# EXPERIMENTAL AND NUMERICAL SIMULATION OF SPACED RECTANGULAR STRIP FOR ENERGY DISSIPATION USING HYDRAULIC JUMP

A DISSERTATION SUBMITTED IN FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF

**MASTER OF TECHNOLOGY**

**IN**

**HYDRAULICS AND WATER RESOURCE ENGINEERING**

By

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# CANDIDATE'S DECLARATION

I do hereby certify that the work presented is the report entitled "**Experimental and Numerical Simulation of Spaced Rectangular Strip for Energy Dissipation Using Hydraulic Jump**" within the partial fulfilment of the requirement for the award of the degree of "Master of Technology" in Hydraulic and Flood control Engineering submitted within the branch of Civil Engineering, Delhi Technological university, is an authentic record of my own work carried out under the supervision of Dr. S. Anbu Kumar, Department of Civil Engineering. I have not submitted the matter embodied inside the report for the award of any other diploma or degree to any other group.

**(** HARSHIT KUMAR JAYANT )
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# CERTIFICATE

This is certified that the work contained in this minor project entitled “**Experimental and Numerical Simulation of Spaced Rectangular Strip for Energy Dissipation Using Hydraulic Jump** "by HARSHIT KUMAR JAYANT (2K16/HFE/10) is the requirement for the fulfilment of the degree of HYDRAULIC AND FLOOD CONTROL ENGINEERINGE at Delhi Technological University. This work was completed under my direct supervision and guidance. The student has completed his work with utmost sincerity and diligence.

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Date :

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# ABSTRACT

In practical life the scouring of downstream bed of hydraulic structure leads to piping, undermining which is very serious case for a Hydraulic structural designer. To defeat these effect many researchers studied to depreciate the downstream energy. In the context of the previous study, In this project, the features of Hydraulic jump on spaced rectangular strip surface is studied and found out experimentally and this result is compared with a previous study as well as ANSYS. An experiment was performed for spacing such as S=3cm, where S is the Spacing between two sequential strips. Flow fluctuations are studied experimentally on a spaced base in a flat rectangular flume. 'Ten' experimental run was performed for spaced rectangular strip sheet considering different-different Froude number ranging from 2 to 8 The important parameters of a Hydraulic jump, including the jump height, jump length was concluded as functions of Froude number and the height and extent of folds. These parameters are related to the consequences of the still bed which shows that rough channel decreases jump length and it is efficient for energy dissipation. The result showed that sequent depth and rise length reduced as compared to a smooth bed. With the help of 'ANSYS,' sequent depth and energy loss are calculated. Mass flow contour, Velocity Contour, Velocity Streamline, Pressure Contour, Velocity vector, Wall shear vector, Volume fraction are plotted. Which shows that providing spaced rectangular strip at downstream is good for energy dissipation .

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**( HARSHIT KUMAR JAYANT )**

**(2K16/HFE/10)**

# CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# ABBREVIATIONS

S = Spacing of two consecutive strips (cm)

b = Base width of single rectangular strip (cm)

H= Height or depth of Rectangular strip (cm)

R =Reynolds number=UY /ν

$F_r$. = Froude number

$Y_1$= Initial depth of free jump;

$Y_2$ = Conjugate depth of jump on rough bed (m)

$Y_2$* = Conjugate depth of classical jump (m)

$L_j$ = Hydraulic jump length (m)

$L_r$ = Hydraulic roller length (m)

ν =Kinematic viscosity of fluid flow

ρ= Mass density of fluid

X= longitudinal distance measured from section where jump begins

$U_1$ = depth-averaged velocity at section where jump .i.e., at X=0

$U_2$= Depth-averaged velocity at section where jump end

Q = mass flow rate ($m^3$/s)

P = pressure (Pa);

$E_L$ = energy losses;

$E_1$ = energy upstream (kg $m^2/s^2$);

$E_2$ = energy downstream (kg $m^2/s^2$)

g= acceleration due to gravity ($m/s^2$);

$L_j/Y_1$ = length of jump ratio

$Y_2/Y_1$ = conjugate depth ratio

# CHAPTER 1

# INTRODUCTION

## 1.1 General

The hydraulic jump takes place when liquid at high velocity discharges into a zone of lower velocity, a rather abrupt rise occurs in the liquid surface. The hydraulic jump is divided into two kinds in line with their bed specialty. The primary kind is a classical hydraulic leap with an easy mattress, and the second kind is a compelled hydraulic bounce. The classical equation to estimate the connection among the proportion of the downstream drift intensity to the upstream flow depth, $Y_2^*/Y_1$ , and the upstream Froude wide variety $Fr_1 = V_1 /(gy_1)^{0.5}$ (in which $V_1$ is the suggested speed at the start of the bounce and g is the acceleration because of gravity) originates from the equation of momentum. Applying the momentum equation to the manage amount surrounded via the upstream and downstream move-sections of the bounce, the subcritical sequent intensity $Y_2$ is computed from Eq. (1.1) "Classical jump".

$$Y^*_2/Y_1=0.5[(1+8F_1^2)^{0.5} -1] \quad .......(1.1)$$

**Mathematical model:**

Using the Buckingham π-theorem, dimensionless equations in functional forms may be produced. The purposeful relationships were worked out in the gift observe, as proven in Equations. (1.2), (1.3), (1.4), where ,$Y_2/Y_1$ , $L_j/Y_1$, and $E_L/E_1$ are, respectively, the sequent intensity ratio, period ratio, and electricity dissipation in a hydraulic bounce.

$$Y_2/Y_1=f_1(Fr, t/Y_1, s/Y_1)....................(1.2)$$

$$(E_2-E_1)/E_1=f_3(Fr, t/Y_1, s/Y_1)............(1.3)$$

$$L_j/Y_1=f_2(Fr, t/Y_1, s/Y_1).....................(1.4)$$

## 1.2 Classification of hydraulic jumps

Hydraulic jumps may be visible in both a stable form, recognised as a "hydraulic soar" and a shifting form, referred to as a wonderful surge or " translation hydraulic jump ".

**(A) Moving jump**

A streaming bore is a sort of hydraulic bounce which happens while the upcoming tide bureaucracy a loops that tour up a tributary or slim vicinity towards the course of the cutting-edge.

**(B) Stationary (desk bound) jump**

The desk bound hydraulic bounce is often seen on tributary, engineered systems including outfalls of dams and watering works. It arise while a waft of liquid at excessive speed discharges into the tributary, engineered shape that could simplest help a decrease pace.

## 1.3 Energy dissipation by a hydraulic jump

The utmost crucial building uses of the water powered bounce is vitality dissemination in channels dam spillways and elective pressure driven structures so the surplus K.E. doesn't damage these structures. The speed of vitality scattering in an exceedingly water powered bounce might be a perform of the pressure driven hop flood, Froude run and furthermore the tallness of the hop.

$$E_L=(Y_2-Y_1)^3/4Y_2Y_1................ (1.5)$$

## 1.4 Characteristics of subcritical and supercritical flows

**Wave propagation velocity**:

'C' is that the wave propagation rate on a flowing water with rate $V_1$. If we have a tendency to take the pace 'C' equal however opposite to the flow rate $V_1$, then the wave stays still and also the steady state conditions is also applied. Writing the energy equation between cross-sections one and a couple of and neglecting the energy loss for a horizontal channel.

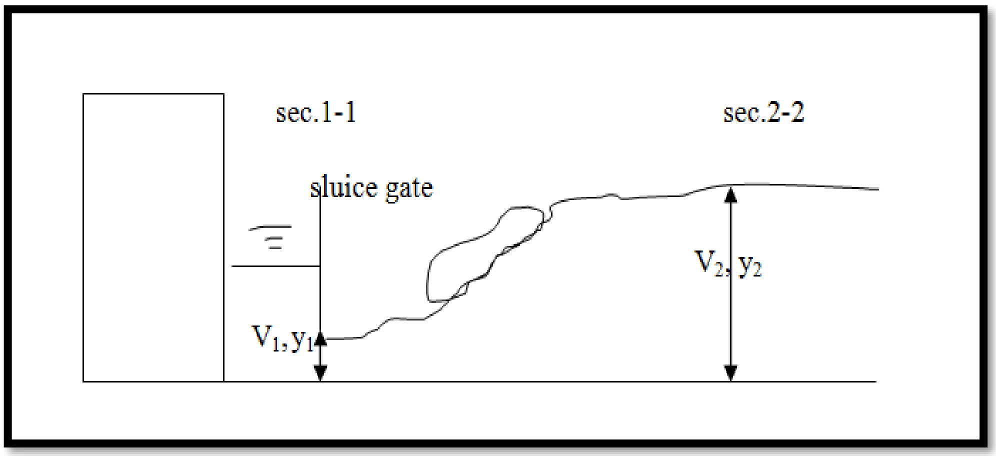


**Figure 1.1**:Cross-sectional view of hydraulic flume

$$Fr= V/(g\ Y)^{0.5} \quad .................(1.6)$$

Where, term $(g.Y)^{0.5}$ is known as "celerity". Froude number depends on depth of water to describe supercritical and subcritical.

## 1.5 Hydraulic jump characteristics

As described earlier, the supercritical flow Froude number influences the property of the hydraulic jump. Bradley and Peterka, after extensive experimental investigations, have classified the hydraulic jump into "five" categories . The hydraulic jump is the development that happens wherever there is associate abrupt shift from crucial waft to sub essential flow in the channel. The foremost necessary issue that affects the hydraulic jump is that the initial Froude range Fr.

$V_1$ is that the longitudinal average rate at the initial section, g is that the speeding up to gravity and D is the hydraulic imply intensity.

**Table 1.1:**Types of jump

| **Pre jump Froude Number** | **Ratio of height after to height before jump** | **Characteristics of jump** | **Energy dissipated by jump** |
|---|---|---|---|
| ≤ 1.0 | 1 | No jump | None |
| 1.0 – 1.7 | 1.0 – 2.0 | Undular | < 5% |
| 1.7 – 2.5 | 2.0 – 3.1 | Weak | 5% – 15% |
| 2.5 – 4.5 | 3.1 – 5.9 | Oscillating | 15% – 45% |
| 4.5 – 9.0 | 5.9 – 12.0 | well-balanced | 45% – 70% |
| > 9.0 | > 12.0 | Strong | 70% – 85% |

The jumps can also arise on horizontal bed or sloping bed. the bounce can take place in substantially diverging, extensively converging, square, unexpected convergence or expansions in plan. the jump can arise in different shape of the cross section of the channel such as rectangular, trapezoidal, parabolic, round channels. the soar can occur inside the conduit both at the loose floor or fully flowing downstream situation. the annular bounce is yet any other type.

The jump is either submerged or submerged condition like within the downstream of sluice gates. The jump is a forced baffles, sills, chute blocks or free. Jump might be either stationary or moving. The jump is in stratified flows like heat and cold water, air and water . The vital megascopic parameters are initial intensity $Y_1$ , sequent,depth $Y_2$ , preliminary. suggest pace $V_1$ , suggest pace on the pinnacle of the jump (go out pace) $V_2$ , jump length (Lj ) and therefore the roller period (Lr).

## 1.51 Conjugate depths versus alternative depths

It is vital not to confuse conjugate depths (momentum is conserved) with alternate depths (strength is conserved). within the case of a hydraulic jump, the drift reports a positive quantity of energy head loss in order that the subcritical flow downstream of the bounce contains less power than the supercritical flow upstream of the soar. change depths are legitimate over strength protecting devices such as sluice gates and conjugate depths are legitimate over momentum holding gadgets which include hydraulic jumps.

## 1.6 Importance of Froude number

- Defines subcritical drift or critical flow.
- A Froude variety larger than one could be a critical flow whereas a Froude variety but one could be a subcritical flow.
- If you want to very own a hydraulic leap the Froude range must be larger than or succesful one.

- A hydraulic soar happens once the flow goes from critical waft (Fr > 1) to subcritical glide (Fr < 1) or, from risky flow to a strong float.
- A hydraulic rise won't arise as soon as a drift goes from subcritical go with the flow (Fr < 1) to a critical flow (Fr > 1).

## 1.7 ANSYS software

### 1.7.1 Introduction

ANSYS software program is used to layout merchandise, as well as to create simulations. ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.

### 1.7.2 Computational Fluid Dynamics

"Computational fluid dynamics" (CFD) is a branch of mechanics of fluid, that uses statistical assessment and statistics systems to answer and have a look at issues that involved fluid flows. laptop systems are used to implement the calculations required to simulate the intercommunication of beverages and gases, with surfaces described through limiting conditions.

### 1.7.3 Methodology

The geometry and bodily limits of the issue can be defined the usage of computer aided layout. From there facts may be certainly processed and the liquid quantity (fluid location) is obtained. The extent involved by the liquid is distributed into discrete cells. The work is apparently uniform or non-uniform, dependent or, unregulated which include a blend of hexahedral, tetrahedral, chromatic, pyramidal or polyhedral factors. The mechanical modeling is described – as an example, the equations of liquid flow ,enthalpy ,radiation , kind protection. Boundary states are defined. This requires defining the liquid behavior and houses at all bounding surfaces of the liquid area. For short troubles, the primary situations are also defined. The simulation is begun and the equations are resolved iteratively as a constant-kingdom or brief. In the long run a postprocessor is used for the evaluation and visualization of the resulting response.

### 1.7.4 ANSYS Fluent

Programming incorporates the wide physical demonstrating abilities needed to adaptation stream, turbulence, warmth switch, and responses for business programs—beginning from air float once again a plane flank to burning in a heater, from droplet segments to fuel stages, from blood float to semiconductor generation, and from clean chamber configuration to wastewater cure factories.

