LOCAL SCOUR AROUND NORMAL AND T SHAPE SPUR DIKES

Submitted in partial fulfillment of the requirements of the degree of

Master of Technology

In Hydraulics and Flood Control Engineering

by

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CERTIFICATE

This is to certify that the major project report entitled "**LOCAL SCOUR AROUND NORMAL AND T SHAPE SPUR DIKES**" being submitted by me is a Bona-fide record of my own work carried by me under the guidance of Dr. MUNENDRA KUMAR in the partial fulfillment of the requirement for the award of the degree of Master of Technology in Civil Engineering with specialization in HYDRAULIC AND FLOOD ENGINEERING, DELHI TECHNOLOGICAL UNIVERSITY, DELHI-110042.

The matter embodied in this project has not been submitted for the award of any other degree.

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Name of the Student: MANISH KRISHNA YADAV

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Signature

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ABSTRACT

A series of experiments were conducted to study the phenomenon of local scour that takes place around a single spur dike installed as a river training structure on straight channel. The objective of this thesis is to study and understand the phenomena of scour around the foundation of spur dike for different shapes at different orientation of flow. The comparison is done of dimensions of scour hole (maximum scour depth, length of scour in upstream side, length of scour in downstream side, and the scour length in transverse direction) for normal and T shape spur dike with different orientation angle. By comparing the scour hole dimensions we can investigate for which orientation angle the scour is minimum for the both type of spur dike. If the scour around the dike foundation is underestimated then the structure will fails or if the scour around spur dike is over estimated than the structure will became uneconomical so that by analyzing the shapes and geometry of scour holes of different cases we can accurately design the foundations of spur dikes at river sites for bank protection. All tests were held under clear water condition, using a horizontal bed consisted of non-uniform sandy soil (Yamuna sand) in the hydraulic laboratory at Delhi Technological University, Delhi. Several equations via graphs were obtained to compute the relative maximum scour hole depth and scour length with different orientation for normal and T shape spur dikes.

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List of symbols

1. Fr = Froude Number
2. V = Velocity of flow in m/sec
3. Q = Discharge in cumecs
4. B = Width of Flume
5. b = Project width of spur dike
6. d_s = Maximum scour depth
7. L_{up} = Length of scour in u/s side
8. L_{down} = Length of scour in d/s side
9. L_y = Length of scour in y axis direction
10. Θ_{up} = Angle of scour in u/s
11. Θ_{down} = Angle of scour in d/s
12. Θ_y = Angle of scour in y axis direction
13. e = contraction ratio

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CHAPTER 1

INTRODUCTION:

1.1 SCOUR;

Scour is the phenomena that used to explains the considerable localized erosion of sediments that occurs when the erosive capacity of liquid exceeds the ability of sediments to resist it. The erosive capacity of the liquid originates with fluctuating pressures while turbulent flows, and the ability of sediments to resist it is a function of inherent sediment material characteristics for example mass strength, dimension, internal friction, and shape and orientation of the material. The terms *erosion* and *scour* have the same meaning. In this experiment we consider only two type of scour Contraction scour and local scour. For the better understanding both are described as follows.

The Contraction type scour happens when the flowing area of a stream channel at a flood stage is decreased or contracted, or else by a natural reduction of stream channel or by plantation of spur dikes, a contraction in flowing area results in increase in bed shear stress and average velocity through the contraction. Therefore, an increase in erosive forces in the contracted area and more bed and side material is displaced from the above contracted area. As the elevation of bed is lowered the area of flow increases for the stream and in that situation, the velocity and shear stress are decrease until relative equilibrium for stream has been reached. For that means the amount of scoured bed material that moved into the area is equal to that removed from the flow area.

The contraction of stream flow around the foundation of spur dike can be caused by either a natural decrease in flow area of the stream channel.
Some other factors that causes contraction type scour in stream are;
(1) The Natural type of stream constrictions in flow.
(2) Natural bends along the banks due to sediment deposits.
(3) Debris in stream.
(4) To growth of vegetation in the channel or floodplain.
(5) Flow with Pressure.

The basic mechanism behind local scour is the formation of vortices at the foundation of spur dike. The vortices occur by the collision of water front on the surface of the obstruction at upstream side and considerable acceleration flow near the toe of the dike.
Near the foundation of spur dike the rate of change in scour bed is higher than away from the foundation of spur dike, by that process a scour hole is takes place around the base of structure. As the depth of scour hole increases, the strength of the horseshoe vortex is decreased, thereby reducing the rate of transport sediment from the base region.

Factors which affect magnitude of local scour depth around the spur dike are:
(1) Upcoming flow velocity.
(2)flowing depth.
(3) Width of the spur dike.
(4) Contraction ratio (e).
(5) Length of the spur dike.
(6) Size and grade of bed particals.
(7) Angle of orientation of spur dike.
(8) Shape of the spur dike.
(9) Bed configuration.
(10) Vegetations and debris.

1.2 SPUR DIKE:

A spur dike can be defined as a transverse structure having one end on the bank of a stream and the other end into the stream current. Spur dikes have been universally used to give the direction to the flow in channels and to protect the stream banks from erosion. They have also enhancing aquatic habitats by causing stable pools in unstable or disturbed channels streams.

And Like other hydraulic structures, when the spur dike is placed in water way than the natural balance of river or a stream is disturbed or unstable, results in a huge disturbance in the flow pattern around a base of structure. This disturbance can further lead to the initiation of scour process. The initiation of scour is considered to be the main reason to failure of foundations of structures. Therefore, the problem of scouring around obstruction like spur dike is placed in a alluvial channel is of huge importance to the hydraulic engineers, because the accurate estimation of local scour around these structures is very important for the purpose of safe and economical designing for the foundations of that structure.

1.3 MOTIVATION:

Engineers of all over the world are responsible for the maintenance of existing infrastructures and buildings and the new infrastructures in a manner so that they will behave like a safeguard for the public, and protect property and the environment. When such structures interface with flowing water, it is important to investigate the potential of the effects of scour. Scouring can leads to failure of infrastructure. The parts of the infrastructure mostly affected by scour include base of spur dike, bridges, dams, pipeline crossings in rivers and oceans.
Additionally the scour in riverbanks and shorelines, are not necessarily always considered that they can adversely affect infrastructure and property. Engineers are required to know that for which structure they have consider the effect of scouring and for which not. Engineers are required to estimate the effects of flowing water on infrastructure and property, and protect the public by designing the suitable systems that will prevent failure.

1.4 OBJECTIVE OF THE STUDY:

High flow in rivers is often leads to erosion of riverbanks. Some of the most populous cities are situated at the bank of the river not only in India but in the whole world. Thus the protection of banks of river is very needful job for civil engineers. The spur dikes are a very simple and effective method to save the river banks from erosion. By the use of spur dike we can make a suitable depth for the navigation and the minimum depth can be maintained for the movement of boats in the waterways and the meandering of the river can be controlled.

If the spur dike is placed in flowing stream then scouring takes place around the foundation of the spur dike. If the scouring is not considered in the design of the dike then it will fail and if the scouring is over estimated then the design will became uneconomical. So in this thesis we are estimating for which attacking angle the maximum scour and scour lengths are minimum for each type of dike and comparing the results to obtain the most suitable dike and attacking angle for a specific situation

1.5 OVERVIEW

Chapter 2 summarizes some of the literature work that describes the local scour around the foundation of spur dike.

Chapter 3 deals with theoretical background that elaborates about the different types of scours that occurs in alluvial channel.

Chapter 4 explains the experimental setup which arranged in the hydraulics laboratory of Delhi technological University.

Chapter 5 deals with experimental results that are explained in the form of six tables for the six different type of dikes.

Chapter 6 analyses the results in the form of graphs that are plotted with respect to the Froude number and the comparison are done for all attacking angle.

Chapter 7 deals with the conclusion of the work.

CHAPTER 2

LITRATURE REVIEW

This thesis work is mainly concentrated on to understand the local scour around spur dikes in alluvial channel. For the better understanding on the scour we are performing a experiment on the hydraulics laboratory in Delhi Technological University. We are using a rectangular flume of 6 meter length and Yamuna sand for the bed of flume. Some of the early researchers have done work to understand and estimate the local scour around spur dikes. Some of them are elaborated below;

In year 1936 Lacey has given a formula for maximum scour depth at the spur-dike. Dependent mainly on the fields observation for alluvial channel, where as Inglis in year 1949 compared the results of maximum scour depths with those obtained by the Lacey's equation. Based upon the studies and experiments with bed material which is ranging in size from 0.06 mm to 0.37 mm, prof. Inglis found that gradation is a factor affecting the value of maximum scour. His study and research also indicated that the value of maximum scour depth depends on the local discharge and on the mean velocity of a flow.

Prof. Ahmad in year 1953 has conducted the research or investigations to study the behavior of spur dikes using alluvial sand of 0.36 mm and 0.9 mm mean diameter and found some valuable conclusions regarding the effect of various parameters on the maximum scour. He studied the effect of different discharge intensity, sand grade, flow concentration and angle of the spur dike to flow on the scour depth and scour pattern around a spur dike.

Prof.Garde in year 1961 performed the experimental work with four sizes of spur dikes which gave the contraction ratio, e = 0.92 ,0.836, 0.667 and 0.530 in a channel of 0.61 metre width. He used four sizes diameter of the sand namely, D = 0.3 mm, D = 0.46 mm ,D = 1 mm, and D = 2.3 mm.

Prof.Tison in year 1962 did the experiments with a 70 cm wide, 20 m long flume with a mean sand size of D = 0.45 mm. He disagree with study of prof Garde done in 1961. Prof.Garde conclude that with some other conditions remaining the same, the maximum scour depth has the maximum magnitude for the spur dike inclination of 90°.

Gill in year 1972 conducted experiments by using a flume of width 0.76 meter, 0.46 meter deep and 12.2 meter long and two different sizes of sand of 1.50 mm and 0.91 mm..

Rajaratnam and Nwachukwu in year 1983 tried to study the phenomena of flow structures near spur dikes by measuring the flow in a straight and tilting rectangular flume, length of 120 ft, 3 ft wide and 2.5 ft deep with smooth bed and smooth and transparent sides. Most of the tests were done with a smooth bed. The shear stress amplification $\sigma\tau\tau$ varies with the ratio of the length of groin and the width of channel b/B ie contraction ratio (e). The $\sigma\tau\tau$ ratio was found to be 6 and 2 for the 6 inch and 3inch groin respectively.

Copeland in year 1983 carried out some tests on model in a sand bed flume with a channel top width of around 8 ft and an average depth of 0.24 ft and length of flume is 130 ft. he suggested that the coarse fraction of the bed material is an important factor that affects the scour depth around the spur dike besides other factors.

Prof Zaghloul in year 1983 conducted experiments with a 36 ft length, 1.5 ft width and 2 ft depth aluminum flume with the Plexiglas wall was used to study the effects of upstream flow conditions, sediment characteristics and spur dikes' geometry on the maximum scour depth and scour pattern around a spur dike.

Suzuki in year 1987 performed experiments to discuss the characteristics of the local bed form around series of spur dikes in an alluvial bed with continuous sediment motion. He used two different flumes, one 0.5m wide and the other 0.4m wide and uniform sand with diameter of 0.6mm. He also found that the local scour around the first spur dike is similar to that of a single spur dike and its depth depends on the flow depth H when H/B is smaller than 1.5.

Prof.Tominaga in year 1997 studied or investigated experimentally the flow and turbulent structures around spur dikes with various values of permeability. The experiments were conducted in an 8m long, 0.3m wide and 0.4m deep tilting flume. Three types of spur dikes were used. The first type is the solid type made of wood, the second one is the semi-porous type made of an gravel filled box frame and the third is the porous type made of only box frame.

Kuhnle in year 1997, 1998, and 1999 performed a series of experiments in a flume with 30 m length, 1.2 m width, and 0.6 m height to investigate the volume of scour holes associated with the spur dikes. By varying or changing the spur dike orientation angles, overtopping flow height and the contraction ratio, respectively. It was found that:

(1) The contraction ratio and flow depth are positively correlated with the volume of the scour for a given elapsed time under steady flow.

(2) The geometry of the scour hole has been shown to be get affected by the value of the overtopping ratio.

(3) For the three angles of spur dike and two contraction ratios being considered, 135^{o} spur dikes had the lowest value, 90^{o} spur dikes has an intermediate value and 45^{o} had the highest bed erosion in the vicinity of a channel bank. The volume of the scour hole was highest for the 135^{o} spur dikes

CHAPTER 3

THEORETICAL BACKGROUND

3.1 Scour: General

Scour means the eroding the earth material from a stable or unstable channel. The scour happens near the any hydraulic structures like spur dike, abutment approaching roads, bank of rivers and around any pier of bridge is important for hydraulics engineers.

3.2Contraction scour

The General scour is a decrement of the streambed across the flow stream bed at the spur. This decrement can be uniform across the bed or non-uniform across the bed, called as scour depth. General scour is can be results from contraction flow the Contraction scour happens when the flow area of a stream channel at a flood stage is decreased or contracted, or else by a natural reduction of stream channel or by plantation of spur dikes, a contraction in flow area results in increase in bed shear stress and average velocity through the contraction. Therefore, an increase in erosive forces in the contraction area and more bed and side material is displaced from the contracted area. As the elevation of bed is lowered, the area of flow increases for the stream and in that situation, the velocity and shear stress are decrease until relative equilibrium for stream has been reached. It means the quantity of scoured bed material that is transported into the area is equal to that removed from the contracted flow area, or the bed shear stress is decreased to a value such that zero sediment transported out of that area.

3.3 Local Scour

Local scour removes the material from around spurs, abutments, piers, and embankments. It is due to acceleration of flow and vortices caused by obstructions in the flow. Local scour can be either clear water or live bed scour. The basic mechanism behind local scour is the formation of vortices at the foundation of spur dike. The vortices results from the collision of water on the upstream surface of the obstruction and considerable acceleration of flow around the toe of the dike. The action of the vortex erodes bed material around the foundation of the obstruction. The rate of transport sediment near the foundation region is greater than the region away from the base region, consequently a scour hole is develops around the base of obstruction. As the depth of scour hole increases, the strength of the horseshoe vortex is decreased, thereby reducing the transport rate of sediment from the base region.

3.4 Clear Water And Live bed Scour

There are two conditions for the contraction and for the local scour, clear water and live bed scour. Clear water scour happens when there is zero movement of bed sediment in the flow.
A typical clear water scour situations includes that,
(1) Coarse bed material in streams,
(2) Flat gradient of the streams during low flow condition,
(3) Local deposits of bigger bed materials.
(4) The vegetated channels or bank areas.

CHAPTER 4

EXPERIMENTAL SETUP

The experiments were performed at Hydraulic Laboratory Delhi Technological University Delhi. A re circulating rectangular flume of length 6 meter, 0.33m width and 0.67m depth was used. A point gauge with a venire scale is attached by the flume and free to move horizontally with the bed of the flume. It is used for the dimension of scour hole and depth of water. Medium grained sand was used as the bed material with constant depth of 0.15meter. A centrifugal pump is used to re circulate the flow in the flume.

For the experimental purpose six different model of spur dike were tested in the flume in three different groups.in the above three groups the first group of model were installed by making 90° by the wll of the flume and the second group is fixed as to make 60° from the wall of the flume and the last group is installed to make 30° with the flume wall. For the controlling of discharge valves are provided in delivery pipe system. measured through the venture-meter is used to measure the discharge. The depth of flow was measured with the help of point gauge and flow alteration depth by the scale provided through the depth of the channel on its wall. A single spur dike is installed at the one side of the channel section of the rectangular flume as shown in Figure (4.1). The shape of the model dike is similar to the spur dike with contraction ratio 0.25. A uniform sediment layer of 15 cm thick is prepared and is spread along the length of the channel 1.8m as a test area along the channel length. The sand is slightly compacted and leveled by hand and we have to confirm that there is no leakage between the flume wall and the spur dike. A stopwatch is also ready for the calculation of flow time.

There are two different type of dike were used in the experiment.

(1) Normal spur dike.
(2) T shaped spur dike.

