CHAPTER 1

INTRODUCTION

1.1 General

The main concern of hydraulics is to control the flow velocities of the river. The high vortex flow velocities eroded the bed surface of the river. The construction of spur dyke in the river plays an important role in controlling the flow velocities of the river or channel stream. The typical manufactured hydraulic structure that runs out of a stream of water from a river bank is called a spur dyke. The spur dyke is used to deflect the current away from the bank or valuable levees for protecting it from erosion, increase the river navigation conditions by deepening the main channel bed, and secure water supply and irrigation by maintaining appropriate effluent discharge. The spur dykes attracted much attention for their aesthetical and environmental impact and enhanced morphological diversities of the channel riverine eco-system. The significant criteria for designing spur dyke are the estimation of maximum scour holes for flow discharge. The scour present at spur dykes is divided into three parts; (i) general scour, (ii) constriction scour, and (iii) local scour. The common or general scour on a channel bed is independent of spur dyke, constriction scours formed due to narrowing of water way in the presence of the spur dyke (Choi et al., 1991). Local scour is formed by local flow structures near the spur dyke. The resultant hydrostatic pressure difference between upstream and downstream flow around the spur dyke causes a whirlpool of disturbance. This disturbing whirlpool flow is the main cause of local scour, which, in the long term, produces large vortexes at the spur dyke head and leads to the failure of the spur dyke.

1.2 Classification of spur dyke

Spur dykes are classified into various types concerning their inclination, permeability, appearance, and submerging conditions shown in Figure 1.1. According to permeability, the spur dyke is commonly divided into two types: An impermeable spur dyke and a permeable spur dyke.

