UNIVERSITI PUTRA MALAYSIA

MODELING OF CLEAR-WATER CONTRACTION SCOUR FOR AN ABUTMENT BRIDGE IN A COMPOUND CHANNEL

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PEZHMAN TAHEREI GHAZVINEI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

January 2014

This thesis is dedicated to my lovely wife and inspiring parents
for their endless support, and encouragement.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for degree of Doctor of philosophy

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January 2014

Chair: Prof. Thamer Ahmed Mohammad Ali, PhD

Faculty: Engineering

Bridge collapse has dramatic consequences in transportation system. Besides losing of life, disruption in service results tremendous effects on the economic growth of the countries. Contraction scour is a common and major cause of bridge failure. Designing the bridge foundation safely needs an accurate estimation of scour depth, underestimation may lead to bridge failure while over estimation will lead to excessive construction cost. Abutment bridges most commonly are used for bridges overcomparatively small channels. Reliability, strength and economy are the main reasons to increase concerning in Abutment Bridges. Commonly, in the compound channels, Abutment Bridgesare protrudedinto the main channel. Consequently, contraction scour expands in the main channel. Prior design approaches treated abutments as being solid structure locating in a floodplain or main channel, individually. The main deficiency of previous studies is that they do not accurately simulated the actual constriction features of Abutment Bridge in a compound channel with a complex geometries. Subsequently, the data and observations lead to unrealistically scour depth estimates.

The main objective of the current research is to provide reliable prediction of geometrical characteristics for protruded abutment bridge in the compound channel on contraction scour depth and its' location. The study required extensive experimentation conducted with laboratory flume, and abutments of realistic design that were subjected to the contraction scour for a range of channel constriction, channel geometries, and embankment protection layers. The experiments on clear-water conditions under steady flow at threshold velocity were conducted at an Abutment Bridge with approach embankment configured in a range of erodiblity conditions: fixed embankment on erodible and then far less-erodible floodplain; riprap, gabion-mattress, and non-erodible embankment on readily erodible floodplain. Flow depth was kept constant for all of the experiments with thecohesionless uniform sediment.

A methodology is developed to predict the maximum contraction scour depth and its' location along the compound channel. Outcomes of verifying the method show that proposed method gives reasonable maximum contraction scour depth and location predictions. The results indicate that the contraction degree, abutments' protrusionfrom floodplain into the main channel, soil, and protection layer properties really affect the final contraction scour depth and its' location. Results allow promoting the Abutment Bridges' design and consequentlyincreasingeconomical andpublic safety by decreasing the bridges' construction cost, saving additional maintenance charges, increasing bridges' stability, and preventing loss of lives.However, application of the currently developed methodology are limited to laboratory conditions. Site verifications are necessary in the future study.

Abstrak tesis dikemukakan kepada Senate Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Doktor Falsafah

PEMODELAN PENGUNCUPAN JELAS-AIR KEROKAN UNTUK PENAMPAN JAMBATAN DALAM RANGKAIAN KOMPAUN

Oleh

PEZHMAN TAHEREI GHAZVINEI

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Keruntuhan Jambatan mempunyai kesan dramatic dalam sistem pengangkutan. Selain kehilangan nyawa, gangguan perkhidmatan menyebabkan impak yang besar terhadap pertumbuhan ekonomi negara-negara. Kerukan pengecutan adalah penyebab umum dan penyebab utama kegagalan jambatan. Mereka bentuk asas jambatan dengan selamat memerlukan anggaran kedalaman kerukan yang tepat, anggaran yang kurang boleh membawa kepada kegagalan jambatan manakala terlebih anggaran akan membawa kepada kos pembinaan yang berlebihan. Jambatan-jambatan penampan lazimnya digunakan untuk jambatan yang merentasi saluran-saluran yang agak kecil. Keandalan, kekuatan dan ekonomi merupakan sebab-sebab utama yang perlu ditingkatkan bagi kes jambatan penampan. Dalam saluran majmuk, Jambatan Penampan lazimnya tersembul ke dalam saluran utama. Oleh yang demikian, kerukan pengecutan mengembang di dalam saluranutama. Pendekatan reka bentuk terdahulu menganggap penampan itu sendiri sebagai suatu struktur pepejal yang terletak di dalam dataran banjir atau saluran utama. Kekurangan utama kajian lepasa dalah ianya tidak mensimulasikan dengan tepat ciri-ciri penyempitan sebenar Jambatan Penampan dalam saluran majmuk denga nciri-ciri geometri kompleks. Kemudiannya, data dan pemerhatian-pemerhatian membawake pada penganggaran kedalaman kerukan yang tidak relistik.

