STUDY OF FLOW CHARACTERISTICS OVER A SHARP-CRESTED TRIANGULAR WEIR USING CFD

A Dissertation submitted in partial fulfilment of the requirement for the

Award of degree of

MASTER OF TECHNOLOGY
IN
HYDRAULICS AND WATER RESOURCES
ENGINEERING

BY

STUTI MISHRA

(2K19/HFE/10)

Under The Guidance of

DR. MUNENDRA KUMAR

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, Stuti Mishra, (2K19/HFE/10) student of M.TECH (Hydraulics and Water Resource Engineering), hereby declare that the project dissertation titled as **"Study of flow characteristics over a sharp crested triangular weir using CFD"** which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in the partial fulfillment for the award of the degree of Master of Technology, is original and not copied from any other source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place- New Delhi
Date- (Stuti Mishra)

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the Project Dissertation titled as **“Study of flow characteristics over a Sharp Crested Triangular weir using CFD”** which is submitted by **Stuti Mishra**, **2K19/HFE/10** Student of **M.TECH (Hydraulics and Water Resources Engineering)**, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place- New Delhi **(Prof. Munendra Kumar)**
Date- **Supervisor**

ACKNOWLEDGEMENT

In this present world of competition there is a race of existence in which those are having will to come forward succeed. Any research Project is like a bridge between theoretical and practical working. With this willing I started this particular project named “Study of flow characteristics over a sharp crested triangular weir using CFD”. First of all, I would like to sincerely thank to my mentor in this project **Dr. Munendra Kumar** (Professor, Civil Engineering Department, DTU) for the guidance and support in completing my project.

I also express my sincere gratitude to all the faculty members for giving me this wonderful opportunity. I am also grateful to the staff members of the Fluid Mechanics and Hydraulics Laboratory of the Civil engineering Department for their support and collaboration in the course of the project and for assisting me in every possible way.

Friendly atmosphere and cooperative business at Delhi Technological University made my stay unforgettable and enjoyable. The love I have got from my batch mates and seniors will always remind me of my days as a student here and I would like to thank both of them warmly. Yes, their advice and recommendations were of great assistance whenever required.

I am grateful to my parents and my colleagues for their moral encouragement and for being supportive at the conclusion of my dissertation. First but not least, I praise the Lord for rewarding and loving me.

Place- New Delhi

Date- (Stuti Mishra)

Abstract

The focal objective of this study was to evaluate the effect of the slope of the channel on the coefficient of discharge for the Sharp crested triangular weir using CFD software (Ansys fluent) for clear flow and simulations on plane gravel bed. Weirs are regularly used to control the stream paces of waterways during times of high release. Floodgate entryways (or now and again the stature of the weir peak) can be adjusted to increment or diminishing the volume of water streaming downstream. In this work, we calculated different parameters including point velocities for the channel and weir. For the validation of results, experimental data for the same setup were being used where data was collected for the clear flow and gravel bed in a rectangular flume over a triangular weir. Modelling of the same setup was done in Ansys fluent using VOF (Volume of Fluid) multiphase analysis and results were compared. Percentage error is thus calculated which was found to be in 5-10% range. Also with the increase in slope the coefficient of discharge tends to increase upto 3% of slope, after that it minutely decreased for next 1% of positive slope.

Using Discrete phase modelling with Erosion/accretion physical models, particles (sizing of 20 microns to 200 microns) were traced with their residence time and 95% of the particles were found to be passing over the triangular weir. Also with Eulerian multiphase model in a 2-Dimensional setup, sediment analysis was done using sand with the help of patch tool. And their flow behavior was tracked down until they went into suspension state.

Keywords: Discharge coefficients, Sediment analysis, Sharp-crested weir, Volume of Fluid, Eulerian Multiphase Model.

Contents

List of Figures

List of tables

INTRODUCTION

1.1 General

The most ordinarily utilized water driven designs to command and quantify flowrate/discharge in streams are Weirs. These are little flood type -dams and are for the most part utilized to raise the stream levels. Weirs cause adequate change of water level in the up-stream side and are usually developed when the flowrate/Q surpasses the limit of a stream to keep the pressure driven framework from flood. Here are two principle sorts of weir: sharp-crested and finite-crested length. Finite crest length weirs can be parted into three sorts: in length, wide, and restricted crest. These sorts are reliant upon the extent of the water head over the weir to the length of the peak estimated longitudinally.

Weirs are arranged by:

1. Kinds of Weirs dependent on the Shape of Opening

--Rectangular weir --Triangular weir --Trapezoidal weir

2. Sorts of Weirs dependent on the Shape of Crest

--Sharp-crested weir –Wide-crested weir –Finite-crested weir -- Ogee- molded weir

3. Sorts of weir determined by Effect of the sides on the arising nappe

--Weir with end constriction (contracted weir) --Weir without end withdrawal (stifled weir)

Sharp crested weirs are quite possibly the most well-known stream estimation structures in open channels. Since, the water driven hypothesis of stream over sharp-peaked weirs are the foundation of the estimation and plan of Broad-Crested Weirs (spillway of dams), the significance of considering them is multiplied. Sharp peaked weir is a dainty vertical plate gave in an open channel to gauge the release. The border of the sharp peaked weir is the downstream side to give a base contact with the streaming water. In the down-stream side the inclined surfaces should make a point somewhere in the range of 45□ and 60□.

The V-indent weir is one of the sharp peaked weirs with a three-sided area, use to measure little release esteems ensuing to the water head over the weir top that is by and large sensitive to changes in stream.

(CFD) Computational.Fluid.Dynamics is the cycle of numerically displaying an actual marvel including liquid stream & settling it mathematically using the computating ability. At the point, when an engineer is entrusted with planning another item, for example a triumphant race vehicle for the following season, streamlined features assume a significant part in the designing interaction. Nonetheless, streamlined cycles are not effectively quantifiable during the idea stage. Normally, the lone route for the architect to improve his plans is to direct actual tests on item models. With the ascent of PCs and always developing computational force (on account of Moore's law!), the field of Computational Fluid Dynamics turned into a regularly applied apparatus for producing answers for liquid streams with or without strong connection. In a CFD programming investigation, the assessment of liquid stream as per its actual properties like speed, pressure, temperature, thickness and consistency is directed. To essentially create an exact answer for an actual wonder related with liquid stream, those properties must be thought about all the while.

The numerical model of the actual case and the mathematical process are used in the CFD editing tool to test fluid distribution. For example, the cases of Navier-Stokes (NS) are determined as the numerical model of the actual case. This brings about a change in one of the real structures of the stream and the movement of warmth. The numerical model varies according to the subject matter, for example, temperature movement, mass exchange, stage change, reaction response, etc. In addition, the consistent quality of CFD research depends largely on the whole construct of collaboration. Validation of the numerical model is essential to make a straightforward case to solve this problem. In addition, validation of appropriate mathematical strategies is a means of producing reliable order. CFD testing is a critical factor in creating the right scale for object improvement, as the number of real models can be significantly reduced.

The focal numerical portrayal for all hypothetical liquid elements models is given by the Navier-Stokes conditions, which depict the movement of gooey liquid areas. The historical backdrop of their revelations is very fascinating. It is an unusual fortuitous event that the renowned condition of Navier-Stokes has been created by Claude-Louis Navier (1785-1836) and Sir George Gabriel Stokes (1819-1903) who had never met. From the start, Claude-Louis Navier directed examinations on a fractional segment of conditions up until 1822. Afterward, Sir George Gabriel Stokes changed and settled the conditions in 1849.

1.2 Governing equations-

The fundamental design of thermoliquids assessment is coordinated by looking at the conditions that depend on the protection law of liquid's actual properties. The fundamental conditions are basically the three laws of conservation;

Protection of Mass: Continuity Equation

Preservation of Momentum: Newton's Second Law

Protection of Energy: First Law of Thermodynamics or Energy Equation

These standards express that mass, force, and energy are steady constants inside a shut framework. Fundamentally everything should be saved.

Testing for fluid flow or discharge with water changes depends on specific factors. Three questions to be considered simultaneously in these three basic conditions for saving speed $\vec{v}$, pressure p and type T. However, P&T is considered to be the 2 required essential thermodynamic components. The latter type of storage conditions also contains four other thermodynamic elements; size ρ, enthalpy h, consistency μ, and warm operation k; the last two of them are additional transport facilities. These four structures are surprisingly described for the importance of p and T.

Liquid stream ought to be examined to know vec v, p and T all through each place of the stream system. This is generally significant prior to planning any item which includes liquid stream. Besides, the technique for liquid stream perception dependent on kinematic properties is an essential issue. Development of liquid can be researched with either Lagrangian or Eulerian strategies. Lagrangian depiction of smooth movement depends on the hypothesis to follow a liquid molecule that is sufficiently huge to recognize properties. Introductory directions at time t0 and directions of a similar molecule at time t1 must be analyzed.

1.3 Objective of the work

The objectives of this project, which focus to carry out on Study of Flow characteristics over a Sharp Crested Triangular weir using CFD, are the following:

- *Selection of the weirs and methodology to be used in the study.*
- *To study the effect of channel slope on coefficient of discharge for sharp-crested triangular weir for clear flow. And their comparison with the available experimental data to the findings from CFD.*
- *To study the effect of channel slope on coefficient of discharge for sharp-crested triangular weir for plane gravel with their comparison to the available experimental data to the findings from CFD.*
- *To study the variation of velocity for sharp-crested triangular weir with experimental available data and findings from the numerical simulation for clear flow simulation and plane gravel bed.*
- *To trace the Particle residence time and discrete phase model erosion rate using injections of different particle size (20 microns-200 microns).*
- *To study the sediment transport (sand) rate on a two dimensional channel using Eulerian Multiphase approach*.

LITERATURE STUDY

2.1 General

Generally, weirs are utilized to forestall flooding, measure water release, and help render waterways more safe by boat. In certain areas, the terms dam and weir are interchangeable, however typically there is a reasonable qualification made between the constructions. Generally, a dam is planned explicitly to seize water behind a divider, while a weir is intended to change the stream qualities. Rectangular weirs and three-dimensional or v indent weirs are frequently used in the provision of water, wastewater and sanitation facilities. They consist of a sharp plate on both sides with a rectangular, triangular or v-indent stream of water.

