Review of Scouring on Integral Bridge and its Possible Protection

Shatirah Akib, Teuku K. Syamsura, S.M. Shirazi, Moatasem M. Fayyadh and Budhi Primasari

Abstract**—**The purpose of this paper is to summarize the following protection of scouring countermeasures by using Bentonite-Enhanced Sand (BES) mixtures. The concept of underground improvement is being used in this study to reduce the void of the sand. The sand bentonite mixture was used to bond the ground soil conditions surrounding the pile of integral bridge. The right composition of sand bentonite mixture was proposed based on previous findings. The swelling effect of bentonite also was investigated to ensure there is no adverse impact to the structure of the integral bridge. ScourScour, another name for severe erosion, occurs when the erosive capacity of water resulting from natural and manmade events exceeds the ability of earth materials to resist its effects. According to AASHTO LRFD Specifications (Section C3.7.5), scour is the most common reason for the collapse of highway bridges in the United States

Keywords**—**bentonite, integral bridge, possible protection, scouring

I. Scouring on Integral Bridge

BRIDGE scour is the old problem faced by bridge engineer. The long milestones version of scouring countermeasure has produced many techniques, measures and practices at existing bridge and abutment. The research and selection of countermeasures were conducted for a long time ago until now. This paper presents laboratory works of the new strategy to prevent scouring on integral bridges. The bentonite will be investigated as an armor countermeasure of scouring on the integral bridge design. One of the current standard bridges constructed in Malaysia is integral bridge due to several advantages and appropriate landscape (Fig. 1). Integral bridge is one of the bridge which acts as a portal frame structure where bearings are limited and the joints are either eliminated. The continuous deck is monolithically connected to the abutments and cannot be separated completely. Vertical piles, usually arranged in a single row are rigidly connected to the abutments. Scour on this bridge type caused by natural flow phenomenon affects the substructure and superstructure.

Shatirah Akib is a Senior Lecturer with Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia (phone: 03-79677651; e-mail: Shatirahakib@yahoo.co.uk).

Teuku K. Syamsura is a student at Department of Civil Engineering of University Malaya, Kuala Lumpur, Malaysia (e-mail:kamilperfect@gmail.com).

S.M. Shirazi and Moatasem M. Fayyadh are with Department of Civil Engineering, Faculty of Engineering, University Malaya, 50603 Kuala Lumpur, Malaysia, (phone: 03-7967 7650: e-mail; shirazi@um.edu.my).

Budhi Primasari is with Department of Civil Engineering of University Malaya, Kuala Lumpur, Malaysia, (phone: 03-79677647; e-mail: bprimasari@um.edu.my)

Therefore, laboratory experiments are needed to incorporate a model of superstructure and substructure to refer to the real conditions in the river that involved complex flow and structure.

Fig. 1 Construction of integral bridge at Phase 2 of East Coast Expressway, Malaysia (Akib, 2009)

Fig. 2 Skewed integral bridge setup for scouring experiment (Akib *et al*, 2011)

Figure 2 shows the experimental set up for the effects of different parameters on the structural behaviour of a skewed integral bridge. Flow velocities affected scouring over time. Scour depth had a direct effect on the structural behavior, such as strains and displacements of the bridge substructure. Strain increased as the scour depth increased for almost all of the strain gauges (STs) and scour depth intervals. Flow velocity had a direct effect on the structural behavior of the integral bridge, due to increase of flow force. Strains and displacement on the slab and piles varied, due to location and the flow velocities. Finally, vehicle location had a different influence on the structural behavior (*Akib et al*, 2011).

II. BENTONITE

Bentonite is plastic clay formed normally from the alteration of volcanic ash. It consists of smectite minerals, usually montmorillonite. The available commercial names of bentonite are predominantly montmorillonite with impurities such as fine quartz particles. There are a few types of bentonite. Their names depend on the dominant elements, such as potassium, sodium, calcium, and aluminum. Montmorillonite with a 2:1 unit layer structure is an alumino-silicate mineral. Individual layers (or lamellae) are about 10 A ° (1 nm) thick. In contrast, up to several orders of magnitude larger in the other directions (Grim, 1968; Mitchell, 1993). Stable montmorillonite unit particles consist of 1 to 16 lamellae (Sposito, 1984) but 2–3 lamellae is typical of sodium montmorillonite (van Olphen, 1991). These unit particles can harden together to form clusters which, due to the tendency of the platy unit particles to align, are anisotropic (Pusch, 1999). Bentonite clusters can consist of many structural element particles (possibly 107 to 109) and can be arranged as size order. Unit layers (Lamellae) are smaller than unit particles and smaller than particle clusters. Bentonite was arranged in size order that consists of particles and voids. Interlayer pores are smaller interparticle pores (micropores) smaller than intercluster pores (after Pusch, 1999; Yong, 1999b). In civil engineering applications, bentonite is used in liquid state as mud for underground constructions (Besq, 2000). Bentonite suspensions are widely used in underground work because of their mechanical and rheological properties. These properties allow them to stabilize the wall of the hole by forming a cake to clean the hole by evacuating the cuttings and to reduce the wear on tools. Bentonite presents strong colloidal properties. Its volume increases several times when coming into contact with water, creating a gelatinous and viscous fluid. The special properties and parameters of bentonite include hydration, swelling, water absorption, viscosity and thixotropy. It is a valuable material for a lot of uses and applications. The bentonite is used in mining to strengthen the wall of mining structure. The research was conducted to study the behavior and increasing strength of soil when inserted the slurry bentonite. Result showed that the bentonite increased significantly the strength of soil structure (Swarsa et al, 2006). The degree of compaction for granular material improves when fine material presences (Wei, 2006). Wei also found the best compaction mixing of sand-bentonite to produce the best compaction. 2 % of bentonite content produced the highest level of compaction with and without curing cases. The compaction is the key to lower scouring without using any material that affects environment, for example concrete.

The scouring countermeasure by using bentonite is a new research. The idea is to fulfill and bond the sand with the bentonite before compaction. This idea can reduce the flow velocity passing through the sand particles. Reducing the flow through the sand foundation of integral bridge can reduce the scouring. The previous researcher used bentonite (Fig.3) to prevent the slope failures due to bearing capacity and lateral earth pressure failures. Bentonite is used in the drilling and geotechnical engineering industry based on its unique rheological properties. This material was chosen as an alternative countermeasure to minimize the impact of scouring action on substructure and superstructure at integral bridge based on the behaviour of bentonite that react to the surrounding water and could form mud. The particle of sand combined with the bentonite that reacted to the water performs a natural countermeasure surrounding of pile and abutment. This phenomenon was studied to establish the possibility of bentonite as a scouring countermeasure.

Fig. 3 Bentonite for scouring countermeasure

III. CONCLUSIONS AND FUTURE DIRECTIONS

This review paper summarized the possibility of using bentonite as a scouring countermeasure. The compactions as one of ground improvement method were applied in this research. The bentonite scouring countermeasure is a new research. The idea is to fulfill and bond the sand with the bentonite before being compacted. This material was chosen as an alternative countermeasure to minimize the impact of scouring action on substructure and superstructure at integral bridge based on the behaviour of bentonite that could react to the surrounding water and form mud. The particle of sand combined with the bentonite that reacted to the water performs a natural countermeasure surrounding of the pile and abutment. The composition of sand bentonite mixture was introduced to the best compaction conditions and avoided the adverse impact of bentonite due to swelling properties.

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