Objektif utama kajian ini adalah untuk menyediakan ramalan yang boleh dipercayai tentang ciri-ciri geometri bagi jambatan penampan yang tersembul ke dalam saluran majmuk, terhadap kedalaman kerukan pengecutan dan lokasinya. Kajian ini memerlukan eksperimen menyeluruh yang dijalankan dengan saluran di dalam makmal, dan penampan-penampan yang mempunyai reka bentuk realistic yang tertakluk kepada pengecutan kerukan bagi suatu julat penyempitan saluran, geometri-geometri saluran, dan apisan-lapisan perlindungan benteng. Eksperimen ke atas keadaan air jernih di bawah aliran mantap pada kelajuan ambang telah dijalankan pada satu Jambatan Penampan menggunakan pendekatan di mana benteng deselaraskan dalam pelbagai keadaankebolehhakisan: benteng di tetapkan ke atas dataran banjir yang boleh hakis dan

kemudiann yayang tidak mudah terhakis; batu lindung, kotak batu (*gabion-mattress*), dan benteng tidak-hakis ke atas dataran banjir yang mudah hakis. Kedalaman aliran telah dimalarkan bagi kesemua eksperimen tersebut bersama enapan seragam tak menjeleket.

Satu kaedah telah dibangunkan untuk meramalkan kedalaman maksimum kerukan pengecutan dan lokasinya di sepanjang saluran majmuk tersebut. Dalam mengesahkan kaedahtersebut, didapati bahawa kaedah yang dicadangkan telah memberikan ramalan kedalaman maksimum kerukan pengecutan dan lokasi yang munasabah. Dap atan kajian menunjukkan bahawa darjah pengecutan, penonjolan penampan daripada dataran banjir ke dalam saluran utama, tanah, dan sifat-sifat lapisan perlindungan benar-benar mempengaruhi kedalaman akhir kerukan pengecutan dan lokasinya. Hasil kajian menunjukkan bahawa reka bentuk Jambatan Penampan berdaya maju untuk diguna pakai, seterusnya dapat meningkatkan ekonomidan keselamatan awam dengan mengurangkan kos pembinaan jambatan, menjimatkan caj-caj penyelenggaraan tambahan, meningkatkan kestabilan jambatan, dan mencegah kehilangan nyawa.Walau bagaimanapun, aplikasi kaedah yang sedang dibangunkan ini adalah terhad kepada persekitaran makmal. Pengesahan di tapak kajian adalah perlu dalam kajian di masa hadapan.

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Last but not least, I am grateful to the unending support of my family, especially my parents. Although they were physically far from me, their constant support made this learning journey possible. I appreciate them more than words can express. To them I dedicate this thesis.

I certify that an Examination Committee has met on15 January 2014to conduct the final examination of Pezhman Taherei Ghazvinei on his Doctor of Philosophy thesis entitled "Modeling of Clear-Water Contraction Scour at Abutment Bridge in a Compound Channel" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that candidate be awarded the Doctor of Philosophy.

I certify that a Thesis Examination Committee has met on 15 January 2014 to conduct the final examination of Pezhman Taherei Ghazvinie on his thesis entitled "Modeling of Clear-Water Contraction Scour for an Abutment Bridge in a Compound Channel" 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 Doctor of Philosophy.

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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Name of Chairman of Supervisory Committee:	Thamer Ahmed Mohamed, PhD	Name of Member of Supervisory Committee:	Bujang Bin Kim Huat, PhD

Signature:	______________________
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The following symbols are used in this note:

b = Channel width [L];

d_s= Scour depth [L];

d = flow depth [L];

$(\mathrm{d_s})_\mathrm{o}$ = scour depth obtained from experiments or laboratory observation (in statistical analaysis) [L];

$(\mathrm{d_s})_\mathrm{c}$ = the corresponding predicted scour obtained from the application of the selected scour formulae (in statistical analaysis) [L];