There are six model of two different type spur dike and both are placed in 5 different discharge and 3 different flow attacking angles (Θ=90°,Θ=60°,Θ=30°). Then for each case the seven parameters are studied with respect to the Froude number. The seven parameters are;

1. d_s = Maximum scour depth
2. L_{up} = Length of scour in u/s side
3. L_{down} = Length of scour in d/s side
4. L_y = Length of scour in y axis direction
5. Θ_{up} = Angle of scour in u/s
6. Θ_{down} = Angle of scour in d/s
7. Θ_y = Angle of scour in y axis direction

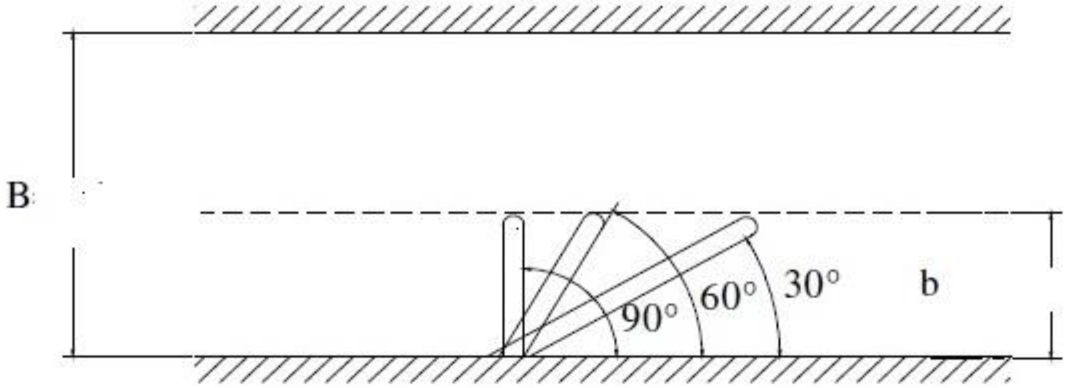

Figure 4.1 Normal dike placed at stream with different angle

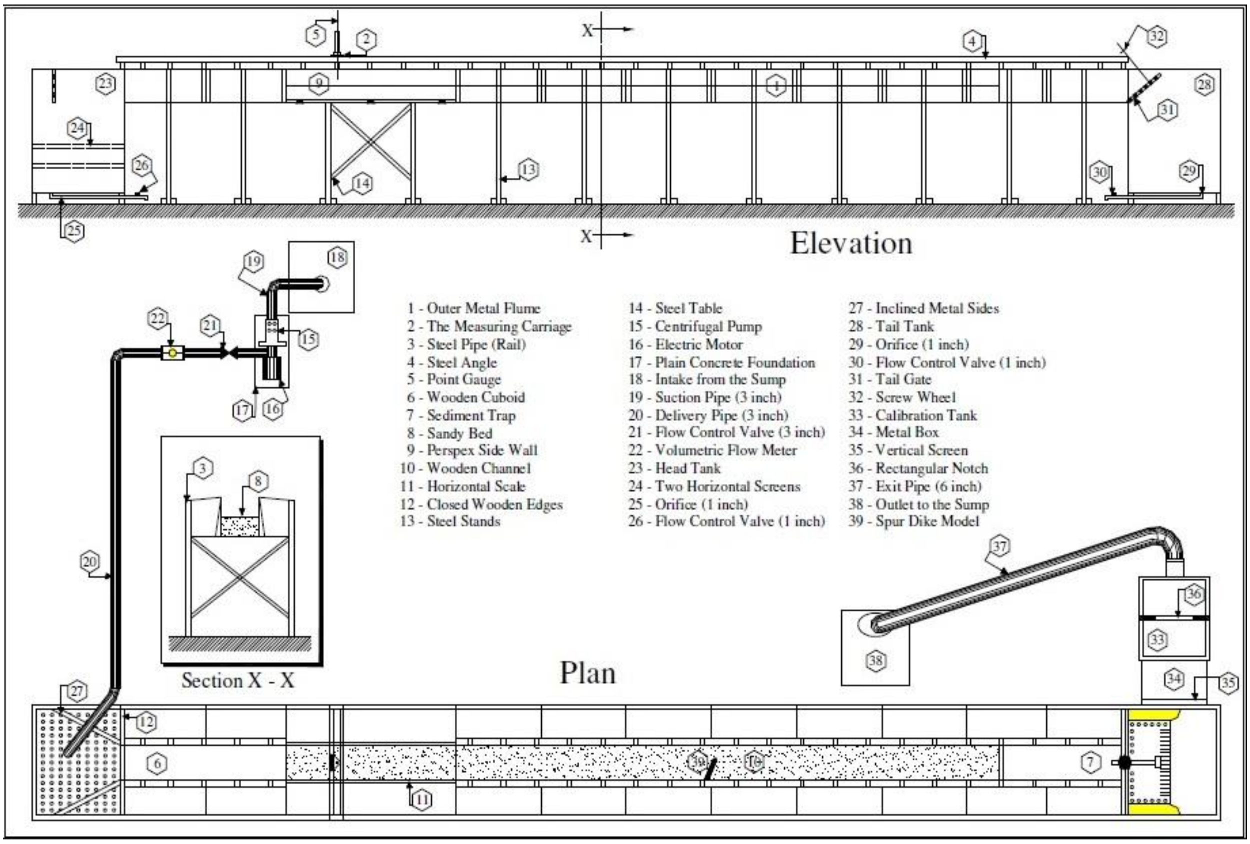

Figure 4.2 Scheme of experimental apparatus and circulating flume

Figure 4.3 normal spur dike before scouring (ϴ=90°).

Figure 4.4 Normal dike before scouring (ϴ=60°).

Figure 4.5 Normal spur dike before scouring (Ɵ=30°).

Figure 4.6 T shaped spur dike before scouring (ϴ=90°).

Figure 4.7 T shaped spur dike before scouring (ϴ=60°).

Figure 4.8 T shaped spur dike before scouring (ϴ=30°).

TEST PROCEDURE

As the all six models of spur dikes were tested in the hydraulic flume under different condition of flow at different angle of attack of flow. A normal dike was tested under three different conditions at five different discharge and constant flow depth.
T shape spur dike was also tested for same flow conditions.

The following procedure was followed to conduct each test:

1. The spur model was placed in the test area of our study reach and the spur is fixed well to prevent any lateral movement.

2. The bed material was leveled properly with the help of leveler to insure that the bed have flatter surface with the same elevation at every point of test area.

3. First, the discharge at very low rate is filled in the flume so that any disturbance of bed material takes place due to the turbulence or the condition should be steady and uniform for the experiment and a tail gate was kept closed in the starting of run then it can be adjusted upto the condition requirement.

4. The required condition of discharge was allowed to run gradually until constant value of required condition of discharge reaches.

5. The tail gate was lowered gently until the required water depth condition reaches.

6. The time is recorded properly for every run of required flow condition.

7. After the flow run in flume for a specific time period, the flow discharge is stopped then the water is dried gently so that there is no movement of sand particles and then the measurement of scour hole is done properly.

8. Repeat above seven steps for different shapes of spurs at different orientation and for different discharge.

CHAPTER 5

EXPERIMENTAL RESULT

The test results are prepared in the form of table with respect to three different attacking angles and a constant contraction ratio. The results in the form of table are listed below;

Table 5.1 Readings of normal spur dike (ϴ=90°)

ϴ	e	Fr no	d_s/b	L_{up}/b	L_{down}/b	L_y/b	$ϴ_{up}$	$ϴ_{down}$	$ϴ_y$
90	25%	0.388	0.387	0.680	1.227	0.813	29.62	17.50	25.43
		0.614	0.613	0.933	1.600	1.000	33.30	20.97	31.52
		0.726	0.653	1.120	1.680	1.053	30.25	21.25	31.82
		0.776	0.720	1.373	1.893	1.093	27.67	20.82	33.37
		0.868	0.813	1.560	2.013	1.253	27.54	21.99	32.98

Table 5.2 Readings of Normal spur dike (ϴ=60°)

ϴ°	e	Fr no	d_s/b	L_{up}/b	L_{down}/b	L_y/b	$ϴ°_{up}$	$ϴ°_{down}$	$ϴ°_y$
60	25%	0.388	0.413	1.040	1.560	1.053	21.67	14.84	21.42
		0.614	0.747	1.533	2.267	1.400	25.96	18.23	28.47
		0.726	0.786	1.693	2.360	1.440	24.92	18.44	28.65
		0.776	0.840	1.853	2.547	1.480	24.38	18.25	29.58
		0.868	1.040	1.947	2.853	1.560	28.11	20.02	33.69

Table 5.3 Readings of normal spur dike (ϴ=30°)

ϴ°	e	Fr no	d_s/b	L_{up}/b	L_{down}/b	L_y/b	$ϴ°_{up}$	$ϴ°_{down}$	$ϴ°_y$
30	25%	0.388	0.280	1.013	2.227	0.853	15.14	7.16	18.17
		0.614	0.427	1.333	3.200	1.067	17.17	7.59	21.80
		0.726	0.467	1.427	3.446	1.120	18.11	7.72	22.62
		0.776	0.520	1.493	3.707	1.187	19.20	7.98	23.66
		0.868	0.626	1.746	4.027	1.293	19.74	8.86	25.85

Figure 5.1 Normal spur dike after scouring occurs (ϴ=90°)

Figure 5.2 Normal spur dike after scour occurs (ϴ=60°)

Figure 5.3 Normal spur dike after scour occurs (ϴ=30°)

Table 5.4 Readings of T shaped spur dike (ϴ=90°)

ϴ°	e	Fr no	d_s/b	L_{up}/b	L_{down}/b	L_y/b	$ϴ°_{up}$	$ϴ°_{down}$	$ϴ°_y$
90°	25%	0.388	0.413	0.653	0.760	0.493	33.32	28.54	39.96
		0.614	0.666	1.333	1.730	0.866	26.52	21.04	37.57
		0.726	0.946	1.493	1.880	0.973	32.37	26.72	44.20
		0.776	1.053	1.586	2.000	1.066	33.58	27.27	44.64
		0.868	1.133	1.746	2.160	1.160	32.98	27.68	44.33

Table 5.5 Readings of T shaped spur dike (ϴ=60°)

ϴ°	e	Fr no	d_s/b	L_{up}/b	L_{down}/b	L_y/b	$ϴ°_{up}$	$ϴ°_{down}$	$ϴ°_y$
60°	25%	0.388	0.400	1.080	1.293	0.946	20.32	17.18	23.00
		0.614	0.533	1.533	1.800	1.333	19.18	16.50	21.80
		0.726	0.826	1.586	1.960	1.426	28.98	22.86	30.09
		0.776	0.933	1.693	2.080	1.520	28.86	24.17	31.55
		0.868	9.986	1.786	2.240	1.610	28.91	23.77	31.45

Table 5.6 Readings of T shaped spur dike (ϴ=30°)

ϴ°	e	Fr no	d_s/b	L_{up}/b	L_{down}/b	L_y/b	$ϴ°_{up}$	$ϴ°_{down}$	$ϴ°_y$
30°	25%	0.388	0.146	0.626	1.640	0.693	13.17	5.11	11.94
		0.614	0.280	0.933	2.466	1.133	16.70	6.48	13.88
		0.726	0.373	1.040	2.560	1.186	19.75	8.30	17.46
		0.776	0.426	1.093	2.893	1.293	21.32	8.39	18.25
		0.868	0.520	1.186	3.173	1.386	23.66	9.31	20.56

Figure 5.4 T shaped spur dike after scour occurs (ϴ=90°)

Figure 5.5 T shaped spur dike after scour occurs (Ө=60°)

Figure 5.6 T shaped spur dike after scour occurs (ϴ=30°)

There are two different type of spur dikes were tested for local scouring around the base of the dikes. By observation of scour hole dimension from figure (5.1) to figure (5.6) and by observing the experimental observations from table (5.1) to table (5.6) we can say .

1. The slope of the scour hole in the upstream direction is steeper and the slope in the downstream direction is milder. The reason of difference between the slopes in upstream and downstream direction is high turbulence and high flow energy in upstream direction as compare to downstream direction.

2. For normal dike the maximum scour occurs near the nose of the spur dike and for T shaped dike the maximum scour occurs in the downstream side from the nose of the dike.

3. The shape of scour hole is like inverted cone and the crown of the cone is near the tip of spur dike.

4. The downstream slope of scour hole is about 50% of the upstream side slope by the magnitude. For normal dikes the average slope of scour hole in upstream direction is about 30° and for the downstream side the value is about 15°.

5. The length of scour hole in the upstream direction is about two times of the length of spur dike and the length of scour hole in the downstream direction is about three to four times of the length of spur dike.

6. The length of scour hole in the transverse direction is approximately same for all type of spur dike and the increment in the length of transverse scour hole due to increase in the Froud number is very less.

7. The upstream scour hole length is about two times the maximum depth of scour hole (ds), and the length of downstream scour hole is about four times of the maximum scour hole depth.

CHAPTER 6

RESULTS AND DISCUSSION

For the analysis of the results shown in the form of tables in chapter 5 we have to draw graphs between dimensional factors (Maximum scour depth, Length of scour in u/s side, Length of scour in d/s side, Length of scour in y axis direction, Angle of scour in u/s, Down, Angle of scour in d/s, Angle of scour in y axis direction) and Froude number and see the effects of all parameters separately.

Analysis of result for Normal spur dike for attacking angle 30°

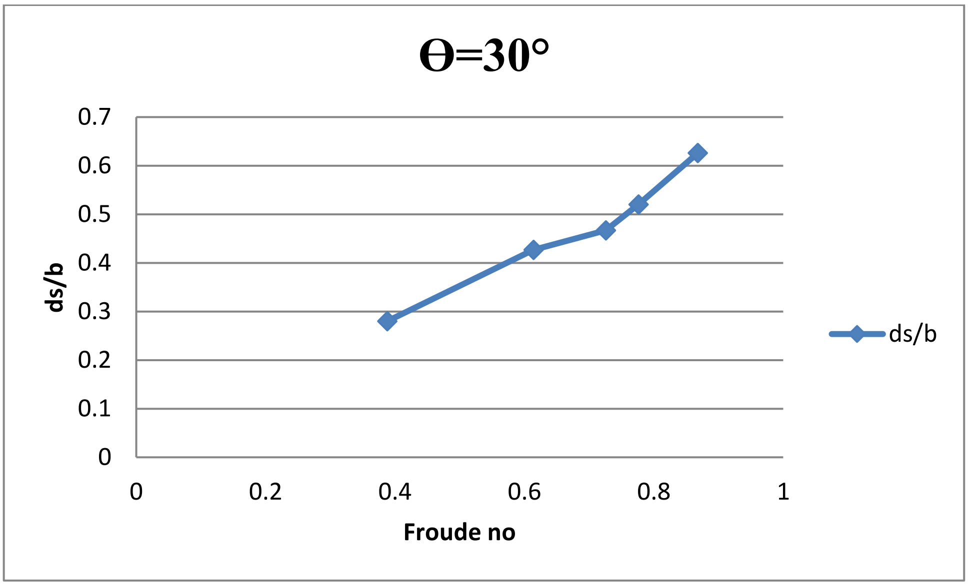

Fig no.(6.1) Graph between ratio of scour depth and length of dike with Froude number for normal dike at ϴ = 30°

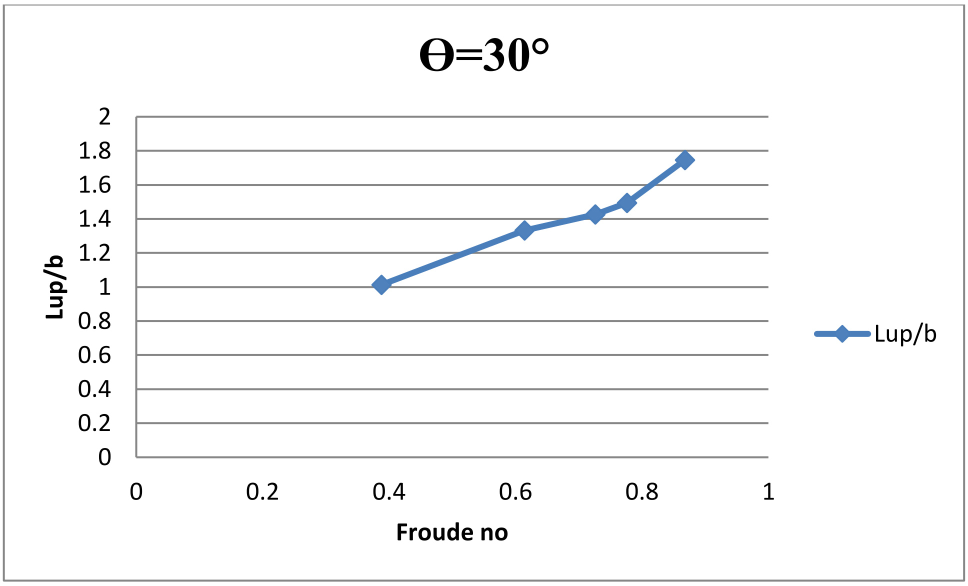

Fig no.(6.2) Graph between ratio of upstream scour length and length of dike with Froude number for normal dike at ϴ = 30°

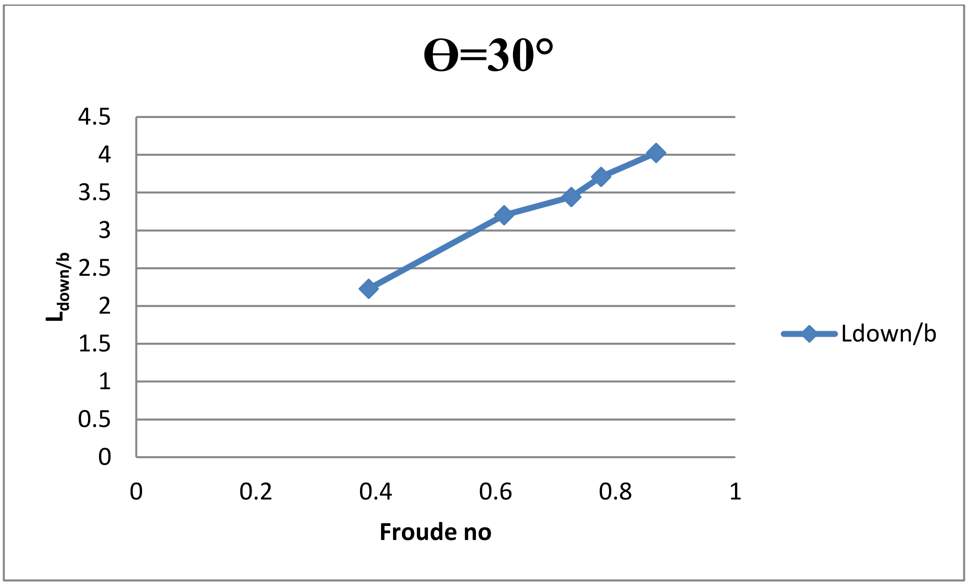

Fig no.(6.3) Graph between ratio of downstream scour length and length of dike with Froude number for normal dike at Ө = 30°

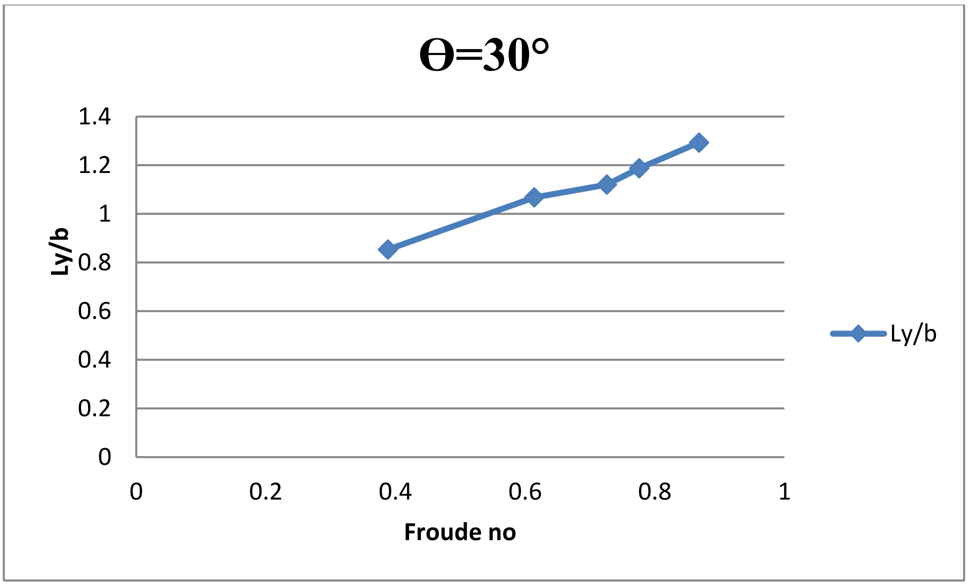

Fig no.(6.4) Graph between ratio of transverse scour length and length of dike with Froude number for normal dike at Ө = 30°

