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Development of a New Formula for a Clear Water Scour around Groynes

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ABSTRACT: *This study based on laboratory experiments for computing depth of local scour around groyne when a different spacing between the groynes using as a countermeasure. This study is conducted using a physical hydraulic model for groyne operated under clear-water condition and using uniform cohesionless sand as bed material.*

A different types of spacing (1, 1.5, and 2) from length of groynes is investigated with different water depths and flow intensities. It is developed a new formula to calculate a local scour around groynes included many parameter. Also, it has been observed that increasing the distance between the groynes leads to increase the depth of the scour about (20)%.

KEY-WORDS: *groynes, Local Scour, Deposition.*

I. INTRODUCTION

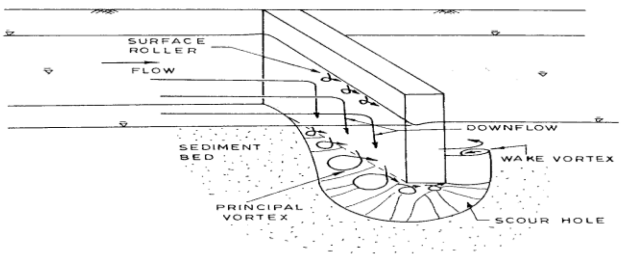
The problem of scour around any obstruction placed in alluvial channel is of great importance to hydraulic engineers. In practice, a channel is often obstructed by a means or another, such as groynes, bridge piers, abutment, and so on. Groynes are hydraulic structures that project from the bank of a stream at some angle to the main flow direction. They are used for two purposes, namely river training and erosion protection of the riverbank. With respect to river training, the primary objective is to improve the navigability of a river by providing a sufficient depth of flow and a desirable channel alignment. Groynes also serve to increase the sediment transport rate through the groyne reach, which decreases channel dredging costs. With respect to erosion protection, groynes can be designed to protect both straight reaches and channel bends. Compared with other methods, such as revetments, groynes are among the most economical structures that may be used for riverbank erosion protection (Shields, 1995).

It is important herein to state that the obstruction caused by the groyne generates a complicated system of vortices which are believed to be the main cause of scour.

The primary horseshoe vortex impinges on the sand bed immediately in front of the groyne and throws up the eroded material which is transported downstream by the main flow. See figure (1).

Development of scouring with time depends on flow condition. If shear stress on bed is less than the threshold of sediment motion (clear water), scour develops first very rapidly and then approaches equilibrium asymptotically, whereas in live bed scour develops rapidly and its depth fluctuates in response to the passage of bed features, (Chabert and Engeldinger, 1956) (Figure 2). Maximum scour depth occurs at the threshold of sediment motion (Breusers and Raudkivi, 1991).

The goal of the present work is to show the effectiveness of number of groyne as a counter measure against local scour which formed around groyne located at a specified location.



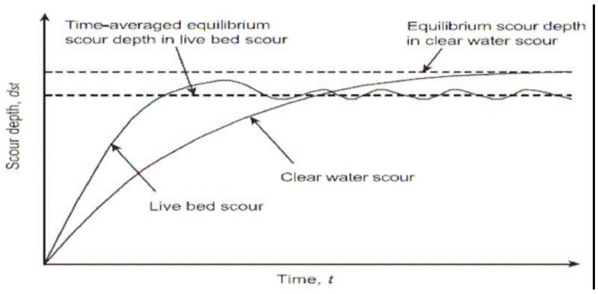


Figure (1): Flow pattern around groyne (Kwan, 1984)
Figure (2): Scouring in clear water and live bed (Raudkivi and Ettema (1983)

II. SCOUR PARAMETERS

Factors which affect the magnitude of the local scour depth at groyne as given by Raudkivi and Ettema (1983) , Richardson and Davies (1995) and Lagasse et al. (2001) are (1) approach flow velocity, (2) flow depth, (3) groyne shape, (4) gravitational acceleration, (5) groyne length if skewed to the main flow direction, (6) size and gradation of the bed material, (7) angle of attack of the approach flow to the groyne, (8) bed configuration, and (9) ice or debris jams. According to Breusers et al. (1977) and Ansari et al. (2002), the parameters that are listed above can be grouped into four major headings, viz.

