# CHAPTER-1

# INTRODUCTION

## 1.1 GENERAL

India is the land of rivers and most of its states are prospered by the rivers flowing through them. Importance of rivers has been recognized since a very long period of time and they have occupied a precious place in process of human development. Rivers with their beneficial features, sometimes proves to be the main cause of concern for humans because of their potential of causing several problems for mankind. The chief factor which is responsible for causing devastating effects is their tendency to change course, due to which they can bring the nearby areas under complete submergence. Therefore, to prevent ourselves from such conditions it is required to understand the basic mechanism behind the flow of rivers. Rivers in our country contains fine grained, non cohesive sediments which gets eroded with the upcoming flow and makes the river training structure less stable, channel banks more prone to over flooding and also making it lose its navigability. Rivers in alluvial plains carries huge amount of sediments as they flow in the rolling terrain therefore along the flow attains a threshold velocity after a point of time which is sufficient enough to destabilize the deposited sediments at the river bed and also carry them downstream.

These two types of sediments which are being carried forward by the flowing water and the one which is eroded at river bed gets accumulated and is carried forward by the flow. During its course along with the flow some of these particles attains sedimentation and some of them gets settled down. This leads to the process of deposition of these particles in the river reach and this combination of continuous erosion, suspension, and deposition of particles changes the natural course of the river and a condition of meandering is attained. Meandering is caused by the continuous erosion and deposition of sediments caused by the erosive eddies formed by the turbulence of water. This continuous erosion and deposition of sediments leads to cutoff which includes change in course of river from its intended course. This change in river flow direction called as meandering of rivers, forces them to follow a deviated path and this deviation from their intended course puts the nearby locality in danger of flood and ultimately into a huge loss of life and money. To control this meandering of rivers certain measures are employed which are categorized under river training works.

Water resource engineers need to know the behavior of alluvial rivers during floods for planning the hydraulic structures. It is not only the discharge that is the prime concern for the designers but also the sediment transport which is equally important for the safe and sound design of hydraulic structures. It is to be noted that sediment supply to the reach is equally important to the sediment transporting capacity of that reach in the channel.

## 1.2 RIVER TRAINING

### 1.2.1 Introduction

River training is defined as the controlling of river flows by either diverting or deflecting the river flow and preventing the formation of cutoff. It comprises of activities and structures which either restricts the flow deviation from its course or the deviated course is diverted back the desired location. River training covers various structures which are either permanently constructed or on a temporary basis. These structures include guide banks, groynes, leeves etc. There should be an effective approach towards their designs so that their durability is up to the desired level. Therefore factors affecting river training structures need to be studied for their variation with the erosion and deposition of the sediments in the channel.

### 1.2.2 Types of River Training works

A river basically has three degrees of freedom as its width, depth and slope. A fourth degree of freedom can be considered as channel pattern which changes with the longer period of time. Important factors that affects river pattern are discharge, sediment load, and bed materials etc. River training works can be classified in three categories mainly:

(i) High water training works that includes discharge as its main concern
(ii) Low water training works that include water depth as its prime importance
(iii) Mean water training works that are used for efficient disposal of sediments and silts

River training structures are basically provided to prevent the rivers from changing its course and to avoid outflanking of structures like bridges, weirs, aqueducts etc. River training structures are also intended to ensure effective disposal of sediment load, to provide minimum navigational depth and to prevent the river banks by deflecting away the river from the attacked banks. River bed may consists of sediments and soils which may vary in their erosional properties. In general flood plains contains fine sediments (clays and silts) which are always prone to erosion by flowing water. These different properties are responsible for the unpredictable nature of rivers in terms of meandering and deviation from their intended course.

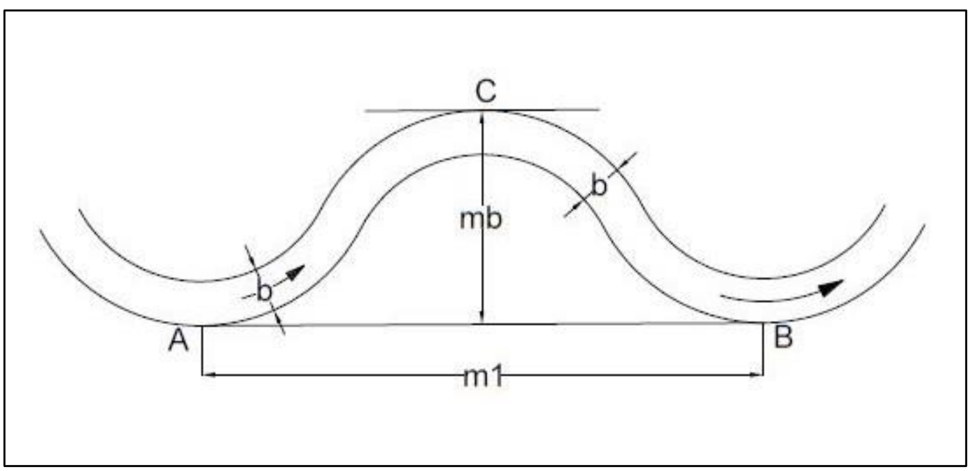


**Figure.1.1** Meander loop in the river

In Figure.1.1 m1 represents the meandering length, mb is the meandering belt and b is the average width of channel during floods. Important questions that arises are what factors are responsible for rapid changes in river profile such as change in depth and slope whereas which factors are responsible for long term changes such as meander and change in channel width.

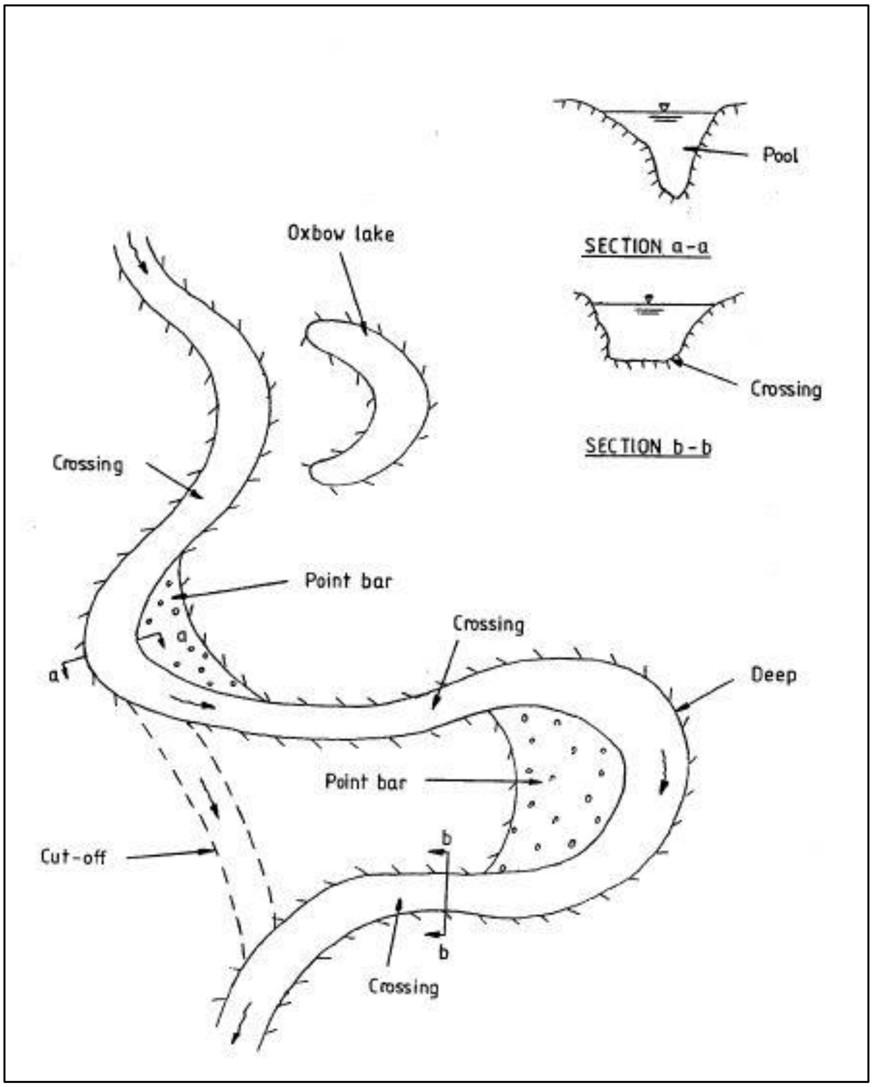


**Figure.1.2** Sketch showing features of meander loop formation

(Source: Wallingford Hydraulic Research "Groynes and Training Works affecting River Planform")

Meandering of rivers in alluvial plains is a well known fact. It includes formation of consecutive curves that are opposite in nature and connected by short straight reaches known as crossing in between them. Most of the rivers are subjected to meandering either by natural topographical features or human activities. Natural formation of meander curves is a long term process but human activities such as construction of dams, agricultural activities etc. leads to change in the course of the river quite rationally and in unpredictable forms.

Naturally meandering rivers should be more focussed upon as they are the ones that need to be trained as every time the catastrophical situation arrives, these rivers plays an important role behind it and therefore an effort has to be made so that meandering of rivers can be controlled as per our needs and necessity. In India number of rivers (Ganges, Brahmaputra, Kosi etc.) are there which continously changes their course and shows special radical shifting in their channels.

## 1.3 EROSION AND SCOURING

Erosion and scouring are related to each other in terms of uplift of the deposited material from the river bed. In meandering channels, the shear stress on the boundary increases as the bank particles are disturbed and the channel width may increase. The size of the disturbed bank material relative to the deposited sediment will influence the resulting pattern. If the bank particles are smaller than the deposited ones, they may be dislodged by the flow and if they are larger, in that case there is reduced erosion of the particles. There is reduction in flow depth as the deposition of the sediment increases on the bank.

Erosion can occur over a wide range of area which includes a general lowering of ground level due to the washing away of the sediments over a certain period of time. Scour occurs where the flood water passes through the obstruction created by the structure foundation at the bed level. As the water flows around an obstruction it must change direction and loosen the soil around it. This change in direction causes the flow to accelerate and carries away the excavated soil with it. Scour is considered as an important area of research as it is very difficult to accurately predict the scour depth that will occur at the structure's foundation. Scour and erosion not only governs the design of hydraulic structures but also play a key role in improving habitat for flora and fauna in the rivers worldwide. Erosion can be reduced by evaluating the flow rate and flow pattern in different area so that we can control the possible damage and ultimately a stable situation is attained. Sedimentation also plays an important role in controlling the scour and erosion as it can be stated that sedimentation and erosion are related to each other as the basic element involved in both of them is same that is the sediment available in channel bed.

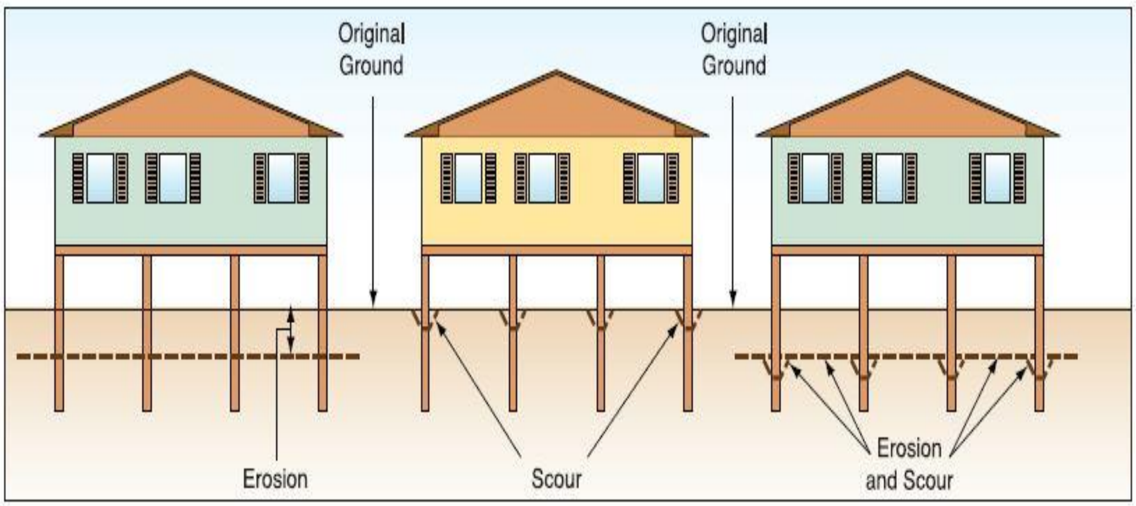


**Figure.1.3** Illustrative sketch for erosion and scour
(Source: Erosion, Scour and Foundation Design, FEMA,2009)

Scour can be classified in two types basically (i) General Scour; defined as the removal of material from the water stream bed without any obstruction. (ii) Local Scour; defined as the removal of material from the stream bed around any obstruction like spur dike, pier, abutment by the erosive action of the activated water.

General Scour can be differentiated on the basis of their duration as long term and short term scour. Long term scour means which requires considerably larger period of time reach the equilibrium condition and short term that requires considerably smaller period of time to attain the state of equilibrium.

Further localized scour can also be classified in two categories (i) Live bed scour ($V/V_c$ >1) and (ii) Clear water scour($V/V_c$<1), where V is the average velocity of approaching flow and $V_c$ is the critical velocity for the bed material. It is also to be noted that time taken to achieve the equilibrium scour depth is smaller in clear water scour as compared to live bed scour.

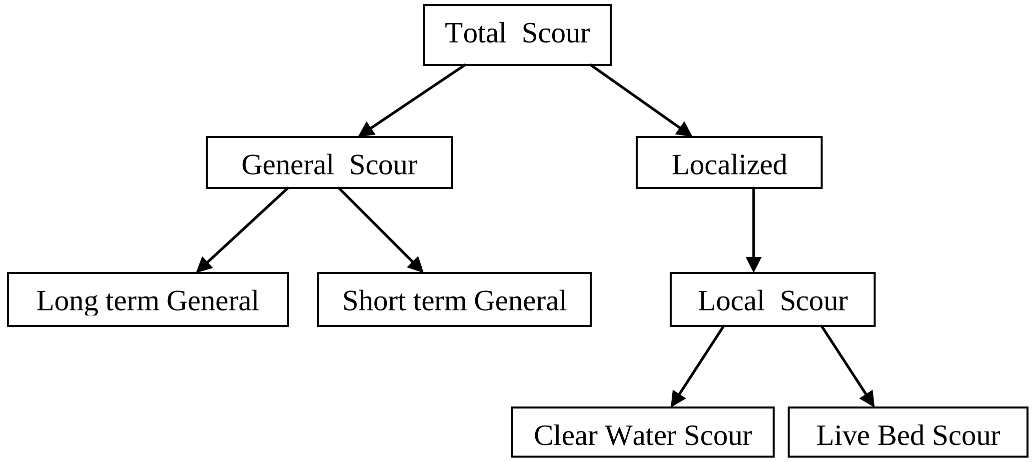


**Figure.1.4** Different types of scour

Local scour is that scour that occurs near a structure that acts as an obstruction to the flow which creates the vortices that removes the deposited sediments. Local scour basically affects the stability of the structures by dislodging the sediment surrounding the foundation of the structure and leading it to the failure condition. Basic features that affect the local scour are :

1. width of the obstruction (piers, abutments etc.)
2. projection length of the structure in the flow
3. angle of approach flow, velocity of approach flow, and length of the obstruction
4. bed configuration and size of bed material

Local scour initially occurs at a very high rate, which diminishes over a period of time, around the tip of the groynes. The bed material load increases locally downstream of the structures, due to the addition of scoured material. The depth and volume of scour are difficult to be estimated accurately. Basic difference between clear water scour and live bed scour is whether or not the mean bed shear stress of the flow upstream of the concerned section is less than or larger than the threshold value of the shear stress needed to remove the bed material. If it is less than the threshold value, the bed material upstream of the concerned section is at rest, this refers to clear water scour.

Any bed material that is removed from a local scour is not replaced by sediment being transported by the approach flow. Live bed scour occurs where the upstream shear stress is greater than the threshold value and the bed material upstream of the concerned section is moving. This means that the approach flow continuously transports sediment into a local scour hole.

**Figure.1.5** Sketch showing the local scour
(Source: Erosion, Scour and Foundation Design, FEMA,2009)

It is to be noted that the maximum scour depth may occur under the initial clear water conditions, and not necessarily when the flood levels peak and live bed scour is underway. River training structures are affected in a way that local scouring around their foundation due to recirculation of flow, the sediment starts dislocating itself which leads to failure of the structure ultimately. Another thing which is of prime importance is that deposition of sediments towards the banks in terms of their protection from flood point of view. Lastly the navigability of channel which is not up to the mark due to the lack of water depth in the main channel. This lack of water depth is due to scouring pattern of the sediments which tends to occur more towards the banks instead of near the middle portion of channel making the channel wider rather than deeper.

## 1.4 GROYNES

River banks are often subjected to the danger of erosion by the flow of water which creates severe conditions for the population living on the river banks. They are subjected to destruction, deformation and erosion including the loss of agricultural lands and infrastructure. Therefore the coastal protection is very critical to prevent these types of losses. Groynes are used as a river training structure extensively on meandering rivers all over the world. They are projected from the bank in lateral direction to the flow and controls the flow either by reflecting or attracting the upcoming flow away from the bank and towards the bank respectively. For a better functioning of groynes it is very important to understand the behavior of the sediment around groynes and possible outcomes of their installation so that maximum protection against the disasters can be attained with the help of groynes. Various researches has been done on different types of groynes but still there is no exact information is available regarding which groyne would be feasible and still there is an important need to expand our knowledge on the basis of experimental studies regarding groynes in actual site conditions and desired behavior of rivers and channels.

### 1.4.1 Types of Groynes

Classification of groynes can be done on various basis. Majorly it includes material used, functionality, appearance of head shape on plan view.

1. On the basis of material used in their construction, groynes can be classified as Wooden groynes, Rock groynes, Concrete groynes etc.

**Wooden Groynes:** These are the groynes made up of wood and sand bags intermixed together to alter the direction of flow according to the situation and requirement. These are considered to be the cheapest of them all and sometimes they are only for temporary purpose i.e their use is intended for a shorter duration of time only.

