COMPARISON OF SCOUR AROUND DIFFERENT SHAPES OF GROYNES IN OPEN CHANNEL

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Abstract: Groynes are the simplest form of river training structures that are placed laterally to the flow direction and used for diverting the flow away or towards the banks. In India different shapes of groynes are used as per the necessity and desired outcome. It is a question of great value that, in given conditions which shape of groyne would be more suitable under the possible conditions of emergency? In this study the scour variation and bed variation with different shapes of groynes was investigated using experimental works. Equilibrium of bed variation in both spur dikes and difference and similarities of the pattern of scour hole formation was also identified and it is concluded that T-shaped groynes are more stable and safe in terms of scour formation. It is also found that the flow diverting capabilities of a T-shaped groyne is far more better than a straight groyne in given conditions of channel. However it is easier to construct a straight groyne and they are the most economical and easy one to design in practical world. By using the suitable contraction ratio(length of spur/width of channel) and spur ratio or contraction ratio(spacing/length) desired outputs can be obtained. In this study contraction ratio of 0.39 and spur ratio of 5 was used.

Keywords: Sediment erosion and deposition, scour, T-shaped groynes, Straight groynes

I. INTRODUCTION

Groynes are the hydraulic structures extending outward from the river bank in the lateral direction to the flow for the purpose of diverting the flow away or towards the bank to protect it. Sometimes they are provided with an inclination in order to divert the high velocity flow away from the bank so that there is minimized erosion of the bank, availability of navigable depth in the channel and increased sediment deposition near the bank of the river. Different shapes of groynes are available with their individual advantages and disadvantages. The obstruction produced by the groynes generates a complicated system of vortices which is the main cause of the scour. Basically scour is of two types (i) General scour; which include the removal of sediments from the bed without any obstruction. (ii) Local scour; which is defined as the removal of bed material from the bed around any obstruction like spur dike, piers, abutment due to the erosive action of water. This local scour makes the hydraulic structures unstable and leads to destructive consequences. Therefore, understanding the mechanism and characteristics as well as investigating flow pattern and scour around groynes are crucial. Various studies has been conducted to understand the basic scour affecting parameters and their respective variations with the geometry of groynes, but still no specific conclusion is available about the variation of scour with shapes of spur dikes. Different shapes of groynes results in different scour formations which are not acceptable from stability point of view of hydraulic structures. Speaking of groynes geometrical variations there are various shapes available such as straight, T shaped, L-shaped , hockey shaped etc. Till now the main focus was emphasized upon the straight groynes with different arrangement. It was observed from design point of view, straight groynes are the first choice of designers but every situation demands a
different solution. Therefore T-shaped groynes are more in use despite of their complex design and possible variations. In this study the formation of scour around two types of spur dikes with different shapes of head was investigated using experimental works. Two studies were conducted; first with straight groynes and second one with T-head groynes. Bed variation in both the runs was observed and differences and similarities of the pattern of scour hole was investigated. Finally an in-depth discussion about the formation of the scour and the deposition of the sediment around these two types of spur dikes was studied in order to evaluate the performance of both the spur dikes. Main aspects of this study was to highlight the factors, that controlling the bank erosion, better navigability and improving biodiversity since these are being directly affected by the shape of groyne’s head. Using a series of T-head groynes would be an advantage as compared to the straight ones.

II. LITERATURE REVIEW

Mushtaq Ahamad, 1951 carried out number of tests on a model for more than one spur dike for bank protection of the river Satluj and from a series of experiments he concluded that, the optimum ratio(spacing of spur/length of spur) for maximum bank protection should be less than or equal to 5.[1]

Garg et al,1980 found that where more than one spurs are constructed, spacing between them being was to be decided according to the angle of the spur and curvature of the flow. The spacing of such spur was proposed around 3 to 4 times their length.[2]

Shafaie et al,2008 performed an experiment to study the effect of minor spur dike on the scouring around the first spur dike in the gravel bed. Three different lengths of minor spur dike were considered with three different flow depths in the gravel bed. Minor spur dike was installed at the upstream of main spur dikes in three different spacings. They concluded that scouring was reduced when a minor spur dike was used as compared to unprotected spur dikes. Scour rate was also reduced from 33% to 10% reaching to its maximum value when the length of minor spur dike was half the length of first spur dike.[3]

M..Ghodsian et al,2010 conducted experimental investigations to analyze the shape effects on bed shear stress distribution around a straight and T-shaped spur dike. It was found that in the straight type, the region of shear stress amplification was adjacent to the upstream part of the separated shear layer whereas in T-shape this region it is shifted towards the centerline and is 35% less than that of straight one. High shear region was confined to a smaller region and is more uniform than straight groynes.[4]

