridges in Vietnam

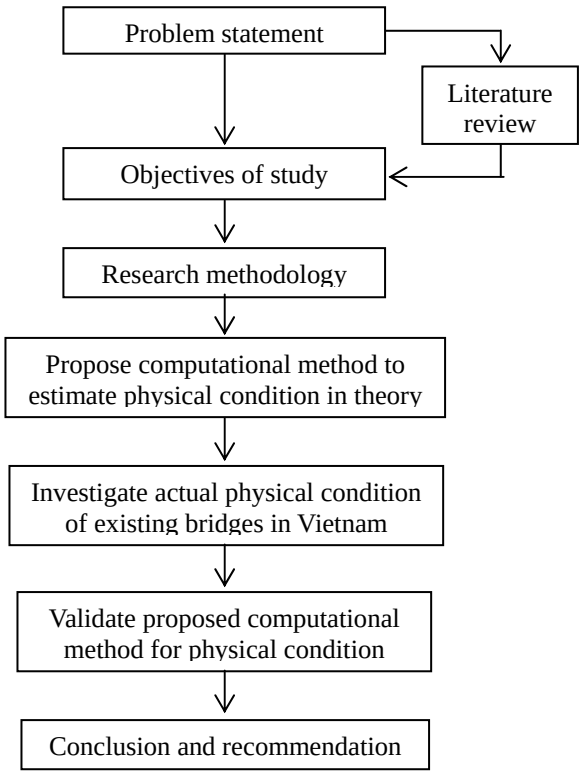


Fig. 2 Consecutive steps of the research

influence factors such as climate, traffic condition, premature aging and human invasion have not been included into this method.

3. RESEARCH METHODOLOGY

In order to obtain three objectives stated above, the research team follows consecutive steps as shown in Fig. 2. Firstly, an appropriate computational method is proposed to theoretically estimate the deterioration curve of bridge physical condition by the time. This curve is changeable for its shape, value and times in accordance with several uncertain external factors such as bridge location, the climate and

traffic volume. The theoretical curve is the subject of validation by using actual deterioration of existing bridges.

The data was collected from more than 60 highway concrete bridges located in Vietnam and scattered between mountains, deltas and coasts. The third author himself directly conducted preliminary visual inspections to identify current physical condition of these bridges. The author afterwards interviewed local personnel who are closely involved in managing and maintaining the inspected bridges in order to confirm findings from the preliminary inspection and to get further information on bridge quality and its deterioration. At the end, an actual deterioration of bridge physical condition is clearly plotted.

Validation of deterioration curve of bridge physical condition is an important step. It combines theory assumption and actual data in order to create a validated curve that most appropriate with actual deterioration of bridge quality for whole bridge population in the country. Thus, even the data is collected in limited numbers of bridges; the result of this paper can be applied for whole bridge population.

In this research, small concrete bridges are selected for analyzing actual and validated deterioration curves. It is because small concrete bridges are typical and majority among other groups of bridges in Vietnam and their data is available in previous research of the authors (Hai, 2006). In addition, the physical condition is the sole indicator chosen while other ones (e.g. load-carrying capacity and surface appearance) may be considered in future researches.

4. CURRENT STATUS OF SMALL CONCRETE BRIDGES IN VIETNAM

In general, highway bridges in Vietnam have a wide range of shapes, commissioning dates, and have been built by various different design standards. Some have been subjected to the impact of wars, the adverse climate, and poor maintenance and management conditions (TMoVN, 2002). Meanwhile, there are differences occurring from geographical locations due to scattering through mountains, deltas and coasts; and the climate as the northern area has four seasons (spring, summer, autumn and winter) and the southern area only has rainy and dry seasons.

Highway bridges are classified by the transport ministry of Vietnam in terms of their lengths, materials, construction time, deck widths and load-carrying capacities. They are mostly in the small and medium size categories, accounting for 65.7% and 22.5% of the total respectively. Concrete is the most common material used in construction as reinforced concrete and pre-stressed concrete bridges encompass 60% and 21% of all bridges. Many weak/very weak and narrow/very narrow bridges are still in service although they can definitely not satisfy the requirement of modern vehicles (trucks, trailers, buses, etc) where there is demand for 25 ton and 14m width normally. The data confirm 28.6% and 18.4% bridges in the 10 ton and 13 ton load-carrying capacities respectively. Meanwhile, 31.8% and 45.2% of bridges have traffic lanes less than 6.5m or from 6.5 to 10m width. The ages of highway bridges are in the medium range of 10 to 50 years with 52.6% bridges built in the period of 1975-1995 and 33.2% bridges built between 1954 and 1975.