$\hat{d}_s = d_s/L$, nondimensional equilibrium scour depth $[\mathrm{M^0L^0T^0}]$;

D= Diameter of smallest non-transportable particle in the bed material [L];

D_a= Diameter of smallest non-transportable particle present in bed material [L];

D_m= Effective mean diameter of the bed material in the bridge = 1.25 D_{50} [L];

$\mathrm{D_{16}}$= 16% of the particles by weight are finer[L];

$\mathrm{D_{50}}$ = Median particle diameter (50% of the particles by weight are finer) [L];

$\mathrm{D_{84}}$= 84% of the particles by weight are finer [L];

e_i= Absolute errors (in statistical analaysis);

f_i = The prediction (in statistical analaysis);

Fr= Froud number (dimensionless);

F_a= Froud number in the floodplain upstream of the end of the abutment (dimensioless);

F_c= Critical Froud number for the initiation of bed material movement (dimensioless);

F_d = Densimetric particle Froude number (dimensionless);

$\mathrm{F}_e = U_e/(\Delta gl)^{0.5} =$ excess abutment Froude number (dimensionless);

g = Gravitaional acceleration force $[\mathrm{LT^{-2}}]$;

h_1, h_2= Depth of the flow [L];

$\hat{h} = h_1/L$;

K= Constant coeficient (dimensionless);

$\mathrm{K_I}$ = Flow intensity factor;

$\mathrm{K_y}$= Flow depth factor;

$\mathrm{K_d}$ = Factor to account for the effect of channel curvature on the shear stress acting on the outside of the bend;

K_σ = Factor of sediment nonuniformity;

$\mathrm{K_s}$ = Roughness height;

K_θ = Foundation aligment factor;

K_G = Approach channel geometry factor;

K_n= $1/21.1$, if D_{50} is measured by meters. Strickler Equation coeficient

K_{yL}= Depth size factor for abutments;

K_u = Constant coefficient in Richardon's Equation.

L= Length of embankment (contraction section) [L];

L_a= Abutment length [L];

L_f= Flood plain width [L];

L_F= Total width of the flood plains in the channel [L];

$\bar{l}$ = L/D_{50};

MAE= Mean Absolute Error (dimensionless);

n = Manning coefficient (dimensionless);

n = The sample size or the number of subjects, things, whatever, in the sample (in statistical analaysis);

N = Shape number;

q= Unit discharge [LT^{-1}];

Q =Total discharge in compound channel [L^3T^{-1}];

Q_a = Flow intercepted by the abutment and diverted towards the main channel, discharge [L^3T^{-1}];

Q_w= Discharge moving in a width of the main channel, in a streamwise directionin the flood-plain section [L^3T^{-1}];

Re= Reynolds number, (dimensioless);

RMSE= Root Mean Square Error;

t_e= Time to achieve equilibrium conditions [T];

T = time;

T_s= Dimensionless time in the proposed method;

U = Theil's coefficient, it is unitless.

u^*= Shear velocity [LT^{-1}];

v_c= Critical velocity for the initiation of bed material movement [LT^{-1}];

v, v_1& v_2= Flow velocity [LT^{-1}];

w= Particle settling velocity [LT^{-1}];

x = The value of data (in statistical analaysis), the unite depends on the data unit.

$\overline{x}$ = The average of data (in statistical analaysis), the unite depends on the data unit.

y_a= Average depth of flow at approach cross section [L];

y_i =The true (measured) value (in statistical analaysis), the unite depends on the data unit.

y = Average depth [L];

ds_R = Reference scour depth [L];

α = 0.59 ~ 0.69.

α_1= 0.066 ~ 0.367.

β = Degree of contraction ratio;

θ = Transition angle, [°];

θ_{c50}= Dimensionless critical shear of meadian-size particle in bed material.

ρ= Mass density of water [ML^{-3}];

ρ_s= Mass density of sediments [ML^{-3}];

σ = Standard deviation (in statistical analaysis).

σ_o = Shear stress on the bed size distribution.

σ_g= Geometric standard deviation of the sediment [$M^0L^0T^0$];

τ_c, τ_1= Bed shear stress; the subscript "c" symbolizes the condition for initial sediment motion [L^2T^2];

τ_*= Shields parameter [L^2T^2];

γ_w = water specific weight [MNL^{-3}]

ω = Fall velocity of bed material based on the D_{50} [LT^{-1}];

Δ= Relative density.