**Rock Groynes:** These are the groynes that are made up by placing the rocks or stones together to form an obstruction to the incoming flow. Theses groynes posses the advantage of being easy in construction, long term durability and ability to absorb the energy due to their semi-permeable nature. They prove to be more costly than the wooden groynes but they can be dismantled and reused at different locations many number of times.

**Concrete Groynes:** These are the groynes that are made up of concrete of such a high grade that can resist the effect of incoming flow. These includes prefabricated boxes of concrete and a suitable foundation is required for their proper functioning. These are advantageous in long term as they are more costlier than previous forms of groynes and should be provided where a continuous threat of damage is observed. They proves to be economical in terms of durability and maintenance.

2. On the basis of functionality groynes are classified are of following types (i) **Attracting groynes** (ii) **Repelling groynes** (iii) **Deflecting groynes**. Attracting groynes points in the downstream direction of the flow. Repelling ones are usually shorter in length and are pointed upstream which  deflects the flow away from the bank. The deflecting groynes only directs the flow away from the bank from which they are projected. Basically it depends upon the angle of inclination of groynes with the incoming flow.

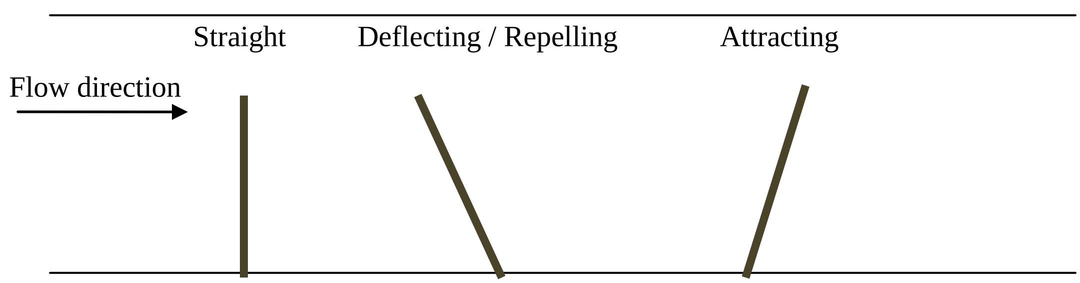


**Figure.1.6** Classification of groynes on the basis of their functions

3. Further on the basis of their head shapes groynes are classified as Straight, T-shaped, L-shaped, Hockey shaped , Inverted hockey shaped. Effectiveness varies with the shapes of groynes which is directly related to the cost of construction, the efficiency of the structures. Generally shape of groynes adopted in our country are straight and T-shaped. Further T-shaped are replaced with L-shaped groynes in certain cases. However variations are available in every shape due to which the desired effects can be obtained in the concerned regions of the channel. In general T shaped groynes are used also in severe conditions

where the straight ones are of no use even with variations in their angle of projections and the aspect ratio. The usual cause of the failure of these structures is the excessive local scour which directly affects the stability of these structures. This makes the prediction of scour depth and volume to be very important for the design of these structures.

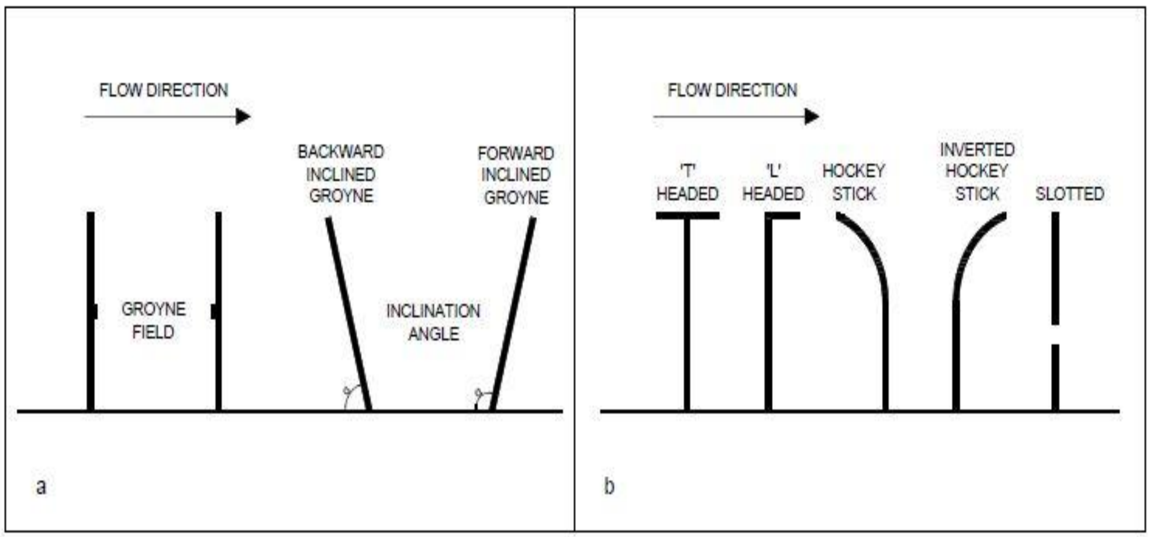


**Figure.1.7** Classification of groynes on the basis of their inclination and head shapes

4. On the basis of submergence level of groynes may be classified as submerged and non-submerged groynes. Submerged are the ones with their crest level below the water surface level and non-submerged are the ones with their crest level below the water surface level. Generally submerged groynes are permeable in nature and non-submerged groynes are impermeable in nature. Scour is generally more in submerged groynes as compared to non- submerged ones.

A special design of groynes are used which are termed as Sand-filled bag groynes. These are provided for a short term problem of prevention against the erosion in flood prone areas. Sand filled bags are laid out in proper alignment to divert the flow according to the situation and the availability of the resources.

In the present study T-shaped and L-shaped groynes are studied for their behavior in alluvial sediments and the effect of their existence in open channel and respective pattern of erosion, deposition and availability of navigable depth in the channel. Groynes like any other river training structure disturbs the natural equilibrium of the river and creates disturbances which sometimes leads to severe circumstances in the structures provided.

**Figure.1.8** Concrete made straight groynes in a river bend on Gamka River, South Africa (Source: “The use of Groynes for Riverbank Erosion Protection”, Hans King,2009)

Groynes induces a slight roughness on the surface of the bank from which it is projected as by reducing the flow velocity in its proximity which results in lowered erosion and more deposition of sediments. Groynes disturbs the flow in a way that it leads to the initiation of the scouring process due to creation of vortex at the bed level which initiates the dislodging of the bed surface. This scouring leads to the failure of the foundation of the structure which makes it more important in terms of design and maintenance of this structure from hydraulic point of view. Failure of the foundation of the structure which ultimately results in the financial losses and social chaos. Therefore for effective and efficient designing of the river training structures scouring has to be evaluated effectively and preventive measures should be provided wherever it is needed.

In order to reduce scouring, attempts have been made to build groynes with sloping crests, from the bank to the head, so that the structure does not excessively disturb the flow and the scour is reduced. Once the right type of groyne has been chosen for the project, it is of great importance that all the following parameters are taken into account because they characterize the design of groyne’s field: Planimetric location , groyne location and orientation relative to the river axis, groyne length(normal to the bank) and height, groyne spacing and number. In case of groynes which provides an obstruction to the approaching water and leads to the formation of scour holes at the tip of groynes head and near the surface. This happens due to the formation of vortices and ultimately these vortices leads to the erosion of sediments at the foundation level of the spurs and the approaching flow carries these eroded particles downstream and they are deposited in the channel depending upon the fluvial properties of flow.

### 1.4.2 Effect of Groynes on flow field

Groynes are subjected to the hydrostatic pressure on their body which adds to the possibility of the failure of these structures. It is critically important for the designers to have knowledge about the scour formation around the groynes and the factors governing it. Complete and efficient knowledge of those parameters which affects the scour formation in any way possible is required.

Groynes are capable of changing the landscape of the shorelines from which they are projected in the stream. They mainly influence the bed load transport and are highly efficient in sandy beaches to protect their erosion and deformation from the impact of flow. Special consideration must be given to the failure possibilities of the design of groynes which not only includes financial losses but also the social and regional chaos.

Hydraulic structures are used to regulate the flow in desired direction, divert a part of the flow in the desired quantity according to the requirements. Groynes are the most efficient hydraulic structure that is used to regulate the flow within the channel and ultimately it can be used in attracting and repelling form depending upon which bank is to be secured and towards which the flow has to be diverted. Therefore for the economical and secured functioning of the groynes, its design has to be made safe and free from any defects which may lead to the failure of these structures and losses. Estimation of local scour in the vicinity of a groyne is very difficult to understand therefore, it is very important for the designers of hydraulic structures to consider the scour forming factors during the designing process. Constructing a spur dike creates an obstruction in the flow due to which there will be a difference in hydrostatic pressure at upstream and downstream of the spur dike. A whirlpool of flow occurs around the groyne which initiates the mechanism of local scouring and with the course of time large eddies are formed around the structure and ultimately the failure occurs. Mean velocity and discharge increases due to construction of spurs.

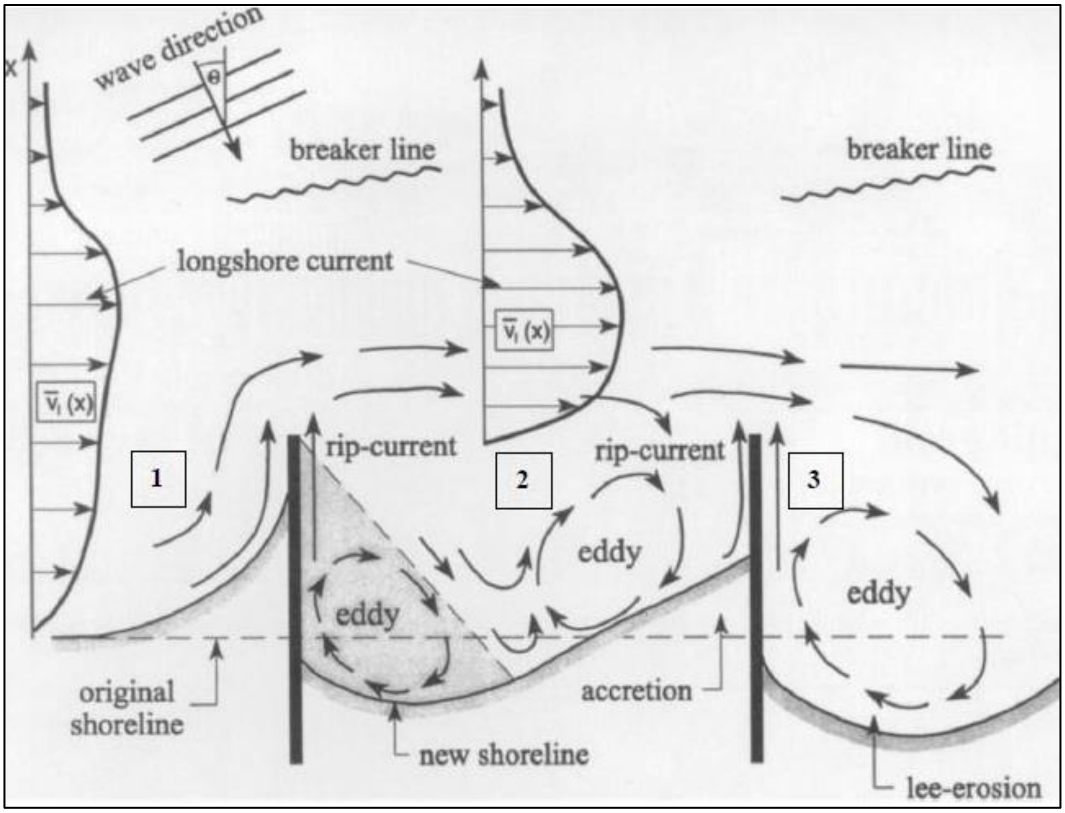


**Figure.1.9** Schematic diagram showing flow lines in groyne field

(Source: "Flow patterns around groynes in the coastal zones" by P.L.Antonio Lucca)

Figure 1.9 shows the path followed by the flow lines around the groynes and in groyne field. Changes observed by the shoreline are also depicted which includes both erosion and deposition of sediment around the spurs. It depicts the effect of groynes on the flow, including the formation of a rip in current both upstream and downstream of the groynes and deviation in the shoreline due to the obstruction created by the spur dikes. This effect can vary with the level of permeability of the groynes as the intensity of eddies can vary depending upon the permeability of groynes.

Basic methods by which groynes offer riverbank protection is to confine the flow in a narrow main channel and creates low flow zones accompanied by the creation of eddies close to the banks and bed of the channel. Flow pattern may also change due the presence of groynes as the water diverted from the main channel into the spur filed , this water flows with a low velocity through the downstream half of the interfacial channel section between the spur field and main channel. This water flows back into the main channel through a smaller width of that section just downstream of the upstream groyne of the spur series.

Ratio of length to width of spur field determines the shape and number of eddies formed in the stagnant flow region. Formation of eddies increases with increase in aspect ratio(spacing/length). Greater the aspect ratio greater the number of eddies formed. Larger eddies are generally formed on the downstream part of spur, known as primary eddies and smaller eddies are formed on the upstream side of groyne, also known as secondary eddies. Sometimes there is a large difference in the water level before and after the groyne which means the slope of water level in main channel differs from the spur field flow. Sometimes the groynes are not exactly perpendicular to the channel, they might be aligned to a certain angle with the approaching flow. This orientation of groynes forms an important aspect while considering the sediment movement, scour and erosion in the proximity of the groynes.

According to the guidelines mentioned in IRC:89-1997 groynes or spurs are provided to fulfill the following purposes:

1.Training of the river course in the desired direction by deflecting, attracting or repelling the flow in a channel.

2. Improving the navigation depth by contracting the wide river channel.

3.Protecting the river bank by keeping the flow away from it and creating a slack of flow for creating a silting zone in the channel.

Further the guidelines discuss about the classification of spurs on the basis of their construction method, material used in it, their functionality and their geometry in the channel in the flow. It is obvious that there no certain thumb rule for directly calculating the length or location of the spurs. These depends directly upon the conditions arising in the field and specific cases.

However it is to be noted that location, orientation and spacing of spurs can be best calculated by the model tests before laying it out on the field. Generally larger spacing should be provided on the concave banks and smaller spacing is adopted for convex banks.

## 1.5 DESIGN OF GROYNES

Basic aim of any design is that the structure can provide the functional safety against the forces acting on it. Groynes are generally designed for various factors which includes the horizontal thrust of the incoming water, the reversing water in between the two groynes, stability of the foundation against erosive measures and many more. Generally spacing is the main parameter which is dependent upon the projection length of the groynes and the physical situations which may vary from place to place. Sometimes they are projected to dissipate the energy of the flow to prevent the important infrastructure in the flood plains. In general length, spacing, height, permeability and orientation of the groynes are the most important parameters to be considered in laying out the design on the field.

### 1.5.1 Length

Length determines the basic efficiency of the groyne. Length of the groyne should be sufficient enough to create an obstruction in the flow. Sediment particles are restricted to travel further along the flow which is basic requirement to provide a navigable depth in the channel. Length of the spurs should neither be too long or too short. Excessive length creates unnecessary obstruction to the flow and shorter spurs causes scour hole near the banks of the channel which is to be avoided as much as possible. Normally 20% of the channel width should be taken as the length of the spur in normal conditions.

### 1.5.2 Spacing

The spacing of groynes is relative to the length of the groynes and should be properly provided in case of series of groynes. Generally two to three times of the length of a groyne is appropriate for the spacing between the groynes. In certain cases where the location at which the groyne is to be provided governs the actual length of the groyne whether it is a bend or a straight reach in the channel. It is also advisable to provide the greater spacing when the water is nearly normal to the bank. Shorter spacing is appropriate for the waves making an angle with the shoreline. Spacing of the spur in straight reaches should be about

3 times the length of the spurs. Whereas in curved channels spacing can be reduced as per the specific objectives and location of the spurs in the bend. Usually a spacing of 2.5 times of their length can be provided without any anticipation.

### 1.5.3 Height

Height of groynes usually governs the amount of sand movement over it and it accounts for the protection of the downstream region from the flow waves over the structure. In general the height of the groynes are relative to their lengths and the post construction possibilities of the shoreline. Sand properties also plays an influential role in governing the height of the groynes sometimes. Sloping and other features also restricts the height of the groynes, a higher slope will require more stability provisions which increases the maintenance cost. Crest portion of the groyne should be horizontal, in exceptional cases it is inclined towards the opposite bank. Basic purpose of adopting an adequate height is to prevent the shorelines structures from the wave reflections etc.

### 1.5.4 Permeability

Permeability of groynes refers to the void spaces along the length of groyne to allow the sediments to pass through them. Permeable groynes reduces the possibility of sediment deposition and creation of barrier in the groyne field. Permeability accounts for a minor reduction in approaching flow velocity whereas non-permeable groynes accounts for a greater major reduction in velocity. This is due to the fact that there is complete obstruction to the flow. Permeable groynes are slightly easier in construction as compared to non-permeable ones and nearly similar in their efficiencies more likely.

Impermeable groynes are constructed with an impermeable core which can be made up of either stones or rock fill to ensure that it can withstand the impact of the flowing water. Suitable top width, side slope and freeboard of 1.5 to 1.8m should be provided for an effective impermeable groyne. Sometimes slopes can be varied on upstream and downstream side of the spur depending upon the discharge intensity and other fluvial properties. Apart from these suitable stone pitching should be done to ensure the safety against the erosion on the sides of spurs. Upstream side of spur should be more taken care of as compared to downstream side of it.These are the groynes which are provided with suitable spaces to allow the incoming flow to pass through them. Their basic purpose is to divert a part of the flow in the intended direction to prevent the erosion of bank from which they are provided. Mainly these type of spurs are provided in the form of tree spurs and pile spurs which consists of vertical obstructions in the form of wooden piles or sheet piles with water tight joints so that they do not loosen out under the adverse effects of the flowing water. Special care should be taken to regularly maintain the void spaces in them as the incoming silt and debris may collect themselves in between the spaces left for the flow to pass through them. This silting up of the groyne leads to a situation in which it starts functioning similar to an impermeable groyne and subsequently its efficiency decreases. It is desirable to protect the bank from erosion and scour phenomenon so that unnecessary silt is not produced in the groyne zone.

