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Prediction of Flow Regimes and Bedform Migration

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ABSTRACT

Regime of flow and migration rate is an important factor to estimate the rate of sediment transport and identify the various shape of bed form geometry in natural Channels. It is also observed that as sediment transport are totally dependent on regimes of flow and its occurrence in natural as well as in laboratory channel is very difficult to predict. This experimental study is devoted to examine the flow regime characteristics over sediment beds in open channel and also investigated the regimes of flow affected by the sediment movement. It comprises a series of flume experiments on sediment bed of median size, d_{50}= 0.38 mm and 0.75 mm. In each set of experimental run the bed-form characteristics are examined. The experimental results are compared with the various flow regime relationships to explore the impact of sediment movement. Also, the bed-form migrations were studied for different flow conditions. Experimental investigations were carried out with velocity measurements by a Pitot tube.

INTRODUCTION

The complexity of bedform in sand bed rivers continuous to challenge engineers and scientists. The large no of dimensionless parameter describing the complex interaction between sediment particles and hydrodynamic forces contribute to elusive understanding of bedforms and flow resistance in alluvial channels. Estimating bed form stage and migration rate is quite important for sediment transport .Accurate regimes of flow prediction depends on various flow parameter. The paper presented here originated in an attempt to explain Prediction of flow regimes and bedform migration. The d_{50} of sediment range from 0.38 mm to 0.75 mm. Complexities in alluvial sand-bed channels stem from the variety of bed-form configurations that arise under different flow conditions. Starting from plane bed without sediment transport, ripples, dunes, washed-out dunes, plane bed with sediment transport, antidunes, and chutes and pools develop in large experimental flumes as the flow intensity increases in magnitude over a bed of loose sand particles.

Liu (1957) used the ratio u_*/ω of the shear velocity u_* to the particle fall velocity ω as a function of the grain shear Reynolds number, $Re_* = u_* d_S / \nu$, suggests that ripples and dunes essentially cannot form in gravel-bed channels. Here d_s=particle diameter.

Albertson, Simons and Richardson (1958)gave a generalized criterion for predicting the regimes of flow. Speculating that the parameters, $Re_* = u_* d_S / \nu$ and u_*/ω, which define the conditions of beginning motion and formation of ripples, may be adequate to predict the other regimes of flow, they plotted the data on a graph with u_*/ω as the ordinate and $u_* d/\nu$ as the abscissa. They have used range of sediment sizes from 0.011 mm to 4.94 mm. Thus knowing the shear stress, the sediment size, kinematic viscosity and the fall velocity, the regimes of flow can be predicted. Considering the orientation of lines describing the regimes, Albertson et al. suggested a modified Liu curve for the beginning of ripple formation, which is more or less parallel to the regime curves.

Garde and Ranga Raju (1958) have proposed a regime criterion using *R/d* and $s/\left[\left(\gamma_s - \gamma_f\right)/\gamma_f\right]$ as the two parameters. The lines demarcating the regimes are at an Inclination less than 45∘ to the horizontal, whereas lines of constant shear stress will be inclined at 45∘. Thus it can be seen that, for a given sediment size, flow can occur at different Regime can occur under different regimes at a constant shear stress. It is in this respect the $s/\left[\left(\gamma_s - \gamma_f\right)/\gamma_f\right]$-R/d criterion differs from the criteria presented by Albertson et al. and Bogardi. Furthermore since this criterian does not involve the velocity of flow, it can be easily used for the prediction of regimes in problem related to resistance. Sugio (1985) has proposed a regime criterion using τ_* and S as the two parameters. This criterion can be converted into a criterion based on the parameters R/d and $s/\left[\left(\gamma_s - \gamma_f\right)/\gamma_f\right]$.

Simons and Richardson (1963) proposed a bedform predictor encompassing both lower and upper regimes by using the stream power as a function of particle diameter. They have considered both flume and field data and their criterion involves the use of R,S,d and According to their result , ripples cannot be found for *ds* >0.6 mm. This bedform predictor is based on extensive laboratory experiments and is quite reliable for shallow streams. However, it deviates from observed bed forms in deep streams.

Karim (1995) developed bed regime prediction from graphical analysis of laboratory data in the form of the following expressions for two limiting Froude numbers, defined as

$$F_t = 2.716\left(d/d_{50}\right)^{-0.25} \quad F_u = 4.785\left(d/d_{50}\right)^{-0.27}$$

Where F_t = Froude number at the beginning of lower regime and F_u = Froude number at the beginning of upper regime. Based on 2.7, 2.8 different bed regimes can be determined from a known Froude number $F_r = (V/\sqrt{gd})$ as follows

