BRIDGE HYDRAULIC PROBLEMS IN MALAYSIA

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Abstract

In various studies conducted in the UK and the USA, bridge hydraulic effects have been identified as the main cause of bridge failure. Yet, bridge engineers tend to pay much more attention to the structural aspects of the design rather than hydraulic considerations. Malaysia experiences very high rainfall intensity, especially during the Monsoon months of December and January. Malaysia is thus not immune to problems caused by the flood water. The Public Works Department Malaysia (PWD) is the custodian of over 6,000 bridges in the country. The approach adopted by PWD in tackling bridge scouring problem has been based on the total quality concept which emphasizes design, surveillance and remedy. In design, hydrological calculations of the design storm and hydraulic design of the waterway are the main exercise. It is important to note that these calculations are at best an intelligent guess of the severity and frequency of the extreme flood event; and are subject to a lot of uncertainties. A good conceptual design of the bridge structure and the waterway is thus equally important. It is also important that an effective system of surveillance exists where potential or existing scouring problems are detected by the district engineers and then reported to the bridge experts in the headquarters for immediate actions. In remedial work, care must be exercised not to block the waterway with the proposed protective systems. This paper discusses PWD's approach to dealing with the bridge hydraulic problem in Malaysia. Common hydraulic defects in Malaysian bridges are discussed.

1.0 INTRODUCTION

In bridge design, two aspects are important: 1) hydraulic design and 2) structural design. Studies conducted in the UK and the USA had identified that bridge hydraulic effects have been the main cause of bridge failure [1,2]. Yet, bridge engineers tend to pay much more attention to the structural aspect of the design rather than hydraulic considerations. Malaysia experiences very high rainfall intensity, especially during the Monsoon months of December and January. Flooding is very common during this period of time. In Malaysia, bridge failure due to structural damage is very rare. Reports of bridge failures, which from time to time hit the headlines in the mass media, are very often caused by the over-topping of the bridge deck or wash-out of embankment during major floods. These failures often result in disruption to traffic and in one incident, the loss of lives.

The responsibility of managing and maintaining Malaysian public roads lies in the hand of Public Works Department Malaysia (PWD). Recent annual bridge inspection exercise recorded an inventory of over 6,000 bridges along the Federal routes. The approach adopted by PWD in tackling bridge hydraulic problems has been based on the total quality concept where equal emphasis has been placed on design, surveillance and remedial actions.

2.0 PWD PRACTICES IN HYDRAULIC DESIGN

Bridges or culverts may fail due to [3]:

i. inadequate flow capacity leading to over-topping of the bridge deck or the approach embankments
ii. increased loading on the structure from water, sediment or debris
iii. failure of the foundations or supports as a result of bridge scouring

A straight-forward solution to the first problem is to provide adequate bridge opening. Conceptually, this would involve the determination of the design discharge Q_{des} and the flow capacity Q_{cap} and the satisfaction of the following equation:

$$Q_{des} \leq Q_{cap}$$

Design discharge can be estimated based upon either stream flow or rainfall records [4]. In order to use stream flow information a sufficient length of records must be available for the catchment in question or for other similar types of catchments. In Malaysia, guidelines for the procedures are contained in a series of documents published by the Drainage and Irrigation Department (DID) under the Ministry of Agriculture [5]. PWD considers a 100-year design storm for bridge design and a 50-year storm for culvert design. A 100-year storm is one which occurs on average once every 100 years. We say that the storm has a *return period* of 100 years.

To counter the second problem would require that sufficient *freeboard* (that is, the vertical clearance between the highest water level and the soffit level of the bridge deck) be provided. PWD often uses a value in the range of 0.3m - 1.0m; the lower value for channels which are not expected to have any debris or floating logs. Where debris or floating logs are likely, besides providing bigger clearance, the force exerted by the debris or logs on the piers must be catered for in the design of piers. The standard PWD practice [6,7] was to consider a force exerted on a minimum depth of 4 feet of debris.

The length of debris to be applied for any one pier shall be one half of the sum of the adjacent spans. As for the floating logs the force shall be calculated based on the assumption that the log weighs 2 tons, and travels at normal stream velocity. The log shall be assumed to be stopped in a distance of 12 inches for timber piers, 6 inches for column type concrete piers and 3 inches for solid type concrete piers.