Subscripts

1= Uncontracted (approach) section and;

2= Contracted section

CHAPTER 1
INTRODUCTION

1.1 Background of the Study

Abutments are located at the two ends of a bridge, that act double purposes of transferring the loads from the superstructure to the footing bed and giving support to the approach embankment. Bridges are characterized by how they support themselves. The simplest type of bridge is the beam bridge. This type of bridge has a single horizontal beam across two supports with articulated structures. A simple beam bridge main structures are shown in Figure 1.1. When it is needed to build a bridge across a wide space and don’t want to sink supports in the middle, thus hoping to build a beam bridge with one very long span. But, a long beam may sag too much in the middle. To avoid sagging, bridge is build with support at the two ends by using cross members to make the bridge stronger. These kinds of bridges without movement joints at the junction of the deck on the abutments named abutment bridge (also called Integral abutment bridges or joint less bridges). Figure 1.2 shows contiguous abutment bridge. Reliability, strength and economy are the main reasons to increase concerning in a bridge structure. Besides, abutment bridges have less initial cost in construction and long-term maintenance in comparison with simple beam bridges. Abutments acquit an extra function as a protector of the embankment against scour during stream in a abutment bridge constructed on a waterway.

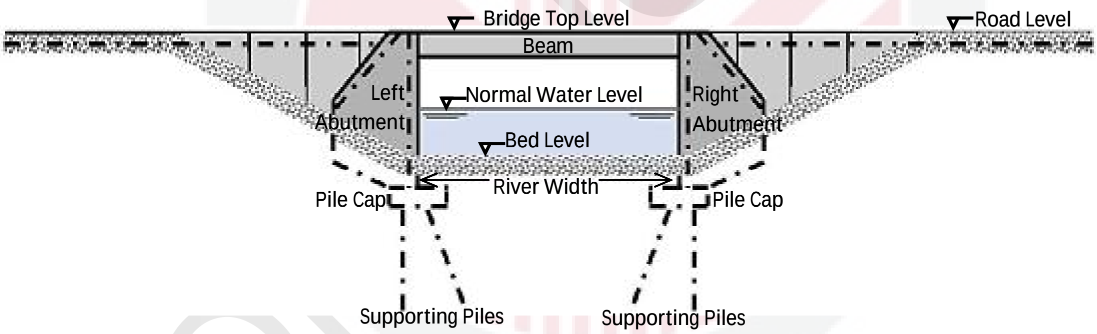

Figure 1.1. A Simple Beam Bridge (Taherei Ghazvinei et al., 2012).

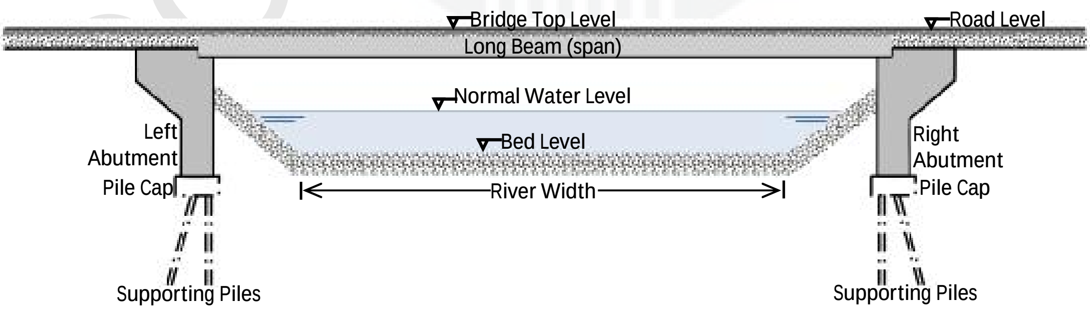

Figure 1.2. An Abutment Bridge (Taherei Ghazvinei et al., 2012).

