PROCESS OF CLAY BED DEFORMATION DUE TO THE ACTION OF MOVING PARTICLES OF BEDLOAD

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Introduction

Many studies had been conducted in the field of sediment transport and deformation of riverbed with non-cohesive sediment. But research on clay riverbeds was hardly conducted, and the knowledge about it was restricted. The authors have been conducting a systematic basic experiment on the erosion of "clay bed" generated by the effect of only water flow as the first stage of research (Nishimori and Sekine, 2009). Furthermore, an experimental study on also affected by bedload supplied from upstream, have been attempted by Sekine, Oka and Nomura et al. (2013), and Sekine and Hiramatsu (2017). Based on these studies, this study focused on the deformation process of clay bed to sand or gravel bed.

Summary of experiment

In this study, a series of experiments were conducted in two types of channels (see Figure 1). Movable bed was composed of clay only, and the sand or gravel was supplied uniformly at the boundary cross-section of upstream end of movable bed.
In a straight channel, the flow rate of water is 0.270 L/min, and the dimensionless tractive force for silica sand No.3 is $\tau^* = 0.079$. The relative sand supply rate q_b / q_e was set to be 0.25, 0.5, and 0.75. In the curved channel, on the other hand, the flow rate was set to be 200 L/min, and relative sand supply rate q_b / q_e was set to be 0.2.

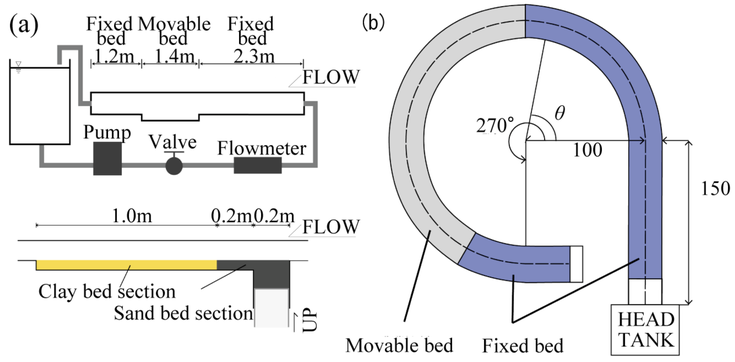


Figure 1. Experimental setup:(a) Straight channel (b) Uniformly curved channel

Clay bed deformation in straight channel

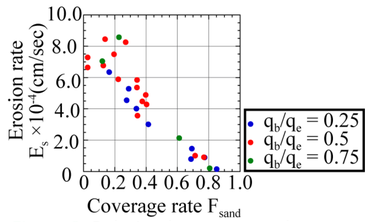


Figure 2. Relation between sand co verage ratio and erosion rate

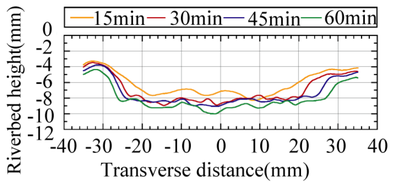


Figure 4. Cross-sectional profile of the riverbed

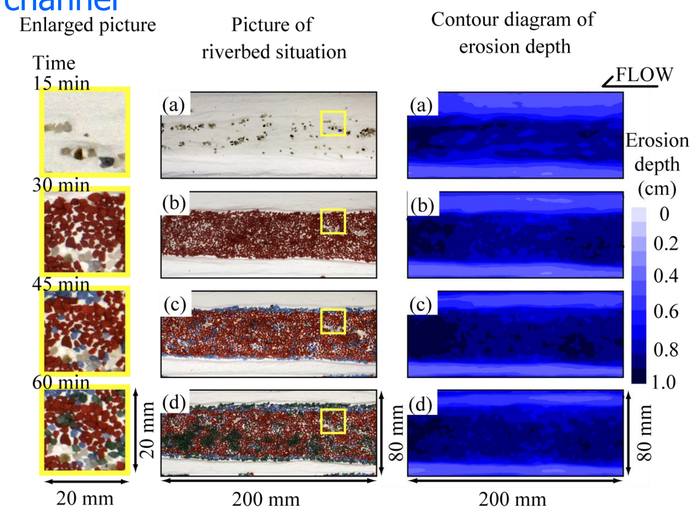


Figure 3. Riverbed situation and contour diagram

Erosion promotion and suppression effects due to moving particles as bedload

Effect of sand transported as bedload on the deformation process of clay bed was investigated quantitatively.