The third problem, scouring, is the removal of stream bed material by stream or tidal currents. Scour can be classified as *local scour* which takes place in localized area around the pier, or as *general scour* which happens around the bridge crossing over the entire channel. It is plausible that if the scour depth can be estimated then necessary protection can be provided for. Although various methods are available for the estimation of scour depth (for example, reference [8]) it is not a common practice in PWD to estimate the scour depth for short and medium span bridges. It is the department's standard practice to use only piled foundations for bridges which has indeed saved many of our bridges from stability problem caused by local scouring.

Two JICA studies [9,10] have found many "hydraulic defects" in Malaysian bridges. They are summarized as below:

i. Inadequate bridge opening
ii. Inadequate slope protection around the abutments
iii. Unsuitable bridge siting at sharp bends
iv. Piers skewed to river flow
v. Obstacles like old bridge piers remain under the bridge
vi. Floating logs or debris not removed
vii. River sand mining activities near the bridge sites

These "defects" have their root causes in the design as well as maintenance. It is important to note that the hydrological calculations in design are at best an intelligent guess of the severity and frequency of the extreme flood event. Also, the hydraulic calculations of the stream flow rely on many site specific information which are subject to a lot of uncertainties. No doubt, uncertainties abound in all natural phenomena; and all engineering designs have to live with uncertainties. But, the uncertainties found in the prediction of hydraulic effects far exceed that in, say, the prediction of load effects due to vehicular loads. As such, although it is still necessary that hydraulic design calculations be carried out, a good conceptual design of the bridge structure and the waterway is also called for.

In this respect, PWD is adopting the following DID's recommendations:

i. the bridge structure should cross the river in perpendicular
ii. abutments should not be inside the waterway
iii. the number of piers in the river should be minimized
iv. the piers should as far as possible be of oval shape
v. the pile caps should be buried

Apparently, these recommendations aim to reduce any obstruction to the water flow.

3.0 BRIDGE INSPECTION

In addition to predicting and taking necessary measures to prevent any adverse hydraulic effects during the design stage it is also important that a system of surveillance exists for identifying any hydraulic problems in existing bridges and to timely report it to the headquarters for immediate remedial actions. In Malaysia, the PWD district offices have traditionally been inspecting bridges and culverts after each flood season. Starting in 1995 the inspection exercise has been expanded to include condition survey and became mandatory [11]. The inspection is essentially visual and involves assigning a numerical rating to each bridge component to indicate its condition. A rating of 1 is given to the best condition while 5 represents the other extreme [12]. Any hydraulic defects would be indicated as a rating of 4 or 5 under slope protection or pier (see the check list in Fig. 1). Descriptions of the damages and proposed maintenance activities are accordingly filled out in the inspection checklist.

Bridge Components	**Ratings**		**Damages**	**Maintenance**
	Old	**New**		
...				
Slope Protection				
Pier				
etc.				

Fig. 1 Inspection checklist

The annual mandatory bridge inspection would be able to detect erosion problems in the approach embankment (slope protection around the abutment) but to detect any scouring problems require more specialized knowledge and techniques. Wherever necessary the department would engage specialist divers to carry out underwater inspection. It is a pity that divers who have bridge engineering background are not easily available in this country.

4.0 REMEDIAL ACTIONS

We have discussed important considerations during the design stage <u>before the bridge is constructed</u>. We have also discussed the need to have a system of inspection and reporting such that hydraulic defects of <u>existing bridges</u> are detected at the sites and reported to the bridge engineers at the headquarters. To ensure total quality in bridge stability against adverse hydraulic effects requires that appropriate remedial actions be taken to rectify the defects.

Many text books have discussed various remedial actions or countermeasures for hydraulic defects. They are summarized and categorized as below:-

i. Replacement of the bridge
ii. Modification of the bridge
iii. Replacement of scoured material
iv. Armor
v. Flow control

Reconstruction of the bridge with due considerations to the hydraulic requirements is obviously very effective. However, it is very costly in terms of the construction cost and also disruption to the traffic. Modifications of the bridge include altering the foundation, addition of extra piles, underpinning and construction of relief culverts. Replacement of scoured material involves placement of erosion resistant material such as crushed stones to replenish the wash-out material. Common materials used are ripraps of crushed aggregates. A word of caution is in order: the placement of the materials had to be properly carried out. Otherwise, the replaced materials may obstruct the flow of water and aggravate the situation. Armor refers to the revetment to protect the substructure or the river bank. Common armors used are gabions, ripraps, grouted ripraps, bagged concrete, sand bags, precast concrete blocks. Flow control is an effective way to overcome the hydraulic problems by training the river to flow using structures like spur dikes or sheet piles.