Following Features are:

Green and bendy Workflow, developed for Multiphysics, clear up complicated fashions with self assurance, cross faster with, excessive overall "performance Computing" (HPC), "Turbulence Modeling", warmth switch & Transmission, Multiphase waft, Reciprocating flow, Acoustics, Fluid-structure interplay.

## 1.8 Need for proposed the study

Scouring the downstream is that the main reason for undermining the hydraulic structure that results in failure of hydraulic structure like dam weir. to produce adequate data for coming up with the downstream bed apron so the erosion will be minimize by minimizing the downstream energy.

## 1.9 Advantages and Disadvantage

### 1.9.1 Advantages

- Dissipates the power of water over a waste weir.
- Bars scouring on the downstream factor of the dam shape.
- Traps air within the water.
- Helpful for removing wastes and pollutants in the water Reverses the flow of water.
- May be wont to mix chemical substances for water purification.
- Keeps a excessive water level at the downstream aspect.
- Beneficial for irrigation capabilities. Its principal intention is to operate as an energy-dissipating tool to reduce the extra electricity of water streams.

- The jump produces important violence within the kind of whirls and reverse flow rollers to promote mixture of substances.

- For the duration of the jump development, great volume of air is entrained so it supports within the aeration of currents that is dirty via bio-degradable rubbish.

- It enables cost-efficient execution of flow measuring operation like flumes.

### 1.9.2 Disadvantages

- Downstream disturbance can cause damage and degradation of flood banks.
- May additionally purpose erosion and degradation on hydraulic surfaces.
- Unwanted circumstance for fish passage.

### 1.9.3 Popular Hydraulic Jumps

- Hoover Dam, Crystal Rapid in Grand Canyo and Cache la Poudre River Spillways .

### 1.9.4 Background of Hydraulic Jump/History

- Leonardo Da Vinci first defined hydraulic jumps within the 16th Century.
- Giorgio Bidone published the primary experimental investigations.

## 1.10 Research objectives and scope

The existing look at is therefore a shot to suit the past studies by using work the Hydraulic move furrowed surface victimization rectangular form of metallic element sheets to reduce the downstream mechanical energy and to search out the effect to reduce sequent depth quantitative relation, roller length, jump length . Inside the occasion that the mattress of the channel on that the hop is made is unsightly, the tail water depth $Y_2$ had to make a bounce can be significantly smaller than the corresponding sequent intensity $Y_2$* on smooth mattress reduce the value of protection by way of imparting roughness apron in downstream.

- To provide a rough idea to engineers for designing hydraulic structure more safely.
- To investigate the effect of corrugation to reduce the downstream energy of Hydraulic structure.
- To investigate the efficient shape of corrugation for energy dissipation.
- To provide a rough idea of optimal wavelength for corrugated sheet on the basis of efficient shape of corrugation.
- To minimize the downstream scouring of bed material by energy dissipation.
- To reduce the piping through hydraulic structure by providing adequate knowledge about rough apron .
- To validate present result with the previous study of rough surface.

# CHAPTER 2

# LITERATURE REVIEW

**Blaisdell, F. W. (1949)** studies the effect of blocks on flowing stream and found that the block should occupy 40 to 55 percent of the floor width, and the best orientation of block are perpendicular to the incoming flow of fluid.

**Peterka, A. J. (1964)** A take-off shaped in a stage, colossal rectangular channel with a easy bed is known as the customary water powered jump and has been pondered widely, It becomes located that because the Froude no increases the jump becomes extra touchy to tail water depth Froude no as eight, tail water depth extra than the conjugate intensity is really useful to be sure that the jump will form at the apron, additionally located that the high Froude numbers will continually happen for waft through extremely small gates.

**Rajaratnam, N. (1967)** A primary examination designated that, if the mattress of the course on that the jump is made is harsh, the tailwater depth $Y_2$ had to make a soar can be tinier than the analogous sequent intensity $Y_2$*. Mentioned that the jumps on firm beds have been drastically smaller than the classical soar.

**Leutheusser, H. J., & Schiller (1975)** directed investigations upon the approaching plane over unpleasant bed. They located that the lifestyles of a advanced crucial flow downstream of the gates or spillways upon rough mattress desires much less length compared to the swish surface. They researched the attributes of mean turbulent movement in an unnaturally harsh channel. In their study, the harsh surface on the entire backside of the channel mattress was built by circles and pieces.

**Nik Hassan, N. M. K., & Narayanan, R. (1985)** explored the stream attributes and furthermore the comparability of scouring profiles downstream from an inflexible cook's garment as a result of a water fly supply from a floodgate. They proposed a semi-empirical approach maintained a special mean speed within the scour hole to expect the summit scour intensity about time and additionally the consequences were in compared with experimental information of experimental value.

**Ali, K. H. M., & Lim, S. Y. (1986)** displayed different articulations to depict the stream attributes volume of scouring and the scour hole depth concerning time due to two- and, 3-dimensional jets, but they didn't research the overskirt condition.

**Husain, D., Alhamid, A. A., & Negm, A. A. M. (1994)** conducted an experiment on horizontal rectangular channel bed using wooden roughness blocks of fixed length with density varying from 0 to 20%. The result showed that 12% roughness density provides the highest quality period of a basin for the float conditions and roughness arrangement under attention.

**Balachandar, R., Kells, J. A., & Thiessen, R. J. (2000)** The after consequence of the tail-water profundity on the scour downstream of a floodgate entryway was examined.

**Ead, S. A., & Rajaratnam, N. (2002)** performed a research center investigation of pressure driven jump on furrowed mattresses for a implication of Froude numbers from four to 10 and two states of the relative harshness $t/Y_1$ from 0.25 to 0.50. Also determined that the quantitative relation $Y_2/Y_1$ of the tailwater intensity to the crucial intensity needed to make a leap for any Froude variety changed into tinier than that for the corresponding bounce on a swish bed.

**Dey, S., & Westrich, B. (2003)** examined the stream attributes on firm base scour downstream of an overskirt due to a immersed level fly resulting from a floodgate establishing and acquired the articulation for mattress shear fear from the association of the von Karman pressure important condition. In contempt of the previously stated examinations, an extensive investigation of the pertinent parameters influencing the cleanse downstream of an overskirt because of a flat submerged fly is by all accounts deficient.

**F., Izadjoo, and M. Shafai-Bajestan (2005)** carried out an experimental look at to research the effect of tetragon fashioned furrowed beds at the traits of hydraulic jump. They showed the consequences of N. Rajaratnam. Additionally else that the bounce period is a lot of smitten by the wave duration of roughness than their amplitude.

**Pagliara, S., Lotti, I., & Palermo, M. (2008)** studied the parameters that have an effect on the sequent intensity and therefore the duration of the hydraulic omit same and non-homogenous difficult surface channels downstream of block ramps. They projected the brand new courting to exercise consultation the correction regular for the overall bounce equation for every uniform and non-uniform tough beds.

**Abbaspour, A., Farsadizadeh, D., Dalir (2009)** Studied hydraulic jumps on corrugated beds using turbulence era, inside the direction of the formation of the hydraulic leap on a corrugated bed, the go together with the float is turbulent water and air blending together. Two-dimensional numerical simulation of hydraulic leap on a corrugated mattress have grow to be evaluated the usage of both standard k-ε and RNG k-ε models. The effects confirmed that k-ε turbulent version and VOF method for predicting the water ground in the leap on a corrugated mattress had been suitable and the relative errors of anticipated water ground profiles and measured rate were interior diverse 2%-8.7%. The consequences of corrugations (t, s) at the number one developments of soar.

**Tokyay, N. D., Evcimen, T. U., & Șimşek, Ç. (2011)** experimented to decide the effects of corrugations on fundamental traits of the jump which include length and electricity dissipation capability results confirmed that the duration of soar turned into minimize about 37% by corrugations, 39% by strip roughness, and 36%–56% by staggered roughness. The tough bed result in 3%–10% greater electricity dissipation than that of smooth mattress.

**Velioglu, D., & Tokyay, N. D. (2012)** Used roughness element as corrugations strip or staggered harness elements or gravels. The effects showed that corrugations, gravels and both strips and staggered roughness sorts have the correct result at the traits of hydraulic bounce. The distance of the jump was minimized about 20-26 % by corrugations, 21% by gravels, 31% by strip roughness, and 35-56 % by staggered roughness compared with a classic hydraulic jump.

**Neluwala, N. G. P. B., Karunanayake (2013)** Inspect the traits of hydraulic jumps customary on difficult, flat channel surface bed underneath totally distinctive float conditions victimization laboratory investigations. The evaluation of experimental knowledge expressed that the difficult mattress reduces the gap to the soar from the gate and additionally the sequent intensity cost relation than the ones on sleek beds at the same time as developing an excessive power loss.

**El-Azab, E. E. D. Y. (2014)** have a look at the impact of the single lineage of groundwater streams at the parameters of scour hole downstream of a swaying structure with completely distinctive jetliner discharges, positions, and tailwater depths. Effects meant that the gadget of cautioned ground water jets gave from five-hundredths to the ninetieth decline in maximum scour intensity and from 40 seconds to 80 fifth decline in scouring hole distance related to the case of the ground while now not water jets. Decreasing Froude range junction rectifier to decreasing the utmost scour depth. Lowering the scour hollow length. Declining the scour index. Shifting the situation of most scour depth toward. For the foremost region of groundwater stream growing the values of jet outflow junction rectifier to improving the utmost scour depth. Growing the scour hole period. Transferring the state of affairs of peak scour intensity far from of the ground finish.

**Kim, Y., Choi, G., Park, H., & Byeon, S. (2015)** compared hydraulic jumps and downstream flow traits constant with completely extraordinary weir kinds, and examine hydraulic characteristics, reminiscent of modifications in water degrees, velocities, and energy. It clearly changed into located that even though sluice gates generated hydraulic jumps form of like the ones of fixed weirs, their vital downstream drift multiplied to finally elongate the hydraulic jumps. In electricity dissipater, set up heights have been determined to be touchy to electricity dissipation. The best energy dissipater height was tenth a part of the downstream loose floor water depth during this test.

**Abbaspour, A., Parvini, S., & Dalir, A. H. (2016)** the end result of embedded plates in erosive surface beds at the intensity of scour downstream of a hydraulic soar emerge as studied. The effects of experiments at some point of which the scour profiles were drawn in dimensionless bureaucracy show that the perspective and position of the plates are important to dominant and decreasing scour depth. In truth, by means of the usage of lowering the angle of embedded plates, the most intensity of scour is furthermore decreased. Moreover, assessment of the consequences of one embedded plate and double embedded plates suggests that victimization two embedded plates on the distances of thirty and forty-five cm from the non-erodible mattress is extra practical in decreasing the scour depth. The best distances of the embedded plates with angles of ninety and fifty from the non-erodible mattress are 45 cm and thirty cm, severally, in the situation with one embedded plate.

**Hamidifar, H., Nasrabadi, M., & Omid, M. H. (2017)** investigated the potency of scouring discount by using suggests that of one-bed, sill1placed downstream of the overskirt as the degree and to estimate its effectiveness at varying lengths from the top of the overskirt. It absolutely became located that the supreme scour downstream of the overskirt declines up to the 95th percentage. What's extra, alterations of the feature,expansions of the scour hole was examined. Also, it absolutely changed into decided that ultimately, buried, sills may not be beneficial.

**Elnikhely, E. A. (2017)** Studied the effects of staggered arrangement compared to the smooth bed using fiber glass sheets as harness elements."The flow traits are marked experimentally on an artificially harnessed base in a horizontal flat flume. It become located that the harshness mattress reduces the relative soar intensity by 24%, enhances the corresponding energy loss by 16% and decline the relative jump length by 8.5%.

# CHAPTER 3

# METHODOLOGY

## 3.1 Material and equipment used

Based on the previous study Rectangular sheet is used for further study for minimizing the kinetic energy of downstream of a hydraulic shape. The main purpose of this study to obtain sequent depth, velocity, wall shear, pressure at different cross sections of spaced rectangular sheet to minimize the kinetic energy of downstream bed. Spacing between the two consecutive strip is 'S' and S is equal to 3cm.Different dimensionless parameters are studied experimentally and wall shear, velocity ,pressure, sequent depth is calculated using ANSYS, on the basis of calculated data conclusions are finalized..Present study is compared with previous study as well as ANSYS.

For experimental purpose aluminum sheets are used. Forrowed type sheet is presented to investigate the effect of spaced rectangular strip to reduce the downstream energy of a hydraulic structure (sluice gate).

Spaced Rectangular sheet of following specification:

- Material of sheet is aluminum.
- 'S' is 3 cm, where 'S' is spacing between two consecutive strip of rectangular strip.
- Height or depth of strip is 2 cm.
- Length of sheet is 300 cm .
- Bed slope is constant for all run.

For performing the experiment following specification are given below :

Experiment was done within the laboratory of hydraulics, Branch of civil engineering, "Delhi Technological University". Rectangular flume 30 cm wide, 40 cm deep-toned and 8.0 m longest. The fences of the flume have been created obvious. Water is drawn from a garage tank to the pinnacle a tub of the flume by a pump. Rectangular films of the spaced strip had been hooked up on the flume bed within the form of way that the crests of the aluminum sheet have been on the identical degree due to the fact the upstream base on which the supercritical movement was presented by means of the use of a sluice gate. As the previous look at on tough apron studied by means of Blaidell (1947), As a result floor blocks must cover between 42 to 56 percent of ground width and the maximum favorable circumstance happens when strips are placed at right angle to the incoming jet, consequently spaced rectangular strip sheet of constant length were used for all experiment. To form the gadget of turbulent eddies in an effort to boom the mattress shear stresses we used spaced rectangular strip surface.In the experiments, the tailgate became managed in order that the leaps were formed on the aluminum sheet . States of $Y_1$ and $V_1$were elected to obtain a huge range of Froude numbers, from 2 to eight. Discharge is estimated with the help of a triangular notch at the end of the flume and it is found in between the range of 35 l/s to 45 l/s. Froude no. greater than 4.5 and less than 9 is good for steady hydraulic jump.