### 1.5.5 Orientation of Groynes

Orientation of groynes is the major factor leading to their functional failures in certain cases. Generally groynes are constructed normal to the shorelines. Inclination to the shorelines are also induced as in attracting or repelling groynes. There is no thumb rule for the alignment of groynes as it is solely dependent upon the particular situation and the availability of resources.

It can be understood that prior to implementing the design in the field its appropriate model studies should be done to minimize the possibility of failure of the design. Suitable steps should be taken in any model studies related to the design of groynes on the river flows. There might be a situation in which the model studies fails due to which both financial and technical losses occurs. Technical aspects of model studies include the degree of accuracy as the main aspect which governs the complete process. In the end, validity of results of model study and interpretation of its results depends upon the experience, sound judgement and knowledge of the experimenter. Figure 1.10 shows different parameters which can affect the functioning of groynes in terms of its orientation.

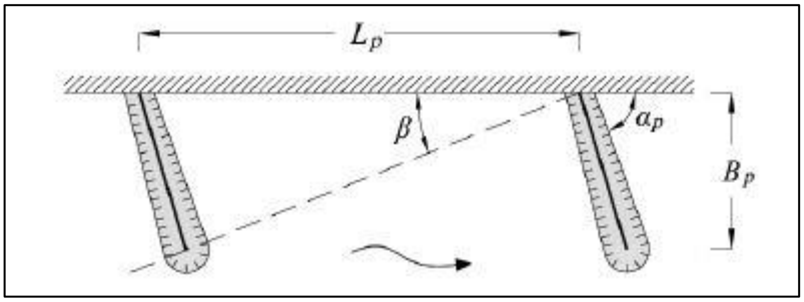


**Figure.1.10** Sketch showing the parameters that affects the functioning of groynes
(Source: A.Armanini et al. 2010, ISSN:978-3-939230-00-7)

**$\alpha_p$ -** groyne orientation relative to river axis

**$B_p$** - Groyne length

**$L_p$** - Groyne spacing

**ß -** Angle between the two consecutive groynes

### 1.5.6 Crest Level and Crest Shape

Groynes are sometimes constructed with their crests sloping downwards away from the bank and sometimes in stepped manner in the direction of flow. Groynes can be designed with their crest levels above or below the designed water level which may fail during the flood conditions. Many authors have recommended to provide the crest level above the maximum water level so that they do not become an obstruction during the navigation.

## 1.6 MAINTENANCE ASPECTS OF GROYNES AND OTHER RIVER TRAINING WORKS

Groynes and other river training structures are meant to be used for indirect coastal training that has a simple as well as a sustainable structure and low execution cost. Groynes might experience impact forces due to the waves and it is very difficult to predict the consequences of the process. Groynes must be designed after the proper consideration of the forces acting on it and after the construction also its wear and tear must be acknowledged for its longer durability. Groynes must be subjected to post construction maintenance on regular intervals to avoid any misfortune in future.

Proper maintenance and repair of river training works is critically important as damages to them can result into sever conditions from both financial and social point of view. Designers of these structures should be well aware of the design parameters that can bring the concerned structure under the threat of possible failure. Engineers responsible for the maintenance of these structures should be well acquainted with the possible causes of failure and the past history of the structure so that a brief idea is available regarding the nature of events to be followed in future.

In general maintenance works can be classified in various categories depending upon the requirement. But in India major classification is done as (i) Pre Monsoon measures and (ii) Post Monsoon measures of maintenance. Basic purpose of this classification is to summarize the nature of work to be done and the approach of making the structures resistant against the possible failures. Pre monsoon measure usually includes both temporary and permanent solution of the failure depending upon the situation and nature of remedial actions. Whereas the post monsoon measures includes only the permanent approach as they are intended for a longer period in their nature and provides greater value for money in them.

# CHAPTER-2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

Basic aim of this study is to analyze and investigate the scour pattern around a series of L-shaped groynes with different configuration of flange that can assist in prevention of scour and failure of hydraulic structures. Effects of flanges were studied on the scouring pattern around the L-shaped groynes on the sand bed consisting of particles finer than 2.36mm.

## 2.2 PAST STUDIES

**Roger A. Kunhle et al. (2002),** performed experimental investigation for measuring the local scour associated with the angled spur dikes. Scour hole measurement was done in a series of experiment which included groynes at different angles of 45°, 90° and 135° with the wall of the channel in the downstream direction. All the spur dikes were installed at a height of 0.16m from the bed of the channel. They formulated an equation which related the volume of scour hole with the time elapsed in forming it.

$$V_i/V_{30} = 0.980\ (T_i/T_{30})^{0.653} \qquad \textbf{(2.1)}$$

Where $V_i$- volume of scour hole at time $T_i$

$V_{30}$ -volume of scour hole after 30 hours of elapsed time $(T_{30})$

Further it was concluded that bank erosion was maximum for the 45° inclined spurs and minimum for 135°. Also the volume of local scour was maximum for 135° inclined spur dikes which ruled out that as long as the opposite bank is not under the threat of erosion the spur dikes with 135° inclination were considered to be the best option.

An equation relating the depth of scour with volume of the scour hole was also given which follows as

$$V_{30} = k\,(Ds_{30})^{3} \tag{2.2}$$

Where $V_{30}$ - volume of scour hole at 30 hours and $Ds_{30}$ represents the depth of the scour hole at 30 hours.

**Wim S.J. Uijttewaal (2005),** performed experimental studies to understand the effect of alternate designs of groynes on their efficiency as a river training structures. It was tried to predict the morphological consequences of a particular groyne shape and provide possible alternate designs for the groynes. Physical model of scale 1:40 was prepared to imitate the natural river flow geometrically. Flume of length 30m and sufficient width to replicate the Waal River was used. Groynes were made up of smooth concrete except for the permeable ones which were prepared by the metal rods. Four different types of groynes were used which were designated as A,B,C,D respectively. A refers to a straight spur dike which has a slope of 1:3 on all sides whereas B has a slope of 1:6 on all sides.Type C includes a permeable part (50% of the total cross sectional area) through which flow can be passed easily. Type D is the combination of B and C. Height of groynes were taken as 0.25m with the flow to be subcritical in nature. P article tracking velocimetry technique was used to measure the flow velocity at various locations. Comparing the type A and B groynes it is observed that slope in groyne B results in increase in velocity by restricting the water depth. It was also observed that the flow pattern around groyne B leads to smaller attacks on the groynes and on the bed. Permeability of groyne C results in unidirectional flow in the groyne field. Groyne type D shows a smooth flow with only a small disturbance in the flow that is due to groyne itself. PTV results were obtained at the free surface and it was concluded that shallowness and impermeability of groynes A and B causes a string velocity gradient which is closer to the bottom of the bed. Type C gives rise to a uniform profile due to the presence of permeability and comparatively large velocity protrusion were obtained for type D. It is clearly understood that the small adaptations to the designs of groynes can lead to bigger consequences for the turbulence properties. It is also concluded that time dependent large scale motions will have to be included in order to be able to draw conclusions regarding maximum shear stress and mechanisms causing scour.

**A.Shafaie et al. (2008),** investigated the effects of a minor spur dike on scouring at the first spur dike in the gravel bed. The effect of orientation and of minor spur dike and its length was also studied. Four spur dikes were used in the study with the spacing equal to the two times the length of the first spur dike. The ratio between the lengths of minor spur dike to the first spur dike length was recognized as a very important aspect in controlling the scouring from the head of spur dikes. It was concluded that the minor spur dike was effective on the group of spur dikes compared to unprotected spur dikes. It reduced the scour holes at the head of the spur dikes about 10 to 33%. Maximum efficiency was observed when the minor spur dike was located at the distance equal to twice the length of the first spur dike upstream of the group of spur dikes and the length of minor spur dike was half of the first main spur dike.

**M.Vaghefi and M.Ghodsian (2009)**, performed experimental studies to analyze the scour behavior around T-shaped spur dikes in a 90º channel bend. The effect on length of groynes on the scour was investigated and the possibility of scour occurrence in the groyne's field was also analyzed. A channel bend was provided between two straight reaches with a centerline radius of 2.5m. Spur dikes of 1cm thickness and four lengths of spur dikes were used as 6, 9, 12 and 15cm fixed to the side of the channel. It was observed that the scoured bed material travel downstream and forms ridges. This movement of sediments is initiated by the vertical vortices formed at the nose of upstream of spur dikes. Horizontal vortices also moves the sediments put of the scour hole in the lateral direction. It was also observed that ridge formation increases with increase in the length of the spur dikes. Flow over the ridges hits the bed surface at downstream and it leads to the formation of vertical vortices which causes the scour formation and its development. Increase in the length of the spur dike leads to increase in velocity near the groynes which in turn increases the shear stress and ultimately it increases the amount of scour. Also by increasing the length of the spur dike not only the scour increases but also the scour hole gets shifted towards the outer wall of the channel. Variation in bed topography is more pronounced due to increase in length of the spur dikes. It was also concluded that the scour hole which were formed in the downstream of the ridge are at a distance of about 7 to 14 times of the depth of flow and the location of ridge formation is about 5 to 10 the depth of flow.

**A.Safarzadeh et al. (2010),** performed experimental study on the effects of head shape on shear stress distribution around a single straight and T-shaped groyne. Results indicated that a considerable difference in bed shear stress distribution occurs between the two types. For a T-shaped groyne, high shear stress zone is smaller as compared to the straight one and the intensity of shear stress decreases in the downstream direction. Straight groyne is much more stable in terms of transverse oscillations and the separated shear layer downstream of the straight groyne. It was also concluded that the maximum bed shear amplification in the T-shape groyne is 35% less than the straight one. It doesn't occur at the groyne tip and shifts toward the channel center. Also the high shear region after the upstream tip of the groyne is confined to a smaller region and is more uniform than straight groyne.

**A.Kadota and K.Suzuki (2010),** performed experimental studies to analyze the bed changes and scour depth changes with the type of groynes in open channels. They also studied the formation of sand wave around groynes with the passage of flow. Three types of groynes were used in this study as T-shaped, L-shaped and I-shaped. Their results were compared and it was observed that scour depth for L-shaped groynes is the minimum and for I-shaped groynes it is the maximum. Suspended sediment is transported from upstream of the groyne to the downstream and the deposition area is formed. Further there is some local scouring behind the deposition area and further the formation of sand wave takes place. It was also concluded that scour depth is larger for L-shaped groynes with their flange portion towards downstream and smaller for upstream ones. Sand wave formation takes place on the opposite side of the channel and wave length and wave height becomes larger with the passage of time.

**A.Armanini et al. (2010),** experimentally investigated a series of fluvial groynes on a hydraulic scale model to understand the flow behavior of Po river in Italy. Model represented a reach of the river and a series of groynes was installed to improve the navigable depth in dry periods. In order to avoid the problems associated with slopes and material friction angles, only geometric scale was validated for all the directions and other parameters were derived from Froude's similarity. Test included the measurement of

Discharge using an electromagnetic flowmeter, Velocity with the help of ADV to analyze the 3D turbulence structure. At the end of each test run the bed was scanned with the help of a laser device to yield a 3D map of the bed elevation along the entire setup. It was observed that the most important parameter in increasing the navigaton depth in the main channel is the spacing between the two consecutive groynes. Shape of the groyne head shape doesn't makes much difference in the depth of the scour hole. The only difference is that in case of rectangular groynes the scour hole is formed further away from the structure as compared to the round ones. It was concluded that the formation of deposition bar started downstream of each groyne and it significantly changed the hydrodynamic field between the groynes.

The localized scouring starts in the proximity of the head of the groyne due to the longitudinal vorticity. When the bed starts being erode, it is brought upward in the form of suspended load. The current of the flow carries this load forward and tends to deposit in the zones near the banks where the flow observes any obstruction.

**Mohd. Alauddin, Takashi Tashiro and Tetsuro Tsujimoto (2011),** conducted experimental investigation of channel responses against different configuration of groynes. Different models of groynes with difference in permeability and alignment were tested and their respective results were compared among themselves to obtain the best possible configuration. Four different types of groynes were used by varying both permeability and alignment. First one was impermeable and straight, second was straight with impermeability only up to the one-third portion of the length from the bank. Third was totally impermeable but was straight for only one-third portion of the length and rest of it was aligned at 70° downstream to the flow direction. Fourth was similar to third one with only difference was that the aligned portion was permeable. In first type of groynes strong separation of flow occurred causing high scour near groyne tip. In the second type of groynes both flow separation and scour was minimized due to permeability. In third type of groynes the scour formation was reduced as compared to the former forms and opposite bank was also less prone to be attacked by the flow. In the last form of groynes the scour and erosion was reduced to minimum as compared to all the forms. Deposition in the main channel was also also observed to be moderate and lower than any other form. Overall it can be concluded that introduction of permeability and alignment of groynes can reduce the scour formation and erosion of the banks up to a considerable level.

**Alireza Masjedi et al. (2011),** evaluated the scour around L-shaped groynes in a 180° channel bend. They performed a series of experiments to analyze the effect of length of groyne on scour. Different angles and lengths of groynes were used in the experiments to understand their effect on the aquatic habitat and bank erosion possibilities. Tests were carried out taking length of groynes as 10%, 15%,20% and 25% of the width of the channel and wing length as 50% of the former length.. It was concluded that scour depth increases as the length of the spur dike increases and maximum scour is obtained at L/B equals to 0.25. They gave the following equation for scour depth and compared the results with the equation which showed accuracy of the equation.

$$ds/y = k\ (F_r)\ (L/B)\ (Ø/180)\ (t/t_e) \qquad \textbf{(2.3)}$$

where, ***k*** - coefficient of proportionality

***Fr*** - Froude's number

***L*** - length of spur dike

***B*** - width of the wing of spur dike

**Ø** - angle of wing of the spur dike with the channel wall

***t*** - time for scour initiation

$t_e$ – time for maximum depth of scour

**Md. Jahir Uddin et al. (2011),** investigated the local scour around bell mouth groin structure and analyzed the scour variation with discharge, flow depth and orientation of the groynes in channel. Dimensional analysis were used to build an relationship for depth of scour with all the parameters that affects the scour formation in channel. They gave an equation as followed:

$$h_s / y = f\ (1/F_r^2) \qquad \textbf{(2.4)}$$

where , ***hs***- depth of scour

***y-*** depth of flow

***Fr***- Froude's number

Four orientation of groynes were considered in this study as 30°, 45°, 90° and 120° from the left bank of the channel. Scour depth increases with increase in Froude number and approaching velocity of flow bearing a direct relationship among themselves. It was concluded that maximum scour occurred for 90° orientation whereas minimum scour was for 45°. Maximum deposition follows a slope less than 1 which means deposition depth is always smaller that depth of scour for the same discharge. It was observed that depth of scour increases with increase in approach flow velocity. Deposition of sediments increases with discharge at upstream of the groynes and further increase in discharge increases the sediment deposition at the downstream face of the structure. Angle of incidence of flow on the structure also comes in to the scenario where the upstream portion of groyne is exposed to the tidal effect of the flow.

**Joongu Kang and Hongkoo Yeo (2011),** performed experimental studies to analyze the flow characteristics around a L-shaped groyne in open channel. They ran hydraulic model tests to observe the critical hydraulic factors such as velocity and thalweg line changes which can be used to design these groynes in the field. Thalweg line is the streamline where the maximum velocity occurs. Thalweg line is an important factor in analyzing the change in main flow and can be used to analyze the change in river bed of the channel. LSPIV (Large Scale Particle Image Velocimetry) technique was used to measure and analyze the flow variation around the groynes. Five different variation of groynes were used in which the flange arm of groynes were varied as 20%,40%,60%,80% and equal to the length of the groyne. Surface velocity measurements were used to identify the thalweg line changes in the study. It was observed that the thalweg line was not influenced by the change in Froude’s number and change in arms length of the groyne. It was concluded that maximum velocity occurs at the central part of the channel where groynes are not installed. The velocity tends to decrease with the arm’s length of the groyne. Also, the velocity increased with a rise in Froude’s number. Velocity in the main flow area according to groyne installation increased by 1.2 to 1.6 times the average velocity at the upstream area. As Froude’s number increased, the velocity rate around the embankment showed differences according to each condition but tended to show gradual decline.

**S. Abbasi et al. (2011),** investigated the effect of groyne models on the flow changes around the groynes using Flow 3D software. A numerical model of flow was prepared and it included four different L-shaped groynes in a constant water depth of 12cm. Geometry of groynes was prepared by AutoCad. Four different angles 30°,45°,60° and 75° were provided with channel bank from which the groynes were installed. L/B ratio were taken as 0.1, 0.15, 0.20, 0.25 and Froude's number was 0.34 which ensure the subcritical flow. It was observed that velocity increased near the spur dike structure and was minimum for 30° and maximum for 75°. By increasing the discharge, the zone of flow velocity around the groynes increased and also increase in L/B ratio resulted in increment of vortex zone.

**Mohd. Vaghefi, Masoud Ghodsian, Seyed Neyshabouri (2012),** performed experimental study on scour around a T-shaped spur dike in a channel bend. They studied the scour hole topography around an unsubmerged T-shaped groyne located in a 90° channel bend. Sediments having an average diameter of 1.28mm was used under clear water conditions. A new equation for scour parameters at a T-shaped spur dike was developed. Results showed that when the spur dike is located at 30° or 45°, the height of the sediment deposition ridge is higher than when the spur dike is located at sections 60° or 75°. Any change in the alignment of spur dike in the downstream direction of the bend increases the scour depth. Also by increasing the radius of the bend, the maximum scour depth decreases. Following equation for scour hole was developed.

$$\frac{\varphi}{Y} = k\left(\frac{1}{L}\right)\left(\frac{\emptyset}{90}\right)\left(\frac{R}{B}\right)\left(\frac{L}{B}\right)\left(\frac{V}{Vc}\right) \qquad (2.5)$$

Where, $\varphi$ - scour hole depth

$Y$ - approach depth of flow

$k$ - proportionality constant

$L$ - length of spur dike

$\emptyset$ - location of spur dike in bend in degrees

$R$ - radius of channel bend

$B$ - channel width

$V$- velocity of approaching flow

$V_C$ - critical velocity for sediments

**Amir Raza Mansoori et al. (2012),** studied the features of flow around sequentially typical groynes using a 3-D numerical model. Channel length before the test area was checked about the availability of sufficient length to fully develop the velocity profile before reaching the spur dikes. For flow computation simple algorithm was adopted and water surface calculation was adopted to fully incorporate the 3-d flow. ADV was used to measure the velocity components in three directions (vertical, horizontal and transverse) in different cross sections both upstream and downstream of the groynes in the planes close to the bed. Two different sequence of spur dikes were used involving straight spur dikes and T-shaped spur dikes. Spacing/length ratio was taken as 1,3 and 6 respectively .