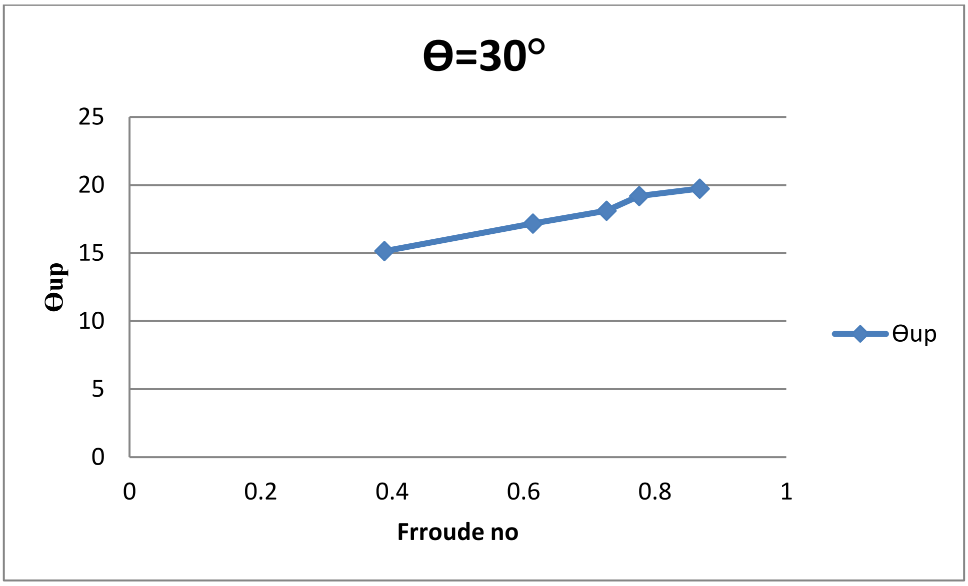

Fig no.(6.5) Graph between upstream scour angle with Froude number for normal dike at ϴ = 30°

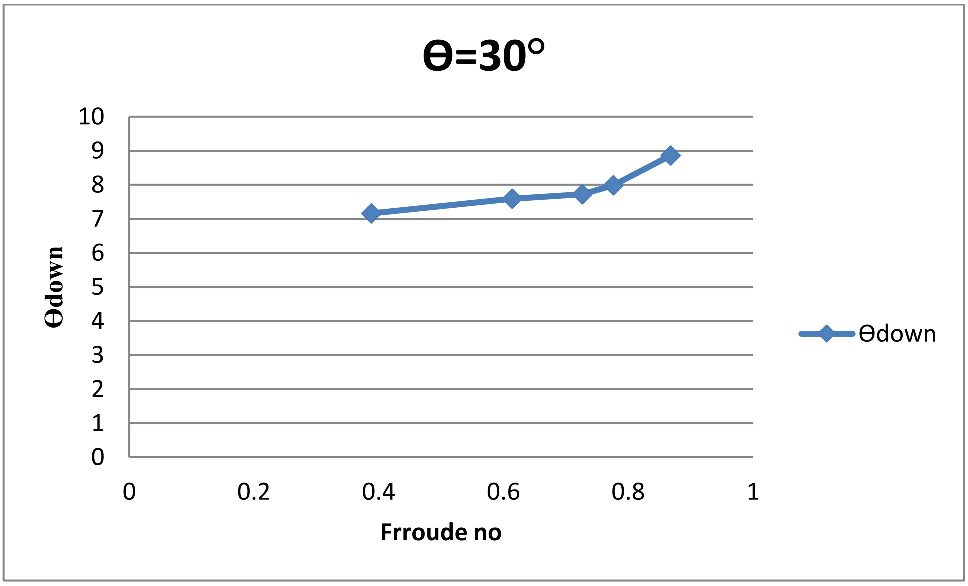

Fig no.(6.6) Graph between downstream scour angle with Froude number for normal dike at ϴ = 30°

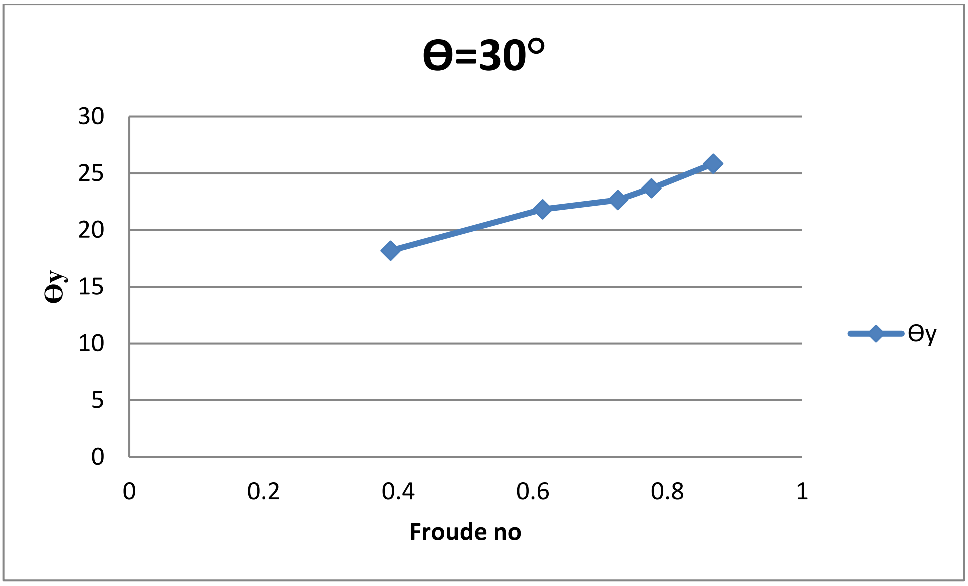

Fig no.(6.7) Graph between transverse scour angle with Froude number for normal dike at ϴ = 30°

<u>Analysis of result for Normal spur dike for attacking angle 60°</u>

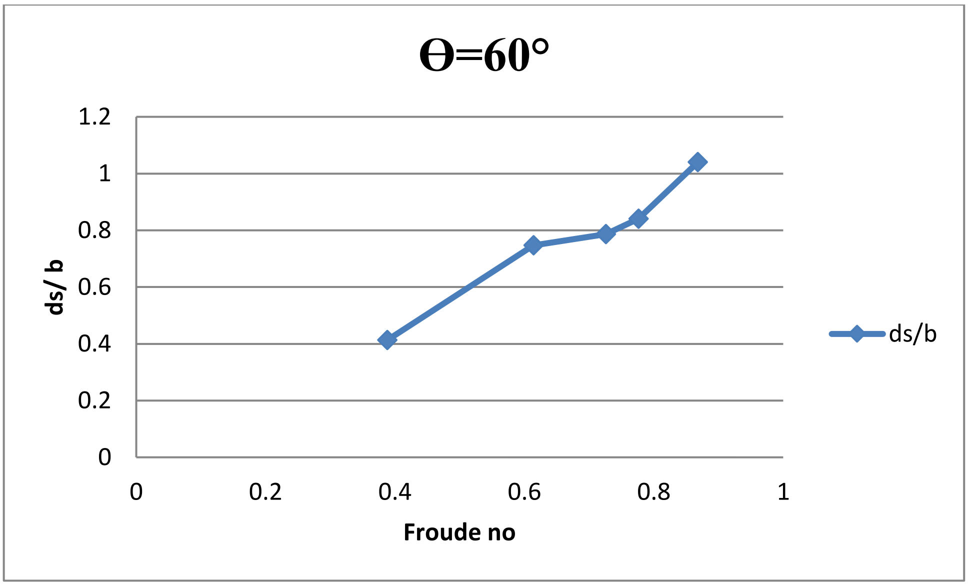

Fig no.(6.8) Graph between ratio of scour depth and length of dike with Froude number for normal dike at ϴ = 60°

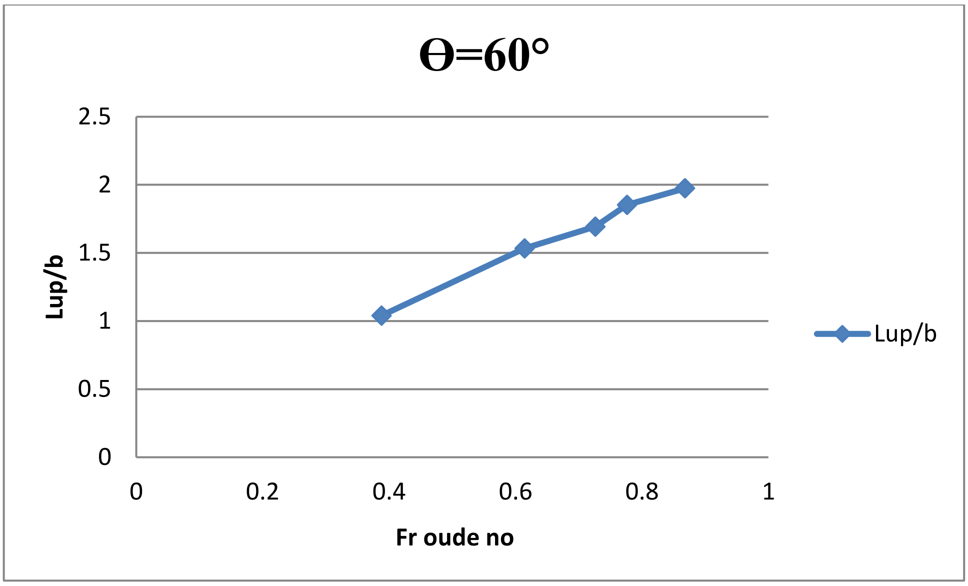

Fig no.(6.9) Graph between ratio of upstream scour length and length of dike with Froude number for normal dike at ϴ = 60°

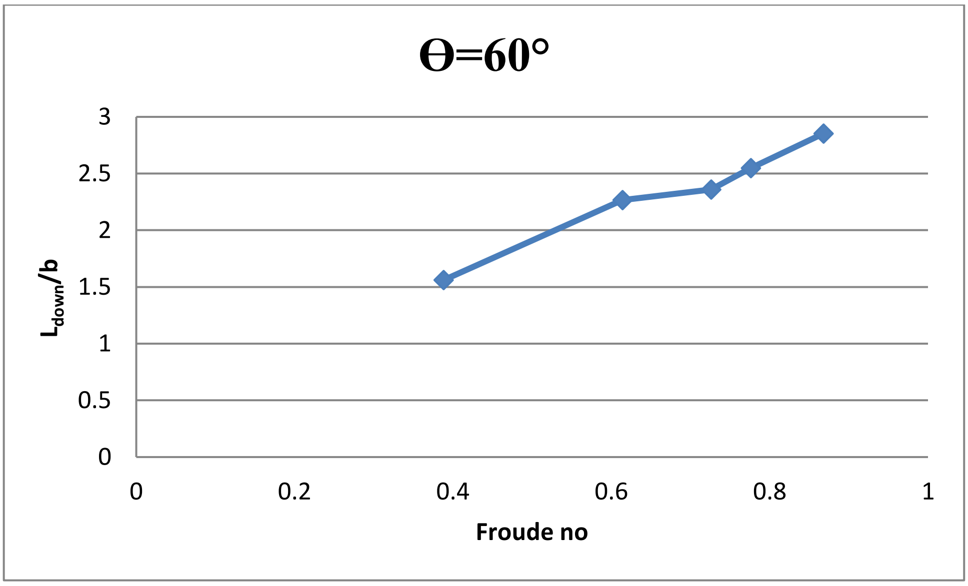

Fig no.(6.10) Graph between ratio of downstream scour length and length of dike with Froude number for normal dike at ϴ = 60°

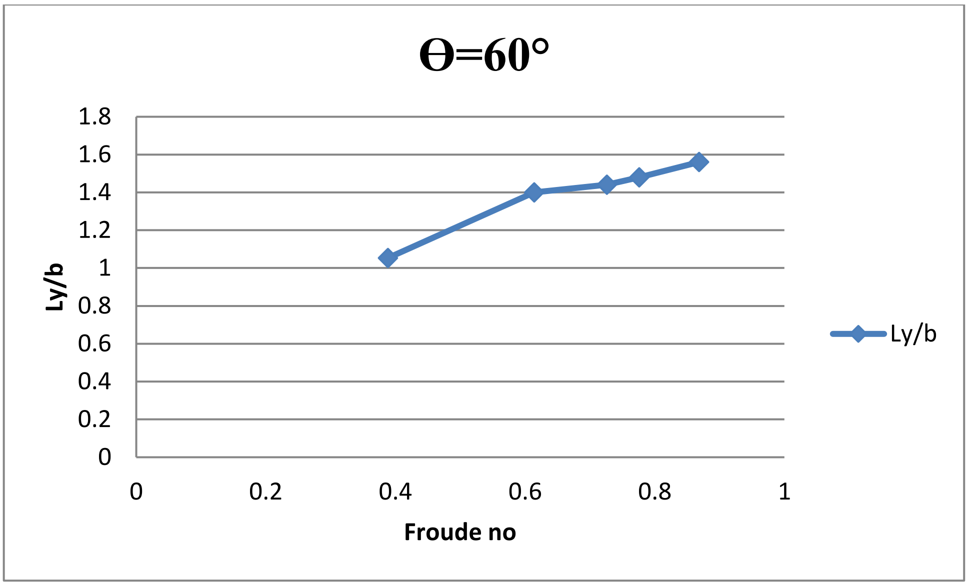

Fig no.(6.11) Graph between ratio of transverse scour length and length of dike with Froude number for normal dike at Ɵ = 60°

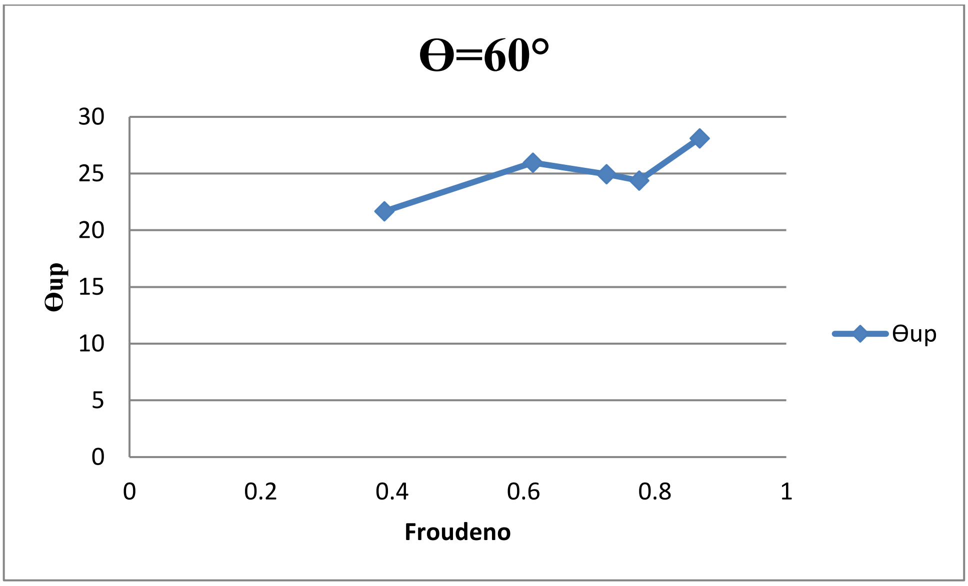

Fig no.(6.12) Graph between upstream scour angle with Froude number for normal dike at Ɵ = 60°

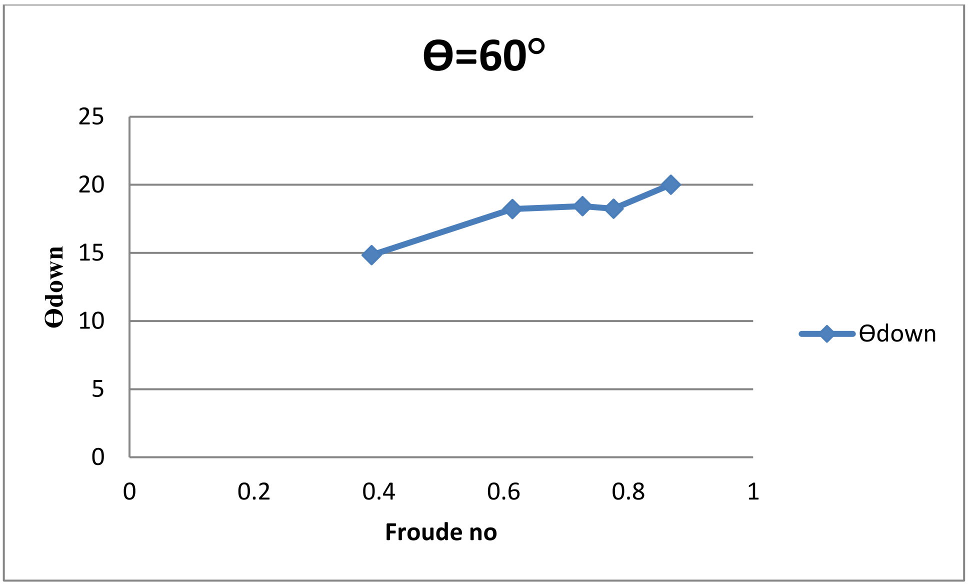

Fig no.(6.13) Graph between downstream scour angle with Froude number for normal dike at ϴ = 60°