2.2 Literature review

Rezazadeh Shiva A,*, Manafpour Mohammad B, Ebrahimnejadian Hamze (2020), The motivation behind this study was to recreate the stream over sharp crested weir and research the impact of mathematical states of sharp crested weirs on water powered qualities of the stream like pressing factor, speed, water level profiles and release coefficients. In this manner the restriction and use scope of sharp crested weirs are explained. In this examination OpenFOAM open source 3D modelling with RNG K-ε model and Volume of Fluid technique (VOF) was utilized to break down the pressure driven stream passing through sharp crested weir. The greatest discharge coefficient is acquired for sharp crested rectangular weir while the sharp crested three-sided weir has least discharge coefficient. Horizontal withdrawal on the sharp crested weirs causes that the water profundity builds upstream of weir and the discharge coefficient diminishes.

Subhojit Kadia, Binit Kumar and Zulfequar Ahmad (2020), To comprehend the stream field and discharge qualities of a three-sided weir with an upstream incline (TW-UR), test concentrate just as computational liquid elements (CFD) recreation were performed. The Ansys CFX module and standard k-ε turbulence model were utilized in the recreation. It was tracked down that the TW-UR model had about 9.8–14.3% higher releasing limit than a sharp-peaked weir of same height and Cd expanded at first with an increment in H and achieved right around a consistent esteem past $H/P \approx 0.65$. Around 10–15% higher discharge was assessed in the CFD recreation when contrasted with the noticed information under a similar head. The TW-UR may be useful in passing residue when contrasted with the traditional weirs due to the presence of the up-stream slope and a profoundly dynamic stream field in the upstream side. It was also concluded that the equation proposed by Di Stefano et al. (2016) seemed more accurate than the equation which was proposed by Azimi et al. (2013) for the used datasets.

U.S. Ansari & L.G. Patil (2020), An examination has been done on lanyrinth side weirs with rectangular parent channel. In this examination, Computational.Fluid.Dynamics (CFD) volume of fluid(VOF) strategy is utilized to research the coefficient of discharge of three-sided labyrinth side weirs in the three-sided straight primary channel. Dimensionless boundaries like dimensionless scruff tallness h/p, Froude number.Fr, the Apex point of three-sided maze side weir, dimensionless weir width and included point of three-sided parent channel influencing on the coefficient of release of three-sided maze side weirs gotten from CFD reproductions are utilized for an experimental condition. Also it was found that water-surface profile along the edge weir opening is influenced by the included point of labyrinth side-weirs as the drop in the head(h) is most extreme for 45° which has the most elevated successful length.

Ansari U.S., Patil L.G. (2019), In this paper a few examinations of researcher with various boundary influencing coefficient of discharge and releasing limit of side weirs are introduced. In review it appears to be that changed boundaries are influencing on release of side weir has been considered in exact conditions given by specialist however couple of boundaries are left for thought. In this paper impact of extra boundaries like side weir thickness and submergence condition is assessed by CFD models which can be an examination apparatus to research future extension. Impact of submergence additionally needed to research since it influence coefficient of release. CFD reproduction can be effectively utilized for examination of various boundaries.

M. Cihan Aydin (2011), The water surface profiles over the three-sided maze side weirs were explored by numerous individuals of the scientists tentatively and hypothetically. In this examination, the free surface stream over the three-sided maze side weir was demonstrated by utilizing Volume of Fluids (VOF) technique to depict the stream attributes in subcritical stream conditions. A substantial technique, Grid Convergence Index (GCI) was utilized to decide the mathematical vulnerability of the results. The weir contrasted and exploratory perceptions, and great arrangements were acquired between the two outcomes. The recreations results concur sensible with trial perceptions. The outcomes in this examination show that the CFD reenactments can assist with deciding the stream qualities of water powered designs including free surface stream like side weirs, possibly along with actual model investigation.

Mohammad A. Al-Dabbagh, Sulaiman D. Al-Zubaidy (2018), In the current examination, three-sided expansive peaked weirs are mathematically explored under various stream conditions. Distinctive inside points of 90o, 100o, 110o and 120o are incorporated for the kick-off of weirs. The streaming water over weirs is recreated utilizing CFD strategies and assessed at various stream systems with channel releases of 0.012 m3 s-1, 0.036 m3 s-1and 0.06 m3 s-1. The recreation results have shown that the water level upstream the weir is conversely relative to the initial point, where an augmentation of 10o in the initial point prompts a drop in water level about 1.5 cm. Furthermore, applying a release of 0.012 m3 s-1, an uncovered district with water is made downstream the three-sided expansive peaked weirs, while the bed downstream of the rectangular wide peaked weir is covered with a dainty layer of water at a similar stream release. The previously mentioned results are contrasted and a relative information show great arrangement. By utilizing three-sided wide peaked weirs, it is critical to gauge the wake district and the hitting purpose of falling water downstream the weirs where this region should be reinforced well to oppose water control and lessen the danger of float.

Hasan Ibrahim Al Shaikhli, Kadhim al-taee (2018), The goal of this paper/work is to anticipate the coefficient of release for different sorts of weirs. For this reason, a condition has created utilizing various non linear relapse (MNLR) and the code of computational.fluid.dynamics (CFD) approaches. A two weirs shape research tentatively and mathematically, knows as rectangular indent with peak width (0.03m) and three-sided V-score with right point (90o), the peak tallness for both rectangular and V-indent weirs is stay steady in test and mathematical examination. The aftereffects of trial study and mathematical code are utilized with deferent peak head to fostering the pressure driven properties of stream over peak weir. Exploratory outcomes details that the increment of peak head cause an expansion in coefficient of release for both rectangular and three-sided score weirs. In CFD, results show that FLOW 3D programming can reenact the pressure driven properties of the open channel stream of stream over weir in both rectangular and three-sided score. M.N.L.R. approach used to foresee the coeff. of release as per the conditions that proposed dependent on dimensional investigations, results show that M.N.L.R. gives a sensible acknowledgment to appraise the coeff. of discharge with efferent relapse equivalent to (R2=0.99) for both rectangular and three-sided V-notch weirs.

Saleh I. Khassaf1, Ali N. Attiyah2, Hayder A. Al-Yousify2 (2016), In this investigation, the coefficient of release over the two compound side weirs (Rectangular and Semi-Circle) were demonstrated by utilizing Computational Fluid Dynamic (CFD) to depict the stream qualities in subcritical stream conditions. (Flow 3D) program was utilized to decide the mathematical vulnerability of the reproduction results. The recreation results were contrasted and trial perceptions, and great arrangements were gotten between the two outcomes. the accompanying things were finished up; the release coefficient of compound Semi-Circle side weir more prominent than that of compound Rectangular side weir, the determined equation for the coefficient of release Cd for compound (square shape and semi-circle) side weirs have been created by utilizing the dimensional examination methods , this recipes were confined to the research facility information and The product Flow – 3D is utilized to demonstrate the trial information utilizing Computational Fluid Dynamic (CFD). Huge relating has been found between the exploratory outcomes and the outcomes acquired from (CFD), and the rate blunder between these outcomes is (0.96% - 5.7%).

M. Umeyama and F. Gerritsen (1992) shows a new blending length rule used to fabricate a computational model for assessing the dissemination of speed for dregs stacked fluid. The arrangement can be acquired from vertical silt gathering. The coefficient from Kármán is free of the heap suspended from 0.4. The expression applies both to the condition of the alluvial ground and the condition of the level bed. There are likewise approaches to adjust the definition to clear-water streaming. The speed condition of clear water streaming comprises of a logarithmic term and terms for the force arrangement which portray the wake impact. The conveyance of the hypothetical speed for dregs stacked stream leaves from the outer layer logarithmic enactment. The degree of takeoff gets higher as the residue load rises. The figures are assessed and applied to five distinct arrangements of recently gathered trial information. The hypothetical discoveries show that such trial tests have a decent relationship in the whole stream layer.

F. Karim (1995) shows another strategy acquainted with figure alluvial-direct obstruction in the feeling of the regular Manning condition. The new technique shows that the monitoring component relates straightforwardly to the part of the bed structure in choosing the opposition of an alluvial surface. The tallness of the bedform is determined, and is then utilized for the opposition because of the drag of the bedform as an autonomous variable. To guarantee the qualities noticed, the system has been stretched out to a wide body (969 surges) of waterway and flume information. For every one of the 969 streams, mean uniform mistakes were around 10% at expected stream profundities and velocities. The cycle can be reached out to regular streams with a composite channel, as this methodology permits to decide the harshness of the chief channel and overbank segments independently. For streams specifically in the lower (wave or hill) or in the upper systems, anyway huge blunders were related with streams in or about the middle of the road beds organization, the forecast yield was commonly better. Future examination is probably going to be put together all through the change system with respect to the stream cycles and bed development.

Rijn (1984) shows that the framework proposed permits the categorisation of bed shapes, the assessment of the size of the bed shape and the effective roughness of the bed shape to be accomplished. Applicable flume and field verification are the subject of the arranged construction. The proof examination utilizing around 1500 (elective) definite flume and field information demonstrates great outcomes in the pressure driven harshness (division factor) assessment. The current strategy yields significantly improved results than the recently proposed strategies for field settings.

Umaru Garba Wali (2013) led investigation to assess the motor energy and force coefficients of the restricted trapezoidal water system channel. A framework with a cyclic progression of water was utilized. The cross-segment of the stream was parted into 10 equivalent parts with nine vertical parts moreover. The stale and deteriorating heads of 1 , 2, 3, 4, 5 or 6 vertical stages were utilized to ascertain the pitot static cylinder. Such estimations were acquired from the channel water free surface at profundities of 0.1h, 0.2h, 0.4h, 0.6h, 0.8h and 0.9h. To gauge the prompt speed at each deliberate, point the contrast between the deteriorating head and the static head was utilized. 3.5, 9.5 and 11.4 l/s were utilized in three separate releases. The discoveries show that the energy and force adjustment factors are not same. The standard channel upsides of α shifts between 1.10 to 1.20 and β somewhere in the range of 1.03 and 1.07. For the crucial water driven investigation of the open channel stream, the energy and force amendment factors are likewise to be considered.