Lower regime (ripples, dunes) = $F_r \le F_t$

Transition regime (washed out dunes) = $F_t \le F_r \le F_u$

Upper regime (plane bed, antidunes) = $F_r \ge F_u$. A relation for the predicting ripple-bed configuration was developed from an analysis of laboratory data reported by Guy et al. (1966) in the form of the following dimensionless number N_*, which is a product of the Shear Reynolds number ($R_{*C} = u_{*c} d/\upsilon$; υ = kinematic viscosity of water) and particle Froude no $F_* = V/\sqrt{g(s-1)d_{50}}$

$$N_* = \left(u_{*c}/d_{50}\right)\left(V/\sqrt{g(s-1)d_{50}}\right)$$

Where, V = Flow velocity, d= flow depth, s = specific gravity of particle and d_{50} = mean diameter of particle.It was found that $N_* < 80$ defines the occurrence of ripples for most of the observed flows with ripple beds in the laboratory data Guy et al. (1966) and (R_* = 10–20 for ripples), proposed by Raudkivi (1997).

Simons et al.(1965) present a bedload transport equation to calculate bedload sediment flux, assumed to be the total sediment flux per unit width (q_s), from average bedform migration rate (V_b) $q_s = (1-p)V_b(H/2) + K$ Where *P* is the porosity of the sand bed, and *K* is the part of load that does not contribute to the propagation of dunes or ripples. Simons et al. (1965) used the equation to calculate sediment flux using 101 flume experiments and found the calculated values agreed well with observations for coarser sand, but underestimated total load for finer sand. The model also failed at higher flows where the bed is in transition to a plane bed.Simons et al.(1965) also attempt to calculate bedform migration rate from measured flow parameters using empirical equations by Znamenskaya (1962) $V_b = K_1[\bar{U} - U_0]d/H$ $V_b = k_2\bar{U}^3/gd$ where *d* is flow depth, $\bar{U}$ is mean flow velocity, U_0 is no eroding mean velocity,K_1 and K_2 are constants. Smith (1970) proposed that when the shear stress is maximum at a bedform crest and minimum over bedform trough, sediment flux follows the same pattern. In this case, erosion occurs on the stoss side and deposition occurs on the lee side resulting in bedform migration downstream without growth and decay (Figure 2.5 a) McLean, (1990).When maximum shear stress shifts upstream of the crest, maximum sediment flux also occurs upstream of the crest resulting in deposition on the crest and hence growth of the bedform (Figure 2.5 b). On the other hand, when maximum shear stress shifts downstream of the crest, maximum sediment flux also occurs downstream of the crest resulting in erosion of the crest and hence destruction of the bedform (Figure 2.5 c).

Van Rijn, (1993) have find that the bedform migration rate cannot be predicted strictly from flow variables, studying the mechanisms of bedform movement would improve our of what controls bedform migration rate. Bedforms move downstream by erosion at the upstream face (stoss side) and deposition at the downstream face (lee side) (Figure 2.6). Bridge, (2003); Jerolmack and Mohrig, (2005); Leclair, (2002); Venditti et al., (2005) have shown that the length and height of an individual dune in a bed may increase or decrease in space and time as it moves downstream under steady and uniform flow conditions. In addition, a population of bedforms can change by constant creation and destruction of individual bedforms. The most common mechanisms that change bedform geometry are overtaking (combining), splitting, trough-scouring.

Allen, (1973); Leclair, (2002) have found that increase in the height of individual dunes is commonly accomplished by trough scouring and or by a fast upstream bedform overtaking and adding to the height of a downstream bedform. The length of the downstream bedform decreases as it is being overtaken, and the length of the combined bedform increases. The speed of the combined dune normally decreases as its height increases, if sediment transport rate is constant in space and time.

Bridge, (2003); Gabel, (2003) and Venditti et al., (2005ba) found that bedform decreases in height as it splits into two or more smaller bedforms. The small-scale Superimposing bedforms move faster than the large bedform and the addition of new bedforms decreases the length of the host bedform. On the other hand, a bedform being overtaken by an upstream bedform may decrease in height or be destroyed when trapped in the flow separation zone of the upstream bedform.

OBJECTIVE

Objective of the study is

1. Identification of different flow Regimes.
2. Characteristics of bed form and with different size bed particles.
3. Variation of bed form geometry with respect to time.
4. Changes in bed profile with the varying velocity and effect of migration rate on bedform geometry for different bed particle.

LABORTARY EXPERIMENTS

Experiments on bedform for sand mixtures were, carried out under controlled conditions of discharge, sediment 'size, slope, temperature, and flow depth. Numerous experiments on bed were carried out in a 0.075 m wide, 5m long,0.4mdeep flume that recirculates both and sediment. Change of bed profile clearly visible through the plexiglass sidewalls. The flume is made by glass and its transparent in both two sides and can be tilt able 0 to 2 %. The maximum capacity of the pumps being 120 Liter/minute.

