CFD SIMULATION OF FLUID FLOW OVER RECTANGULAR WEIR

A DISSERTATION SUBMITTED IN FULFILMENT OF THE
REQUIREMENT FOR THE AWARD OF DEGREE OF
MASTER OF TECHNOLOGY
IN
HYDRAULICS AND WATER RESOURCE ENGINEERING

Submitted by:
ESMATULLAH REHAYEE
(2K19/HFE/16)

Under the guidance of
Prof. S. ANBUKUMAR

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi–110042

June, 2022

Department of Civil Engineering
Delhi Technological University
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE’S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled "**CFD Simulation of Fluid Flow Over Rectangular Weir**" in partial fulfillment of the requirements for the award of the MASTER OF TECHNOLOGY and submitted in the civil Engineering department of the Delhi Technological University, Delhi is an authentic record of my own work carried out during a period from August 2021 to June 2022 under the supervision of Prof. S. Anbu Kumar, professor, Department of Civil Engineering, Delhi Technological University, Delhi, India.

The matter presented in this thesis has not been submitted by me for the award of any other degree in this or any other information.

(ESMATULLAH REHAYEE)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(Prof. S. ANBUKUMAR)

Supervisor

Date: 04-07-2022

`

ABSTRACT

Weirs are a sort of hydraulic structure that is used in irrigation systems to manage water levels, monitor flow, and divert water. Weirs are one of the earliest and most fundamental hydraulic structures, having been used for many years in open channels by hydraulic engineers for flow monitoring, energy dissipation, flow diversion, flow depth management, flood passage, and other uses. Many experimental investigations on various types of weirs have been conducted in the past years, but there is a limitation on literature on simulation techniques. The aim of this study is to examine the flow behavior of the rectangular weir using the CFD simulation. For this study, a full width rectangular weir with two separate crests was used (sharp and normal) in order to find out the flow behavior. The finding of the present study are in good agreement with past studies or research. ANSYS post processing is used to create velocity contours, volume fractions, streamlines, and velocity vectors, among other things. The discharge coefficient was studied for various (h/p) ratios, and the findings revealed that the discharge coefficient decreased nonlinearly when the (h/p) ratio increase up to certain level than it shows constant trend.

ACKNOWLEDGEMENT

I would like to thank Vice Chancellor of Delhi Technological University and Prof. V.K.MINOCHA (Head of Department, Civil Engineering) for providing all the facilities and equipment's in the college to carry out this project work.

I would like to convey my thanks, great indebtedness and gratitude to my supervisor Prof. S. ANBUKUMAR, Department of Civil Engineering, Delhi Technological University, New Delhi, for his kind supervision, remarkable comments and constant encouragement professors and faculties of the Department of Civil Engineering, DTU, have always extended their full co-operation and help. I would also like to thank Mr. Rahul Kumar Meena and Deepak Singh Ph.D. research scholar for his continuous guidance for this numerical simulation.

ESMATULLAH REHAYEE

CONTENTS

LISTOFTABLES

LISTOFFIGURE

NOTATION

CFD: computationional fluid dynamic

VOF: volume-of-fluid

DPM: discrete phase model

b: width of weir

V_1: velocity of approach

C_d: discharge coefficient

h: head over the weir crest

g: acceleration due to gravity

P: weir height

ρ: density of fluid

Re: Reynolds number

u: average velocity component

t: time

x: space dimension

CHAPTER-1
INTRODUCTION

1.1 General

Controlling the amount of water in a river is advantageous in a variety of ways. Mills have traditionally used water power to operate saws, grinding wheels, and other machinery. Raising the river's water level allows boats and ships to transit locations that would otherwise be unreachable. Finally, having control over a river can aid in reducing the damage caused by floods.

A weir is a small structure built across a river to control the upstream water level. Weirs have been used to regulate the flow of water in streams, rivers, and other bodies of water for decades. Unlike large dams that create reservoirs, the idea is to build a weir across a river is to take control over the water level rather than to create storage. Over time, the term "weir" has evolved to describe to any hydraulic control system that allows water to flow over its top, also known as the crest, in engineering. On the spillways of numerous large dams, weirs are employed as control structures.

1.2 Flow in Open Channels

Flow in an open channel is defined as the flow of a liquid through a partially filled channel or conduit with a free surface, subjected to constant pressure and accelerated by gravity. When the flow moves downstream in a continuous uniform flow under free discharge conditions, the water surface height gradually decreases or drops. Natural and man-made open channels are the two forms of open channels. Streams, rivers, and estuaries are examples of natural open channels that were generated by natural processes and have not been considerably changed by people.

1.3 Measurements of Flow in Open Channels

The elevation or head of the stream as it passes over a barrier in the stream is a typical way of measuring flow across an open channel. Open channel flow meters use ultrasonic level innovation and have a contactless sensor placed above the flume or weir. The water level, or "Head," is precisely calculated by monitoring the duration between transmitting an ultrasonic pulse and receiving an echoes. Flumes and weirs are stream forms that are specifically intended to control the flow of water.

The elevation or head of the stream as it passes over a barrier in the stream is a typical way of measuring flow across an open channel. Open channel flow metres use ultrasonic level innovation and have a contactless sensor placed above the flume or weir. The water level, or "Head," is precisely calculated by monitoring the duration between transmitting an ultrasonic pulse and receiving an echoes. Flumes and weirs are stream forms that are specifically intended to control the flow of water.

1.4 Weirs

A weir is obstruction in a canal with a somewhat uniform cross section that promotes water to flow over it. Weirs are used to control the amount of water in an upstream channel or to monitor the discharge precisely. Water flow over a crest, which is a surface or a boundary. A nappe is a water-filled sheet or sheet that streams over a weir or dam. The peak of a dam or weir creates a well-defined features on the top and lower water surfaces. When describing and estimating the creation of a nappe, hydraulic engineers distinguish between these two water formations. 'h' is the depth of water flowing over crest and the p is height of the weir. Figure 1.1 depicts these phrases. Flow over weirs is influenced by head, fluid properties and temperature influences, as well as upstream and downstream conditions, weir shape and measurement accuracy.

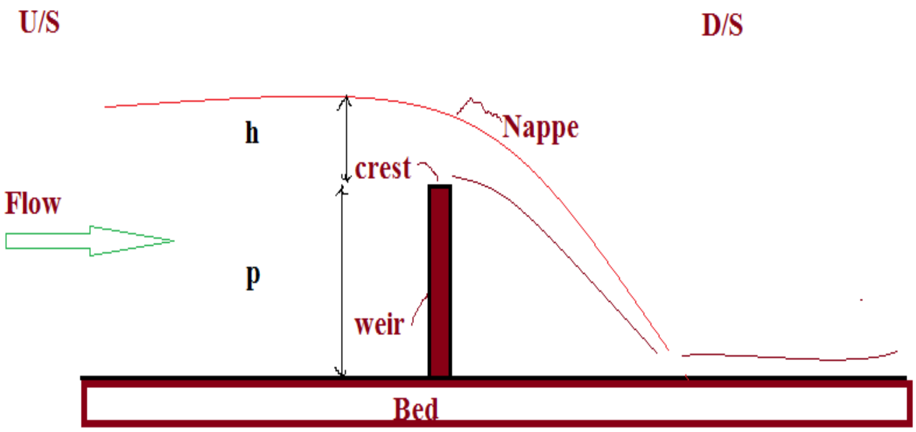


Figure 1.1 Free flow of water over a weir

1.4.1 Advantages of weir

- Capable of monitoring a broad range of flows precisely.
- Flumes and orifices tend to offer more accurate discharge.
- Simple to assemble.
- Has the ability to be both portable and customizable.
- The majority of floating debris passes above the building.

1.4.2 Disadvantages of weir

- For free flow conditions, a somewhat big head is necessary. Because of that weirs cannot be used to assess the flow in flat locations because of this.
- Incold weather can compromise readings.
- Weir maintenance is costly.
- Discharge must be free-spilling.

On the upstream side of a sharp-crested weir, the water is permitted to flow freely. Pointy weirs have a sharp upstream corner or edge where the water leaps free of the peak. The restricted weir's length (L) is shorter than the width of the approach channel. The length (L) of non-contracted weirs is equivalent to the width of the channel.

Weirs are divided into two categories:

- Sharp-crested weirs, which are often used to measure flowing water, and another is normal-crested weirs, which are commonly employed as part of hydraulic structures.
- Other classifications based on shapes are Rectangular Weir, Triangular Weir, Trapezoidal (Cipolletti) Weir, and Broad-Crested Weir.

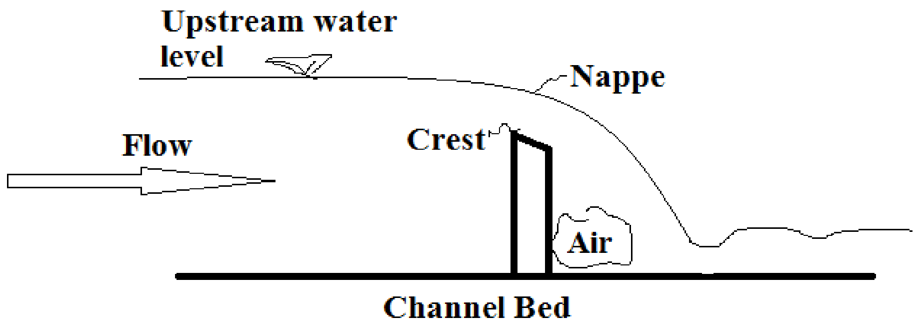


Figure 1.2 Sharp-crested weir

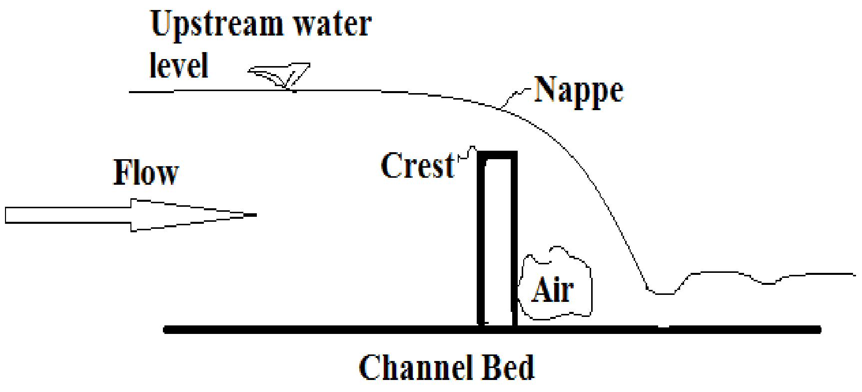


Figure 1.3 Normal-crested weir

1.5 Sharp-Crested Weirs

Sharp crested weirs are used to measure the water head in the upstream of the weir to determine outflow in open channels. Irrigation techniques, labs, and industry all make substantial use of weirs. Rectangular, trapezoidal and triangular sharp-crested weirs are available in a variety of forms and sizes (or V-notched). A rough sketch of anon-contracted sharp-crested weir is shown in Figure 1.2.The thickness of a sharp-crested weir should be less than half the height of water on the weir, i.e. $b<H/2$, where b=weir thickness. H is the height of the water over the weir's apex.

The sharpness of a sharp-crested weir's edge must be maintained properly; otherwise, changes in the crest's sharpness will affect the weir's qualities. In tiny open channels where precision is necessary, sharp crested weirs are commonly employed to measure the discharge. Weirs may be precise to 2% or even 1%, they are frequently employed in hydraulic system laboratories as measurement device, but they also have practical uses.

1.6 Weirs Normal-Crested (Without Sharp Crest)

When used to collect discharge data over long periods of time, sharp-crowned weirs are difficult to maintain because the crown becomes duller is destroyed by debris. A weir with a thicker crown, which must be more than 2mm, may be desirable in certain conditions. This type of weir is commonly seen in the overflow sections of dams. Non-sharp-edged weirs are often used as controls in hydraulic systems with flow measurement as a secondary purpose. Finite crest weir are often designed for use in the field and are therefore able to handle large discharges. The cross-sectional shape and crest shape of a weir without a sharp crest controls the volume of fluid that flows through it. Non-sharp-crested weirs occur in a variety of cross-sectional shapes and have similar surface contraction as sharp-crested weirs, but conditions at the crest are different and vary by cross-sectional shape. Weirs without a sharp crest are classified according to the shape of the weir cross-section. Among the weirs without a pointed crest, the most common is the rectangular weir with a horizontal crest. For the flow through a rectangular weir with an upstream sharp corner, four types of finite-crest width weirs may be identified based on the value of h/t (h is the depth of water above crest and t is the thickness of weir).

1.7 Selection of weirs

Selection of weir depends upon the accuracy needed in test, pressure drop, cost, regulatory limits, range of flow rates, types of measurements and recording required, maintenance needs, instrument standardization and calibration, and other factors which play an important role in selecting the best water meter. The ease with which a discharge can be measured or managed is often more important as it reduces operational costs. The range of discharges to be measured, the accuracy required and whether or not the weir can be calibrated after installation will define the type of weir to be used. Previous studies predict that a sharp crown weirs have the advantage of duplicating laboratory calibration conditions in the field with great accuracy. Each weir has its own characteristics that make it ideal for specific applications. A triangular weir is used for accurate measurement at low discharges, but a rectangular weir is used at high discharges. A trapezoidal weir can handle a variety of discharges. The measurement of a triangular weir is more accurate than that of a rectangular weir, but the measurement of a trapezoidal weir is less accurate than that of a triangular or rectangular weir.

