Suppression Condition of Alternate Bar Migrations in Sine-Generated Meander Channels

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Introduction

Alternate bars develop during floods in river channels that have been artificially straightened. The channels have sets of deep narrow pools, shallow rifles, And broad bars. The broad bars are located alternately along both river banks. Water routes with a pool-riffle sequence meander from one bank to another. At flooding, the flow concentrates and speeds up at pool areas near the bank, then diffuses toward the downstream opposite bank. Bed sands under high -velocity flow are scoured away, and most of the sand is deposited beyond the front edges of bars. Thus, alternate bars move downstream while retaining their blade-like shape.

They also migrate in moderately curving and meandering channels, but not in more strongly meandering ones. Kinoshita and Miwa (1974) studied bar behavior in meander flumes and documented critical bend angles. Each meander flume was constructed from straight segments joined at an angle to reproduce repeated downvalley change. They experimented with many types of flumes, bend angles, and straight segment lengths, and found critical bend angles beyond which bars do not migrate through meander flumes.

Langbein and Leopold (1966) and Parker et al. (1983) showed that sine-generated traces represent river meander shapes, particularly at low amplitude. While the behavior of alternate bars in sine-generated meanders was studied by Whiting and Dietrich (1993) and Toyabe et al. (1993), critical bend angles have not been well clarified.

We studied critical bend angles in sine-generated meander channels with wavelengths 6 to 18 times the channel width. We also studied the relationship between angles and differences in alternate bar lengths developed in straight flumes with three sets of hydraulic quantities.

Experimental Design

We studied critical bend angles required to suppress alternate bar migration, choosing three sets of hydraulic quantities (Table 1) under which alternate bars develop clearly in a 26-cm-wide straight channel. Mean bar length differs with each set of quantities. Before imposing flow of a certain discharge, sieved sands were flattened carefully on the channel bed at a certain slope. At the beginning of flow, water depth is almost equal at every longitudinal section, and stream lines are approximately parallel to the bank. Bed sands move straight in the downstream direction. A few minutes later, alternate bars are seen in all reaches of the 19.8-m-long channel. Alternate bars gradually elongate and migrate steadily downstream, while maintaining their morphology (Figure 1). Their lengths disperse little from the average.

Table 1. Hydraulic variables in straight channels under 3 hydraulic condition

Ser. No.	d_m(cm), s	I	Q (l/s)	V_m (cm/s)	h_m (cm)	B/h_m	V_m^2/gh_m	$h_mI/(s-l)d_m$
I	0.08, 2.49	1/200	1.6	35.2	1.75	14.9	0.72	0.073
II	0.08, 2.49	1/100	1.0	32.9	1.17	22.2	0.95	0.098
III	0.15, 2.49	1/100	1.6	39.1	1.58	16.5	0.99	0.071

d_m: Mean diameter of bed materials, 0.08 (cm) sand sieved between 0.06 and 0.10 cm, 0.15 (cm) sand sieved between 0.10 and 0.20 cm, s: Specific gravity of sand, I: Initial channel bed slope, Q: Flow discharge (l/s), V_m: Mean velocity measured in the early stage by the tracer method (cm/s), h_m: Mean water depth calculated from the flow discharge and mean velocity (cm), B: Channel width (0.26 m in our experiments), g: Gravitational acceleration

Figure 1. Alternate bars in straight channel under the hydraulic condition II
(Pool areas are seen as white because white paint solution was poured into water)

We constructed many meander flumes whose traces are sine-generated curves

$$\phi = \omega \sin 2\pi \{(s/m) - 0.5\}$$

with varied ω and m (Figure 2). Angle ϕ is at distance s measured along the channel trace. Bend angle ω is the maximum bend angle that the channel makes downvalley at the inflection between bends. Length m is the channel length measured along the channel centerline over one waveform. Length m can be changed to meander wavelength λ.

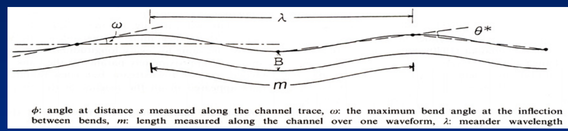

Figure 2. Experimental flume with sine-generated curve trace

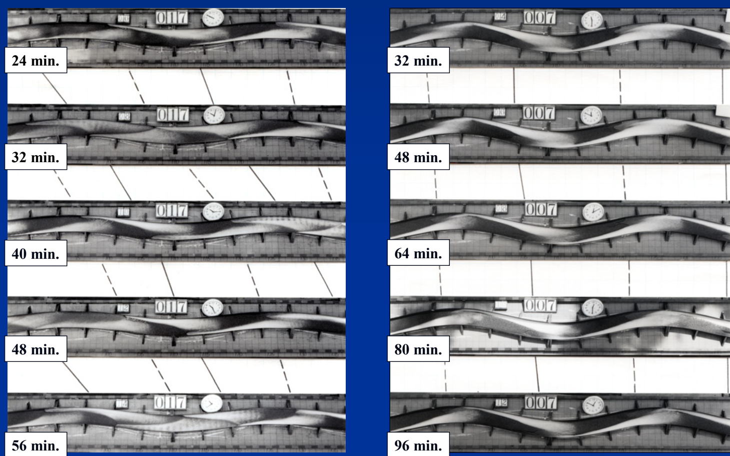

Figure 3. Migration and suppression of alternate bars in a meander channel
(λ/B=12, ω=7.5°and ω=12.5°, Hydraulic Condition III)

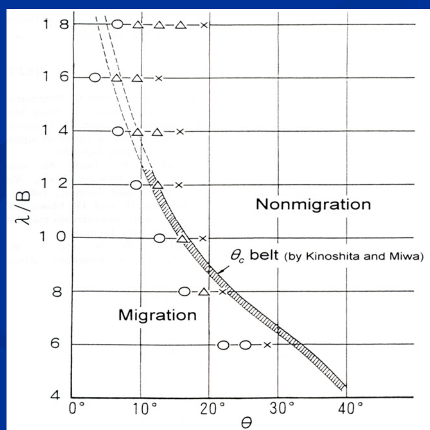

Figure 4. Comparison of our and Kinoshita and Miwa's experimental results
(○: bar migration under the 3 hydraulic condition, △: mixed migration and non-migration under the 3 condition, ×: non-migration under the 3 condition)

Summary of Experimental Results

The results of migration follow (Figure 3 and Figure 4).

(1) Bar migration is suppressed by smaller meander angles as wavelengths of meander channels increase.

(2) In meander channels whose wavelengths are from 6 to 12 times the channel width - common in Japan - critical angles are roughly equal even under the three different hydraulic conditions.

(3) In meander channels whose wavelengths are greater than 14 times the channel width, critical angles are not equal under any of the three hydraulic conditions. Especially under condition II, larger angles are needed to suppress bar migration than under other conditions, because short bars migrate easily.

(4) In the longest-wavelength channels in our experiments, the critical angle for λ/B =18 is larger than that for λ/B =16, under all hydraulic conditions.

(5) Under hydraulic condition I, alternate bars lose their shape and diagonal cross-stripe-shaped bars migrate downstream through meander channels whose wavelengths are larger than 10 times the channel width and whose angles are roughly equal to critical angles.