The water from the storage tank flows into the flume through the strainer which helps to reduce the disturbances in the flow. A regulator valve is connected with rotatometer to control discharges and calibrated rotatometer is used to measure discharge. At the end portion of flume a hooper is connected with storage tank which diverts water to flume to storage tank for recirculating.

At the Start of experiment, we allow the water to flow in to the flume. Water level is maintained according to flow parameter by using adjustable gates at the outfall. Aggregates of Sand size of d_{50} 0.38 mm and d_{50} 0.75 mm is used here as a test material. A uniform thickness of 40 mm bed is made in flume through its whole length. The discharge of rotatometer is adjusted and the flume is filled with water to a certain depth. The pitot tube is adjusted at the top of the flume and the readings are measured over the bed set in flume in a test section. We followed these steps for different fine aggregate, different slope and with different discharges. Test Readings are taken over the bed and measured the velocity, types of bedform and their geometric shape with migration rate. All sediments collected into a separated tank at downstream which is fixed above storage tank. Before every experimental test sediments are mixed properly and leveled properly into the glass flume.Bed form dimensions, change of bedform stage and bed form dimensions are obtained through a digital camera which is fixed with the glass flume. For a particular test run with the help of digital camera, video has been recorded of a test section for 30 minutes period. This video of test section has been converted in to images and these images converted into graph with the help of PLOT DIZITIZER. In test section few reference points was given to covert the image resolution into graphs

with almost accurate scale. By following these steps for every test run the types of bed form and its dimensions at 5sec interval has been identified. As Bedform translation can be measured by tracking bedform crests as demonstrated in Simons et al. (1965) similarly by using Time variation graph we can find out migration rate of bed form from our graph.

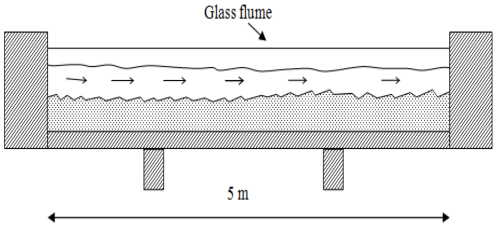


Fig.1. Schematic of Flume

OBSERVATION AND RESULT

Sediment movement and Prediction of Regimes of Flow

Shields diagram is a functional relationship between non dimensional shear stress τ_{*c} and shear Reynolds no R_* and the curve is knows as shields curve. shields diagram of the laboratory data indicates that all size particles are in motion except run no 14, 15,16,17,18 & 19 where sediment size was 0.75mm and slope 0.00 1 & 0.002 .R_* values reflect the transition zone between turbulent flow over smooth boundary (4 <R_*< 11.6) and turbulent flow over rough boundary (11.6 <R_*< 70). the value of the shields parameter required higher value to form antidune with sediment motion than other types of bedform like ripple, dune & transition.

In Fig.4 non dimensional Shear stress has a functional relationship with Non dimensional particle diameter. Here all the Shear Reynolds no lines are drawn from the Reference of Julien-Raslan ASCE98.In this graph when d_* value is less than 10, It was found that the position of the non-dimensional diameter of bed particle is laid in between R_* value 4 to 11 and 11.6 to 20. Points which are between R_* value 4 to 11 are called hydraulically smooth zone and between11.6 to 20 it is called hydraulically transition zone. But in case of d_* value 18 It is observed that the position of the non-dimensional diameter of bed particle is coming between R_* value 11.6 to 70.Similarly Points which are between R_* value 11.6 to 70 which is called hydraulically transition zone and when it is in between more than 70 it is called hydraulically Rough zone. It was found that for sediment size 0.38mm No bed form and dune is observed in Transition to smooth zone and but for Transition and anitdune type is in under transition to Rough zone. Again in case of 0.75 mm sediment sizes only no bed form is observe under transition to smooth zone, rest other types are under Transition to smooth zone. So in both cases it is common that transition and antidune type of bedform are in Transition to Rough zone.