1.8 Accuracy of flow measurement

Standard design or careful selection of water meters, careful manufacture and installation, quality calibration data and analysis, and proper user operation with appropriate frequent inspection and maintenance routines are all critical components. All flow measurement methods, like all scientific and technical measurements, are subject to error. Even under perfect conditions, repeated measurements of a reference standard will result in slightly different instrument readings that are either greater or less than previous reading of simulation. If the strategy is implemented thoroughly, errors will be reduced. If the result is accompanied by an indication of possible inaccuracies, the flow measurement is significantly improved and favored. The deviation between the real discharge and the discharge calculated from the observed water level using the correct head equations is called the error.

Accuracy refers to the degree of conformity of the measurement to a standard or true value. It is desirable to offer a range that has a high probability of covering the true value of the measured quantity.

1.9 Coefficient of discharge

Because friction, viscosity, and turbulence must be considered, real fluids are difficult to quantify as it flow. The discharge equation can only be determined if the real liquid behaves like an inviscid or ideal liquid (i.e. without taking it into account). As a result, many equations need not be exact. This can be adjusted by empirically finding, which allows simple equations for a perfect fluid to give the right solutions for a real fluid. C_d is the discharge coefficient:

$$C_d = \frac{Q_{act}}{Q_{The}} \qquad (1.1)$$

Obtaining correct C_d readings for various flow measurement has taken much time and effort for a researcher. The accuracy of the flow measurement is affected by the accuracy of the flow coefficient as well as the ability of the theoretical equations to describe the flow. The accuracy of the substituted variables in the equation, such as head and flow cross-sectional area, are also critical measurement criteria.

1.10 Problem statement

The basics of flow measurement in open channels are well known, but the evaluation of empirical discharge equations and coefficients requires a number of experimental readings. At this reading can be done by supplementing existing evidence with new data, particularly in current practice. Weirs have been studied and used as flow monitoring devices and water control structures in a range of agricultural, chemical and municipal applications. Most of the research do not using the numerical simulations to study the surface profile, pressure distribution, velocity distribution, air entrainment, fluid property effects, discharge coefficient, and discharge equations. Various discharge equations are available for rectangular, sharp-topped weirs with various weir heights, weir heads, and discharges, but similar equations for rectangular, flat-topped slot weirs are uncommon. Due to the lack of discharge equations for water flow over confined, rectangular, flat-topped slot weirs, engineers and waterworks operators are unable to predict discharge and discharge coefficient. The contracted rectangular slotted weir with a flat crown should be useful as a weir selection option in acceptable situations.

1.11 Objectives

The following is a list of the research's aim:

- To compare the effect of discharge coefficient on sharp crest and normal flat crest weir.
- To investigate the effect of head to weir height on discharge coefficient for a particular type of weir (rectangular).
- To determine the best mesh size to validate the work.
- To validate the work of Mehtabi and Rehbock.

CHAPTER - 2
LITERATURE REVIEW

Rehbock (1929) one of the earliest experimental attempts with C_d was carried out by him. Tested full-width weirs and presented the following equation for $h/P<5$, which does not account for viscous and surface tension effects.

Murthy & Prakash (1995) designed a straight line shape and provide it's a practical quadratic weir in the shape of a rectangular weir with an inward trapezoidal weir, width 2w, and vertex angle 2α at the crest, fixed at an ideal depth, $p = 0.95d$ above the weir crest, d being the entire depth of the inward trapezoidal weir. The flow over such a weir is proportional to the square root of head h is calculated from a datum of 0.5d above the crest in the range of $p < h < 2.95p$ with a maximum error of 2% from the precise theoretical discharge. The weir settings that resulted in the maximum quadratic head discharge relationship were optimized using a numerical optimization technique. Experiments show good compliance, with an average discharge coefficient (C_d=0.61) that is practically constant. The weir can be used to measure flow in bypass in an open channel. Furthermore, the sensitivity of the weir is emphasised.

Prakash & Shesha (2004) presented a research on flow through an inverted V-notch that is inclined. An inclination-head-discharge equation is created by varying the inclination of the weir plane with 0° (normal), 15, 30, 45, and 60° weirs. The linear head-discharge relationship for an inclined inverted V-notch is derived using an unique general algebraic optimization technique that is superior than earlier. The estimated discharge computed with the calibrated equation was found to be well within 6.5 percent of the actual discharge, indicating good agreement with the expert analysis.

Mish & Prakash (2006) worked on a trapezoidal inclined weir and provided a theoretical and experimental research. Calibrated a generic head-discharge equation for the inclined trapezoidal weir in terms of the angle of inclination of the weir's plane with respect to the vertical plane. Also stressed the benefit of inclination in terms of minimizing the amount of free board required on the weir upstream in the channel. Demonstrated that the existing general-head discharge equation can predict discharge between +9% and -6% inaccuracy of the actual discharge for flow over the inclined trapezoidal weir. Also discovered that the flow via the inclined weir is 77% greater than the discharge through the standard weir. This reduces afflux and may be utilized effectively in predesigned channels with fixed and restricted free board to prevent water from spilling out of the channel.

M.Y. El-Ansary.et.al. (2010) certain water flow metering equipment that was acceptable for on-farm management was tested and validated. The calibration was done with an ultrasonic flow meter. At low discharges, the v-notch was determined to be the most accurate device, whereas at high discharges, the rectangular weir was shown to be the most accurate. The inaccuracy percentage in the v-notch measurements rise when the discharge rate was raised from 5 to 35 l/s. on the other hand, the corresponding error percentages in readings of both the rectangular weir and the cutthroat flume were significantly decreased. As the rate of discharge rises, the inaccuracy appears to be diminishing. The time interval appears to have an irregular influence on the error percent. The v-notch or weir is preferred for measuring discharges between 5 and 10 l/s, according to the data, after which the rectangular weir, as well as the cutthroat flume, are preferred.

SheshaPrakash.et.al (2011)a discharge–head–inclination model is designed to assess flow over an inclined rectangular weir. The discharge capacity was found to be proportional to the weir tilt in relation to the vertical plane. A new inclined-weir-discharging index is defined as a measure of the weir discharging capability in relation to its usual position.

Anand V. Shivapur.et.al (2012) the use of an inclined compound notch-weir produced by two distinct side slopes of a triangle weir has been documented. The generalized head-discharge equation was derived by using a semi-analytical technique to analyze experimental data. When compared to a standard weir, there was a significant increase in the rate of discharge. Exponential flows are occasionally acquired through the upper half of the weir, while weaker flows are handled by the bottom triangular component of the weir. With the reduction in afflux, the channel's free board demand is lowered, and the channel may be planned more affordably. Also that they Showed in comparison to a normal notch-weir, it can help draw suspended silt and, as a consequence, minimize silting upstream of the notch-weir site, particularly in unlined channels.

Rasool Ghobadian.et.al (2012) a circular sharp-crested weir for measuring discharge in open channels, tanks, and reservoirs, these weirs are placed at the bottom of straight-approach canals and perpendicular to the sides. Complex patterns of flow passage through circular sharp-crested weirs were explored, and the stage-discharge relationship for wears was determined using an equation with experimental correlation coefficients. A theoretical stage-discharge relationship is created by solving two separate non-linear equations while assuming critical flow over the weir crest. To derive the theoretical stage-discharge relation, 58 tests were conducted in a 30 cm wide flume on six circular wires with varied crest heights and diameters. The findings of the analysis revealed that the measured discharge above the weirs is lower than the theoretical discharge for each stage, and that this discrepancy grew as the stage progressed.

C.DiStefano.et.al. (2013) the outflow mechanism of a triangular in plan sharp-crested is calibrated using imperfect self-similarity theory and dimensional analysis. The test is carried out using measurements from the literature, and a new stage-discharge is theoretically calculated. Finally, determined that the stage-discharge equation may be developed using a power equation, with an exponent and coefficient based on the ratio of the weir height to the side wall angle and crest length.

JahanshirMohammadzadeh-Habili.et.al. (2013) curvature type-crested weirs or overflow structures are used to plan and evaluate flow in open waterways, as well as flood control in reservoirs. Using Newton's second law and Bernoulli’s energy equation, a differential formula of velocity distribution at the crest portion of a circular-crested weir is generated and used as the discharge equation for a rectangular fluid particle on a convex streamline. A mathematical formulation of velocity profile is used to compute the weir’s discharge coefficient, crest velocity profile and crest pressure. A wide range of existing circular-crested weir experimental data is used for enhanced validation, and the results show good correlation data.

S. Gharahjeh.et.al. (2014) in general, energy constraints are used to develop the head-drain formula. After providing acceptable hypotheses, the discharge coefficient fits the experimental evidence. In this study, the weir velocity is calculated as a function of the mean velocity over the weir section, the shape of the weir, and the head well above the weir. The pronounced behavior of weir velocity versus weir height is independent of weir size and is characterized by weir attributes to estimate discharge without using a discharge coefficient for a fixed weir width to channel width ratio. Discharge is calculated using a simple formula that combines weir velocity data for different weir widths. Weir velocity has a simpler functional relationship to weir specifications than discharge coefficient.

A. Zahiri.et.al (2017) for flow discharge computation, compound rectangular sharp-crested in the form of side weirs can be utilized. Rectangular compound side weirs are a type of weir in which a tiny rectangular weir in the bottom part is used to monitor low flow rates, while a large rectangular section alongside it measures higher flows. Because determining the C_d for such a complex side weir is challenging, the coefficient of discharge must be calibrated using laboratory testing in a large set. As a result, based on practical design technique, a novel strategy for forecasting flow discharge across compound side weirs was presented, which was tested against experimental data in subcritical flow conditions and found to be extremely close to the experimental data. For overflow rate computation, the suggested approach is independent of discharge coefficient, resulting in a reliable and easy instrument for flow measurement of compound side weirs and associated water surface profiles. The overall mean and absolute relative errors recorded throughout the experiment are 1.6 and 7.8%, respectively.

Shesha Prakash.et.al (2018) with a novel technique, a generalized inclined head-discharge relationship for flow via a triangle weir was developed. A weir is an impediment placed across a flow so that the head above the crest (fluid level on the upstream side) may be measured and the flow amount estimated. Weirs are also used to regulate the flow of water. Because of its considerable disadvantage in afflux formation, sharp crested weirs are normally utilized in labs rather than in field channels for flow measurements due to their more precise and constant performance. In comparison to rectangular weirs, triangular weirs have several benefits. Its discharge may be increased more effectively than a rectangular weir with a higher head. Researchers have sought to decrease afflux by constructing weirs that are angled toward the channel bed. The discharge coefficient has enhanced as a result of this process of using thin plate weirs of regular geometric shape. The goal of this study is to test, analyze, and create a new technique for measuring flow over an inclined triangle weir. The new approach is straightforward, and the error analysis reveals that the estimated discharge is well within 2% of the actual discharge, which is far lower than prior flow analysis methods. The study effort is of great academic relevance since it demonstrates that the head index is not affected by the head index. It was discovered that when the weir angle is increased in relation to the normal (vertical) position, the coefficient of discharge rises, minimizing the afflux and prompting field channel users to build these weirs using a simple head-discharge-inclination equation.

Bhukya Ramakrishna.et.al (2018) provided a flow resembling that of a steep crested weir. Weirs are a flow measuring instrument that is often used. Sharp crested weirs are widely employed in enterprises, labs, and irrigation canals to quantify outflow. The major of study goal is to look at the flow behavior of various sharp crested weirs and calculate the coefficient of discharge for various bed slope situations. The major feature of discharge analysis through sharp crested weirs is head measurement above the weir crest. The discharge coefficient and, as a result, the discharge are affected by the width of the weir aperture. The average discharge coefficients for several thin plate weirs (i.e. rectangular weir, V-notch weir, Trapezoidal weir, Sutro weir) were 0.697, 0.798, 0.578, and 0.598, respectively, according to the results.

Arun Goel (2006) produced a flow meter that is simple to manufacture, use, and maintain and is used to monitor irrigation channel discharge. The flow meter may also be used to measure flow in irrigation canals in small catchments, and the flow rate can be determined for both free and submerged flow situations. In comparison to previous critical depth flumes, the suggested flow measurement device is cost effective due to its simple shape. It's also shorter in length and doesn't have a bed slope, which isn't always necessary. The proposed flow meter is more practical owing to the fact that the modular limit of the flow meter is large.

ArunGoel.et.al. (2015) employing mild steel sheet mounted in rectangular flume with four type width limits, and 90^o in the direction of flow, performed tests in the laboratory channels in the created sharp-edged restricted flow meters, More than 400 trials of upstream and downstream depths, with discharges ranging from 2 l/s to 30 l/s, were recorded and plotted for both free and critical submergence. To compute the discharge for each circumstance, curves were created. one of the most efficient devices is one that permits maximal critical submergence with a contraction ratio of 2:1.

Vishal B. Raskar (2017) devised a standard discharge measurement method for open channel flow created a novel discharge measuring approach based on Venturi-flume calibration, which will result in a more efficient method of attaining economy and accuracy. The process is fine-tuned by creating a real model and a suggested model, assessing the experimental data, and creating graphical output.

