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Publication date
2017

Document Version
Final published version

Citation (APA)
Jammers, S. M. M., Paarlberg, AJ., Mosselman, E., & Uijttewaal, W. (2017). *Sediment transport over sills at longitudinal training dams with unaligned main flow*. 86-87. Abstract from NCR-Days 2017, Wageningen, Netherlands.

Netherlands Centre for River Studies

Nederlands Centrum voor Rivierkunde

Book of abstracts

NCR days 2017
February 1-3, 2017
Wageningen University & Research

NCR is a corporation of the Universities of Delft, Utrecht, Nijmegen, Twente and Wageningen, UNESCO-IHE, RWS-WVL and Deltares

Sediment transport over sills at longitudinal training dams with unaligned main flow

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Introduction

Longitudinal training dams (LTDs) are constructed in the River Waal in the Netherlands. They are aligned parallel to the river shore and divide the river into a main and side channel. The existing groynes are removed yielding more discharge capacity at high flows. The side channel creates possibly a sheltered environment for species compared to the traditional groyne field (Collas, 2014). Although the lay-out of the LTDs has been extensively studied using numerical models (e.g. Huthoff et al., 2011), the morphodynamic response is yet unclear and depends strongly on the dimensions (length and height) of the openings. The inlet and openings (see Fig. 1) are sill-type structures which can be changed relatively easy.

These sills are designed in such a way that they serve as a barrier for water and bed load sediment. To make long-term morphological predictions, it is necessary to understand the bed load transport processes over these sills. Suspended sediment transport is not considered in this study. We developed an analytical model to predict sediment transport paths on a slope, using a correction on the well-known critical Shields parameter.

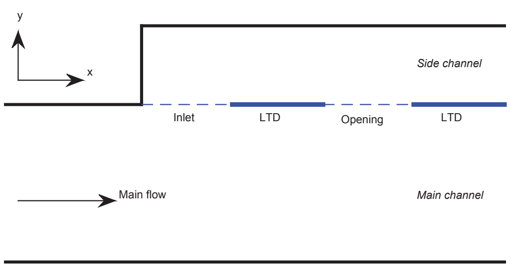

Figure 1. Schematisation of river – top view.

Correction for main flow aligned with sill

If the main flow is aligned with the sill, the flow is parallel to the depth isolines of the sill. This part of the sill is schematised as a transverse slope in the main channel with main flow in x-direction, see Fig. 2.

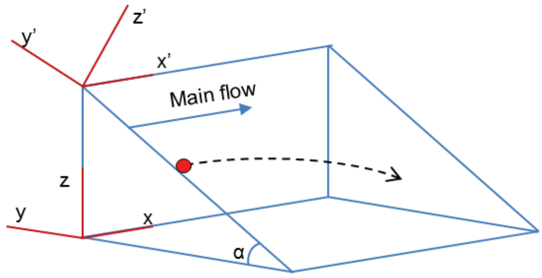

Figure 2. Path of sediment particle on transverse slope.

Shields, (1936) performed sediment transport experiments on a horizontal bed in a straight flume and derived a critical condition for the initiation of motion, the critical Shields parameter (Θ_{c0}). Dey, (2014) uses the approach of Shields, (1936), Yang, (1973) and Ikeda, (1982) to describe the sediment transport on a transverse slope in terms of an adapted critical Shields parameter. Due to gravity sediment particles tend to move towards the main (horizontal) river bed. He proposed a 'correction factor' ($\hat{\Theta}_{c\alpha}$) for the critical Shields parameter (on a horizontal bed) given the situation where the flow is in downstream direction on a transverse slope (α). Equation (1) describes this correction factor.

