UNIVERSITI PUTRA MALAYSIA

LOCAL SCOUR AT COMPLEX BRIDGE PIERS

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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The prediction of scour depths at bridge piers is a necessary input to the design of the pier foundations. Local scour around bridge foundations is one of the most significant causes of bridge failures. Many studies about local scour around bridge piers have been conducted, but because of difficulties in understanding the nature of flow and scour mechanisms around bridge foundations there remain problems in scour prediction. The main objective of this study is to investigate the local scour at different selected complex piers in the laboratory and to use the collected data for validation of the existing methods for estimation of local scour around complex pier. In addition, the isolated components of complex piers effect on local scour were quantified for each model too.

In this study, a methodology for estimating equilibrium local scour depths at complex pier under clear-water conditions at threshold flow intensity is used. This application of the methodology is limited to bridges that are composed of up to three components namely column, pile cap and pile group. All of the components are exposed to the approaching flow.

The experimental procedure has been conducted for five selected complex piers from existing bridges in Malaysia to investigate the effect of complex pier shape on local scour. Cohesionless uniform sediment with the mean particle sizes, d_{50}=0.23 mm was used in all the experiments. Flow parameters such as discharge, depth and velocity measured by using an Area Velocity Model (AVM). Apart from the shape of complex piers, the other parameters such as flow intensity, flow depth, sediment size, alignment or angle of attack were kept constant during the experimental procedures.

In base of measured data in this study total scour depth of all components of each model is greater than of complex pier. The scour depths measured in the laboratory show among these selected models, model number 3 and 4 have the lower scour depth. In the

other words, these two models have the optimum shapes of complex pier compared with the others. The measured values of local scour were compared to compute values obtained from Federal Highway Administration (Hydraulic Engineering Circular No. 18, HEC-18), Florida Department of Transportation (FDOT) and Coleman methods for complex piers. The results show that for predicting local scour at selected complex pier bridges in the same experimental condition, HEC-18 methodology is recommended.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KEROKAN TEMPATAN DI TIANG SAMBUT KOMPLEKS JAMBATAN

Oleh

MAHBOUBEH NAJAFZADEH

March 2014

Pengerusi: Prof. Thamer Ahmed Mohamed, PhD

Fakulti: Kejuruteraan

Ramalan kedalaman kerokan di tiang sambut adalah input yang diperlukan untuk reka bentuk asas tiang sambut. Kerokan tempatan di sekitar asas jambatan adalah salah satu punca yang paling signifikan terhadap kegagalan jambatan. Banyak kajian mengenai kerokan tempatan di seluruh tiang sambut jambatan telah dijalankan, tetapi kerana kesukaran dalam memahami sifat aliran dan mekanisma kerokan di sekitar asas jambatan, masalah dalam ramalan kerokan dikekalkan. Objektif utama kajian ini adalah untuk mengkaji kerokan tempatan di tiang sambut kompleks yang berbeza yang telah dipilih di dalam makmal dan untuk menggunakan data yang telah dikumpulkan bagi mengesahkan kaedah yang sedia ada dalam menganggar kerokan tempatan di sekitar tiang sambut kompleks. Di samping itu, kesan komponen terasing pada tiang sambut kompleks di kerokan tempatan juga dikira untuk setiap model. Dalam kajian ini, suatu kaedah bagi menganggarkan keseimbangan kedalaman kerokan tempatan di tiang sambut kompleks di bawah keadaan air-jernih di paras ambang keamatan aliran digunakan. Aplikasi metodologi ini adalah terhad kepada jambatan-jambatan yang terdiri daripada tiga komponen iaitu tiang, topi cerucuk dan kumpulan cerucuk. Semua komponen adalah terdedah kepada pergerakan aliran. Proses ujikaji telah dijalankan untuk lima tiang sambut kompleks yang dipilih dari jambatan-jambatan sedia ada di Malaysia bagi mengkaji kesan bentuk tiang sambut kompleks terhadap kerokan tempatan. Sedimen tidak berjeleket seragam dengan purata saiz partikel, d_{50} = 0.23 mm telah digunakan dalam semua eksperimen. Parameter aliran seperti kadar alir, kedalaman dan halaju diukur dengan menggunakan Area Velocity Model (AVM). Selain dari bentuk tiang sambut kompleks, parameter lain seperti keamatan aliran, kedalaman aliran, saiz sedimen, penjajaran atau sudut serangan adalah malar semasa proses uji kaji. Pada dasarnya pengukuran data dalam kajian ini jumlah kedalaman kerokan dari semua komponen pada setiap model adalah lebih besar daripada tiang sambut kompleks. Kedalaman kerokan yang diukur dalam makmal menunjukkan di antara model-model yang telah dipilih, model nombor 3 dan 4 mempunyai kedalaman kerokan yang lebih rendah. Dalam kata lain, kedua-dua model ini mempunyai bentuk