Deficiency of load capability and bridge scouring are the most reasons of bridge collapse. The erosive action of flowing water sources scour, which excavates and carries away materials from bank's bridge foundations and streambeds through the normal flood flowing or water. Scour is a natural occurrence caused by the flow of water over an erodible boundary, whereas flowing water generates the shear stress that is the basic erosive stress on the streambed. The materials of the streambed provide the resisting stress against scouring. Scour reaches its equilibrium standing when these two stresses get balanced. Excessive scour can lead to the undermining of the bridge foundations. Different materials scour at different rates. Under constant flow conditions, scour will reach maximum depth in sand and gravel bed material in hours; cohesive bed material in days; glacial till, sandstones, and shale in months; limestone in years and dense granite in centuries. Under flow conditions typical of actual bridge crossings, several floods may be needed to attain maximum scour (Arneson et al., 2012).

Total scour is comprised of the three components: Aggradations or degradation, contraction scour and local scour. Aggradations or degradation is long-term streambed elevation changes due to natural or human-induced causes within the reach of the river on which the bridge is located. Contraction scour involves the removal of material from the bed and banks across all or most of the width of the channel. This scour can be resulted from the approach flow constricted by the embankments encroaching in the floodplain or into the main channel. Such an encroachment are due to the change in downstream control of the water surface elevation or from the location of the bridge in relation to a bend. In each case, scour is caused by an increase in transport of bed material in the bridge cross section.

Local scour occurs around piers, abutments, spurs and embankments and is caused by the acceleration of the flow and the development of vortex systems induced by these obstructions to the flow (Li, 2005). Relevant with location in the main channel or floodplain of a river, abutments are susceptible to failure by scour.

Abutment bridges most commonly are used over comparatively small channels. In these situations, abutments are very close and they may still be located at the banks of a main channel or may protruded to the main channel to reduce the cost of the bridge consrtuction. When a channel is constricted, the approach flow accelerates and causes an increase in the bed shear stress and related turbulence. The embankments and abutments shorten the necessary bridge span, but consequently contract the flow through the waterway. As the bed shear stress exceeds the critical shear stress of the bed material, contraction scour expands. That construction advantage, however, can lead to a potentially severe scour situation as a contraction scour at a site of the abutment bridge.

The most common cause of bridge failures is attributed to scouring around foundations during floods. Study of 503 bridge structure's failures in the United States from 1989 to 2000 indicated that the main reasons for failure or damage of the bridges are those interconnected to scouring at the abutments and piers of the bridges (Wardhana and Hadipriono, 2003). Bridge collapse reasons were evaluated in Colombia based on the study of 63 real cases of reported failures since 1986. Through the analysis of each failure event, the main reasons of total or partial collapse of the bridge structures were recognized and studied. The 64% of the cases studied corresponds to concrete bridges that collapsed mainly because of scour effect and overloads; and the remaining 36% corresponds to steel structures that failed mainly because of structural deficiencies (Diaz et al., 2009).

In Malaysia, the use of abutment bridge has also dramatically increased in recent years. However, since the development of abutment bridge is still new in Malaysia, factors that caused bridge failure other than loading must be investigated. Flood is one of the recent interests in abutment bridge structure because it can cause scouring (Akib et al., 2011; Akib et al., 2008; Fayyadh et al., 2011). In Malaysia the main responcible governmental agency for bridges construction and mainenace is called Public Work Department or in local language in Malaysia, Jabatan Kerja Raya (JKR). There are about more than 7133 bridges in Malaysia. Table 1.1 shows a statistics of bridges in Malaysia.

Table. 1.1 Statistics of Malaysia Bridges (Heng, 2008).

Department	Bridge (Nos)
JKR Federal	7133
JKR State	7000
JKR Sabah	1730
JKR Sarawak	1540
Toll Concessionaires	560
Malayan Railways Department (in local language in Malaysia; Keretapi Tanah Melayu, KTM)	920

Figure 1.3 displays the numbers of bridge constructed along the federal roads under JKR, based on the material type (Heng and Hamid, 2009; Nadzri, 2011).