Zohrab Samani (2017) designed and calibrated three basic flumes for open channel flow monitoring as part of his research. Flumes are designed using the critical flow in open channels principle. By compressing the flow cross section, the cylindrical columns are vertically positioned in an open channel to produce a Critical flow. The flume prototypes are calibrated using model analyses. Full - scale field flumes are used to validate the equations, and a design example for free flow conditions is provided. The three flumes that have been designed can be used in hexagonal channel systems trapezoidal, rectangular, and circular.

Mahtabi et. al.(2018) performed experiments on a sharp-crested weirs under free-flow conditions, the ideal form of the discharge coefficient equation was derived only use an optimization algorithm based on the coefficient of determination and root mean square error. Fluent software capabilities was also employed to investigate a numerical technique for modelling flow over the weir.

CHAPTER - 3
METHEDOLOGY

3.1 Simulation technique and the fundamentals of it:

Software package is used to study the flow on the weir. ANSYS FLUENT provides significant additional features for a wide range of incompressible and compressible, laminar and turbulent fluid flow problems. A steady-state or intermittent analysis can be performed. ANSYS FLUENT combines the ability to simulate complex shapes with a comprehensive purely mathematical models for transportation operations. ANSYS FLUENT applications include non-Newtonian linear motion flows in process equipment, conjugate heat transfer in turbo machinery and automotive engine components, pulverised fuel combustion in utility heating systems, external aerodynamic performance, and flow through condensers, pumps, and fans, and multiphase flows in bubble columns and fluidized beds. Various important elements are offered to allow modelling of fluid flow and associated transport phenomena in industrial equipment and processes. Porous media, lumped parameter (fan and heat exchanger), stream wise-periodic flow and heat transfer, swirl, and moving reference frame models are all examples of these. Modeling single or multiple reference frames is possible with the moving reference frame family of models. A time-accurate fuzzy entropy technique, as well as a mixing plane model for computing time-averaged flow fields, may be utilised to simulate numerous stages in turbo machines operation. Another incredibly significant group of models in ANSYS FLUENT is the collection of free surface and multiphase flow models. These may be used to examine gas-liquid, gas-solid, liquid-solid, and gas-liquid-solid fluxes. For all these types of problems, ANSYS FLUENT iincludes the volume-of-fluid (VoF), mixture, and Eulerian models, as well as the discrete phase model (DPM). The DPM computes Lagrangian trajectory calculate for scattered phases, including coupling with the continuous phase. Multiphase flows include channel flows, sprays, sedimentation, separation, and cavitations. The ANSYS FLUENT modelling package includes turbulence models that are both resilient and accurate. The dynamic models provided span a wide range of applications and account for additional physical phenomena such as buoyancy and deformability. Concerns with near-wall accuracy have received considerable attention because to the introduction of enlarged wall functions and zonal models. Natural, forced, and mixing convection, with or without conjugate heat transfer, porous medium, and other heat transfer methods can all be simulated. For modelling participating medium, a wide range of radiation models and related sub-models are available, some of which may account for burning issues. A unique strength of ANSYS FLUENT is its ability to characterise combustion events using a variety of models, including eddy dissipation and probability density function models. For reacting flow applicant, there are a range of different models available, including coal and droplet combustion, surface reaction, and pollutant generation simulations it is a powerful and widely used form of commercial Computational Fluid Dynamics (CFD) software. ANSYS Fluent covers two-dimensional (2D) and three-dimensional (3D) challenges of open channel flow, channel flow confinement and sediment transport with models of enhanced turbulence. It is also possible to break the current through steep cress at weirs. 2D transient continuity and momentum equations for liquids and air (Liu et al., 2002) are the governing equations:

3.2 Basic equations:

Continuity equation:

$$\frac{\partial\rho}{\partial t}+\frac{\partial(\rho\upsilon)}{\partial x}+\frac{\partial(\rho\upsilon)}{\partial r}+\frac{\rho\upsilon}{r}=Sm \text{ ....(3.1)}$$

Momentum equation;

$$\frac{\partial(\rho\upsilon)}{\partial t}+\nabla.(\rho\upsilon\upsilon)=-\nabla\mathrm{p}+\nabla.(\text{ɍ})+\rho g+F\text{.................................(3.2)}$$

Here, published data from (Mahtabi at el. 2018) is used to formulate the flow, which is then evaluated by the current study. ANSYS was used to construct more than ten (3D) configurations in this investigation. The best mesh created for each model (for example, Fig. 1) was chosen. After that, the best mesh was used in the simulation. The calculation region was 4 meters long, 0.25 meters wide and 0.50 meters deep. Rectangular components were used to structure the mesh. When there were at least 3148 nodes, the results were found to be independent of grid size. Depending on the type of flow, corresponding criteria must be defined at domain boundaries. The pressure entry and exit boundary conditions were specified in this study simulation. The velocity at the fixed boundaries was set to zero by the skid resistance constraint, and the walls and bed were assumed to be smooth. A pressure outlet boundary condition has been added to the top surface. To mimic the flow near the wall, the normal wall function was used. RANS equations can be solved in a number of ways. In this work, the control-volume approach was used to describe multiphase flows, and the renormalized group (RNG) k-ε turbulence model was chosen to model the turbulent flow.

3.3 Steps involved in ANSYS:

3.3.1 Pre-Analysis:

For ANSYS FLUENT to solve a real engineering problem numerically few boundary condition is required. This can be either the real scenarior collect data to represent the real situation. In addition, to get equivalent theoretical or experimental data to compare with present simulation. These phases are critical, especially to get the right boundary condition. For example, if a work need to simulate airflow over the wing of a commercial airplane, then need to know the wing's speed range, as well as previous experimental or numerical results and relevant theories. Similarly for the presence work here experimental boundary conditions are examined.

3.3.2 Geometry:

To create the geometry ANSYS Design Modeler is used. As the geometry is not a complicated one so here design modular is able to sketch with ease.

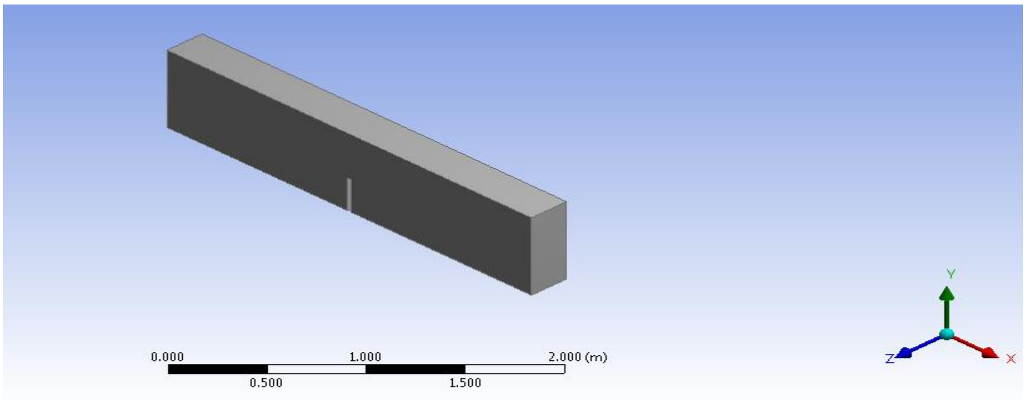


Figure 3.1 Geometry of flume with weir

3.3.3 Meshing:

One of the most crucial steps in simulation is meshing. Mesh quality has an impact on simulation outcomes. Poor mesh quality can lead to poor simulation results, including divergence. These are pre-possessing steps.

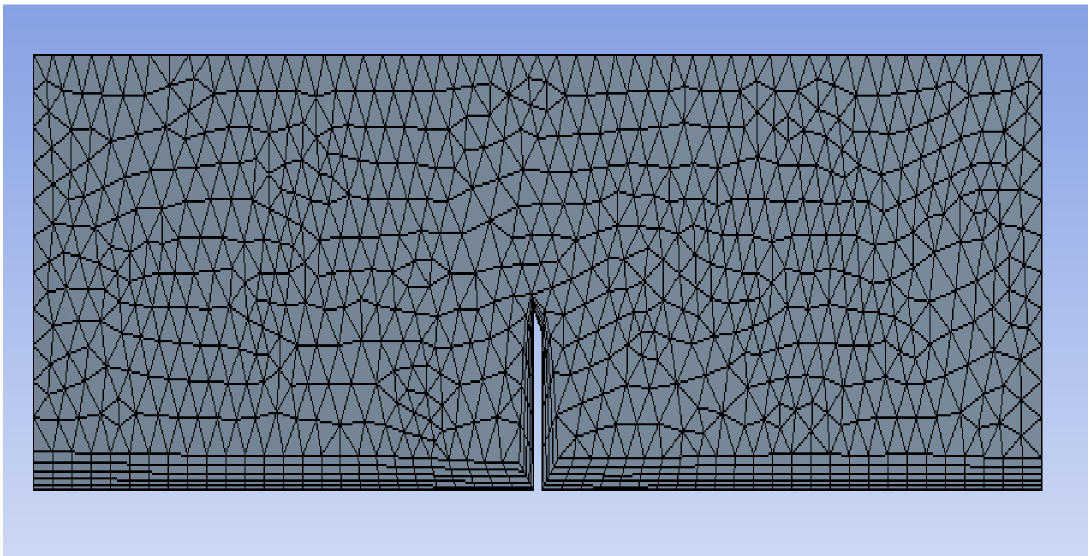


Figure 3.2 Meshing of 0.05 m

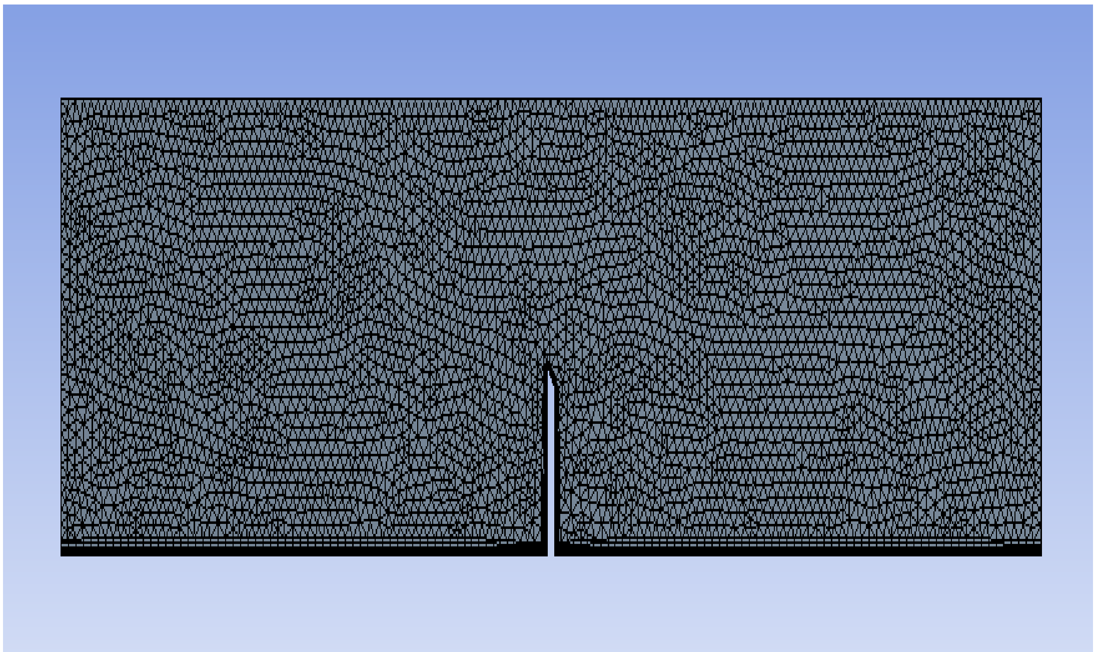


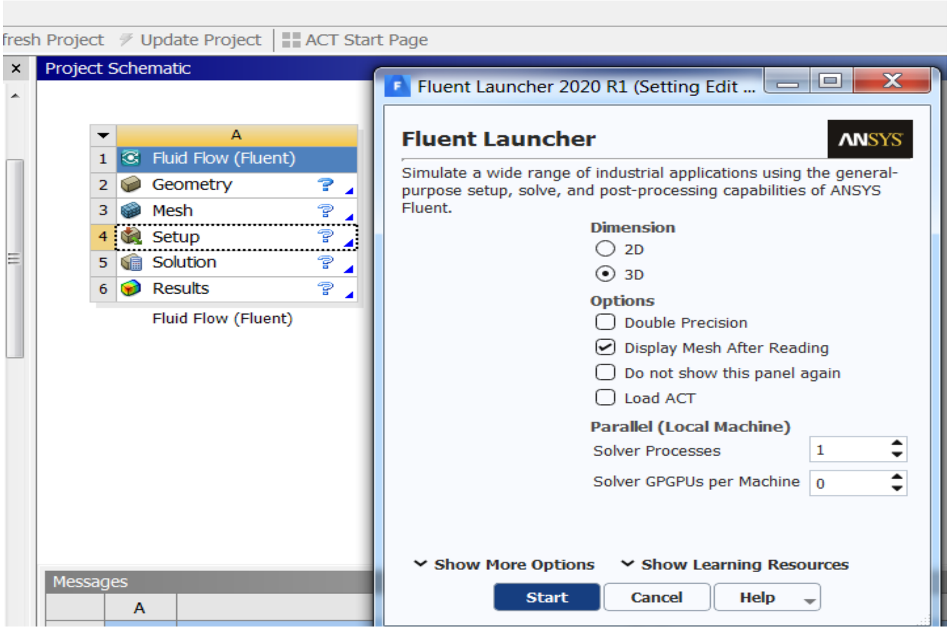
Figure 3.3 Meshing of 0.02 m

Table 3.1 Mesh nodes and elements

Domain	Nodes	Elements
Solid	51041	226421

3.3.4 Physical Setup:

This is done by the ANSYS solver. The main focus is on understanding and performing the physical setup, the numerical results, and verification and validation. It provide inputs for solution accuracy, boundary conditions, physics involved, material involved, properties involved, etc. In the physics setup process.



