CERTIFICATE

It is certified that the work contained in the thesis titled **“ STUDY OF FLOW FIELD AND SCOURING AROUND SPUR DYKE IN REVERSE BEND MEANDERING CHANNEL”** by ***“MR. RAVI PRAKASH TRIPATHI”*** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy, and SOTA for the award of Ph.D. Degree.

Signature: Supervisor

Dr. K.K. Pandey

Dept. of Civil Engineering

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DECLARATION BY THE CANDIDATE

I, ***"RAVI PRAKASH TRIPATHI",*** certify that the work embodied in this thesis is my novel bonafide work and carried out by me under the supervision of ***"DR. KAMLESH KUMAR PANDEY"*** from ***"July 2015"*** *to* ***"August 2021",*** at the ***"DEPARTMENT OF CIVIL ENGINEERING"***, **Indian Institute Of Technology (BHU), Varanasi**. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not will fully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, theses, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

Date: 23 Aug. 2021 Signature of the Student

Place: Varanasi (***Ravi Prakash Tripathi***)

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It is certified that the above statement made by the student is correct to the best of my knowledge.

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Signature of Head of Department

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Title of the Thesis: Study of Flow Field and Scouring Around Spur Dyke in Reverse Bend Meandering Channel.

Name of the Student: Ravi Prakash Tripathi

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Date: 23 Aug, 2021

Place: Varanasi

Signature of the Student

(*Ravi Prakash Tripathi*)

…Dedicated To My Family

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Ravi Prakash Tripathi

ABSTRACT

A spur dyke is a manufactured hydraulic structure that extends outward from the river bank into the water stream and protects the bank from erosion by deflecting the flow away from the bank. It is beneficial in enhancing an aquatic habitat by creating stable pools in unstable water streams, amplifying the river navigation conditions by deepening the main channel bed and securing water supply by maintaining suitable flow discharge and water stream. Spur dykes are commonly built at an angle or perpendicular to the revetment or channel bank. To optimize design parameters of spur dyke it is essential to discuss the dimensions and geometric characteristics of scour holes, including erosion in vertical and longitudinal dimension. With their physical environment indicator near spur dyke such as deep pool shoal and the flow structure. The working of spur dyke in enhancing morphological diversities of the riverine system and its importance in flow diversion to prevent bank erosion has gained the significant attention of the researcher community. Various researchers have done lots of work in straight channel spur dyke, and the curved channel or channel bends. A comprehensive study for analyzing the flow field pattern with and without spur dyke along with inflow Froude number, bed resistance, and spur dyke parameters on flow field has been conducted in this work. To achieve this objective of the experiment, a meandering channel with two bends of reverse order and central angle of the bend was kept 180^0 to obtain maximum deflection. Two consecutive bends were connected to the flume's straight inlet and outlet channels in the experimental setup. The downstream tail gate controlled the water depth of the channel and the sharp-crested rectangular weir measured the discharge. The maximum deflection of the flow field was observed in the reverse meandering channel by experimental findings. Consequently, it generates high turbulence and secondary flow condition for simulating the maximum scour around the dyke. Secondary flow transported the sediment

toward the inner bank, creates few dunes near the inner wall. It was observed that the local scour hole extended in case of high discharge and high Froude number.

The diverted flow on the spur dyke head is attributed to the return current flow toward the river bank. Experimental findings indicate that scour depth increases with Froude number and also with the location of the spur dyke from the entry of the channel bend. Temporal variation of scour depth was the longitudinal trend with time. Empirical relation for temporal and maximum scour depth developed by experimental finding is the function of Froude number and the position of the structure in the channel bend. This relationship provides more reliable results with other proposed using data from physical model analysis. The new relationship equation shows good accuracy with the experimental data of $R^2 = 0.895$ with a percentage error ranging in between 1.28%-18.33%.

Along with this, we see that the proposed equation overestimates the maximum scour depth with the average factor of 1.19, 1.41, and 2.2 for Masjedi et al (2011). In the thesis, the flow characteristics near around T-shape spur dyke situated in a reverse meandering channel having a rigid bed are simulated using Renormalization Group (RNG) $k - \varepsilon$ turbulence model with an ANSYS 2018 Fluent software. To solve the model in 3D ways we used Navier-Stroke's equation based on the principle of conservation of mass and momentum within a moving fluid. For studying the flow characteristics, Computational Fluid Dynamics was applied with all geometric parameters, and the turbulence was simulated using (RNG) $k - \varepsilon$ equations of the model. In simulation, the structured messes are used with different diameters and the diameter of the mess is high at the exit channel for obtaining accuracy in the result. In this study, we mainly focus on the effect of Froude number on flow pattern and several other characteristics like velocity distribution, flow separation, bed shear stress distribution. The final result of this research work is compared with the condition when no structure is present in the channel and the result of our non-dimensional equation is very much fitted with the other previous equations having a significantly minor error.

In thesis, the focus will also turn on the new soft programming used to predict maximum scour depth with the extended version of Gene programming the GEP. The GEP is an alternative approach in modeling, which predicts the maximum scour depth. Introducing the GEP model can be applied to different boundaries with the part-full flow, and approaches give excellent results compared to previously existing data. The result of the GEP model gives standard data and shows very little error for tested data ($R^2 = 0.94, MAE = 0.06566, and\ MSE = 0.0056$). Therefore, the outcomes of the present study are more useful for a realistic estimation of various performance measurement parameters and may be used as a valid input to different simulation approaches.

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ABBREVIATIONS AND SYMBOLS USED

a = Width of scour

a_1, a_2, a_3, and a_4= Constant

B = Wing length of spur dyke

c = Upstream length of scour

d = Downstream length of scour

d_z = Scour depth at any time instant t

d_s = Temporal scour depth

d_{sm}= Maximum scour depth

d_{50}= Median grain size

D_{gr} = Dimensionless grain size $= D\left(\frac{g\,(s-1)}{\nu^2}\right)^{\frac{1}{3}}$

D_m = Maximum scour depth

F_r = Froude Number = $\frac{V_s}{\sqrt{g\Delta d}}$

g = Acceleration due to gravity$\left(\frac{L}{T^2}\right)$

k_i Where i = 1, 2, 3, 4, 5, and 6 = Constant

L = Length of spur dyke

l = Wing length of spur dyke

R_c = Central radius of the bend

R^2 = Coefficient of correlation

S_0= Bed slope

s = Ratio of mass density of sediment to that of the fluid

t_e= Time required reaching equilibrium or maximum scour depth

t, = Time of scouring

V = Approach velocity

V_{*c}= Critical shear velocity

V_0= Scour volume

V= Average velocity

V_c = Critical velocity

ν = mean unidirectional flow velocity $\left(\frac{L}{T}\right)$

W = Width of channel

y = Approach flow depth

φ = Maximum dimension of scour parameters

τ= Bed shear stress

θ= Location of spur Dyke in the bend

α = Angle of spur Dyke with bank

μ = Dynamic viscosity of the fluid

ρ_s= Density of sediment

∅ = Friction angle of sediment

θ = Location of spur Dyke in the bend

Δ= Relative density of sediment in water = $\left(\frac{\rho_s}{\rho}\right) - 1$

ρ = Fluid density,

ρ_s = Buoyant sediment density

AI Artificial Intelligence

ANN Artificial Neural Network

1D One-Dimensional

2D Two-Dimensional

3D Three-Dimensional

ET Expression Tree

GA Genetic Algorithm

GEP Gene Expression Programming

GP Genetic Programming

MAE Mean Average Error