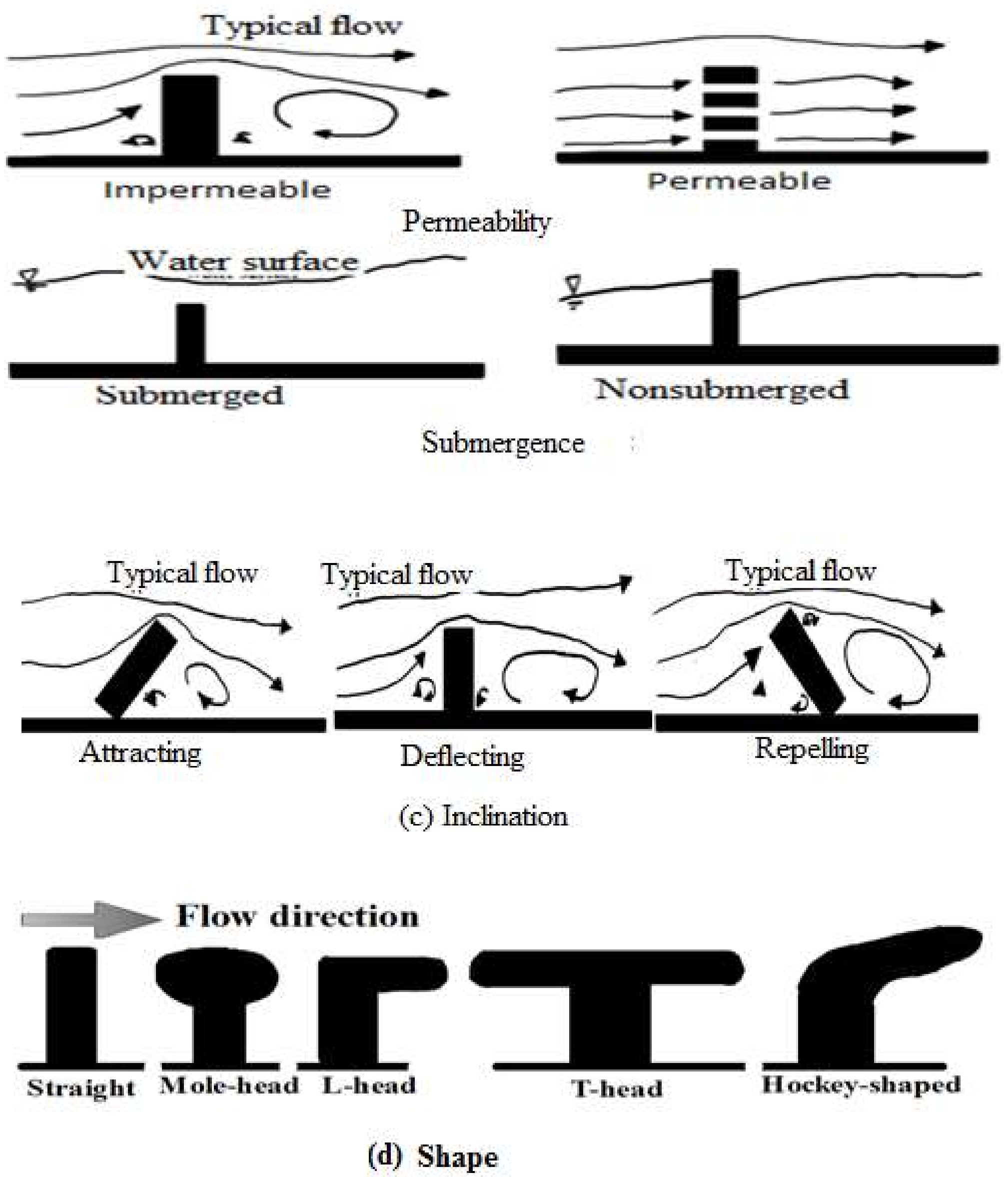

Figure 1.1 Classification of spur dyke (Zhang and Nakagawa, 2008)

Unlike an impermeable one, the permeable spur dyke allows the flow to pass across it, though at low velocity. The submerged and non- submerged spur dyke may be distinguished based on submergence conditions. A spur dyke may also be classified as attracting, deflecting, or repelling spur dykes according to their inclination concerning stream direction. An attracting spur dyke inclined in the downstream direction and attracts the downstream flow towards its head and thus to the river bank or channel. In contrast to attracting spur dyke, a repelling spur dyke inclined upstream and diverts the flow away from itself. A deflecting spur dyke deflects the normal flow of the stream and is placed normal to stream direction. According to the appearance of the head, the spur dykes are further differentiated into several others, including a mole-head, L-head, I-head, or hockey-shaped.

1.3 Flow structure around a spur dyke

The spur dyke structure restricts the flow velocity of the river. When the spur dyke is present at the concave bank of an eroded river curve or straight channel in such a condition, the flow velocity is very high and it shifts towards the centre of the channel. A new velocity is balanced through channel depth, local sediment scours, and deposition. The obstruction caused by the spur dyke generates a complex of vortex formation. The primary vortex impacts the bed immediately in front of the spur dyke, destroys the bedding material, enters the decaying material in the flow, and is carried downstream by the main flow (Ahmad, 1953). Intermittent vortices of low strength occur along with both the upstream and downstream faces of the spur dyke shown in Figure 1.2. In general, an insight into the nature of the flow is a prerequisite for understanding the scour process in the vicinity of the spur. The flow structure of the stream can initiate and controls the formation of scour. The flow past over spur dyke is commonly more complex and the complexity enhances with the formation of scour hole, flow separation zone, and vortex shedding. The flow past near spur dyke can be differentiated into three zones.