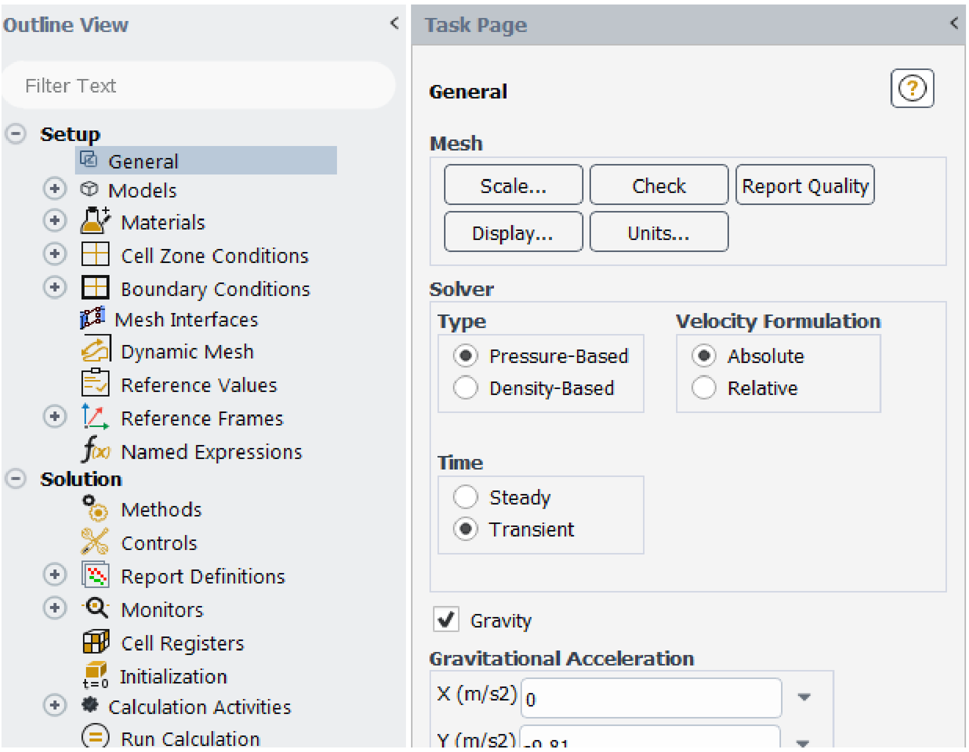
Simulate a wide range of industrial applications using the general-purpose setup, solve, and post-processing capabilities of ANSYS Fluent.

Dimension
○ 2D
● 3D

Options
☐ Double Precision
☑ Display Mesh After Reading
☐ Do not show this panel again
☐ Load ACT

Parallel (Local Machine)
Solver Processes: 1
Solver GPGPUs per Machine: 0

Figure 3.4 Setup launcher



Type: ● Pressure-Based ○ Density-Based

Velocity Formulation: ● Absolute ○ Relative

Time: ○ Steady ● Transient

☑ Gravity

Gravitational Acceleration

X (m/s2) 0

Y (m/s2)

Figure 3.5 Setup window (solver)

Table 3.2 Domain Physicuss for FFF

Domain - solid	
Type	cell

Table 3.3 Boundary Physics for FFF

Domain	Boundaries	
Solid	**Boundary - Inlet**	
	Type	PRESSURE-INLET
	Boundary - outlet	
	Type	PRESSURE-OUTLET
	Boundary - wall	
	Type	WALL
	Boundary - wall sol1d	
	Type	WALL

3.3.5 Result:

For phase 1 and phase 2, the route of the contour for mass flow, pressure, velocity, kinetic energy dissipation and volume fraction as well as the course of streamline and velocity vector in flow direction are shown.

3.3.6 Relation between C$_d$ and h/P

For weirs, several past studies scholars have made connections between discharge and head. Discharge over a sharp-edged weir (Q) in an open channel is usually given by the following well-known equation under free-flow conditions (Mahtabi et. al. (2018)).

$$Q = \frac{2}{3} C_d (2g)^{o.5} h^{1.5} \text{..............................(3.3)}$$

Where b is the width of the weir opening, C$_d$ is the discharge coefficient, h is the height above the weir crest and g is the acceleration due to gravity. C$_d$ is determined by the flow properties and the shape of the channels and weirs. Runoff is a function of various variables and can be described numerically using the following equation (Mahtabi et. al. (2018)).

$$Q = f_1(f, b, P, \rho, \sigma, \mu, g) \text{....................(3.4)}$$

Where P is the weir height, the fluid density, the surface tension and the dynamic viscosity of the fluid. According to dimensional analysis, the discharge coefficient is a function of the following factors (Mahtabi et. al. (2018)).

$$C_d = f_1(Re, We, \frac{h}{b}, \frac{h}{P}) \text{.............................(3.5)}$$

The Reynolds number is Re while the Weber number is We. one of the earliest experimental studies on C$_d$ was performed by (Rehbock et al. (1929)). He tested full-width weirs and presented the following equation for h/P<5, which does not account for viscous and surface tension effects.

$$C_d = 0.611 + 0.08\frac{h}{P} \text{....................................(3.6)}$$

The equation for the optimal discharge coefficient was determined by evaluating various typesof mathematical equations using the optimization approach. The optimal equation was chosen based on the highest R^2 and lowest RMSE values. According to Mahtabi et. al. (2018) was the optimal equation.

$$C_d = 0.0434^{(\frac{h}{P})^{0.522}} + 0.653 \text{.....................................(3.7)}$$

3.3.7 Observation

Data are tabulated below from the simulation result and the coefficient of discharge is calculated based on past research theory listed in section 3.4.

Table 3.4 Coefficient of discharge at p=0.20 m

			C_d calculated in the present study using below resercher's proposed formula	
	h (m)	**h/p**	Using Rehbock (1929)	Using Mahtabi (2018)
p=0.20	0.032	0.16	0.623	0.952
p=0.20	0.068	0.34	0.638	0.821
p=0.20	0.110	0.55	0.655	0.753
p=0.20	0.144	0.72	0.668	0.724

Table 3.5 Coefficient of discharge at p= 0.15 m

	h (m)	**h/p**	**C_d calculated in the present study using below researchers’ proposed formula**	
			Using Rehbock (1929)	Using Mahtabi (2018)
p=0.15	0.022	0.15	0.623	0.964
p=0.15	0.040	0.27	0.632	0.858
p=0.15	0.075	0.5	0.651	0.765
p=0.15	0.094	0.63	0.661	0.738

Table 3.6 Coefficient of discharge at p= 0.10 m

	h (m)	**h/p**	**C_d calculated in the present study using below researcher’s proposed formula**	
			Using Rehbock (1929)	Using Mahtabi (2018)
p=0.10	0.043	0.43	0.645	0.785
p=0.10	0.065	0.65	0.663	0.734
p=0.10	0.081	0.81	0.675	0.713
p=0.10	0.085	0.85	0.679	0.709

CHAPTER - 4

RESULT & DISCUSSION

4.1 Flow over Sharp Crested Rectangular Weir

(a)At time of 30s having velocity 0.1 m/s at the inlet with a depth of water 0.2m.

