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The effect of transverse bed slope and sediment mobility on bend sorting

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Problem definition

Lateral sorting (= bend sorting) is observed in natural meanders, where the inner and outer bend are fairly fine and coarse, respectively (e.g. Julien and Anthony, 2002; Clayton and Pitlick, 2007). This is caused by the mass differences between grains on a transverse slope, leading to coarser grains being dragged down net more than finer grains (Ikeda et al., 1987). The slope of the transverse bed influences the degree of bend sorting greatly.

Also vertical sorting occurs. Grainflows at the lee side of dunes result in a net fining upward trend (Kleinhans, 2005). The degree of vertical sorting depends on flow velocity and sediment mixture characteristics.

Most previous studies focused on the development of the transverse slope using small ranges of uniform sediment, so spatial sorting was absent. Yet, it was argued that there is a feedback mechanism between bend sorting and the transverse slope (Ikeda et al., 1987). So, it is of key importance to attain better understanding of how sorting in river bends comes about, which can improve current numerical models.

It is the objective of this study to examine experimentally the effect of transverse bed slope and sediment mobility on spatial sorting of bed load in a meander.

Methodology

A rotating annular flume was used in order to isolate all parameters (Baar et al., in prep.). A rotating lid steered the flow. Counter-rotation of the flume itself introduces a centrifugal force on the flow low in the water column, thereby weakening helical flow intensity (Booij and Uijttewaal, 1999).

A near-unimodal sediment mixture was used with a median grain size d_{50} = 0.75 mm and first standard deviation mass percentiles d_{16} = 0.53 mm and d_{84} = 1.49 mm. The mixture was chosen such that armouring was unlikely to occur.

A total of 34 experiments were conducted with varied helical flow intensity and sediment mobility. Bed elevation at morphodynamic equilibrium was scanned at 10 radii (Fig. 1), using an echo sounder. 13 experiments were sampled when meeting the following criteria to acquire local grain size distributions:

- Transverse slope between 0 and 0.25
- $\theta/\theta_{cr} < 3.6$
- small dune height $\Delta < 0.1$ m

where θ = dimensionless bed shear stress and θ_{cr} = dimensionless bed shear stress threshold of motion. Using these criteria, bed morphology resembled natural rivers best. In total, 340 samples were taken over the width of the flume at the dune top, in the dune trough and over the vertical deposit at the lee side of a dune (= bulk samples) (Fig. 1).

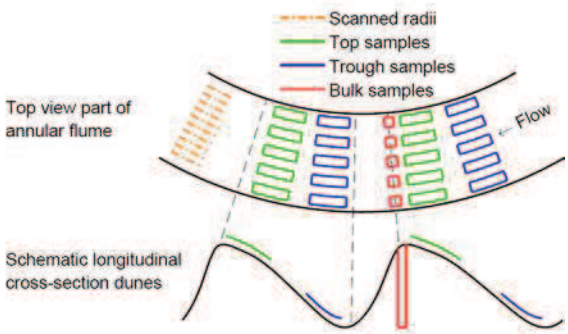

Figure 24. Sampling locations and scanned radii of bed elevation. Based on the scanned bed elevation, a mean transverse slope was computed. Lee side was removed up to the brinkpoint before sampling over the vertical.

Results and conclusion

Typical bed morphology at morphodynamic equilibrium was a transverse slope with dunes in the outer bend and ripples in the inner bend (Fig. 2). Generally, the outer bend was coarser than the inner bend.

Lateral separation of grain size shows clear correlation with the transverse bed slope, with coarser grains in the outer bend and finer in the inner bend; the larger the transverse slope, the more distinct bend sorting became (Fig. 3). Especially slopes larger than 0.15 caused a sharp transition, where all coarse grains were in the outer bend (Fig. 3). For smaller slopes, the transition was more gradual.

Higher sediment mobility leads to higher dunes and a thicker active layer and likely more turbulence. This resulted in slightly less distinct separation of grain sizes over the lateral.

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Figure 25 Top view of a section of the bed in the annular flume. Flow was from left to right. In the outer bend, there is a dune top, followed by a coarse trough. In the inner bend, there are ripples that collapse downstream of the dune's brinkpoint.

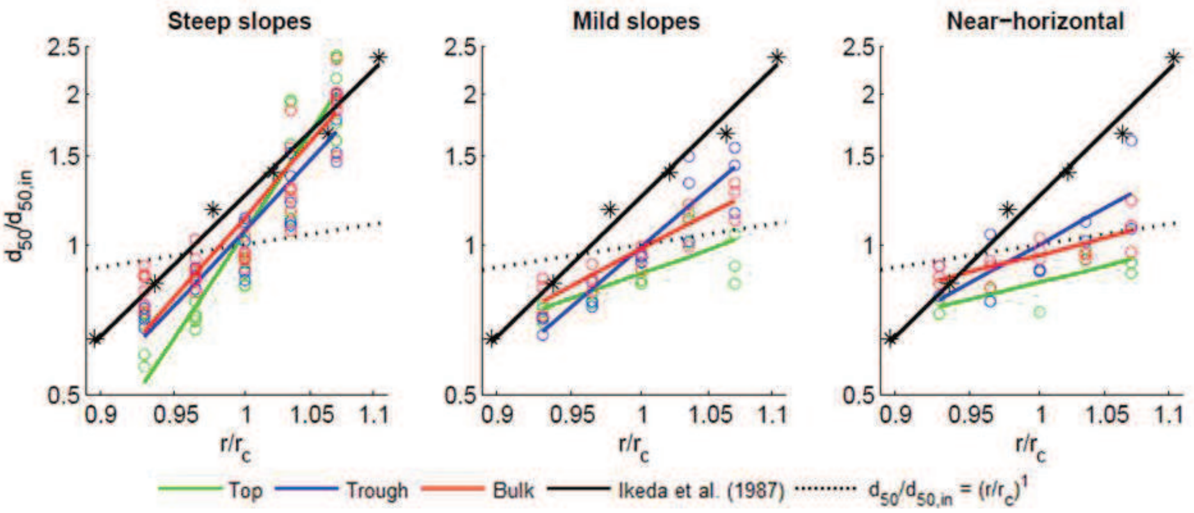

Figure 26. Relative median grain size over the width of the flume. $d_{50,in}$ = median grain size of initial, unsorted mixture, r = local radius and r_c = radius at channel axis. Power of power fit increases with transverse slope, indicating a larger transition from fine to coarse.