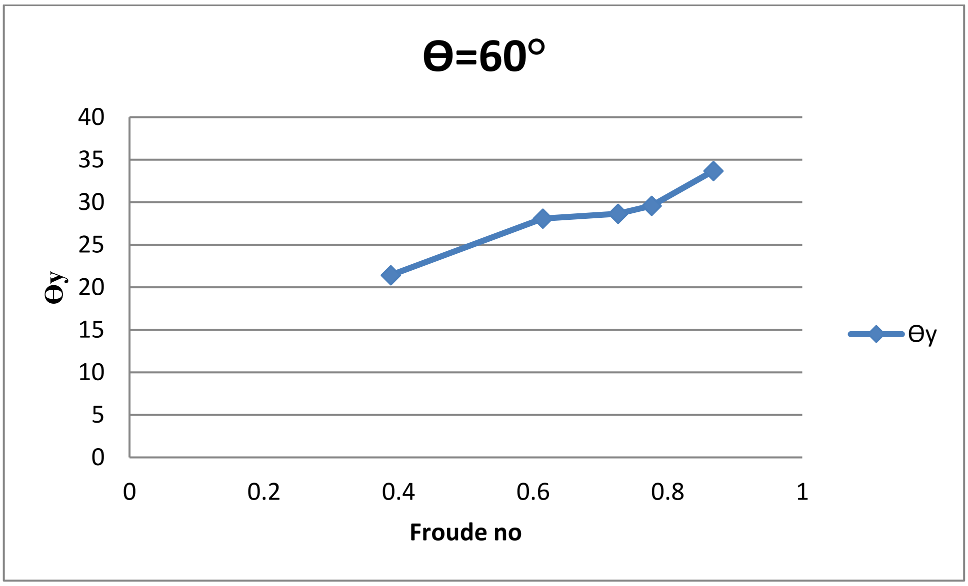

Fig no.(6.14) Graph between transverse scour angle with Froude number for normal dike at ϴ = 60°

Analysis of result for Normal spur dike for attacking angle 90°

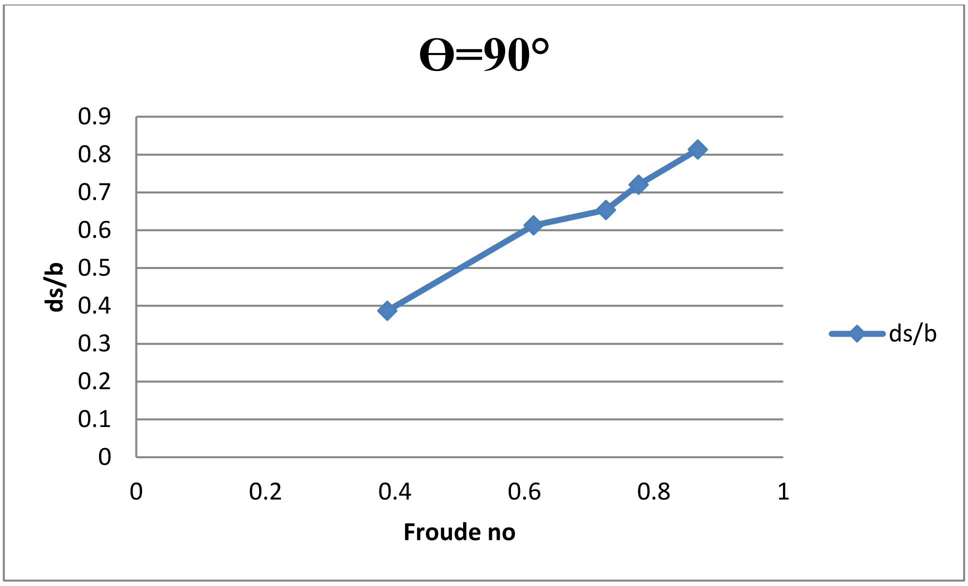

Fig no.(6.15) Graph between ratio of scour depth and length of dike with Froude number for normal dike at ϴ = 90°

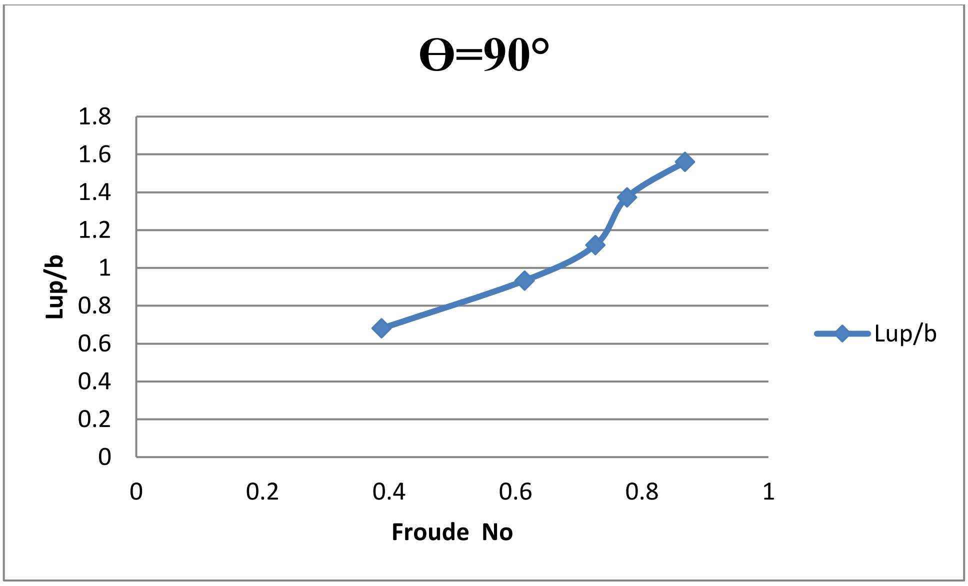

Fig no.(6.16) Graph between ratio of upstream scour length and length of dike with Froude number for normal dike at ϴ = 90°

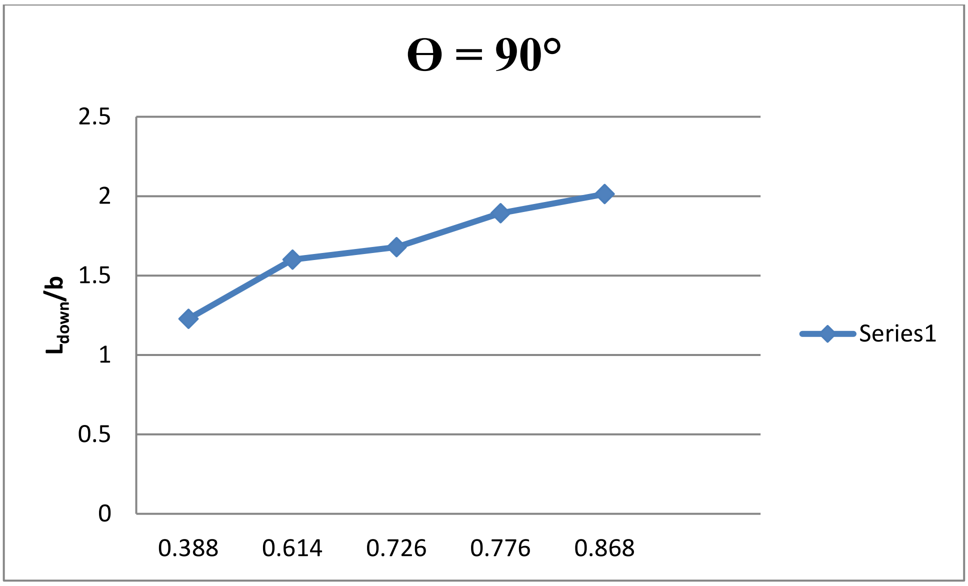

Fig no.(6.17) Graph between ratio of downstream scour length and length of dike with Froude number for normal dike at ϴ = 90°

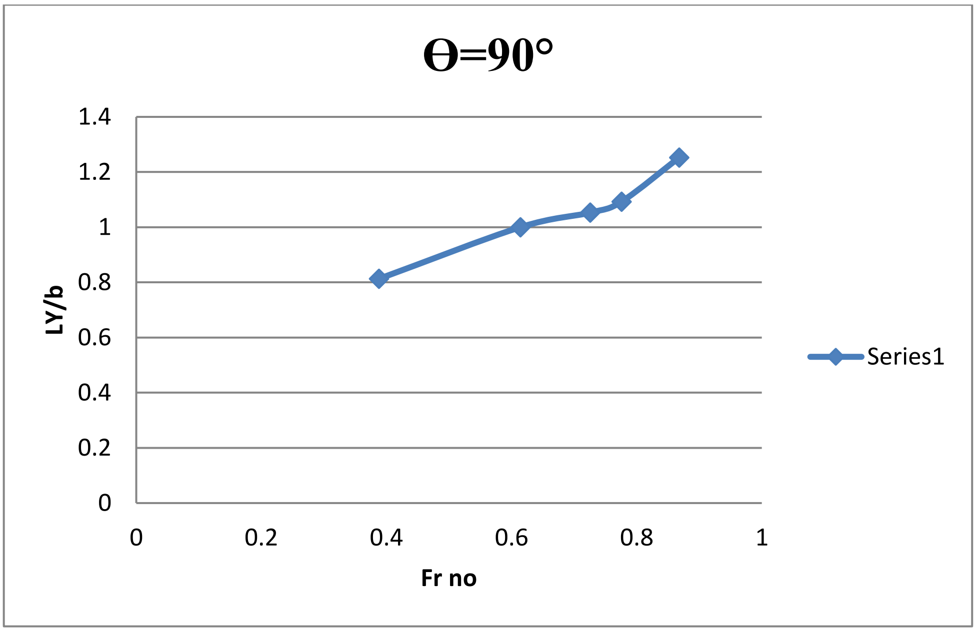

Fig no.(6.18) Graph between ratio of transverse scour length and length of dike with Froude number for normal dike at ϴ = 90°

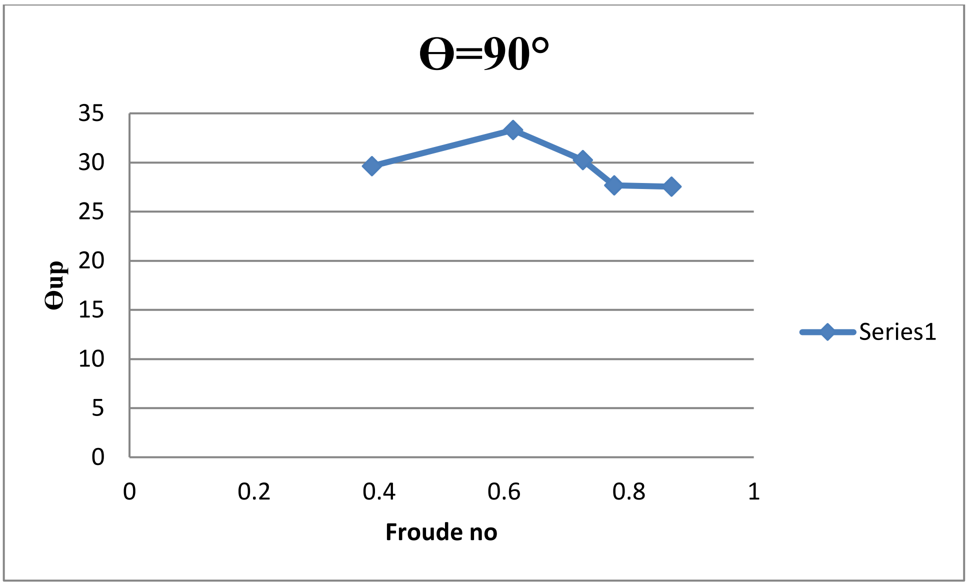

Fig no.(6.19) Graph between upstream scour angle with Froude number for normal dike at ϴ = 90°

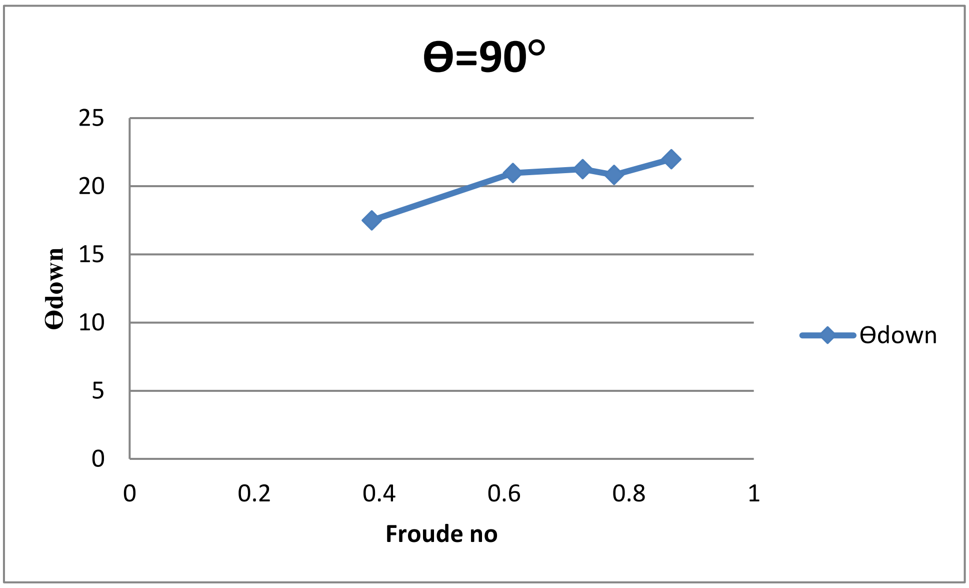

Fig no.(6.20) Graph between downstream scour angle with Froude number for normal dike at ϴ = 90°

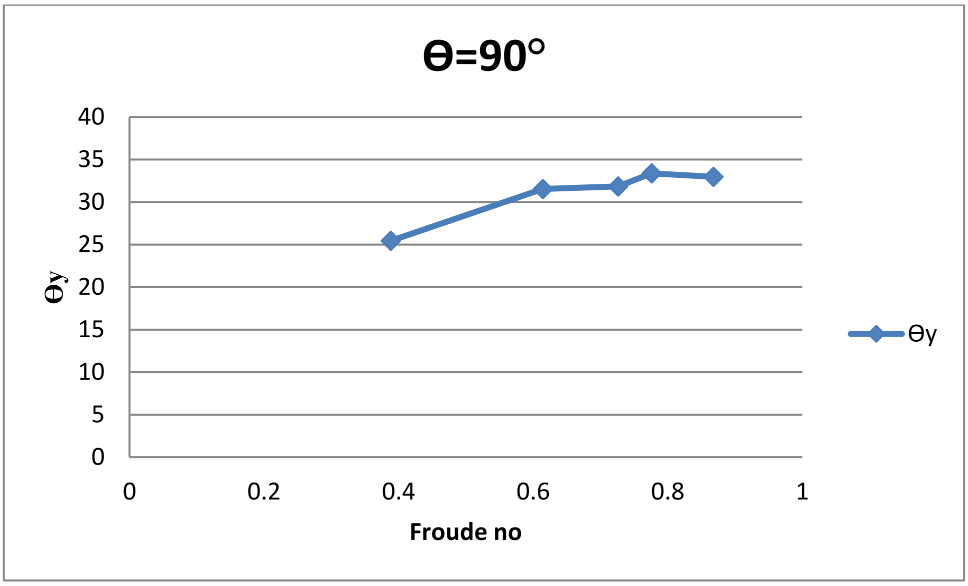

Fig no.(6.21) Graph between transverse scour angle with Froude number for normal dike at ϴ = 90°

- For attacking angle 30° slope are milder of L_{up} L_{down} and Ly. And as the slope is milder it means that the change in length of scour is relatively slow with respect to change in Froude number.
- For Froude number less than 0.726 the value of slopes of scour hole in upstream and downstream direction are not much dependent on the change with Froude number for normal dike.
- The value of maximum scour is directly proportional with change in Froude number.

Analysis of result for T shaped spur dike for attacking angle 30°

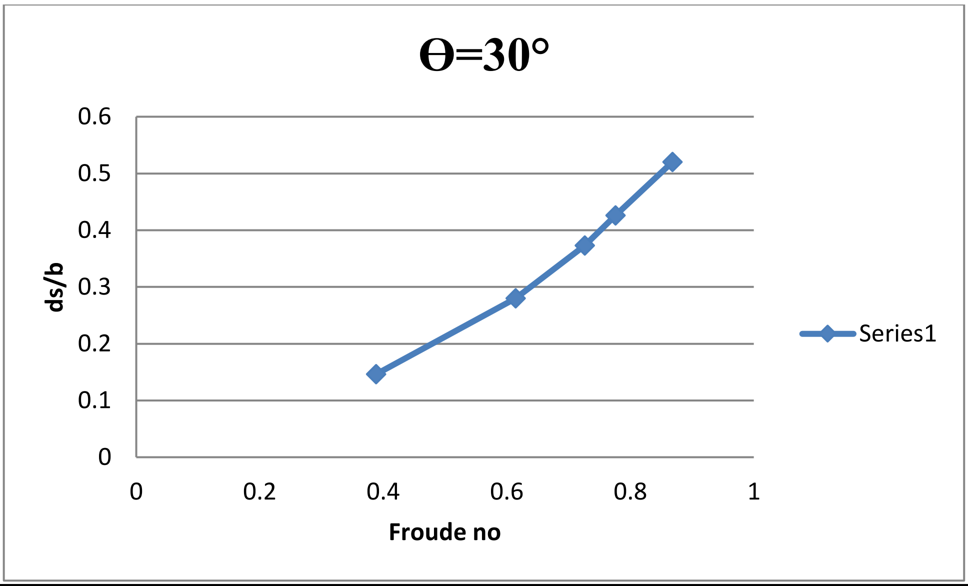

Fig no.(6.22) Graph between ratio of scour depth and length of dike with Froude number for T shaped dike at ϴ = 30°

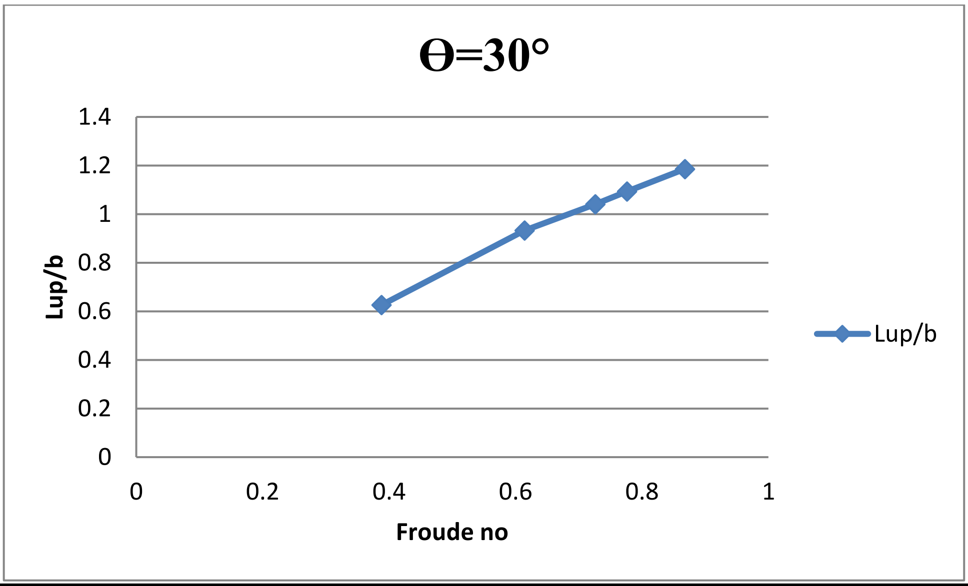

Fig no.(6.23) Graph between ratio of upstream scour length and length of dike with Froude number for T shaped dike at ϴ = 30°