Tomasz Janusz Teleszewski (2018) conveyed research, a test examination of the revision factor for dynamic energy (Coriolis) in the laminar, transient and turbulent progression of a clear, smooth line with a Reynolds number up to 25000 is completed. Speed profiles are created utilizing the Doppler Velocimeter (LDV) laser. Based on the trial discoveries acquired for Re < 25000, summed up relationship for the dynamic energy adjustment factor as an element of the Reynolds number are given. The discoveries of the investigation are identified with the trial results distributed by different researchers. Anticipated relationship for the motor energy change part might be a truly significant device for water powered liquid estimations by means of roundabout channels.

Vito Ferro and Giorgio Baiamonte (1994) did speed estimations in a rectangular lab with a rock bed are given. Estimations are made for four unique sizes of beds and for two conditions with little and enormous size, described by various degrees of coarser parts. The examination shows the Dean model can be utilized to test all water driven conditions as for the speed profile. Inexact computation of the Dean coefficients is proposed with restricted water driven conditions. Vito Ferro (2003) did speed tests by an acoustic doppler velocimeter (ADV) in a rectangular research center flume with a rock bed are given. Six vertical lines of the cross segment of the channel with a separating (from 4 cm to 38.5 cm) from the flume divider decide the speed profiles. Five separate bed arrangements are directed in research center trials, which differ between different proportions and two medium-and huge scope roughness conditions. Speed estimations are first used in all pressure driven settings to check the pertinence of the senior member profile and the log-related profile adjusted by the strategy for contrasts proposed in this article. The non-dimensional boundary of the erosion factor will at that point be determined for each worth of the profundity silt proportion h/d84 by coordinating the projected speed dispersion into the distinctive vertical cross-areas. The condition for semi-logarithmic stream opposition is at last derived observationally.

DuBuat guaranteed in 1786 (Rouse and Ince, 1963; Bray, 1982) that one of the primary issues in the field of hydrodynamics was the estimation of the speed of the stream, of which the distance, profundity and incline are perceived. After 200 years, the topic of estimating the normal speed in the rock bed water, which alludes to the properties of the channels filling in as a protection from the flood, is as yet an effective concern. To request to decide the stream speed profile and the standard of opposition in a rock bed trench, it is essential to separate between a condition of limited scope unpleasantness (Bathurst et al., 1981; Bray, 1987), for example where the uniform stream profundity h is far higher than the trademark size of the particles coordinated at the limits of the trench (breadth d50 of the ground particles for which half of the balance is balance). The worth of the water powered state is ascribed to the different structures expected by the speed profile (Bathurst, 1988; Ferro and Baiamonte, 1994).

Baiamonte et al. (1995), looked at the 25 test speed dispersions completed in the research facility flume hub with the hypothetical profiles of Equations 1 and 4 (Dean – Finlay (DF) model) reasoned that the DF model is versatile to the speed estimations in rock bed streams for one or the other wide or limited scope harshness conditions (Ferro and Giordano, 1993). The speed estimations taken in a rectangular lab flume with a rock bed by the Acoustic Doppler Velocimeter (ADV) were first used to assess how the speed profile fluctuates as stone segments are scattered and how the profundity silt proportion shifts. Speed computations are then used to follow the activity of the DF profile and the logarithmic profile as altered by the cycle of disparity introduced in this Article for circumstances of little or huge scope Roughness.

S. Salehi and A. H. Azimi (2019) shows the release properties of the stream over and under different weir-door structures were contemplated utilizing dimensional examination and multivariate relapse strategies. Based on the structure and plan of the weir-doors, seven weir-entryway frameworks were characterized. In a wide range of weir-door models, the connection part, characterized as the extent of noticed releases around and underneath the weir-entryway framework to the measure of anticipated weir and entryway releases. To explore the motion discharge qualities over and beneath the restricted peak range, six Weir-entryway models have been tentatively assessed. For all weir-entryway models, cooperation factors were contrasted and calculation boundaries with a mean choice coefficient of 0.85. There are various control plots created for the development of weir-entryway frameworks as stream gadgets for a sharp-edged weir-door and a restricted peak with counterbalance weir. The proportion of weirs and scaffolds to various weir-stream mathematical prerequisites is outlined in the systems. An essential standardized head has been added, because of the equivalent appropriation of the stream over the weir-to-pate framework.

S. C. Mehrotra (1983) shows the hypothetical meaning of the fitting speed change factor utilized in open channel hydrodynamics is gotten. The meaning of fundamental unit tractive power is utilized in logical determination. The hypothetical affiliation is differentiated to the genuine empiric bend. The arrangement has been discovered to be fine.

A. S. Ramamurthy et al. (1997) shows move through a two-dimensional sharp-edged weir arranged toward the finish of a flat rectangular line, trial tests were acquired as for speed and pressing factor dissemination in the district of the nappe close to the weir peak and the pressing factor appropriation on the weir side. The overall connection between the Cd-weir discharge coefficient and boundary H/W (or W/H) is dictated through the force standard based on trial discoveries and nonexclusive hypothetical suspicions. The current exploratory discoveries affirmed that the weir release coefficient was proposed.

R. E. Baddour (2008) shows that polynomial weirs can be utilized to produce an assortment of head-removal exercises including the relative (direct) qualities of the Sutro weir in horticultural and civil designing exercises. The accompanying note depicts a framework where sharp peaked weirs with openings characterized by n polynoms of any request are resolved in head-release conditions. Models are given of the activities of the fourth request polynomial weirs.

S. M. Borghei et al. (1999) shows the release coefficient in the weir condition should be perceived to decide the outpouring over a rectangular sharp-edged side weir. While this sort of framework has been created by water driven designers and broadly utilized, the release coefficient is by and large not proper. To assess the impact of water driven streams just as the mathematical, channel and weir shapes on the coefficient, the outcomes were investigated and in excess of 250 tests were led. The discoveries show that the De-Marchi consistent energy assumption is fitting for the subcritical stream and ought to be applied to the climate release. It has additionally been found that the De-Marchi release coefficient relies upon the upstream volume of Froude and the connection between the upstream profundity and the upstream profundity and the weir width and the channel size, though the fluvial slant might be overlooked by the subcritical flood. An appropriate recipe is then applied for the release coefficient.

A. H. furthermore, Coşar. Agaccioglu (2004) did an investigation with an aggregate of 1,735 tests, which brought about sharp three-sided side weir release coefficients in both the straight and the twist. It was noticed that the three-wheel load coefficients in the bend depend on Froude upstream in the fundamental channel (F), side-wheel zenith point (T), and curve point (α). Since the optional stream rate is significantly higher because of sidelong stream with an expanding flood recurrence, the pinnacle point <= 120°C has all the more frequently got solid three-sided side-weir releasing coefficients than different coefficients, besides under subcritical stream conditions at the straight channel. The bended line has a lot more prominent point of difference on one or the other side, which is associated with F and L/b, on account of the course of most extreme speed and the optional current delivered by the twisting. The three-sided side-wheel discharge coefficients in the twist are therefore bigger than the qualities got in the straight line.

C. Bautista-Capetillo et al. (2014) shows three-sided weirs are broadly used to survey open-channel release, and is a financially savvy, exact strategy for controlling the dispersion of water. In this investigation, the stream profiles from the upper and lower napkin over completely circulated air through three-sided weirs were portrayed in a low-speed photographic strategy. Tests covering various points (30° to 90°), peak (8-10 cm), and releases (0.01–7.82 l/s) were directed at an aggregate of 112. To get a prescient condition for the weir discharge coefficient, the trial nappe profiles are numerical and joined with free-vortex hypothesis segments. The determined Cd, the proposed release coefficient condition and the conditions of release coefficients portrayed in the writing were thought about. A Cd with mean gauge blunder (MEE) of 0.001 is anticipated by the proposed condition, 0.004 root-mean square mistake (RMSE) and 0.984 accord records (IA). This outcome possibly builds the condition proposed by Greve in 1932 and has similar total worth of MEE in the trial states of this investigation.

X. Zhang et al . (2010) shows that solitary free-stream frameworks identify with the estimations of release coefficients accessible for sharp-covering weirs. The basic tops of the transmission stream framework and head-release proportions for the sticking and free stream were tentatively tried based on more than 300 test focuses, with a head of 0.0048 to 0.0455 m, for the motivations behind extending the range of release estimations through a rectangular sharp weir. The outcomes show that there is no progress from connection to free stream and the other way around. For these advances, the basic top and lower heads, Hu, crit and Hl, crit, can be found. For the condition examined, there is a persistent connection of the contact of the mind between the grasp and the free stream. Articulations were produced for the unloading coefficient for the glue flood.

Galip Seckin et al. (2009) conveyed the investigation in which the vertical and horizontal speed dissemination of the compound channel cross-segment was determined to break down the dynamic energy and force change coefficients for nine separate test releases. Investigations were performed for subcritical stream conditions and the Froude number (Fr) and profundity proportion (Dr) went from 0.87 to 0.95 and 0.17 to 0.48, individually. Motor energy and force adjustment coefficients, α and β, were resolved for each test situation. Yuan SY, Xiao Ch, Li ZY, Zhu JY (2003) were the results of this survey. Assessment of Bactrocera dorsalis (Hendal) lab reproducing methodologies. It is comparative with the test aftereffects of different flumes with various cross-sectional structures containing different specialists. Mean qualities for dynamic energy and force change coefficients, α and β were gotten as 1,094 out of 37 individual trial cases.

Issam A. (2013) led different research facility examinations to explore the coefficients of force and motor energy change in topsy-turvy rectangular compound cross-segment organizations. The quantity of Reynolds differed from 14,348.9 to 54,868.2 as the relative profundity (Yr) rose from 0.155 to 0.825. Motor energy and force adjustment coefficients, α and β, were resolved for 9 separate adaptations. Thus, the upsides of α and β given 106 information focuses connected to 9 distinctive cross-areas estimated 1,1525 and 1,1261, separately.