Table 01

Sl no	*Run no*	*d_{50} (mm)*	*S*	*Q (LPM)*	*k_s*	*h_o(m)*	*V (m/s)*	*u_**	*R_{e*}*	*f_0*	*R/d_{50}*	*Θ*	*D_**	*Θc*	*Fr*	*τ_0*	*τ_{0c}*	*Type of Bedforms*	*H (mm)*	*L (mm)*	*Mc(m m/s)*
1	1	0.38	0.001	60	78.029	0.045	0.28	0.02	8.04	0.002	54.16	0.03	9.61	0.03	0.44	0.20	0.31	nomotion			
2	2	0.38	0.001	80	78.029	0.054	0.32	0.02	8.73	0.002	58.16	0.04	9.61	0.03	0.45	0.22	0.31	nomotion			
3	3	0.38	0.001	120	78.029	0.070	0.35	0.03	9.82	0.001	63.64	0.04	9.61	0.03	0.48	0.24	0.31	nomotion			
4	4	0.38	0.002	60	78.029	0.035	0.38	0.03	10.99	0.002	48.02	0.07	9.61	0.03	0.64	0.43	0.31	Ripple & dune	4.00	105.00	3.85
5	5	0.38	0.002	80	78.029	0.042	0.43	0.03	11.93	0.002	52.05	0.08	9.61	0.03	0.66	0.47	0.31	Ripple & dune	8.00	120.00	5.50
6	30	0.38	0.002	90	78.029	0.045	0.45	0.03	12.34	0.002	53.71	0.08	9.61	0.03	0.67	0.48	0.31	Ripple & dune	8.00	125.00	5.94
7	31	0.38	0.002	100	78.029	0.048	0.47	0.03	12.72	0.002	55.18	0.08	9.61	0.03	0.68	0.49	0.31	Ripple & dune	7.00	117.00	6.44
8	32	0.38	0.002	110	78.029	0.050	0.49	0.03	13.07	0.002	56.51	0.08	9.61	0.03	0.69	0.51	0.31	Ripple & dune	6.00	135.00	7.00
9	6	0.38	0.002	120	78.029	0.053	0.50	0.04	13.40	0.002	57.72	0.08	9.61	0.03	0.70	0.52	0.31	Ripple & dune	7.00	130.00	7.26
10	7	0.38	0.004	60	78.029	0.030	0.43	0.03	12.59	0.003	45.40	0.10	9.61	0.03	0.75	0.59	0.31	Ripple & dune	6.00	135.00	4.00
11	8	0.38	0.004	80	78.029	0.040	0.47	0.04	13.65	0.002	49.40	0.10	9.61	0.03	0.78	0.64	0.31	Ripple & dune	8.00	140.00	5.72
12	33	0.38	0.004	90	78.029	0.040	0.50	0.04	14.12	0.002	51.06	0.11	9.61	0.03	0.79	0.67	0.31	Ripple & dune	7.00	132.00	6.10
13	34	0.38	0.004	100	78.029	0.043	0.52	0.04	14.55	0.002	52.54	0.11	9.61	0.03	0.80	0.69	0.31	Ripple & dune	7.00	125.00	6.54
14	35	0.38	0.004	110	78.029	0.045	0.54	0.04	14.95	0.002	53.87	0.11	9.61	0.03	0.82	0.70	0.31	Ripple & dune	6.00	137.00	7.25
15	9	0.38	0.004	120	78.029	0.047	0.55	0.04	15.33	0.002	55.09	0.12	9.61	0.03	0.83	0.72	0.31	Ripple & dune	7.00	132.00	7.20
16	10	0.38	0.008	80	78.029	0.030	0.57	0.05	18.37	0.003	43.68	0.21	9.61	0.03	1.10	1.30	0.31	Transition			6.25
17	36	0.38	0.008	90	78.029	0.032	0.63	0.05	18.99	0.003	45.29	0.22	9.61	0.03	1.13	1.35	0.31	Transition			6.00
18	37	0.38	0.008	100	78.029	0.034	0.66	0.05	19.56	0.003	46.75	0.23	9.61	0.03	1.14	1.39	0.31	Transition			7.00
19	38	0.38	0.008	110	78.029	0.036	0.69	0.05	20.09	0.002	48.08	0.23	9.61	0.03	1.16	1.43	0.31	Transition			7.50
20	11	0.38	0.008	120	78.029	0.038	0.66	0.05	20.22	0.002	49.65	0.23	9.61	0.03	1.15	1.41	0.31	Transition			7.40
21	12	0.38	0.016	60	78.029	0.023	0.68	0.06	22.01	0.004	35.26	0.35	9.61	0.03	1.41	2.16	0.31	Antidune	8.00	75.00	4.25
22	13	0.38	0.016	80	78.029	0.025	0.75	0.06	23.81	0.004	38.89	0.39	9.61	0.03	1.49	2.38	0.31	Antidune	12.00	123.00	5.60
23	14	0.38	0.016	120	78.029	0.030	0.89	0.07	26.65	0.003	44.31	0.44	9.61	0.03	1.59	2.71	0.31	Antidune	14.00	129.00	7.70
24	28	0.38	0.025	80	78.029	0.024	0.82	0.07	27.74	0.004	36.21	0.55	9.61	0.03	1.77	3.37	0.31	Antidune	11.00	115.00	5.85
25	39	0.38	0.025	100	78.029	0.025	0.90	0.08	29.49	0.004	39.05	0.59	9.61	0.03	1.84	3.64	0.31	Antidune	12.00	117.00	6.50
26	40	0.38	0.025	110	78.029	0.026	0.94	0.08	30.28	0.003	40.30	0.61	9.61	0.03	1.87	3.76	0.31	Antidune	10.00	119.00	8.00
27	41	0.38	0.025	120	78.029	0.027	0.98	0.08	31.02	0.003	41.46	0.63	9.61	0.03	1.90	3.86	0.31	Antidune	11.00	125.00	8.60
28	29	0.38	0.025	120	78.029	0.028	0.96	0.08	31.02	0.003	41.46	0.63	9.61	0.03	1.90	3.86	0.31	Antidune	13.00	127.00	9.40
29	15	0.75	0.001	60	69.669	0.050	0.25	0.02	16.39	0.002	28.24	0.02	18.97	0.03	0.40	0.21	0.61	nomotion			
30	16	0.75	0.001	80	69.669	0.055	0.29	0.02	17.81	0.002	30.26	0.02	18.97	0.03	0.41	0.22	0.61	nomotion			
31	17	0.75	0.001	120	69.669	0.075	0.34	0.03	20.04	0.001	32.99	0.02	18.97	0.03	0.43	0.24	0.61	nomotion			
32	18	0.75	0.002	60	69.669	0.045	0.32	0.03	19.38	0.003	26.57	0.03	18.97	0.03	0.49	0.31	0.61	nomotion			
33	19	0.75	0.002	80	69.669	0.050	0.38	0.03	21.05	0.002	28.62	0.03	18.97	0.03	0.50	0.34	0.61	nomotion			
34	20	0.75	0.002	120	69.669	0.063	0.43	0.03	23.67	0.002	31.43	0.03	18.97	0.03	0.53	0.37	0.61	nomotion			
35	21	0.75	0.004	60	69.669	0.032	0.43	0.04	27.84	0.003	22.99	0.06	18.97	0.03	0.75	0.74	0.61	Ripple & dune	4.00	85.00	3.50
36	42	0.75	0.004	70	69.669	0.035	0.45	0.04	29.08	0.003	24.08	0.06	18.97	0.03	0.76	0.78	0.61	Ripple & dune	8.00	134.00	4.25
37	22	0.75	0.004	80	69.669	0.038	0.46	0.04	30.20	0.003	25.02	0.07	18.97	0.03	0.78	0.81	0.61	Ripple & dune	10.00	145.00	4.90
38	43	0.75	0.004	100	69.669	0.043	0.52	0.04	32.18	0.003	26.61	0.07	18.97	0.03	0.81	0.86	0.61	Ripple & dune	6.00	138.00	5.00
39	44	0.75	0.004	110	69.669	0.045	0.54	0.04	33.08	0.002	27.29	0.07	18.97	0.03	0.82	0.88	0.61	Ripple & dune	11.00	149.00	6.20
40	23	0.75	0.004	120	69.669	0.048	0.54	0.05	33.91	0.002	27.91	0.07	18.97	0.03	0.83	0.90	0.61	Ripple & dune	7.00	145.00	5.90
41	24	0.75	0.008	80	69.669	0.032	0.54	0.05	37.43	0.003	22.92	0.11	18.97	0.03	1.00	1.35	0.61	Transition			5.10