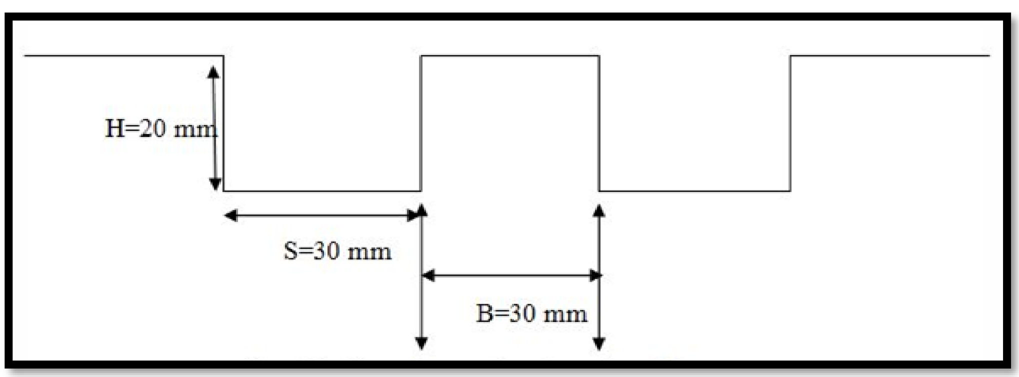


**Figure 3.1:**Specification of spaced rectangular strip

## 3.2 Side view of experimental setup

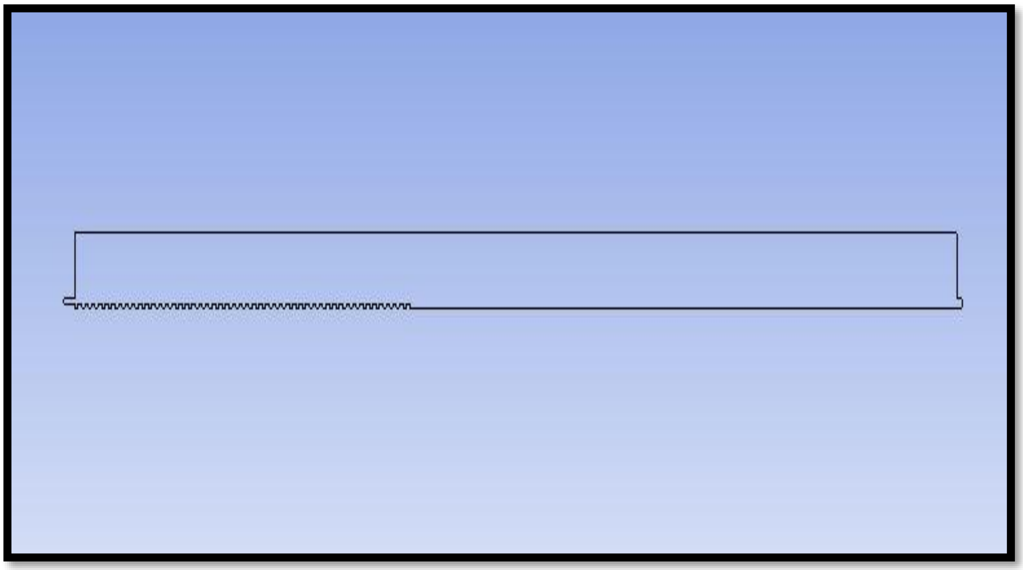

**Figure 3.2:**Setup geometry

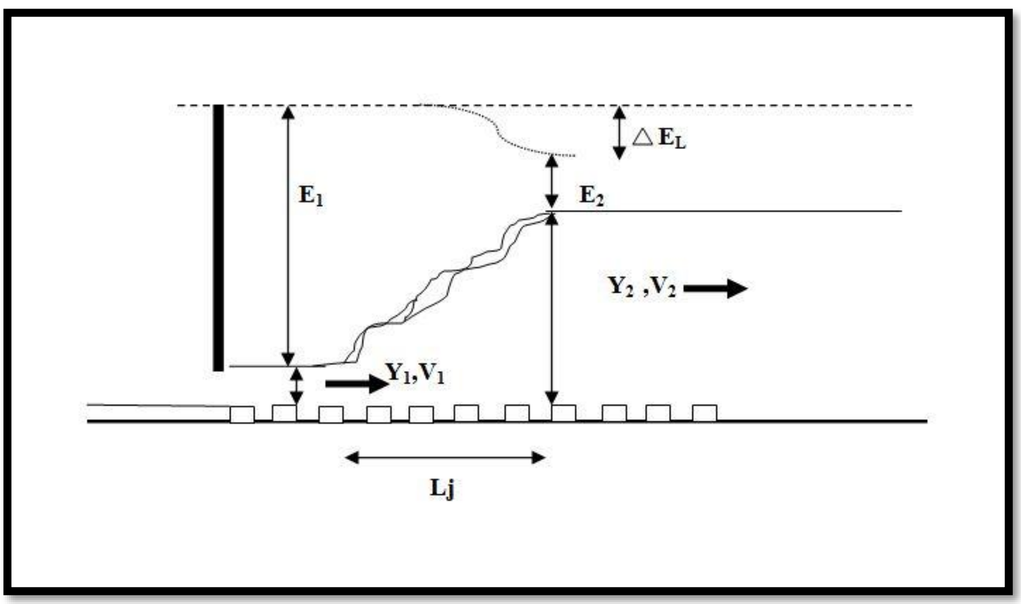


**Figure 3.2:**Laboratory setup

## 3.2 Photographs of aluminum sheets used for experiment.

**Figure 3.3:**Rectangular sheet of spacing 'S'

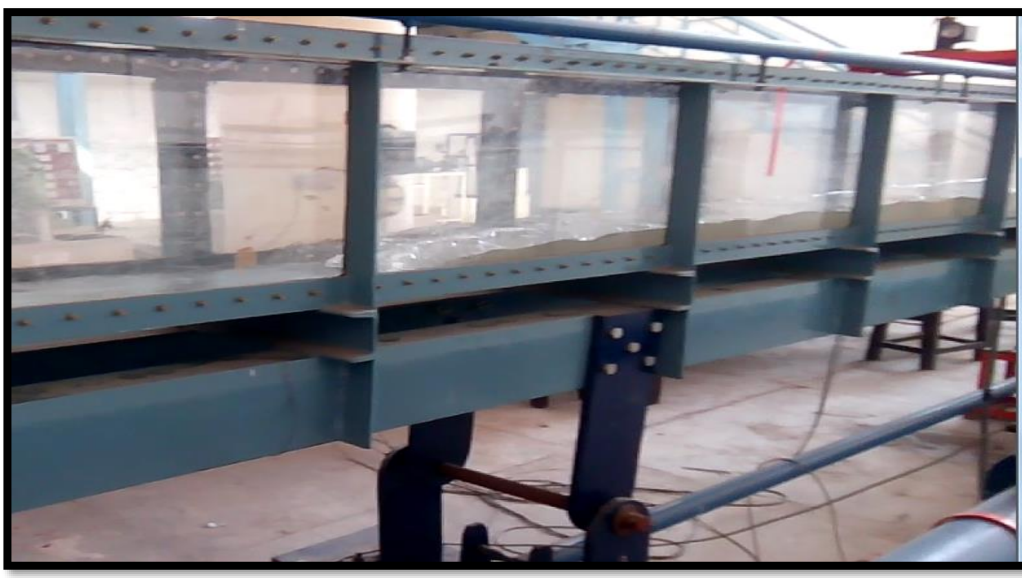

**Figure 3.4:**Formation of hydraulic jump on smooth surface

**Figure 3.5:**Formation of hydraulic jump on rough surface.

**Figure 3.6:** Formation of hydraulic jump on rough surface

**Figure 3.7:**Digital pressure meter

# CHAPTER 4

# OBSERVED DATA & VALIDATION OF RESEARCH

## 4.1 Observed data and dimensionless parameters.

(a) Tail water depth $Y_2$ needed to build a rise on a rough bed in comparing with $Y_2$* of the corresponding classical jump.

(b) Length of the surface roller $L_r$.

(c) Length of the jump $L_j$.

(d) Y the extent of flow at any station X

(e) Discharge at the end of flume using V-notch.

(f) Velocity and pressure at centre and different-different cross sections.

(g) Water surface profile.

## 4.2 Dimensionless parameters with Froude number are following:

- $Y_2/Y_1$ and Fr no.
- Depth dimensionless index D and Fr no.
- $L_r/Y_1$ and Fr no.
- $L_r/Y_2$ and Fr no.
- $L_r/Y_2^*$ and Fr no.
- $L_j/Y_1$ and Fr no.
- $L_j/Y_2$ and Fr no.
- $L_j/Y_2^*$ and Fr no.

## 4.3 Table for observed data

**(a)** For smooth bed (All units are in 'Metric' form).

**Table 4.1** Data for smooth bed

| $Y_1$ (m) | U(m/s) | $F_r$ | $Y_2$ | $Y_2$* | $L_r$ | $L_j$ | D |
|---|---|---|---|---|---|---|---|
| **0.03** | 2.12 | 3.91 | 0.121 | 0.151 | 0.881 | 1.12 | 0.20 |
| **0.03** | 2.5 | 4.61 | 0.158 | 0.181 | 0.964 | 1.21 | 0.12 |
| **0.03** | 2.88 | 5.31 | 0.197 | 0.211 | 1.21 | 1.5 | 0.06 |
| **0.03** | 3.2 | 5.90 | 0.220 | 0.236 | 1.03 | 1.32 | 0.06 |
| **0.03** | 3.49 | 6.43 | 0.230 | 0.258 | 1.07 | 1.37 | 0.10 |
| | | | | | | | |
| **0.04** | 2.58 | 4.12 | 0.226 | 0.214 | 0.712 | 0.89 | -0.05 |
| **0.04** | 2.43 | 3.88 | 0.201 | 0.200 | 0.784 | 0.98 | -0.00 |
| **0.04** | 2.61 | 4.17 | 0.227 | 0.217 | 0.87 | 1.03 | -0.04 |
| **0.04** | 2.82 | 4.50 | 0.252 | 0.235 | 0.89 | 1.08 | -0.07 |
| **0.04** | 3.11 | 4.96 | 0.269 | 0.262 | 0.91 | 1.1 | -0.02 |

| $L_j/Y_2$* | $Y_2/Y_1$ | $L_r/Y_2$* | $L_r/Y_2$ | $L_j/Y_2$ | $L_r/Y_1$ | $L_j/Y_1$ |
|---|---|---|---|---|---|---|
| 7.39 | 4.03 | 5.81 | 7.28 | 9.25 | 29.36 | 37.33 |
| 6.68 | 5.26 | 5.32 | 6.10 | 7.66 | 32.13 | 40.36 |
| 7.11 | 6.56 | 5.74 | 6.14 | 7.61 | 40.33 | 50.00 |
| 5.6001 | 7.33 | 4.36 | 4.68 | 6.00 | 34.33 | 44.00 |
| 5.30 | 7.66 | 4.14 | 4.65 | 5.95 | 35.66 | 45.66 |
| | | | | | | |
| 4.16 | 5.65 | 3.32 | 3.15 | 3.93 | 17.80 | 22.25 |
| 4.89 | 5.02 | 3.91 | 3.90 | 4.87 | 19.60 | 24.50 |
| 4.75 | 5.67 | 4.01 | 3.83 | 4.53 | 21.75 | 25.75 |
| 4.58 | 6.30 | 3.78 | 3.53 | 4.28 | 22.25 | 27.00 |
| 4.2 | 6.72 | 3.47 | 3.38 | 4.08 | 22.75 | 27.50 |

(b) For rectangular strip beds

**Table 4.2** Data for rectangular strip bed

| $Y_1$ (m) | U (m/s) | $F_r$ | $Y_2$ | $Y_2$* | $L_r$ | $L_j$ | D |
|---|---|---|---|---|---|---|---|
| **0.03** | 2.12 | 3.91 | 0.090 | 0.151 | 0.15 | 0.18 | 0.406 |
| **0.03** | 2.50 | 4.61 | 0.112 | 0.181 | 0.20 | 0.24 | 0.382 |
| **0.03** | 2.88 | 5.31 | 0.127 | 0.211 | 0.31 | 0.36 | 0.397 |
| **0.03** | 3.20 | 5.90 | 0.130 | 0.236 | 0.32 | 0.41 | 0.448 |
| **0.03** | 3.49 | 6.43 | 0.135 | 0.258 | 0.36 | 0.44 | 0.477 |
| | | | | | | | |
| **0.04** | 2.58 | 4.12 | 0.120 | 0.214 | 0.17 | 0.21 | 0.439 |
| **0.04** | 2.43 | 3.88 | 0.145 | 0.200 | 0.28 | 0.31 | 0.276 |
| **0.04** | 2.61 | 4.17 | 0.151 | 0.217 | 0.28 | 0.34 | 0.303 |
| **0.04** | 2.82 | 4.50 | 0.154 | 0.235 | 0.29 | 0.36 | 0.346 |
| **0.04** | 3.11 | 4.96 | 0.159 | 0.262 | 0.35 | 0.41 | 0.392 |

| $t/Y_1$ | $Lj/Y_2$* | $Y_2/Y_1$ | $L_r/Y_2$* | $L_r/Y_2$ | $L_j/Y_2$ | $L_r/Y_1$ | $L_j/Y_1$ |
|---|---|---|---|---|---|---|---|
| 0.667 | 1.18 | 3.000 | 0.99 | 1.66 | 2.000 | 5.049 | 6.000 |
| 0.667 | 1.32 | 3.733 | 1.10 | 1.78 | 2.143 | 6.036 | 8.000 |
| 0.667 | 1.70 | 4.233 | 1.47 | 2.44 | 2.835 | 7.024 | 12.000 |
| 0.667 | 1.73 | 4.333 | 1.35 | 2.46 | 3.154 | 7.857 | 13.667 |
| 0.667 | 1.70 | 4.500 | 1.39 | 2.66 | 3.259 | 8.612 | 14.667 |
| | | | | | | | |
| 0.500 | 0.98 | 3.000 | 0.79 | 1.41 | 1.750 | 4.250 | 5.250 |
| 0.500 | 1.54 | 3.625 | 1.39 | 1.93 | 2.138 | 7.000 | 7.750 |
| 0.500 | 1.57 | 3.775 | 1.29 | 1.85 | 2.252 | 7.000 | 8.500 |
| 0.500 | 1.52 | 3.850 | 1.23 | 1.88 | 2.338 | 7.250 | 9.000 |
| 0.500 | 1.56 | 3.975 | 1.33 | 2.20 | 2.579 | 8.750 | 10.250 |