• ***Approaching Stream Flow Parameters****:* Flow intensity, flow depth, shear velocity, mean velocity, velocity distribution, and bed roughness.

• ***Groyne Parameters***: Lenght, geometry, spacing, number, and orientation of the groyne with respect to the main flow direction (i.e., angle of attack).

• ***Bed sediment parameters****:* Grain size distribution, mass density, particle shape, angle of repose, and cohesiveness of the soil.

• ***Fluid Parameters***: Mass density, acceleration due to gravity, and kinematic viscosity.

III. LABORATORY FLUME

The laboratory flume used in this study is shown in figure (3) .The main flume structure is a glass fiber moulded in steel stiffeners which has a 6.6 m length, 0.4 m wide and 0.4 m depth.

The flume consists of an inlet tank 1.0 m length in upstream, a working section 5.6 m is divided into three parts, in the middle layer of sand with depth and the length 0.1m and 2m respectively, it is filled with erodible uniform sediment. The upstream and downstream portion each have 1.25m length and the bed is raised 0.1m with compressed, coated and non swelling wood to obtain more stable water surface. This tank consists of three screens to avoid entering of any unwanted particles and debris into the working section of the flume. The flume has closed system water. Water is supplied from the reservoir under the ground by a centrifugal pump that is situated on a fabricated steel base plate. The centrifugal pump lies beside the flume at upstream.

The depth of flow is controlled by an adjustable tail gate at the downstream of trap basin. For flow discharge measurement a sharp crested rectangular weir is fabricated which have width of 0.4m and the height of 0.25 and it is mounted at the upstream section of flume.

All depth measurements are carried out using a point gauge with accuracy ±1mm mounted on a carriage which can move to any position above the working area transversely and longitudinally. The scour hole is obtained by performing 4-hours continuous run under clear water condition.

At the end of each experiments, the flume is carefully drained and sand bed level is straightened for next experiments with a scraper, and for more accuracy in bed straightening two thin woods with the same depth and length of the working section on the both sides of working section .this enabled the scraper to slide from beginning to the end of working section over woods, which were mounted on the glass side walls

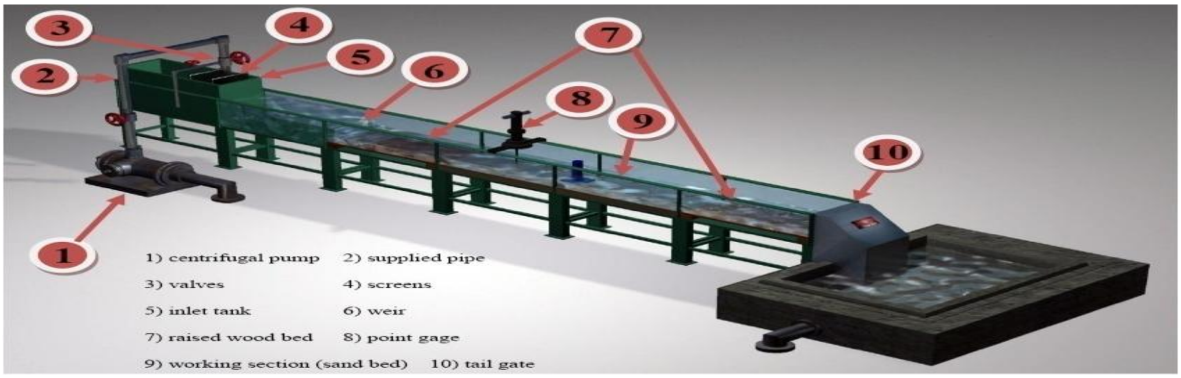


Figure (3): Laboratory Flume

IV. GROYNE MODELS

The groyne models used in the experiments were made of plywood having a thickness of (10) mm and height (20) cm and length (13) cm . Three different spacing between the groynes (1, 1.5, and 2) from length of groynes are used in the experimental works to cover the aims of this work, where more economical design and reliable practical application can be used with new relationship. These models were smoothly finished and painted to prevent any roughness or changes in dimensions resulting from swelling when they are immersed in water for a long period of time.