42	45	0.75	0.008	100	69.669	0.036	0.62	0.05	39.86	0.03	24.49	0.12	18.97	0.03	1.04	1.44	0.61	Transition			5.50
43	46	0.75	0.008	110	69.669	0.038	0.64	0.05	40.95	0.03	25.16	0.12	18.97	0.03	1.05	1.48	0.61	Transition			6.10
44	47	0.75	0.008	120	69.669	0.040	0.67	0.06	41.98	0.03	25.78	0.12	18.97	0.03	1.07	1.52	0.61	Transition			6.20
45	25	0.75	0.008	120	69.669	0.042	0.64	0.06	41.98	0.03	25.78	0.12	18.97	0.03	1.07	1.52	0.61	Transition			5.90
46	26	0.75	0.025	80	69.669	0.025	0.76	0.08	56.48	0.05	19.07	0.29	18.97	0.03	1.61	3.51	0.61	Antidune	11.00	105.00	5.95
47	48	0.75	0.025	100	69.669	0.026	0.85	0.08	60.06	0.04	20.54	0.31	18.97	0.03	1.68	3.78	0.61	Antidune	13.00	114.00	6.67
48	49	0.75	0.025	110	69.669	0.028	0.89	0.08	61.67	0.04	21.18	0.32	18.97	0.03	1.71	3.90	0.61	Antidune	13.00	132.00	7.40
49	50	0.75	0.025	120	69.669	0.029	0.92	0.08	63.18	0.04	21.78	0.33	18.97	0.03	1.73	4.01	0.61	Antidune	15.00	145.00	7.95
50	27	0.75	0.025	120	69.669	0.030	0.91	0.08	63.18	0.04	21.78	0.33	18.97	0.03	1.73	4.01	0.61	Antidune	16.00	160.00	8.00

Here, g = 9.81 m/sec^2, υ = Kinematic viscosity = 10^{-6} m^2/ sec, d_{50} = particle Diameter, S = Bed Slope, Q = Discharge. K_s = Roughness Coefficient, f_0= Friction factor, h_0 = Flow Depth, V= Flow Velocity (m/sec), U_*= Shear Velocity, R_* = Shear Reynolds no, Θ&Θ_c= Shields and critical Shields parameters respectively, τ_0 = Shear stress, τ_{0c} = Critical shear stress, H & L= Bedform height and length respectively, D_* = Non dimensional Particle Diameter, M_c = Bedform Migration rate.