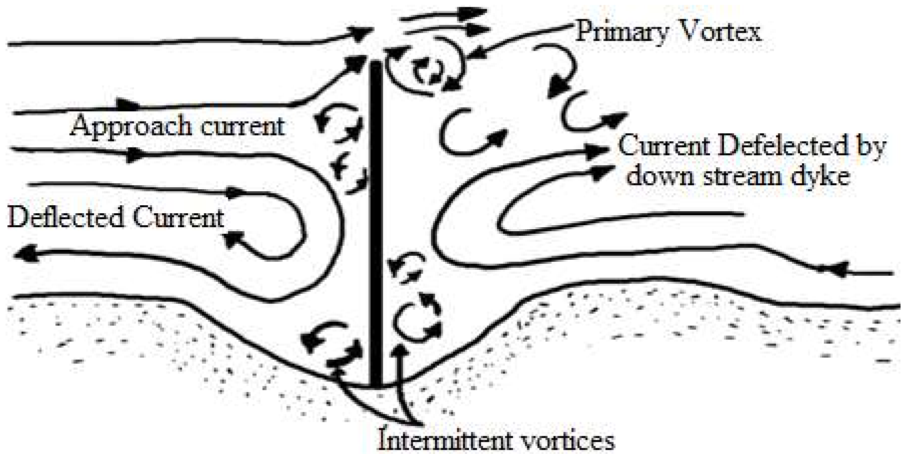

Figure 1.2 Plan views of Flow Patterns at a Spur dyke or Exposed Groin (Copeland, 1983)

The first zone is the main flow zone that starts from the head of the spur dyke to the opposite side of the channel. The second is a wake zone that lies behind the spur dyke. The third is the mixing zone, which combines both the first and second zones shown in Figure 1.3.

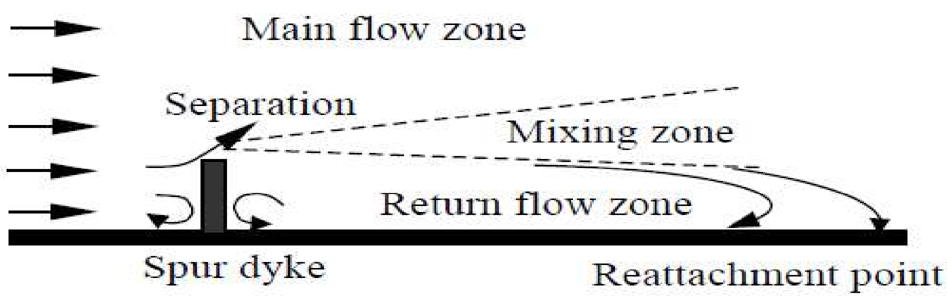

Figure 1.3 Flow zones around spur dyke (Zhang and Nakagawa, 2008)

1.4 Flow structure in the scour area

The flow in the local scour is three-dimensional. The flow field near the spur dykes can be categorized into different components concerning streamline patterns. At the front of the spur dyke, due to stagnation of approaching flow, there exists a bow wave near the water surface and a downflow towards the channel bed. The flow separation and development of a horseshoe-shaped vortex in the area of the local scour hole is started, and a wake vortex system is also formed behind the spur dyke of the channel shown in Figure 1.4.

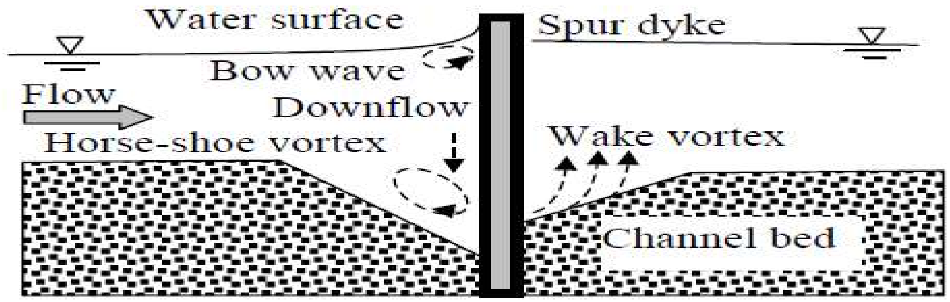

Figure 1.4 Longitudinal section passing through the spurs dyke (Zhang and Nakagawa, 2008)

