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Turbulence Characteristics for Flow Past a Spur Dyke on Rigid Bed Meandering Channel

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Abstract- **In the présent study tturbulence characteristics in the presence of spur dyke on rigid bed meandering channel with trapezoidal cross-section have been presented. Acoustic Doppler Velocimeter (ADV) was used to measure the velocities. The results show that, the magnitude and location of maximum turbulence intensities and Reynolds stresses changes according to the location of the spur dyke. The maximum turbulence intensities are observed along the boundary of separation zone. The turbulence intensity in longitudinal direction is higher than lateral and vertical direction component. In addition, the turbulence intensities near the bed are higher than the middle of flow depth for most of the locations..**

Keywords: Channel, ADV, Turbulence Characteristics, Reynolds Stresses

I. INTRODUCTION

Spur dykes are one of the river training structures used to protect the river banks from erosion and to deepen the main channel for creating navigational channel. Characteristic parameters of a spur dyke are dyke length (b), height, width, shape, inclination to the downstream bank (α) and permeability.

The flow field and flow separation zone due to a spur dyke in a straight rectangular channel with rigid bed have been studied experimentally and numerically by various researchers[6]. Separation zones are observed both on the upstream and downstream sides of a spur dyke[6].

Various instruments such as Pitot-tube, micropropeller, electromagnetic current meter, Nixon 403 Streamflow-speed miniature current flow meter were used to measure the velocity field in open channel flow. The instantaneous velocity measurement was not possible by the above mentioned equipments. With the advancement of technology, Acoustic Doppler Velocimeter (ADV) and Lasser Doppler velocimeter (LDV) was used by various researchers to measure the three-dimensional velocity field. Instantaneous velocities measured by ADV and LDV are used to calculate turbulence characteristics in the channel.

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II. WHY TURBULENCE CHARACTERISTICS

Originally, bed shear stresses were calculated from the slope of a linearregression fit to the meanvelocity profiles from the bedto 20 percent of the flow depth. Variousmethods for estimation of bedshear stress by logarithmicvelocity profile, Reynolds stresses, turbulent kineticenergy (TKE) and energy dissipationhave the limitations[1]. It can be observed that unlike logarithmic velocity profile, Reynolds stresses and TKE methods not require the depthwise variation of velocity. The nearbed Reynolds stresseswasusedto calculate the bedshear stresses[1, 2 and 4].

The sediment motion and scouring in the channelisalso the function of meanbedshear stress and turbulence [5 and 7] and the sediment transport increases markedly with increasing turbulence level.

Thus, the main objective of the presentstudyis to present the turbulence characteristics due to flow past a perpendicular spur dyke in rigid bed meandering channel.

III. EXPERIMENTAL PROCEDURE

The experiment has been carried out in the Hydraulics Laboratory of the Indian Institute of Technology, Kanpur. The channel center line follows a sine generated curve represented by with $\theta^0 = 50^0$, the length of the sine-generated channel $\theta = \theta_0 \cos\left(2\pi s/L\right)$ along the channel centre line, L = 6.2m and the wave length, λ = 4.65m Fig. 1[6]. Water from a constant head reservoir is supplied to the channel. A honey-comb is used at the upstream of the channel to ensure calm entrance of water. A tail gate is used at the downstream end of the channel to control the flow depth. The spur dyke used in the present study is a wooden block of height = 0.25m and thickness = 0.03m. The three-dimensional velocity field is measured with the help of a downward looking ADV attached to atraverse.

Any space in the channel is defined by a curvilinear coordinate system (s = along the center line of the flume, n = along lateral direction and z = along vertical direction)[6]. The corresponding non-dimensional coordinates are defined as s* = s / L, n* = n / B and z* = z / Hrep, where, B = channel half width at half of the representative flow depth and H_{rep} = representative flow depth defined by the water surface measured at the channel center = 0.12m at s = -2.55m. The discharge is estimated by the velocity area method. All velocity measurements are recorded for 120s with a frequency of 25Hz. The cross-section being trapezoidal, b is defined as the length at z* = 0.50. The measurements are performed at two elevations i.e. at z* = 0.167 (0.02m from bed) and z* = 0.50 (0.06m from bed) and in a grid with Δs*= 0.0208 and Δn*= 0.156. In this study, all output data from ADV were processed and filtered using public domain software WinADV-version 2.027.