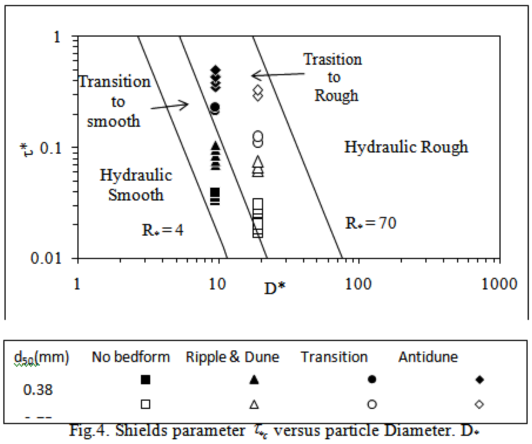


Fig.4. Shields parameter τ_c versus particle Diameter. D*

Albertson, Simons and Richardson gave a criterion for predicting the regimes of flow. Speculating that the parameters $Re_* = u_* d_S / \nu$ and u_* / ω, which define the conditions of beginning motion and formation of ripples, may be adequate to predict the other regimes of flow. They plotted the data on a graph with u_* / ω as the ordinate and $u_* d/v$ as the abscissa. Our Experimental data are plotted into Albertson, Simons and Richardson graph and it is found that mostly of experimental data are in well agreement with Albertson & Simson criterion of flow regime but here also few data's are not matching. Comparing Albertson & Simon criterion of flow regime with shields graph it was found that Sediment of 0.38 mm size are in motion condition for bed slope 0.001, But experimentally it is observed that they are not forming any specific shape and in case of sediment size 0.75 mm they are in no motion condition for both slope 0.001 & 0.002 . According to Richardson and criterion of flow regime parameters for above mentioned condition are laid in between Ripple zone. So it is observed that Experimental data for lower regime especially when bed is in no motion condition are not satisfied With Albertson, Simons and Richardson criterion of flow Regime.

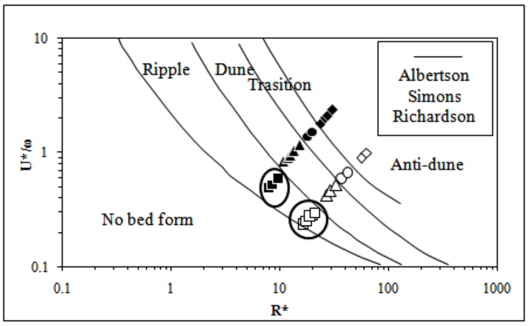


Fig.5 Comparison of observed data with Albertson-Simons-Richardson criteria for Regime of flow.

Southard and boguchawal has given a criterion of flow regime by using flow depth (h) as afunction of Velocity (v), considering sediment size 0.1 0 to 1.80 mm. Experimental data has been plotted into Southard and boguchawal graph and found that mostly of experimental data are in well agreement with Southard and boguchawal but here also few data's are not matching. Here also comparing Southard and boguchawal graph with shields graph it is found that sediment of 0.38 mm size are in motion condition for bed slope 0.001, but experimentally it is observed that they are not forming any specific shape and in case of sediment size 0.75 mm they are in no motion condition for both slope 0.001 & 0.002 .According to Southard and boguchawal criterion of flow regime parameters for above mentioned condition are laid in between Ripple Dune zone.

So based on experimental parameter it is observed that Experimental data for lower regime condition especially when bed is in no motion or no bed formation condition are not satisfied Southard and boguchawal of flow Regime.