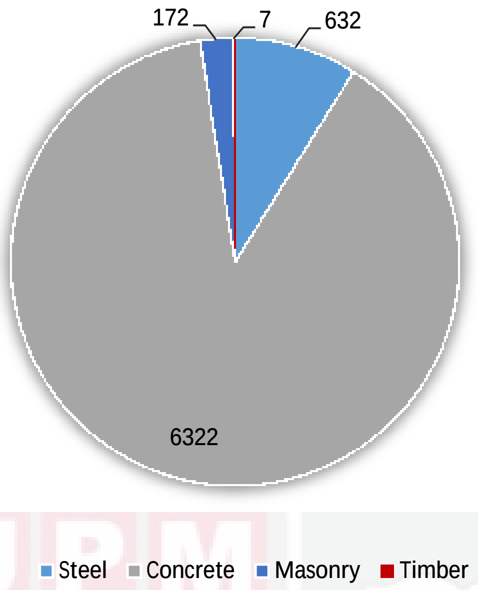

Figure 1.3. Types of Bridges in Malaysia Along the Federal Routes (Heng and Hamid, 2009; Nadzri, 2011).

As a country located in Southeast Asia, Malaysia is categorized as equatorial, being hot and humid throughout the year with annual rainfall exceeds 2000.

Malaysia experiences very high rainfall intensity, especially during the Monsoon season from October to January. Flooding is very common during this period. Ng and Razak (1998) reported that bridge failure due to structure damage is very rare in Malaysia, while bridge failures are very often caused by scouring the footing structure during major floods. A governmental report presented JKR experiences in facing hydraulic problems in Malysia (Meng et al., 2000). Revetment of Pukin river bridge, Keratong river bridge and Plentong river bridge were cited as case history. It is later learned that the Pukin River Bridge was badly scoured at both abutments during heavy flooding in December 2006 (Heng, 2010). Scouring problems are the main, if not only cause of bridge damage in Malysia. The most scour hazards to the abutments of bridges in Malaysia are shown in Table 1.2.

Table. 1.2 Malaysian Experience; Defect Due to Scour Hazard (Heng, 2008).

No.	Location of Bridge	Date of Failure	Problems
1	Kota Tinggi, Johor	1989	Collaped due to scour at abutments after big flood
2	Port Dickson, Negri Sembiln	1995	Collaped due to scour at abutments after big flood
3	Calvert bridge, Sungai Semiar, Jeneri, Pahang	1996	Filled Embankement was washed away after big flood
4	Sungai Batang Busu, Gombak, Selangor	2003	Collaped due to scour at abutments after big flood
5	Sungai Buaya, Selangor	2005	Collaped due to scour at abutments after big flood

Recent floods at past two years in Malaysia had serious damage and failure of bridges. For instance, heavy rain at 20 february 2012, that lasted six hours caused over topping the bridge of the Pari river. The water levels had risen to a dangerous level and the whole area had been flooded. At the same area, strong currents also caused the bridge at Wing Onn Garden to collapse. Figures 1.6 shows the overflow during the flooding for that area (Loh and Hew, 2012).

Figure 1.4. Flooding At Pari River On February 2012 (Loh and Hew, 2012).

Figure 1.5. Pari River Bridge After The Recent Flood On Febuary 2012 (Loh and Hew, 2012).

Figure 1.6. Evacuation During Flooding Of Pari (Loh and Hew, 2012).

Furthermore, as a latest abutment bridge collapsed on24 October 2013, due to abutment scour at Cameron Highlands (Figure 1.7). Also, 4 people have died after the flood surrounded the areas (Today, 2013).

Figure 1.7. View Of The Destroyed Bridge In Cameron Highlands (Today, 2013).

1.2. Problem Statement

Bridge collapse has dramatic consequences in transportation system. Besides loss of life, disruption in service results tremendous effects on the economic growth of the countries. In many developing countries, bridges are constructed with less quality control and limit adherence to the design code. Designing the bridge foundation safely needs an accurate estimation of structure footing depth. Therefore, engineers need reliable methods for predicting scour depth and location which, affect the bridge foundations. Such consistent methods can applied in estimating any damage or collapsed due to scouring for the bridges in design stage or constructed bridge to design erosion protection.

Underestimation may lead to bridge failure while overestimation will lead to excessive construction cost.

