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Plan Form Variation of Meandering Channels with Bank Erosion

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1. Introduction

Bank erosion in meandering bends are common feature in the alluvial rivers. Over the last few decades, considerable efforts have been made in order to elucidate the physical reason of meandering river bank erosion. But processes of meander plan form deformation and mechanism of meander bend migration in the fully alluvial context is yet to be clarified. The variation of the meander plan form has been presented here on the basis of a series of hydraulic experiments.

2. Summary of the experiments

2.1 Procedure: All the experiments were performed in the same experimental flume with identical initial cross sections and plan forms as used by Rahman et al. (1996). The initial hydraulic conditions are listed in Table. 1. For Run 1 ～ Run 3 the bank line changes and cross sectional variations were measured with suitable time interval , whereas, for Run 3～Run 14, bank line changes and near bank surface velocity were determined using photography and video technique respectively. Moreover, near bank water depth (2 to 3 cm away from bank line) was measured at each time. The measured data were then used for analysis.

Table 1. Experimental condition

Run no	Q (l/s)	D_0 (cm)	$2B_{w0}$ (cm)	U_0 (cm/s)	U_{*0} (cm/s)	ω	L (m)	I	Run time (min)
1	1.98	3.00	26.00	33.00	3.12	30°	2.0	1/300	125
2	2.57	3.50	28.00	34.90	3.22	30°	2.0	1/300	240
3	0.63	1.10	18.40	34.90	3.85	30°	2.0	1/100	240
4	0.43	0.95	17.80	28.46	3.50	30°	2.0	1/100	240
5	1.00	1.42	19.68	41.82	4.42	30°	2.0	1/100	110
6	1.42	1.72	20.88	57.34	5.76	30°	2.0	1/100	240
7	1.42	2.33	23.32	32.67	3.05	30°	2.0	1/300	360
8	1.73	2.52	240.8	32.50	2.68	20°	3.0	1/300	240
9	1.73	2.52	24.08	32.50	2.68	20°	2.0	1/300	240
10	0.63	1.10	18.40	34.90	3.85	20°	2.0	1/100	240
11	0.63	1.10	18.40	34.90	3.85	20°	3.0	1/100	240
12	1.00	1.42	19.68	41.82	4.42	20°	3.0	1/100	110
13	0.43	0.95	17.80	28.46	3.50	20°	2.0	1/100	240
14	0.43	0.95	17.80	28.46	3.50	20°	3.0	1/100	240

2.2 Definition of some terms: Sinuosity (*K*): It is expressed as the ratio of the channel wave length to linear wave length in the channel center line. Bend Development (*D*): *K* of a certain bend increases with time from its initial value. Straightening (*S*): *K* decreases with time from its initial and certain value.

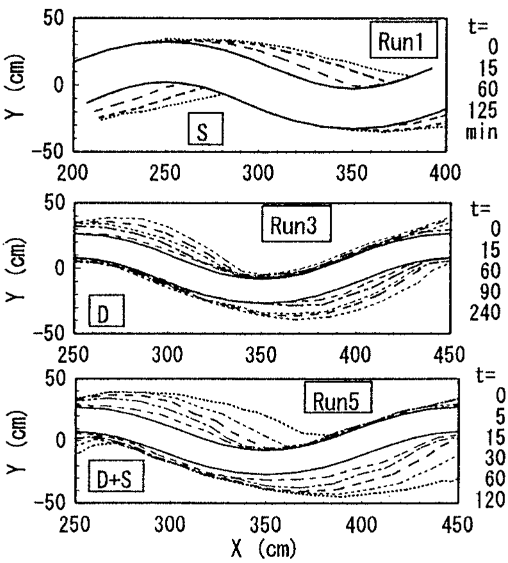

Fig. 1. Temporal variation of plan forms

3. Experimental results and discussions

3.1 Variation of meander plan form: The channel plan form variation was different depending on initial hydraulic and geometric condition. Plan forms were straightening (*S*) in Run 1, 2, 7 and 9, whereas, bend development (*D*) was observed in Run 3, 4, 8, 11, 12, 13 and 14. During Run 5, 6 and 10, initially bend development was observed, but straightening started on the way and we express this phenomenon as *D+S*. The typical examples for plan form variation in Run 1, Run 3 and Run 5 and temporal variation of sinuosity can be seen in Fig. 1. and Fig. 2, respectively.