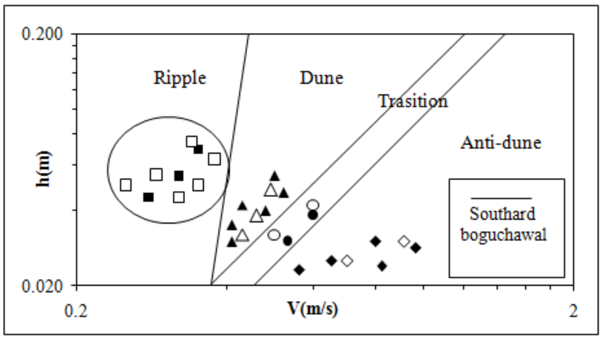
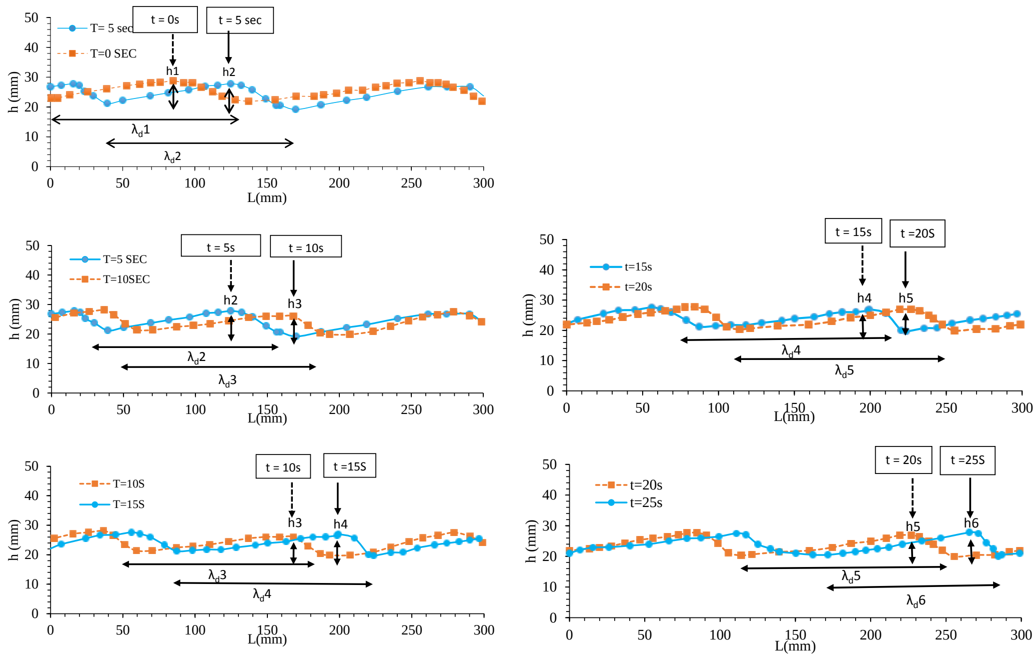


Fig.6. Comparison of observed data with Southard and boguchawal criteria for Regime of flow.

Bedform Migration

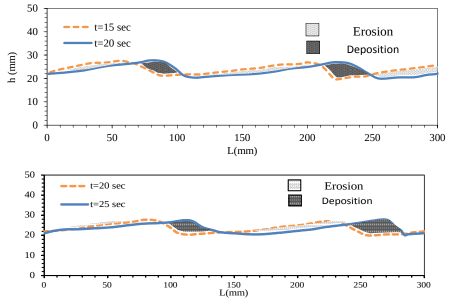
The ability to predict bedform migration in rivers is critical for estimating bed material load, yet there is no relation for predicting bedform migration (downstream translation) that covers the full range of conditions under which subcritical bedforms develop. Here, the relation between bedform migration rates and transport stage is explored using a flume data sets. Transport stage is defined as the non-dimensional Shields stress divided by its value at the threshold for sediment entrainment. As transport stage increases for a given depth to grain-size ratio, migration rates increase. For a given transport stage, the migration rate increases as the flow depth to grain-size ratio gets smaller.

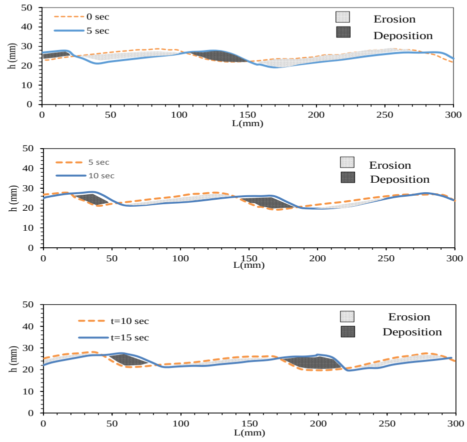
Bedform heights were measured from the peak to the trough on the lee side of the bedform in test section in each time interval. Average height for each survey was obtained by summing all the heights of each time interval from the time variation profile and dividing by the number of total readings taken. Bedform lengths were measured between two continuous troughs, and since bedforms were continuous, their average length was obtained by measuring the length of bedform at each time interval, and divided the sum of total bedform length by the number of total readings taken into test section .It is noticed that for ripple and dune length and height remains almost same or slightly varied as they progress into the test section but in case of Transition, height of ripple and dune gradually decreases with respect to time and turned into a plane bed. As the slope has been increased it is found that for the same discharge bed is forming like wave and it is called antidune .Similarly same procedure has been maintained with other runs to find out its wave length and height .It is found that wave length and height of antidune comparatively larger than wave length of dune and Ripple.