(c) Water surface profile

**Table 4.3** Data for water surface profile

| X(m) | Y(m) | Fr=7.51 | Fr=4.5 | Fr=5.38 | Fr=6.88 | Fr=6.19 |
|---|---|---|---|---|---|---|
| **0** | | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 |
| **0.05** | | 0.04 | 0.04 | 0.03 | 0.04 | 0.05 |
| **0.1** | | 0.08 | 0.06 | 0.07 | 0.05 | 0.07 |
| **0.15** | | 0.08 | 0.06 | 0.08 | 0.07 | 0.07 |
| **0.2** | | 0.10 | 0.07 | 0.10 | 0.09 | 0.08 |
| **0.25** | | 0.12 | 0.07 | 0.11 | 0.10 | 0.09 |
| **0.3** | | 0.15 | 0.09 | 0.11 | 0.11 | 0.10 |
| **0.35** | | 0.15 | 0.09 | 0.10 | 0.11 | 0.11 |
| **0.4** | | 0.16 | 0.08 | 0.10 | 0.13 | 0.12 |
| **0.45** | | 0.15 | 0.08 | 0.11 | 0.13 | 0.12 |
| **0.5** | | 0.14 | 0.07 | 0.11 | 0.15 | 0.12 |

## 4.4 Validation of research

Validation is divided into two segments one is graphical method another is Numerical simulation i.e. ANSYS

### 4.4.1 Graphical method

**(a) Variation of sequent depth and Froude number**

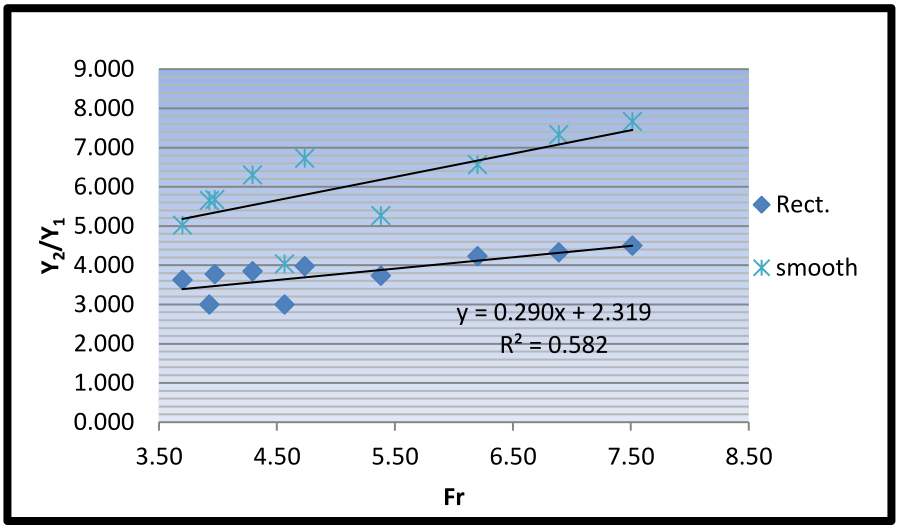


**Figure4.1:**Experimental results of present study are plotted between sequent depth and Froude number

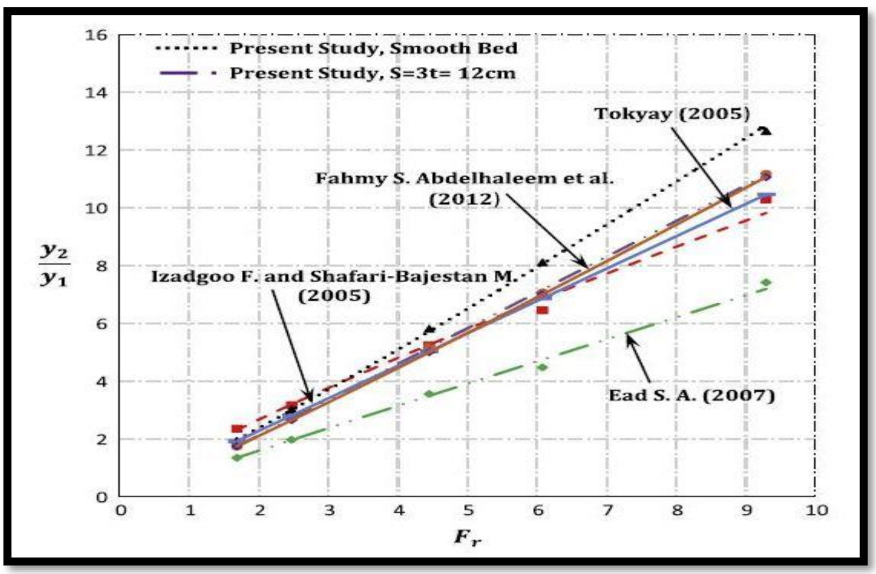


**Figure 4.2:**Experimental results of previous study (H.M.Ali, M. E. Gendy 2014) are plotted between sequent depth and Froude number

**Comment:** In present study sequent depth for rectangular strip bed is reduced to 40 % as compare to smooth bed and this result is almost similar to past study of Ead S.A.(2007) Izadgoo F.(2005) etc **.**

**(b) Variation of $L_j/Y_1$ and Froude number**

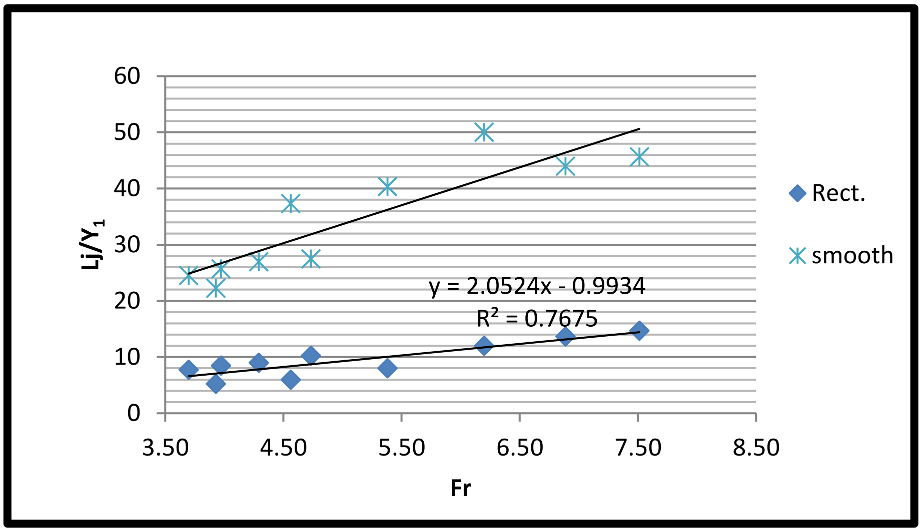


**Figure 4.3:**Experimental results of present study are plotted between $Lj/Y_1$ and Froude number

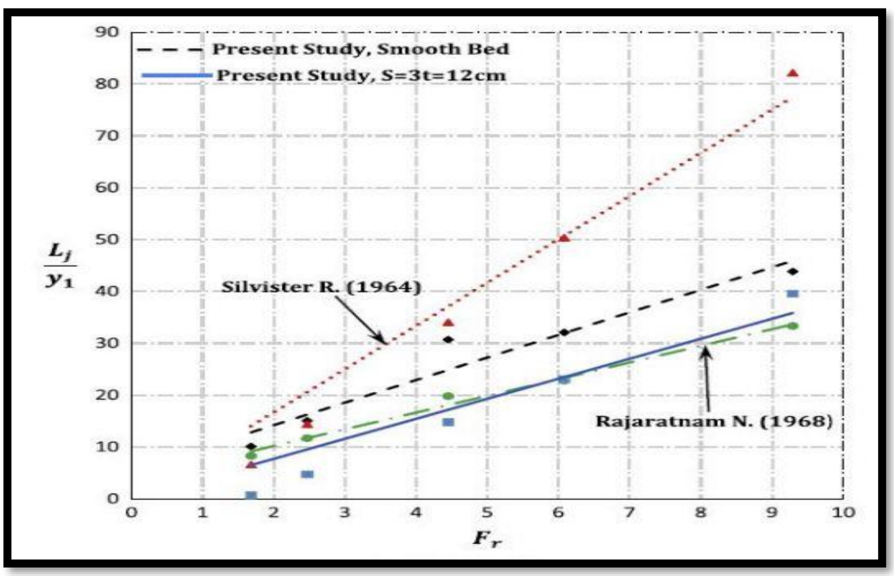


**Figure 4.4:**Experimental results of previous study (H.M.Ali, M. E. Gendy 2014) are plotted between $Lj/Y_1$ and Froude number

**Comment:** In present study dimensionless parameters like length of jump ratio corresponding to initial depth for rectangular strip bed is reduced to 70 % as compare to smooth bed and this result is almost similar to past study of Rajaratnam(1968).

**(c) Variation of depth deficit factor and Froude number**

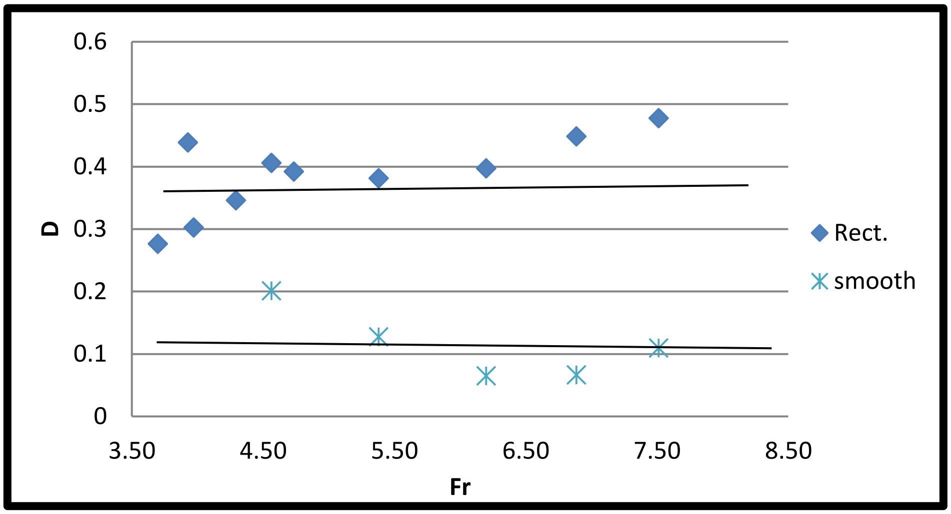


**Figure 4.5:**Experimental results of present study are plotted between depth deficit factor and Froude number

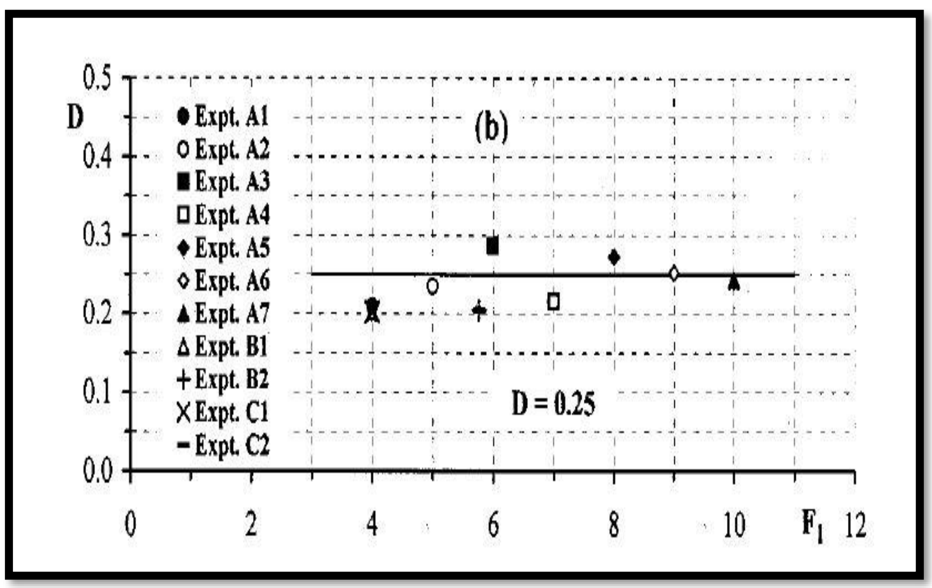


**Figure 4.6:**Experimental results of previous study (S. A. Ead, N. Rajaratnam 2002) are plotted depth deficit factor and Froude number

**Comment:** In present study Depth deficit factor for rectangular strip bed is within the range of 0.3 and 0.4 and for smooth bed it is 0.1**.**Whenever the depth deficit factor is high then it is good for reducing the sequent depth and past study Rajaratnam on rough bed is in between 0.2 and 0.3.