While comparing the two shapes of spur dikes it was observed that velocity in between the two consecutive groynes is lower for T-shaped ones as compared to straight ones. It means T-shaped spur dikes provide more stable embayment compared to straight ones. It was also comprehended from the velocity contours that high velocity zone for straight spur dikes is more than that for T-shaped spur dikes. It was also found that presence of flange portion reduces the scour formation by deflecting the high velocity zone towards the opposite bank and also there is reduction in the bed shear stress which is the prime concern in controlling the erosion.

**Ravindra A.Oak and Pramod B.F (2012),** verified the various results and guidelines provided by earlier researches regarding the spacing and length of the groynes. They conducted graphical analysis on the spurs constructed in the field and found out that guidelines were similar to the actual results obtained in the field analysis. Main objective of their study was to verify the conclusion that governs the contraction ratio or spur ratio (Spacing / Length of groynes) should lie between 2.5 to 5. In field study it was found out that irrespective of the size of the river and this rule provided satisfactory results in terms of maximum length of bank protection. Authors conducted field study on a reach of Kosi river and considered Radius of curvature (R), angle of inclination (Ø), length of the spur(d) and spacing of spurs(L) as the important parameters for the observations. Using the graphical studies, relation between the parameters discussed above were determined.

Following relations were given relating the parameters involved:

$$R^2 = \{R- 0.7d\}^2 + (L/2)^2 \quad (2.6)$$

$$\sin(Ø/2) = (L/2)/R \quad (2.7)$$

**R-** radius of curvature of the river

**d –** length of spur

**Ø** – angle subtended by the spur to the river axis.

It was concluded that the L/d ratio should be 1.5 to 5 and also special attention should be devoted to special cases where discharge and depth of flow condition are prone to be affected by the flood conditions and might results in improper functioning of groynes. Therefore designer must observe the effectiveness of the structures provided.

**Saleh I. Khassaf and Alaa Mhseen Dawood (2013),** developed a new formula for a clear water scour around groynes. They performed experimental study for computing the depth of local scour around groyne using different spacing between the groynes as a countermeasure. It was also observed that increasing the distance between the groynes leads to increase in depth of the scour about 20%. Groynes made up of plywood having a thickness of 10mm and height of 20mm and length of 13cm were used. Three different spacing between them were used (1,1.5 and 2) from the length of groynes to cover up the aim of the study. Conclusion stated that maximum scour depth was observed at the nose of groyne at the upstream. For a constant spacing between the groynes, the scour depth increases due to increase in the Froude number, flow velocity and flow depth. It was also stated that scour depth is a function of variables which can be represented as follows:

$$D_s/y = f\ (V/V_c, Fr, B) \quad (2.8)$$

Where,

$D_s$ - Depth of scour

$y$ - flow depth

$V$- velocity of approaching flow

$B$ - channel width

$V$c- critical velocity for sediments

$Fr$- Froude's number

**Amir Raza Mansoori et al. (2013),** conducted laboratory study on bed variation due to installation of spur dykes with different head shapes. The equilibrium of bed variation in both spur dikes was studied and the differences and similarities of the pattern of scour hole were also investigated. T-shaped and I-shaped spur dikes were tested in series there corresponding scour pattern was studied. Results of this experiment showed that T-head groynes were more suitable to prevent scour inside the embayments and a uniform pattern of bed level was observed. It was also observed that bed level changes were significant in the initial embayments and in the latter ones local effect of current was more significant rather than the head shape of spur dike.

**Javad Ahadian et al. (2013),** studied the effects of changes in hydraulic conditions on the velocity distribution around L-shaped spur dikes at the river bend. They analyzed the flow pattern around a series of impermeable L-shaped spur dikes and also evaluated the velocity distribution around them. It was tried to analyze the effect of geometry and distance on the flow pattern was tried to be studied. Spurs were installed at angles of 30°,45°,60°,75° and 90° to the direction of flow and placed in a 180° channel bend. All the conditions were improvised in a model using a software known as Flow-3D. It uses fluid equations are solved using finite difference approximations. It was concluded that using a series of groynes reduces the turbulence up to 60% as compared to the condition in which only a single spur dike is used and ultimately the scour reduces. Maximum speed limits, the flow rate and the vortex flow at the head of the spur dike are reduced while moving along the direction of flow . With increasing flow rate and the Froude number, the maximum speed limit increases near the head of spur dike series and its shapes is also elongated in the direction of flow.

**Feng Cai and Akihiro Tominaga (2013),** performed experimental studies on flow structure around a submerged groyne using a PIV (Particle Image Velocimetry). They used a box groyne to observe the flow behavior and measure the velocity on both horizontal and vertical plane. The box consisted of a straight and a L-shaped groyne with head directed in upstream and downstream both. The velocity was measured using PIV up to 4cm upstream and downstream of the groyne. It was concluded that the mean velocity in the groyne zone of most of the cases with downstream block increases while that of cases with upstream block decreases. Discharge is increased in the low level of the main stream, while the high discharge and strong velocity distribution is observed at the bottom in the case with downstream block. Thus the arrangement of longitudinal block clearly improves the dimensions of the flow in the groyne zone.

**Kate Porter et al. (2014),** performed experimental studies to investigate the advantages and disadvantages of variety of techniques and compare their results in scour measuring abilities. Techniques used were photogrammetry, echosounder method and calibrated pile method. Basic aim of this study was to provide accurate measurements over the full scour hole. In calibrated pile method a circular pile of diameter 5cm was placed in the middle of the section. Pile was marked with concentric circles at 5mm intervals and scour around it was measured. Marking on the pile provided a benchmark in estimating the variation of scour hole formation along the height. It was a straight forward and low cost method with direct measurements and without any data processing.

Second technique studied was using a 1Mhz echosounder which was enabled with a narrow beam angle (less than 3°) and its smaller sensor diameter of 30mm also assisted in easy and accurate measurements. It was mounted on a sliding rail upon the flume and it was made sure that its sensor should not be place closer than 2cm to the edge of the pile. 2D profiles were measured along the centerline of the scour hole in the direction of the flow. The echosounder was allowed to collect data at least for 30 seconds in 1cm intervals. It proved to be less accurate on the sharp slopes and suspended sediment also affected the results. It was also a direct measuring device and a manual support was required in its movement. It proved to be costlier than the previous method and also no processing was involved for the data measurements.Lastly the photogrammetry system involved placing of two cameras outside the flume. A grid like structure of dots was projected on to the bed for the positioning of the points at which the measurements needed to be taken. The cameras were positioned in such a manner that best angle and clarity in images should be obtained. In this method it was assumed that light rays travel in a straight line from the camera to the point of object. Image processing and mathematical computations were done using a software package named as VMS. This software is able to provide the explicit solution of the collinearity equation as follows.

$$X_A = X_0 - \mu R^t Y_A \qquad (2.9)$$

Where $Y_A$ - 2D coordinate of the measurement points in the images

$X_A$ – 3D coordinate of the measurement point of the object space

$X_0$ – parameter for position of the camera

$R^t$ – orientation of the camera in degrees

$\mu$ - dynamic viscocity of the fluid

It was stated that minimum of 4 coordinates of the object space and minimum 2 images of from different positions should be taken to solve the collinearity equation. Least square iterative approach is used by simultaneously computing a number of points from a set of images. It is a lengthy but efficient method in estimating the scour depth variation accurately. It is costlier than calibrated pile but cheaper than the echosounder method.

Conclusively it was stated that photogrammetry system was superior to echosounding device as the accuracy of echosounder was affected by the slopes in the channel bed. Photogrammetry method is the most promising one but it should be free from refraction from the images which might deviate the results from accuracy.

**M.Mehraein and M.Ghodsian (2015),** experimentally investigated the scour and flow fields around two spur dikes with different submergence ratios. The turbulent flow parameters around a submerged T-shaped groyne in a 90$^o$ channel bend was studied and the submergence effects were analyzed on the flow field. Flow pattern investigation around the spur dikes showed that the approach flow separated into two parts in the vicinity of the spur dike. One moved towards the water surface and another moved towards the bed surface. The scour started from the upstream nose of the spur dike and elongated toward the downstream end of the spur dike. In the initial stages of the flow the sediment moved as sediment load whereas in the later stages of the flow it moved as bed load. Deposition of the sediment was more pronounced in the recirculation zone in the high submergence condition as compared to the low submergence condition. Scour rate was higher for low submergence as compared to high submergence spur dikes. The maximum shear stress occurred near the upstream nose of the spur dike and the maximum value in the low submerged spur dike was greater than that in the high submerged spur dikes. This confirms that flow around low submerged spur dike is more prone to scour and erosion. It can be confirmed with the fact that flow around low submerged spur dike is higher than high submerged spur dikes but the overflow from the high submerged spur dike is higher than the low submerged spur dike. It was also concluded that the strong vortices with high reoccurrence near the spur dike are some effective parameters on scour process and the scour depth increases by decreasing the submergence of the spur dike.

**A.M.Najafabadi and M.M.Bateni (2017),** performed experimental investigation of flow pattern around repelling and attracting T-head spur dikes on flat bed. Main objective of their study was to investigate and compare the flow pattern around submerged attracting and repelling T-head groyne in a flat bed. It was observed that maximum scour depth occurred near the upstream wing of the spur dike which means flow velocity at that point is crucial. Transverse component of the velocity is maximized at the tip of the head for both the spur dikes. Deviation of flow toward the opposite bank at downstream of the spur dike for attractive one is more profound. Moreover the maximum shear stresses were observed at the wing of the spur dikes which were caused due to the increased flow velocity and turbulence.

**Utpal Kumar Misra and Dharmendra Nath (2017),** performed experimental studies to investigate the changes in scour mechanism around spur dike with variation in opening ratios and angle of inclination in an open channel. They performed experiments on live bed conditions with three different opening ratios with three different inclination angles with the flow direction. Wooden models of groynes were used on a sand bed with medium particle size($D_{50}$) 0f 0.490mm. Spur lengths of 11.5cm,14.5cm and 17.5cm with opening ratios of 0.88,0.85 and 0.82 respectively. Each spur was laid at an angle of 60°,80° and 90° with the flow direction. Duration of test run was 3 hours after which scour depth calculation was done. It was observed that scour hole upstream of the groyne was shape of inverted conical shape and downstream of groyne was elongated and comparatively shallower than upstream. Maximum scour occurs at the tip of the groynes and deposition of sediments on the downstream of the spurs. Scour parameters increases as the Froude's number increases and with decrease in opening ratio the scour hole depth, length and width increases. As the inclination of spur dike decreases from 90° to 60° the scour depth also decreases. For the same inclination, opening ratio and flow conditions it was observed that minimum scour depth occurs for spur dikes inclined at 60°.

**Fatemeh Veisi and Ahmad Jafari (2017),** investigated the turbulence intensity in longitudinal as well as lateral direction around L-shaped groynes. Velocity measurements were taken by Acoustic Doppler Velocimeter (ADV) in three dimensions. Groynes models made up of glass having web of 10cm and wing of 5cm were used. Turbulent flow conditions were ensured and flow regime was subcritical. Velocity measurement was done in 20 lateral sections and 7 vertical levels with an ADV using Vectrino software. It was concluded that in upstream areas of groynes, the flow lines are relatively parallel and diverge away from the groyne towards the center portion of the channel due to which velocity in this region increases.

In computation of lateral components of velocity, measurements were taken at depth of 4 and 60% from the bed and it was found that flow velocity in front of the groynes is higher that any other zones due to decrease in channel width.

While computing the vertical component of the velocity at the depth of 4 and 60% from the bed, it was found that flow velocity reduced in front of the groynes and maximum velocity was found in the downstream of groyne at the level close top the bed and at the surface the velocity is slightly lower than at the bed. It was also concluded that turbulence intensity is maximum in the vicinity of groyne’s wing. It is higher in the longitudinal direction and lowest in vertical direction. It was stated that maximum turbulence for groynes with flange upstream is higher than those with flange in downstream. Conclusively it was stated that maximum vertical velocity component occurs around groyne’s wing and minimum at web and it is higher for flange upstream than flange downstream groyne.

## 2.3 OBJECTIVE OF PRESENT STUDY

Past researches have proven that installation of groynes in a channel leads to local scouring around these groynes and this eroded material can form a series of point bars downstream of groynes. Over a period of time these bars would interrupt the river navigation and ultimately the pattern of the flow would change. A risk of flooding might also occur due to these sandbars. Therefore it is very important to understand the behavior of groynes when placed in series in an channel. This study is concerned with scour formation around the L-shaped groynes and the changes in scour pattern with the different arrangement of flange portion of these groynes. It is a well known fact that different types of groynes are available with difference in their shapes which reflects in their behavior in the flow. This variation in the flow controlling mechanism of the groynes with the change in their head shapes is analyzed in this study and it has been tried to explain the differences in the scour formation in the groyne's field which is the prime concern for the stability of any hydraulic structure.

This study mainly focuses upon:

1. Study of scouring patterns by different arrangement of flange of L-shaped groynes.
2. To study the local scouring around the groynes and analysis of scouring patterns corresponding to different arrangements of groynes (at the same inclination for the lose sediment provided as bed material).

During the course of the study it was ensured that the equipment used should not interfere with the experiment. Measurements should be accurate in vertical as well as in horizontal directions.

# CHAPTER-3

# EXPERIMENTAL SETUP AND METHODOLOGY

## 3.1 INTRODUCTION

All the experiments were performed in the Hydraulics Laboratory of Civil Engineering department of Delhi Technological University, New Delhi. In this chapter complete experimental setup, procedure and methodology involved in this study will be discussed in detail.

## 3.2 MATERIALS AND METHODS

In this study following apparatus are used to examine the scour pattern around the given groyne system in the channel and obtain the basic guidelines for scouring around the given groyne arrangement.

1. Hydraulic flume with a pumping set
2. Sediment or soil in sufficient quantity
3. Digital Velocity meter
4. Different models of groynes at intended spacing with contraction ratio of 0.203
5. Point gauge and measuring tape

### 3.2.1 Hydraulic Flume

A tiltable hydraulic flume of 8m length is used to perform the experiments. It is 40cm deep and 30cm wide with acrylic glass section in the middle of it to monitor the flow during its passage along the channel. A recirculating pumping set up is provided to circulate the water through it. The bed slope is taken as 1/2000. Before the test run a dummy run is conducted along the channel to ensure that there is no working failure in any part of the setup.

**Figure.3.1** Hydraulic Flume used in the study

### 3.2.2 Sediment used as bed material

Locally available non cohesive sand is used to replicate the river bed. It is attempted to maintain a uniform bed level so that a leniency can be observed in the results. It is made sure that no lumps are present in the sand during the experiment and it is completely dried before using it in the flume after a briefed screening of it to make sure there is no organic impurities present in it. Sieve analysis is done to determine the mean size of the sand ($D_{50}$). Scouring of this sediment is analyzed in the groyne system used and also its deposition in the embayments. Usually the basic aim is to ensure that no flaky or elongated particle is present in the bed material during the flow.

**Sediment Properties:** Sediment properties can be classified in two categories as (i) those related to particle itself and (ii) those related to sediment mixture. When the sediment particles are non cohesive, mechanical forces dominate the behavior of the sediment in water. The three most important properties that govern the hydrodynamics of the sediments are particle size, shape and specific gravity.

Particle size is the most significant sediment property of non cohesive natural sediments. In general particle size is defined as the length of a square opening through which the given particle will pass. Particle shape is an another important term which governs the behavior of particle and is defined in terms of shape factor (SF).

$$\mathbf{SF} = \boldsymbol{c}/\sqrt{(\boldsymbol{ab})} \qquad \mathbf{(3.1)}$$

Where a, b, c are the lengths of the longest axis, the intermediate axis and the shortest axis respectively. It is to be noted that these axes should be mutually perpendicular to each other. For the sediment used in this study the specific gravity would lie between 2.65 to 3 as the inorganic sediment is used only.

For a better understanding of the sediment used in the study it is classified in three different categories as follows: (i) Initial sand which is laid down in the channel to imitate the river bed. (ii) Sand which is eroded out of the channel during the test run under the effect of flow and (iii) Sand which remained in the channel despite of the turbulence generated by the flowing water. To observe the uniformity of the sand , its geometric standard deviation is also defined which enable us to get an estimate about the grading of the sand. Geometric standard deviation is defined as $\left(\sqrt{\frac{D_{84}}{D_{16}}}\right)$. $D_{84}$ and $D_{16}$ represents the sieve size through which 84% and 16% of the particles can pass through respectively. This ratio describes the uniformity in the gradation of the sand which assists in estimating the behavior of the sediment in flow conditions.

### 3.2.3 Sieve Analysis

Sand which is used to replicate the river bed is analyzed before using it in the experiments. Its particle size distribution analysis is done to understand the basic nature of the sand used in the experiment. It is divided in three categories to understand the sand properties in different stages of the experiment and obtain the detailed analysis of the sand particles. It is divided in three stages as follows:

1. Sand in its initial state
2. Sand which is retained in the channel after the flow
3. Sand which got eroded out of the channel during the flow.