The groyne locations were chosen to be within the second third of flume to achieve a well established flow. The groynes were fixed vertically in the sand bed.

Groynes were fixed firmly to the side wall of the flume by using silicon adhesive which was fixed on the external wall of the flume. A tape was used to seal the space between the end of groynes and wall of the flume. As shown in plate (1) found groynes before the completion of the experiments.

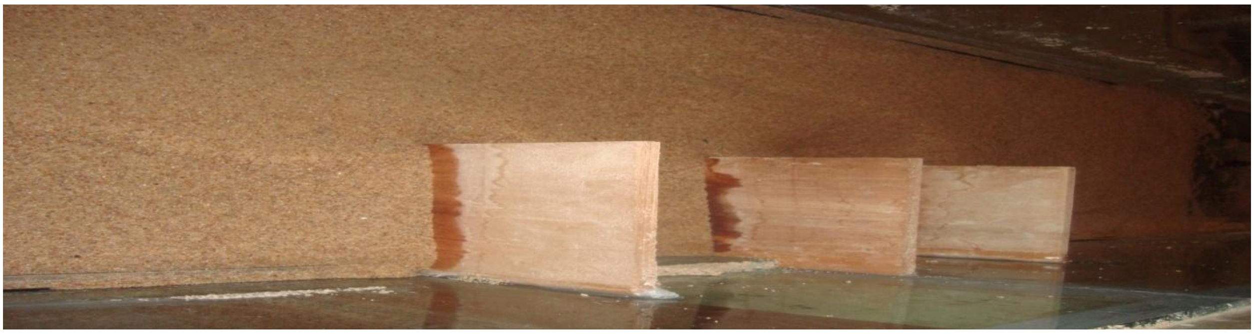


Plate (1): Front view of the groynes

V. SEDIMENT

The result of test showed that the bed material consists of cohesionless sand with a median particle size (d_{50}) equal to 0.71mm. The geometric standard deviation of the sand size (σ_g) equal to 1.31, which is implies that the sand is of uniform size distribution. See figure (4).

The sediments used in this study were well uniform, so that the results do not include the effect of sediment no uniformity in order to eliminate the reduction of local scour that would be expected to occur in no uniform sand due to armoring effect.

If the ratio of the abstraction width to the grain size exceeds a value about 25, the effect of sediment size can be negligible (Melville, 1997). The groyne length is chosen in which the effect of sediment size on the local scour can be negligible.

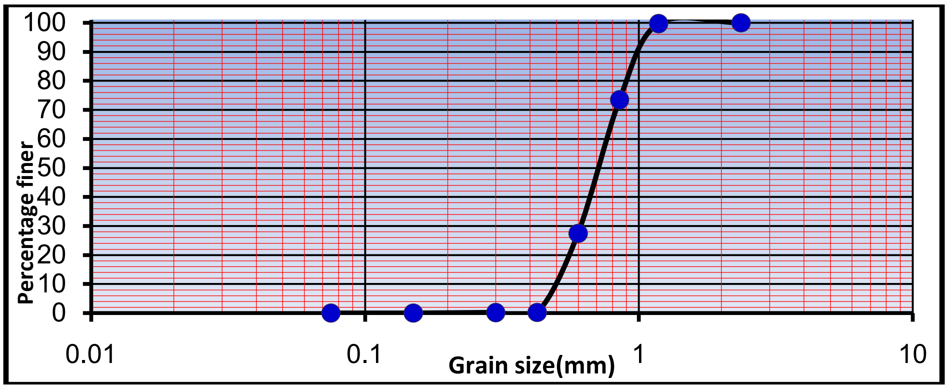


Figure (4): Grain size distribution curve for bed material

VI. THE EXPERIMENTAL WORK AND ITS PURPOSE

All experiments were performed for steady subcritical flow, clear water condition with plain bed.