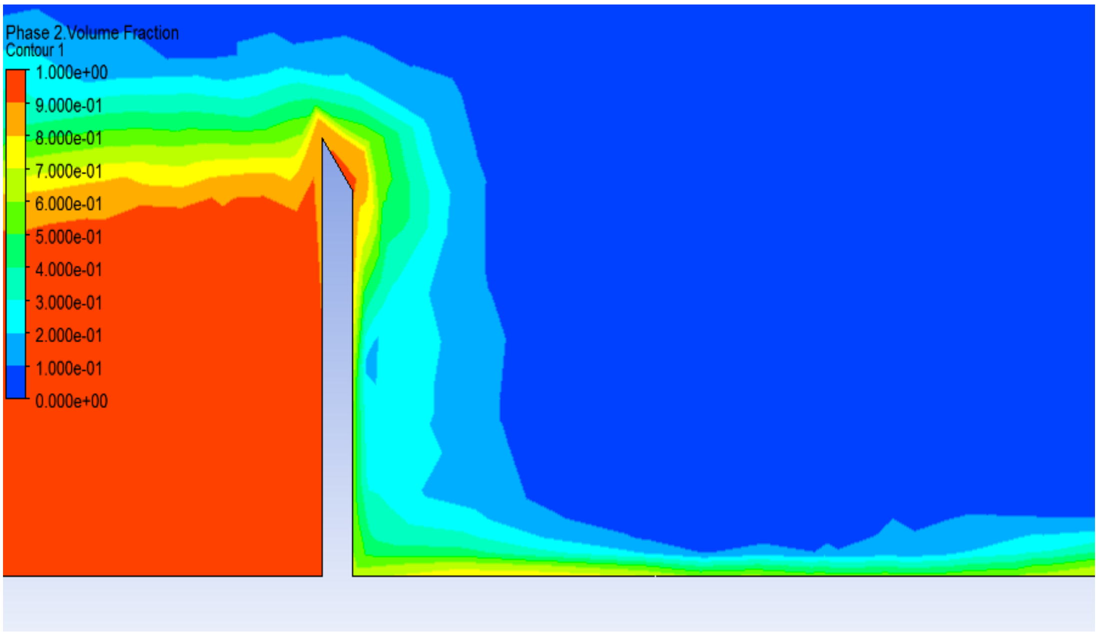


Figure 4.1 Flow profile

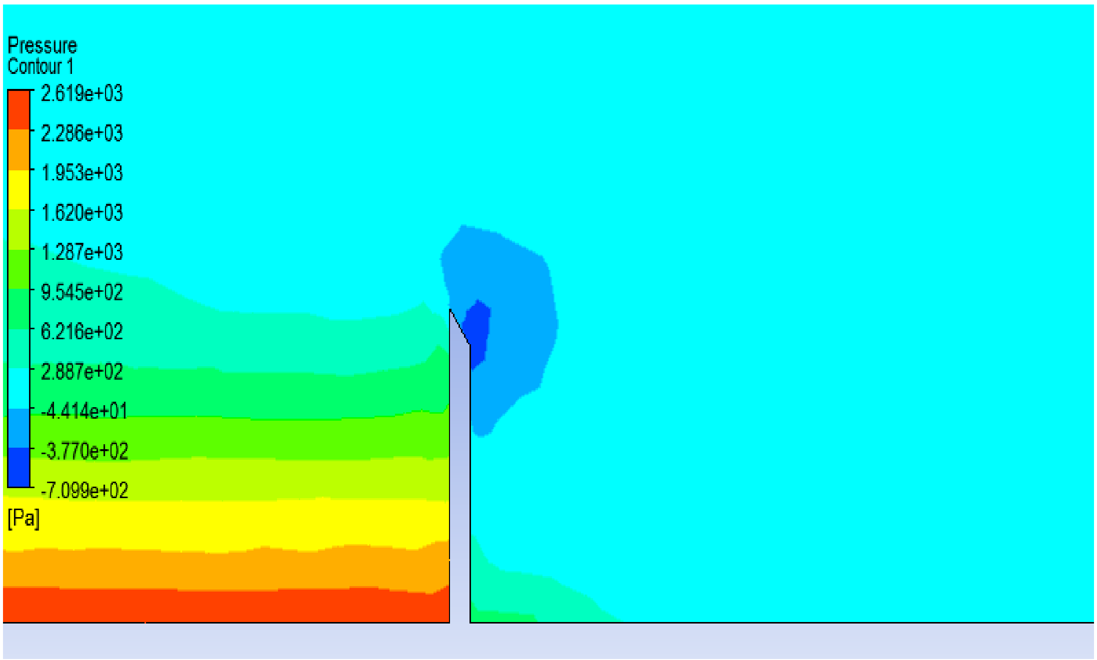


Figure 4.2 Pressure variation

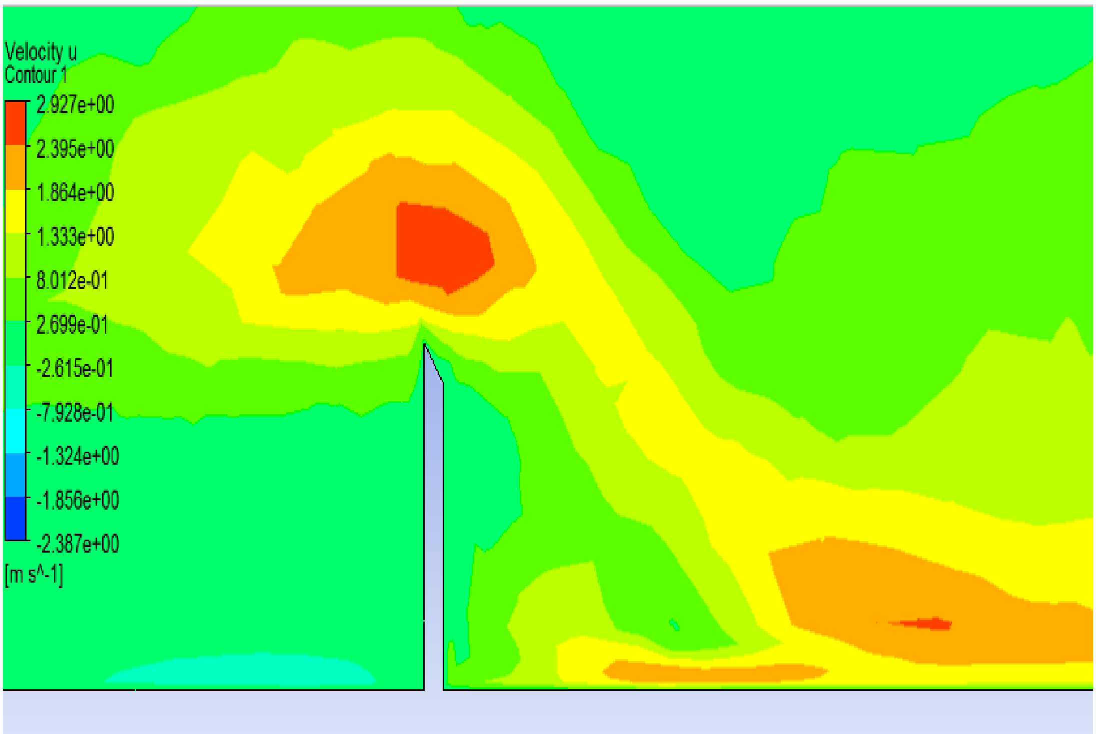


Figure 4.3 Pressure variation

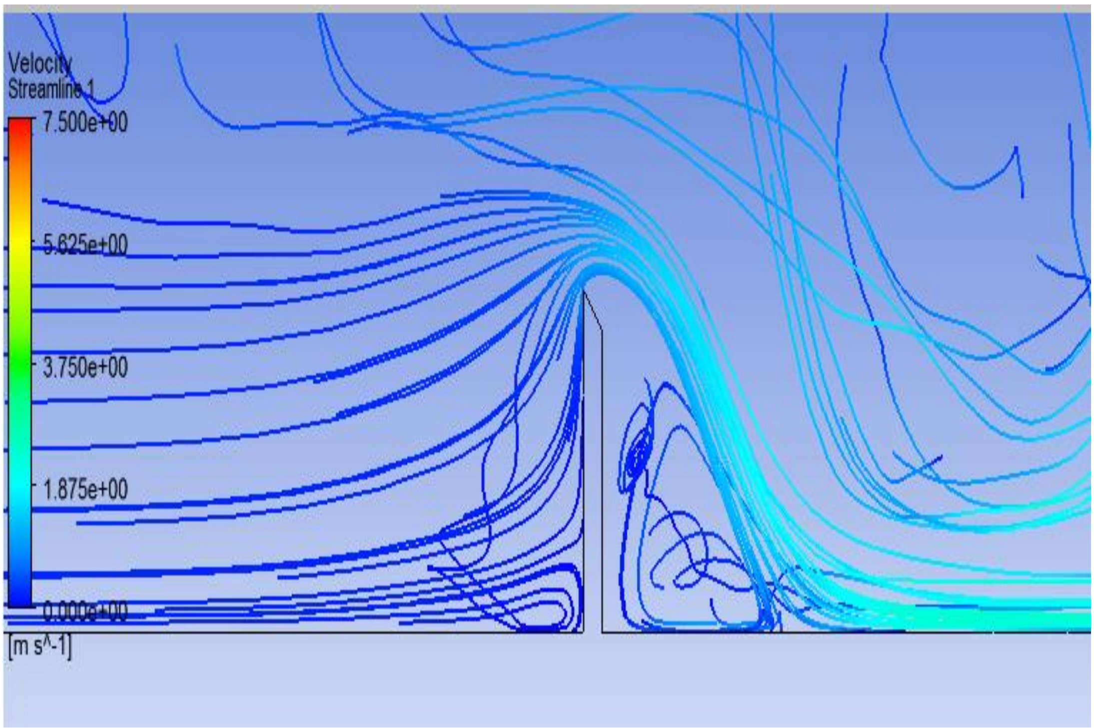


Figure 4.4 Velocity streamline

(b) At time of 52 s having velocity 0.3 m/s at the inlet with a depth of water 0.3 m.

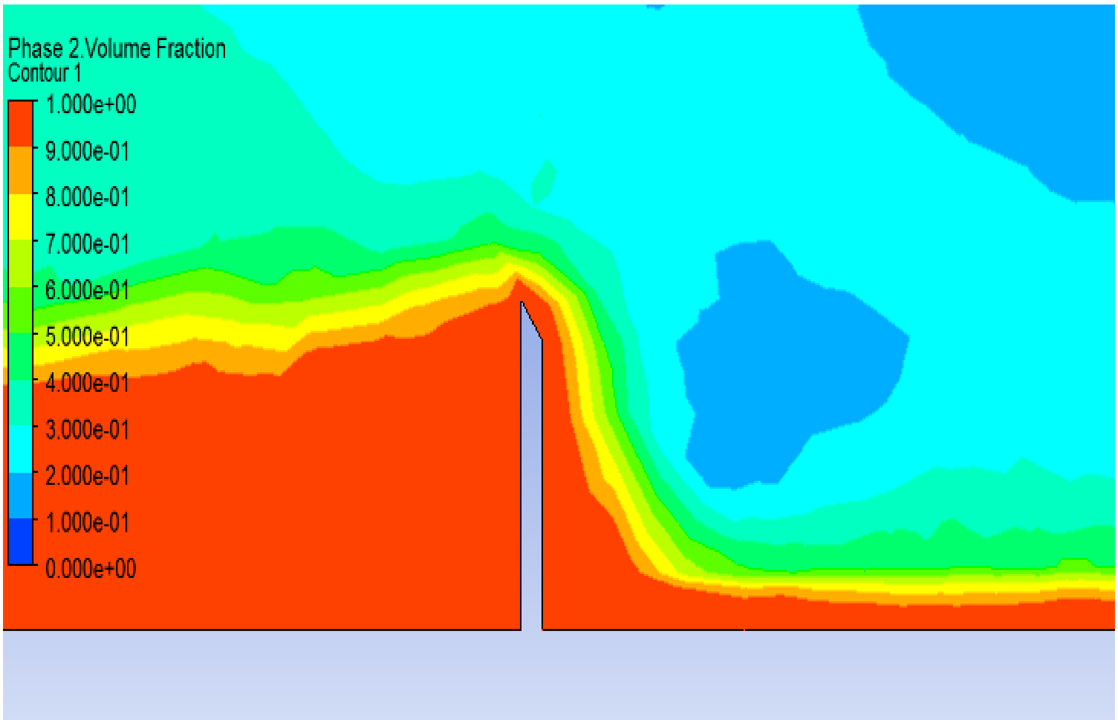


Figure 4.5 Flow profile

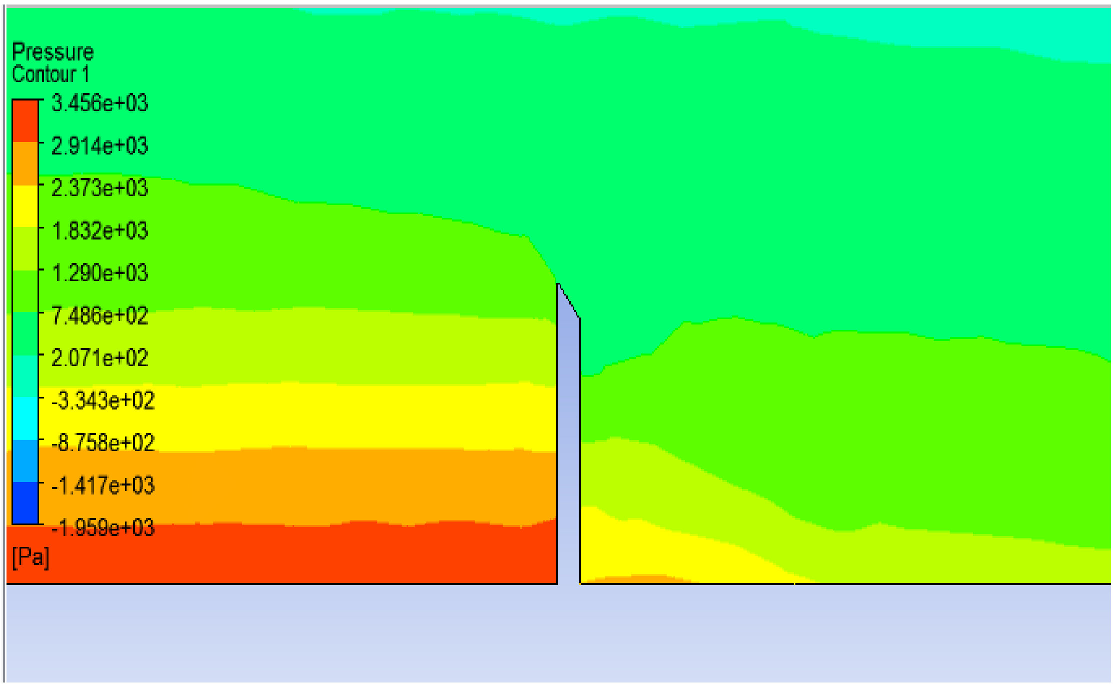


Figure 4.6 Pressure variation

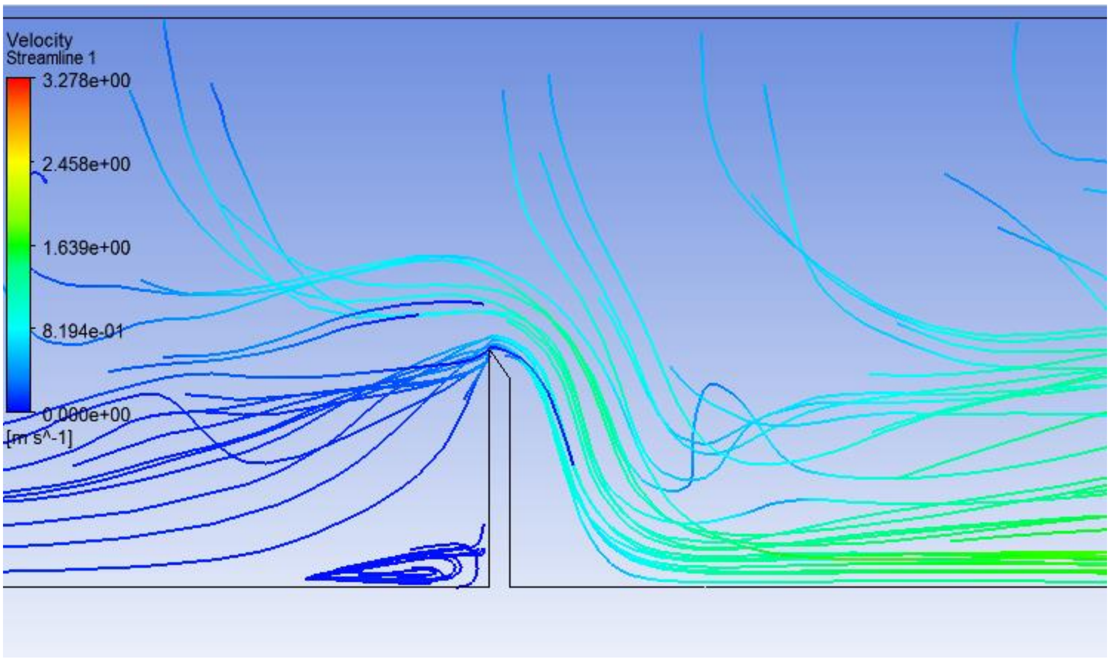


Figure 4.7 Velocity variation

4.2 Flow over Normal Rectangular Weir

Another type of weir crest is used to investigate the flow profile and it is found that the variation on normal type crest is just similar as sharp edge crest.

