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DETERMINING THE FLOOD FLOW CHARACTERISTICS OF SUBMERGED BRIDGE SUPERSTRUCTURE

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BEng (Hons) in Civil Engineering

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DECLARATION

I, Chen Chee Lie hereby declare that the art of work that presented by this report entitled "Determining the flood flow characteristics of submerged bridge superstructures" is totally a record of my original work done and my own investigation under the guidance of my academic supervisor, Mr. Munir Hayet Khan. Except for point of reference, the reference that was used in this report were plucked from the data and resources from journals and published data. The result embodied in this project has yet to be published by anyone of other University and Institution or to be found in the internet.

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ABSTRACT

Bridges are a critical component of the nation's transportation network. Highway bridge superstructures over large waterways may become partially or completely submerged during a flood event. During flood periods, the presence of bridges may cause backwater and this is considered as obstruction. In addition, flood flows add possible forces such as drag force and uplift force on the bridge structure thus causing damages to the bridge superstructure and lead to failure. General practices in highway engineering make it necessary to give more attention to aspects of hydraulic design which determine the security of a structure against action of water where the bridges are placed. A study based on theoretical and experimental procedures using a prototype of bridges in laboratory was conducted to investigate and analysis the backwater occurred to the bridge superstructure and forces on submerged bridge. The results show that the higher the inundation depth of the bridge superstructure is, the higher backwater height occurred at the upstream of the bridge. While for drag force, it is found out that is directly proportional to the Froude Number and inundation depth. Lift force increases as inundation depth increase, but it decreases as the Froude Number increases.

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1. CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF STUDY

Bridges are commonly and widely been construct over watercourses such as, river , lake or sea, to link the population areas. The bridges can be in different form, such as simply service crossings, footpaths, roadways or railways. In order to achieve the standard in terms of safety and produce an efficient design of bridge structure, some factors including the hydrology, hydraulics and geomorphology of the watercourse need to be studied and discussed and the effects that will brought by these factors on the bridge structure.

The action of flowing water in undermining bridge piers, abutments, and approaches has long been respected. Hydraulic issues were avoided as far as possible in earlier times by selecting bridge sites where channels were straight, banks were stable, and a square crossing could be arranged. Occasional overtopping of the approach roads by flood waters was tolerated and generous lengths of bridge were also provided (Neill,1973).

These procedures have changed as a result of a number of reasons: the increasing priority given to high-standard road alignments and grade lines requiring acceptance of more difficult water crossing sites; the increasing width, height, and cost of bridges and the consequent need to keep their lengths to a minimum; and public demands for a free flow of traffic at all times requiring the handling of reasonably predictable flood flows by the structure (Neill, 1973).

In old times, bridges has also brought many issues among public's life. During flood periods, the presence of bridges will cause backwater and this was considered as disturbance. The public asserted that this has influenced their livelihood as bridges has replaced ferries and boats. In addition, there were no methods in determining exactly the amount of backwater that might cause by the bridge, thus it was hardly to forecast the worse effects of bridges.

In an age of rapid transportation, bridges are very important as they allow for roads and railroad to cross over otherwise impassable obstacles such as rivers or other roads. Progress in structural design has as well kept pace with the times. Therefore, this places demands on the hydraulic engineer, to promote and develop a more scientific approach to the bridge waterway problem (Bradley,1978).

Nonetheless, due to the lack of hydrological and hydraulic information on the waterways, it is difficult for hydraulic engineer to establish the suitable length and vertical clearance and the location to construct the bridge. General practices in road engineering make it necessary to pay more attention to aspects of hydraulic design, including the calculation of many hydraulic factors which determine the security of a structure against action of water where the bridges are placed.

Through a study on failure of bridges, 70 out of 143 cases failed by flood event. This shows the importance of understanding the relationship of bridge structure and water flow, rather than taking the bridge structure is segregation. In bridge design, a hydraulic analysis is vital to the proper design of the span length, low chord, abutments, and piers.

1.2 PROBLEM STATEMENT

Flood incidents are frequently happen in global and it brings huge prejudice to people. When the flood flows meet restriction which is the bridge piers in the natural stream, adjustments will take place in the restricted region. The flood flow contracts as it enters the bridge and then expand as it exits the bridge. The process of the contraction and expansion of the flow, overcoming fiction and disturbances related with piers requires an exchange of energy. The upstream flow will increase in its depth, termed as backwater, reflects this energy exchange.

If insufficient clearance is provided above the design high water level and as a result the flow reaches the bottom of the bridge superstructure, the bridge will act as a short culvert. If the leading edge of the bridge's underside is sharp-cornered, the height of afflux (backwater) may rise rapidly after the opening is occupied by water (Neill,1973).

During a flood event, highway bridge superstructures over huge watercourse may partially or completely submerged in the water flow. Momentous hydrodynamic loading will acting on bridge superstructures, causing shearing or overturning of the bridge deck and failure of the bridge superstructures. Usually, the study of the water flow on the bridges have relied on exclusive scaled experiments to provide estimates of the flow field and structural response (Kerenyi et al., 2008).

