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Design of Spur Foundation in River Training Works

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Abstract—*Flood embankments are constructed along river banks to protect the countryside from flood damages due to spilling of river banks. Flood embankments often breach due to a number of reasons, resulting in damage to standing crops, loss of human and animal life, destruction of properties, dislocation of communication and unimaginable sufferings of people which cannot be measured in terms of money. Spurs are often constructed along the river banks for protection of embankments against direct attack by the river and also, to train the river flow to the required alignment.*
The study of the maximum scour depth on sand bed around unsubmerged spur dike located at different angles to bank and their different lengths were carried out in a channel. Clear-water scour conditions are used in the experiments. The effects of orientation angle on the different lengths of spur dike are experimented. The three-dimensional turbulent flow field around a spur dike in a sand-bed in laboratory open channel was studied experimentally by measuring scour hole dimensions. Experimental results showed that there are two vortices namely, primary vortex near to the deepest scour hole and secondary vortex above this. The experiments showed the orientation of the spur and its length controls and the magnitude of scour depth. Using projected length and shape factor, the maximum scour depth at the tip of a spur dike can be predicted using a modified vortex theory for spur dikes which is developed for abutments and piers. With known water depth, effective length, angle of orientation of spur, discharge intensity and grain size parameters, a good prediction of scour depth can be made. This helps in the designing the depth of spur foundation and also protection measures to be taken to avoid scouring action.

1. INTRODUCTION

A spur is a structure that projects from a stream bank into the river channel and causes redirection of water away from the bank towards the tip of the spur. Spurs can be useful in stream by protecting stream banks from erosion and limiting sediment recruitment, reducing velocities near the banks, creating still water areas that encourage deposition, and channelling flows to reduce widths and create a defined channel [10].

An engineer must consider the effect of the structure on the hydraulics of the river and the best ways to train the river such that the structure performs satisfactorily and also there is no significant damage to the riverine environmentfor constructing a hydraulic structure across a river. At times, people residing very close to the flood zones of a river may have to be protected from the river's fury. This is done by providing embankments along the river sides to prevent the river water from spilling over to the inhabited areas.

In order to limit the movement of the bank of a meandering river, certain structures are constructed on the riverbank, which are called riverbank protection works. Sometimes, an embankment like structure, called a Groyne or a Spur, is constructed at right angles to the riverbank and projected into the river for attracting or deflecting the flow of the river towards or away from the riverbank.

Spurs are a standard structural training technique in river engineering to protect river banks from erosion, to concentrate the flow to the river centre and to promote sustainable ecological conditions along the river shores. A spur may be submerged during flood conditions or exposed from the water for low flows. In the latter case, spurs behave hydraulically similar to a bridge abutment. Much relevant research on spurs has been conducted in the past, including that of Richardson et al. 1975[2] giving some rules of thumb, and Lagasse et al. 1995[3] providing information on the length of impermeable spurs, the spur height, and the riprap protection to the spur head and faces. Melville and Coleman et al. 2000[4] presented a concise summary on the currently available information on spur hydraulics [5].

2. AIM

The effect of length and angle of orientation of spur for an unsubmerged state on the scour depth is investigated.

3. DETAILS OF EXPERIMENTATION

The experiments are conducted in a trapezoidal flume of length *5.5m* having a cross section of *1m wide* and *300mm deep* in the *Bernoulli* Hydraulics and Hydraulic Machines Laboratory, Department of Civil Engineering, Siddaganga Institute of Technology, Tumakuru. The side slopes of the channel is *11:15 (H:V)*. The plan of the flume as in Fig. 1 and the photographic view of the flume is in Fig. 2. The spur is made of mild steel of size *460mm x 460mm x 8mm (thick)* and painted to avoid rusting, and embedded vertically inside the channel bed and horizontally inside the embankment.