P. K. Mohanty (2013) performed tests in a reasonable, level, trapezoidal focal channel flanked by two balanced floodplains with a width proportion of 12. The point speed in the cross-part of the compound was determined and the isovel designs assessed with the active coefficient of energy (α) and the coefficient of energies (ß) under changing stream states of Froude no. somewhere in the range of 0.277 and 0.444 and the relative profundity somewhere in the range of 0.11 and 0.43 were assessed. The qualities for α and β are 2.09 and 1.39, separately and essentially higher than the qualities for compound cross areas of various sizes and shapes recorded by past researchers. For the computation of the assessed α and β upsides of R2 esteem more prominent than 0.97, new cooperations are proposed. Clear rules for the plan and investigation of trapezoidal compound waterways are remembered for the current discoveries.

B. R. Samaga (1986) gave speed conveyance conditions that have as of late been set up based on silt loaded stream information over an unbending flatbed are tried with test stream information over alluvial residue blend beds and discovered to be unacceptable in the present circumstance. Utilizing the current informational index and the information acquired by different examiners, a two-layer model of speed dissemination across alluvial beds has been made. The model demonstrates solid arrangement with the Rhine and Middle Rio Grande region estimations.

Lei Jiang, Mingjun Diao *, Haomiao Sun and Yu Ren (2018), The goal of the examination was to assess the impact of the up-stream point on stream over a trapezoidal expansive peaked weir dependent on mathematical reenactments utilizing the open-source tool kit Open-FOAM. Eight trapezoidal expansive peaked weir designs with various up-stream face were examined under free-stream conditions. The volume-of-fluid(VOF) strategy and 2 turbulence models (the standard k-# model and the SST k-w model) were utilized in the mathematical recreations. The mathematical outcomes were thought about with the exploratory outcomes acquired from distributed papers.

Samadi and H. Arvanaghi (2014),The point of this examination is three-dimensional reenactment of stream on contracted-compound angled rectangular sharp-peaked weir by utilizing Familiar programming. For multi-phase stream reenactment, VOF technique is utilized and for recreation of fierce stream, RNG k-ε disturbance model is utilized and the aftereffect of mathematical model is contrasted and trial information. The consequences of this investigation show that; FLUENT reenact stream on contracted-compound angled rectangular sharp-peaked weirs with high exactness and we can utilize this product for decide the release coefficient on contracted-compound weirs. Relative mistake of Cd for different upsides of the round circular segment stature; doesn't have a certain proportion and by lessening the overall mistake of water profundity in upstream of the weir diminishes and the other way around. Impact of channel side dividers (actual qualities of model) and exactness of test information, are among the components that reason contrasts among lab and mathematical information.

A. S. Ramamurthy et al. (1997) shows move through a two-dimensional sharp-edged weir arranged toward the finish of a flat rectangular line, trial tests were gotten as for speed and pressing factor dispersion in the district of the nappe close to the weir peak and the pressing factor appropriation on the weir side. The overall connection between the Cd-weir discharge coefficient and boundary H/W (or W/H) is controlled through the force rule based on exploratory discoveries and nonexclusive hypothetical presumptions. The current trial discoveries affirmed that the weir release coefficient was recommended.

R. E. Baddour (2008) shows that polynomial weirs can be utilized to create an assortment of head-removal exercises including the relative (straight) qualities of the Sutro weir in horticultural and civil designing exercises. The accompanying note depicts a framework where sharp peaked weirs with openings characterized by n polynoms of any request are resolved in head-release conditions. Models are given of the activities of the fourth request polynomial weirs.

Sadiq S. Muhsun; Abdul-Sahib T; Al-Madhhachi ,Zainab T; Al-Sharify (2020), The destinations of this exploration are; to determine an appropriate peak profundity position as control segment for assessing the flowrate(Q) over a bended crump-weir at ten distinctive longitudinal inclines and to look at the proposed flowrate(Q) via estimated and computational liquid elements (CFD)-reproduced flowrates. In this exploration, the peak point of the bended crump weir was viewed as a control area, identifying with the basic profundity as an element of the peak profundity. Tests with eight distinctive lab flowrates of flume were proposed at ten diverse channel inclines going from 0.0 to 2.5%. Measurable examination of straight relapse demonstrated that the connection between basic profundity and peak profundity is 0.913 overall. In view of this tracking down, another condition was determined to anticipate the release over the crump-weir, which showed an astounding match contrasted with the reasonable and C.F.D.-mimicked results (a most extreme contrasts of 4% dependent on a few standard blunder files and a single direction ANOVA). The CFD procedure was performed to recreate the speed and stream example of the bend crump weir dependent on the volume of division strategy.

Chapter 3 – Sharp Crested weirs:

3.1 General

Sharp crested weirs (or notches) are by and large used to gauge the release in little open-channels where precision is required. Since such weirs can be precise to ±2% or even ±l %, they are frequently utilized as estimating gadgets in water power labs, however they additionally have commonsense application. For example, the drainage through dam might be estimated by diverting it over sharp-peaked weir. Since the weirs do have slight, sharp peaks they are not appropriate for estimating the release in huge streams where they would be inclined to harm by the effect of skimming flotsam and jetsam. Substantial designs like the wide peaked weir are utilized for this, & they work on a very surprising standard from those depicted here. The two sorts of weir ought not to be befuddled.

A sharp-crested weir is generally shaped from a sheet of metal, which won't rust. A score is then removed of the plate, the state of which characterizes the calculation of the weir.

Normal shapes for the sharp-peaked weirs (are rectangular, three-sided and another shape is trapezoidal viz. (Cipolletti Weir)). The weir should have a precisely completed square up-stream edge, a peak width of under 2mm, with an angle on the down-stream boundary. With delayed utilize the peak may get worn and adjusted, and this can unfavorably influence the precision.

The weir plate should be introduced with the up-stream face vertical. Ordinarily the length of the weir peak is not exactly the width of the channel ($b < B$) thus, in arrangement, the stream needs to agreement to go through it. Essentially, the peak is typically set over the lower part of channel, so the smoothe out need to rise up-wards to disregard the weir. The peak, or ledge, of the weir must be sufficiently high for the water to fall unreservedly into the downstream channel, with the goal that the stream over the main weir isn't influenced by the down-stream water level. The water streaming over the peak, that is the ‘nappe’, should spring clear of the flow down-stream essence of the weir plate. This is mainly the 'free' condition where both the upper & lower surfaces of the nappe are presented to the air. This empowers an advantageous expectation to be made, that is the pressing factor conveyance all through the nappe is near barometrical.

Assuming the sort of weir plate in graph beneath is utilized, the free condition should exist normally at everything except the littlest of releases. In any case, the weir peak traverses the full width(b) of current channel with the goal that; b = B, this is known as the stifled condition. Then this boosts the release over weir for a specific channel breadth, which might be alluring in certain conditions, yet implies that the air under the nappe is currently caught. Step by step the air gets entrained in the outgoing nappe and is out of control. This leaves air at low pressing factor under the nappe, which empowers the back-water to further rise. At the point when, most or the entirety of the atm. air has been eliminated, the nappe falls and holds fast to the essence of the weir plate, shaping a sticking nappe (as in graph 3 beneath).

This is bothersome in light of the fact that the weir won't work as a precise estimating gadget like this. To forestall the arrangement of a sticking nappe with the stifled condition, it is important to give an air vent or line to concede air to under-side of the nappe.

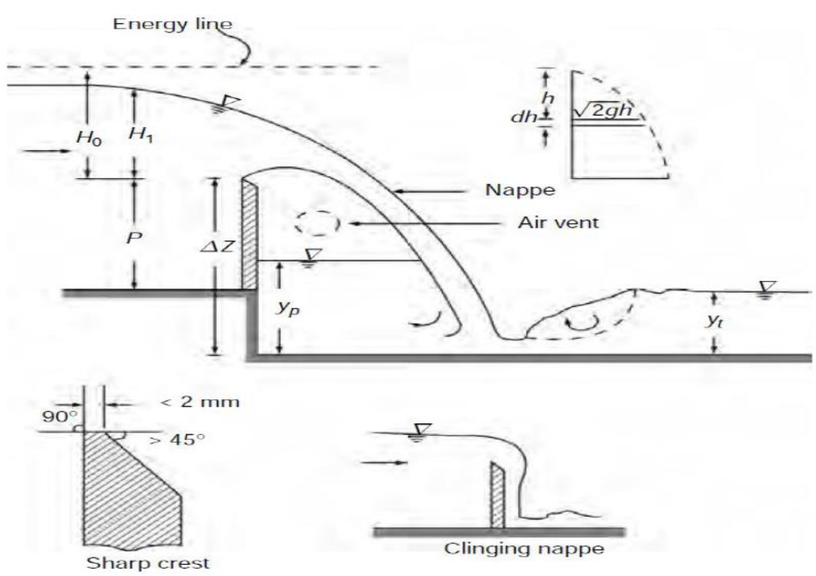


Figure 3.1.1. Definition sketch of a sharp crested weir

3.2 Triangular Weir

The three-sided thin plates weir is widely utilized for estimating stream of water in flumes and in open channels. The plan of weir is straightforward and can without much of a stretch produced using promptly accessible materials, economical, advantageous to utilize and simple to keep up. Three-sided weir is more attractive due to the more noteworthy adaptability in low streams and a decreased powerlessness to the engendering of the channel design and speed of various kinds of weir or flume. Three-sided dainty plate wear is a moderately precise instrument, since it produces sufficient information over a scope of streams and is planned, introduced and used with sensible consideration.