5. ASSESSMENT METHOD FOR QUALITY DETERIORATION OF EXISTING BRIDGES

The research carries out surveys of limited number of existing concrete bridges, but wants to apply the theory result on whole bridge population of the country. Thus, theoretical assumption must be validated to make its conclusions appropriating with actual collected data. In this section, theoretical deterioration curve is firstly proposed by the authors. This curve will be compared with actual deterioration curve collected from 60 small concrete bridges in Vietnam in order to draw accurate practical factors. Finally, validated deterioration curve is concluded and appropriated with whole bridge population.

5.1 Theoretical Estimation for Bridge Quality

Although present performance of a specific bridge can be manually estimated by experience inspectors, it is not recommended for whole bridge population due to high costs and the time it would take. Thus, prediction of quality depreciation is suggested to perform bridge analysis with assistance of computer simulation. Physical condition encompasses *durability* as ability to resist deterioration and *surface appearance* which is defined from total damage, execution of works and serviceability.

This paper constructs its own method to predict physical condition for highway bridges in Vietnam. Theoretical assumptions were made to clarify for the method.

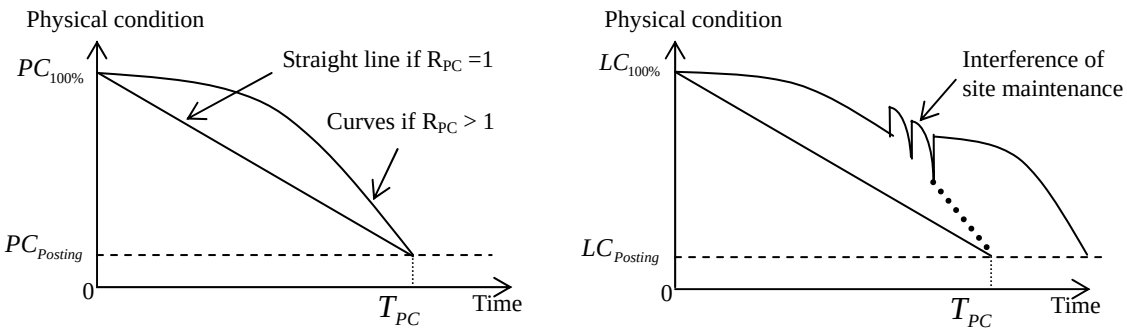


Fig. 3 Deterioration curves of bridge physical condition

- Deterioration of a bridge is drawn as integrated convex curves because deterioration processes rapidly with its age. Hai (2006) practically proposed Equation (1) to plot quality deterioration of existing bridges by the time to reflect specific local condition of Vietnam. Vertical axis represents the percentage remaining of physical condition (*PC*), while horizontal axes are for elapsed time (Fig. 3). R_{PC} (>1) is experimental constants depending on external conditions of the climate, traffic volume, etc. The value of R_{PC} decide the shape of the curve. *t* is the bridge age. $PC_{100\%}$ is the physical condition when newly-built bridge enters service. On the other hand, this value respectively is $PC_{Posting}$ for the bridge when being removed from service.

$$PC = PC(t) = (PC_{100\%} - PC_{Posting})[1-(\frac{t}{T_{PC}})^{R_{PC}}] + PC_{Posting} \quad (1)$$

- The deterioration curve starts from time 0 when newly-built bridge enters in service. At that time, the physical quality is in 100%. On the other hand, posting level is moreover set at the end of lifespan to remove the bridge from service. In general practice, the value of posting level is assumed to be 25% of totally new-built bridges.
- Site maintenance that has an influence on the physical condition of bridges is included in the deterioration prediction.

5.2 Actual Deterioration of Existing Bridges

Bridge physical condition (e.g. quality and surface appearance), by the time will be decreased under adverse impacts of the climate, traffic, material aging, human invasion, etc. The small concrete bridges in Vietnam are not in exception when their physical conditions timely deteriorate under attacks of surrounding environment. The data of bridge deterioration was collected from more than 60 small concrete bridges of highway network located in Vietnam and scattered between mountain, delta and coast. Preliminary visual inspections are conducted to identify current bridges' *durability* and *surface appearance*. The authors afterwards interviewed local personnel who are closely involved in managing and maintaining the inspected bridges in order to confirm findings from the preliminary inspection. A subsequent site inspection was carried out to reconfirm bridges' *durability* and *surface appearance*. Afterwards proposed levels of bridge physical condition are finally concluded to base on intuition, experience and current regulation in Vietnam. The actual deterioration curve is practically drawn in Fig. 4 in accordance with local data collected from 60 small concrete bridges in Vietnam.