#### 3.2.3.1 Sand in its initial state

In this category the sand is sieved in its natural state in which it is available. Only the coarse impurities are screened out and detailed fine sieving is done in the sieve shaker. From the sieve analysis data shown in Figure.3.2 it is evaluated that mean particle size for the sand in its natural state is 0.232mm and its geometric standard deviation is 1.515. It shows that the sand is of uniform size distribution and uniformity in size of the particles does not influence the behavior of these particles during the flow and the scour mechanism will not be affected during the flow.

**Table 3.1** Sieve Analysis of sand used as bed material in its natural state

| Sieve size(mm) | Wt. retained (gm) | Wt. retained (%) | cumulative Wt. retained (gm) | cumulative Wt. retained (%) | % finer |
|---|---|---|---|---|---|
| 2.36 | 6 | 0.6 | 6 | 0.6 | 99.4 |
| 1.4 | 9 | 0.9 | 15 | 1.5 | 98.5 |
| 1.18 | 13 | 1.3 | 28 | 2.8 | 97.2 |
| 1 | 16 | 1.6 | 44 | 4.4 | 95.6 |
| 0.5 | 8 | 0.8 | 52 | 5.2 | 94.8 |
| 0.425 | 13 | 1.3 | 65 | 6.5 | 93.5 |
| 0.3 | 260 | 26 | 325 | 32.5 | 67.5 |
| 0.212 | 229 | 22.9 | 554 | 55.4 | 44.6 |
| 0.18 | 251 | 25.1 | 805 | 80.5 | 19.5 |
| 0.15 | 74 | 7.4 | 879 | 87.9 | 12.1 |
| 0.075 | 59 | 5.9 | 938 | 93.8 | 6.2 |
| 0.063 | 18 | 1.8 | 956 | 95.6 | 4.4 |
| 0.05 | 0 | 0 | 956 | 95.6 | 4.4 |
| Total | 956 | | | | |

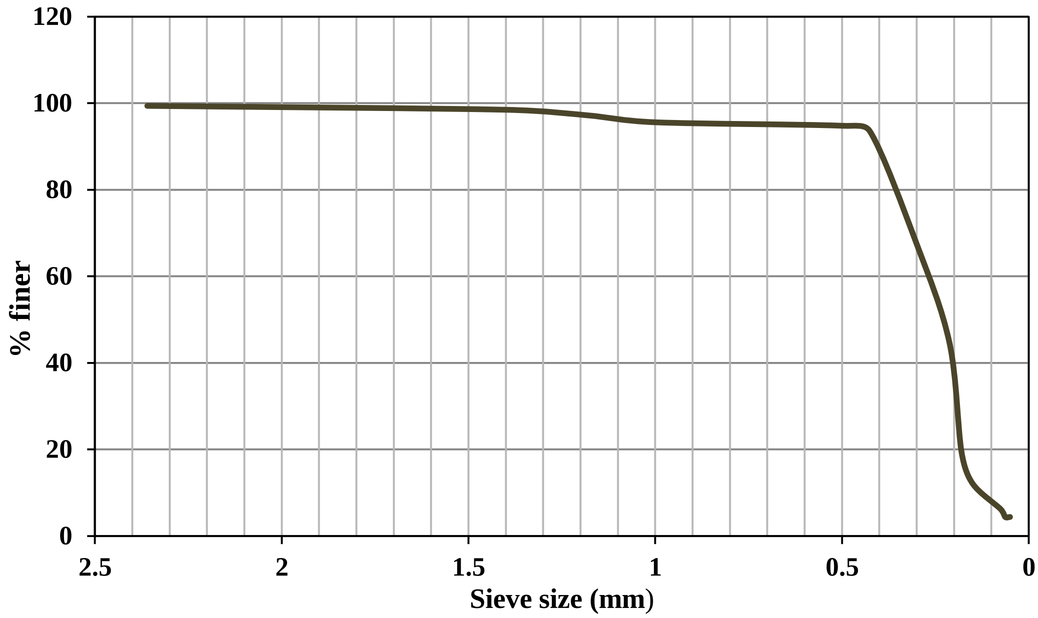


**Figure.3.2** Particle size distribution of sediment used as bed material in its natural state

From Figure.3.2 it is observed that sand in its initial state is poorly grade for particle size ranging from 0.4mm to 2.4mm and beyond that is comparatively well graded or uniformly graded from size 0.2 to 0.4mm.

#### 3.2.3.2 Sand retained in the channel after the flow

**Table 3.2** Sieve Analysis of sediment retained in the channel after the flow

| Sieve size(mm) | Wt. retained (gm) | Wt. retained (%) | cumulative Wt. retained (gm) | cumulative Wt. retained (%) | % finer |
|---|---|---|---|---|---|
| 2.36 | 16 | 1.6 | 16 | 1.6 | 98.4 |
| 1.4 | 7 | 0.7 | 23 | 2.3 | 97.7 |
| 1.18 | 1 | 0.1 | 24 | 2.4 | 97.6 |
| 1 | 3 | 0.3 | 27 | 2.7 | 97.3 |
| 0.5 | 9 | 0.9 | 36 | 3.6 | 96.4 |
| 0.425 | 14 | 1.4 | 50 | 5 | 95 |
| 0.3 | 740 | 74 | 790 | 79 | 21 |
| 0.212 | 37 | 3.7 | 827 | 82.7 | 17.3 |
| 0.18 | 73 | 7.3 | 900 | 90 | 10 |
| 0.15 | 25 | 2.5 | 925 | 92.5 | 7.5 |
| 0.075 | 44 | 4.4 | 969 | 96.9 | 3.1 |
| 0.063 | 6 | 0.6 | 975 | 97.5 | 2.5 |
| 0.05 | 1 | 0.1 | 976 | 97.6 | 2.4 |
| total | 976 | | | | |

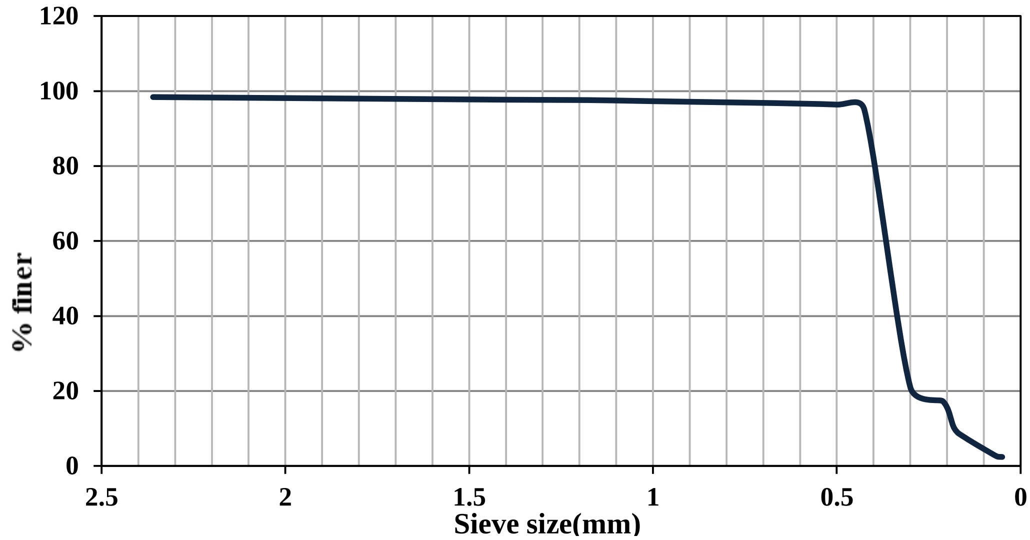


**Figure.3.3** Particle size distribution of sediment retained in the channel after the flow

From Figure.3.3 it can be concluded that mean particle size for the sand in its natural state is 0.3489mm and its geometric standard deviation is 1.406. It shows that it is of uniform size distribution and uniformity in size of the particles does not influence the behavior of these particles during the flow and there is no probability of any changes in scour mechanism during the flow.

### 3.2.3.3 Sand eroded from the channel during the flow

**Table 3.3** Sieve Analysis of sediment which got eroded during the flow

| Sieve size(mm) | Wt. retained (gm) | Wt. retained (%) | cumulative Wt. retained (gm) | cumulative Wt. retained (%) | % finer |
|---|---|---|---|---|---|
| 2.36 | 18 | 1.8 | 18 | 1.8 | 98.2 |
| 1.4 | 9 | 0.9 | 27 | 2.7 | 97.3 |
| 1.18 | 1 | 0.1 | 28 | 2.8 | 97.2 |
| 1 | 10 | 1 | 38 | 3.8 | 96.2 |
| 0.5 | 10 | 1 | 48 | 4.8 | 95.2 |
| 0.425 | 9 | 0.9 | 57 | 5.7 | 94.3 |
| 0.3 | 555 | 55.5 | 612 | 61.2 | 38.8 |
| 0.212 | 79 | 7.9 | 691 | 69.1 | 30.9 |
| 0.18 | 175 | 17.5 | 866 | 86.6 | 13.4 |
| 0.15 | 14 | 1.4 | 880 | 88 | 12 |
| 0.075 | 101 | 10.1 | 981 | 98.1 | 1.9 |
| 0.063 | 11 | 1.1 | 992 | 99.2 | 0.8 |
| 0.05 | 2 | 0.2 | 994 | 99.4 | 0.6 |
| Total | 994 | | | | |

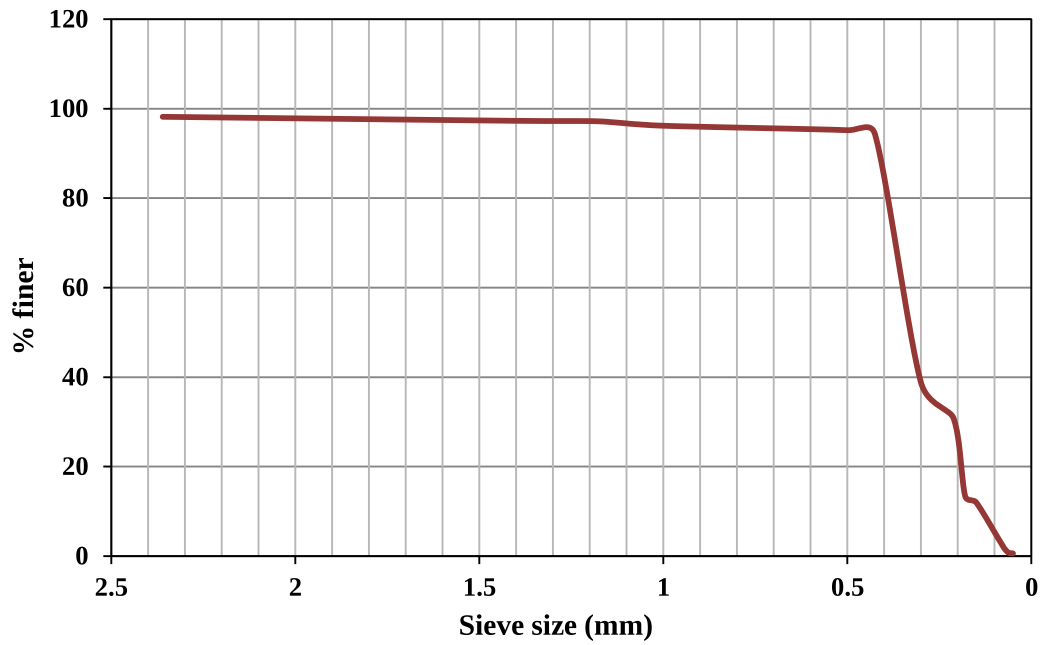


**Figure.3.4** Particle size distribution of sediment eroded out from the channel during the flow

From the Figure.3.4 it is concluded that mean particle size for the sand in its natural state is 0.325mm and its geometric standard deviation is 1.473. This ensures the uniformity in size distribution and size of the particles. There is no influence of such properties on the scour mechanism during the flow. Mean size of this category is lesser than that retained in the flume for obvious reasons as the smaller particles are more prone to be eroded from the flow and the heavier particles are comparatively stable in terms of erosive actions of the flow

**Strickler formula :** $\mathbf{n = (D_{50})^{1/6} / 21.1}$ **(3.1)**

**n** – roughness coefficient

$\mathbf{D_{50}}$ – mean size from which 50% of the particles are finer (metres)

Equation 3.1 is used to compute the coefficient of roughness for all the three classifications of sand and it was found to be as 0.012. It shows that roughness of the sand was almost same whether it remained in the flume or eroded out of it. Further it can be used to cross check the average discharge of the flow.

### 3.2.4 Digital Velocity Meter

The digital velocity meter is an highly accurate instrument for measuring the velocity in streams, open channels, partially filled pipes etc. It consists of a rotating propeller to which is provided with an extendable handle ending with a digital display unit. It can be used for monitoring velocities in rivers and canals up to a depth of 2m and can be easily moved back and forth along the channel. It consists of three important parts such as rotating propellers, adjustable handle and digital display unit. FP-111 model of digital velocity meter is used in this study for velocity measurements.

**Figure.3.5** Digital Velocity Meter to measure the flow velocity
(Source: Globalw.com)

**Rotating Propellers:** The velocity meter consists of a propeller which is provided in a casing of diameter of 2 inches to protect it from debris etc. It uses the accurate displacement technique for velocity sensing. It can be directly laid on to the bed of stream up to a depth from 2 inches to 2m. Propeller rotates inside the flow and magnetic material inside it picks up the signal and passes it to the digital display unit through an internal cable. Magnetic signals collected from the propellers are directly converted into the velocity readings that are displayed on the display unit. Digital velocity meter can display the minimum, maximum and average value of velocity of the flow.

**Figure.3.6** Rotating Propeller of Digital Velocity Meter (Source: Globalw.com)

**Adjustable Handle:** The flow probe handle can extend up to a length of 3 feet to 6 feet which can further be elongated as per the requirement by adding extra handle in between. It is easy to use and easy to carry specially in remote areas where the accuracy in measurement is the main priority.

**Digital Display Unit:** Flow probe is provided with a digital display unit which is equipped with LED screen to display the readings accurately up to three decimal digits. The data can be reviewed later for analysis and four buttons are provided to reset and change the units of display according to feasibility. A replaceable battery is provided inside the display unit which ensures a continuity in use and functioning.

**Figure.3.7** Digital display unit of Velocity Meter (Source: Globalw.com)

### 3.2.5 Groynes models used

Different wooden models of groynes are used in this study to analyze the scour pattern around them. To correctly imitate the natural flow conditions certain factors are kept under consideration such as their aspect ratio, spacing between the groynes so that guidelines mentioned for their construction are not overruled. L-shaped groynes are used in three different test runs with variation in the position of flange portion.

Contraction ratio (length of groyne/width of channel) of 0.203 is provided for the groynes assembly in the channel and it is ensured that there is no geometrical change in the groynes after the submergence in the water. They are stuck with the boundary of channel with the help of a tape which didn’t affects their hydraulic mechanism. Groynes models are laid out on the sand bed prepared by laying the sand in a 7cm thick layer uniformly.

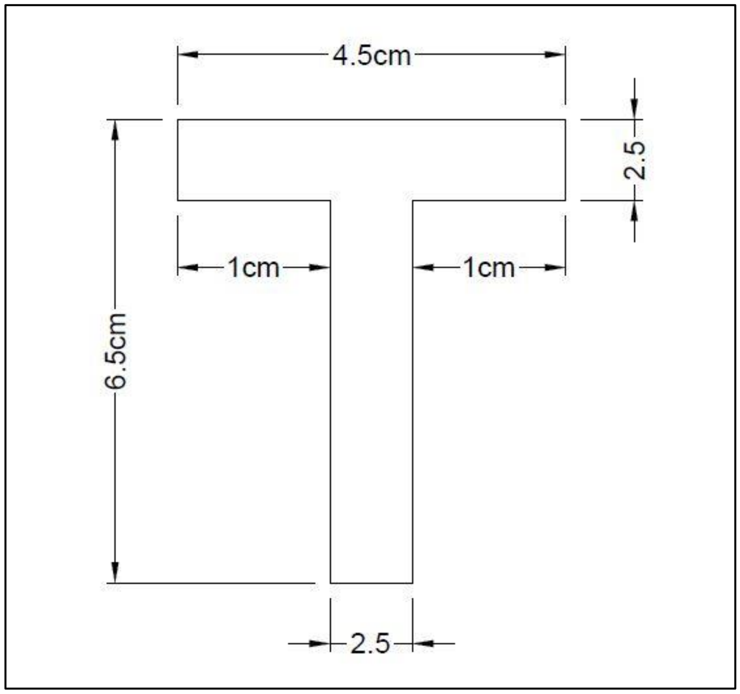


**Figure.3.8** Groyne model used in Test run-1 (**TG**)

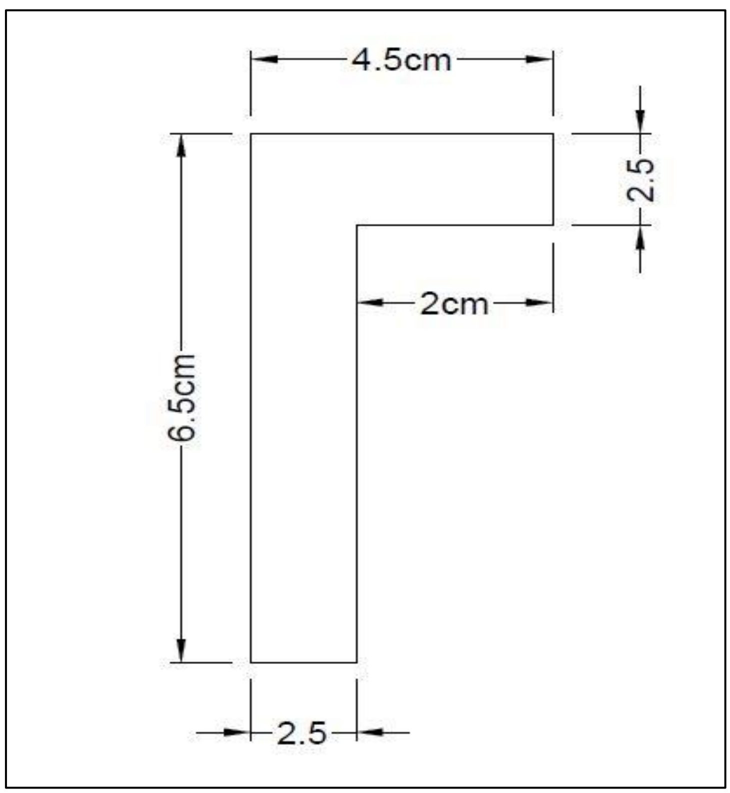


**Figure.3.9** Groyne model used in Test run-2 (**LU**)

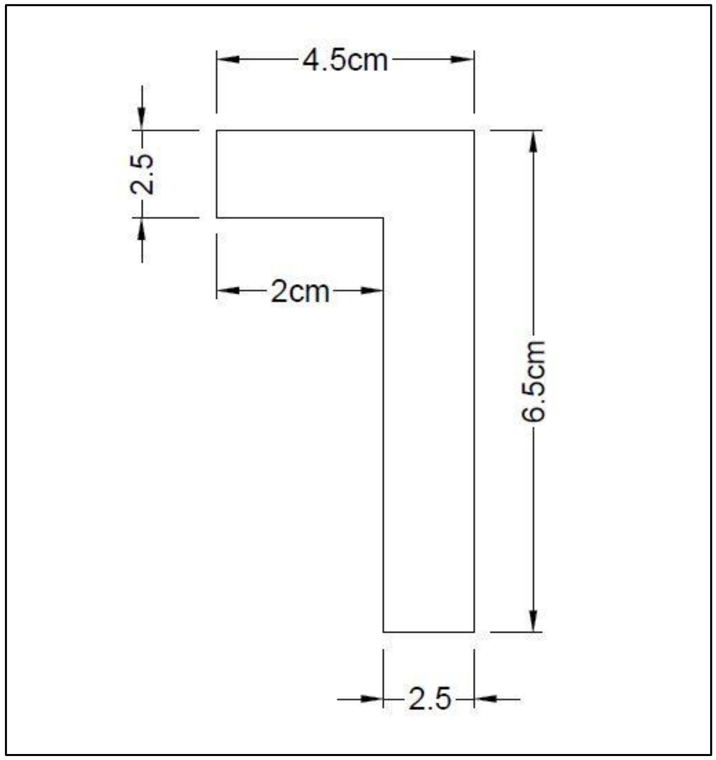


**Figure.3.10** Groyne model used in Test run-3 (**LD**)

Figure.3.8 to 3.10 shows the plan of the groynes models used in the study. All the models are 18cm deep and are provided in series along the longitudinal direction. All the models are free from any deformation and any kind of deviation from the concerned measurements.