$$\Theta_{c\alpha} = \hat{\Theta}_{c\alpha} \cdot \Theta_{c0} \qquad (1)$$

Correction for main flow not aligned with sill

In this case the flow over the sills is not in the x-direction, but has a component in both x and y (transverse) direction, see Fig. 3. In analogy with the previous section a new correction factor ($\hat{\Theta}_{c\gamma}$) is presented in Equation (2) (CIRIA et al., 2007). The term α is the angle the transverse slope (i.e. sill) has, $\tan\phi$ is the natural angle of friction (also known as μ), finally γ is the flow angle with respect to the x' direction in the x'-y'-plane (see Fig. 3).

$$\Theta_{c\gamma} = \frac{\sin\alpha\sin\gamma}{\tan\phi} + \cos\alpha\sqrt{1 - \frac{\tan^2\alpha\cdot\cos^2\gamma}{\tan^2\phi}} \quad (2)$$

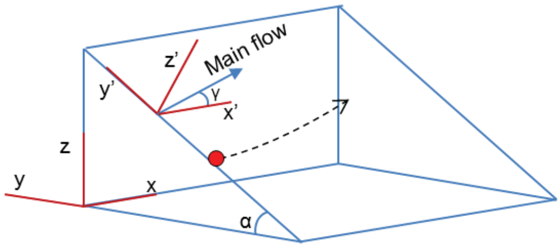

Figure 3. Particle path of sediment particle on transverse slope with different flow angle (γ).

Using Equation (2) the critical Shields parameter can be calculated for various flow situations. In Fig. 4 the Shields diagram is presented for different flow angles (γ). The figure shows that increasing the flow angle, increases the critical Shields parameter. This means that the moment at which sediment particles start to move (initiation of motion) is different for each flow angle.

Conclusion

The initiation of motion will start at a higher critical Shields value, i.e. critical shear velocities for larger positive flow angles (γ). Nevertheless, the distance to the crest of the sill is shorter for large positive angles. Therefore further investigation is needed to investigate at which flow angles the bed load sediment is transported into the side channel. It is thereby necessary to include the length scales of the sill as well.

Outlook

The analytical model – currently under development – can model the path a sediment particle travels. We will use this model to assess whether sediment particles will reach the top of the sill and eventually be transported into the side channel. Following, a numerical flow and transport model (in Delft3D) will be made together with another student at Delft University of Technology (Bart van Linge). In this model a section of the river is modelled including the sill, LTD, main and side channel. It will be assessed if the current bed load formulations are sufficient to model bed load sediment transport. If not, it will be investigated how the formulations used in the numerical model can be improved.

Acknowledgment

I would like to thank HKV Consultants and Deltares for their support during this research.

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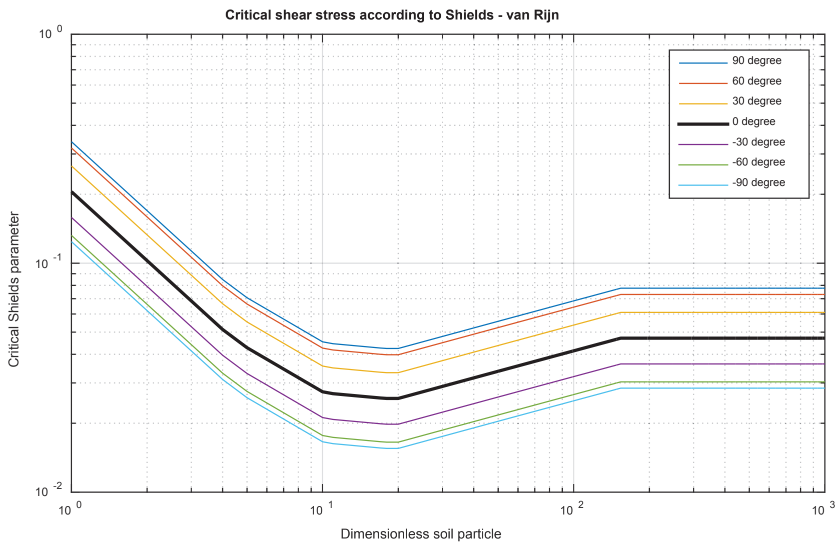

Figure 4. Shields diagram for different flow situations.