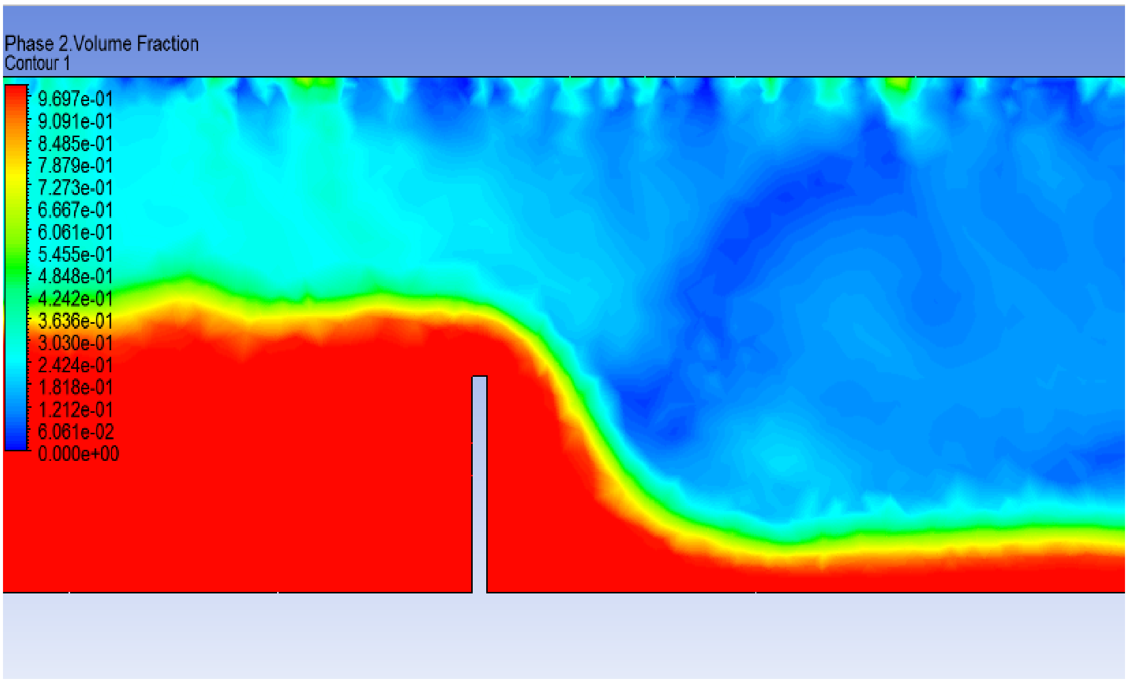


Figure 4.8 Flow profile

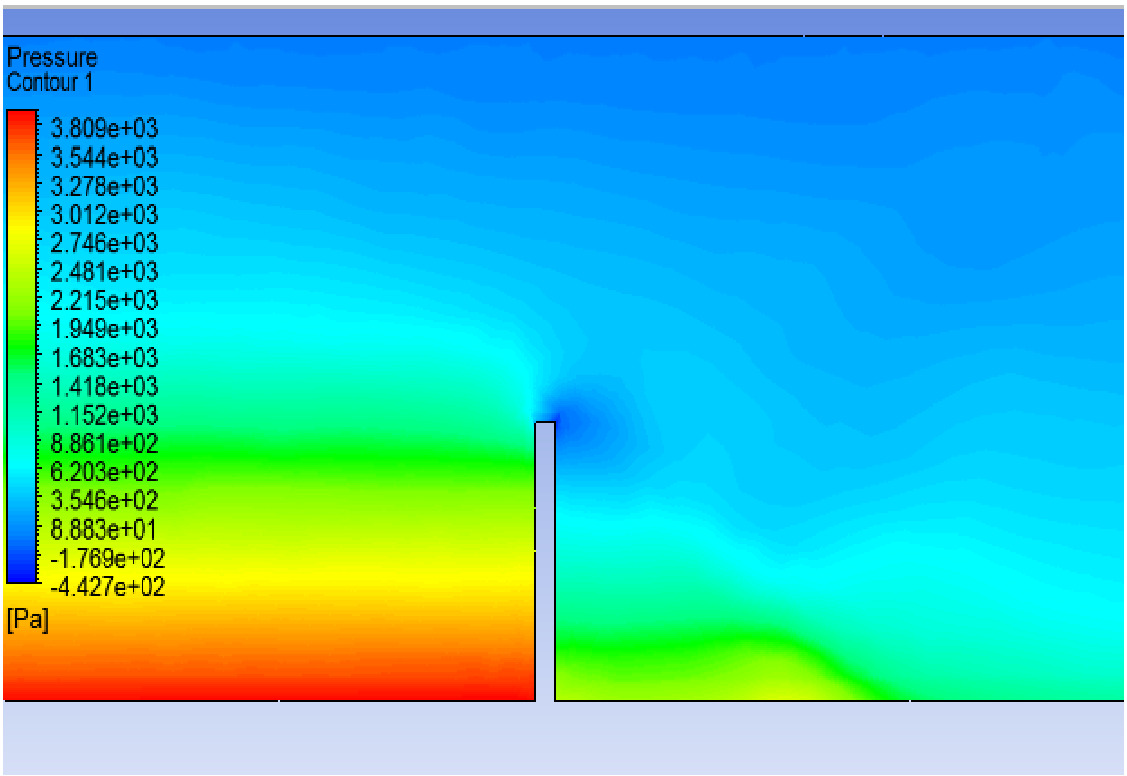


Figure 4.9 Pressure variation

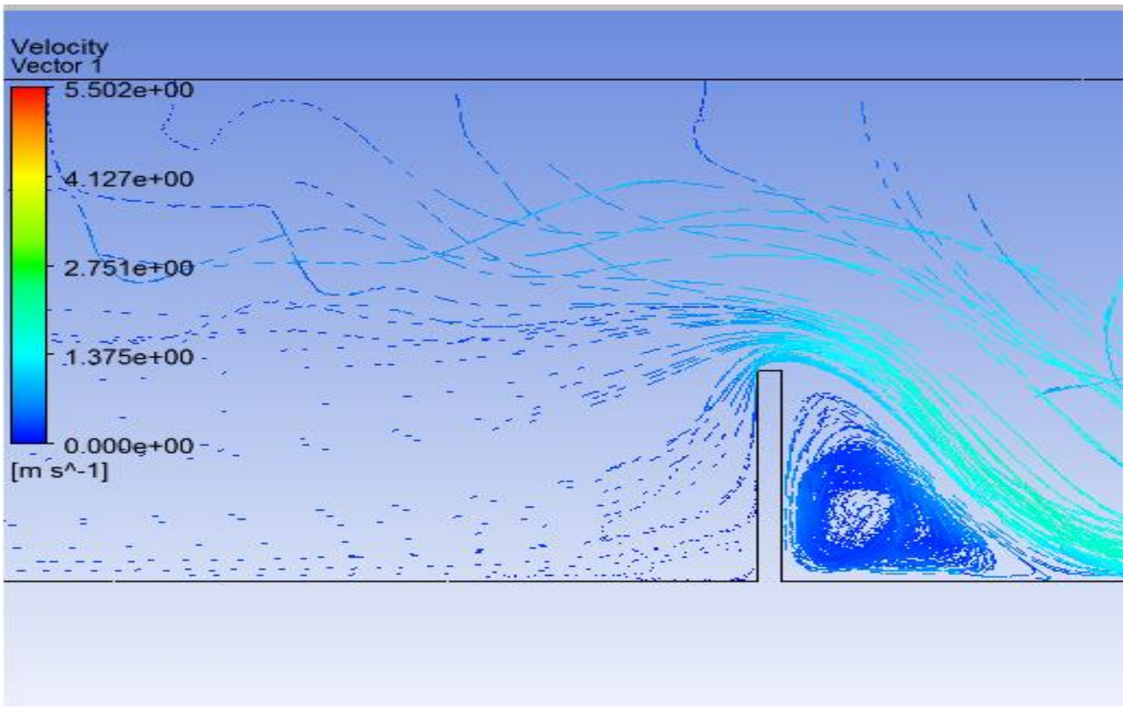


Figure 4.10 Velocity vector variation

4.3 Validation of the result:

In the published paper only the results are plotted in graphical manner here tried to plot the same variation over weir & discharge coefficient corresponding to simulation result is plotted against h/p.

(a)

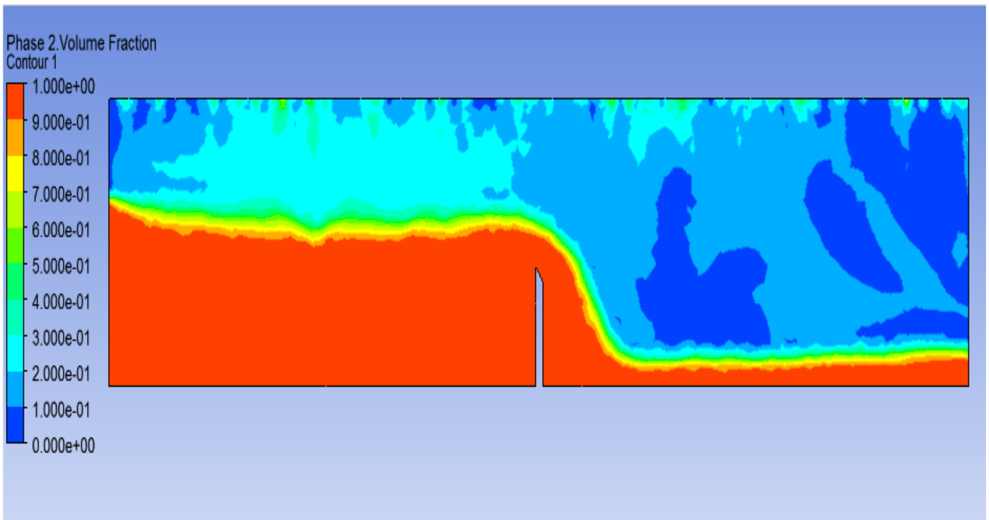


Figure 4.11 Volume contour (Flow profile) plotted in the present study

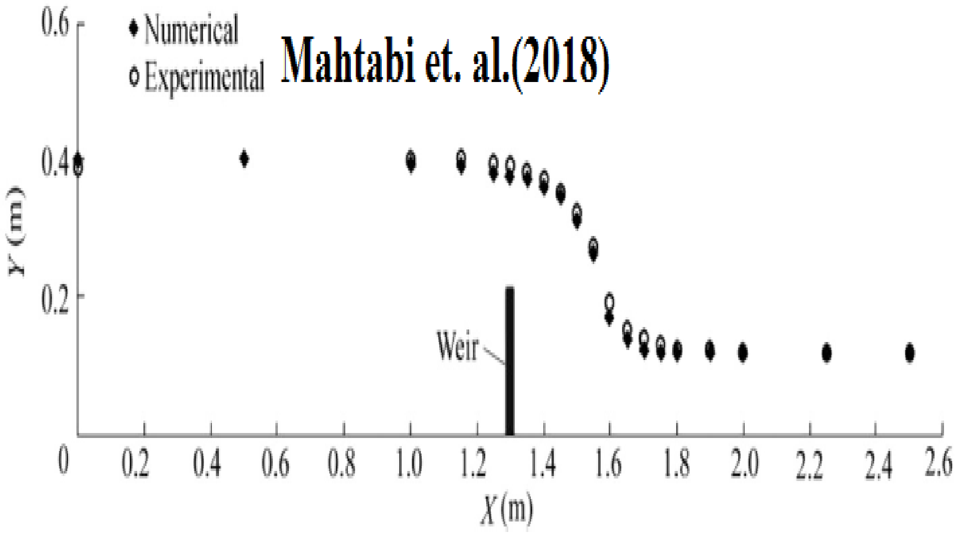


Figure 4.12 Flow profile plotted in the previous study Mahtabi et. al. (2018)

Remark: Fig. 4.11 & 4.12 compares numerical and previous experimental water surface of Mehtabi (2018) profiles through the weir at h=0.20 m and P=0.20 m. The results showed agreement between the numerical and experimental results. Percent error of the numerical results with respect to the experimental data is acceptable, within the ± 5% error limit. In addition, numerical models predicted the discharge well. Velocity vectors passing through the weir and contours of velocity magnitude are shown in Fig. 4.10. The vortex zone with returning velocity vectors is found downstream from the weir. The returning velocity vectors increased near the bed. Approaching velocity vectors began increasing almost over the weir and reached uniform distribution at the end of the vortex zone. At the center of the vortex zone, the velocity magnitude reached a value of approximately zero. Also, a stagnation zone is seen upstream.