1.5 Gene expression programming

GEP is a modern technology based on artificial intelligence and considered as the extended version of gene programming (GP) (Dehuri et. al., 2008). This combination of genetic programming and genetic algorithms provides modest fixed-length chromosomes and a branching structure called expression tree as phenotype. In hydraulics engineering it is impossible to do the experimentation work with more accuracy in all parameters at the same time. Hence, GEP aims to develop a few simple arithmetic models such as an arithmetical function can be prepared by providing a data set of the GEP model (Eldrandaly, and Nigam, 2008). Most of the mathematical preparation of GEP belongs to a genetic algorithm genotype. This genotype generates the random chromosomes of the primary population and is further evaluated with fitness function in contrast to the group of fitness conditions (Ghaniet.al.,2001; Xie et. al., 2004). The selection of chromosomes relies upon these fitness values, as higher fitness values have a more chance to be selected for the next generation (Khan et al., 2012). After this, in selected chromosomes, the genetic operation is introduced to make a change. This genetic operation includes inversion mutation transposition of the gene, roots inversion sequence transposition (RIS) insertion sequence transposition (IS), recombination of the gene, and a single or double cross-over recombination as described in detail in the Ferreira, (2001a, 2001b). This process is repeated until a more accurate result has been found or a few generations as passed (Dehuri et. al., 2008).

1.6 Need of the study

In hydraulics, physical modelling is costly and impossible to predict all parameters accurately at the same time. Spur dyke is extensive, and no definite hydraulic design criteria have been developed. Design is primarily based on experience and judgment within some geographical areas. This is due to the presence of a wide range of variables that affect the performance of spur dyke and the importance of these variables also differ in their applications. Parameters affecting spur dyke design are (1) channel characteristics like channel sinuosity, properties of bed material and its transportation rate, flow velocity, flow depth and flow width, etc. and (2) spur characteristics like shape and size, angle of orientation, placement and spacing of spur, etc. In hydraulics engineering, most studies have been conducted in a straight channel with a straight spur. Still, very few studies have been conducted using a T-shaped spur dyke in a meandering river channel. Also, no such study was performed in which optimum length of spur dyke and optimum spur arrangement was made. Thus, there is a need to conduct experimental and numerical studies of the flow field around T- shaped spur dyke placed in a mobile bed meandering channel.

1.7 Objectives

The present work is related to the experimental and numerical study of flow fields around the T-shaped spur dyke at different locations in 180^0 reverse bend meandering channels. The main objectives of the present work are:

1. To measure the flow field (velocity field, water surface profile) without spur dyke and study the effect of inflow Froude number and bed roughness on the flow field.

2. To analyze the changes in the flow field due to a spur dyke placed at different locations of the channel.
3. Experimental study of the flow field and scour pattern around the T- shaped spur dyke placed at a different azimuthal angle in reverse bend meandering channel.
4. Derivation of empirical equation for equilibrium scouring based on dimensional analysis and experimental data.
5. Computational Fluid Dynamics (CFD) based numerical simulation for equilibrium scouring around the spurs was placed at a different azimuthal angle and validated the result using the simulation data.
6. To compare the performance of Gene Expression Programming (GEP) to predict the equilibrium scour depth.

1.8 Organization of thesis

For detail and the sequential presentation of the whole work, the thesis report is organized in the following manner:

Chapter 1: This chapter provides an overview and objectives of the work carried out in the present thesis of the intersection along with various intersection parameters.

Chapter 2: This chapter contains a critical review of the earlier research work done on the scour around the spur dyke in meandering and the straight channel.

Chapter 3: This chapter describes a complete experimental setup with different parameters along with their procedure. The relations between different equations for maximum scour depth are also discussed in this chapter. Later discussing the methodology involved in the experiment and the final result and validation of the experiment are also given in the chapter.

Chapter 4: Simulation of maximum scour depth for T-shaped spur dyke using the CFD 2D, and 3D Volume of Fluid (VOF) method has been carried out with ANSYS Fluent solvers.

Chapter 5: Simulation using Gene Expression Programming (GEP) for scour around spur dyke have been carried out.

Chapter 6: Conclusion and further Scope of the study.