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Review

Innovative countermeasure for integral bridge scour

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Advantages of integral bridges include reduction of initial construction and maintenance cost. Scour was the main problem which caused the bridges to fail and collapse during heavy rain and flooding. Most of the previous studies focused on the scouring impact on conventional and traditional bridge. Very few studies investigated on scouring effects on integral bridge and its countermeasure. This paper highlighted the innovative countermeasure to prevent the impacts and consequences of scouring on integral bridge.

Key words: Countermeasure, innovation, integral bridge, scour.

INTRODUCTION

Many bridges around the world failed or damaged because of extreme scour around piers and abutments. Better understanding of the water-structure interaction of integral bridge abutments, piers and combined piles is clearly desired. Increasing numbers of integral bridges are being built in recent years, in Malaysia. Integral bridges are constructed without movement joints at the junction of the deck with the abutments. They are also called integral abutment bridges or jointless bridges where the construction is continuous (England et al., 2000).

Any constructed bridges must be continuously monitored for any changes in the structure of the bridges that usually focus on the changes of the soil in the area of the bridges constructed. The typical changes can be seen is from the bridge scouring or in this case, integral bridge scouring is usually not being taken seriously. The engineers supposed to have a better understanding of the effect of scouring before any construction of integral bridges started (Jennifer and Michael, 2011).

The advantages of this type of bridge include reduction in initial construction cost and long-term maintenance expenses. It improves seismic resistance and extends long-term serviceability (Kunin and Alampalli, 2000). Other advantages of this type of bridges are it is simpler and intensely economical in construction, hugely improved ride quality and more capable of going through events like earth quake or tsunami. Furthermore, the replacement of the bridge is not difficult to be done and remarkably fast without any problem at all (Phillip et al., 2010).

Integral bridges are alternatively referred to as integral bent bridges and rigid-frame bridges. Most of the previous researches concentrated on the piers, abutments, or combined piles separately. Since the concept of integral bridge is like a portal frame, there is a need to combine superstructure and substructure together in two floodplains referring to the real situation which involved complex structure and complex flow. Sturm and Janjua (1994) conducted laboratory studies on abutment scour in compound channel to consider the effect of compound channel hydraulics on scour around long abutments in wide and shallow floodplain flow. However, only one part of the bridge components was considered in the study. Bridge with combined piles on deep alluvial riverbeds could prevent scouring because the process cannot lead to a failure by undermining. In contrast, general scour can produce permanent bed lowering (Martin-Vide et al., 1998). The authors suggested width-weighting method after analyzing the tests results, so that the closer the base of the pier to bed, the greater influence on the scour.

Scour depth estimation at bridge foundations is a problem that has increased curiosity and perplexed designers for ages. Nevertheless, the interesting problem to be explored is extensive (Melville, 1992). Therefore, estimation of the scour depth due to the local scour is very important in the field of hydraulic structure. It is very important to predict the depth of scour hole for the safety and cost-effective design of the hydraulic structures such as bridge piers, abutments and piles. Underestimation of the scour depth would lead to uneconomical maintenance expenses. The phenomenon of scour is caused by the

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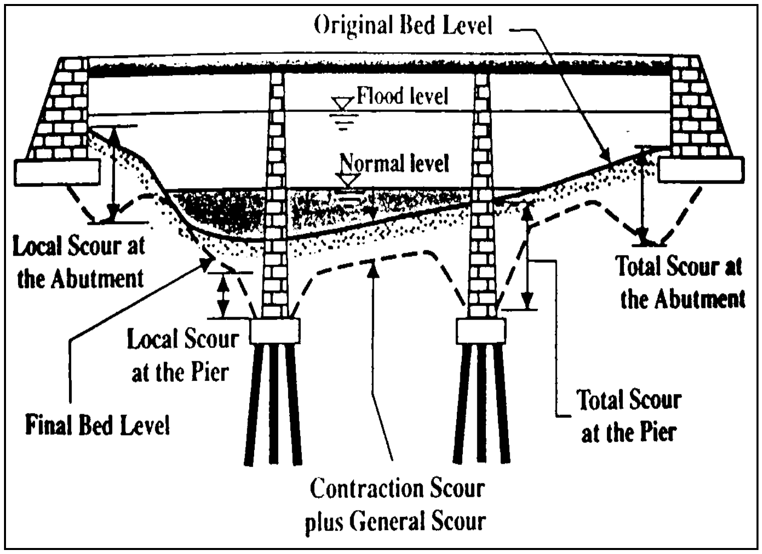

Figure 1. Types of scour occurred at a bridge (Melville and Coleman, 1999).

morphologic changes of rivers and man-made structure (Breusers and Raudkivi, 1991).