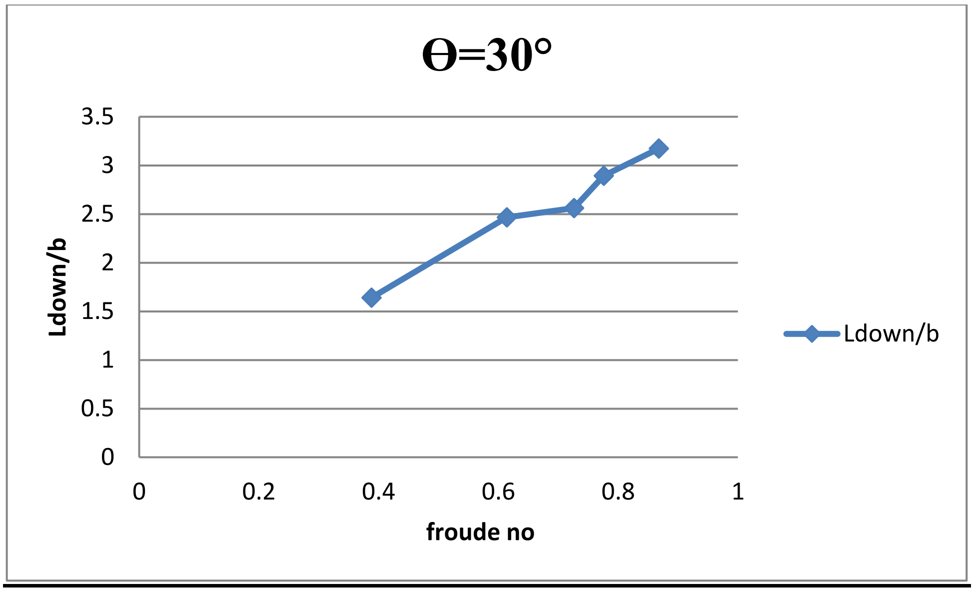

Fig no.(6.24) Graph between ratio of downstream scour length and length of dike with Froude number for T shaped dike at ϴ = 30°

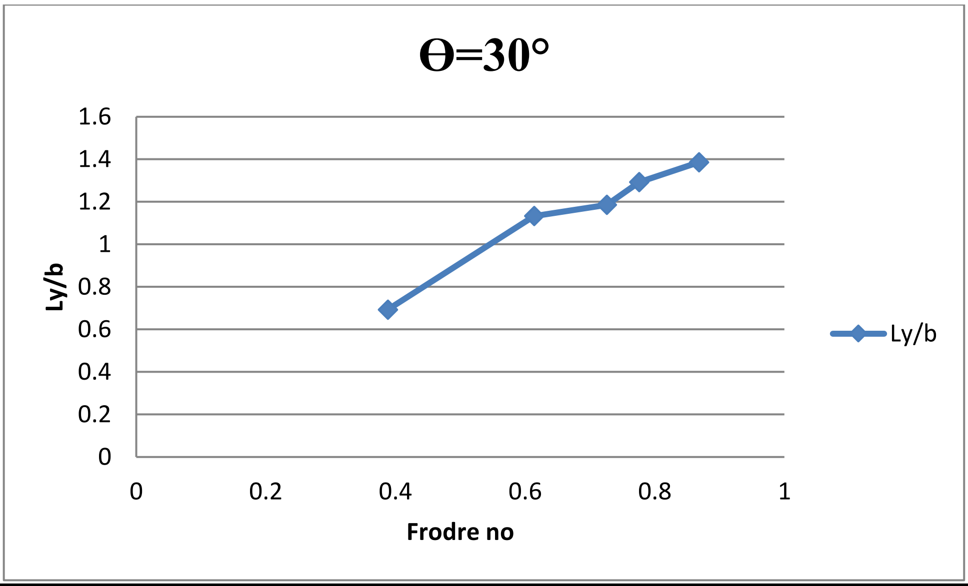

Fig no.(6.25) Graph between ratio of transverse scour length and length of dike with Froude number for T shaped dike at ϴ = 30°

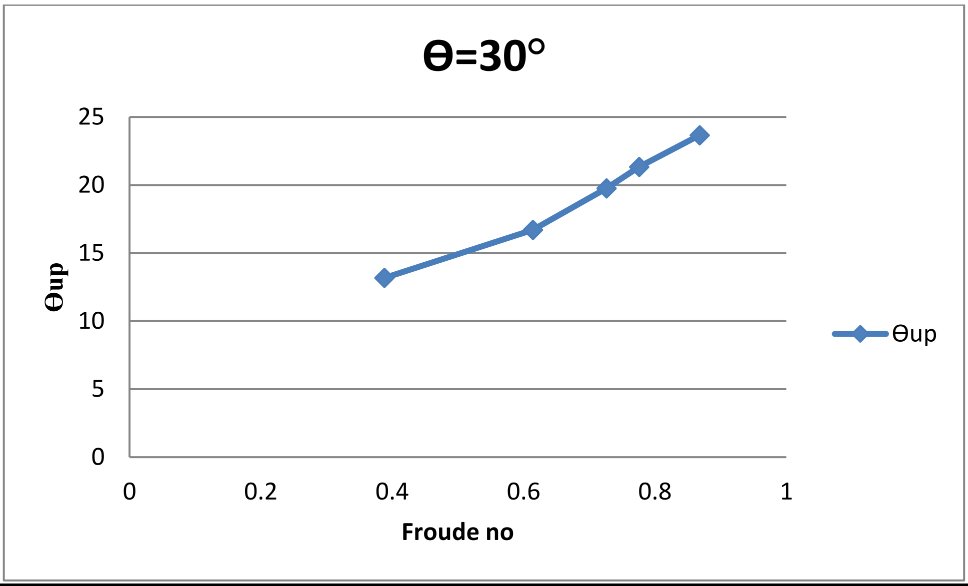

Fig no.(6.26) Graph between upstream scour angle with Froude number for T shaped dike at ϴ = 30°

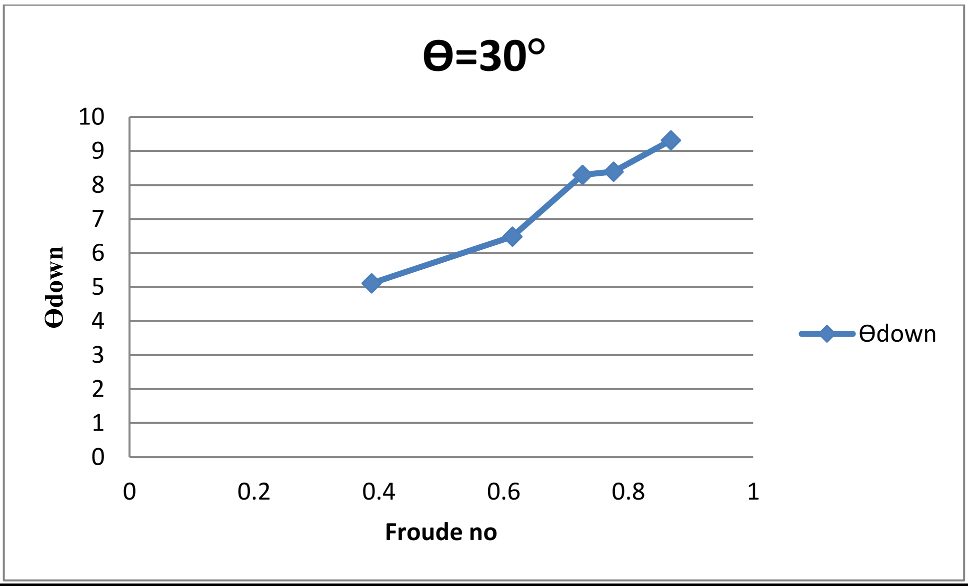

Fig no.(6.27) Graph between downstream scour angle with Froude number for normal dike at ϴ = 30°

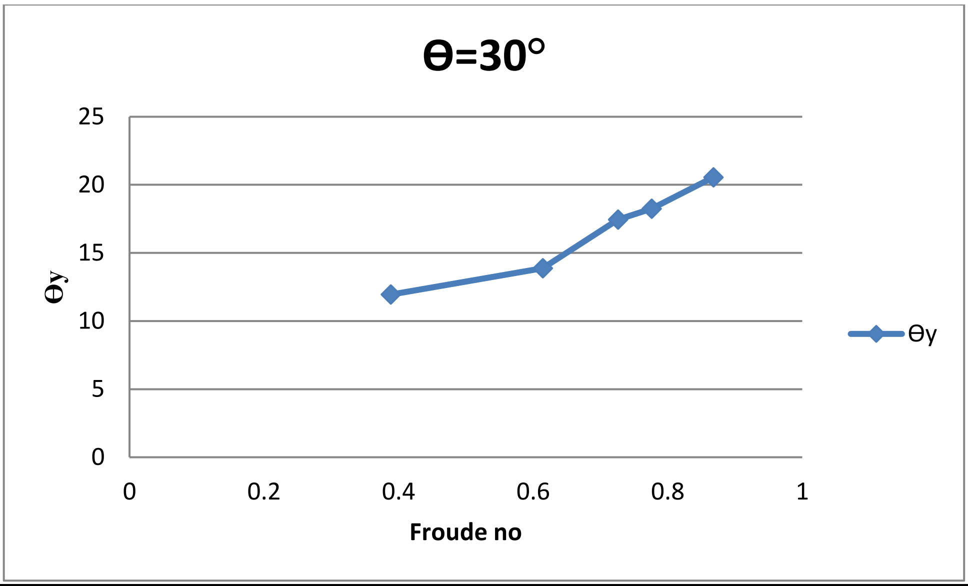

Fig no.(6.28) Graph between transverse scour angle with Froude number for normal dike at ϴ = 30°

Analysis of result for T shaped spur dike for attacking angle 60°

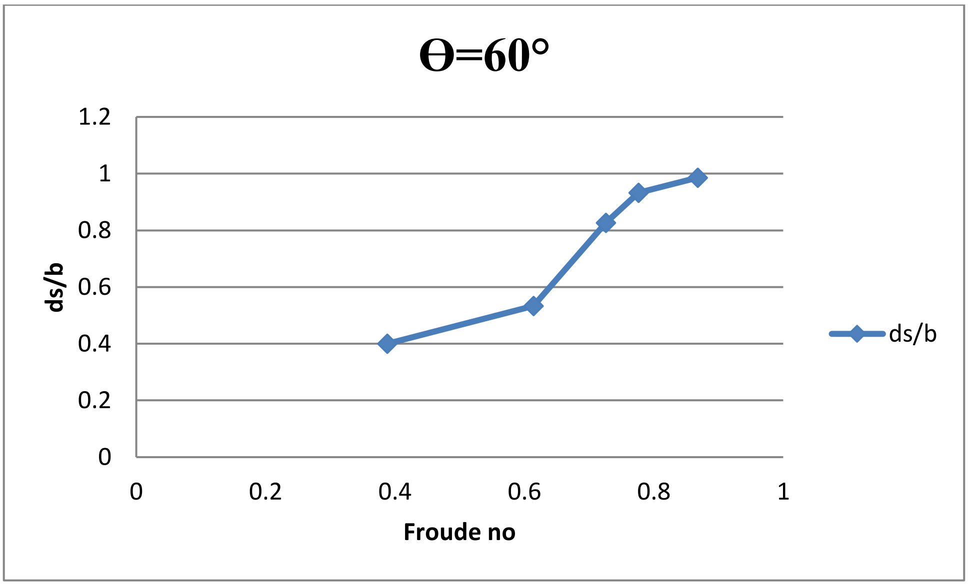

Fig no.(6.29) Graph between ratio of scour depth and length of dike with Froude number for T shaped dike at ϴ = 60°

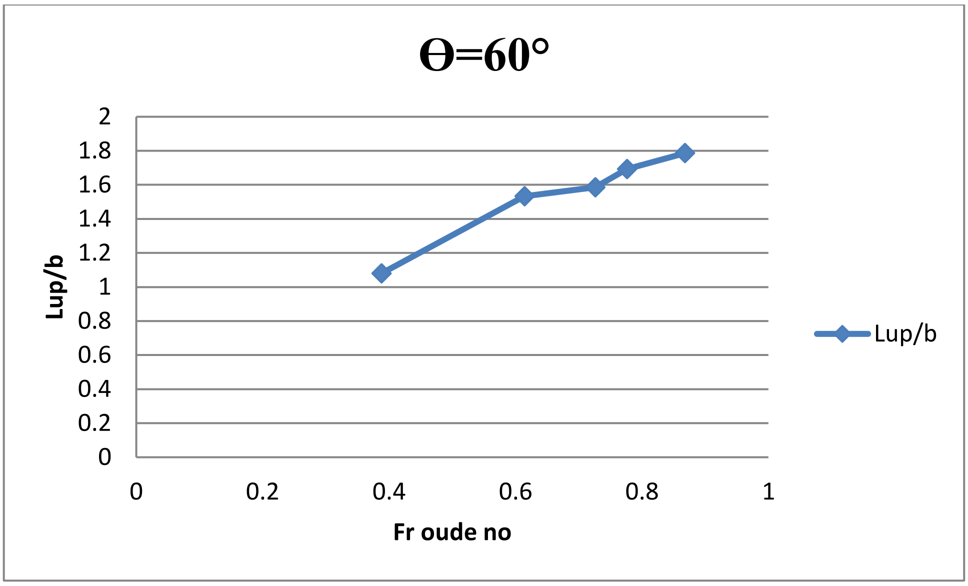

Fig no.(6.30) Graph between ratio of upstream scour length and length of dike with Froude number for T shaped dike at ϴ = 60°

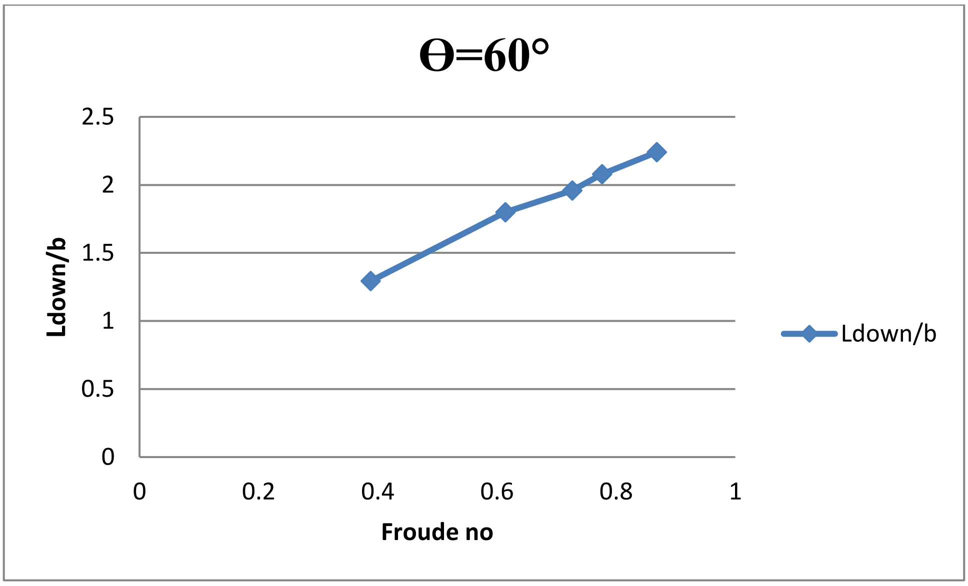

Fig no.(6.31) Graph between ratio of downstream scour length and length of dike with Froude number for T shaped dike at ϴ = 60°

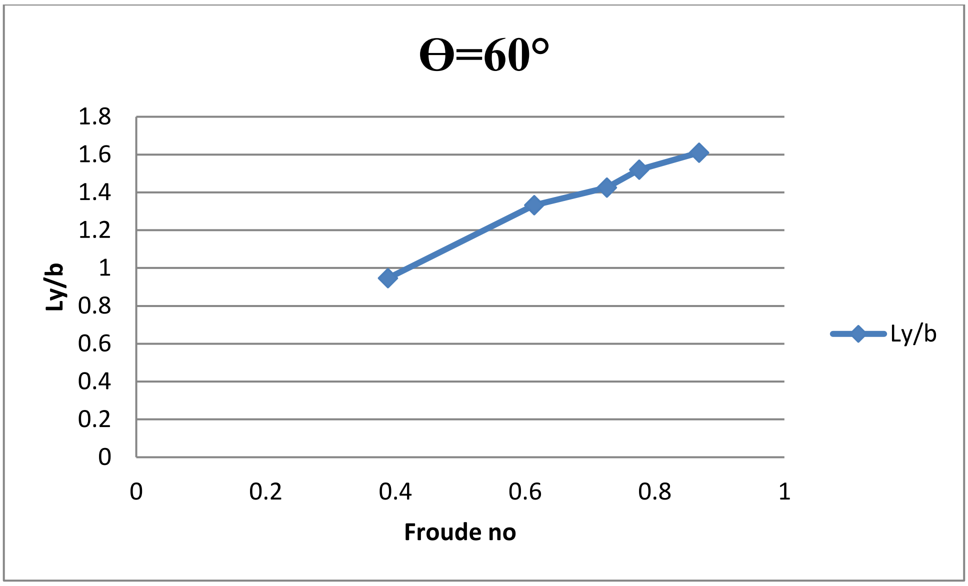

Fig no.(6.32) Graph between ratio of transverse scour length and length of dike with Froude number for T shaped dike at Ө = 60°