**(d) Variation of $L_r/Y_1$ and Froude number**

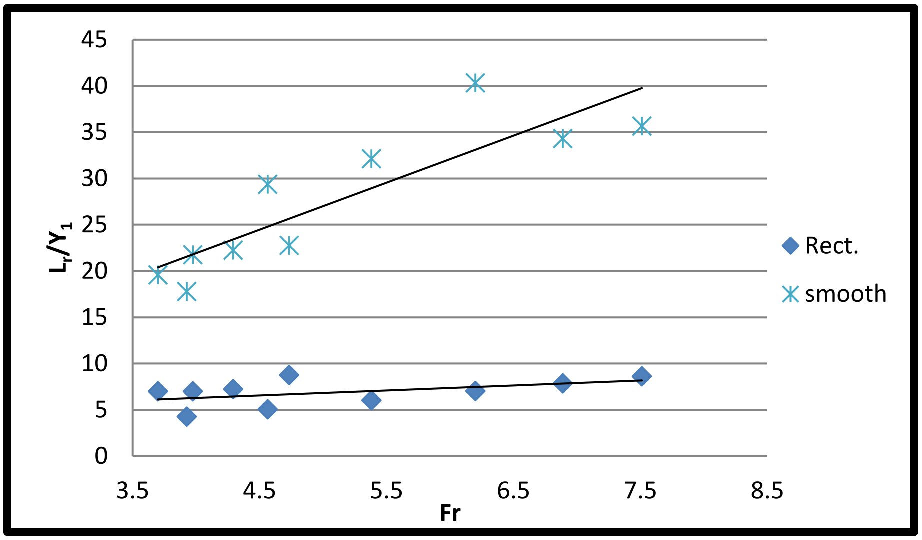


**Figure 4.7:**Experimental results of present study are plotted between $Lr/Y_1$ and Froude number

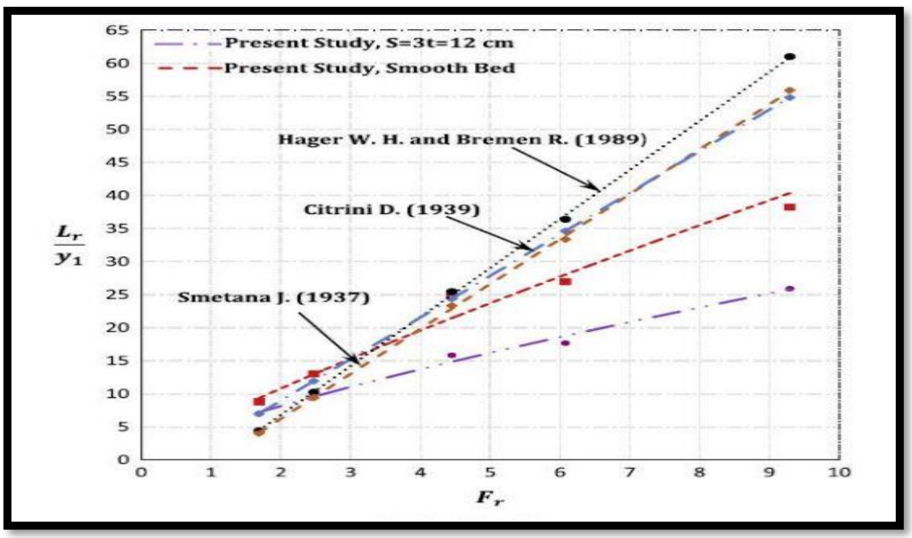


**Figure 4.8:**Experimental results of previous study (H.M.Ali, M. E. Gendy 2014) are plotted $Lr/Y_1$ and Froude number

**Comment:** In present study dimensionless parameter roller length ratio corresponding to initial depth for rectangular strip bed is reduced to 75 % as compare to smooth bed and this result is almost similar to past study of Smetana (1937) ,Hager (1989) etc .

**(e) Variation of $L_j/Y_2$* and Froude number**

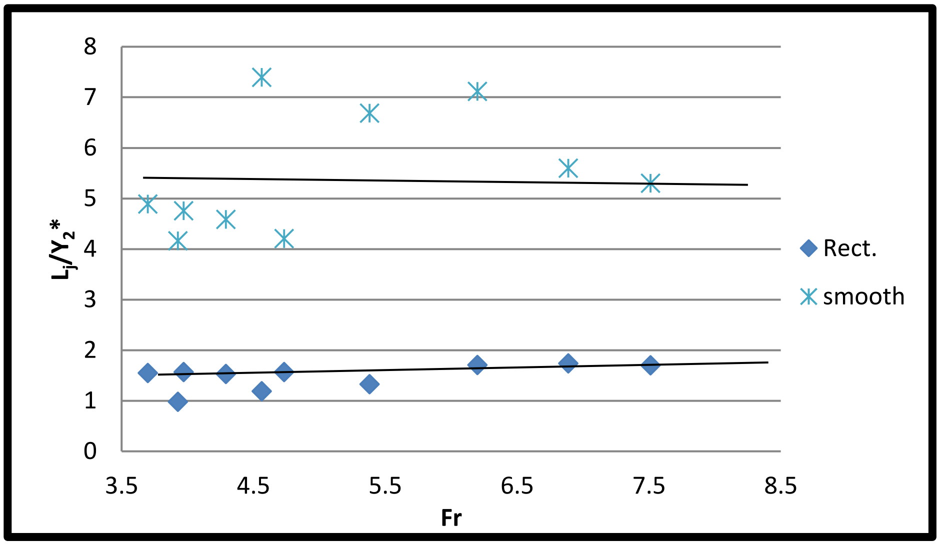


**Figure 4.9:**Experimental results of present study are plotted $Lj/Y_2$* and Froude number

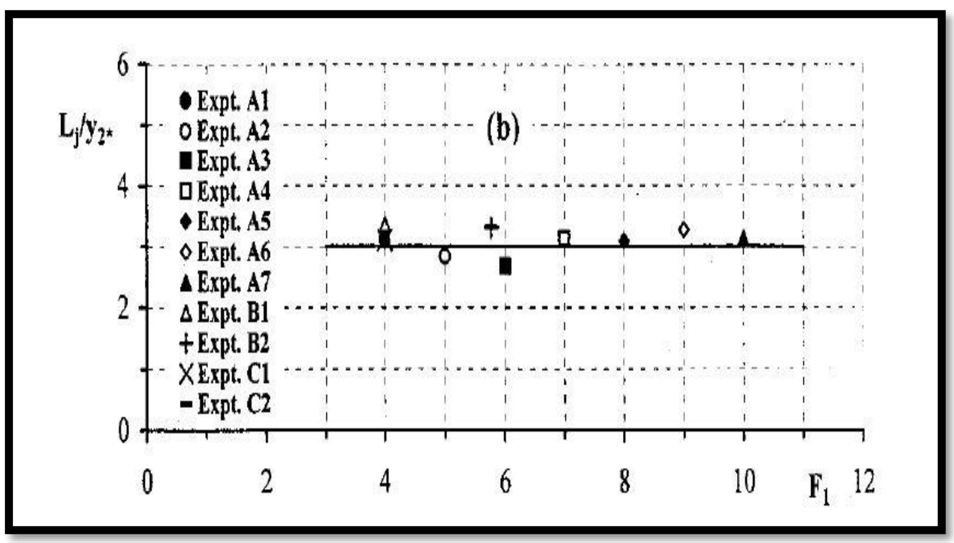


**Figure 4.10:**Experimental results of previous study (S. A. Ead, N. Rajaratnam 2002) are plotted between $Lj/Y_2$*and Froude number

**Comment:** In present study dimensionless parameter jump length ratio corresponding to $Y_2$* for rectangular strip bed is reduced to 83 % as compare to smooth bed and this result is almost similar to past study of Rajaratnam.

### (f) Variation of $L_r/Y_2*$ and Froude number

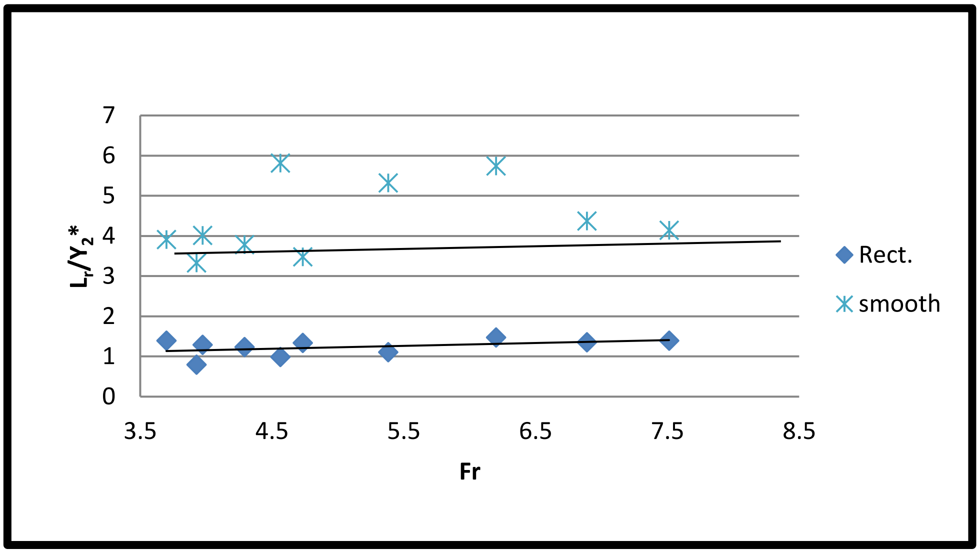


**Figure 4.11:**Experimental results of present study are plotted between Lr/$Y_2$* and Froude number

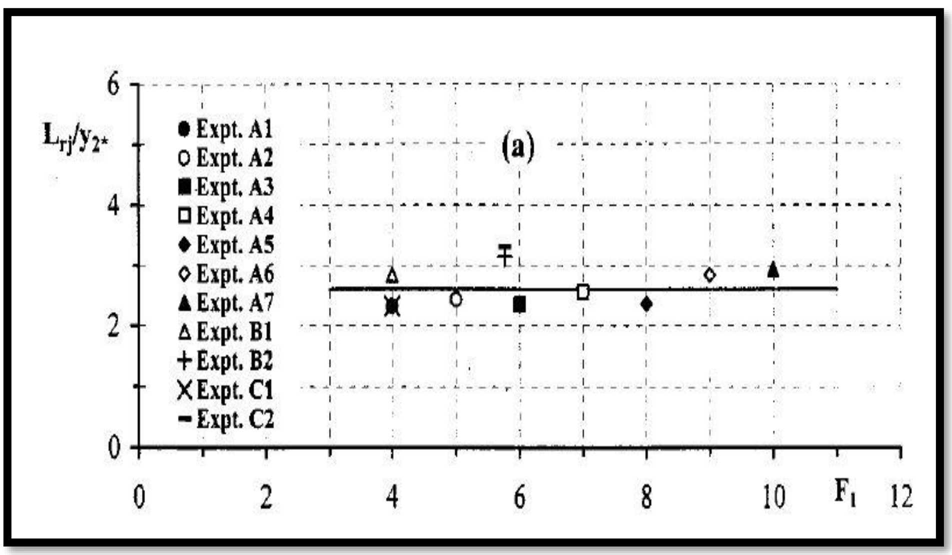


**Figure 4.12:**Experimental results of previous study (S. A. Ead, N. Rajaratnam 2002) are plotted between Lr/$Y_2$*and Froude number

**Comment**: In present study dimensionless parameter roller length ratio corresponding to $Y_2$* for rectangular strip bed is reduced to 65 % as compare to smooth bed and this result is almost similar to past study of Rajaratnam.

**(g) Variation of $L_j/Y_2$ and Froude number**

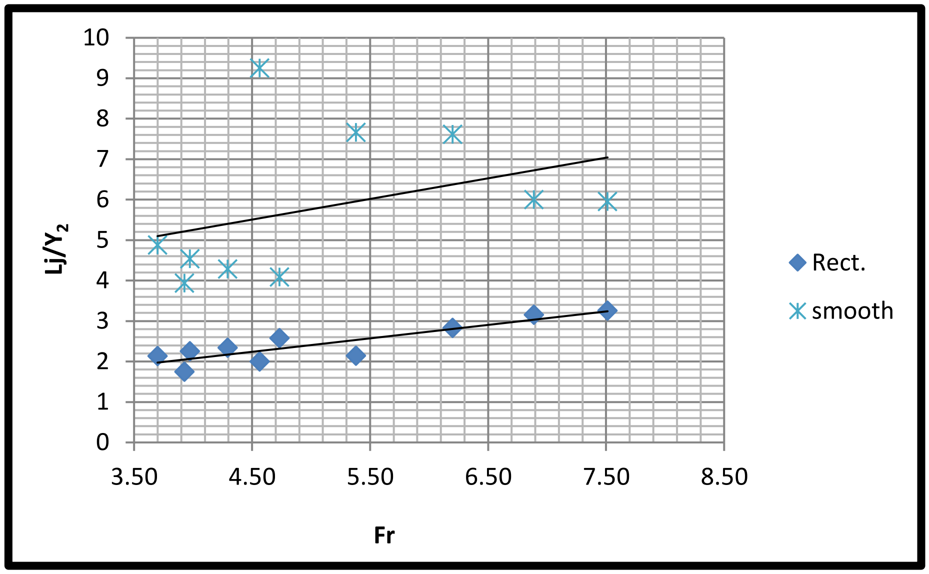


**Figure 4.13:**Experimental results of present study are plotted between $Lj/Y_2$ and Froude number

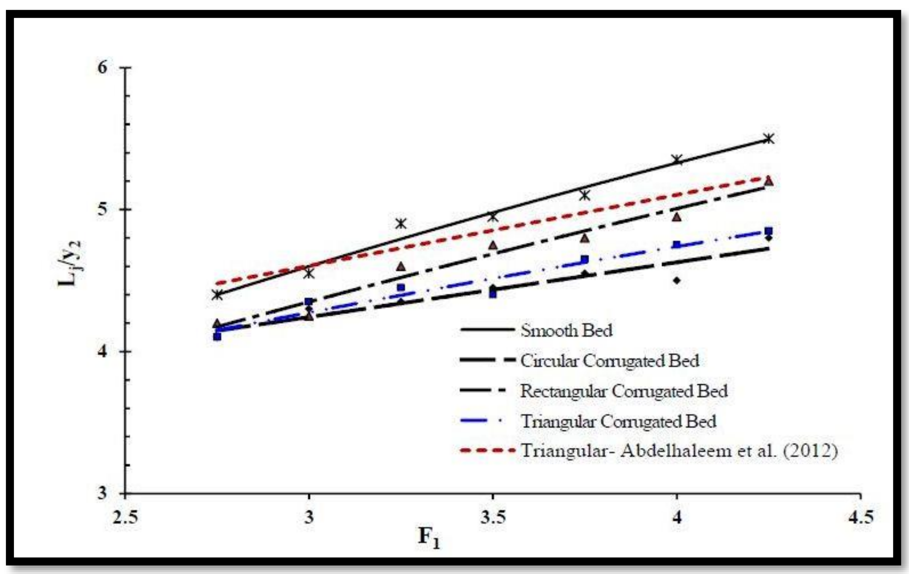


**Figure 4.14:**Experimental results of previous study (H.M.Ali, M. E. Gendy 2014) are plotted between $Lj/Y_2$ and Froude number

**Comment:** In present study dimensionless parameter jump length ratio corresponding to $Y_2$ for rectangular strip bed is reduced to 60 % as compare to smooth bed and this result is almost similar to past study of Abdelhaleem(2012).