All the above countermeasures except spur dikes had been used by PWD Malaysia. A summary of some of the projects undertaken by the department is presented in Table 1. The department tends to favour using a flexible revetment systems (for example, the sand bags) rather than the rigid revetment systems like concrete blocks. In the case of Sg. Plentong, a number of protective systems had failed to work in separate efforts. The department is contemplating doing some river training work as a long term solution.

5.0 CONCLUSIONS

This paper has discussed the hydraulic problems in Malaysia and the approach adopted by Public Works Department (PWD) Malaysia to tackle them. The approach adopted by PWD in tackling these problems has been based on the total quality concept which emphasizes design, surveillance and remedy. In design, hydrological calculations of the design storm and hydraulic design of the waterway are the main exercise. It is important to note that these calculations are at best an intelligent guess of the severity and frequency of the extreme flood event; and are subject to a lot of uncertainties. A good conceptual design of the bridge structure and the waterway is thus equally important. It is also important that an effective system of surveillance exists where potential or existing scouring problems are detected by the district engineers and then reported to the bridge experts in the head-quarter for immediate actions. In remedial work, care must be exercised not to block the waterway with the proposed protective systems.

Table 1 PWD Cases of Bridge Hydraulic Problems

River Names	Defects/Problems	Countermeasures
Sg. Semiar, Kedah	Twin-pipe culvert washed out	Replacement with a bridge
Sg. Plentong, Johor	General and local scour; earlier protection work washed out	Armor using gabions, sheetpiles and precast concrete interlocking blocks
Sg. Pukin, Pahang	General and local scour	Armor using precast concrete interlocking blocks
Sg. Trolak, Perak	Collapse of approach embankment	Reconstruction of approach embankment using RE system with gabions
Sg. Keratong, Pahang	General and local scour	Gabions and sand bags (proprietary products)
Sg. Buloh, Selangor	Pier on footing scoured and settled	Replacement with a bridge
Sg. Salor, Kelantan	General and local scour	Armor using sand bags (proprietary products)
Sg. Geliga, Terengganu	General and local scour	Underpinning and replacement with a bridge

6.0 REFERENCES

1. Smith, D. W., "Why Do Bridges Fail?" Civil Engineering, ASCE, Nov., 1977.

2. Byers, W. G., "Frequency of Railway Bridge Damage," Structural Engineering, ASCE v3, n8, Aug. 1985.

3. Riddell, John, "Introduction and Bridge Hydraulics," Advice notes for Short Course on Hydraulic Stability of Bridges organized by Coastal & Offshore Engineering Institute, Universiti Teknologi Malaysia, 15-16 Sept. 1997.

4. Flavell, D. J., "Waterway Analysis for Bridges, Culverts and Flood-Crossings and Bridge Protection Works," pp. 2-5, Reference Papers Volume 2 for Road Engineering Course 1982 arranged by The National Association of Australian State Road Authorities.

5. Ministry of Agriculture, A series of hydrological procedures which include but not limited to HP #1 (Estimation of the Design Rainstorm), HP #4 (Magnitude and Frequency of Floods in Peninsular Malaysia), HP #5 (Rational Method of Flood Estimation for Rural Catchments in Peninsular Malaysia), HP #11 (Design Flood Hydrograph Estimation for Rural Catchments in Peninsular Malaysia) and HP #16 (Flood Estimation for Urban Areas in Peninsular Malaysia).

6. Public Works Department Malaysia, "Bridge Loading," Lecture notes for Bridge Design Course organized by Bridge Unit, Design & Research Branch, 1982.

7. Public Works Department Malaysia, "Chapter 6 Pier" Buku Panduan Rakabentuk Jambatan (Bridge Design Guide), 1985.

8. Victor, Johnson D., *Essentials of Bridge Engineering*, 3rd Ed. Mohan Primlani, Oxford & IBH Publishing Co., 1980.

9. Japan International Cooperation Agency and Public Works Department Malaysia, *The Study on the Standardization of Bridge Design in Malaysia* Final Report, Volume II, Main Report, Aug. 1996.

10. Japan International Cooperation Agency and Public Works Department Malaysia, *The Study on the Maintenance and Rehabilitation of Bridges in Malaysia* Final Report, Volume II, Main Report, Oct. 1992.

11. Yusof, N. M., "Annual Mandatory Bridge Inspection: Results and Findings," International Seminar on Bridge Engineering and Management, Jakarta, Indonesia, Sept. 10-13, 1996.

12. Public Works Department Malaysia, Annual Bridge Inspection Manual, Mar. 1995.