3.2 Mechanisms for development or straightening: A typical example for the distribution of temporal variation of near bank shear stresses along the right bank are shown in Fig. 3. In Run 5, initially, bend

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development was observed as the shear stresses exceeded the critical value at around the bend apex (X=350 cm) causing major erosion started from the bend apex. The bend development was continued up to 30 minutes and after that the zone of excess shear stresses was shifted downstream of X=400 cm, causing prominent erosion around that area and straightening was resulted.

3.3 Criteria for meander bend development: (a) Criteria for meander development have been examined using Eq. (1) which is derived as the condition for the occurrence of positive velocity deviation due to a point bar (Hasegawa, 1984).

$$m > \frac{2B_w}{\sqrt{\frac{1}{8(\frac{\pi}{4}A+1)}\left\{\sqrt{8(\frac{\pi}{4}A+1)(\frac{\pi}{4}\gamma A-1)(\frac{f_o}{\pi\varepsilon})^2+1}-1\right\}}} \quad (1)$$

where, $\varepsilon = D/B_w$, $\gamma = 4/3$, $f_o = 2gDI/U^2$ and A = transverse bed slope parameter, estimated as $\eta/R/2B_wD$, where η' is the difference between the maximum and minimum bed level at apex.. The final state for Run 1, 2 and 9 (corresponds to B_w/D=15) and Run 3, 11, 12, 13 and 14 (corresponds to B_w/D=35) are tested for the straightening or development of meander bends in Fig. 4. The observed results show good agreements for straightening or development of meander bends.

(b) We tested the dependence of meander plan form variation on some derived non dimensional hydraulic and geometric parameters from the governing equations of flow and sediment transport in meandering channels. It was found that among different parameters, straightening and development zone can be well distinguished in the $Fro(D_o/d)^{3/2} \sim m/D_o$ plane as shown in Fig. 5.

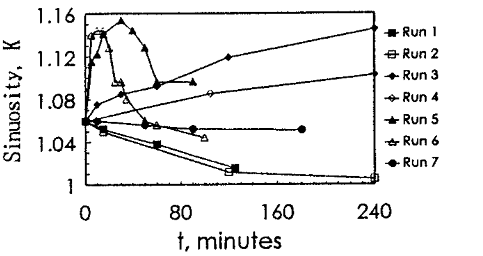

Fig. 2. Variation of sinuosity (*K*) with time

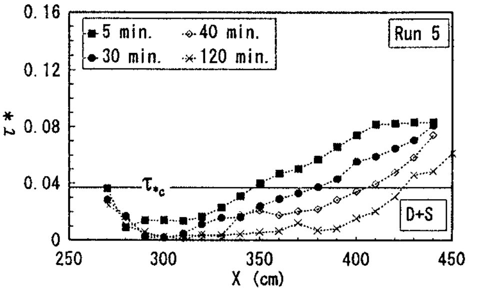

Fig. 3. Longitudinal variation of shear stresses

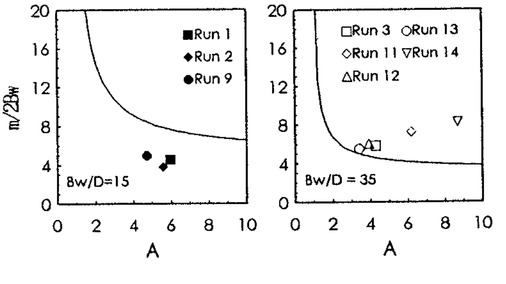

Fig. 4. Criteria for meander development

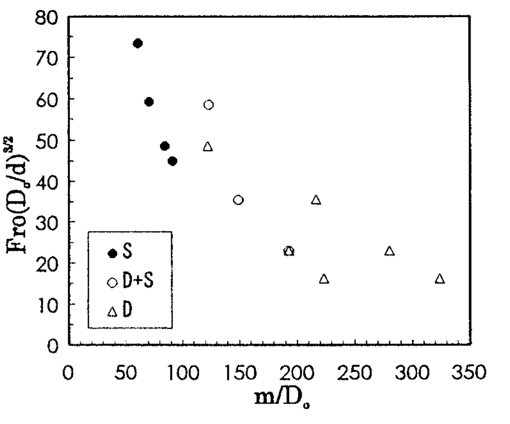

Fig. 5. Dependence of plan form variation on non-dimensional parameters

4. Conclusions

The longitudinal distribution of the near bank shear stress variation is an important factor for determining whether bend development or straightening would occur. It was found that if the shear stress exceeds its critical value at around the apex of the outer bank, development would occur, otherwise, straightening would occur if it exceeds at around inner side of the bend apex. The dependence of plan form deformation has been discussed on the basis of some initial non-dimensional parameters have been discussed.

References

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