The examination was done on a three-sided sharp-peaked weir with a point of peak of 90o and a stature of 8 cm. Earlier the same set up was done experimentally in the laboratory and we had all the data including that of geometry. Same was applied in CFD to validate the results of the experiment.

$$Q = \frac{8}{15} C_d \sqrt{2g} \times \tan\frac{\theta}{2} \times H^{5/2}$$

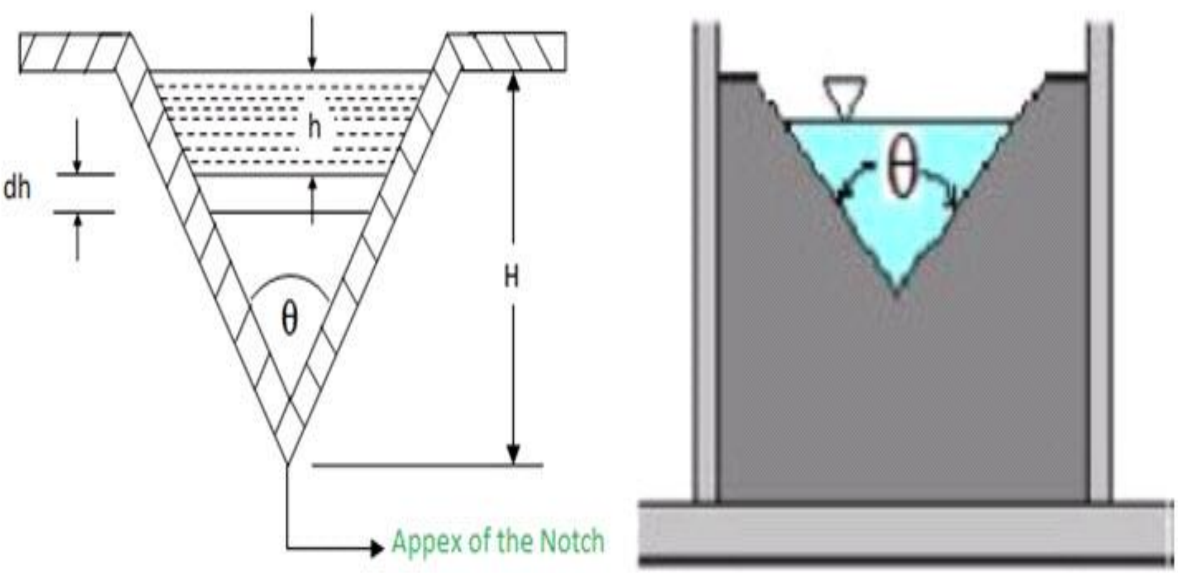


Figure 3.2.1. Triangular weir

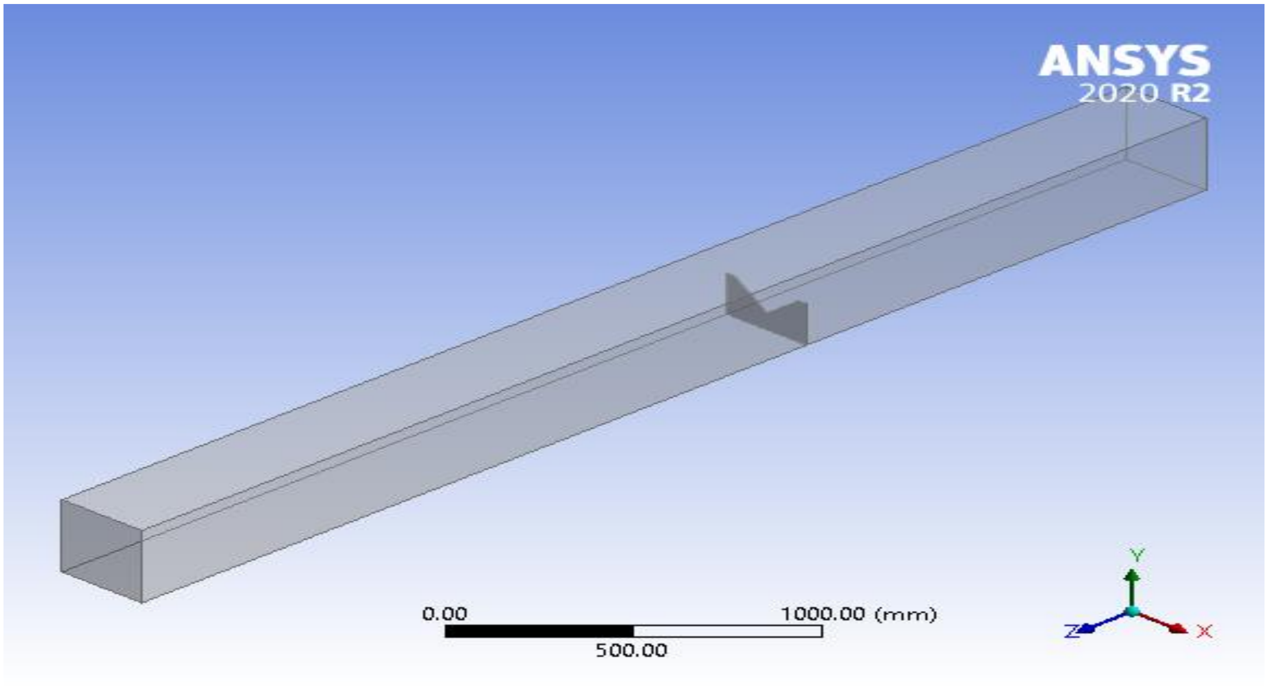


Figure 3.2.2 90º Triangular weir set up in a rectangular flume

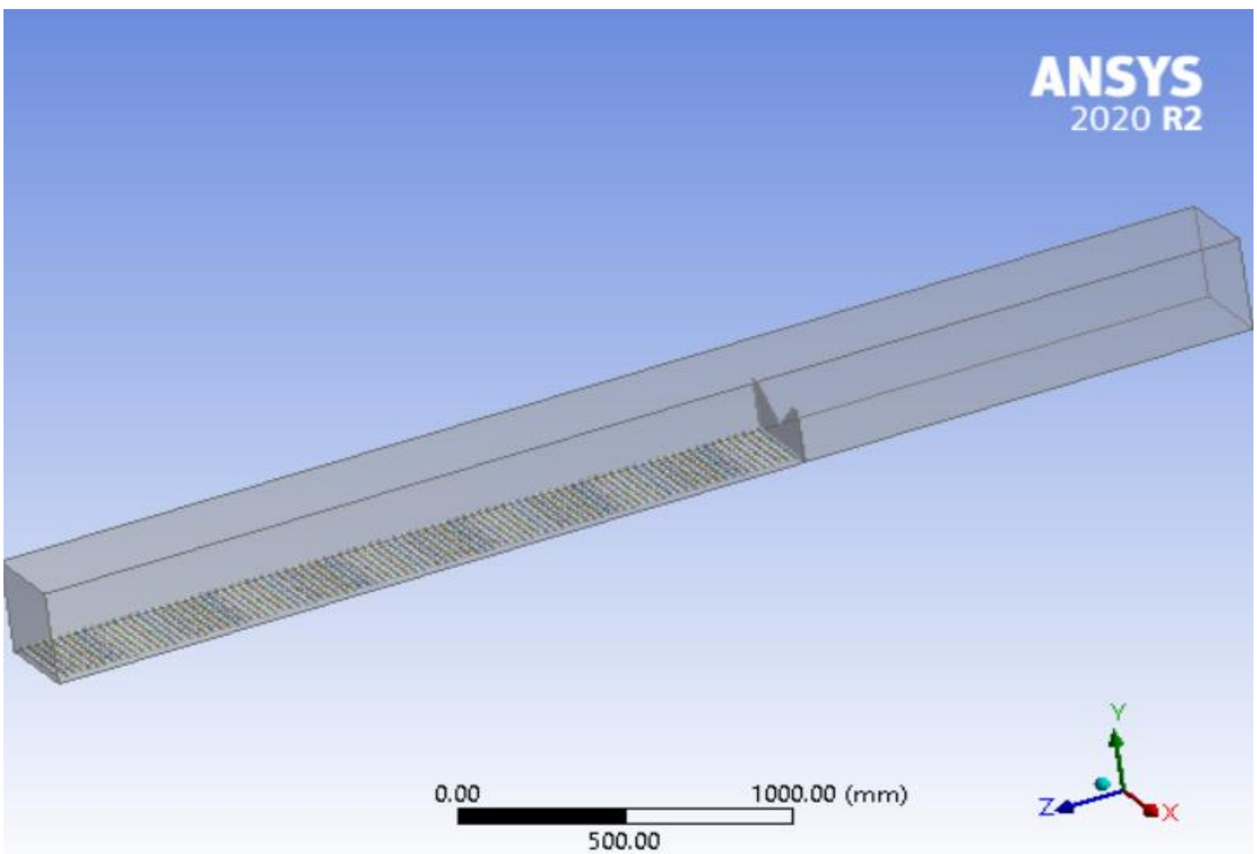


Figure 3.2.3 90º Triangular weir set up in a rectangular flume for plane gravel bed

4. METHODOLOGY

4.1 General

The research was performed on Ansys Fluent software for a Tilting Flume. Simulations were performed over a 4 m long and 30 cm wide tilting flume, using a triangular weir pattern. Earlier in 2019, same setup was analyzed experimentally in the laboratory lab of Delhi Technological University. Replica of the same model is used for CFD analysis and the results obtained from experiment were analyzed with the results obtained from CFD configuration and simulation.

In the prior experiment sediment analysis was also done. In this research work we would be doing CFD computation for clear flow and with plane gravel bed using VOF modelling. With the DPM injection method we would be tracking done the particles along their path.

Same model would be set up in 2 Dimensional frame and would be analyzed with the help of Eulerian approach and how the sand particles disperse with the given provided velocity.

The weir was placed at 2.5m distance from inlet and clear water was allowed to pass over the notch at different flow rate for the computation. The calculation of discharge coefficients(cd) at multiple channel slopes ranging from adverse to positive slope (-0.5% to 4.0%) at an interval of 0.5%, were done and compared with the already available results from experimental method. The velocity profile of the individual discharge at each slope was calculated at an interval of 1 cm with the tools and XY plot provided in the fluent.

4.2 Volume of Fluid

The volume of fluid strategy addresses a Robust technique for following the air-water interface, and offers a few choices for recreating the interface with exactness while saving the partial volume of liquid. Nonetheless, VOF rapidly becomes bulky when it is important to figure the arch of the interface or some other smooth properties. Besides, the definition of VOF in three space measurements takes after more the lines in a PC code than a thorough numerical strategy. At long last, albeit the small amount of liquid volume in a computational cell has all the earmarks of being a sound actual property of the issue, it is really a mathematical antiquity that is advected like some other scalar variable by the liquid.

For this research work, Volume of Fluid multiphase model was used. Where air was the primary phase and Water being the secondary phase. For the Global setting, Surface tension force modelling was done with Surface tension force coefficient equals to 0.072 n/m.

The VOF sub-models being Open channel flow with Open channel wave BC.