Mohammed Alauddin et al,2011 investigated the response of channel against different configuration of groynes and found that the semi permeable groyne with a slight alignment towards downstream, minimized the strong return currents and the relative aspect ratio could be increased. Moreover, the maintenance of these groynes is expected to be lower than that for the conventional ones, Which only added to the sustainability of the concept of inducing permeability to the groynes.[5]

M.Vaghefi et al,2012 performed experimental investigations on scour around a T-shaped spur dike in a channel bend. It was stated that when the spur dike was inclined at an angle of 30° to 45°, the height of sediment deposition ridge is higher than when the spur dike is located at sections 60° to 75°. Any change in the position of the spur dike toward the downstream portion of the bend increases the scour depth.[6]

Roger A. Kuhnle et al, 2012 carried out work on local scour around the spur dike aligned at 45°, 90°, and 135° and compared the result with the equation proposed by the Melville (1992).
\[
\frac{d_s}{y_\infty} = 2K_M\eta^{(1-\delta)}
\]  

(1)

After experiment it was concluded that the scour hole was more concentrated in the 90° spur whereas it was more elongated in the case of 45° and 135°. More elongation was seen in 45° case near the wall of the flume.[7]

Kedar Sharma and Pranab K. Mohapatra, 2012 carried out work on separation zone in flow past a spur dike in a rigid bed meandering channel. Straight groyne was placed in meandering channel one by one on left as well as on the right bank moving in the downstream direction. Separation zone increased when moving in the downstream direction. Less separation zone was observed when groyne was placed at left bank.[8]

Saleh. I. Khassaf, Alaa Mhseen Dawood, 2013 performed an experiment to compute the depth of local scour around groynes by using the spacing between the groynes as a countermeasure. Uniform cohesionless sand was used as bed material and it was observed that increasing the distance between the groynes leads to increase in depth of the scour of about 20%.[9]

Hamid Shamloo et al., 2014 compares the result of numerical simulation of the angle of groyne installation on separation zone with the experimental data of the Yeo et al (2005). A total of 69 experiments were done by Yeo et al with the variation of groyne length, angle of installation and degree of permeability. The Centre of smallest eddy was at a distance equal to length of groyne whereas, the Centre of largest eddy was at a distance equal to six times the length of groyne. The separation zone for the impermeable groyne was 12 times the groyne length for groyne of length 0.3m. Incidence angle calculated of the separation zone by numerical simulation was 4.78 degree whereas through experiment it was 5 degree.[10]

Salamatian et al., 2016 investigated the flow pattern and stress distribution around spur dikes located in ninety degree bend using 2D velocity meter. Experiment was done by locating the spur dikes at a spacing of 5° around ninety degree bend as (30, 35, 40, 45, 50, 55, 60, 65, 70, 75 degrees). Maximum scouring was observed in the case of 75 degree bend. Separation zone increased by increasing the distance of spur dike along the bend.[11]

Bateni et al., 2017 performed an experiment to investigate the flow pattern around repelling and attracting T-head spur dikes on a flat bed. It was concluded that downflow velocity and length of the separation zone are more significant for attractive spur dikes than for repelling spur dikes. Maximum longitudinal component of velocity vector occurred at tip of the spur dike. Maximum shear stress was observed at the wing of the spur dike and this increase in shear stress around the spur dike are due to increased flow velocity and turbulence.[12]

Vijaya Kumar and Lokesh Aggarwal, 2018 investigated and compared the scouring around impermeable straight groynes aligned at different angles. Groynes were installed at 45°, 90° and 135° to the wall of the channel. It is concluded that scouring depth increases with increase in velocity and follows a decreasing trend along the downstream direction of the channel.[13]
Vijaya Kumar and Devesh Tyagi, 2018 performed experimental studies on scouring around T-head groynes in open channel. Three different configurations of flanges were used. It was observed that symmetric T-head groynes are more efficient in scour prevention and control as compared to the other forms of T-head groynes. Symmetry in flange should be preferred over the upstream and downstream shift in the flange.[14]

III. PRESENT STUDY
In this study scouring pattern for straight and T-shaped groynes was analyzed and compared in an open channel. This experiment focuses only upon measuring the local scouring around the groynes and analyzing these scouring patterns for the different shape of groynes under the similar fluvial conditions. Further it was also tried to understand the deposition mechanism of the bed material around the groynes to provide the suitable navigable depth in the channel. Both categories of groynes were tested at the same location and similar spacings without any inclination in the upstream or downstream direction of the flow.