Bed erosions and depositions

Bed erosion and deposition are represented here at 5 sec interval for bed form. In case of Ripple and dune as they progress in the flume, sediment of trough and crest deposited into stoss side of next adjacent Ripple dune. Deposition is largely limited to the lee face of the bedform and erosion occurs from the trough and continues along the stoss side of the bedform. As the bedform migrates by deposition on the lee face it forces the trough, and its region of scour, further downstream, up the stoss slope of the next-downstream bedform. Thus, as one ripple or dune migrates it consumes the next-downstream ripple, and so on. Figure 5.13 illustrates the condition where is deposition and erosion occurred on a bed during ripple migration; as the bedform migrates the volume of sediment deposited on the lee face will be equal the volume of sediment removed from its stoss side .





50 nos of test has been conducted in a laboratory flume with two different material and it has been observed that for dune , ripple & antidune in erosion and deposition have similarities during their movement in test section and as the bedforms migrates scoring occurred from the back of stoss side and this sediment deposited in the front or lee side. But this type of deposition and scoring are temporary and fully dependent on bedform migration rate. But in case of transition there are no similarities into erosion and deposition pattern and it is very difficult to notify erosion and deposition as they continuously changing their shape and turned into a plain bed so only scouring measurement is possible by measuring bed depth over time interval.

Table 2

Time (sec)	Bed form Height, h (mm)	Length, λ_d (mm)	Migration Rate Mc(mm/s)	Stoss side angle (α)	Lee side angle (β)
0	6	123		4.28°	7.94°
5	8	130	7.5	5.37°	10°
10	6	127	8.0	3.15°	13.5°
15	7	136	6.6	3.5°	16.26°
20	5	134	6.6	2.70°	10.12°
25	7	134	7.6	4.25°	17.65°

SUMMARY AND CONCLUSION

1 Experimental works has been performed in a glass flume of a total length of 5m with a depth of 0.400m and a width of 0.075m which is tiltable 0 to 2 percentage. Maximum discharge was 120 lpm which is very less compare to other bedform studies in natural as well as laboratory channel but within this low discharge, lower & upper regime flow and all types of bedform in a laboratory channel with different material has been created successfully. So, it is understood from this study that upper regime bedforms also can be created with low discharge if the bedslope is very steep.

2. Migration rate of bedform in a 5 second interval has been monitored with the help of a high resolution digital camera, where it was found that bedform migration rate fluxates in stream wise direction of flow but change of rate is very less. Geometrical shape of bedform also changes with migration Rate for all the type bedform. Ripple and dune type of bedform have geometrical shape which is similar to triangle and where stoss side angle is always lesser than lee side angle. In case of transition zone it is found that bedform have no specific shape with respect to time. Bedform in transition zone during migration lost their shape and turned into a plane bed and after few second or few minutes again they gain their shape in a cyclicorder. But in case of it is found that antidune has wave type of geometrical shape and water surface also turned into a wave form.

Migration rate for each type of bedform has been monitored and found that antidune have more migration capability than other types of bed form, Ripple dune ranges from 3 to 7 mm per second and for transition and antidune migration rate is close to 10 mm per second. It is found from regression analysis that migration rate directly co related with bed slope.

Migration rates range from 0.003 to 0.07 m/s for ripples and dunes and 0.005 to 0.01 m/s for transition and antidune. Migration rate of each type of bed form categorize has been plotted into graph and found that for a particular bedslope in a regression analysis migration rate is well correlated with transport stage parameter. But it is also observed that in a regression analysis comparison between test data of different bedslope giving poor coordination with Transport stage parameter

5. Again the aspect ratio (H / L) of ripples and dunes data ranges from 1.5 to 4.5 in τ_*/τ_{*c} and from 0.03 to 0.0.06 in H/L. Antidune data range from 9 to 19 in τ_*/τ_{*c} and from 0.90 to 0.120 in H/L. But in some cases of Antidunes have also ratio less than 0.1. We have found from our experimental results that function of bedform e.g height, length, migration rate, bed share stress and transport strength are correlated with each other

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NOTATION

h = Flow depth.

d_{50} = Sediment grain size.

Fr = Froude number.

g = Gravitational acceleration.

H =Bedform height.

H_c =Characteristic bedform height.

L= Bedform length.

L_c= Characteristic bedform length.

H/L= Bedform aspect ratio.

R^2 = Regression Correlation

Q = Discharge of water

Re_* = Grain Reynolds number

S = Slope of the water surface

V = Mean velocity

u_* = Shear velocity

V_b = Bedform migration rate

B = Width of flume channel

ω = Grain settling velocity

α = Stoss side angle.

B = Lee side angle.

ν = Kinematic viscosity of water

R = Hydraulic Radius.

ρ = Water densities

ρ_s = Sediment densities

τ = Boundary shear stress

τ_c = Critical boundary shear stress.

τ_* = Shields number

τ_{*c} = Critical Shields number

M_c= Migration Rate.

T_p = Transport stage parameter