Further spur ratio (Spacing/length) of 4.615 is provided which ensures that a sufficient space is available in between adjacent groynes for the sediment to dislodge under the effect of incoming flow.

### 3.2.6 Point Gauge and Measuring Scale

Point gauge is a device which is used to measure the depth of flow, depth of scouring within the channel. Calibrated pointer gauge with a least count of 0.1cm is used in scour and sand bed measurements. It is mounted on a movable trolley which can slide back and forth on the guide rails on the boundaries of the flume channel. It is provided with a mechanism by which it can slide up and down in the channel. Measuring scale of 1.5 meter length is used to measure the length of scouring. Fig.3.9 shows the point gauge used in the study.

**Figure.3.11** Point gauge used in the study for measurements

## 3.3 EXPERIMENTAL SETUP

Uniform flow in the recirculating flume with the dimensions 8m(l)x0.30m(w)x 0.40m(h) is maintained with the help of control valves and the pumping mechanism. Spur models are placed in the flume in such a way that they are not dislocated by the upcoming water. Point gauge mounted on a trolley which can slide forward and backward in the longitudinal direction of flume. Uniformity in level of bed material is maintained and discharge under a specific run of tests is controlled so as to maintain uniformity in the flow depth.

A sand bed is laid out in the channel after suitable distance from the head gate, so that the flow can attain its regime after entering the channel. Apart from the groyne's tip two points are also considered for measuring the velocity and depth of scour labelled as point A and B respectively which marks the starting and ending of the sand bed in the channel. Proper spacing between the groynes is provided as per the Indian Standards and considering the length of groynes and width of the channel. Sufficient length of sand bed is available before the first groyne and after the last groyne in the series. Same setup is repeated for the three test runs with the only difference of groynes models used.

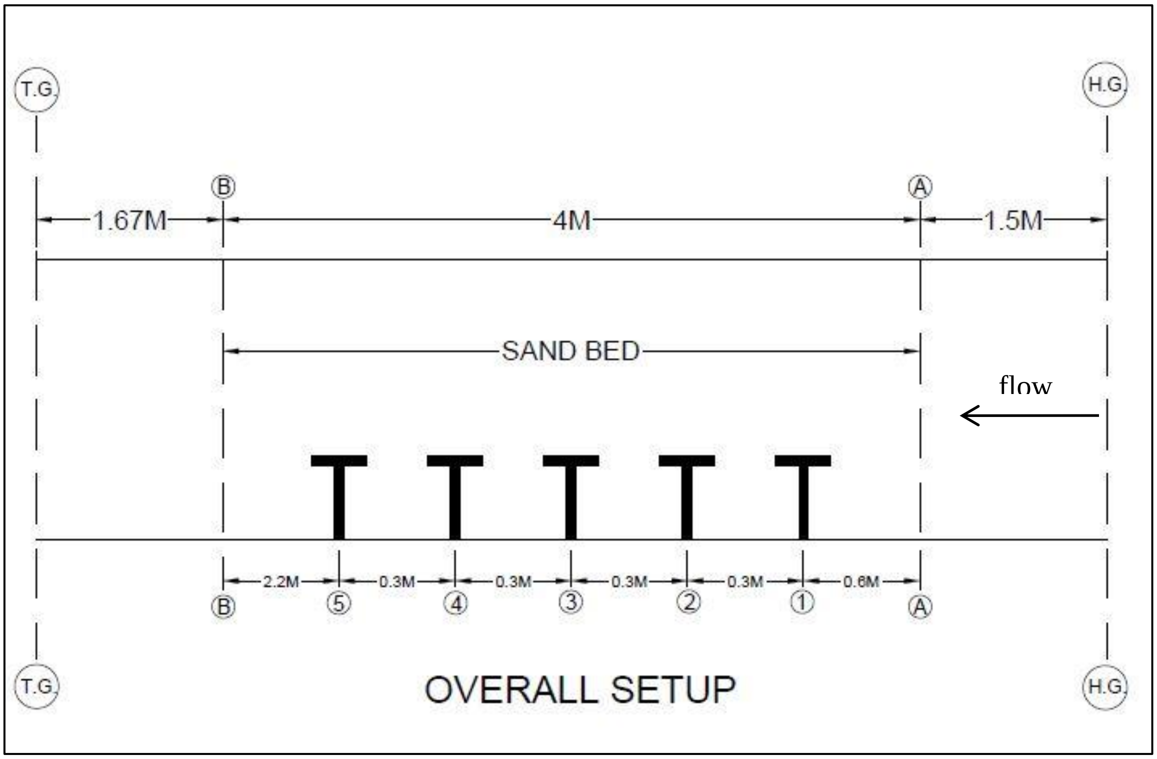


**Figure.3.12** Illustrative sketch of experimental setup for Test Run-1 (**TG-groynes**)

**Figure.3.13** Image showing experimental setup before Test Run-1 (TG-groynes)

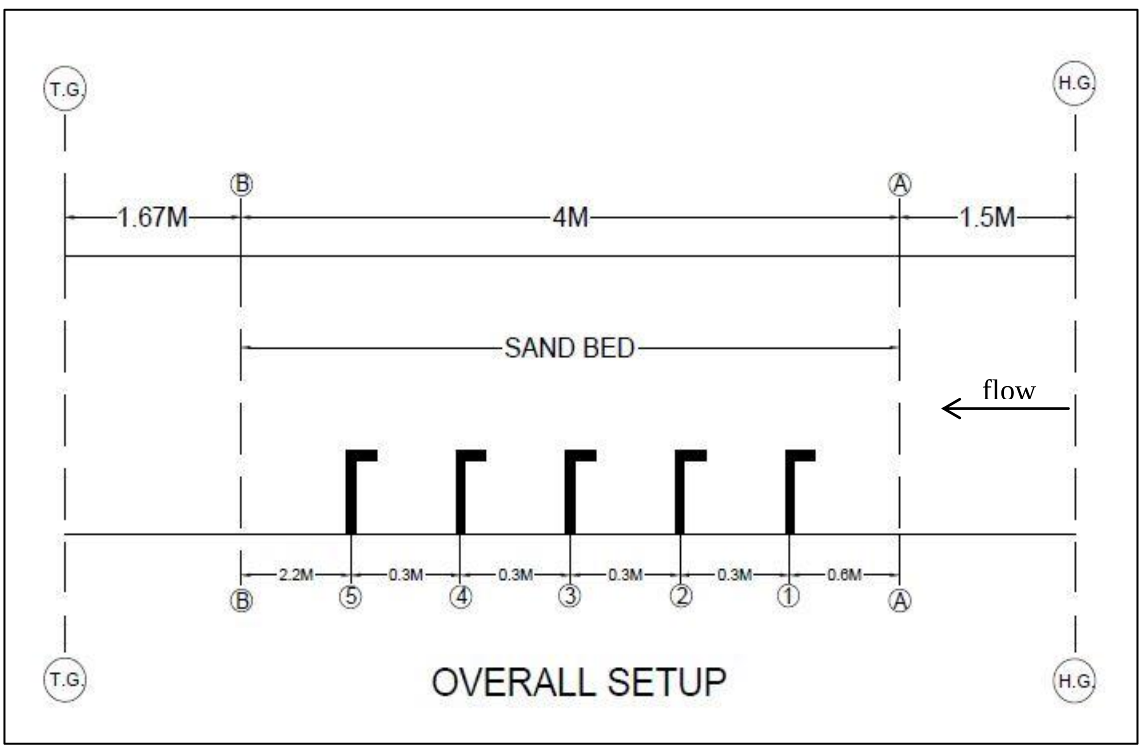


**Figure.3.14** Illustrative sketch of experimental setup for Test Run-2 (**LU-groynes**)

**Figure.3.15** Image showing experimental setup before Test Run-2 (LU-groynes)

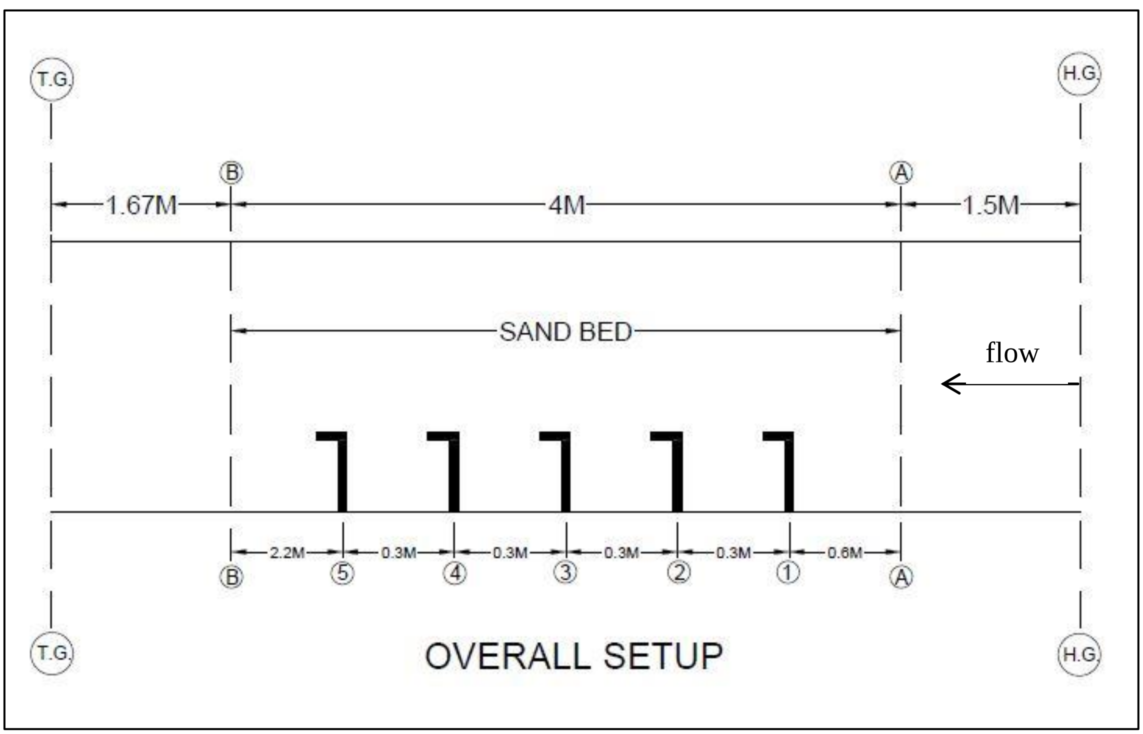


**Figure.3.16** Illustrative sketch of experimental setup for Test Run-3 (**LD-groynes**)

**Figure.3.17** Image showing experimental setup before Test Run-3 (LD-groynes)

Before the actual test run the setup is tested for the limitations that might occur during the flow. It is found that sudden entrance of water into the channel might leads to some unwanted erosion of the sand bed and therefore it is controlled by placing a wooden plank for ensuring a smooth entry of water on to the sand bed. Considerable length is made available for the flow to minimize the turbulence in it before it hits the sand bed and the groynes series. Similarly a it is tried that flow should reach the outlet of the channel as smoothly as possible and in order to achieve that uniformity a sufficient length is available beyond the end point of sand bed, for the flow to become uniform. This also helped in restricting the eroded sediment from entering the recirculating pump assembly.

**Figure.3.18** Image showing projection of groynes in Test Run-2

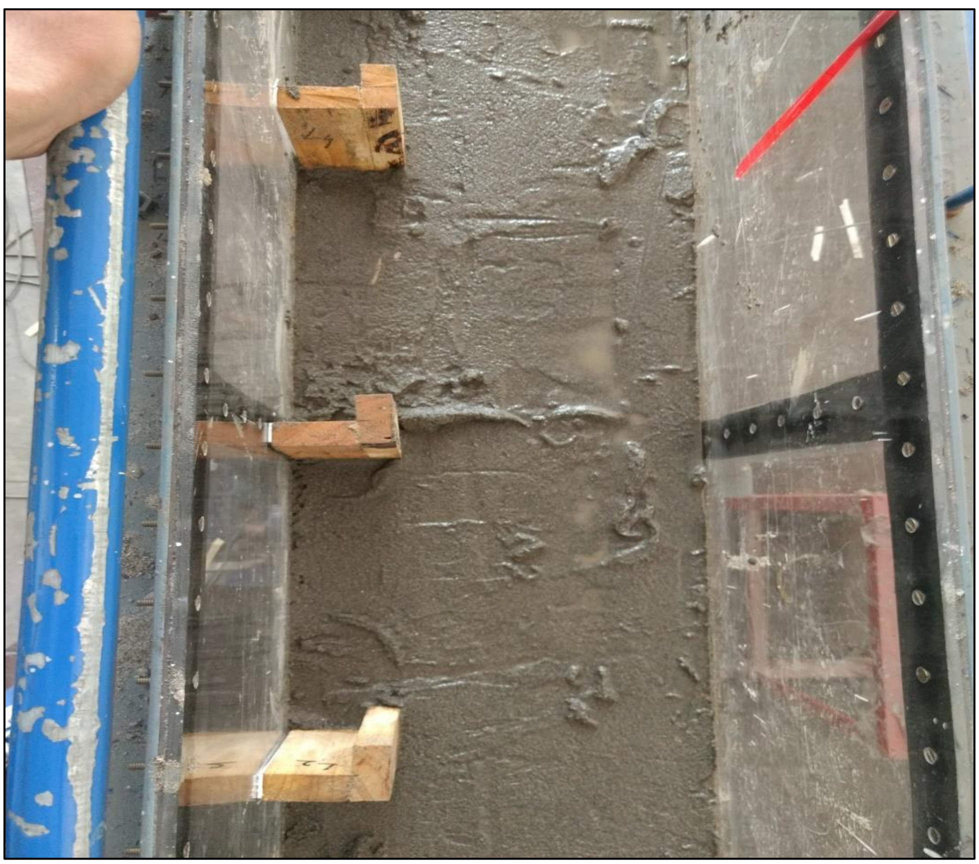

**Figure.3.19** Image showing projection of groynes in Test Run-3

### 3.4 FLOW CONDITIONS

Experiments are performed under uniform and subcritical flow conditions. Smooth entry of flow over the sand bed is ensured by placing a wooden plank at the point A from where the sand bed is laid down in the flume. Due to this turbulence of flow doesn't lifts up the bed material at the starting point of the sand bed. The flow is kept below the incipient condition for the sediments which is ensured by the physical observation of regime of the channel bed. Flow rate is controlled by the control valves provided with the pumping set. Groynes models are non-submerged through out the flow and constant water depth of 8cm is provided over the 7cm thick sand bed which ensures that some part of groynes is still remains non-submerged in water.

**Figure. 3.20** Image showing the regime of the channel bed

**Figure.3.21** Initiation of uplift of sediment around the groynes

**Figure.3.22** Image showing submergence of groynes during the flow

**Figure.3.23** Image showing erosion of sediment in the groyne field

**Figure.3.24** Image showing recirculation of flow in between two groynes in Test Run-3

### 3.5 METHODOLOGY

Experiments are carried out in Hydraulics Laboratory of Delhi Technological University on a tiltable flume of dimensions 8m(l)x32cm(b)x40cm(h). Before running the flow the slope of the flume was adjusted to 1:2000. The locally available sand is screened before using it in the flume to remove the impurities present in it. It is followed by sieve analysis of the sand to obtain its particle size distribution.

A uniform layer of sediment is laid down in the flume channel to imitate the natural river bed followed by installation of groynes models in the channel at suitable spacing before running the flow through the channel. Double tape is used to stick the groynes on the sides of the channel rigidly so that they are not affected by the turbulence of the flow.