Different sets of experiments (24 runs) were conducted to deduce the effect of the following parameters on the maximum depth of scour:

(a) Prolonged running time;
(b) Flow rate;
(c) Upstream water depth;
(d) Froude number upstream of the groyne; and
(e) Spacing between the groynes (1, 1.5, and 2) from length of groyne.

Summary of all experimental series are given in table (1)

Table (1) Experimental range of influence parameter for the groynes.

Run	y (mm)	v (m/sec)	v_c (m/se)	b (mm)	Fr	v / vc	b / y	d_s (mm)	d_s / y
1	20	0.233	0.245	260	0.526	0.95	13	49	2.45
2	20	0.208	0.245	260	0.47	0.85	13	48	2.4
3	20	0.184	0.245	260	0.415	0.75	13	35	1.75
4	20	0.159	0.245	260	0.359	0.65	13	26	1.3
5	45	0.192	0.285	260	0.293	0.674	5.78	74	1.644
6	35	0.192	0.273	260	0.328	0.705	7.43	52	1.486
7	25	0.192	0.256	260	0.388	0.75	10.4	40	1.6
8	15	0.192	0.231	260	0.5	0.831	17.33	28	1.867
9	20	0.233	0.245	195	0.526	0.95	9.75	42	2.05
10	20	0.208	0.245	195	0.47	0.85	9.75	40	2.0
11	20	0.184	0.245	195	0.415	0.75	9.75	33	1.65

Table (1):Cont.

12	20	0.159	0.245	195	0.359	0.65	9.75	27	1.35
13	45	0.192	0.285	195	0.293	0.674	4.33	71	1.578
14	35	0.192	0.273	195	0.328	0.705	5.57	50	1.429
15	25	0.192	0.256	195	0.388	0.75	7.8	35	1.4
16	15	0.192	0.231	195	0.5	0.831	13	27	1.8
17	20	0.233	0.245	130	0.526	0.95	6.5	39	1.95
18	20	0.208	0.245	130	0.47	0.85	6.5	35	1.75
19	20	0.184	0.245	130	0.415	0.75	6.5	30	1.5
20	20	0.159	0.245	130	0.359	0.65	6.5	26	1.3
21	45	0.192	0.285	130	0.293	0.674	2.89	63	1.4

22	**35**	**0.192**	**0.273**	**130**	**0.328**	**0.705**	**3.71**	**48**	**1.371**
23	**25**	**0.192**	**0.256**	**130**	**0.388**	**0.75**	**5.2**	**32**	**1.28**
24	**15**	**0.192**	**0.231**	**130**	**0.5**	**0.831**	**8.67**	**26**	**1.733**

Plate (2): After run (1)

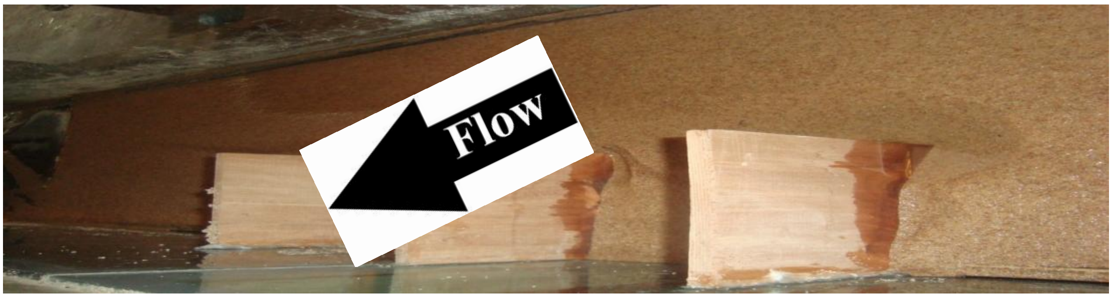


Plate (3): After run (9)

Plate (4): Before run (17)