The most common cause of highway bridge failure is due to unpleasant hydraulic action. Therefore, sufficient of attention need to be paid to the prevention of such failure when designing new bridges over watercourses. Damage or losses on bridge due to hydraulic action need to be minimized.

Thus, the purpose of this project is to improve the current understanding and knowledge on the flood flow characteristics of the bridge superstructure and how the flood flow affect and be affected by the bridge structural design.

1.3 AIM

The aim of this project is to determine the flood flow characteristics of the submerged bridge superstructures under various condition of the bridge's dimension and the flood level.

1.4 OBJECTIVE

1. To determine and study the hydraulic flow profile of backwater occurs upstream of the bridge.
2. To determine the relationship between the uplift force by the flow on the bridge superstructure and the inundation depth of the bridge superstructure.
3. To determine the relationship between the drag force by the flow on the bridge superstructure and the Froude Number, Fr of the flood flow.

1.5 SCOPE OF WORK

1.5.1 LITERATURE REVIEW

The literature studies are mainly focused on the bridge modeling parameters based on the bridge hydraulic concept. Several equation related to hydraulic and geomorphology are also discussed.

1.5.2 BRIDGE MODELING

An experiment with a model of bridge crossing watercourse will be conducted. There are 2 bridge model to be use in the experiment with different dimension in terms of height and width. The flood level will be manipulated in each bridge model.

1.5.3 ANALYSIS OF DATA

Different set of flow analysis graphs will be plotted from the data obtained from the experiment according to the dimension of bridge model and the flood level. Comparison will be made on the result from different set of flow analysis graph.

2. CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION TO BRIDGE BACKWATER

When water flow through a bridge opening, there are several unique concepts in hydraulics that occur. If the bridge opening causes constriction to the floodplain, there is energy loss upstream of the bridge and water surface profiles will rise upstream. The end result is that the water surface will be higher upstream of the bridge than it would be if the bridge is absent. This phenomenon is generally known as backwater (Knox Country Tennessee Storm water Management Manual, 2001).

As described above, bridge structures will cause some consequence on the flow of the watercourse. The effects are cause by the appearance of bridge structure within the channel of the watercourse and causing obstruction of water flow. Bridges that are crossing the watercourse are usually more than one span, therefore, there will be piers located in the water course to support the bridge, which direct water to flow around them.

When the water flowing in the channel meets a bridge superstructure that obstructs its flow area, the water flow is forced to contract so that the flow can pass through the bridge before recover to the full channel width. As the flow that under restriction passes through the obstruction of the bridge, it will increase in velocity, causing a decrement in depth of water surface. When the flow expands to the original width, then the water level recovers to its downstream boundary condition level. This consecutive contraction and expansion results in a local head loss, which is results by an increase in water level upstream of the bridge. This phenomenon is known as afflux, or the backwater effect (Sarah Kingston, 2006).

2.2 NATURE OF BACKWATER

Normally, it is seldom economically feasible or necessary to construct a bridge for the entire width of a stream as it occurs at flood flow. The approach embankments are extended out onto the flood plain as the conditions permitted to reduce costs, on the other hand, the extended embankments will constrict the flow of the stream during flood events. This is acceptable practice so long as it is done within reason.

The water-surface profile of the flow which is contracted in passing through a channel constriction is illustrates in Figure 1. The flow bounded by each adjacent pair of streamlines is the same (1,000 c.f.s). Note that the channel constriction appears to produce practically no alteration in the shape of the streamlines near the center of the channel. A very marked change is evidenced near the abutments, however, since the momentum of the flow from both sides (or flood plains) must force the advancing central portion of the stream over to gain entry to the constriction. Upon leaving the constriction, the flow gradually expands (5 to 6 degrees per side) until normal conditions in the stream are again reestablished.

Constriction of the flow causes a loss of energy, the greater portion occurring in the re-expansion downstream. The loss of energy is reflected in a rise in the water surface and in the energy line upstream from the bridge. This is best illustrated by a profile along the center of the stream, as shown in Figure 2A. The normal stage of the stream of a given discharge, before constricting the channel, is represented by the dash line labeled as normal water surface. The nature of the water surface after constriction of the channel is represented by the solid line which is the actual water surface. Note that the water surface starts out above normal stage at section 1, passes through normal stage close to section 2, reaches minimum depth in the vicinity of section 3, and then returns to normal stage a considerable distance downstream, at section 4. Determination of the rise in water surface at section 1, denoted by the symbol h_1* and referred to as the bridge backwater, is the primary objective of this publication. Attention is called to a common misunderstanding that the drop in water surface across the embankment, Δh, is the backwater caused by a bridge. This is not correct as an inspection of Figure 2A will show. The backwater is represented by the symbol $h1*$ on both figures and is always less than Δh (Bradley, 1978).