**(h) Variation of $L_r/Y_1$ and Froude number**

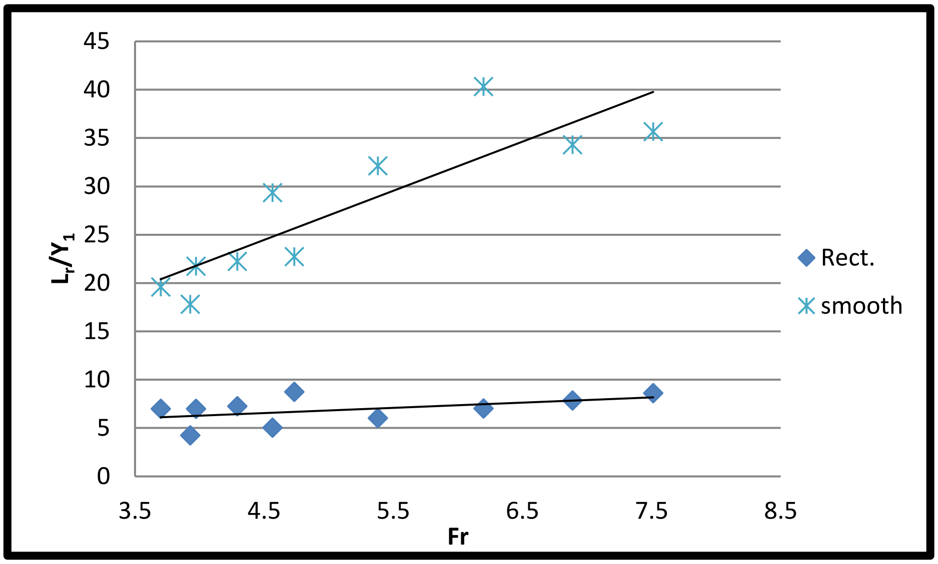


**Figure 4.15:**Experimental results of present study are plotted $Lr/Y_1$ and Froude number

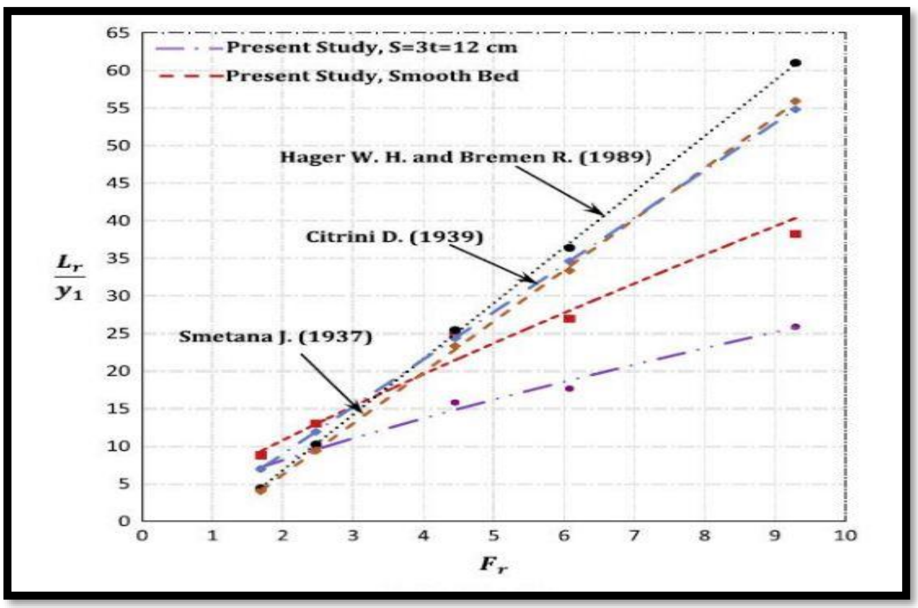


**Figure 4.16:**Experimental results of previous study (H.M.Ali, M. E. Gendy 2014) are plotted between $Lr/Y_1$ and Froude number

**Comment:** In present study dimensionless parameter roller length ratio corresponding to $Y_1$ for rectangular strip bed is reduced to 75 % as compare to smooth bed and this result is almost similar to past study of Smetana (1937) ,Hager (1989) etc

### (i) Variation of water surface profile

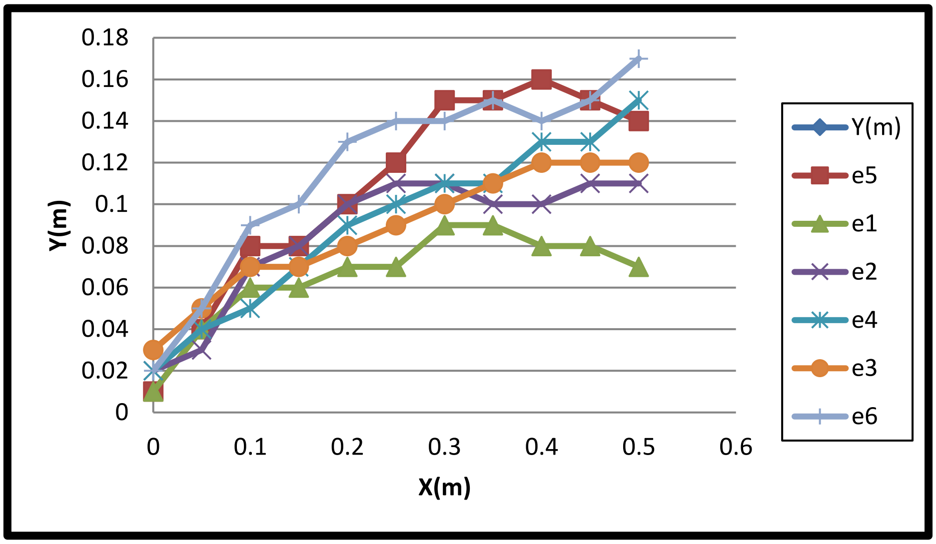


**Figure 4.17:**Experimental results of present study are plotted for water surface profile

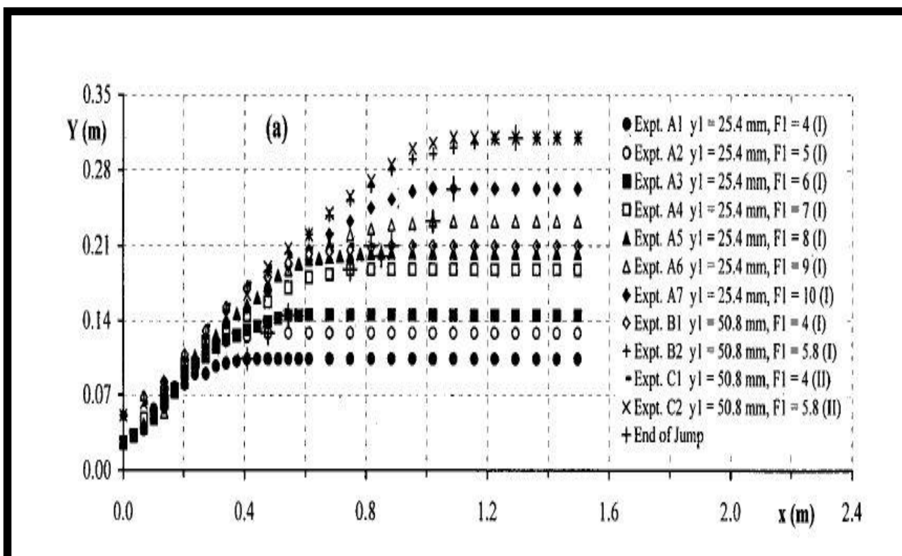


**Figure 4.18:**Experimental results of previous study (S. A. Ead, N. Rajaratnam 2002) are plotted for water surface profile

**Comment:** In present study water surface profile is recorded for rectangular strip bed and this result is almost similar to the ANSYS simulation as well as past study of Rajaratnam on rough bed.

### 4.4.2 Numerical simulation method i.e ANSYS

Parameters which are cross checked and calculated :

(a) Sequent depth $Y_2$

(b) Dimensionless parameter $Y_2/Y_1$ and corresponding loss percentage.

(c) Energy loss is calculated at different sections with the help of total head.

(d) Mass Flow Contour,Velocity Contour ,Velocity Streamline ,Pressure Contour ,Velocity vector ,Wall shear vector, Volume fraction are plotted.

### 4.5 Steps followed in ANSYS simulation:

(a) Geometry

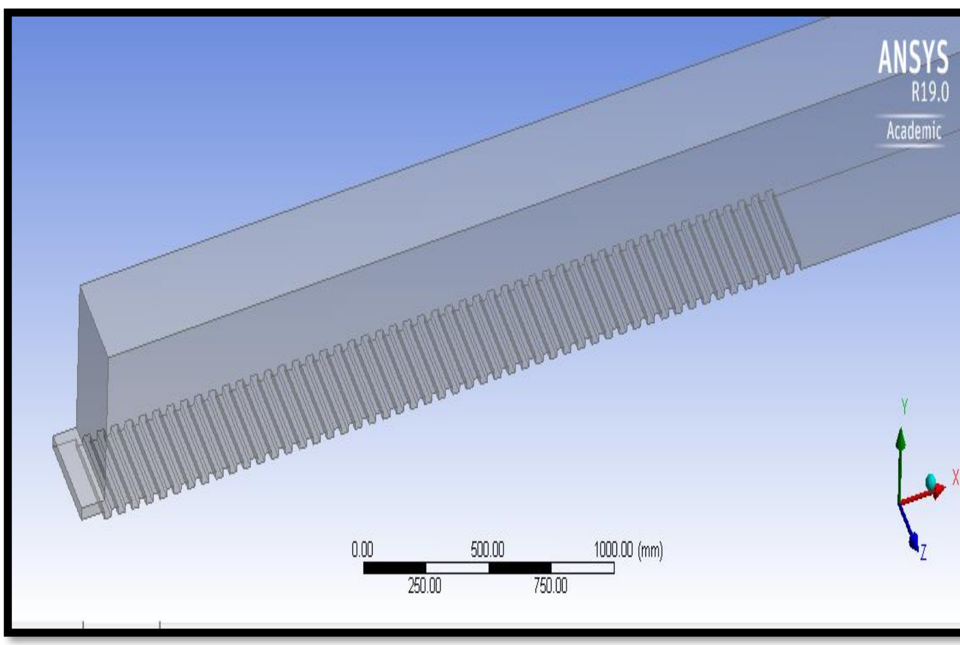


**Figure 4.19:**ANSYS Geometry

(b) Meshing

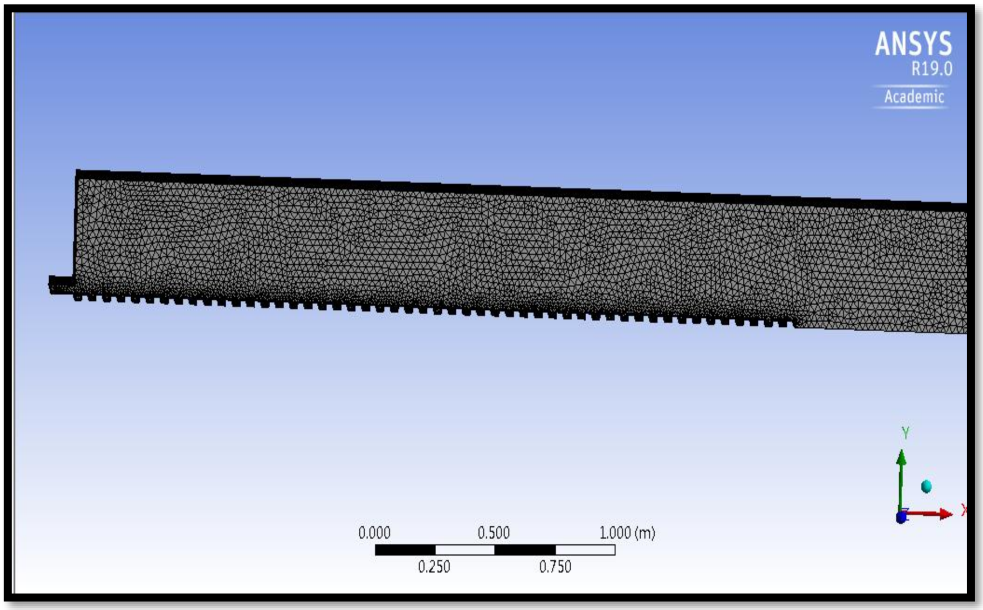


**Figure 4.20:**ANSYS Meshing

(c) Setup

Data provided to software (ANSYS) like Units, Boundary conditions, Mesh named selection etc are listed as table format.