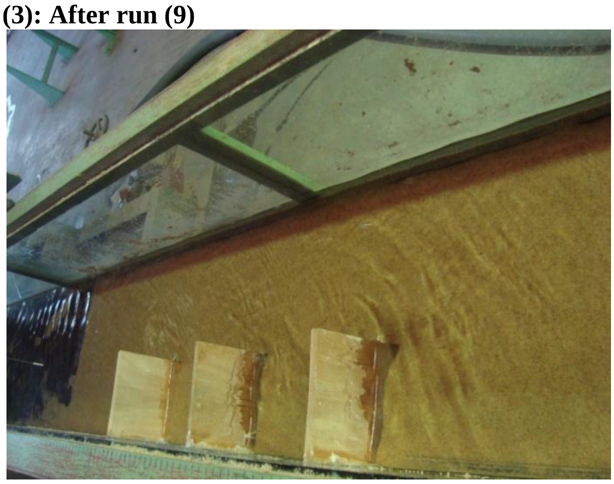


Plate (5): During run (17)

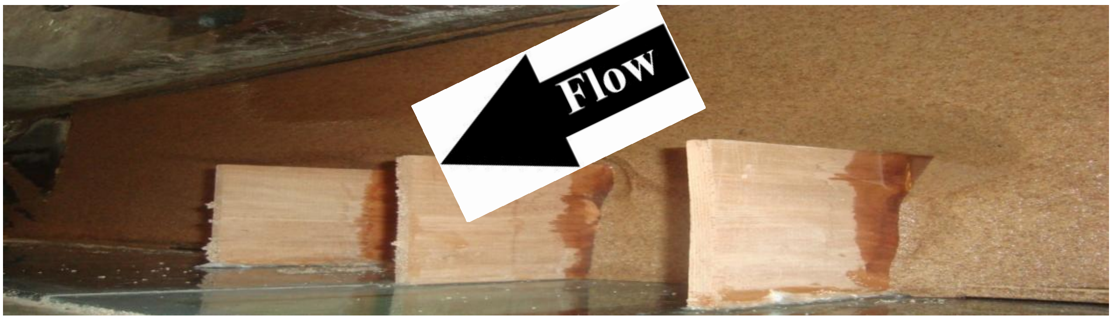


Plate (6): After run (17)

VII. DEVELOPMENT OF A NEW FORMULA

The scour depth is a function of some variables. The non dimensional formula is presented:

$d_s/y = F$ (v/ vc, Fr, b) ………………………..(1)

The computer package (STATISTICA) was used to make analysis for the equation through a non- linear regression analysis.

$d_s/y = C_1 \times \{ (v/vc)^{C2} \times (Fr)^{C3} \times (b)^{C4} \}$…………………………..(2)

C_1= 7.590216 C_2= 0.751151 C_3= 0.764262 C_4= 0.178201

R^2 = 0.952

The coefficient of determination (R^2) for this formula is (0.952).

After simplifying and rearranging the above formula becomes:

$d_s/y= 7.590 \{ (v/vc)^{0.751}\ Fr^{0.764}\ b^{0.178} \}$ ………………(3)

Another data is used to testing the equation, a statistical comparison of equation is used to show the convergence of the predicted to observed records, the value of (R^2= 0.922) are given a good agreement for all data as shown in figure (5).