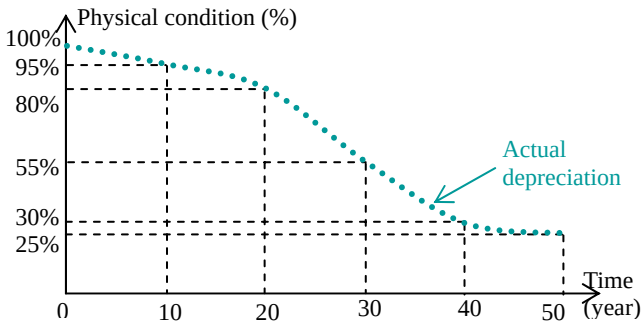


Fig. 4 Actual deterioration measured for small concrete bridges in Vietnam

5.3 Validated Estimation of Bridge Deterioration

The research found that there was a gap between actual deterioration and theoretical assumption. Thus, the assumed deterioration curve should be accurately validated to approach theoretical assumption as close as possible to actual condition. The practical factor is the R_{PC} used in Equation (1) depends on external conditions of traffic volume, climate, society, material used, etc. In this research, the authors try to identify most appropriate value of the practical factor R_{PC} by using the result of site inspection of 60 existing bridges. In the future, this factor must be independently surveyed and

decided by bridge authority or authorized agencies to reflect local conditions of bridges.

In this research, actual deterioration was collected within interval spans of 10 years. Based on the value of bridge quality at both end of time internals of 10 years and actual shape of the curves, the experimental factor R_{PC} is practically calculated from the Equation (1) to have values as shown below. The values indicated that the deterioration curve has been changed its shape by the time of 10 years. In order to be more accurate, bridge data can be collected within shorter time periods (e.g. 5 years or even 1 year). The authors plan this matter for future researches.

- Year 0-10: $R_{PC} = 1.082$
- Year 10-20: $R_{PC} = 1.142$
- Year 20-30: $R_{PC} = 1.664$
- Year 30-40: $R_{PC} = 1.790$
- Year 40-50: $R_{PC} = 0.980$

The difference from the value of the experimental constants R_{PC} (1.082, 1.142, 1.664, 1.790 and 0.980) for internal time of 10 years indicated that the deterioration curve changed its shape in these periods. In accordance with the Equation (1), the validated deterioration curve is manually drawn in Fig. 5. The computer simulation is automatically processed as well to plot the deterioration curves on the screen as shown in Fig. 6. Upon the result of deterioration curves are generated, field practitioners can use these in practice of maintenance and management for whole bridge population

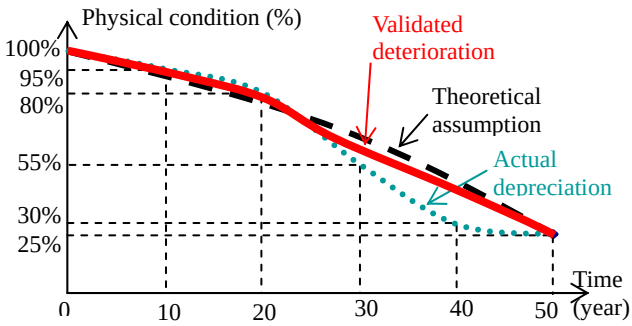
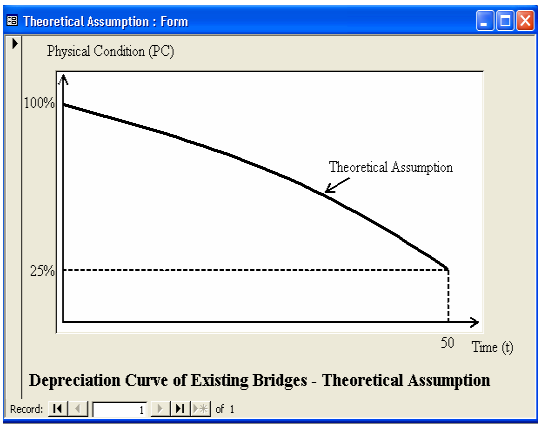
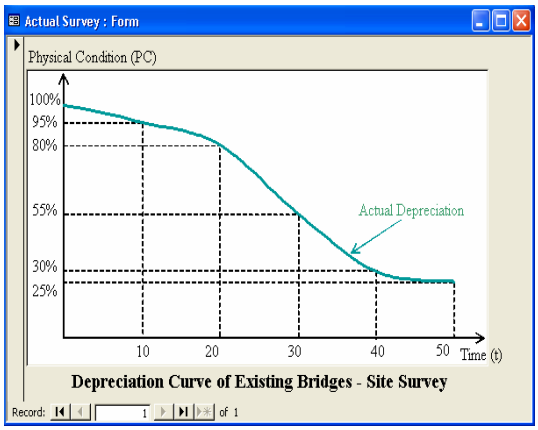