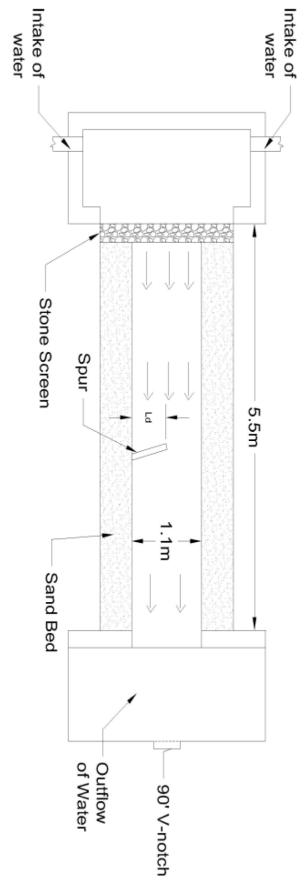

Fig. 1: Plan of flume

The spur is installed at *2.3m* from the flume entrance i.e. at almost centre of flume. Gravel sized stones *7-14mm* was placed in the form of mat at both ends of the flume to prevent erosion of sand. The remaining recess is filled with uniform sand having $d_{50}=0.80mm$. The flow depth is maintained at an average of *75mm*. At the test section, deepening is made by having 0.5m depth and width of 1m. Sand is filled into this test section. To reduce the disturbance of water entering into channel, water is allowed to pass through stone screen of width of *300mm* with height equal to channel bank. Prior to start of each experiment the sand bed is levelled and the flume is carefully filled with water so as not to disturb the planar bed. The discharge was measured using a 90^o *V – notch* provided at the end of the flume after the sediment trap. The co-efficient of discharge C_d is assumed as *0.60*. The velocity is computed at different sections by measuring the corresponding average depth of flow. Each experiment is run for a period of *10 hours*. A vertical point gauge of *0.1mm* precision (least count) on the Vernier scale was used to measure the vertical dimensions like scour depth, depth of water flow, depth of bed level etc. This is of sliding type where point gauge assembly is placed on a horizontal member which can be moved along the channel. Critical shear velocity $v_{*c}$and the flow parameter F_{le} for sediment particle are determined. The equivalent width/diameter concept is used to evaluate the flow parameter F_{le}. The point gauge readings were noted at *0, 1, 60, 120, 180, 240, 300, 360, 420, 480, 540* and *600* minutes. The readings of bed level at spur tip, at upstream of spur, water levels at spur tip and upstream along with the discharge height above crest level of 90^o *V – notch* to measure discharge and velocity. The bed level along the spur is also noted down before the start of the experiment, in turn to measure the average depth of bed level.

Fig. 2: Front view of flume

4. METHODOLOGY

As mentioned above *460mm x 460mm* mild steel plate of 8mm thick and inserting it halfway under the sandy channel bed using it as the spur. The presence of pebbles or stones (if any) on the sandy bed will cause some disturbance in readings during the flow. So the same is removed all these materials before the start of experiment. The length of the spur from bank will be noted down.

Then the bed level along the spur at every *100mm* up to the other side of the bank is noted down using the sliding vertical point gauge. After this, the values of the bed level at a distance of *1m* on the upstream side of the spur at centre, at left and at right have recorded.

The flow of water through channel bed is started. The discharge should be increased gradually until the flow becomes to the expected discharge. After the flow reached the expected level, the readings of water level at the distance of *1m* on the upstream side from the spur at centre, at left and at right is taken. The readings of bed levels at the same position are also noted down. The bed level and water level are also noted near the tip of the spur.

To measure the discharge, the height of water at the crest level is noted initially and after the start of experiment, for each readings the height of water level is recorded. The difference of height of water at crest and height of water gives the actual height of water available above crest. This is used in the discharge and velocity calculations.

The readings of bed level and water level on the upstream is taken initially and then at an interval of *240 minutes* and finally at the end of *600 minutes*.

The readings of bed level and water level at spur tip along with height of water near notch is recorded every *60 minutes*, due to scour occurred at spur tip for continuous flow of water. And at the end of *600 minutes*, scour profile is recorded.

After the experiment for that length of spur is completed, the spur is re-installed by inserting *50mm* inside the right bank and the same procedure is repeated for that experiment. Until the length of spur becomes *50mm* from bank, the reading has to be recorded in this position.