**Table 4.4** ANSYS unit

| | |
|---|---|
| Unit Used | Metric (m, kg, N, s, V, A) rad/s Degrees Celsius |
| Given Angle | Degrees |
| Given Rotational Velocity | rad/s |
| Tempareture | Celsius |

**Table 4.5** ANSYS Geometry
Model (A3) > Geometry

| Objects Name | *Geometry* |
|---|---|
| State of body | Fully Defined |
| **Definition** | |
| Source | E:\harshit\hk 1_files\dp0\FFF\DM\FFF.agdb |
| Type of modeler used | Design Modeler |
| Length Unit | Meters |
| **Bounding Box** | |
| Length -X | 8.05 m |
| Length -Y | 0.42 m |
| Length -Z | 0.3 m |
| **Properties** | |
| Taken Volume | 0.98805 $m^3$ |
| Scale Factor Value | 1. |
| **Statistics** | |
| Bodies | 1 |
| Active Bodies | 1 |
| Nodes | 267177 |
| Elements | 968932 |
| Mesh Metric | None |
| **Basic Geometry Options** | |
| Parameters | Independent |
| Parameter Key | DS |
| Attributes | No |
| Named Selections | No |
| Material Properties | No |
| **Advanced Geometry Options** | |
| Use Associativity | Yes |
| Coordinete Systems | No |
| Reader Mode Saves Updated File | No |
| Use Instences | Yes |
| Smart CAD Update | No |
| Compare Parts On Update | No |
| Analysis Type | 3-D |
| Decompos Disjoint Geometry | Yes |
| Enclosur and Symmetry Processing | No |

**Table 4.6** ANSYS Parts
**Model (A3) > Geometry > Parts**

| | |
|---|---|
| Object Name | *Solid* |
| State of mesh | Meshed |
| **Graphics Properties** | |
| Visiblilty | Yes |
| Given Transparency | 1 |
| **Definition** | |
| Suppressed | No |
| Taken coordinate system | Default Coordinate System |
| Behavior | None |
| Reference Frame | Lagrangian |
| **Material** | |
| Assignment | |
| Fluid/Solid | Defined By Geometry (Solid) |
| **Bounding Box** | |
| Length- X | 8.05 m |
| Length -Y | 0.42 m |
| Length- Z | 0.3 m |
| **Properties** | |
| Volume | 0.98805 $m^3$ |
| Centroid- X | 4.0716 m |
| Centroid- Y | 0.19152 m |
| Centroid- Z | 5.1501e-017 m |
| **Statistics** | |
| Taken Nodes | 267177 |
| Taken Elements | 968932 |
| Mesh Metric | None |

**Table 4.7** ANSYS Coordinate System
**Model (A3) > Coordinate Systems > Coordinate System**

| | |
|---|---|
| Object Name | *Global Coordinate System* |
| State of body | Fully Defined |
| **Definition** | |
| Type of coordinates | Cartesian |
| Coordinate System ID | 0. |
| **Origin** | |

| | |
|---|---|
| Origin- X | 0. m |
| Origin- Y | 0. m |
| Origin- Z | 0. m |
| **Directional Vectors** | |
| X Axis Data | [ 1. 0. 0. ] |
| Y Axis Data | [ 0. 1. 0. ] |
| Z Axis Data | [ 0. 0. 1. ] |

**Table 4.8** ANSYS Mesh
Model (A3) > Mesh

| | |
|---|---|
| Object Name | *Mesh* |
| State of mesh | Solved |
| **Display** | |
| Display color | Body Color |
| **Defaults** | |
| Physics | CFD |
| Solver Preference | Fluent |
| Export Format | Standard |
| Export Preview Surface Mesh | No |
| Element Order | Linear |
| **Sizing** | |
| Size Function | Proximity |
| Max Face Size | 2.5e-002 m |
| Mesh -Defeaturing | Yes |
| Defeature -Size | 5.888e-004 m |
| Growth Rate Taken | Default (1.20 ) |
| Max Tet | 3.e-002 m |
| Proximity Min Size Provided | 1.1776e-003 m |
| Num Cells Across Gap | Default (3) |
| Proximity Size Function Sources | Faces and Edges |
| Bounding Box Diagonal | 8.06650 m |
| Average Surface Area | 5.7601e-002 $m^2$ |
| Minimum Edge Length | 2.e-002 m |
| **Quality** | |
| Review Mesh Quality | Yes, Errors |
| Target Skewness | Default (0.900000) |
| Smoothing | Medium |

| | |
|---|---|
| Mesh Metric | None |
| **Inflation** | |
| Automatic Inflation | None |
| Inflation Option Provided | Smooth Transition |
| Taken Transition Ratio | 0.272 |
| Maximum Layers Provided | 5 |
| Growth Rate | 1.2 |
| Inflation Algorithm | Pre |
| View Advanced Options | No |
| **Assembly Meshing** | |
| Method | None |
| **Advanced** | |
| Number of CPUs for Parallel Part Meshing | Program Controlled |
| Straight Sided Elements | |
| Number of Retries | 0 |
| Rigid Body Behavior | Dimensionally Reduced |
| Triangle Surface Mesher | Program Controlled |
| Topology Checking | No |
| Tolerance | Default (1.0598e-003 m) |
| Generate Pinch on Refresh | No |
| **Statistics** | |
| Taken Nodes | 267177 |
| Taken Elements | 968932 |

**Table 4.9** ANSYS Mesh Controls
**Model (A3) > Mesh > Mesh Controls**

| | |
|---|---|
| Object Name Provided | *Inflation* |
| State of Body | Fully Defined |
| **Scope** | |
| Scoping Method | Geometry Selection |
| Number of Geometry | 1 Body |
| **Definition** | |
| Suppressed | No |
| Boundary Scoping | Geometry Selection |
| Given Boundary | 202 Faces |
| Inflation Option | Smooth Transition |
| Transition Ratio Taken | Default (0.272) |
| Maximum Number of Layers | 5 |
| Growth Rate | 1.2 |
| Inflation Algorithm | Pre |

**Table 4.10** ANSYS Named Selections
**Model (A3) > Named Selections > Named Selections**

| | | | |
|---|---|---|---|
| Object Name | *inlet* | *outlet* | *ambient* |
| State of Body | Fully Defined | | |
| **Scope** | | | |
| Scoping | Geometry Selection | | |
| Geometry | 1 Face | | |
| **Definition** | | | |
| Send to Solver | Yes | | |
| Protection | Program Controlled | | |
| Visiblity | Yes | | |
| Program Controlled Inflation | Exclude | | |
| **Statistics** | | | |
| Type of Setting | Manual | | |
| Total Selection | 1 Face | | |
| Given Surface Area | 9.e-003 $m^2$ | 8.1e-002 $m^2$ | 2.37 $m^2$ |
| Suppressed | 0 | | |
| Used by Mesh Worksheet | No | | |