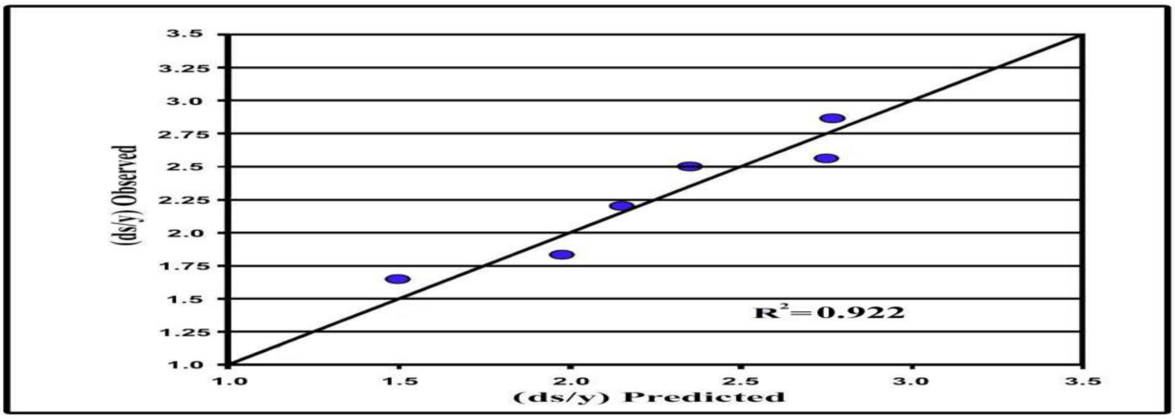


Figure (5): Comparison of equation (3) with experimental data

VIII. ANALYSIS AND DISCUSSION OF RESULTS

Estimating of maximum possible scour depth around groynes is an important step in the design of groyne foundation. To examine such a phenomenon, sets of experiments are performed using straight models to represent the main shape used for groyne.

Flow Depth

The scour process is directly proportional to flow depth. Many investigators showed that the propagation of scour occurs with increasing flow depth and the rate of this propagation decelerates up to a limiting value of flow depth at which its influence is absent.

Flow Velocity

The intensity of flow has direct influence on the scour depth regardless of flow depth. A linear increase of scour depth with velocity is observed for velocities below the threshold value. This finding is in agreement with these of previous investigation for clear water condition.

Spacing between the groyns

A set of experiments are conducting for evaluating the relationship between scour depth and spacing between the groynes. These experiments are shown in the Figure (6).

For b=length of groyne totally excludes the wake vortex system from the scour volume around the groyne and alters the flow field, which is probably influencing on the horse shoe vortex. For b=1.5 from the length of groyne, the spacing between seems to act less on the horse shoe vortex, more on the lower part of the wake vortex system.

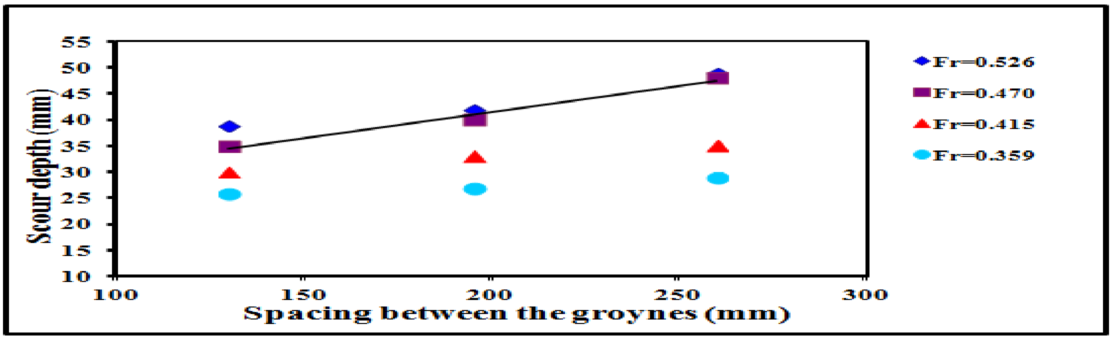


Figure (6): Development of scour depth with spacing between the groynes

IX. CONCLUSIONS

The problem of local scour around the groyne has been studied experimentally.

Under the limitations imposed on this investigation the following conclusions can be drawn.

a) The maximum scour depth was observed at the nose of groyne at the upstream.
b) For a constant spacing between the groynes, the scour depth increases due to increasing the Froude number, flow velocity, and flow depth.
c) The deepest scour occurs at the head of the first groyne because of its objection to the flow.
d) The scour depth is increased about (20)% by increasing the spacing between the groynes about (0.5) from the length.

List of symbols

b Spacing between the groyne
ds Depth of scour around the groyne
d_{50} Median size of the sediment particle
Fr Froude number ($Fr = V/\sqrt{gD}$)
g Acceleration due to gravity
ρ Water density
Re Reynolds number
V Mean approach flow velocity
V_c Critical velocity
y Flow depth
μ Dynamic viscosity

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