In the Volume of Fluid strategy, the free surface is treated by presenting a work f(xyy,t) that is characterized to be solidarity anytime involved by the liquid and zero somewhere else. At the point when found the middle value of over a cell of the computating network, ftJ is the fragmentary volume of the cell ij involved by liquid. Accordingly, if ftJ=l the cell ij is loaded with liquid, and if fjj=0 the cell ij is vacant of liquid. At the point when 0<flJ<l the cell ij is incompletely loaded up with liquid , in this way it contains the interface.

In the V.O.F, methodology, if the flowing fluid is assumed to be in incompressible state, the volume fraction (Ck) is evolved by the following advection equation

$\partial Ck\ \partial t + \nabla\cdot(Cku) = 0$

and mass + momentum conservation are defined as

$\nabla\cdot u = 0,$

$\partial(\rho u)\ \partial t + \nabla\cdot(\rho uu) = -\nabla p + \nabla\cdot(\mu(\nabla u + \nabla\ T\ u)) + F,$

where u is the velocity-field, p is the pressure, F is any body force, ρ & μ are the fluid density & viscosity, respectively, evaluated as following

$\rho = \sum k\ \rho kCk$ and $\mu = \sum k\ \mu kCk$; subscript k refers to fluid, k.

4.3 Navier-stokes equation

The ‘Navier-Stokes equations’ consists of a time-dependent continuity equation* for the conservation of mass, three time dependent conservation of momentum equation and a time dependent conservation of energy equations.

Incompressible form of ‘Navier-Stokes Equations’ in Cartisian Coordinates.

The momentum conservation equations in the x,y and z directions are as follows;

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+\rho g_x$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+\rho g_y$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+\rho g_z$$

The ‘conservation of mass’ equation;

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

Compressible Form of Navier-Stokes Equations;; The conservation of mass equation-

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

4.4 Explicit Vs Implicit Numerical Methods

In computational fluid dynamics, the administering conditions are nonlinear, and the quantity of obscure factors is commonly exceptionally huge. Under these conditions verifiably planned conditions are quite often addressed utilizing iterative methods.

Cycles are utilized to propel an answer through a grouping of steps from a beginning state to a last, combined state. This is genuine whether the arrangement looked for is it is possible that one stage in a transient issue or a last consistent state result. Regardless, the cycle steps look like a period like interaction. Obviously, the cycle steps generally don't compare to a sensible time-subordinate conduct. Indeed, it is this part of a certain strategy that makes it alluring for consistent state calculations, on the grounds that the quantity of cycles needed for an answer is frequently a lot more modest than the quantity of time steps required for an exact transient that asymptotically moves toward consistent conditions.

> An explicit arrangement result from a technique that is free of multiple qualities (for a similar level), a solitary condition being utilized to assess new nodal factors for solitary time frame step.

> An implicit arrangement contains data obtained from settling synchronous conditions for the full framework for each single time step. This is computationally seriously requested however takes into account bigger time steps and better solidness.

For our research work we have taken Implicit formulation with active implicit body force. And the number of Eulerian phases being 2.

4.5 Set of Equations (turbulence model)

K-epsilon (k-ε) turbulence model is an express arrangement results from a technique that is free of many different qualities (for a similar level), a solitary condition is utilized to assess new nodal factors for a singly time frame step.

A verifiable arrangement contain data accumulated from settling synchronous condition for the full framework for each time step. This is computationally seriously requesting however takes into account bigger time steps and better solidness. Unlike in the earlier turbulence models, k-ε model focuses on the mechanism that affect the turbulent kinetic energy(K.E.) .

The specific k-ε conditions contain numerous obscure and immense terms. For a significantly more reasonable methodology, the standard k-ε disturbance model (Launder and Spalding, 1974[3]) is utilized which depends on our best comprehension of the important cycles, hence limiting questions and introducing a bunch of conditions which can be applied to countless fierce applications.

For turbulent kinetic energy k

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho k u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_j}\right] + 2\mu_t E_{ij}E_{ij} - \rho\varepsilon$$

For dissipation ε

$$\frac{\partial(\rho\varepsilon)}{\partial t} + \frac{\partial(\rho\varepsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\frac{\mu_t}{\sigma_\varepsilon}\frac{\partial\varepsilon}{\partial x_j}\right] + C_{1\varepsilon}\frac{\varepsilon}{k}2\mu_t E_{ij}E_{ij} - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}$$

u_i represents the velocity component in our corresponding direction

E_{ij} represents the component of rate of the deformation

μ_t represents the eddy viscosity ; $\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$

And $C_\mu = 0.09 \qquad \sigma_k = 1.00 \qquad \sigma_\varepsilon = 1.30 \qquad C_{1\varepsilon} = 1.44 \qquad C_{2\varepsilon} = 1.92$

4.6 Eulerian model

The Eulerian multi-phase model in ansys fluent tool takes into consideration the displaying of different independent, yet: communicating stages. The stages can be - fluids, gases, or solids in almost any blend(form). An Eulerian treatment is utilized for each stage, as opposed to the 'Eulerian-Lagrangian' treatment that is utilized for the main discrete stage model.

With the Eulerian multi-phase model, the quantity of optional stages is restricted exclusive by memory necessities & combination conduct. Quite some auxiliary stage can be demonstrated, given that the adequate memory is further accessible. For the complex multi-phase streams, in any case, we may find that our answer is strictly restricted by union conduct.

Ansys fluent's Eulerian multi-phase model doesn't recognize liquid and liquid strong (granular) multiphase streams. A granular stream is essentially one that further includes at any rate one stage that has been assigned for a granular stage.

The ansys fluent arrangement depends on the accompanying:

--A solitary pressing factor is shared by all stages.

--Force and progression conditions are settled for each stage.

--The accompanying boundaries are accessible for granular stages:

Granular temperature (solids fluctuating energy) can be determined for every strong stage. You can choose either a mathematical definition, a consistent, a client characterized work, or a fractional differential condition.

Strong stage shear and mass viscosities are gotten by applying motor hypothesis to granular streams. Frictional consistency for displaying granular stream is likewise accessible. You can choose suitable models and client characterized capacities for all properties.

A few interphase drag coefficient capacities are accessible, which are proper for different sorts of multiphase systems.

We would be using Eulerian model with two phases. While the water would be the primary phase, sand would be added through the patch technique as a secondary phase.

4.7 Finite Volume method

Finite volume method (FVM) can be utilized on all differential conditions, which can be written in the uniqueness structure. This viably composes the condition utilizing dissimilarity administrators. The condition is then coordinated over the volume. We would then be able to apply Gauss' hypothesis changing over the volume essential over the difference into a surface necessary across the limits. The necessary is along these lines abandoned coordinating the differential of the reliant variable within the cells into surface integrals of the motions of the reliant variable across the limit of the cells. These integrals can generally be determined utilizing appropriate mathematical estimation strategies. This improves on the differential condition significantly.

4.8 Mesh and Setup

Making the most proper mesh is the establishment of designing recreations. The cross section impacts the exactness, intermingling, and speed of the reproduction. PCs can't settle reproductions on the CAD model's real calculation shape as the overseeing conditions can't be applied to a self-assertive shape. Mesh components permit administering conditions to be settled on typically formed and numerically characterized volumes. Regularly, the conditions tackled on these cross sections are incomplete differential conditions. Because of the iterative idea of these estimations, acquiring an answer for these conditions isn't reasonable by hand, thus computational strategies like Computational Fluid Dynamics (CFD) are utilized.

With the element order (triangular) size 1.45e-0.002 m, and skewness being at 0.90 numbers of elements came out to be 496031 with a good inflation across the boundaries.

Further in the setup, different inlet and outlet conditions were analyzed with set of head provided and average flow velocity was calculated at 10 cm interval from the inlet. Also the crest level head was analyzed for the calculation purposes. The discharge was once calculated with eproduct of velocity head and width of the channel and once with the ideal formula for the triangular notch and thus coefficient of discharge was calculated.

4.9 Discrete Phase modelling (DPM injection)

A discrete phase model (DPM) is utilized when the point is to explore the conduct of the particles from a Lagrangian see and a discrete viewpoint. Indeed, the distinction between the Lagrangian and the Eulerian see is that liquid conduct in Lagrangian see is analyzed based on a molecule following of a molecule of liquid stream; Whereas liquid conduct is considered in Eulerian see dependent with the understanding of a limited volume component in the liquid stream way.

In the event that the conduct of discrete particles within the sight of a nonstop stream field is influenced by constant stream, the cooperation with the consistent stage should be actuated. Additionally, if the molecule following is generally temperamental after some time, the shaky molecule following choice should be enacted. The discrete stage can be applied in different actual structures, the sort of which relies upon the issue model. One of the actual characterizing modes is the two-way fierce coupling mode, which is utilized to contemplate the impacts of changes in the violent amounts brought about by molecule damping and Eddy disturbance.

In this research work we would be dealing with the erosion state of particles at the bottom of the surface and for how long they can travel upto the weir and also how many the pass through the triangular notch.

Soil particles of size 20 microns, 50 microns, 100 microns, 150 microns and 200 microns were injected with varied velocity and their erosion rate with particle residence time was found.