IV. GROYNES MODELS USED

![Fig.1 T-head groyne (TG) used in the study with total length of 12.5(all units in cm)](image1)

![Fig.2 Straight groyne (SG) used in the study (all units in cm)](image2)
V. EXPERIMENTAL SETUP

All the experiments were conducted in the hydraulics laboratory of Delhi Technological University. A tiltable flume 8m long, 0.40m deep and 0.32m wide was used as channel section which comprised a pumping system to recirculate the water through the channel. Flume includes a central part made up of acrylic glass sheet to observe the flow and the changes in bed profiles of the channel section. Groynes were made of wood and it was made sure that there is no change in geometrical features of the groynes after the submergence in water. Two models of spur dikes were used with a variation in their head only. Spacing between the groynes were kept constant except in the first groyne as the major effect of scouring is observed at the first groyne itself. Pointer gauge with an accuracy of 0.01% was mounted on a trolley which was attached to the flume. With the help of the trolley the pointer gauge which is movable in both directions and this was used to measure the depth of sand bed, scour around the groynes and depth of the flow. Groynes models were made of wood and a uniform sediment bed of 5cm thickness was provided in the flume. Sand bed was provided for total of 6.3m distance in the flume which started from the head gate along the flow direction. First groyne was installed at 2.5m from the head gate to allow the flow to be in regime condition initially. Spacing of 0.6m was provided in between the groynes so that erosive and deposition of sediment can be allowed. Scouring was also measured at a point 1.32m upstream of the first spur dike so that the erosive action of free flow can also be analyzed.

VI. EXPERIMENTAL PROCEDURE

Firstly, uniformity of sand bed was ensured by a wooden plank and groynes were installed at suitable locations with the help of tape and it was ensure that they do not fail during the test run. Fluid was allowed to flow in the flume from recirculation tank through centrifugal pump so as to drain the bed.

Sand bed readings were taken at the head, downstream and upstream side around the groynes. Two points were chosen (A) at 1.2m distance from the head gate and (B) after the last groyne so as to observe the scouring due to turbulence flow at (A) and deposition at (B) in the downstream direction. Main spur
dike was installed at a distance of 2.8m from the head gate so as to reduce the effect of turbulence on the scouring. Flow depth was maintained in the flume with the help of tail gate.

Pressure difference was measured with the help of tilting flume lodger at the head/tip of every groyne to maintain accuracy in measuring the discharge. Pressure difference was calculated at critical points in the channel and at the locations of groynes from which velocity and discharge at those points were calculated.

\[
\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2
\]

Bernoulli’s equation was used to find out the velocity and further the discharge from the pressure readings.

\[\text{Discharge} = \text{Area} \times \text{velocity}\]

Area is flow depth * width of the flume. Width of the flume is constant (30cm) so by varying the depth of the flow velocity can be varied.

Test run of 45 minutes for each type of groyne were made and the scour depth was measured. Shape of the scour hole, elongation and deposition in between the groynes were also analyzed. To cut out any possibility of error three runs were made for both type of groynes and average values were taken.

VII. SEDIMENT USED

Locally available sand was used as the bed material to imitate the alluvial channel. Before using the sand in the flume it was made sure that it is free from any impurities and air lumps by coarse sieving. Fine sieving was done to calculate the mean size of the particles which is 0.215mm with the geometric standard deviation of 2.625. Sieve analysis data of sand is shown in figure.4.

![Sieve analysis of sand used as a bed material](image)

VIII. FLOW CONDITIONS

Experimental runs were performed in a uniform flow conditions and a smooth entry of flow into the channel was ensured by adjusting a suitable floating wooden plank at the entrance of flow into the channel. This way the turbulence was prevented to hit the bed material. Any unwanted erosion in the
channel was minimized by keeping the flow below the incipient condition by physical observation of the regime of channel bed. The flow was kept uniform and subcritical with the help of flow controlling valves provided with pumping set. A horizontal channel was ensured by controlling the longitudinal slope and channel bed was levelled with a horizontal plank so that the bed material remains uniformly distributed throughout the channel.

IX. RESULTS AND DISCUSSION
Scour depth for both shapes of groynes was calculated and their respective erosion rate was found to be influenced by the flow rate.

Scour depth Variation
Test Run-1: T-shaped groynes (TG)
It is evident from the Figure. 5 that for T-shaped groynes, the scour depth increases initially and reaches a maximum value and then starts decreasing, reaching its minimum value towards the end of the channel while the velocity follows a decreasing trend throughout the channel. Obstruction effects are minimum in the channel and scour occurs maximum in the latter stages of the channel.