Initially water is allowed to enter the flume gently and when the entire flume is wetted dimensions of channel bed profile is noted down. Flow is then allowed to enter the flume and it is controlled through the control valves provided with the setup, as a stable condition is intended to begin the flow run. Constant depth of flow is maintained with the help of tail gate at the end of the flume marking the beginning of the run time which extends up to 45 minutes during which velocity is measured with the help of digital velocity meter. Velocity measurements are done at the distance of 2.5cm from the tip of the groynes and 5cm below the water level. Same process is repeated for each groyne and points A and B in the channel. Then the flow is stopped and water is drained out of the channel before measuring the depth of scouring, distances up to which scouring has occurred around the groynes and within the channel due to the obstruction in flow by the groynes, the deposition pattern of scoured sand in the channel. All the depth measurements are taken with the help of a point gauge with accuracy of ±2mm mounted on a carriage which can move to any position above the working area transversely and longitudinally. The procedure is repeated for three different variations of groynes models.

Next step involves analyzing the scour at different locations and measuring scour depth along the channel. Variation in scour pattern with respect to the shapes of groynes is also observed. Projecting a data table for the different groynes and showing the effect of their variations. Analyzing the scour formation and their possible effects in the vicinity of the channel.

# CHAPTER-4

# RESULTS AND DISCUSSION

## 4.1 INTRODUCTION

This chapter includes the detailed results and the findings of the study. It completely provides the observation tables and the graphical output from the experiments. Results are discussed in detail and all the observation includes complete accuracy approximately.

## 4.2 EXPERIMENTAL OBSERVATIONS

Scour depth for different arrangements of groynes is calculated and their respective variation is analyzed. Erosion of sediment is found to be directly influenced by flow rate and depth of flow. In order to maintain the desired water depth, flow rate was kept constant through out the test runs and its maximum value was kept smaller than the threshold value for the sediment.

**Scour**

Scour phenomena depends upon two basic parameters which are classified as: (i) Fluvial parameters – discharge, velocity, depth of flow, bed slope etc. (ii) Sediment parameters – grain size distribution, cohesiveness and geometrical features etc.

To determine the exact scour forming phenomena, all these parameters needed to be studied for their variation with the scour forming possibilities and therefore an adequate knowledge of scour and its formation in the channel can be obtained. Among the various factors only velocity and depth of the flow related properties are under control up to a certain permissible limit. Therefore it becomes critically important for the designers of hydraulic structures to have a basic background knowledge of the features that affects the stability of these structures and ultimately this leads to an estimation which can only be safe on the basis of past research on these parameters. In this study the variation of scour depth in groyne system is tried to be analyzed with the effects of these groynes, so that their respective spacing and alignment can be properly designed in a flow which is prone to scouring. Firstly the variation of scour depth and velocity is analyzed and is done in three test runs which differs on the basis of the types of groynes used in them. Secondly the variation of scour depth at these groynes is compared among themselves which could be helpful in placing the appropriate groyne at a particular location in the channel.

### 4.2.1 Velocity-Scour depth variation

Scour depth is directly affected by the depth of the flow. Depth of scour is measured at the tip of the groynes and its variation with velocity along the flow is represented in graphical manner. Three different test runs for different shapes of groynes are conducted and observation are made.

**Figure.4.1** Velocity measurement using Digital Velocity Meter flow probe

#### 4.2.1.1 Test Run 1: Flange portion in central position (TG)

Test Run for TG groynes is conducted for a duration of 45 minutes with a constant discharge of 0.006 $m^3/s$. Depth of flow above the bed is 8cm .Velocity measurement is done at the tip of the groynes and at the points A and B in the channel. Groynes are installed rigidly to the side of the channel so that it is not dislocated under the action of incoming flow. The measurements are taken in such a manner that the setup doesn't gets affected which may lead to variation in the investigation of the data.

After the test run water is allowed to drain out of the channel and scour measurements are taken with proper care to avoid any inaccuracy.

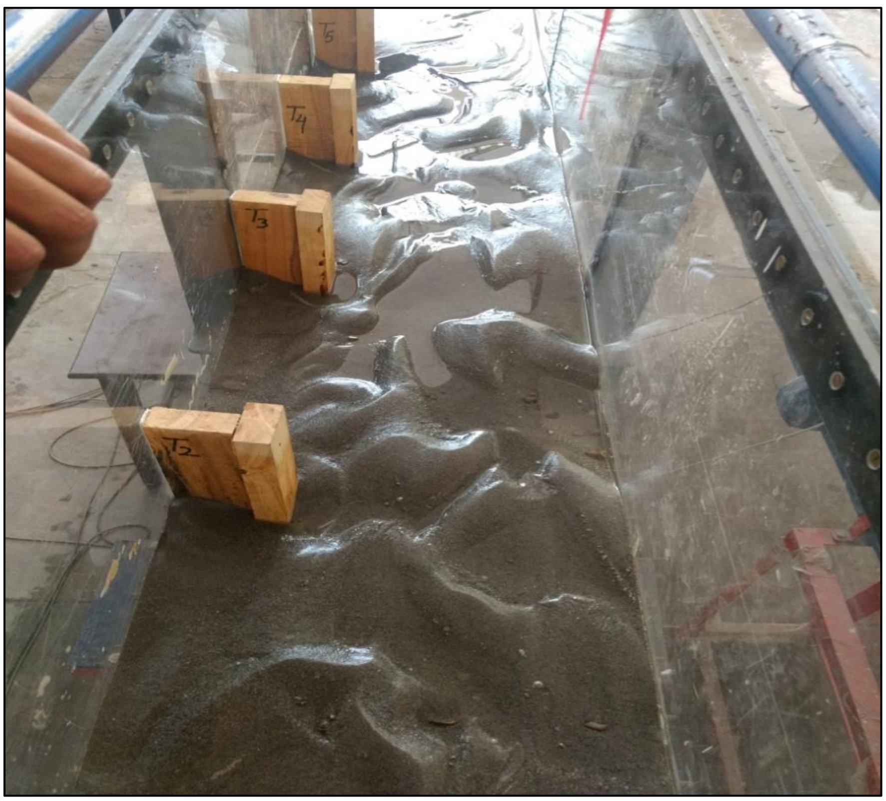


**Figure.4.2** Image showing the channel bed after Test Run-1

**Table 4.1** Observation table for Test Run-1 (TG groynes)

| Groyne | Bed level(cm) | Velocity(m/s) | Fr | Depth of scour(cm) |
|---|---|---|---|---|
| pt.A | 7.0 | 0.41 | 0.462 | 0.7 |
| TG1 | 7.0 | 0.38 | 0.428 | 1.2 |
| TG2 | 7.1 | 0.36 | 0.403 | 1.8 |
| TG3 | 7.0 | 0.313 | 0.353 | 2.6 |
| TG4 | 7.2 | 0.212 | 0.242 | 1.9 |
| TG5 | 7.1 | 0.156 | 0.177 | 1.4 |
| pt.B | 7.0 | 0.112 | 0.115 | 1 |

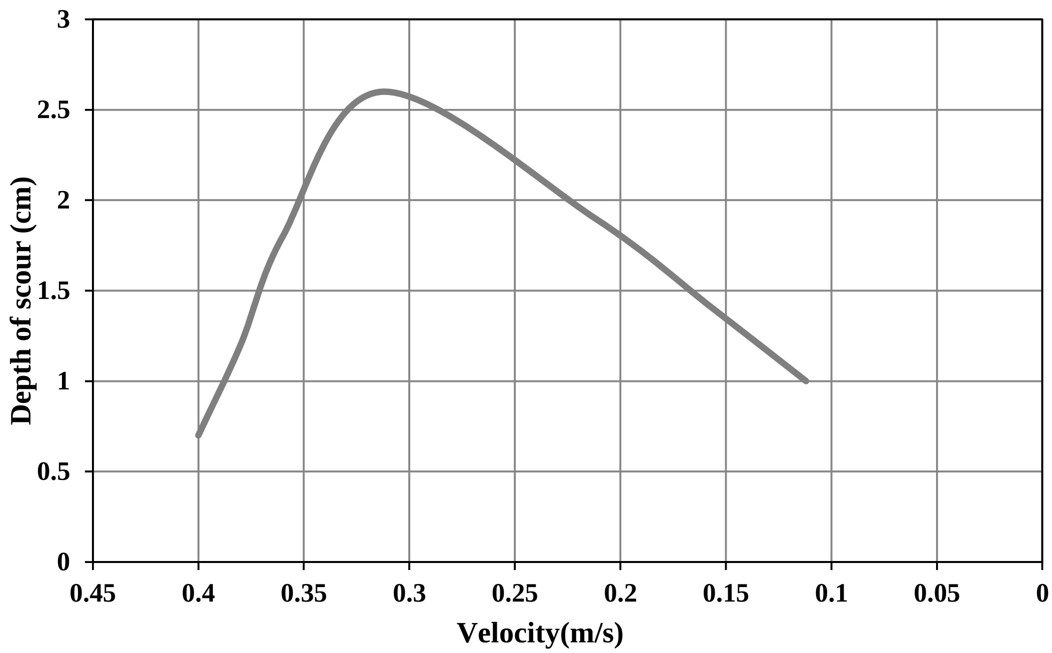


**Figure.4.3** Variation of Scour Depth with Velocity for TG groynes

From Figure.4.3 it is observed that the depth of scour for the groynes with flange portion in central position follows an increasing trend initially and then decreases after reaching up to its maximum value. It is also observed that velocity of flow decreases along the flow direction. Scour in initial reaches of the channel increases quite abruptly while the its reduction is comparatively gradual and also smaller in terms of magnitude. This trend can also be explained by the effect of velocity which has greater emphasis on sediment in the initial portion of channel and it reduces with the flow along the channel.

**Figure.4.4** Scour formation around TG-1

**Figure.4.5** Scour formation around TG-2

**Figure.4.6** Scour formation around TG-3

**Figure.4.7** Scour formation around TG-4

**Figure.4.8** Scour formation around TG-5

From the observation of channel bed after the test run-1 it is discovered that local scour around the groynes is directly affected by the velocity and the eroded sediment gets deposited in between the groynes. Opposite bank is also affected by the recursion of the flow created by the obstruction due to groynes. However this is only in the upper reaches of the channel only and in the latter part of channel opposite bank is safe from the threat of erosion as compared to upper reaches.

#### 4.2.1.2 Test Run 2: Flange portion towards upstream direction (LU)

Test Run-2 is conducted for the groynes with flange portion in upstream direction. Duration of run is 45 minutes as it is for TG groynes. Discharge is maintained as 0.006 $m^3/s$ with help of control valves so that flow depth of 8cm is maintained over the sand bed. Flow is subcritical through out the channel.


**Figure.4.9** Image showing channel bed after Test Run-2

**Table 4.2** Observation table for Test Run-2 (LU groynes)

| Groyne | Bed Level(cm) | Velocity(m/s) | Fr | Depth of scour(cm) |
|---|---|---|---|---|
| pt.A | 6.9 | 0.36 | 0.40 | 1.0 |
| LU1 | 6.9 | 0.332 | 0.37 | 1.2 |
| LU2 | 7.0 | 0.31 | 0.34 | 1.1 |
| LU3 | 7.0 | 0.3 | 0.33 | 1 |
| LU4 | 6.9 | 0.27 | 0.302 | 0.9 |
| LU5 | 7.1 | 0.22 | 0.249 | 0.6 |
| pt.B | 7.0 | 0.19 | 0.21 | 0.4 |

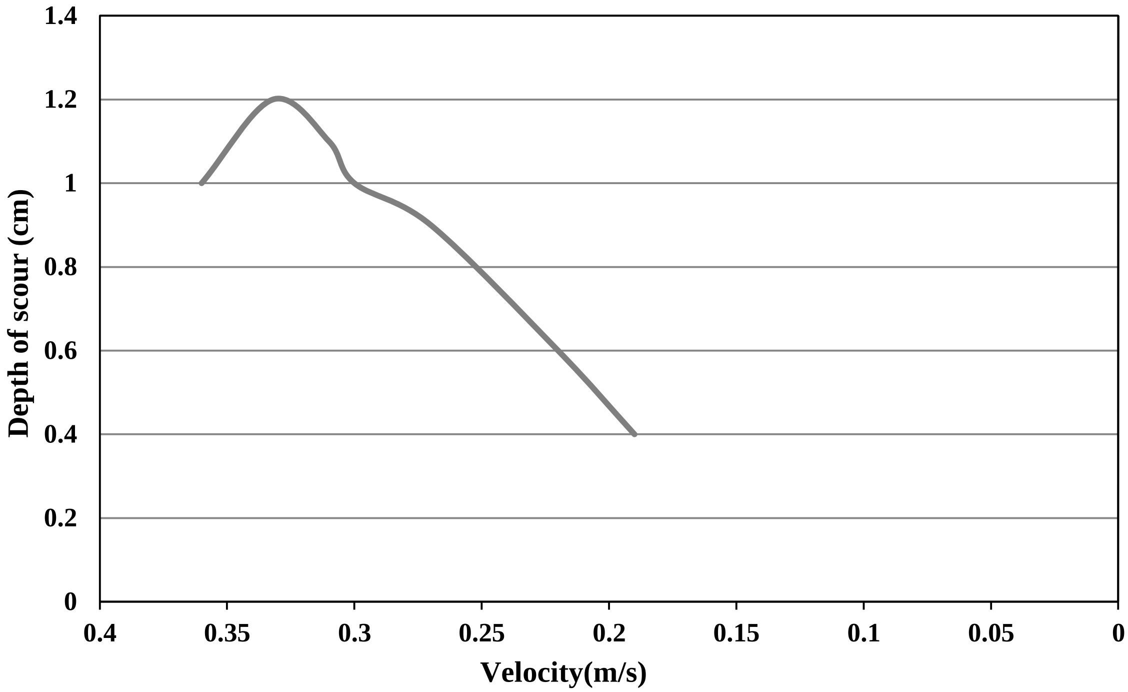


**Figure.4.10** Variation of Scour Depth with Velocity for LU groynes

Considering the results shown in Table 4.5 and Figure.4.10 for the Test Run-2, it is seen that in case of groynes with flange portion towards upstream direction the depth of scour slightly increases in the initial points and then follows a declining trend. Velocity of flow decreases while moving downstream. It is to be noted that there is not much of a difference in the magnitude of the scour as only a minor change is observed when it increases at the first groyne. This increase in the scouring is due to immediate obstruction created by the flange portion which is held towards upstream direction of the channel. Presence of flange provides an obstruction to the upcoming flow which results in the formation of vortices at the bed level and uplifts the particles. It is also seen that depth of scour decreases as we move along the flow, this is due to reduction in the flow velocity due to the obstructions created by the flange portions. Velocity of flow towards the end of channel is decreased by such magnitude that it falls short of the threshold value required for the initiation of the movement of and particles.

**Figure.4.11** Scour formation around LU-1

**Figure.4.12** Scour formation around LU-2

**Figure.4.13** Scour formation around LU-3

**Figure.4.14** Scour formation around LU-4

It is clear from Figure.4.11 that at the first groyne in test run-2 the shape of scour hole is not circular rather it is nearly a stretched pattern of scour. While at second groyne it results in to a rather concentric shape as compared to first one. Scour is observed only in the upstream of groynes and not in downstream part of it. In regions around third and fourth groyne the channel bed it observed to be nearly unaffected in terms of regime and the effect of flow is only limited near the groynes base. Uplift of sediment is only prevailed in the upstream of the groynes and not in the downstream of it with maximum at the tip of the groyne.

#### 4.2.1.3 Test Run 3 : Flange portion towards downstream direction (LD)

Test run-3 is conducted using the groynes with their flange portion towards downstream direction. Uniform bed level around 7cm is placed between points A and B over which a flow depth of 8cm is maintained with the help of controlling valves. Flow is kept subcritical in nature through out the channel with a flow rate of $0.006 m^3/s$.

**Figure.4.15** Image showing flow profile during Test Run-3

**Table 4.3** Observation table for Test Run-3 (LD groynes)

| Groynes | Bed Level (cm) | Velocity(m/s) | Fr | Depth of Scour(cm) |
|---|---|---|---|---|
| pt.A | 7 | 0.38 | 0.428 | 0 |
| LD1 | 7 | 0.37 | 0.417 | 0.8 |
| LD2 | 7.2 | 0.34 | 0.388 | 1.5 |
| LD3 | 7.1 | 0.3 | 0.340 | 1.9 |
| LD4 | 7 | 0.25 | 0.282 | 2.2 |
| LD5 | 7.2 | 0.21 | 0.240 | 2.4 |
| pt.B | 7 | 0.15 | 0.169 | 2.6 |

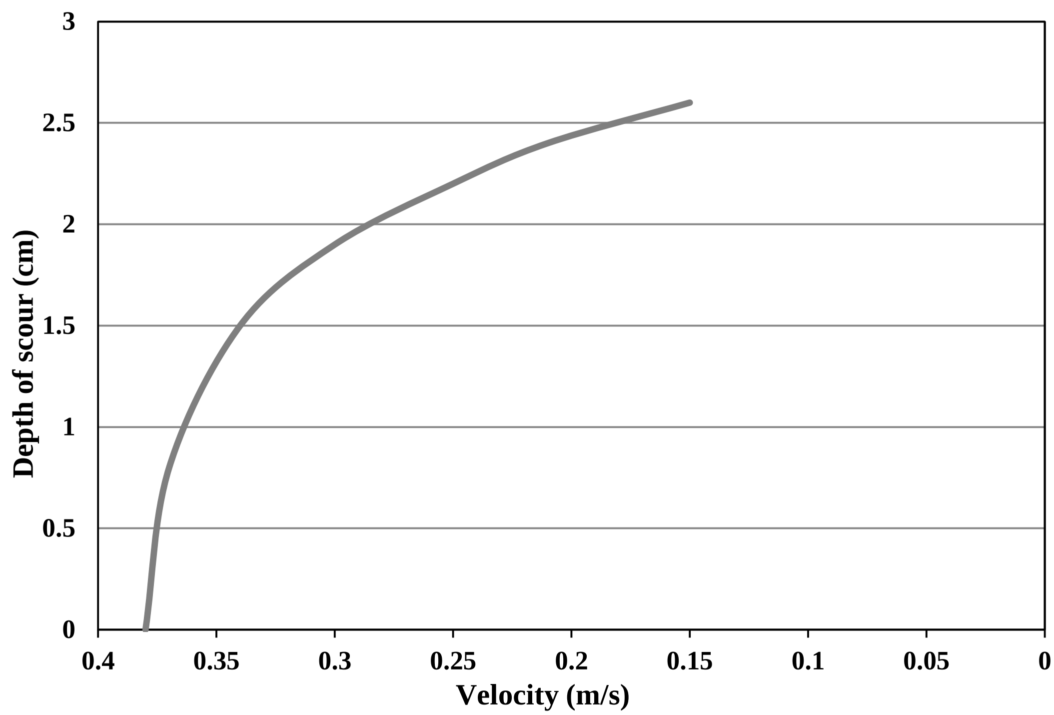


**Figure.4.16** Variation of Scour Depth with Velocity for LD groynes

From Figure.4.16 showing the variation of scour depth with velocity for test run-3 involving the use of groynes in which the flange portion is towards downstream, it is observed that scour depth increases while the velocity decreases in the direction of flow. It is to be noted that in the initial reaches of the channel, velocity doesn't decreases and rather remains almost constant upto second groyne after that it follows almost a linear trend reaching its minimum value at the end of the channel.