The Reynolds decomposition into mean and fluctuating positions is used to analyzing turbulence velocity fields ($u_j = \bar{u}_j + u'_j$). Here, $u_j (j = s, n, z)$ is the instantaneousvelocity, $\bar{u}_j$ is mean velocity and u'_j is fluctuation velocity. In the present study, resultant velocity is defined as $\bar{U} = \sqrt{\bar{u}^2 + \bar{v}^2}$.

The RMS of the turbulence denotes the standard deviation of the samples taken by the Vectrino and is equal to the turbulent intensity for the respective velocity component. For example, the RMS turbulence for the s velocity component is:

$$RMS[u'] = \sqrt{\overline{(u')^2}} = \sqrt{\frac{\sum(u - (\sum u/n))^2}{n-1}}$$

The non dimensional turbulence intensities are defined as $u_j^+ = RMS[u'_j]/U_{rep}$. The Reynolds stress is a transport effect resulting from turbulent motion induced by velocity fluctuations with its subsequent increase of momentum exchange and of mixing (Chanson 2008). The three Reynolds stress are defined as $\overline{u'v'}$, $\overline{u'w'}$ and $\overline{v'w'}$. The corresponding non-dimensional Reynolds stresses are $(uv)^+ = -\overline{u'v'}/U_{rep}^2$, $(uv)^+ = -\overline{u'w'}/U_{rep}^2$ and $(vw)^+ = -\overline{v'w'}/U_{rep}^2$.

The non – dimensional turbulent Kinetic energy is defined as:

$$TKE = 0.5\{(u^+)^2 + (v^+)^2 + (w^+)^2\}$$

IV. RESULT

The present study takes into account 24 different cases to evaluate the effects of spur dyke location, spur dyke length and inflow Froude Number on the turbulence intensity and Reynolds stresses (Table 1).

Fig. 1: Experimental Setup

Table 1: Cases considered in the present study

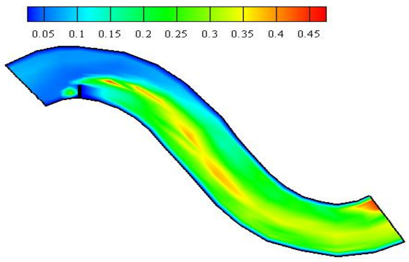
Effect of	Case	Given conditions			
		Spur dyke location		b (m)	$\bar{U}_{rep}$ (m/s)
		Bank	s*		
Location	1	Right	0.125	0.160	0.225
	2	Right (Apex 1)	0.250	0.160	0.225
	3	Right	0.375	0.160	0.225
	4	Right (Cross-over)	0.500	0.160	0.225
	5	Right	0.675	0.160	0.225
	6	Left (Apex 1)	0.250	0.160	0.225
	7	Left	0.375	0.160	0.225
	8	Left (Cross-over)	0.500	0.160	0.225
Spur Dyke Length	9	Right	0.250	0.135	0.225
	10	Right	0.250	0.110	0.225
	11	Right	0.500	0.135	0.225
	12	Right	0.500	0.110	0.225
	13	Left	0.250	0.135	0.225
	14	Left	0.250	0.110	0.225
	15	Left	0.500	0.135	0.225
	16	Left	0.500	0.110	0.225
Inflow Velocity	17	Right	0.250	0.160	0.141
	18	Right	0.250	0.160	0.281
	19	Right	0.500	0.160	0.141
	20	Right	0.500	0.160	0.281
	21	Left	0.250	0.160	0.141
	22	Left	0.250	0.160	0.281
	23	Left	0.500	0.160	0.141
	24	Left	0.500	0.160	0.281