Chapter 5- Results and conclusions

5.1 Results

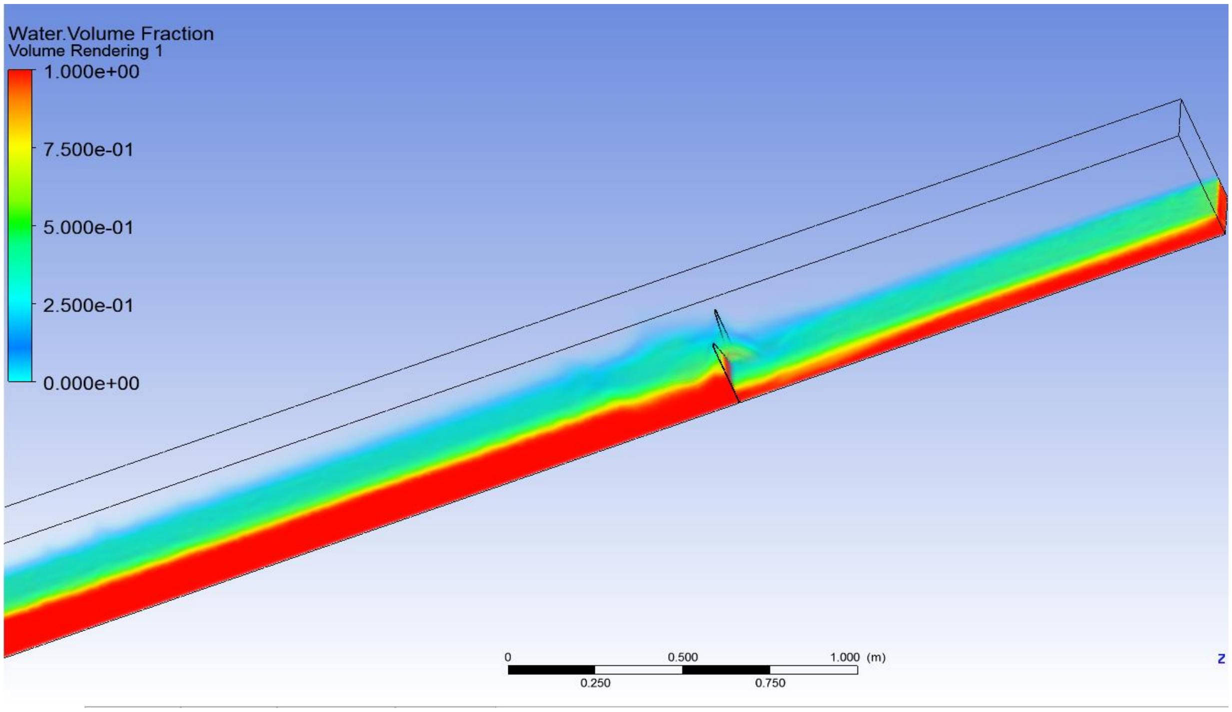


Figure 5.1.1 Volume rendering of water fraction

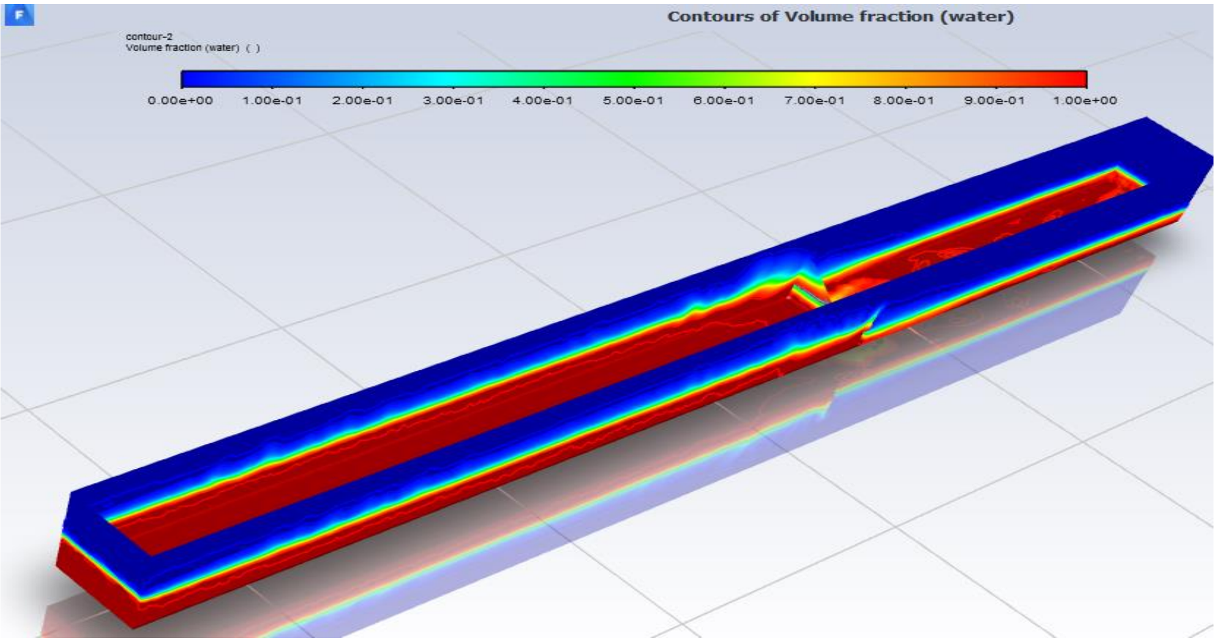


Figure 5.1.2 Contours of water volume fraction

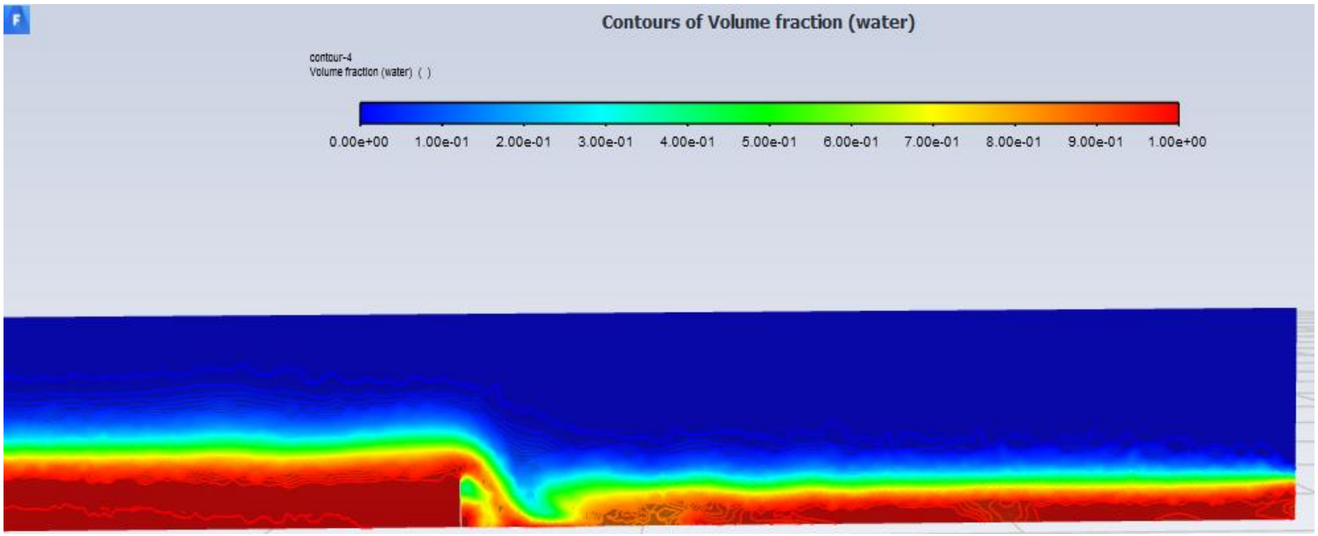


Figure 5.1.3 Contours of the water volume fraction at the notch point in YZ plane

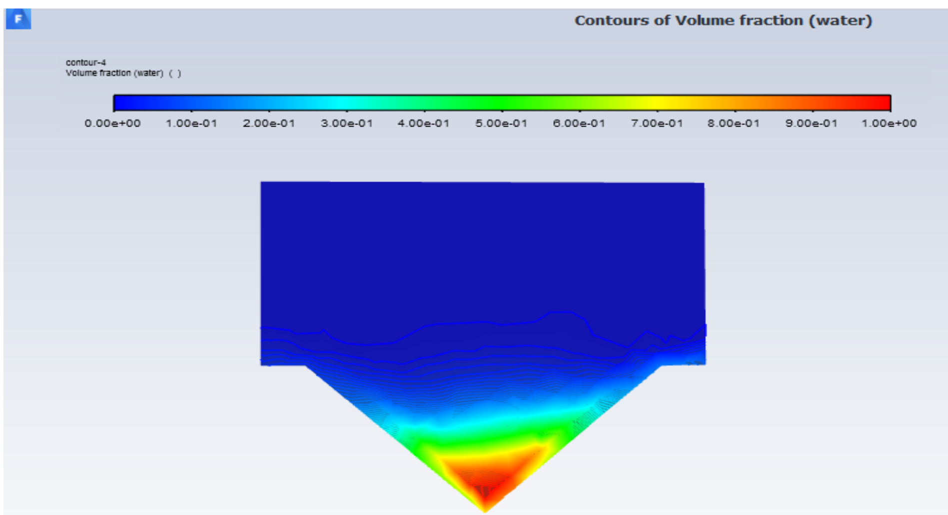


Figure 5.1.4 Contours of water Volume fraction at the notch and at the upstream in XY plane

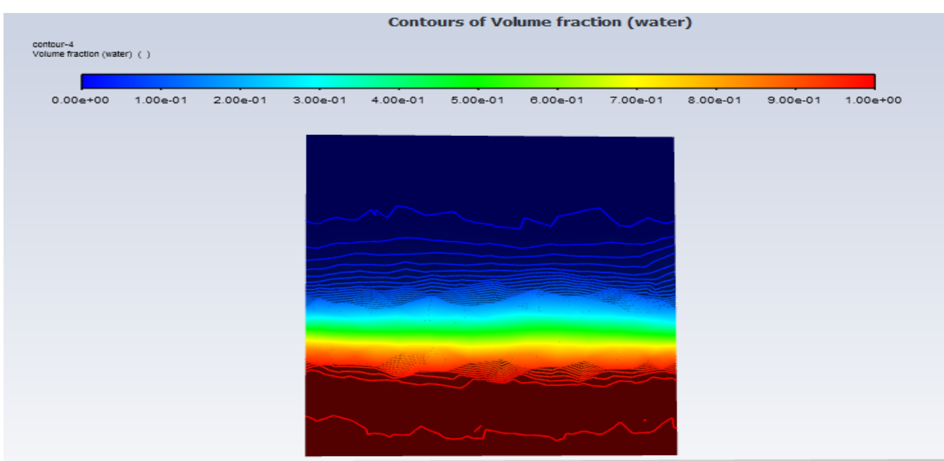


Table 5.1.1 Coefficient of Discharge for Triangular weir with clear flow

Channel slope (%)	Head (m)	Experimental Cd	Average	Numerical Cd	Average	/% Error/
-0.5	0.119	0.563	0.603	0.521	0.590	2.16
	0.125	0.591		0.559		
	0.130	0.606		0.567		
	0.138	0.627		0.648		
	0.145	0.629		0.655		
0	0.128	0.503	0.549	0.551	0.543	1.1
	0.133	0.523		0.564		
	0.137	0.545		0.502		
	0.144	0.571		0.513		
	0.155	0.604		0.589		
+0.5	0.120	0.529	0.574	0.561	0.592	3.2
	0.126	0.559		0.574		
	0.131	0.576		0.581		
	0.139	0.600		0.627		
	0.149	0.609		0.613		
+1	0.119	0.563	0.624	0.619	0.631	1.2
	0.128	0.586		0.621		
	0.134	0.624		0.583		
	0.137	0.654		0.621		
	0.141	0.690		0.712		
+1.5	0.106	0.582	0.680	0.574	0.665	2.3
	0.117	0.642		0.599		
	0.119	0.704		0.682		
	0.127	0.707		0.728		
	0.137	0.763		0.742		