Many abutment bridges are located on compound channels whose geometry and hydraulic characteristics are markedly site-specific. Moreover, the channel is formed of various types of soils occupying different locations within a bridge site. Sands or gravels may form the bed of main channel. Rocks and various types of concrete elements may have been placed as erosion protection for the abutments as well, along adjoining riverbanks. Scour at abutment bridges typically occurs at two-phase process, including hydraulic erosion of the main channel or floodplain and thereafter, a geotechnical slope stability failure of the river banks adjacent or earth-fill embankment. This two-phase process makes scour prediction more complicated in comparison with contraction scour in a simple rectangular channel. Prior studies treated abutments as being solid structure locating in a floodplain or main channel, individualy. Some studies, however, have illustrated some of the processes causing scour, remarkably scour referable to flow contraction through a bridge waterway. These studies have described certain parametric trends related with flow contraction and have developed tentative design relationships for estimating scour depth. In case of contraction scour, the relief bridges in flood valleys, with a small width, require a special procedure to evaluate the scour (Schreider et al., 2001). According to the result of the perfect laboratory experiments which often applying simple rectangular channels and uniform sediment, it was concluded that the accuracy of scour depth estimate is less than the measured scour depth of the field or laboratory conditions (Hong, 2005). Recent research on the bridge scour has focused on local scour, such as scour around bridge piers or near abutments; by comparison, contraction scour at abutment bridges in compound channel has received much less attention. Most of the techniques and guidelines that are available for predicting contraction scour at abutment bridge have been developed from small scale hydraulic modelling conducted in laboratories (Azamathulla, 2012; Coleman et al., 2003; Dey et al., 2008; Ettema et al., 2004; Husain et al., 1998; Kouchakzadeh and Townsend, 2000; Lim and Cheng, 1998; Martin-Vide, 2007; Mueller and Wagner, 2005; Yanmaz and Celebi, 2004). Limited amount of empirical data along with unreliable observations has been acquired from simulated real situations. However, few conditions of flow, boundary erosion and alluvial-sediment transport are more complex than those related with scour in compound channels at abutments bridge. Therefore, several essential aspects of scour at abutment bridge has remained little understood, the main deficiency of prior studies are:

1. They do not consider contraction scour development at abutments bridges in a compound channel. Most of the abutments are located in the bank line or protruded into the main channel in a compound river. However, the existing contraction scour equations focused on setback abutments.
2. Guidelines and available relationships to predict contraction scour do not adequately take into account the complexities of the channel geometry and bed materials. Most of the contraction scour studies conducted in a simple rectangular channel, while most river morphologies are compound.
3. Abutment bridges, are found to be a primarily concern for bridges over smaller waterways than the large rivers. The applicability of the previous contraction scour equations are in the long contraction, while bridges typically causes short contraction.

4. Previous studies are commonly dedicated to determine maximum scour depth around bridge foundations. Besides, most of the studies are conducted in clear water conditions that are generally based on the prediction the equilibrium scour depth at bridge abutments. Not only application degree of the scour countermeasures materials is determined by the maximum depth of scour but also by the characteristics of volume and surface area of the scour hole around such foundations (Yanmaz and Kose, 2007).

It has been recognized that along with new prediction of the maximum contraction scour depth and location concepts, current design and construction guidelines need to be developed to protect bridge abutments and approach embankments from scour damage and to reduce the depths to which expensive deep foundations may have to be placed. That is why bridge engineer designers are interested in scouring which affect the abutments and alongside the contracted section. Therefore, it is not surprising that several aspects of scour related with abutments remain to be resolved. Requirement to more research on scaled most in used abutment bridge in Malaysia within a compound channel, led us to conduct a new series of experiments.

The major concentrations of the current study will be the clarification of scour processes at contracted section of the abutment bridges and improvement of relationship for estimating contraction scour depth and location in clear-water conditions in a compound channel using empirical methods. These improvements are based on formulation supported by laboratory experiments. Credible predictions of contraction scour depths can assist the design engineers to promote the bridges' design, monitor and correct the scour problem before any bridge failure, and decreasing the bridges' cost in construction and maintenance processes.

1.3 Scope and Objectives

Natural contraction caused by abutment bridge in a compound channel with complex geometry is more multifaceted. There are many issues of scours in contracted channel from the practical point of view that were not clarified in previous studies. Briefly, there are four relatively pronounced weakness in previous studies on scour in contracted channels:

1. For the small rivers, abutments encroach on the main channel banks, the floodplains portion of the contracted section no longer exist. Abutments being sited in the bank line or protruded in to the main channel in a compound river. However, the existing contraction scour methods focused on setback abutments or bank line abutments in a compound channels. Further study on scour at abutment sited in the main channel of a compound river is necessary.