tiang sambut kompleks yang optimum berbanding dengan yang lain. Nilai-nilai kerokan tempatan yang telah diukur dibandingkan dengan nilai-nilai kiraan yang diperolehi daripada Pentadbiran Persekutuan Lebuh Raya (Pekeliling Hidraulik Kejuruteraan No 18, HEC-18), Jabatan Pengangkutan Florida (FDOT) dan kaedah Coleman untuk tiang sambut kompleks. Keputusan menunjukkan bahawa untuk meramalkan kerokan tempatan di tiang sambut kompleks jambatan yang telah dipilih pada keadaan eksperimen yang sama, metodologi HEC-18 adalah disyorkan.

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The experiments were conducted in the hydraulic laboratory in National Hydraulic Research Institute of Malaysia (NAHRIM) which these supports are strongly appreciated. The experiments were carried out with the prodigious help of hydraulic laboratory staff at NAHRIM to whom I express my gratitude.

APPROVAL

I certify that a Thesis Examination Committee has met on 31 March 2014 to conduct the final examination of Mahboubeh Najafzadeh on her thesis entitled " Local Scour at Complex Bridge Pier" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Master of Science. Members of the Supervisory Committee were as follows:

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a	pier width
a^*_{pg}	equivalent full depth pile group
a_{proj}	sum of non-overlapping projected widths of piles
b	width of pile cap
B	pier projection width
b^*_{pg}	width of a full depth solid pier that would yield the same scour depth as the full depth pile group
b_c	width of column component at complex pier
b_e	equivalent cylindrical pier diameter relative exposure of the column, pile-cap and pile-group elements
b_{pc}	width of pile cap component at complex pier
D	diameter of cylindrical pile
D*	effective diameter for complex pier components
d_{50}	median sediment size
D_e	the equivalent diameter of the nonuniform pier
f_{cb}	extension length of pile cap face out from column face
f_{cl}	extension length of pile cap face out from column face
f_{pb}	extension length of pile cap face out from nearest pile centerline
f_{pl}	extension length of pile cap face out from nearest pile centerline
K	correction factors for specific conditions
K_1	correction factor for pier nose shape
K_2	correction factor for angle of attack of flow
K_3	correction factor for bed condition
K_4	correction factor for armoring by bed material size
K_D	sediment size factor
K_h	pile group height adjustment factor
K_{hpg}	the height factor for pile group at complex piers
K_I	flow intensity factor
K_m	coefficient for number of aligned rows
Ks	foundation shape factor
K_{Smn}	correction factor for spacing at exposed pile group arrangements
K_{sp}	coefficient for pile spacing
K_t	time factor
K_{yb}	flow depth-pier size factor (dimension of length)
L_{pc}	length of pile cap in line with flow
L	length of pier
l_c	length of column component at complex pier
m	number of pile in line with flow
n	number of piles normal to the flow
N	number of data
Q	flow rate
s	distance between centerlines of adjacent piles in a pile group
s_m	distance between centerlines of adjacent piles in line with the flow in a pile

	group
s_n	distance between centerlines of adjacent piles perpendicular to the flow in a pile group
s_g	ratio of sediment density to the density of water ρs / ρ
T	pile cap thickness
V	mean depth averaged velocity
V_c	critical depth averaged velocity
W_p	projected width of the piles in the pile group
W_{pi}	projected width of a single unobstructed pile
y_s	equilibrium scour depth
μ	dynamic viscosity of water
ν	kinematic viscosity of water
ρ	mass density of water
ρ_s	mass density of sediment mineral
σ	measure of the sediment gradation
τ	stream bed shear stress
τ_c	critical stream bed shear stress
τ_u	upstream bed shear stress
τ_0	maximum bed shear stress in local scour hole

CHAPTER 1

INTRODUCTION

1.1 Background

Bridges are important in the today`s society since they are essential in the transport network. It is a construction built to provide a way through across a valley, water body, road and other physical obstruction. Studies have been conducted from the late 1950s and they have focused on a scour on bridge piers. Despite these studies, problems still exist as a result of difficulties in an understanding of the complicated flow and scouring mechanisms coupled with complex bridge geometries and the erodible nature of building materials like gravel, sand and clay.