The same procedure has been carried out by changing the positions of spur through an angle of 15^o, 30^o and 45^0 with respect to right bank measured (+) upstream and (-) downstream from 90^o spur position with respect to the bank and also, by orienting towards upstream and downstream. The same experiments are carried out for all angular direction of the spur by inserting *50mm* inside the bank.

5. ANALYSIS OF RESULTS

The sediment median size (d_{50}) is found to be 0.80mm and geometrical standard deviation of soil (σ_g) is 1.814.

Scour depth is related to flow parameter F_{le}. The depth of scour at tip is calculated by drawing the graph between flow parameter for the length of spur and $[(h+h_s)/L_e]$, in turn the scour depth h_s is found, which is the main parameter in the design of foundation of spur.

Flow parameter (F_{le}) is obtained from Veerappadevaru et al. 2011[6]

$$F_{le} = q / [(l_e^2 h) * \{(\rho_s - \rho_f)/\rho_f\} * g * d_{50} * v_{*c}]^{1/3}$$

Where,

q – discharge intensity, m^2/s

l_e- effective length of spur, m

h – height of water level in flume, m

ρ_s– density of sand = 2650 kg/m^3

ρ_f – density of fluid (water) = 1000 kg/m^3

g – acceleration due to gravity = 9.81 m/s^2

d_{50} – grain size diameter = 0.80 mm

v_{*c} – shear velocity, m/s

Maximum scour depth at the tip of the spur for different orientations with respect to bank and for different lengths of spur are found to follow a curve as shown in Fig. 3 given by an equation:

$$[(h+h_s)/l_e] = 0.4551(F_{le}) - 0.1336$$

Using the above equation, one can predict the maximum scour depth at front tip of rectangular vertical spur.

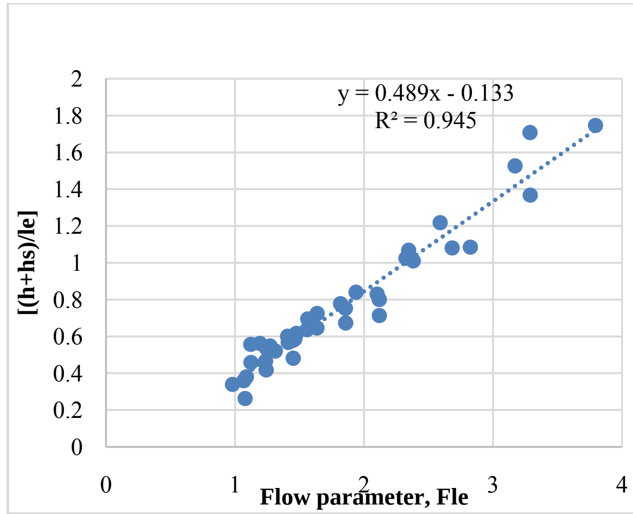

Fig. 3: Compiled graph of all experiments

6. CONCLUSION

Experiments are carried out to find the maximum scour depth at the tip of the spur. Spur can be treated as long abutment. Vortex power concept to predict equilibrium scour around abutment is formulated. This concept will be extended for the prediction of equilibrium scour around spur tip. Results showed an agreement between the experimental results and extended concept for spur dikes. This study will be useful in the design of foundation structure for the spur tips.

List of notations

The following symbols are used in this report:

d_{50} – mean grain size diameter

d_{84} – size in mm such that 84% particles are finer this size

d_{16}–size in mm such that 16% particles are finer this size

F_{le} – Flow parameter

g – acceleration due to gravity = 9.81 m/s^2

h – depth of water level in flume

h_s - scour depth

l_e- effective length of spur

Q – discharge

q - discharge intensity

R_{*o} – Grain shear Reynold No.

u – velocity of flow

v_{*c}– shear velocity

ρ_s– density of sand = 2650 kg/m^3

ρ_f – density of fluid (water) = 1000 kg/m^3

γs – Unit weight of sand = ρs*g

γ_f – Unit weight of fluid(water) = ρ_f*g

ν – Kinematic viscosity of fluid (water)

τ_o– Shield's Critical shear stress parameter

σ_g – sediment non-uniformity = $\sqrt{(d_{84}/d_{16})}$

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