The contour of non-dimensional turbulence intensities, u^+, v^+ and w^+ at z* = 0.50 for Case 2 (spur dyke is located on right bank at s* = 0.25) is presented in Fig. 2. Estimated turbulence intensities show that the spatial distribution of u^+, v+ and w+ is almostsimilar and u^+> v+ > w+. Zone of higher u^+, v+ and w+ exist near the bank with spur dyke in the upstream and along the boundary of separation zone in the downstream of spur dyke. The distribution of u^+, v+ and w+ in lateral direction is such that these are minimum near the bank with spur dyke, increase towards the opposite bank and attain maximum value near the boundary of separation zone. The lateral extent of w^+ is smaller than the u^+ and v^+. The width of higher u^+, v+ and w+ zone is minimum near the spur dyke and increase as the flow moves downstream.

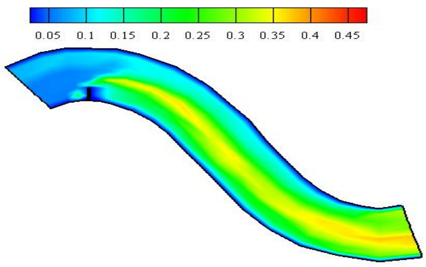
For various locations of the spur dyke itcanbeobserved that maximum turbulence intensity is observed along the boundary of separation zone, irrespective the location of maximum velocity. The higher turbulence intensities are observed at some distance in the downstream instead of just near the tip of the spur dyke. The magnitude of u+, v+ and w+ is higher when the spur dyke is located in the zone of higher velocity. The maximum and the minimum u+, v+ and w+ are observed for Cases 2 and 6, respectively. The maximum, u+ = 0.46, v+ = 0.38 and w+ = 0.28. The maximum and minimum influence of spur dyke on flow field is also observed for these locations. For Case 2, higher u+, v+ and w+ are observed in a small zone near the opposite bank in the downstream of Apex 2. Similarly, for Case 6, higher u+, v+ and w+ are observed near the opposite bank in downstream of Apex 1.

It can be observed that u+ are greater for z* = 0.167 in comparison to z*= 0.50 at most of the locations. The location of higher u+ zone is almost same for z* = 0.167 and 0.50. However, the width of this zone is higher for u+ at z* = 0.167.

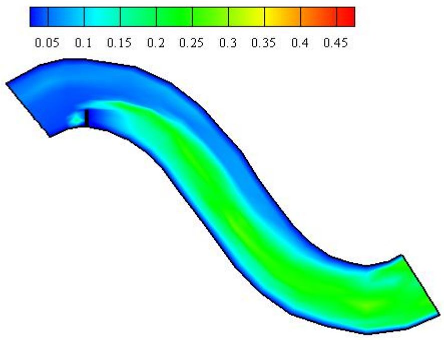
Unlike the turbulence intensities, the higher Reynolds stress components are found along the separation zone boundary. The magnitude of uv^+ is higher than uw^+ and vw^+. When the spur dyke is located on the right bank, the uv^+ is observed in the positive range. However, it is negative when spur dyke is located on the leftbank. The uw^+ is negative for most of the locations. In comparison to uv^+ and uw^+, vw^+ is equally distributed around zero for most of the locations.



u^+



v^+



w^+

Fig. 2 : Turbulence Characteristics near spur dyke

V. CONCLUSIONS

An experimental study was conducted in a rigid bed meandering channel to find the turbulence characteristic field due to various locations of the spur dyke.
The main conclusions of the present study are:

(1) The maximum turbulence characteristics are observed along the boundary of separation zone.
(2) The spatial distribution of u^+, v^+ and w^+ is almost similar and $u^+ > v^+ > w^+$.
(3) Turbulence intensities and Reynolds stresses decreases with decrease in contraction ratio.

Turbulence intensities and Reynolds stresses increases with increase in inflow Froude number

VI. REFERENCES

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