Fig. 5 Validated deterioration curve applied for small concrete bridges in Vietnam



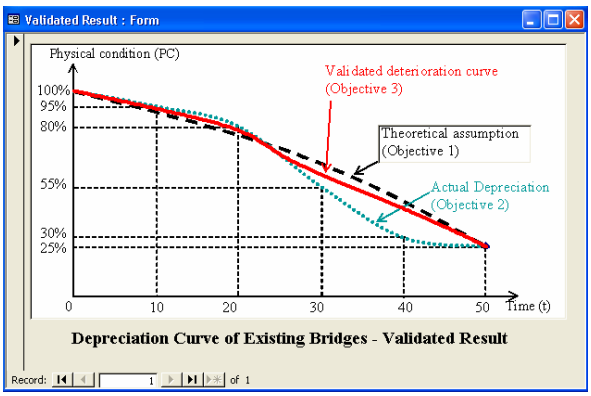
Step 1: Theoretical assumption

The deterioration curve is plotted in accordance with the equation (1)



Step 2: Actual deterioration

The deterioration curve is plotted in accordance with the actual collected data



Step 3: Validated and predicted depreciation curve

The deterioration curve is plotted in accordance with the actual collected data

Fig. 6 Computerized database for simulation of deterioration curve on small concrete bridges in Vietnam

The validated deterioration curve falls in between theoretical assumption and actual deterioration. The result indicates that in the first half of bridge life span from year 0 to year 25, deterioration of bridge quality is not much different between actual data and theoretical assumption. However, there is a big difference in the second half of bridge lifespan between years 25-50 as theoretical assumption shows faster quality depreciation than actual one. At this period of time when bridge quality fall under certain level, the authorities normally impose several restriction on these bridges to prevent them from reaching posting level. This is the reason to prove the difference as theoretical assumption is not taken this fact into prediction.

In the future research when data can be collected within shorter interval spans of 5 years or even 1 year, the validated curve will be much closer with actual deterioration or the result of computer simulation is more appropriating with the actual data. Moreover, several practical factors of the climate, materials used, society, etc., should be seriously considered to generate more accurate results of prediction and validation. This means the experimental constants R_{PC} should be carefully calculated to reflect local and social conditions of existing bridges.

6. CONCLUSIONS

This paper introduces a research to estimate physical condition of small concrete bridges in Vietnam. Three objectives are accomplished to:

- Propose a theoretical method in estimation of physical condition of typical small concrete bridges.
- Investigate actual deterioration of bridges in Vietnam throughout the time.
- Validate the proposed method for appropriating theoretical assumption with actual deterioration.

In addition, a computerized database is also introduced to systematically draw up deterioration curves of bridge physical condition. The research result has been pilot-tested since late 2005 for over 60 existing small concrete bridges in Vietnam. The accuracy of validated deterioration curve was undoubted evidence of its validation on actual condition for bridges in Vietnam. This is a very important aspect to feasible apply for Vietnam for managing and maintaining its bridges.

In order to full-scale practical application in Vietnam, the recommendation is to carry out further practical validations on various actual conditions of Vietnam. Necessary modification of the deterioration curves of bridge quality may be needed for several groups of bridges those differ from geographical condition, the climate, imposed traffic, society, and so on. The influence of practical factors into bridge quality should be considered too to accurately eliminate man-made errors of the estimation. Further research needs also to make the estimation of bridge quality more robust with better automatic functions throughout entire country for strategically information sharing and decision-making processes.

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