Continuous change in natural river geometry due to interaction between the flow and movement of bed sediment is the main problem that results in collapse and failure. Scour phenomenon lowers the riverbed level and weakens the support soils beneath a foundation. Different types of scour may occur simultaneously at a bridge crossing as illustrated in Figure 1.

The types of scour that can occur at a bridge site could be grouped as follows:

1. General scour is a process of streambed erosion or degradation. It is associated with the natural variations in the flow and occurs irrespective of the presence of the bridge.
2. Contraction scour results from general increases in the velocities where the flow is constricted when it approaches the bridge opening and is characterized by a general lowering in the bed elevation due to the contracted section.
3. By contrast, local scour is due to changes in the local flow pattern at the bridge, which is usually associated with three-dimensional flows and vortex systems. It is also characterized by the formation of scour holes at the base of the bridge foundation. In other words, local scour is a continuous process of streambed degradation which results from turbulence of water at the floodplains and underneath the bridge.

Localized scour is the combination of local and contraction scour. The types of localized scour include clear-water scour and live-bed scour. When the bed resistance upstream of the scoured area is equal to or lesser than the critical or threshold shear stress for the commencement of the particle motion, clear water scour occurs. The maximum scour depth in clear-water scour is attained when the flow is not able to get rid of the particles from the scour hole anymore.

Live-bed scour is also known as scour with sediment transport. It occurs when general bed load is transported by the stream. Similar scour depths are achieved when the materials removed from the scour hole is equal to materials supplied to the scour hole from upstream after some time. Differentiation of the two types of scour is needed because it is the main key point of the increment of the scour hole with time and approach flow velocity (Raudkivi and Ettema, 1983).

Other place of scouring is the area around the base of cylinder embedded in a loose bed. This particular area has being studied in a long time ago because of the importance in bridge pier foundation design. But the studies that have being done mostly are on calculation and theoretical experiment and less on modeling experiment (Subhasish and Sujit, 1994).

There are many analytical solutions to most of scouring problem including analytical solution for long wave reflection by a rectangular obstacle with two scour trenches. The reflection effect for both depth and width of two trenches is investigated using computational results. It has being shown by the result that if the depth of the trenches is left to be constant, then the wider the trench is, the reflection follow with increasing value. If the width is left to be a constant, the deeper the trench goes, the larger the reflection effect is (Jian et al., 2011).

Many studies have been carried out to develop a relationship for the maximum scour depth at bridge abutments under clear-water scour condition. Some investigators had studied the effect of flow intensity, flow shallowness, sediment coarseness and time and velocity

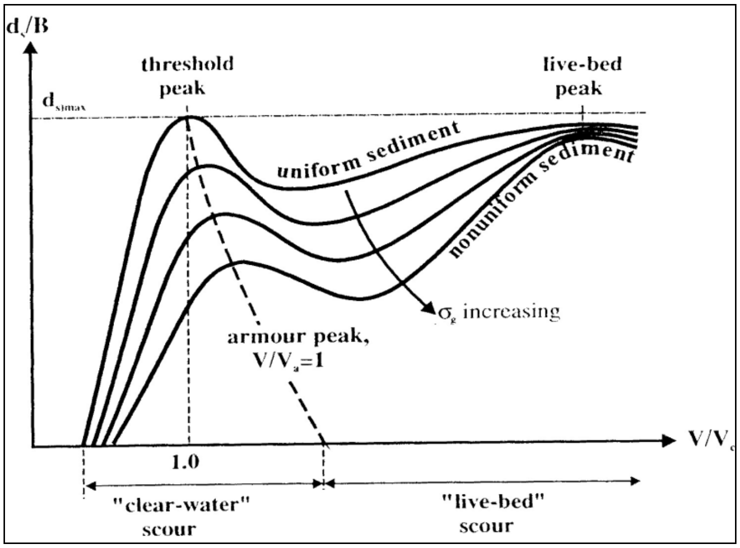

Figure 2. Local scour depth variations with flow intensity (Melville, 1992).

distribution on scour development.