Depth of scour increases in the latter part of tht channel which can be understood by the positioning of flange towards downstream. It is observed that intially the flow is deflected away from the bank which allows the sediment near the foot of the groynes to be unaltered in the intial regions. This deflection of flow is followed by formation of a reciculation zone in the central portion of the flowduw to which flow is redirected towards the next groyne and leading to the formation of flow vortices and ultimately the depsoited sediment is eroded from its position and carried with the flow. It is also noted that the shape of scour around the groynes is irregular in the initial portion of the channel and forms a confined circular shape towards the latter part of the channel. Groynes 4 and 5 are found to have explicit circular shape of scour hole.

**Figure.4.17** Scour formation around LD-1

Figure.4.17 shows the defelction of flow away from the groyne which induces the formation of scour near the next groyne after it hits the oposite bank and hits back the next groyne.

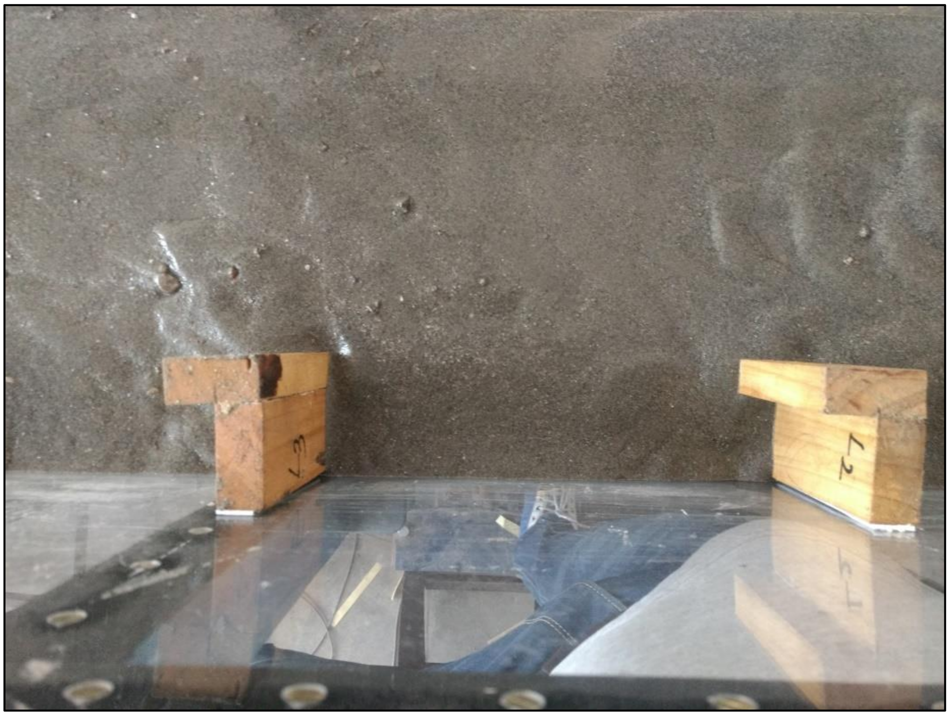

**Figure.4.18** Scour formation around LD-2 and LD-3

**Figure.4.19** Scour formation around LD-4

**Figure.4.20** Scour formation around LD-5

## 4.2.2 Comparison of scour depth for different forms of groynes

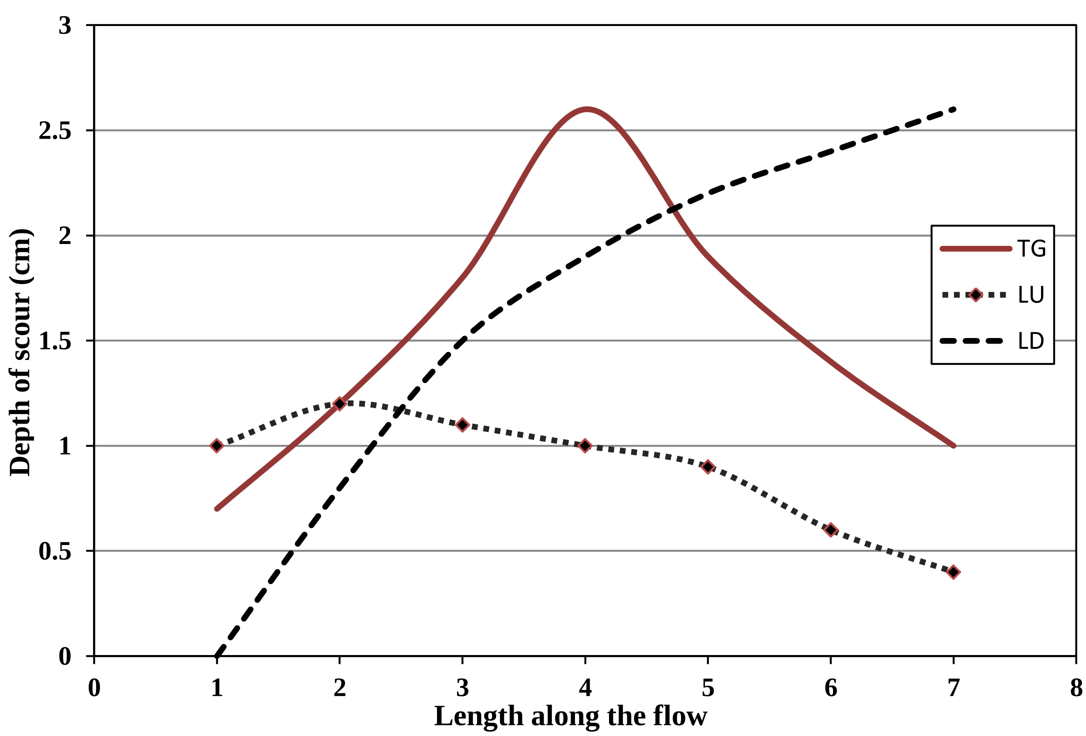


**Figure.4.21** Comparison of Scour Depth for different groynes

Figure.4.21 compares all three configuration of groynes is shown in terms of their scour depth variation along the channel. It is observed that overall scour depth is higher for TG groynes and minimum for LU groynes. Lowest value of scour depth is observed at the first LD groyne and the highest value for the last LD groyne. Orientation of flange results in increased scour depth in the same direction as seen for LU and LD groynes. For TG groynes the scour follows increasing trend and then decreases which can be justified with the presence of flange on both sides of the main axis of installation.

For LU groynes the scour depth is higher in the initial reaches of the channel and decreases towards the end of the channel that is because of the greater emphasis of velocity in the beginning and the obstruction generated by the flange of the groynes provides sufficient turbulence to uplift the sediment particles from their positions.

In case of LD groynes the scour depth increases in the direction of flow which can be inferred by the orientation of flange portion towards downstream which directs the flow away from the groyne and creates havoc situations near the groynes situated downstream in the flow.

In general it can be summarized that flange does affects the scour and its orientation is the prime factor in deciding the possible socur occuring situations which might result in its failure and furhter losses. Therefore, flange portion of groynes should be carefully decided and properly laid out in the field otherwise the intention for which they are provided may not be fulfilled for the duration intended.

# CHAPTER-5

# CONCLUSION

The use of groynes as a means of riverbank protection and erosion control measures has been employed for many decades and it has proved to be successful in terms of protection against the adverse effects of the rivers. It has been used to prevent the infrastructure from the devastation due to the unintended behavior of rivers.

The objective of this study were to investigate the effect of variation in flange portion of the L-shaped groynes on local scouring around these groynes and analyze their corresponding efficiencies in controlling the erosive actions of the flow in open channel.

Results of experiments performed showed that symmetry in orientation of the flange portion proves to be more prominent in prevention against scour in the channel. It is observed that when flange portion is symmetrically placed on the web, scour follows an increasing trend initially and then decreases in the end, which means that channel bed is quite stable in the upper and lower reaches of the channel and only possible threat of failure is in the central portion of the series of groynes. Flange portion not only reduces the flow velocity but also deflects the high velocity zones towards the opposite side of the channel. Which causes more possibility of erosion at the downstream of the groynes in the beginning of the flow. By the time flow reaches the end of the channel flow velocity has been reduced with the passage of time and ultimately the scour producing vortices are less in number at the base of the groyne and it results is reduced scouring around the groynes.

For the groynes with flange portion towards upstream direction, it has been observed that scour is higher in the initial portion of the channel whereas it reduces towards the end. However, a small increase in the scour magnitude is observed before the first groyne in the series which is due to the combination of high flow velocity and immediate obstruction produced by the flange of the first groyne. Flange towards upstream direction of flow directly confronts the approaching flow and breaks its momentum due to a part of it forms the vortices near the bed of the channel and results in erosion of sediment around the groyne. This results in reduction of scour depth in the downstream direction of the flow.

For the groynes with flange portion in the downstream, it has been observed that scour depth is increasing along the flow in the downstream direction and reaches its maximum value in the end of the channel. More importantly it has been observed that depth of scour hole is greater than the ones formed by the groynes with flange in upstream direction. Increase in the scour depth along the flow can be explained by the fact that flow is being deflected away from the groynes. This is followed by a situation in which the flow reflects back towards the next groyne and by creating turbulence around it. Ultimately the sediment deposited is dislocated form its position and carried away with the flow.

It is to be noted that in these types of groyne the scour is dominant in the upstream part of the groyne and the effect of turbulence generated by the flow is more prominent once it crosses the initial portion of the channel.

Overall it is concluded that L-shaped groynes are capable of controlling the adverse effects of the flow in open channels. It can be done by varying the flange portion carefully as per the situation and the desired consequences. It is obvious that positioning of flange affects the scouring. More scouring is observed in the direction in which the flange is placed. Therefore, to prevent the upstream region of the channel flange should be placed in the downstream direction and if the important region to be prevented lies in the downstream of the groyne , the flange should be provided in upstream direction.

# CHAPTER-6

# REFERENCES


1. ROGER. A. KUNHLE et al. "Local Scour Associated with the Angled Spur Dikes". *Journal of Hydraulic Engineering–10.1061/ASCE-0733-9429(2002)128:12(1087).*

2. WIM S.J. UIJTTEWAAL "Effects of Groyne Layout on the Flow in Groyne Fields: Laboratory Experiments". *Journal of Hydraulic Engineering © ASCE / SEPTEMBER-2005.*

3. A.SHAFAIE et al. "The Effect of Minor Spur Dike on Scouring at the First Spur Dike in the Gravel Bed". *Fourth International Conference on Scour and Erosion,2008.*

4. M.VAGHEFI and M.GHODSIAN. "Experimental Study on the Effect of a T-shaped Spur Dike Length on Scour in a 90º Channel Bend". *Arabian Journal for Science and Engineering, October 2009, 242270624.*

5. A.SAFAZADEH et al. "Experimental Study of Head Shape Effects on Shear Stress Distribution Around a Single Groyne". *River flow 2010- Dittrich, Koll, Aberle & Geisenhainer (eds) ISBN 978-3-939230-00-7*.

6. A.KADOTA and K.SUZUKI. "Local Scour and Development of Sand Wave Around T-type and L-type Groynes". *Hydraulic Engineering Repository, Fifth International Conference on Scour and Erosion, November 2010, USA.*

7. A.ARMANINI et al. "Analysis of Fluvial Groynes System on Hydraulic Scale Model". *River Flow,2010, Dittrich Koll Aberle & Geisenhainer, ISSN:978-3-939230-00-7*.

8. M.ALAUDDIN, T.TASHIRO, T.TSUJIMOTO "Experimental Investigation of Channel Responses Against Different Configurations of Groynes". *Advances in River Engineering,JSCE,Vol.17,July 2011*.

9. ALIREZA MASJEDI et al. “Evaluating Scour at L-Shaped Spur Dike in a 180° Channel Bend”. *World Applied Science Journal 15(12):1740-1745,2011, ISSN-1818-4952 © IDOSI PUBLICATIONS 2011.*

10. MD. JAHIR UDDIN et al.“Local Scour Around Submerged Bell Mouth Groin for Different Orientations”. *Journal of Civil Engineering (IEB) ,39(1)(2011) 1-17.*

11. JOONGU KANG and HONGKOO YEO “Experimental Study on the Flow Characteristics of L-type Groyne”. *Journal of Scientific Research,3,ISSN:1002-1011,2011*

12. S.ABBASI et al. “Numerical Investigation of Angle and Geometric of L-shape Groin on the Flow and Erosion Regime at River Bends”. *World Applied Sciences Journal 15(2): 279-284, ISSN:1818-4952,2011.*

13. M.VAGHEFI, M. GHODSIAN, SEYED NEYSHABOURI “Experimental Study on Scour Around a T-shaped Spur Dike in a Channel Bend”. *Journal of Hydraulic Engineering, ASCE, ISSN-0733-9429/2012, Vol.138, May 2012.*

14. AMIR RAZA MASOORI et al. “ Study of the Characteristics of the Flow around a Sequence of Non-Typically Shaped Spur Dikes Installed in Fluvial Channel”. *Annuals of Disaster Prevention and Resisting Institute, Kyoto University, No-55B,2012.*

15. RAVINDRA A. OAK and PRAMOD B.F “Relation between Spur Spacing and Safety Margin of Protected Bank: A Field Verification”. *International Journal of Advanced Engineering Research and Studies, Vol.1, Issue.4,ISSN:2249-8974,2012.*

16. SALEH. I. KHASSAF and ALAA MHSEEN DAWOOD “Development of a New Formula for a Clear Water Scour Around Groynes”. *International Journal of Modern Engineering Research,Vol.3,Issue-4, JULY-AUGUST 2013 pp 2083-2088, ISSN:2249-6645.*

17 AMIR RAZA MANSOORI et al. “Laboratory Study of Bed Variation Due to the Installation of Spur Dykes With Different Head Shapes”. *Annuals of Disaster Prevention and Restoration Institute, Kyoto University, No-56 B,2013.*

18. JAVAD AHADIAN et al. “Effect of Changes in the Hydraulic Conditions on the Velocity Distribution Around a L-shaped Spur Dike at the River Bend using Flow-3D Model.” *Technical Journal of Engineering and Applied Sciences © 2013-3-16/1862-1868, ISSN:2051-0853.*

19. FENG CAI and AKIHIRO TOMINAGA. ”Three Dimensional Flow Structure Around Submerged Box Groyne with Longitudinal Block.” *Journal of Japan Society of Civil Engineers, B1, Vol-69-4, I_61-I_66,2013.*

20. KATE PORTER et al. “Comparison of Three Techniques for Scour Depth Measurement: Photogrammetry, Echosounder Profiling and a Calibrated Pile”. *Journal of Coastal Engineering-2014, University of London, UK.*

21.M.MEHRAEIN and M.GHODSIAN “Experimental Study on Relation Between Scour and Complex 3D Flow Field”. *Scientia Iranica A (2017) 24(6), 2696-2711.*

22. A.M.NAJAFABADI and M.M.BATENI “ Experimental Investigation of Flow Pattern Around Repelling and Attracting T-head Spur Dikes on Flat Bed”. *Journal of Fundamental and Applied Sciences, ISSN 1112-9867,2017.*

23. UTPAL KUMAR MISRA and DHARMENDRA NATH “Experimental Study of Local Scour Around Single Spur Dike in an Open Channel”. *International Research Journal of Engineering and Technology, Vo:4, Issue:6, e-ISSN-2395-0056,June 2017.*

24. FATEMEH VEISI and AHMAD JAFARI “Laboratory Study of Turbulence Intensity inLongitudinal, Transverse and Deep Directions and Turbulent Burst Event around Various L-shaped Groynes”. *International Journal of Science and Engineering Investigations, ISSN: 2251-8843,Vol-6, Issue-67, August 2017.*

25. HANS KING “ The Use of Groynes for Riverbank Erosion Protection*”. Research Gate Publications, 2009.*

26. ARENDE DANIEL DE WAAL VAN DEN HEEVER “An Investigation of the use of groynes as a means of riverbank erosion protection”. *STELLENBOSCH UNIVERSITY, March 2013.*

27. P.L.ANTONIO LUCCA “Flow Patterns Around Groynes in Coastal Regions” *University of KwaZulu-Natal, Durban,2013.*

28. IS-8408:1994 “Planning and Design of Groynes in Alluvial River - Guidelines (First Revision)”.

29. IRC-89:1997 “Guidelines for Design and Construction of River Training and Control Works for Road Bridges”.

30. Groynes and Training Works Affecting River Planform- A Literature Review, *Hydraulic Research,Wallingford,1990.*

31. Erosion, Scour and Foundation Design, *FEMA, January 2009.*

32. K.SUBRAMANYA “Flow in Open Channels”. *Tata McGraw Hill Publications. Fourteenth Reprint,ISBN:978-0-07-008695-1, 2012.*

33. S.K.GARG "Irrigation Engineering and Hydraulic Structures". *Khanna Publications, 27th Revised Edition,ISBN:81-7409-047-9, 2013.*