(b) Velocity profile

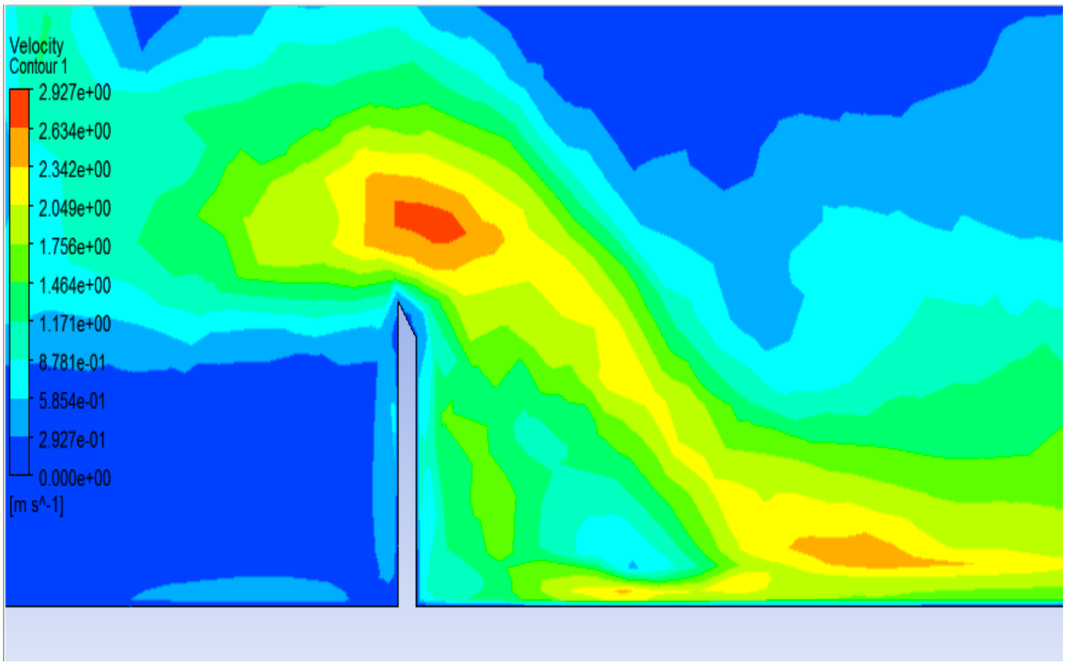


Figure 4.13 Velocity profile plotted in the present study

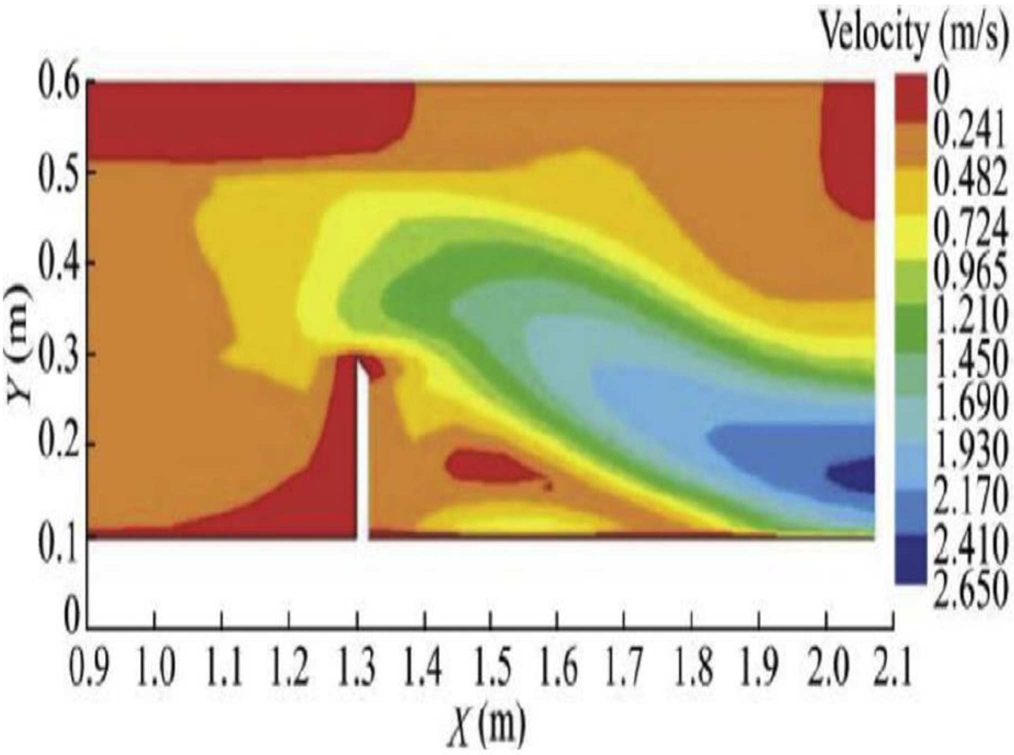
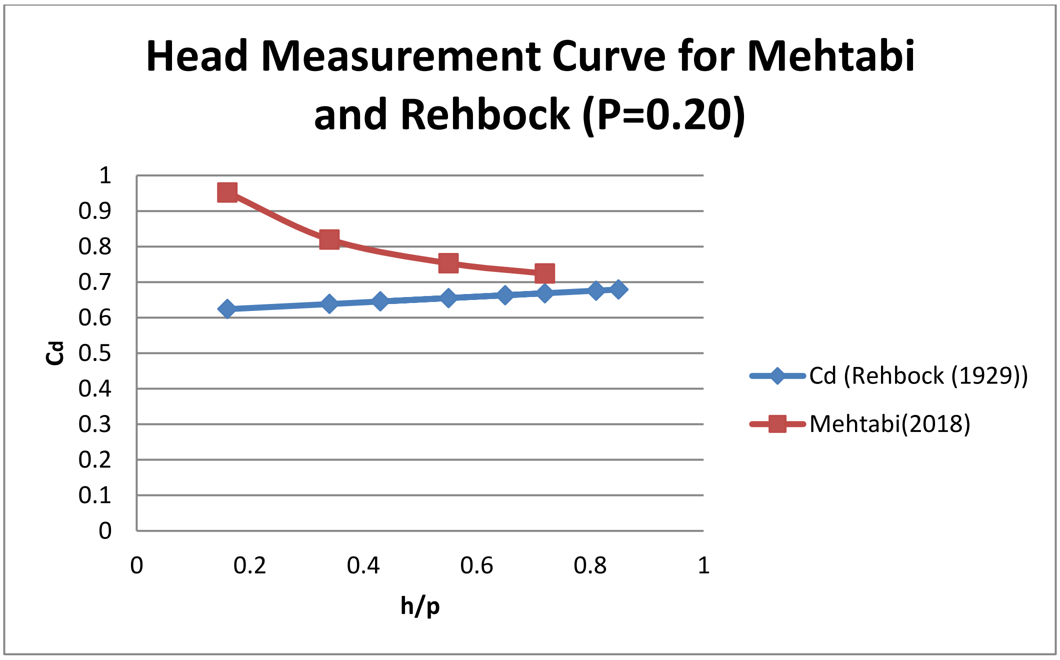
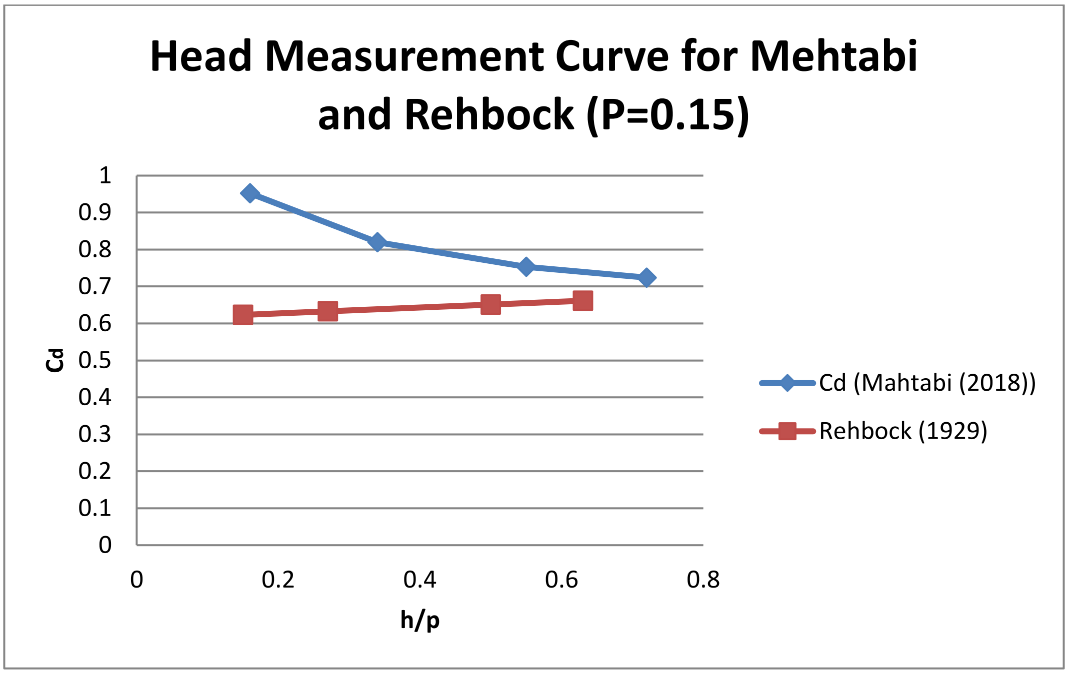


Figure 4.14 Velocity profile plotted in the previous study (Mahtabi at. el. 2018)

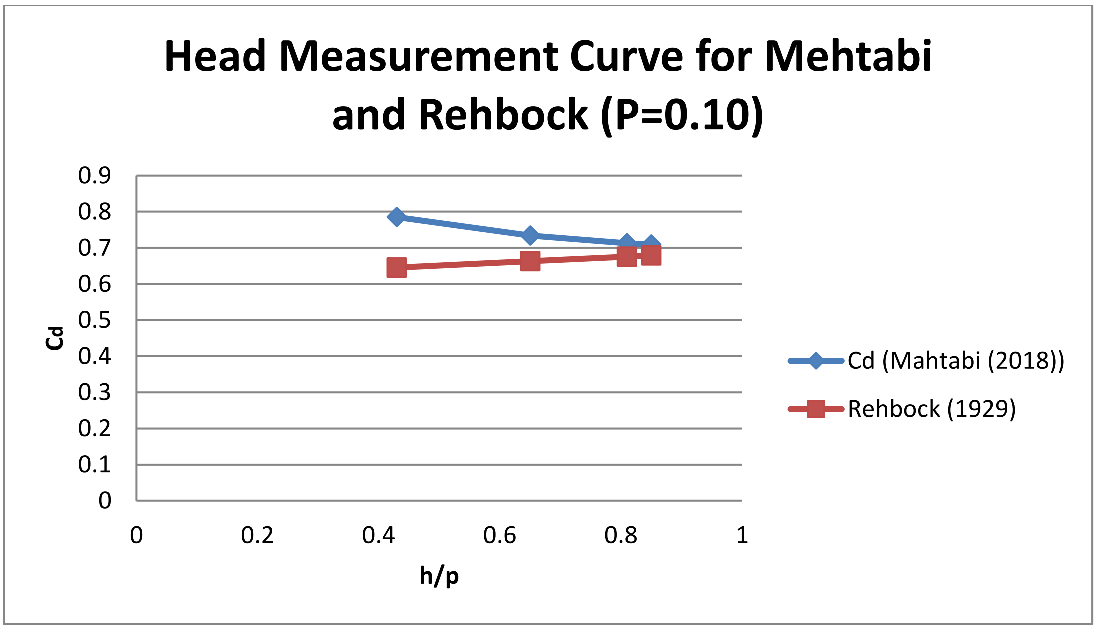
(c) Past result of discharge coefficient is plotted against h/p ratio as per Mehtabi (2018) & Rehbock (1929).



(a)



(b)



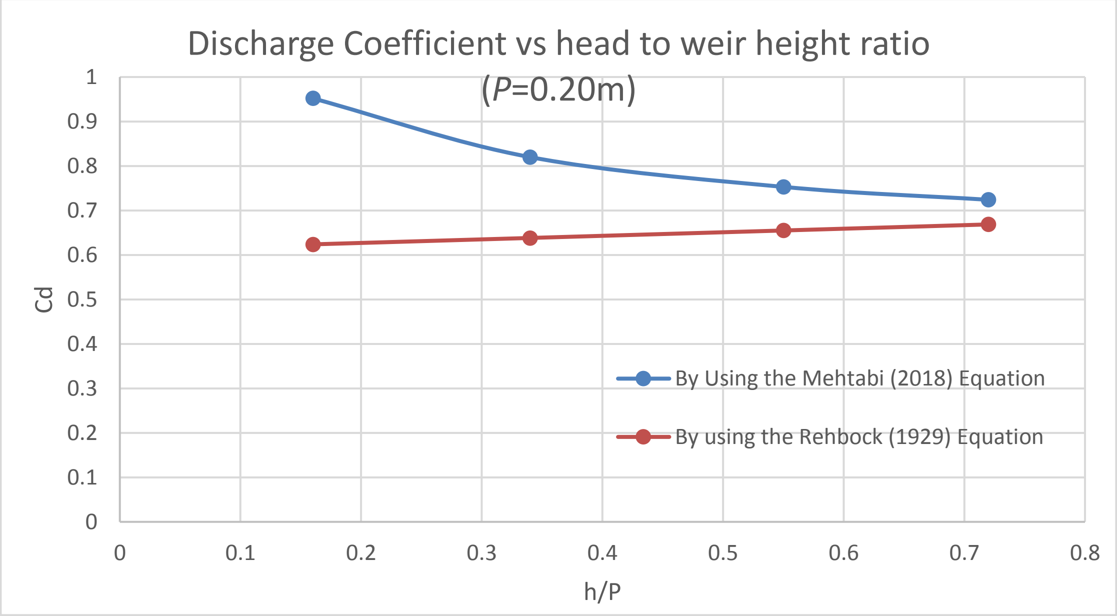
(c)

Figure 4.15 C_d **vs h/p graph plotted in the present study at (a) p=0.20, (b) 0.15 & (c) 0.10 m using Mehtabi (2018) & Rehbock formula(1929).**