(d) Results

(a)Mass Flow Contour

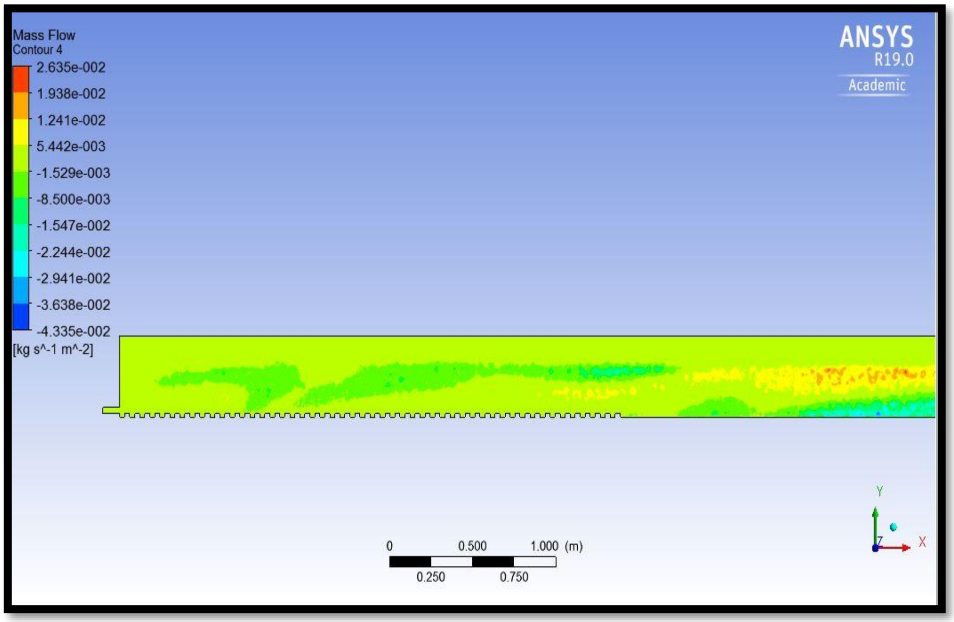


**Figure 4.21** Mass Flow Contour

(b) Velocity Contour

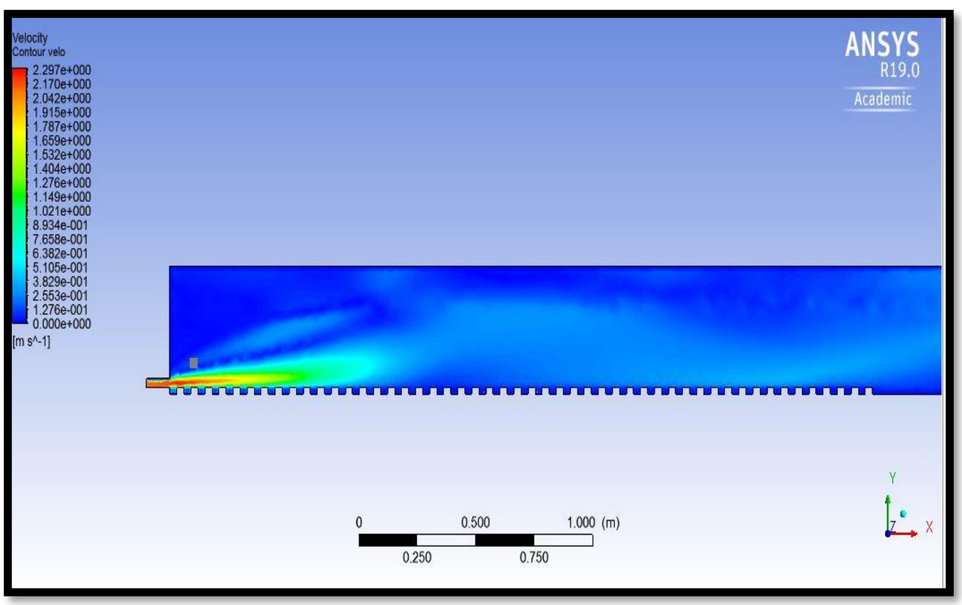


**Figure 4.22** Velocity Contour

(c) Velocity Streamline

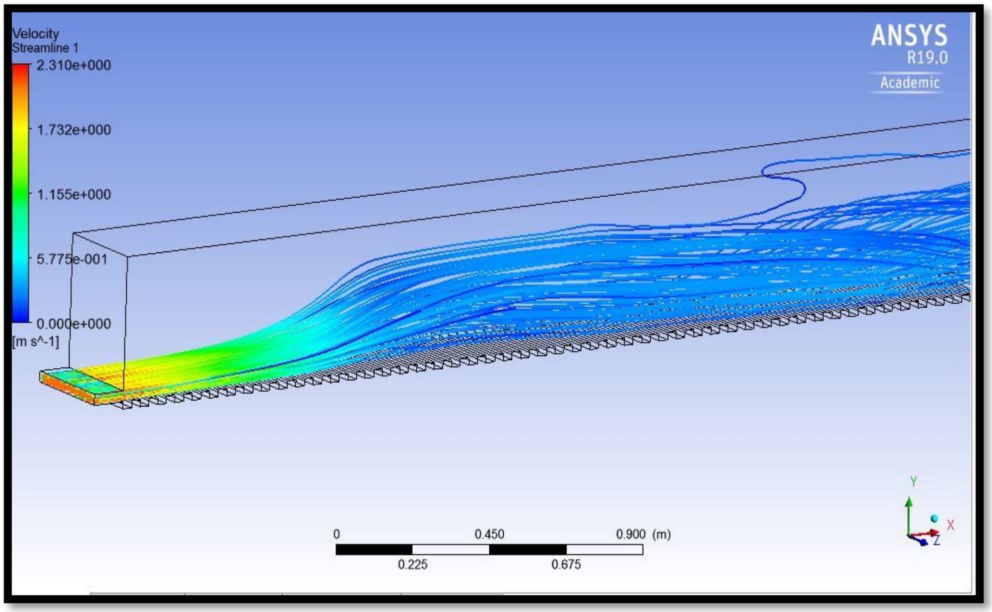


**Figure 4.23** Velocity Streamline

(d) Pressure Contour

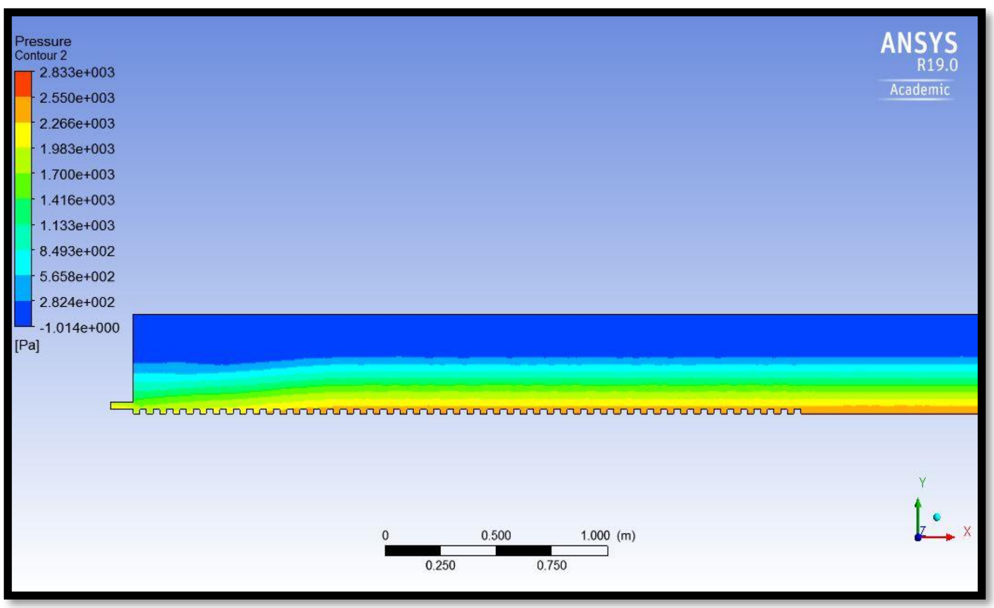


**Figure 4.24** Pressure Contour

(e) Velocity vector

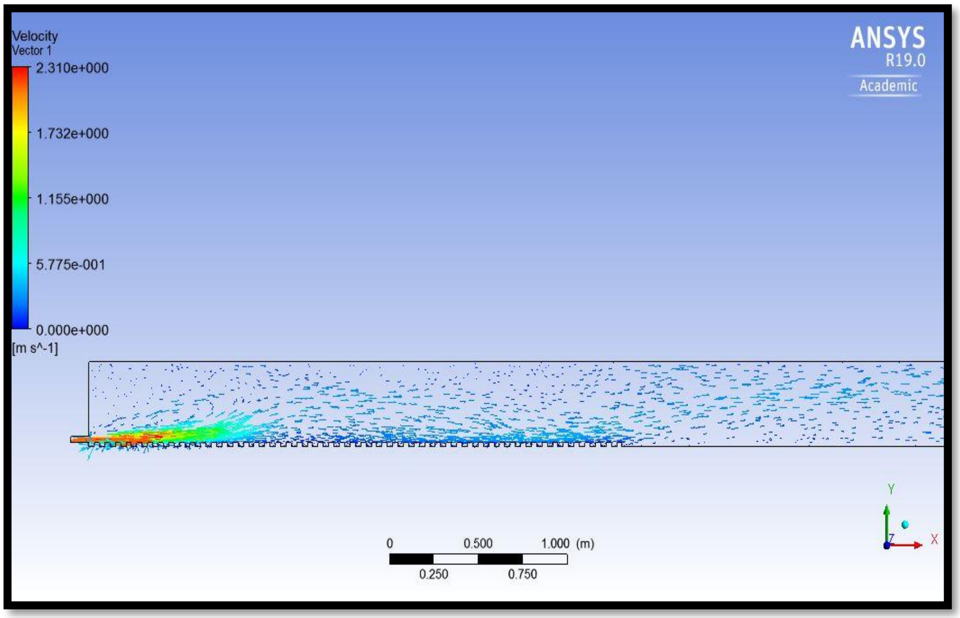


**Figure 4.25** Velocity vector

(f) Wall shear vector

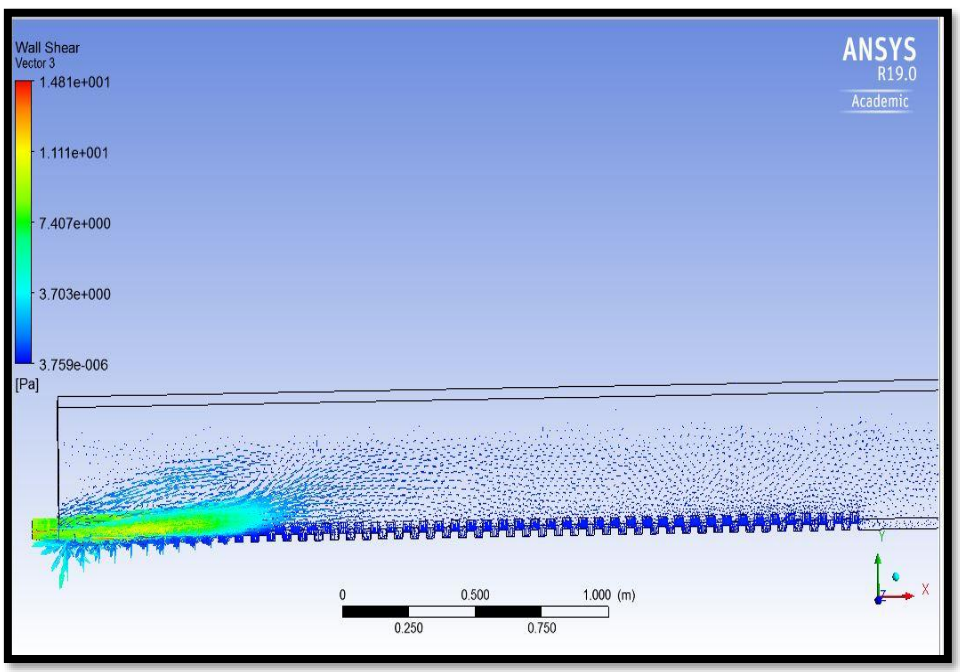


**Figure 4.26** Wall shear vector

(g) Volume fraction

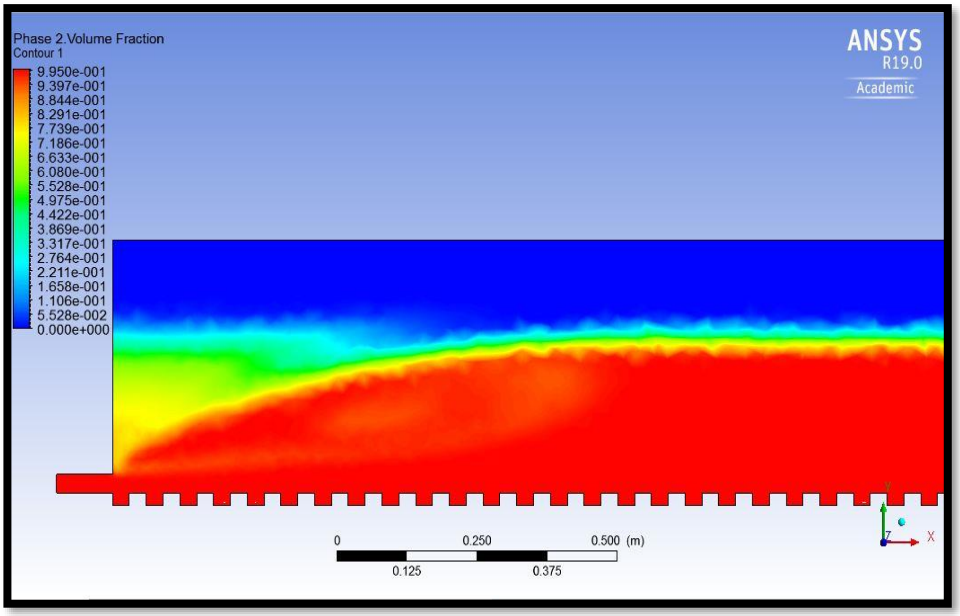


**Figure 4.27** Volume fraction

**Table 4.11:**Data for comparison of sequent depth

| $Y_1$ (m) | Velocity (m/s) | Fr | $Y_2$ (m) (Experimental) | $Y_2$ (m) ANSYS | $Y_2/Y_1$ (Experimental) | $Y_2/Y_1$ (ANSYS) | Error % |
|---|---|---|---|---|---|---|---|
| **0.03** | 2.12 | 3.91 | 0.09 | 0.11 | 3 | 3.66 | -22.22 |
| **0.03** | 2.5 | 4.61 | 0.112 | 0.1 | 3.733 | 3.33 | 10.71 |
| **0.03** | 2.88 | 5.31 | 0.127 | 0.09 | 4.233 | 3 | 29.13 |
| **0.03** | 3.2 | 5.9 | 0.13 | 0.11 | 4.333 | 3.66 | 15.38 |
| **0.03** | 3.49 | 6.43 | 0.135 | 0.121 | 4.5 | 4.03 | 10.37 |

Table 4.12 Data for energy loss

| Distance (m) (in the direction of flow measured from sluice gate) | Pressure (Pa) | Velocity (m/s) | Datum Head | Press Head | Velocity Head | Total Head |
|---|---|---|---|---|---|---|
| **0.12** | 1729.87 | 2.26 | 0.015 | 0.1763 | 0.260 | 0.451 |
| **0.2** | 1128.68 | 0.127 | 0.08 | 0.1150 | 0.000 | 0.195 |
| **0.3** | 991.086 | 0.138 | 0.1 | 0.1010 | 0.0009 | 0.202 |
| **0.4** | 559.483 | 0.206 | 0.15 | 0.0570 | 0.0021 | 0.209 |
| **0.5** | 422.377 | 0.255 | 0.17 | 0.0430 | 0.0033 | 0.216 |
| **0.6** | 215.925 | 0.268 | 0.2 | 0.0220 | 0.0036 | 0.225 |
| **0.8** | 93.13 | 0.220 | 0.23 | 0.0094 | 0.0024 | 0.241 |
| **1** | 42.7823 | 0.030 | 0.25 | 0.0043 | 4.68E-05 | 0.254 |

**Initial Energy=** 0.451929

**Final Energy =** 0.254408

**Energy loss =**43.70 %

# CHAPTER 5

# RESULT & DISCUSSION

1. Conjugate depth, For hydraulic jumps over furrowed bed with a supercritical intensity ($Y_1$) and common influx speed $U_1$, the conjugate intensity ($Y_2$) can be demonstrated to be characteristic of $f(Y_2,Y_1,U_1,g,t,s,\rho,\nu)$ .Using Buckingham's theory it is introduced as relation $Y_2/Y_1$ is function of Reynolds no, Froude no ,$t/Y_1$,$S/Y_1$ .
2. Here ,wide range of Reynolds no. is used hence the effect of viscosity may be neglected thus calculation of Reynolds no. is not significant . Now we have only 3 parameters "Froude no ,$t/Y_1$,$S/Y_1$ ".
3. Using the Experimental data, the relation between dimensionless parameters are plotted and compared with previous study .
4. Graphical trend of present study is similar in nature of previous study.
5. Result confirms that sequent depth and period of hydraulic soar is decreased in case of rectangular sheet in comparison with smooth bed.
6. Depth Deficit factor of rectangular sheet of is slightly greater than smooth bed, It shows that the rectangular sheet of strip shape may be a good option among various options available in the past to decrease the downstream energy to minimize the scouring and undermining of the hydraulic structure.
7. Wall shear stress may be assumed to occur on the basis of lower in soar period,roller length it can be concluded that shear stress may be the main factor for decreasing the length of jump. Wall shear stress is calculated using ANSYS.
8. Shear stress might be propagate just because of depression of corrugation by increasing turbulent and eddies.
9. Velocity at fixed cross section are calculated and decrease in velocity in the direction of flow occurs.

10. Due to decrease in velocity it can be referred that kinetic energy might be reduced in downstream bed .
11. Velocity on rough bed is less as compare to smooth bed in ANSYS simulation.
12. Sequent depth for different Froude numbers are compared with ANSYS result and error percentage is calculated in the range of 10 % to 25 %.
13. For Froude number 3.91 'Total Head' is calculated at two cross sections.
14. Using concept of 'Total Head', energy loss is calculated.
15. Energy loss on rough bed like rectangular strip is found out to be 43.70 percentage.
16. Further study with new thickness and wavelength can increase the energy loss.
17. Hence work is validated .

# CHAPTER 6

# CONCLUSION

1. Harsh beds like separated rectangular strip verified higher overall performance than flat base channel in improving hydraulic leap traits (jump) .

2. The roller duration of jump is affirmed to be depended totally on harsh bases, and the outcomes of recent work take a look at previous work.

3.Rough or depressed surface confirmed the effectiveness dissipation of energy at downstream hydraulic structures and lessen the prices of the maintenance.

4. If D is the "dimensionless depth deficit factor", equal to $(Y_2^*-Y_2)/Y_2^*$, for the variety of parameters examined, D was almost in among 2.5 and 4 and this result is in the range of previous study of S.A. Ead and N. Rajaratnam.

5.The normalized Jump length $L_j/Y_2^*$ was found to be in between 3 and 4 compared to a value 2.25 introduced by S. A., Ead, and I. H. Elsebaie for their experiments on jumps of triangular corrugated beds. The normalized jump duration for Peterka's basin is 6.

6.On comparing both type of channel shape sheet ,the rectangular sheet is more effective than smooth bed. For reducing downstream erosion of cohesion less soil, rectangular shape roughness can be used.

7.Shear stress might be generated just because of depression of corrugation by increasing turbulent and eddies. Shear stress is also effective to minimize the downstream energy.

8.Shear stress is found to be a function of Froude number.

9.Graphical trend of present study is similar in nature of previous study hence it can conclude that present work is reliable.

10.Velocity on rough bed is less as compare to smooth bed in ANSYS simulation which is as good sign to reduce the downstream energy.

11.Further research can be perform with new thickness and wavelength for more energy dissipation .

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