Table.1 Observation table for T-shaped groynes (TG)

<table>
<thead>
<tr>
<th>Test Run</th>
<th>Flow depth (cm)</th>
<th>Velocity (m/s)</th>
<th>Discharge (l/s)</th>
<th>Scour depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG1</td>
<td>7.5</td>
<td>0.54</td>
<td>12.96</td>
<td>0.9</td>
</tr>
<tr>
<td>TG2</td>
<td>7.8</td>
<td>0.53</td>
<td>13.2</td>
<td>1.6</td>
</tr>
<tr>
<td>TG3</td>
<td>7.7</td>
<td>0.525</td>
<td>13.03</td>
<td>1.7</td>
</tr>
<tr>
<td>TG4</td>
<td>8.7</td>
<td>0.52</td>
<td>14.8</td>
<td>1.2</td>
</tr>
<tr>
<td>TG5</td>
<td>7.9</td>
<td>0.517</td>
<td>13.06</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig.5 Variation of scour depth with velocity for T-shaped groynes (TG)
From figure 8 it is concluded that for straight groynes the scour depth follows a decreasing trend along the flow in the downstream direction. Velocity also decreases as the flow reaches the end of the channel. It is observed that the scour depth is considerably large in the upstream portion of the channel and in the downstream portion of the channel it decreases.
Table 2: Observation table for straight groynes (SG)

<table>
<thead>
<tr>
<th></th>
<th>Flow depth (cm)</th>
<th>Velocity (m/s)</th>
<th>Discharge (l/s)</th>
<th>Scour depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG1</td>
<td>5.7</td>
<td>0.525</td>
<td>7.34</td>
<td>2.4</td>
</tr>
<tr>
<td>SG2</td>
<td>5.7</td>
<td>0.517</td>
<td>9.42</td>
<td>2.23</td>
</tr>
<tr>
<td>SG3</td>
<td>5.3</td>
<td>0.514</td>
<td>8.71</td>
<td>2.1</td>
</tr>
<tr>
<td>SG4</td>
<td>4.3</td>
<td>0.512</td>
<td>7.21</td>
<td>1.8</td>
</tr>
<tr>
<td>SG5</td>
<td>6.6</td>
<td>0.5</td>
<td>11.02</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Fig. 8: Variation of scour depth with velocity for straight groynes (SG)

Fig. 9: Scour around straight groyne (SG)
Comparing the scour depth for both groynes as shown in figure 10 it is seen that T-shaped groynes are more safe as compared to straight groynes throughout the channel. Scour depth for straight groynes follows a decreasing trend along the channel whereas for T-head groyne it increases in the initial reaches of the channel and after reaching a maximum value it starts decreasing to its minimum value in the end of the channel. One important thing that is observed is that, the scour for a straight groyne is always greater than that of T-shaped groyne at every location which makes it less stable than T-shaped in terms of protection against scouring and stability of structures.

X. CONCLUSION

T-shaped groynes are more efficient than straight groynes in scour protection and reducing the failures of hydraulic structures. It is to be noted that scour is deeper for straight groynes as compared to T-shaped groynes. For straight groynes the scour reduces along the flow towards the downstream direction. For T-shaped groynes it increases initially and then decreases after attaining its maximum value while moving towards the downstream direction. Series of straight groynes is useful in stabilizing the bed against scour and by using the T-head groynes scouring can further be reduced up to its minimum value. Straight groynes are useful for economical protection of structure whereas T-head groynes proves to be a bit costlier but gives more stability in protection against scour.

Where important hydraulic structures are to be protected ,T-shaped groynes are recommended and straight groynes should be used where deflecting and diverting of the flow is the only concern.

NOMENCLATURES

TG: T-shaped groynes
SG: Straight groynes
Ds: Scour depth
p: Pressure (kg/cm²)
v: Velocity(m/s)
ρ: Mass density of water (kg/m³)
g: Acceleration due to gravity(m/s²)
REFERENCES

I. M.Ahamad, 1951 study of bank protection on Satluj river. International journal of advanced engineering research and studies, E-ISSN2249-8974

II. Garg.et.al, 1980 study of groynes on the basis of their angle of inclination and curvature of flow. International journal of advanced engineering research and studies. E-ISSN2249-8974


IV. A.Safarzadeh, S.A.A.Salehi Neyshabouri and M.Ghodsian. Experimental study of head shape effects on shear stress distribution around a single groyne, 2010. ISBN-978-3-939230-00-7

V. M.Alauddin, T.Tashiro, T.Tsujimoto. Experimental investigation of channel responses against different configurations of groynes, Advances in River Engineering, JSCE 2011


XII. A.M. Najafabadi and M.M.Bateni. Investigation of flow pattern around repelling and attracting groyne on flat bed, Journal of Fundamental and Applied Sciences, 2017. ISSN 1112-9867

XIII. Vijaya Kumar and Lokesh Aggarwal. Estimation and comparison of depth of scouring around straight partially submerged impermeable groynes aligned at different angles. IJWRE eISSN :2456-1606, Vol-4:Issue 1, 2018

XIV. Vijaya Kumar and Devesh Tyagi. Experimental study on scour around T-head groynes in open channel. IJWRE eISSN :2456-1606, Vol-4:Issue 1, 2018