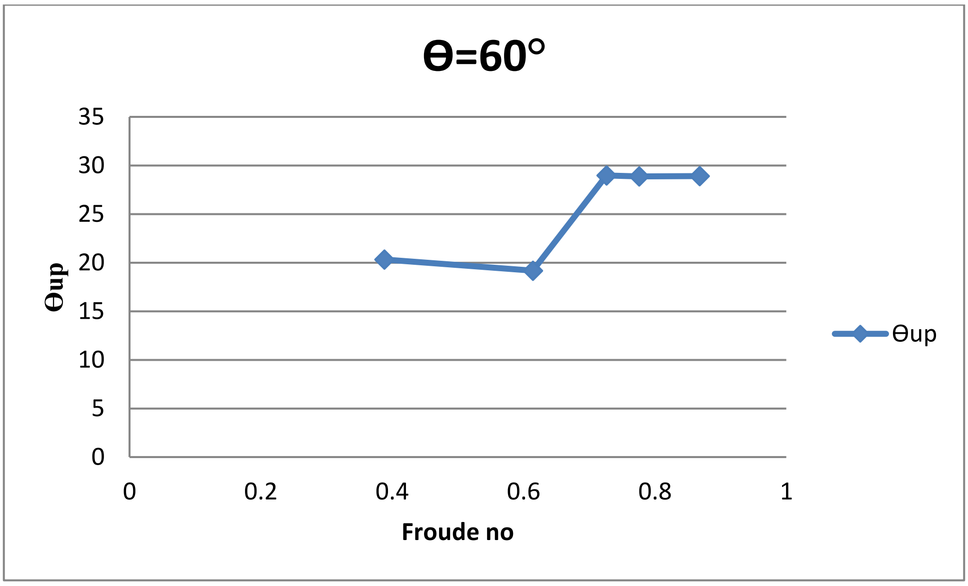

Fig no.(6.33) Graph between upstream scour angle with Froude number for T shaped dike at Ө = 60°

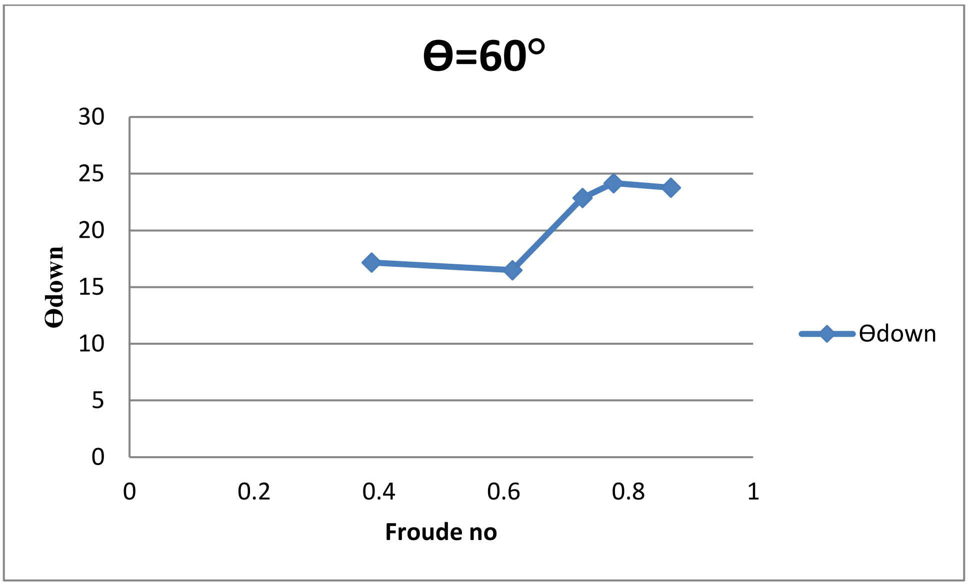

Fig no.(6.34) Graph between downstream scour angle with Froude number for T shaped dike at ϴ = 60°

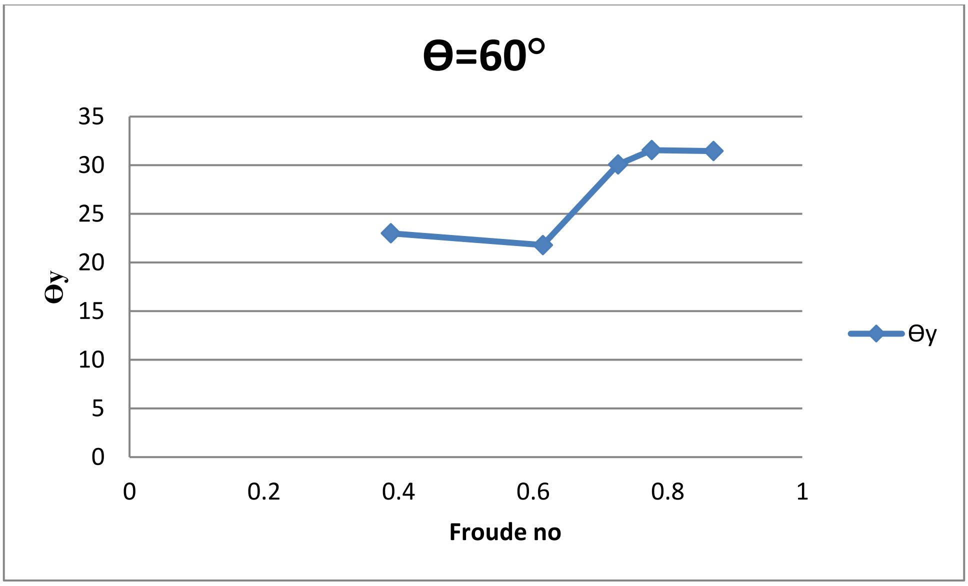

Fig no.(6.35) Graph between transverse scour angle with Froude number for T shaped dike at ϴ = 60°

<u>Analysis of result for T shaped spur dike for attacking angle 90°</u>

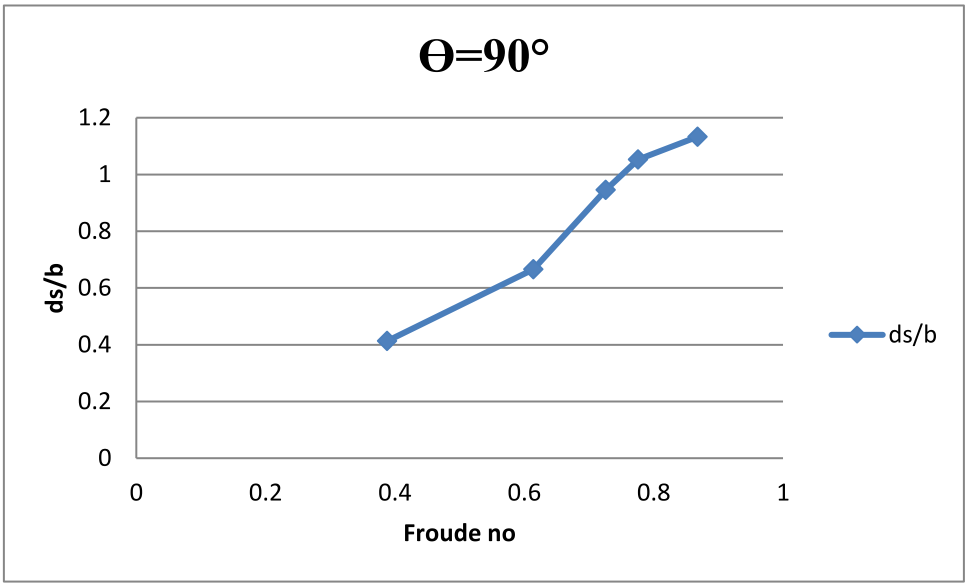

Fig no.(6.36) Graph between ratio of scour depth and length of dike with Froude number for T shaped dike at ϴ = 90°

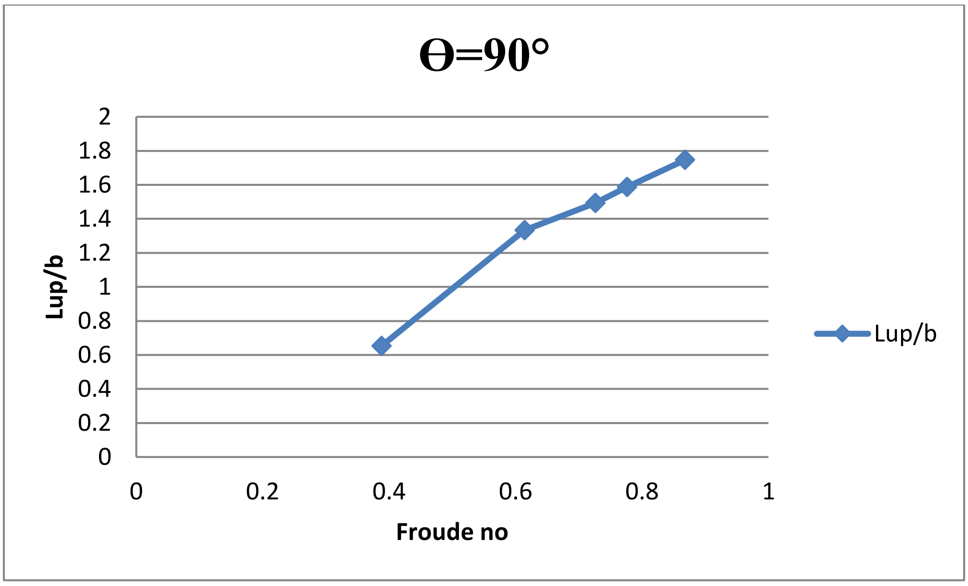

Fig no.(6.37) Graph between ratio of upstream scour length and length of dike with Froude number for T shaped dike at ϴ = 90°

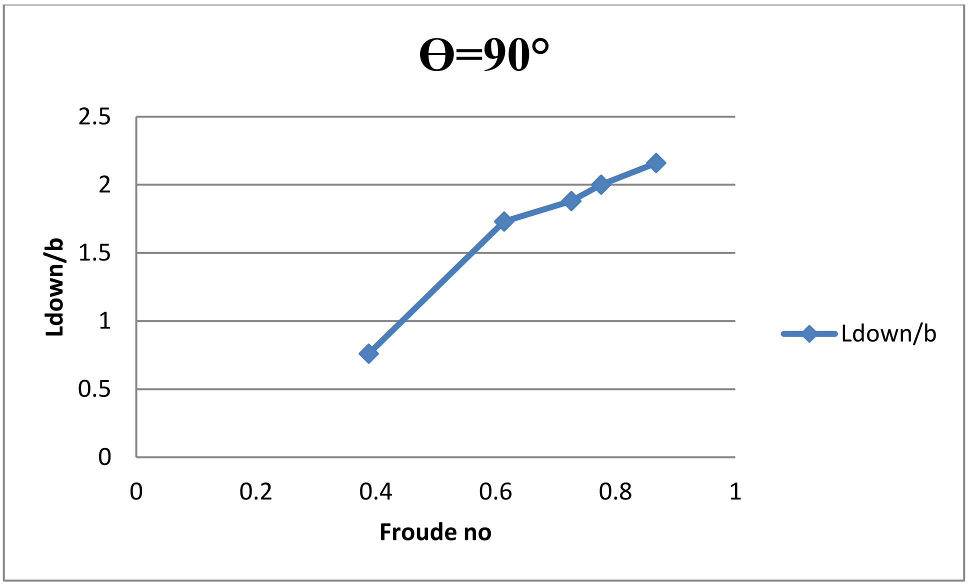

Fig no.(6.38) Graph between ratio of downstream scour length and length of dike with Froude number for T shaped dike at ϴ = 90°

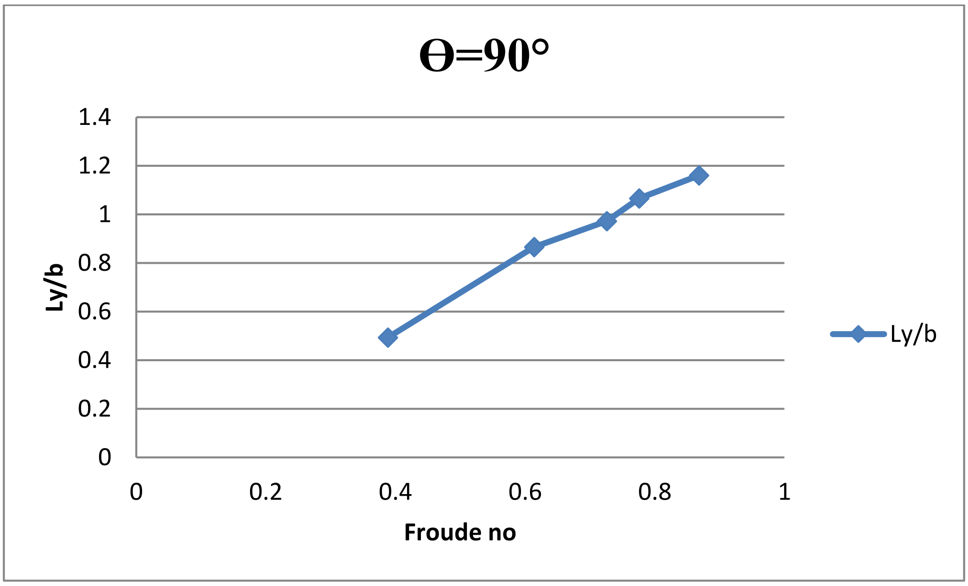

Fig no.(6.39) Graph between ratio of transverse scour length and length of dike with Froude number for T shaped dike at ϴ = 90°

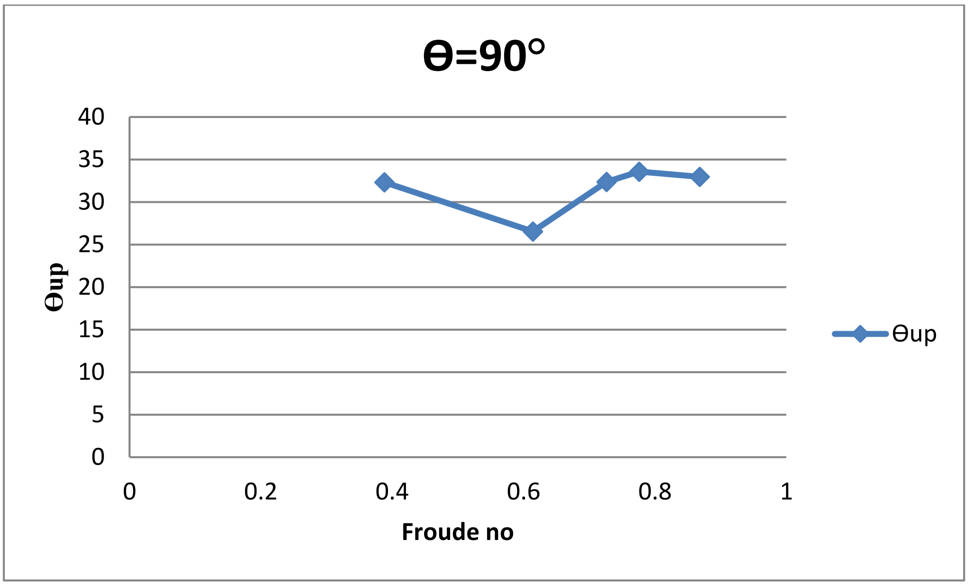

Fig no.(6.40) Graph between upstream scour angle with Froude number for T shaped dike at ϴ = 90°

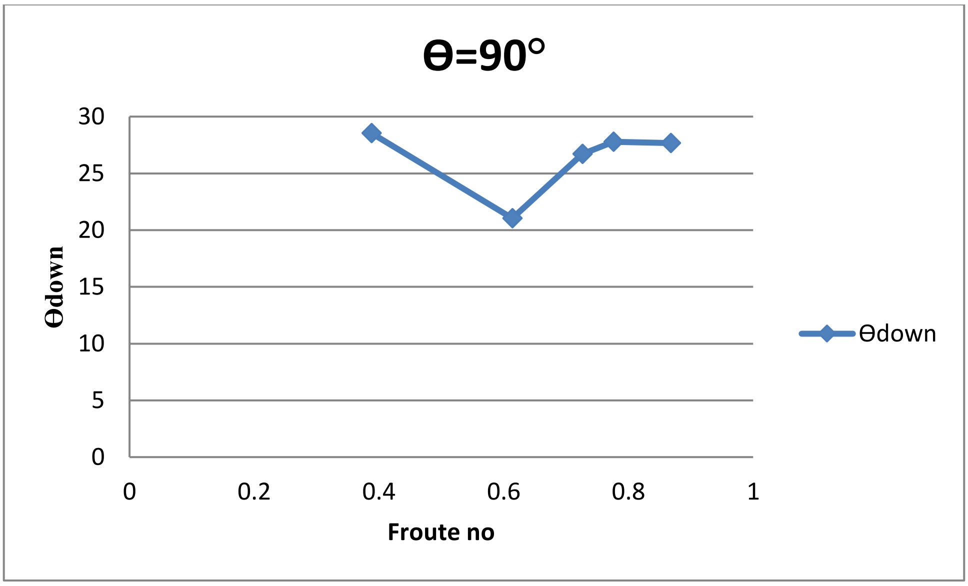

Fig no.(6.41) Graph between downstream scour angle with Froude number for T shaped dike at ϴ = 90°

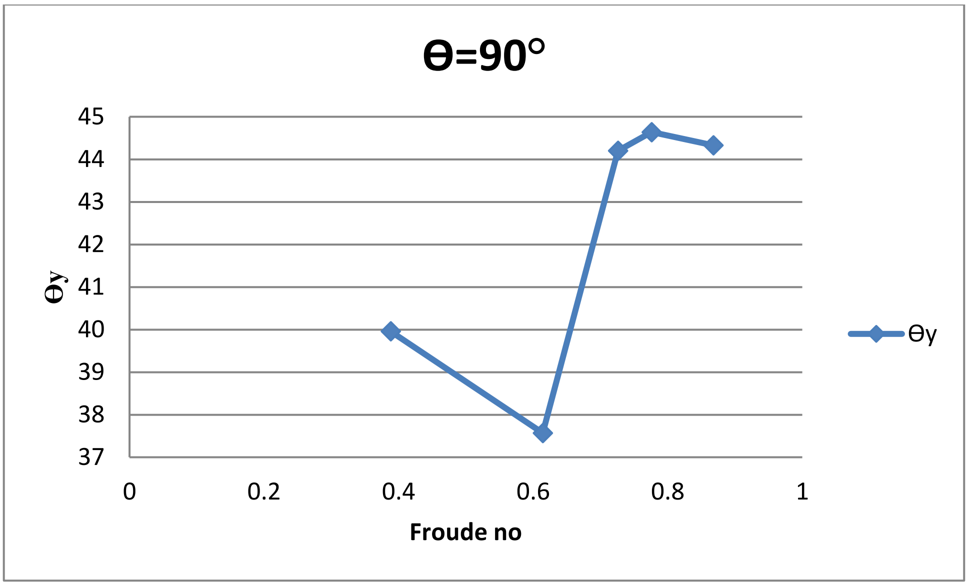

Fig no.(6.42) Graph between transverse scour angle with Froude number for T shaped dike at ϴ = 90°