- From Figure 2, it can be seen that the erosion rate decreases as the sand coverage rate on the bed surface increases. And the relation is independent of relative sand supply rate q_b / q_e. This means that sand covered with the bed surface play a role to suppress the erosion of clay bed.
- In the initial stage of this phenomena, on the other hand, the erosion rate increases as time passes, because the transported sand particles contact the clay bed surface and promote clay erosion significantly.

As was explained above, this process is controlled by both "erosion promoting effect" and "erosion suppressing effect" on clay bed by sand or gravel transported as bedload.

Process of mixed layer formation

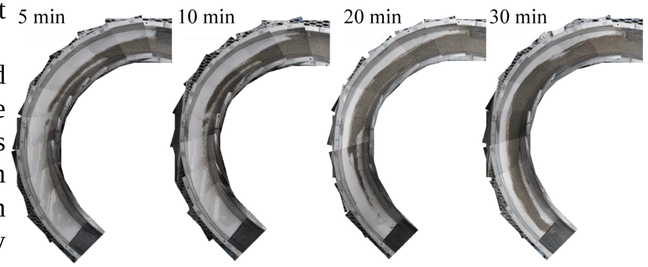
- As is seen from left photograph in Figure 3, sand remaining on the riverbed surface is in the state where half of the particle is buried in clay bed and forms a layer together with clay. This layer of sand and clay is called the "mixed layer" in this paper.
- From Figure 4, eroded inner-channel like a ditch was formed, and the channel widening occurred in transverse direction.

The process of this bed deformation can be summarized as follows; (1) a streak-like erosion occurs in the central portion due to the concentration of bedload, (2) erosion in the vertical direction proceeds but is suppressed as the coverage of sand proceeds, (3) lateral erosion occurs gradually in transverse direction, and (4) finally, the sand coverage proceeds over the wide range of bed.

Phenomena of clay bed erosion in uniformly-curved channel

Phenomena of clay bed deformation was investigated by using a uniformly curved channel where a secondary current can develop considerably.

- Photograph 1 (a)-(d) shows that sand is initially deposited along the inner side-wall due to the influence of the secondary current, and erosion of clay bed occurs initiates from the area. Dark portion along the inner wall in Photograph-1 denotes such area. White portion in Photograph-1, on the other hand, is the clay bed hardly eroded yet. The eroded area extends laterally toward outer wall gradually as time goes on.
- Figure 5 shows the cross-sectional profile of riverbed at each time. The left half with minus transverse distance corresponds to the outer half of bed, and the right is inner half. It can be seen that the remarkable erosion initiates in the inner half and the point of maximum erosion migrates toward the outer side wall as time goes on. The location where this erosion is most active is along the boundary between the area mixed layer developed and the area clay is exposed on the bed surface.



Photograph 1. Riverbed situation in a curved channel

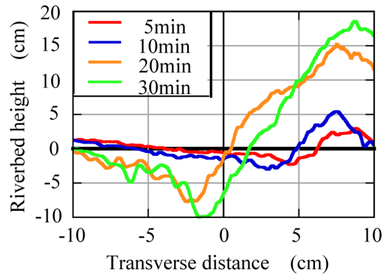


Figure 5. Cross-sectional profile of the riverbed at different times

Conclusion

In this study, we conducted an experimental study to elucidate the deformation mechanism of clay river bed under the influence of transporting sand and gravel as bedload as well as running water. It was found from a series of experiments that sand or gravel moving as bedload promotes the erosion of clay bed significantly. Such effect was made clear in both the straight channel and the curved channel. In addition, the formation of the mixed layer composed of clay and sand (or gravel) on the bed surface also proceeds, which reduces clay bed erosion by being covered with deposited sand or gravel. This process initiates in the central portion of the riverbed gradually, and then the lateral widening proceeds in a straight channel. In case of uniformly curved channel, such process is from the inner side to the outer side due to the influence of secondary current, but the essential mechanism is same as the one in straight channel.

References

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Sekine, M. Oka, K. and Nomura, M. (2013). *Journal of JSCE*, Ser. B1 (Hydraulic Engineering).
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