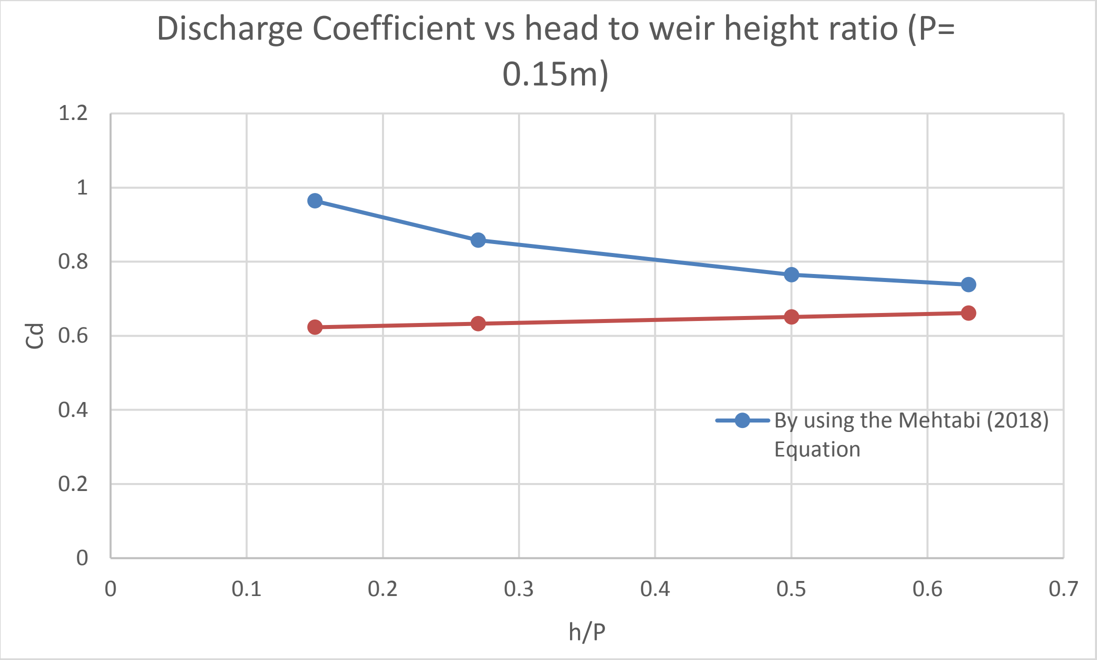
Figure 4.15 shows results of past experimental and numerical C_d versus h/P for different weir heights. C_d decreased nonlinearly with increasing h/P. For values of h/P greater than 0.6, C_d approximately reached the fixed value of 0.7 for different weir heights. In other words, the variation of h/P had no effects on the discharge coefficient when h/P=0.6. In Fig. 5, the numerical results were very close to experimental ones when P/h>0.4. There were only a few differences between experimental and numerical results when h/P=0.4 for P= 0.10 m. With increasing P, the experimental and numerical results were almost the same when h/P>0.2. These results indicate that fluent software can simulate the flow over the weir very well. Mehtabi and Rehbock developed mathematical equations which is evaluated using the optimization method to determine the best discharge coefficient equation. The best equation was selected based on the maximum $R^2$and minimum RMSE parameters.

Remark: The above graph is plotted between coefficient of discharge and dimensionless parameter h/p on the basis of proposed formula by Rehbock, it is indicate that the C_d is independent of h/p and the value of C_d lies in the range of 0.60-0.69.

(d) Present work for discharge coefficient is plotted against h/p ratio at a constant weir height of 0.20 m using Mahtabi (2018) & Rehbock (1929) formula.



(a)



(b)

(c)

Figure 4.16 C_d vs h/p graph plotted in the present study at (a) p=0.20, (b) p=0.15 & p=0.10 m using Mahtabi and Rehbok developed formula.

Figure 4.16 shows results of present numerical C_d versus h/P for different weir heights. C_d decreased prabolically with increasing h/P. For values of h/P greater than 0.6, C_d approximately reached the fixed value of 0.65 for different weir heights which is in good agreement with past studies. In other words, the variation of h/P had no effects on the discharge coefficient when h/P=0.6. The numerical results were very close to past result of Mehtabi and Rehbock. With increasing P, numerical results are almost the same in nature with past studies when h/P >0.2. Here fluent software simulate the flow over the weir very well. Mehtabi and Rehbock developed mathematical equations are cross verified using the proposed numerical relationship between C_d and h/P.

A weir is a structure that measures discharge as well as a hydraulic structure, and when we compared the discharge coefficients of full width rectangular sharp crested and normal crested weirs, the results are practically identical hence the effect of crest shape has negligible effect on coefficient of discharge for the same type of weir. The discharge coefficient is correlated using the dimensionless parameter h/p, and it is discovered that when h/p increases, the discharge coefficient falls parabolically and tends to a constant value. The coefficient of discharge is computed using the previous study's h/p ratio, which is similar to the previous study's h/p ratio. Mesh analysis is performed, and it is discovered that at a mesh size of 0.02 m produced superior results which means a finer size grid is good for simulation work. Accuracy of the result is dependent on fineness of mesh. A comparison of observed and numerical water surface and other parameter findings revealed that fluent software can accurately model flow over the weir.

CHAPTER – 5
SUMMARY AND CONCLUSION

5.1 Summary:

A weir is a structure that measures discharge as well as a hydraulic structure, and when we compared the discharge coefficients of full width rectangular sharp crested and normal crested weirs, the results are practically identical hence the effect of crest shape has negligible effect on coefficient of discharge for the same type of weir. A comparison of observed and numerical water surface and other parameter findings revealed that fluent software can accurately model flow over the weir.

1. for a particular type of weir (rectangular in present case), the effect of crest has negligible influence on discharge coefficient as the discharge coefficient is found in the range of 0.62-0.65.
2. By increasing the h/p ratio, discharge coefficient varies parabolicaly and approaches to a constant value of 0.65.
3. K-ε turbulent model is found reliable to achieve the aim of the present study.
4. Finer mesh of 0.02 m is found better than coarser mesh.

Future scope

1. It is obvious from the preceding description that much research has been done in the subject of sharp crested rectangular weir. However, in the instance of the contracted sharp crested rectangular weir, adequate work had not yet been completed, and further work may be completed.
2. The discharge features of constricted sharp crested weirs in terms of weir velocity and for slit weirs can also be investigated.
3. The discharge characteristics of trapezoidal weirs can still be studied further.

REFERENCES

Akoz, M.S., Gumus, V., Kirkgoz, M.S., 2014. Numerical simulation of flow over a semi cylinder weir. J. Irrigat. Drain. Eng. 140(6), 04014016. https:// doi.org/10.1061/(ASCE)IR.1943-4774.0000717.

A. V. Shivapur MISH & M. N. Shesha Prakash 2006 “Study on Discharge Characteristics of Sharp Crest Inclined Trapezoidal Notch” ISH Journalof Hydraulic Engineering ISSN: 0971-5010 (Print) 2164-3040 (online).

A. Zahiri, X. Tang and S. Bagheri 2017 “Flow discharge computation over compound sharp-crested side weirs” ISH Journalof Hydraulic EngineeringVol. 23, No. 3, 341–345 ISSN: 0971-5010 (Print) 2164-3040 (online).

Amanda l. Cox, Christopher I. Thornton, Steven R. Abt, (2013) “Supercritical Flow Measurement Using alarge Parshall Flume”, Journalof Irrigation and Drainage Engineering, ASCE, 139(8) pp 655-662

Anand V. Shivapur M.ISH, Raviraj H. Mulangi and H. S. Govardhan Swamy 2012 “Use of Inclined Compound Triangular Notch-Weir to Improve Discharge Range” ISH Journalof Hydraulic Engineering ISSN: 0971-5010 (Print) 2164-3040 (online).

Arun Goel 2006 “on a flow meter for discharge measurement in irrigation channels” Flow Measurement and Instrumentation 17 (2006) 255–257.

Arun Goel, D. V. S. Verma, Sanjeev Sangwan 2015 “open Channel Flow Measurement of Water by Using Width Contraction” World Academy of Science, Engineering and Technology Vol:9 2015-08-02.

Bhukya Ramakrishna, Shaik Vaheed, P.S.V. Adilakshmi 2018 “Flow Characteristics of Sharp Crested Weirs” International Journalof Advanced Research in Science Engineering and Technology Vol. 5, Issue 12, December 2018 ISSN: 2350-0328.

C. Di Stefano, V. Ferro 2013 “A new approach for deducing the stage-discharge relationship of triangular in plan sharp-crested weirs” Flow Measurement and Instrumentation 32 (2013) 71–75

Gharahjeh, S., 2012. Experimental Investigation on Sharp Crested Rectangular Weirs. M. S. Dissertation. Middle East Technical University, Ankara

Jahanshir Mohammadzadeh-Habili, Manouchehr Heidarpour 2013 “Application of convex streamline theory to circular-crested weir” Biosystems Engineering 116 (2013) 326-334.

Jalam Singh, S.K. Mittal, H.l. Tiwari 2014 “Discharge Relation for Small Parshall Flume in Free Flow Condition”IJRET:International Journalof Research in Engineering and Technology eISSN: 2319-1163 pISSN: 2321-7308.

K. Keshava Murthy and M. N. Shesha Prakash 1995 “Alternative Design of Square-Rooting Measuring Device in open Channel” Journalof Irrigation and Drainage Engineering, Vol. 121, No.6, November/December, 1995. ©ASCE, ISSN 0733-9437/95/0006-0374-0377/.

K. Subramaya, Flow in open Channel 2nd Ed., (New Delhi. Mc Graw-Hill Companies ltd. 1997).

Kaoru Yokoyama, Naoya Kashiwaguma, Tomoyuki okubo, Yasushi Takeda, 2004 “Flow Measurement in an openChannel by UVP” 4th International Symposium on Ultrasonic Doppler Method for Fluid Mechanics and Fluid Engineering Sapporo, 6.-8. September, 2004.

Mahtabi, G. and Arvanaghi, H., 2018. Experimental and numerical analysis of flow over a rectangular full-width sharp-crested weir. *Water Science and Engineering*, *11*(1), pp.75-80.

M. N. Shesha Prakash 1994 “Some Studies on linear Proportional Weirs” Ph.D. Thesis, Indian Institute of Science, Bengaluru, India.

M. N. Shesha Prakash and A. V. Shivapur, 2003 “Flow over Inclined Sharp Crested Triangular Weir” ISH Journalof Hydraulic Engineering, Vol. 9, 2003.

M. N. Shesha Prakash and A. V. Shivapur, 2004 “Generalized Head-Discharge Equation for Flow over Sharp-CrestedN Inclined Inverted V-Notch Weir” Journalof Irrigation and Drainage Engineering, Vol. 130, No. 4, August 1, 2004. ©ASCE, ISSN 0733-9437/2004/4-325–330/

M.N. Shesha Prakash, M. B. Ananthayya and Gicy M. Kovoor “Inclined Rectangular Weir-Flow Modelling” Earth Science India, eISSN: 0974 – 8350 Vol. 4(II), April, 2011, pp. 57-67.

M.N. Shesha Prakash, Nandan N Shenoy and GS Suresh 2018 “Generalised Head-Discharge-Inclination Relationship for Flow Through Inclined Triangular Weir with New Approach” International Journalof Science, Environment and Technology, Vol. 7, No 3, 2018, 978 – 991 2277-663X (P) ISSN 2278-3687 (o).

M.Y. El-Ansary1 M.A. Awad A.A. Nassar A.A. Farag 2010 “Calibration of Three Common Flow Measurement Devices for open Channels” MISR j. AG. Eng., 27 (1): 151- 169.

Rehbock, T., 1929. Discussion of precise weir measurements. Transmission93, 1143e1162

R. l. Parshall, “The Improved Venturi Flume”, Transactions, ASCE, 89, 841-880, 1926.

Rasool GHoBADIAN, Ensiyeh MERATIFASHI 2012 “Modified theoretical stage-discharge relation for circular sharp-crested weirs” Water Science and Engineering, 2012,5(1):26-33doi: 10.3882/j.issn.1674-2370.2012.01.003.

S. Gharahjeh, I. Aydin, A.B. Altan-Sakarya 2014 “Weir velocity formulation for sharp-crested rectangular weirs” Flow Measurement and Instrumentation 41 (2015) 50–56.

V. T. Chow, “open Channel Hydraulics.” McGraw Hill Book Co., New York. 1959.

Vishal B. Raskar 2017 “New Technique for measurement of Discharge in open channel flow” IJSART - Volume 3 Issue 2 ISSN [oNlINE]: 2395-1052.

W. H. Hager, “Venturi Flume of Minimum Space Requirements”, J. of Irrigation. & Drainage Engg., ASCE, Vol.114, No.2. May 1988.

Zhang, l.T., Wagner, G.J. and liu, W.K., 2002. A parallelized meshfree method with boundary enrichment for large-scale CFD. *Journal of Computational Physics*, *176*(2), pp.483-506.

Zohrab Samani 2017 “Three Simple Flumes for Flow Measurement in open Channels” Journalof Irrigation and Drainage Engineering, © ASCE, ISSN 0733-9437.

Zohrab Samani and Henry Magallanez 1993 “Measuring Water in Trapezoidal Canals” Journalof Irrigation and Drainage Engineering, Vol. 119, No. 1, January/February,1993. ©ASCE, ISSN 0733-9437/93/0001-0181/.

Zohrab Samani and Henry Magallanez 2000 “Simple Flume for Flow Measurement in open Channel” Journalof Irrigation and Drainage Engineering, Vol. 126, No. 2, March/April, 2000. ASCE, ISSN 0733-9437/00/0002-0127–0/.