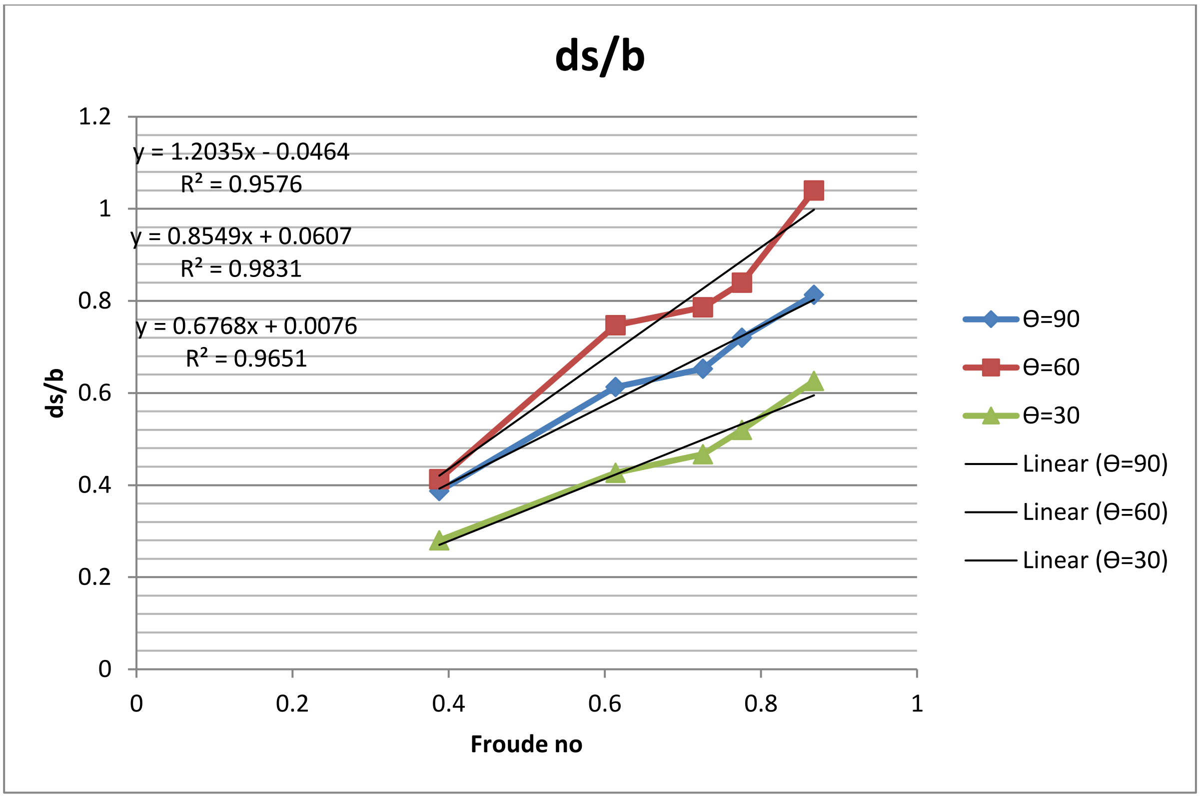

Figure no (6.43) Comparison of maximum scour for normal spur dike with different orientation angle.

- For Ө = 90° the trendline equation is y = 0.854x + 0.060
  And for the straight line value of R^2=0.983

- For Ө = 60° the trendline equation is y = 1.203x – 0.046
  And for the straight line value of R^2=0.957

- For Ө = 30° the trendline equation is y = 0.676x + 0.007
  And for the straight line value of R^2=0.956

- Where; x = Froude Number
  y = Ratio of maximum scour depth and length of dike

- Angle 60° have impractical angle, it shows a major difference with angle 30° at same Froude number.

- Angle 90° and angle 60° shows approximate same result for lower value of Froude number.

- The shape of scour hole in angle 90° is approximately circle but in angle 60° and 30° the shape will change to oval.

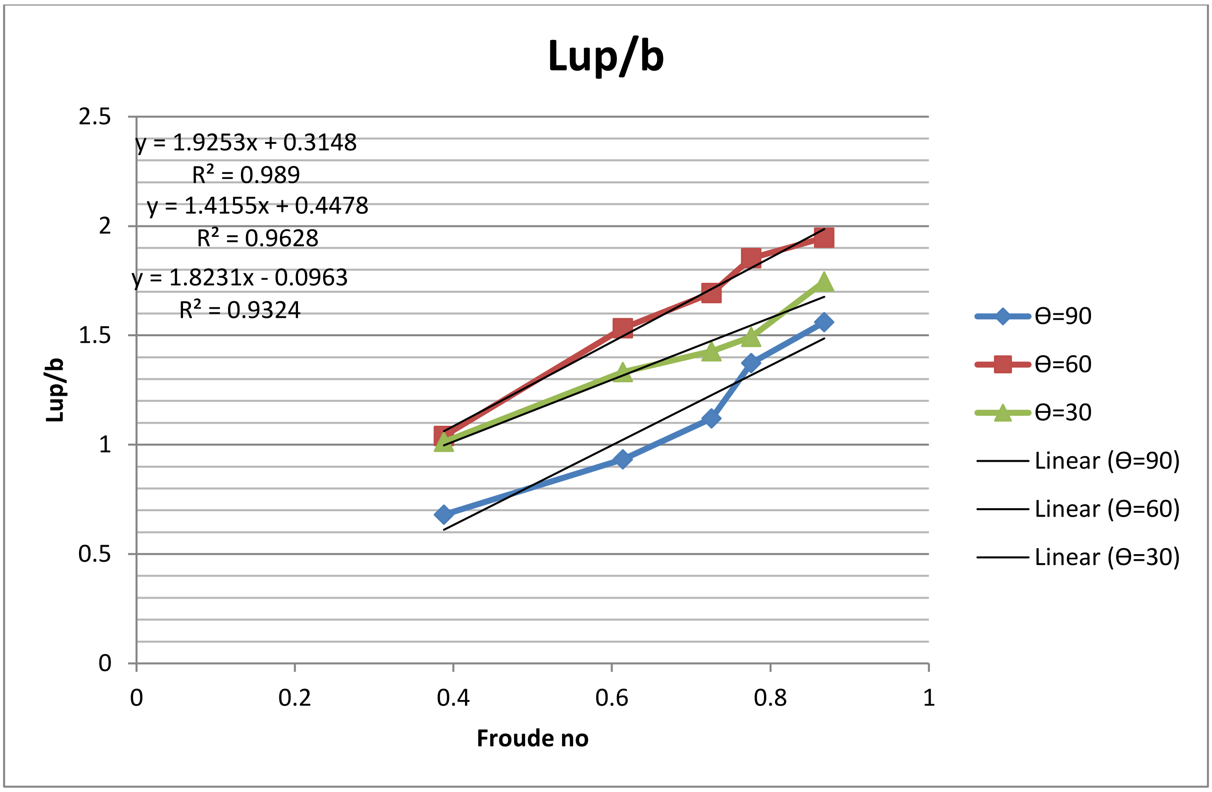

Figure no. (6.44) Comparison of length of scour for normal spur dike in upstream direction with different orientation angles.

- For Ө = 90° the trendline equation is y = 1.823x – 0.096
  And for the straight line value of R^2= 0.962

- For Ө = 60° the trendline equation is y = 1.925x – 0.314
  And for the straight line value of R^2= 0.989

- For Ө = 30° the trendline equation is y = 1.415x + 0.447
  And for the straight line value of R^2= 0.962

- Where; x = Froude Number
  y = Ratio of scour length in upstream and length of dike

- Length of scour in upstream direction is considerably depends on the attacking angle for the lower value of Froude number the length of scour is same in the attacking angle 60° and 30°.

- Hear length of scour is more in attacking angle 30° but the angle of scour hole is approximately half with respect to attacking angle 90° so the scour in angle 30° is safe.

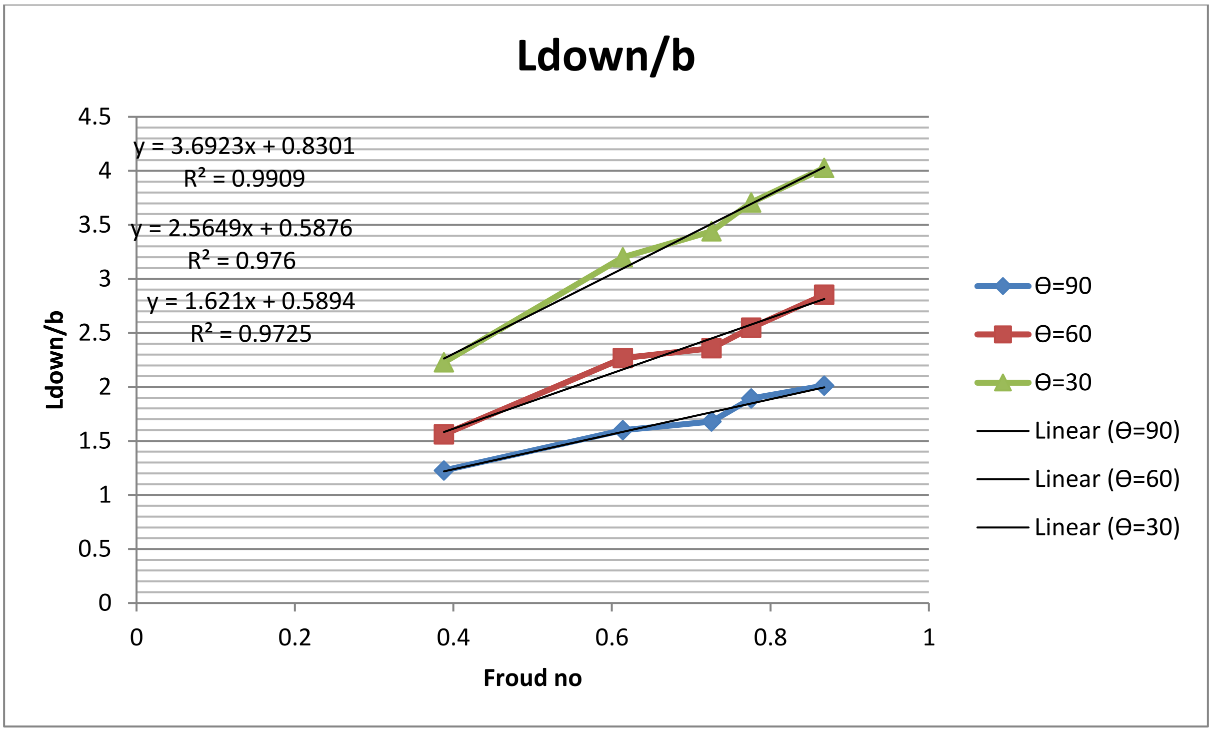

Figure no (6.45) Comparison of length of scour for normal spur dike in downstream direction with different attacking angle.

- For ϴ = 90° the trendline equation is y = 1.621x + 0.589
  And for the straight line value of R^2= 0.972

- For ϴ = 60° the trendline equation is y = 2.564x + 0.587
  And for the straight line value of R^2=0.976

- For ϴ = 30° the trendline equation is y = 3.692x + 0.830
  And for the straight line value of R^2= 0.990

- Where; x = Froude Number
  y = Ratio of scour length in downstream and length of dike

- Length of scour in downstream direction is high in angle 30° and the minimum length of scour is obtain in angle 90°.

- Scouring in downstream direction in angle 30° is shallow as compare to angle 60° and 90°.

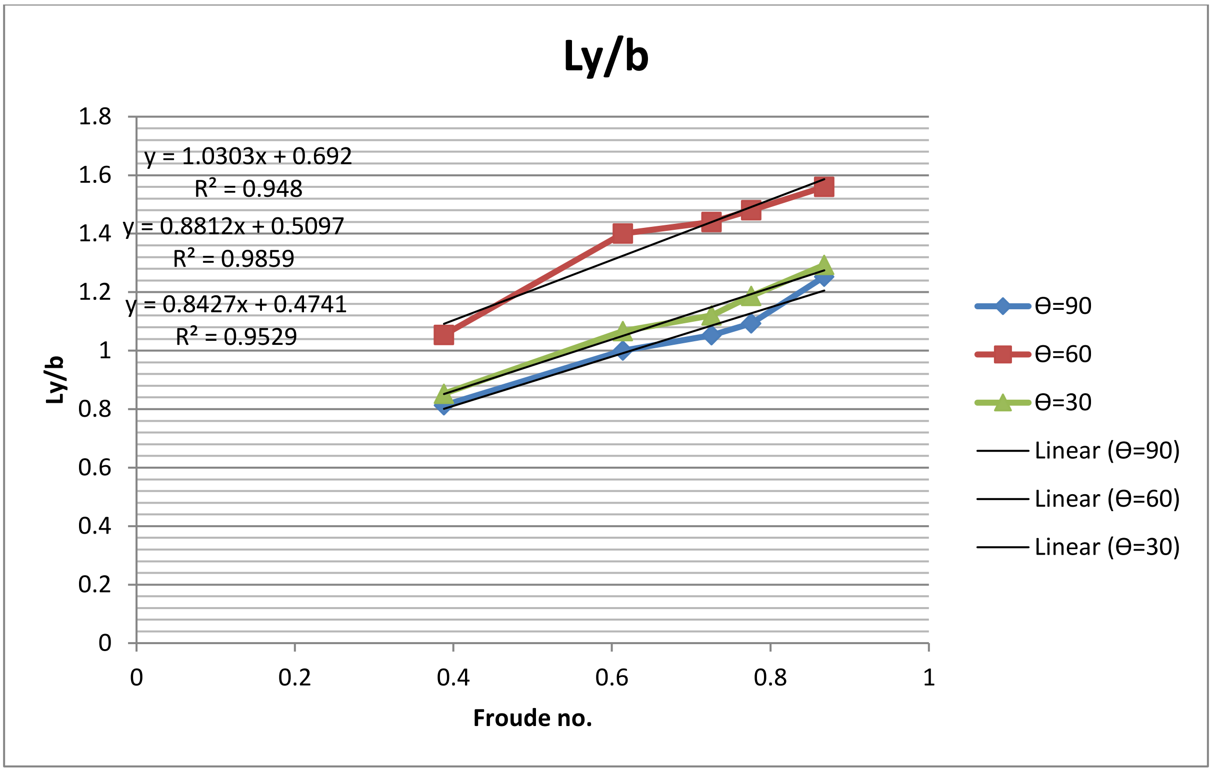

Figure no (6.46) Comparison of length of scour for normal dike in transverse direction with different attacking angle.

- For Ө = 90° the trendline equation is y = 0.842x + 0.474
  And for the straight line value of R^2= 0.952

- For Ө = 60° the trendline equation is y = 1.030x + 0.692
  And for the straight line value of R^2=0.948

- For Ө = 30° the trendline equation is y = 0.881x + 0.509
  And for the straight line value of R^2= 0.985

- Where; x = Froude Number
  y = Ratio of transverse scour length and length of dike

- Length of scour in transverse direction is minimum and approximately same in angle 30° and 90° but the length is considerably more for the angle 60°.

- It is obvious that the length of scour will increase with increase in Froude number.

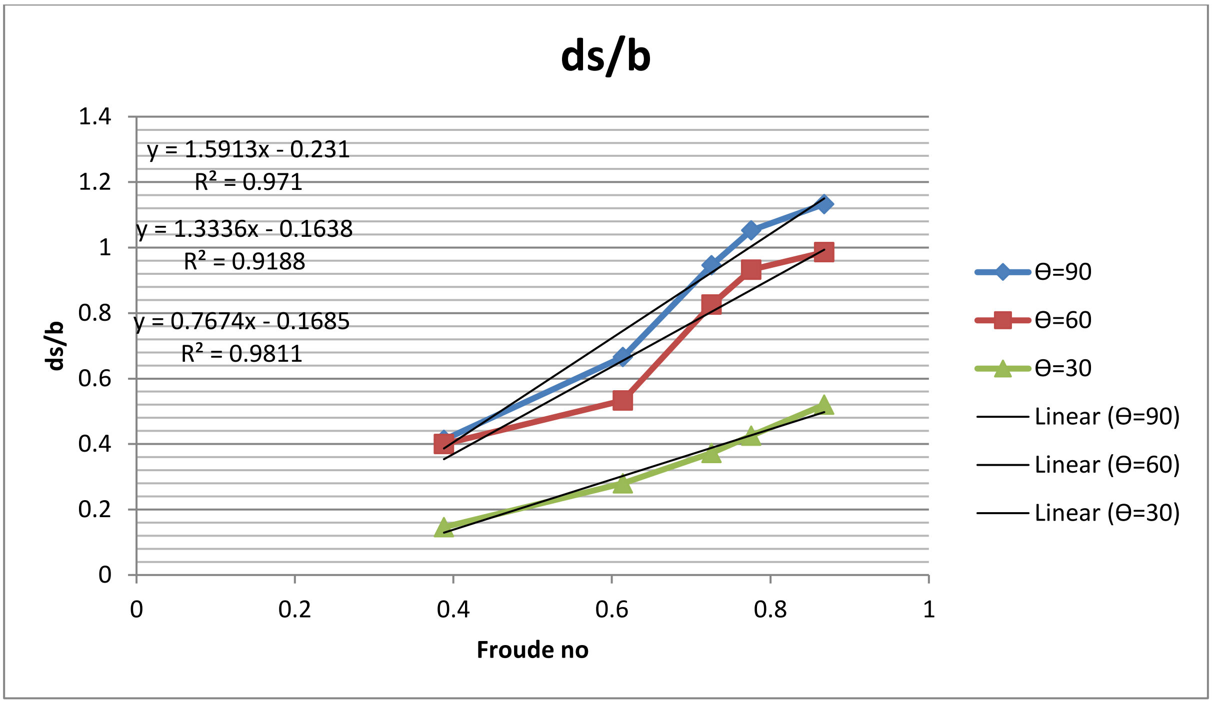

Figure no (6.47) Comparison of maximum scour depth for T shaped spur dike with different attacking angles.