Apart from their relevance in the existing bridges, they are also vital in the new bridges` safe design. Researches for many years focused on understanding better the scouring mechanism, methods of scour prediction and bridge scour measurements (Alabi, 2006). In spite of experimental and numerical researches focused on the determination of the behavior of rivers and quantifying the scours equilibrium depth, researchers still have interest gaining a basic understanding of the scour mechanism.

Many studies conducted for determination of scour depth, y_s, around bridge piers. Most of them have been on bridge piers having a uniform cross section (Melville and Sutherland 1988; Raudkivi and Ettema 1983; Hannah 1978). Due to geotechnical and economical reasons complex piers became the popular bridge designs (Melville and Coleman 2000; Coleman 2005; (Ataie-Ashtiani and Beheshti 2006)). Figure 1.1 shows the components of complex piers. The complex pier is made of column, pile cap and pile group.

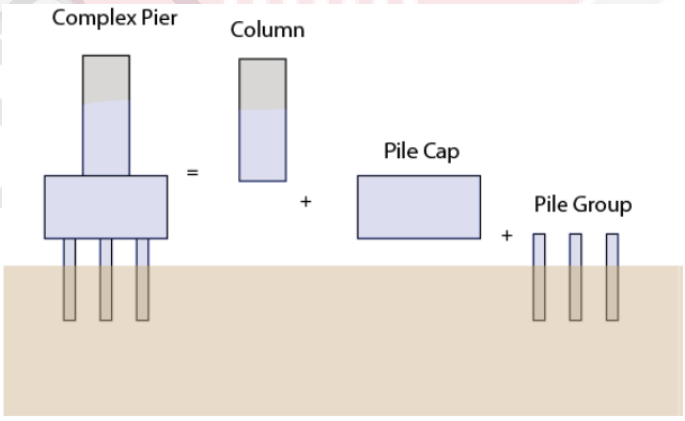

Figure 1.1. Complex Pier Components (Jones and Sheppard 2004)

1.2 Problem Statement

Hydraulic effects are the main causes of bridge failure as per recent research results. Bridge engineers focus on the design structural aspects rather than considering the hydraulic effects. Higher rainfall intensities are usually experienced in Malaysia during the December and January monsoons. Because of this Malaysia is not immune to flooding problems.

The Malaysian Public Works Department (PWD) is the custodian of more than 6000 bridges in the country. PWD`s approach in handling bridge scour problems is based on quality designs, surveillance and remedy. Regarding design, hydrological computations of the design storm and hydraulic design of the water represent the main exercise.

Cases of bridge hydraulic problems are presented in Table 1.1. As is indicated in this table, the main cause of bridge failure is scouring not the structural problems. Numerous experimental studies for bridge pier scour have been conducted, but most of them are based on the experiments have been done for simple bridge geometry or used typical types of complex piers not the actual ones. In this study, local scour at scale-down size of actual models of complex piers in Malaysia were investigated. Results presented in this experimental study will improve the method of calculating local scour at bridge piers and increase the safety of bridge against local scour.

1.3 Objectives

The main objective of the study is to determine the effect of complex pier with different shapes on local scour. The specific objectives of the study are:

1. To investigate the scour depths at each component of the complex pier models.

2. To investigate the effects of each components of complex pier on local scour

3. To evaluate several exciting methodologies for computing local scour depth at complex pier.

Table 1.1 PWD Cases of Bridge Hydraulic Problems (Ng and Razak 1998)

River Names	Defects/Problems	Countermeasures
Sg. Semiar, Kedah	Twin-pipe culvert washed out	Replacement with a bridge
Sg. Plenton g, Johor	General and local scour; earlier protection work washed out	Armor using gabions, sheet piles 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

1.4 Scope and Limitation of the Study

Recently, researches have focused in local scour at complex piers. In their studies typical types of complex piers are utilized instead of the actual ones. So, this study investigates the local scour at scale-down sizes of selected existing complex piers in Malaysia. In this research the effect of shapes of complex piers on local scour was studied. Other parameters such as sediment size, flow intensity, sediment gradation, alignment, channel arrangement and time are not effective under the following local scour conditions:

- $V/V_c \approx 1$, that is, the threshold condition
- $B/d_{50}>50$ that is , coarse sediment
- $\sigma_g<1.3$, that is, uniform sediment
- $\theta=0^o$ (90^o) , that is, aligned piers
- Rectangular channels
- Equilibrium scour

REFERENCES

Alibi, P.D. (2006). Time Development Of Local Scour At A Bridge Pier Fitted with A Collar. Master thesis. Department of Civil and Geological Engineering, University of Saskatchewan, Saskatchewan, Canada

Amini, A., Melville, B., Ali, T., and Ghazali, A. (2011). "Clear-Water Local Scour around Pile Groups in Shallow-Water Flow." Journal of Hydraulic Engineering 138(2): 177-185.

Ansari, S.A., Kothyari, U.C. and Ranga Raju, K.G. 2002. Influence of cohesion on scour around bridge piers. Journal of Hydraulic Research, IAHR, 40(6): 717-729.

Ataie-Ashtiani, B. and A. A. Beheshti (2006). "Experimental investigation of clear-water local scour at pile groups." Journal of Hydraulic Engineering 132(10): 1100-1104.

Beheshti, A. A. and B. Ataie-Ashtiani (2010). "Experimental study of three-dimensional flow field around a complex bridge pier." Journal of Engineering Mechanics 136(2): 143-154.

Bozkus, Z. and O. Yildiz (2004). "Effects of inclination of bridge piers on scouring depth." Journal of Hydraulic Engineering 130(8): 827-832.

Breusers, H. N. C., G. Nicollet, et al. (1977). "local scour around cylindrical piers." Journal of Hydraulic Research 15(3): 211-252.

Chabert, J. and Engeldinger, P. 1956. Etude des affouillements autour des piles de points (Study of scour at bridge piers). Bureau Central d'Etudes les Equipment d'Outre-Mer, Laboratoire National d'Hydraulique, France.

Cheremisinoff, N.P. and Cheng, S.L. 1987. Hydraulic mechanics 2. Civil Engineering Practice, Technomic Publishing Company, Inc., Lancaster, Pennsylvania, U.S.A. 780 p.

Chiew, Y.M. and Melville, B.M. 1987. Local scour around bridge piers. Journal of Hydraulic Research, IAHR, 25(1): 15-26.

Coleman, S. E. (2005). "Clear water local scour at complex piers." Journal of Hydraulic Engineering 131(4): 330-334.

Dargahi, B. (1990). "Controlling Mechanism of Local Scouring." Journal of Hydraulic Engineering 116(10): 1197-1214.

Dey, S. 1997. Local scour at piers, part 1: A review of development of research. International Journal of Sediment Research, IJSH, 12(2): 23-46.

Dey, S. 1999. Time-variation of scour in the vicinity of circular piers. Water & Maritime Engineering Journal, Proceedings of the Institution of Civil Engineers, Thomas Telford Journals, London, 136(2): 67-75, Paper 11426, June.

Ettema, R. (1980). Scour at Bridge Pier. Rep.No.216, School of Engineering, University of Auckland, Auckland

Fotherby, L.M. and Jones, J.S. 1993. The influence of exposed footings on pier scour depths. Proceeding of Hydraulics Conference, ASCE, New York: 922-927.

Franzetti, S., Larcan, E. and Mignosa, P. 1982. Influence of tests duration on the evaluation of ultimate scour around circular piers. International Conference on the Hydraulic Modelling of Civil Engineering Structures, Organised and Sponsored by BHRA Fluid Engineering, University of Warwick, Coventry, England, September 22- 24, 16 p.

Grimaldi, C., R. Gaudio, et al. (2009). "Control of Scour at Bridge Piers by a Downstream Bed Sill." Journal of Hydraulic Engineering 135(1): 13-21.

Hannah, C. R. (1978). Scour at Pile Groups. Research Report No. 28-3, Civil Engineering Department, University of Canterbury, Christchurch, New Zealand

Heidarpour, M., Khodarahmi, Z. and Mousavi, S.F. 2003. Control and reduction of local scour at bridge pier groups using slot. Proceedings, XXX IAHR Congress, Thessaloniki, Greece, August 24 - 29, 7 p.