PREVIOUS INVESTIGATION

Cardoso and Bettess (1999) confirmed the validity of Melville's suggestion for the configurations tested in the experiments on scouring effects of time and channel geometry at bridge abutments. They performed experiments measuring scour development for abutments located within a compound channel. They identified three phases of development: the initial, principle and equilibrium phase. Scour depths reach equilibrium faster than the scour hole remaining solely within the floodplain when a scour hole penetrates the main channel. The authors also found that flow interaction at the main-channel floodplain interface is the cause of this phenomenon.

The ratio V/Vc is a measure of flow intensity and determines whether grain motion occurs on the bed channel. Melville and Coleman (1999) stated that clear-water scour develops for both uniform and non-uniform sediments when flow intensity V/Vc < 1 or [V-(Va-Vc)]/Vc <1. Live bed scour occurs for uniform sediment, when σg < 1.3 to 1.5 when V/Vc > 1. For non-uniform sediments (σg > 1.3), armouring occurs on the channel bed and in the scour hole. Armour layer formation within the scour hole reduces the local scour depth. The ratio V/Va is a measure of flow intensity for scour with non-uniform sediments.

Figure 2 shows that for V/Vc > 1, under live-bed conditions, ds initially reduces with increasing flow intensity, reaches a minimum value and then increases again towards a second maximum. The second maximum occurs at about the transition flat-bed stage of sediment transport on the channel bed and is termed the live-bed peak.

INNOVATION AND FUTURE DIRECTION

Global warming and climate change increases chances of heavy raining and flash floods. The unusually heavy rainfall is in line with global findings that extreme weather events have become more frequent world-wide over the past decade. Scouring occurs frequently during flooding. Eco friendly countermeasures are needed to promote green technology and solve scouring problems at integral bridges. Crushed concrete bag made from abandoned concrete could be an innovative idea for future work.

Crushed concrete as geobag filler is proved as an alternative to normal sandbag for use as a bridge scour countermeasure. Crushed concrete as geobag has decreased the scour rates for each velocity. Furthermore this crushed concrete is from recycled concrete which add marks to environment friendly. Crushed concrete as geobag is a better solution compared to crushed concrete as riprap. This may due to the fact that the dimension of a crushed concrete needed to be design with restriction while a geobag dimension is designed by the engineer in more flexible way.

The cost of crushed concrete as geobag is cheaper than crushed concrete as riprap. The geobag is easier to obtain because of the raw material itself is in the construction yard. The transformation from crushed concrete to geobag will increase the construction cost in the short term. In contrast, it will preserve the environmental in the long term effects.

Fine and mixture crushed concrete are better than coarse crushed concrete as a countermeasure. The reason is the flexibility of finer and mixture crushed concrete of the cement paste part compared to coarse crushed concrete, which is comprised of aggregate part.

Figure 3 shows the fine crushed concrete and abandoned concrete in two bags. Fine and a mixture of

Figure 3. Abandoned concrete and crushed concrete.

Figure 4. Geobag filled with crushed concrete.

crushed concrete also is a good way to reduce the water from sipping it through in a short time in comparison to only crushed concrete in the geobag (Figure 4). It maybe increases the cost of construction because fine material is not cheap. However, if the crushed concrete can be crushed into smaller diameter, then it will become as same as the fine material. Moreover, a huge amount of money could be saved without the usage of fine material such as Bentonite.

CONCLUSION

Scouring is one of the issues and problems occur during flooding and natural disaster. It caused the bridges to fail and collapse during heavy rain and flooding. Integral bridges are designed to reduce the initial construction and maintenance cost. Most of the previous studies focused on the scouring impact on conventional and traditional bridge. Very few studies investigated on the scouring effects on integral bridge and its countermeasure.

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