- For Ɵ = 90° the trendline equation is y = 1.591x - 0.231
  And for the straight line value of R^2= 0.971

- For Ɵ = 60° the trendline equation is y = 1.333x - 0.163
  And for the straight line value of R^2=0.918

- For Ɵ = 30° the trendline equation is y = 0.767x - 0.168
  And for the straight line value of R^2= 0.981

- Where; x = Froude Number
  y = Ratio of maximum scour depth and length of dike

- The value of maximum scour is considerably low in attacking angle 30°.

- Depth of maximum scour is approximately same in the angle 60° and 90° but as compare to angle 60°, angle 90° have much economical due to less length of structure

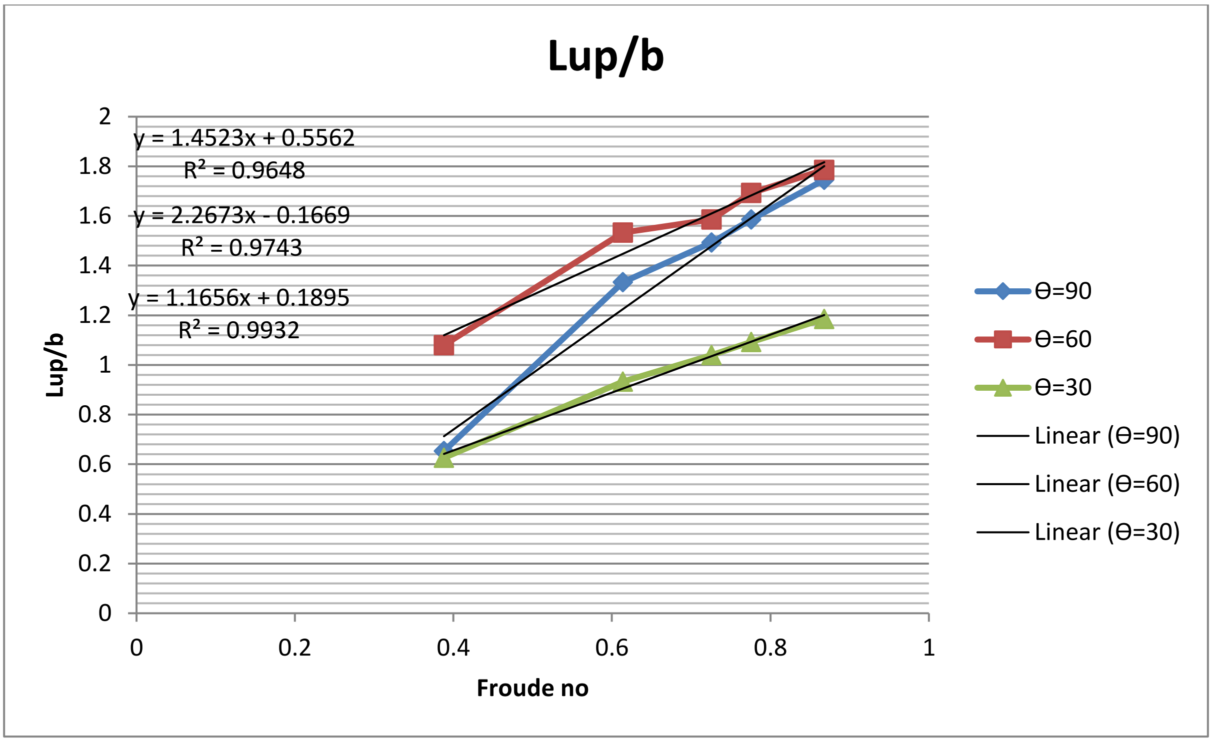

Figure no (6.48) Comparison of length of scour for T shaped spur dike in upstream direction with different attacking angle.

- For ϴ = 90° the trendline equation is y = 2.267x - 0.166
  And for the straight line value of R^2= 0.974

- For ϴ = 60° the trendline equation is y = 1.452x + 0.556
  And for the straight line value of R^2=0.964

- For ϴ = 30° the trendline equation is y = 1.165x + 0.189
  And for the straight line value of R^2= 0.993

- Where; x = Froude Number
  y = Ratio of scour length in upstream and length of dike.

- Value of length of scour in upstream direction in T shaped spur dike is low in angle 30°, and the value is high in the angle 60°, but the angle 90° shows a drastically increase with increment in the Froude number.

- It is obvious that the length of scour in T shaped spur will also increase with increase in Froude number.

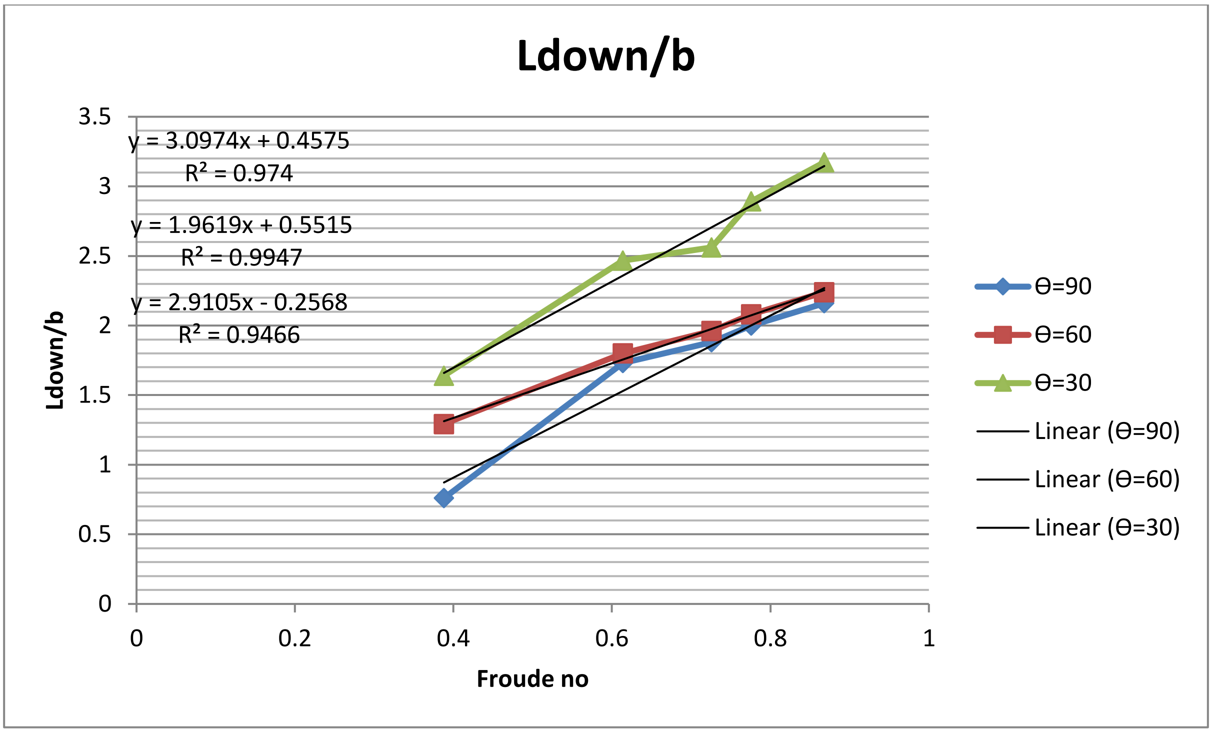

Figure no (6.49) Comparison of length of scour for T shaped spur dike in downstream direction with different attacking angle.

- For Ɵ = 90° the trendline equation is y = 2.910x + 0.256
  And for the straight line value of R^2= 0.946

- For Ɵ = 60° the trendline equation is y = 1.961x + 0.551
  And for the straight line value of R^2=0.994

- For Ɵ = 30° the trendline equation is y = 3.097x + 0.457
  And for the straight line value of R^2= 0.974

- Where; x = Froude Number
  y = Ratio of scour length in downstream and length of dike.

- Length of scour in downstream direction for T shaped spur dike is high in angle 30° and the minimum length of scour is obtain in angle 90°.

- Length of scour in downstream direction for T shaped spur dike is same for the angle 90° and 60° but for the less value of Froude number the difference is visible.

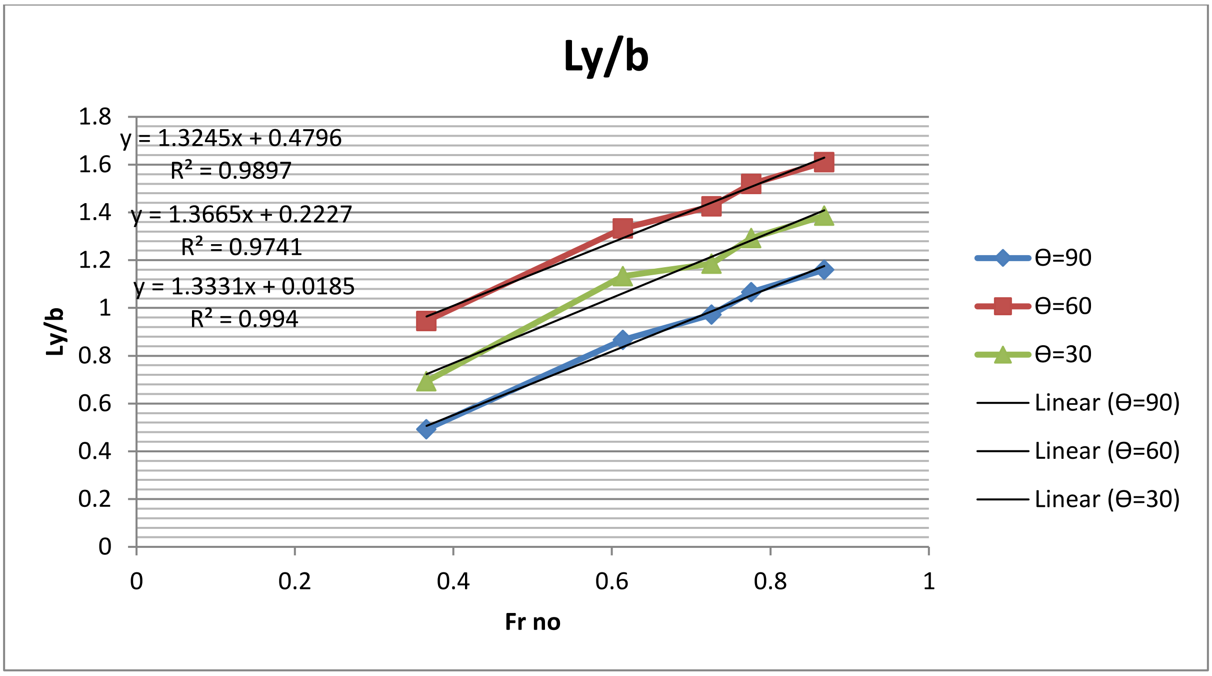

Figure no (6.50) Comparison of length of scour for T shaped spur dike in transverse direction with different attacking angle

- For Ө = 90° the trendline equation is y = 1.621x + 0.589
  And for the straight line value of R^2= 0.972

- For Ө = 60° the trendline equation is y = 2.564x + 0.587
  And for the straight line value of R^2=0.976

- For Ө = 30° the trendline equation is y = 3.692x + 0.830
  And for the straight line value of R^2= 0.990

- Where; x = Froude Number
  y = Ratio of transverse scour length and length of dike

- The value of length of scour in transverse direction is minimum in angle 90° and maximum in angle 60°.

- Some scour in transverse direction is helps in navigation so angle 30 have acceptable scour.

- There is not any much significant difference in all three orientation angle for the length of scour in transverse direction.

On Scour Hole Characteristics effect of Flow Conditions

After installing spur dike in the flowing stream the channel width for the flow is reduced so the velocity profile of flow is changed around the spur dike. Hence, the role of flow velocity and Froude number is become very important in the analysis of scour dimensions. Due to decrease is the flow area the flow velocity is increase and due to increase in flow velocity Froude number is increased and due to increase in Froude number the carrying capacity of water is increased and due to increase in carrying capacity the ability to create scour hole is also increased. So we are analysing the scour hole dimension with the different increasing Froude number. The Froude numbers are,

Fr = 0.388,
Fr = 0.614,
Fr = 0.726,
Fr = 0.776,
Fr = 0.868,

All Froude numbers are applied for each model, to determine the influence of flow conditions on the dimensions of scour hole. The value of Froude number is increased in such a way that the value of Froude number does not exceed from unity, because the flow should be in experiment is stable and the test will have to perform in clear water condition. If the Froude number exceeded from unity then turbulence will create then the water will became turbid so the condition of test will perform in clear water will not satisfy.
If we increase the Froude number then all dimension of scour hole was increased. We analysing the scour hole dimension for different value of Froude number and by analysing the graphs pattern we found that the best fit between Froude number and relative scour hole parameters in all cases was found to be linear. It means by increasing the Froude number the other parameters will increase linearly.
From Table (5.2), we can say that for Fr = 0.868 the maximum scour depth is nearly equal to length of dike. It means the ratio of maximum depth of scour hole and the length of spur dike is about one. But for Froude number ranging between 0.614 and 0.726 the maximum scour hole depth has an average value of 0.6 to 0.8 times of length of dike for all models.
For the orientation $\Theta = 30^{o}$, the obtained results are most suitable for the foundation of the structure. The value of maximum scour is reduced very significantly for that angle. The average value of the maximum scour for the orientation angle $\Theta = 30°$ is reduced to 0.45 times of the length of spur dike.
As the Froude number gets smaller the value of the maximum scour depth and the length of scour hole in upstream, downstream and transverse direction will reduced and if the value of Froude number gets increased the value of the maximum scour depth and the length of scour hole in upstream, downstream and transverse direction will also increased.

Effect of Spur Dike Alignment

If a spur dike may is positioned facing upstream then it called repelling groin, and if placed normal to flow than it will called deflecting groin and if it positioned facing towards downstream than it treated as attracting groin. Every orientation of dikes towards the flow affects the river current in a different manner. In this study we are considering deflecting groin and attracting groin. The orientation angle tested in this study was ϴ = 90º, ϴ = 60º and ϴ= 30º.

Figures 4.2 show the arrangement of the spur dikes for the experiment. by the figure (4.2) we can also understand the angle of orientation for this study. It is clear from the figure (6.1) to figure (6.42) that for normal and T shaped spur dike both, the orientation angle 30º has shown minimum scour depth for different Froude number. Because spur-dike with orientation angle 30º does not act as an obstacle for stream flow as the orientation angle 60º or 90º does.

For the greater Froude number the effect on flow is gentler by the spur dike with the orientation 30°. For the purpose of bank protection the dike with orientation angle 30° has better performance. Even for the high value of Froude number the performance is satisfactory. For orientation angle 30º, the maximum scour depth occurred just after downstream of the spur tip, and the base of scour hole is about a circle. By studying the graphs we can say that the scour depth is reduced gradually as orientation changes from ϴ = 90º to ϴ = 30º. Due to contraction in flowing area the flow velocity is increased near the tip of the spur dike but by changing the attack angle we can reduce it significantly.

But for the consideration of scour length spur dike alignment does not show a significant effects on scour hole length at the upstream of the spur dike, but for with higher Froude number, angle 30º shows its effect on reducing scour length and angle 60º gives the longer upstream scour hole length in most cases. For the downstream scour hole length the orientation angle 30° shows the greater value but the slope in downstream side is milder for the orientation angle 30°.

CHAPTER 7
CONCLUSIONS

By observing the tables in chapter five and the graphs in the chapter six we conclude for the clear water local scour experiment which conducted for a single spur dike installed in a alluvial channel are,

1. The slope of the scour hole in the upstream direction is steeper and the slope in the downstream direction is milder. The reason of difference between the slopes in upstream and downstream direction is high turbulence and high flow energy in upstream direction as compare to downstream direction.

2. For normal dike the maximum scour occurs near the nose of the spur dike and for T shaped dike the maximum scour occurs in the downstream side from the nose of the dike.

3. The shape of scour hole is like inverted cone and the crown of the cone is near the tip of spur dike.

4. The downstream slope of scour hole is about 50% of the upstream side slope by the magnitude. For normal dikes the average slope of scour hole in upstream direction is about 30° and for the downstream side the value is about 15°.

5. The length of scour hole in the upstream direction is about two times of the length of spur dike and the length of scour hole in the downstream direction is about three to four times of the length of spur dike.

6. The length of scour hole in the transverse direction is approximately same for all type of spur dike and the increment in the length of transverse scour hole due to increase in the Froud number is very less.

7. The upstream scour hole length is nearly twice the maximum scour hole depth (ds), and the downstream scour hole length is about four times of the maximum scour hole depth.

8. Length of scour in upstream direction is considerably depends on the attacking angle for the lower value of Froude number the length of scour is same in the attacking angle 60° and 30°.

9. Depth of maximum scour is approximately same in the angle 60° and 90° but as compare to angle 60°, angle 90° have much economical due to less length of structure .

10. Value of length of scour in upstream direction in T shaped spur dike is low in angle 30°, and the value is high in the angle 60°, but the angle 90° shows a drastically increase with increment in the Froude number.

11. Length of scour in downstream direction for T shaped spur dike is high in angle 30° and the minimum length of scour is obtain in angle 90°. Length of scour in downstream direction for T shaped spur dike is same for the angle 90° and 60° but for the less value of Froude number the difference is visible.

12. The length of scour in upstream side is more for the T shaped spur dike for the same orientation of flow.

13. The orientation angle 60° seems to be unpractical angle for the attracting type of groin. In the angle 60° the shape of scour hole is larger and deeper as compared with orientation angle 30°by take other parameters are constant. Also, when compared with angle 90°, it gives an average the same hole dimensions or even larger. In addition, it's actual length will be longer than deflecting groin which leads to higher construction cost.

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