Hoffmans, G.J.C.M. and Verheij, H.J. 1997. Scour manual. A.A. Balkema, Rotterdam, Netherlands, 205 p.

Jones, J. S. and D. M. Sheppard (2004). Scour at wide bridge piers, Minneapolis, MN.

Jones, J.S. and Sheppard, D.M. (2000). Local Scour at Complex Pier Geometries. Joint Conference on Water Resources Engineering and Water Resources Planning and Management, ASCE, July 30 – August 2, 2000, Minneapolis, Minnesota, U.S., 10 p.

Lagasse, P.F., Zevenbergen, L.W., Schall, J.D. and Clopper, P.E. 2001. Bridge scour and stream instability countermeasures: Experience, selection, and design guidelines. FHWA NHI 01-003: Federal Highway Administration, Hydraulic Engineering Circular No. 23, 2nd ed., U.S. Department of Transportation, Washington, D.C.

Laursen, E.M. and Toch, A. 1956. Scour around bridge piers and abutments. Iowa Highway Research Board, Bulletin # 4, Bureau of Public Roads, Iowa.

Lee, S. O. and T. W. Sturm (2009). "Effect of sediment size scaling on physical modeling of bridge pier scour." Journal of Hydraulic Engineering 135(10): 793-802.

Lu, J. Y., Z. Z. Shi, et al. (2010). "Temporal variation of scour depth at nonuniform cylindrical piers." Journal of Hydraulic Engineering 137(1): 45-56.

Mashair, M.B., Zarrati, A.R. and Rezayi, A.R. 2004. Time development of scouring around a bridge pier protected by collar. 2nd International Conference on Scour and Erosion, ICSE-2, Singapore, 8 p.

Melville, B.W. and Coleman, S.E. 2000. Bridge scour. Water Resources Publications, LLC, Colorado, U.S.A., 550 p.

Melville, B. W. and Y. M. Chiew (1999). "Time scale for local scour at bridge piers." Journal of Hydraulic Engineering 125(1): 59-65.

Melville, B. W. and A. J. Raudkivi (1996). "Effects of foundation geometry on bridge pier scour." Journal of Hydraulic Engineering 122(4): 203-209.

Melville, B. W. and A. J. Sutherland (1988). "Design method for local scour at bridge piers." Journal of Hydraulic Engineering 114(10): 1210-1226.

Nadzri, A.M. (2011). Effects of Pier Alignment on Scouring Depth. Master research. Department of Civil Engineering, University of Putra, Malaysia

Nazariha, M.(1996). Design Relationship for Maximum Local Scour Depth for Bridge Pier Groups. Ph.D. Thesis, University of Ottawa. Ottawa, Canada

Ng, S. K. and Razak R.A. (1998). Bridge Hydraulic Problems in Malaysia. Proceedings of the 4th International Seminar on Bridge and Aqueducts 200. Mumbai, India

Oliveto, G. and W. H. Hager (2005). "Further results to time-dependent local scour at bridge elements." Journal of Hydraulic Engineering 131(2): 97-105.

Raudkivi, A. J. and R. Ettema (1983). "Clear-Water Scour at Cylindrical Piers." Journal of Hydraulic Engineering 109(3): 338-350.

Richardson, E.V. and Davies, S.R. 1995. Evaluating scour at bridges. Rep. No. FHWAIP- 90-017 (HEC 18), Federal Administration, U.S. Department of Transportation,Washington, D.C.

Salim, Mohammad. and J. Sterling Jones, 1999,"Scour Around Exposed Pile Foundations" Proceedings of the ASCE North American Water and Environment Conference; Anaheim, CA

Shen, H., and Schneider, V. (1969). Local Scour around Bridge Piers. Journal of the Hydraulics Division, 95 (6), 1919-1941

Sheppard, D. M., M. Odeh, et al. (2004). "Large scale clear-water local pier scour experiments." Journal of Hydraulic Engineering 130(10): 957-963.

Sheppard, D. M., and Renna, R. (2005). Bridge Scour Manual. Florida Department of Transportation, 605 Suwannee Street, Tallahassee, Florida

Simarro, G., C. Fael, et al. (2011). "Estimating Equilibrium Scour Depth at Cylindrical Piers in Experimental Studies." Journal of Hydraulic Engineering 137(9): 1089-1093.