2. Local and contraction scour equations were typically developed in uniform sands. However, what would be the behavior in armored layers which protect the bridge structures?

3. Most of the available equations are limited to predict the uniform scour depth in a long contraction channel. But the knowledge on how the scour distributes, location and depth of the maximum contraction scour are more critical in scour evaluations at short contraction caused by abutment bridges.

4. Bridge typically impose short, abrupt contraction. The applicability of the long rectangular contraction solution is uncertain for this case. Further study on influence of contraction degree and bridge openning width is necessary for a comprehensive understanding of the bridge scour in contracted channel.

The main cause of bridge failures built across small rivers is attributed to the problem of scour around bridge abutments. In this experimental study, contraction scour at abutment bridges is investigated in detail to achieve the main objective. In order to generalize the final results to other similar cases, it is needed to select an abutment bridge for scaling down in a laboratory model, as a representative prototype in footing and structure with the most in used abutment bridges in Malaysia and other countries. Besides, compound channel geometry within a abutment bridge model need to be scaled down hydraulically and geometrically to generalize the outcomes of the study to similar rivers and bridges bathymetries in and out of the Malaysia. Within scope, the study set out to produce practical guidelines for accurate contraction scour estimation by civil engineers. The main goal of this study is to develop a methodology for predicting contraction scour depth and location within full scaled abutments model of the most in used abutment bridge specially in Malaysia. The outcomes of the study will promote bridge design method in river environments by increasing estimation accuracy of maximum contraction scour depth which affect the final abutment footing depth and consequently bridge constraction cost. This goal will be achieved by encounter the following set of specific objectives:

1. To simulate contraction scour for abutment bridge in a compound channel.
2. To quantify the contraction scour depth and location produced by individual components of the contraction degree, floodplain erodibility and slope protection resistance with propose of correction coeficients in improved proposed method.
3. To evaluate the existing methodologies by concentrating on the ability of the methodologies to be used as design equations for predicting contraction scour depth with complex geometries.
4. Evaluting the accuracy of proposed theory to determine the contraction scour hole geometry under clear-water conditions due to variations in the compound channel with complex geometries.

For the objectives, a semi-emperical approach to determine clear water contraction scour depth at abutment bridges is presented.

1.4 Thesis Organization

Based on the results of preliminary work done in getting underway with the study, there are some important keys in understanding scour at abutment bridge and developing useful relationships to predict depths of the contraction scour. Previous researcher were concentrated only on long contraction scour.

1. Are the common types of abutment configuration, and thereby scour conditions, of essential and practical importance?
2. How do floodplain and main-channel flows combine and contribute to scour at abutments located in compound channels formed of floodplain beside a main channel?
3. Why scour-prediction relationships developed from laboratory flumes seems to predict larger scour-depths than the depths observed at actual bridge abutments?

In the current study, laboratory experiments were conducted using common model of the selected abutment bridge in Malaysia in the compound channel. The time history of the scour and the velocity in the bridge section were measured. For this case, comparisons were made among flume measurements of scour depth (experimental results), and predicted contraction scour depth using existing formulas and proposed equation for scour-prediction. The experimental results were used to assess the relative contribution of contraction scour at abutment bridge to the final design of the bridge foundation depth.

The background of scour related to bridge abutments will be explained in details in chapter 2. It will include several sections, bridge structure, abutment characteristics, bridge scour and it's fundamental. In addition, several approaches to study the bridge abutment scour depth will be reviewed. Analytical methods are discussed for obtaining both the equilibrium contraction scour depth and its' location. The experimental studies based on dimensional analysis are presented to explain the effects of several parameters. Also, a review of physical model studies are undertaken and at least scour component method performance are discussed.

Chapter 3 focuses on the location and bed elevations for selected bridge sites. Moreover, the instrumentation which will be used in measuring the flow characteristics, the type of sensors being used to monitor the abutment bridge scour and how the data are collected and recorded are explained. Physical modeling and experimental procedures for this study are given in this chapter.

In Chapter 4 the results which are derived from experimental tests including the scour contours at abutment bridge are investigated. The data of the maximum contraction scour at abutment bridge have been collected. The effect of channel contraction degree, the effect of abutment aspect ratio, the effect of abutment protection materials, and the effect of the compound channel configuration are taken into account. The final chapter provides conclusions and recommendations for future study.

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