Channel Slope (%)	Head (m)	Experimental Cd	Average	Numerical Cd	Average	/% Error/
+2.0	0.128	0.670	0.723	0.683	0.731	1.2
	0.131	0.720		0.749		
	0.138	0.731		0.713		
	0.141	0.736		0.702		
	0.151	0.756		0.799		
+2.5	0.123	0.662	0.749	0.682	0.771	3.0
	0.126	0.746		0.781		
	0.130	0.757		0.762		
	0.133	0.785		0.810		
	0.136	0.798		0.818		
+3.0	0.115	0.738	0.765	0.756	0.799	4.4
	0.126	0.746		0.766		
	0.130	0.757		0.814		
	0.133	0.785		0.836		
	0.139	0.800		0.820		
+3.5	0.127	0.707	0.754	0.672	0.762	1.7
	0.131	0.720		0.755		
	0.138	0.731		0.792		
	0.142	0.795		0.810		
	0.144	0.816		0.782		
+4.0	0.132	0.686	0.743	0.699	0.731	1.7
	0.135	0.715		0.683		
	0.141	0.736		0.719		
	0.143	0.764		0.726		
	0.149	0.812		0.831		

Table 5.1.2 Point Velocities just weir Upstream for triangular weir

Depth (cm)	Point velocities (cm/s) at channel slope (%)									
	0.0		1.0		2.0		3.0		4.0	
	Exp.	Num.	Exp.	Num.	Exp.	Num.	Exp.	Num.	Exp.	Num.
6	7.47	8.50	8.30	8.95	9.27	9.02	10.43	11.63	11.61	13.02
7	8.70	9.62	8.90	9.91	10.65	9.96	11.71	12.90	12.77	13.90
8	9.66	9.96	10.79	11.21	11.78	12.65	12.77	13.92	13.8	14.70
9	10.59	10.90	11.67	12.99	12.77	13.20	13.89	15.56	14.88	15.93
10	11.41	11.88	12.68	13.56	13.78	14.89	14.78	16.78	15.79	16.96
11	12.19	12.92	13.59	14.98	14.59	16.35	15.63	16.92	16.78	17.92
12	13.18	13.64	14.42	15.62	15.48	16.90	16.52	17.67	17.70	19.45
13	14.22	14.59	15.43	16.78	16.58	18.20	17.57	18.98	18.57	21.20
14	15.42	15.62	16.91	18.01	17.89	19.50	18.79	19.78	19.89	22.14

Table 5.1.3 Point velocities at mid-channel for Triangular weir

Depth (cm)	Point velocities (cm/s) at channel slope (%)									
	0.0		1.0		2.0		3.0		4.0	
	Exp.	Num.	Exp.	Num.	Exp.	Num.	Exp.	Num.	Exp.	Num.
6	8.46	7.20	9.21	10.21	10.16	12.80	11.24	13.45	12.43	14.50
7	9.26	8.59	10.13	11.42	11.15	12.98	12.47	13.90	13.67	13.99
8	9.98	11.23	10.87	12.87	11.89	13.45	13.41	14.87	14.78	15.23
9	10.71	12.45	11.59	14.12	12.61	14.97	14.21	15.46	15.58	16.12
10	11.28	12.62	12.08	14.93	13.22	15.23	14.59	15.96	16.22	16.78
11	11.48	13.49	12.31	15.62	13.38	16.31	14.64	16.91	16.33	17.33
12	11.32	13.20	12.17	15.37	13.35	15.90	14.54	16.78	16.11	16.99
13	11.00	12.96	11.98	13.99	13.02	13.65	14.33	15.12	15.69	15.66
14	10.34	12.49	11.56	13.20	12.62	13.31	13.93	14.73	15.00	15.36

Table 5.1.4 Coefficient of Discharge for Triangular weir with plane gravel bed

Channel slope (%)	Head (m)	Experimental Cd	Average	Numerical Cd	Average	/% Error/
-0.5	0.1277	0.580	0.580	0.607	0.6026	3.9
	0.1395	0.576		0.586		
	0.1471	0.619		0.636		
	0.1557	0.550		0.582		
	0.1617	0.573		0.602		
0	0.1312	0.479	0.523	0.508	0.5524	5.6
	0.1347	0.554		0.581		
	0.1560	0.524		0.571		
	0.1656	0.545		0.562		
	0.1737	0.509		0.540		
0.5	0.1417	0.582	0.541	0.623	0.5706	5.5
	0.1560	0.534		0.574		
	0.1642	0.501		0.543		
	0.1727	0.520		0.531		
	0.1797	0.561		0.582		
1.0	0.1404	0.573	0.581	0.606	0.6100	4.99
	0.1456	0.570		0.612		
	0.1547	0.599		0.592		
	0.1624	0.617		0.634		
	0.1801	0.548		0.582		

Table 5.1.5 Point velocities at just weir upstream for Triangular weir with plane gravel bed

Depth (cm)	Point velocities (cm/s) at channel slope (%)			
	0.0		1.0	
	Exp.	Num.	Exp.	Num.
6	5.46	8.95	6.31	9.63
7	6.71	10.21	7.63	10.98
8	7.67	11.36	8.78	12.45
9	8.58	12.17	9.66	12.98
10	9.42	13.36	10.67	13.87
11	10.28	14.74	11.58	15.12
12	11.17	15.06	12.41	15.88
13	11.93	16.12	13.29	16.72
14	12.45	16.45	13.97	17.04

Table 5.1.6 Point velocities at mid-channel for Triangular weir with plane gravel bed

Depth (cm)	Point velocities (cm/s) at channel slope (%)			
	0.0		1.0	
	Exp.	Num.	Exp.	Num.
6	6.45	8.82	7.20	9.31
7	7.25	9.36	8.12	10.78
8	7.97	10.21	8.86	11.21
9	8.70	11.36	9.58	12.63
10	9.27	13.69	10.07	13.97
11	9.47	14.21	10.3	14.00
12	9.31	13.26	10.16	13.68
13	9.00	12.26	9.97	12.82
14	8.33	11.45	9.55	11.64

Figure. 5.1.5 Contours of Static pressure at the mid channel in XY plane

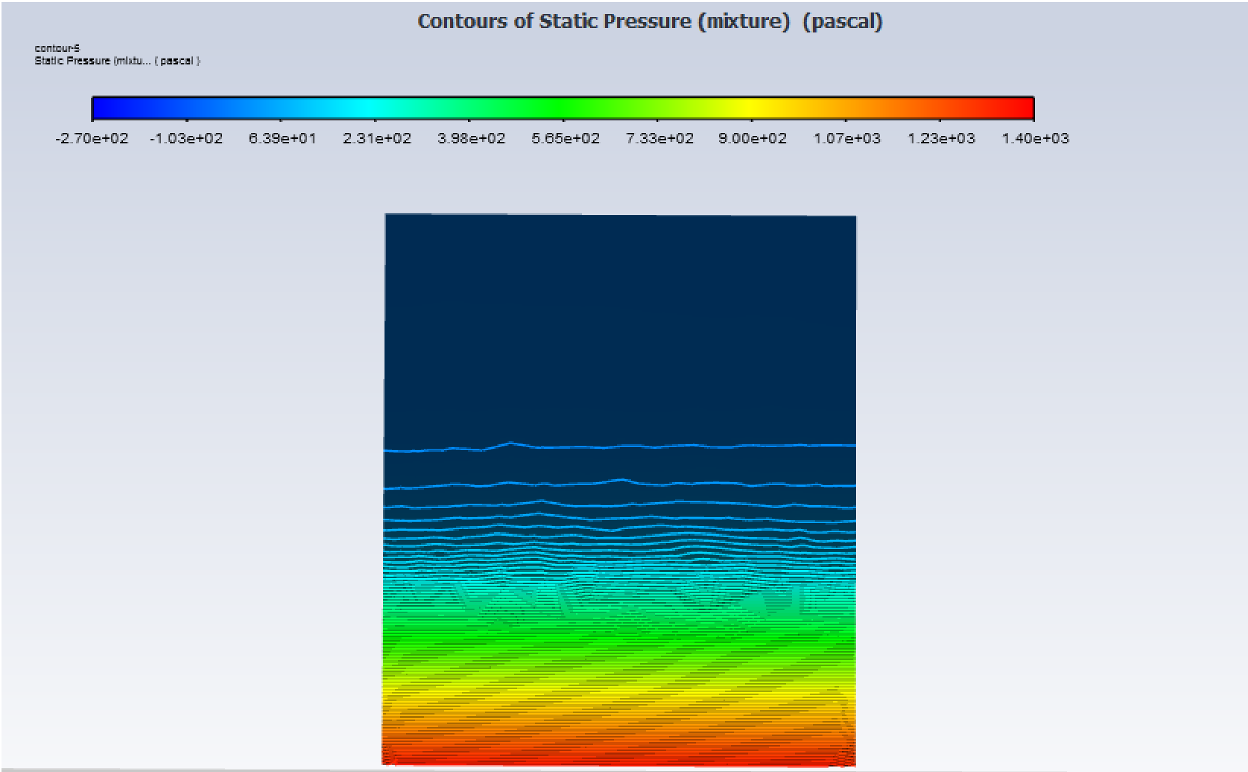


Figure. 5.1.6 Contours of Static pressure at the notch in XY plane

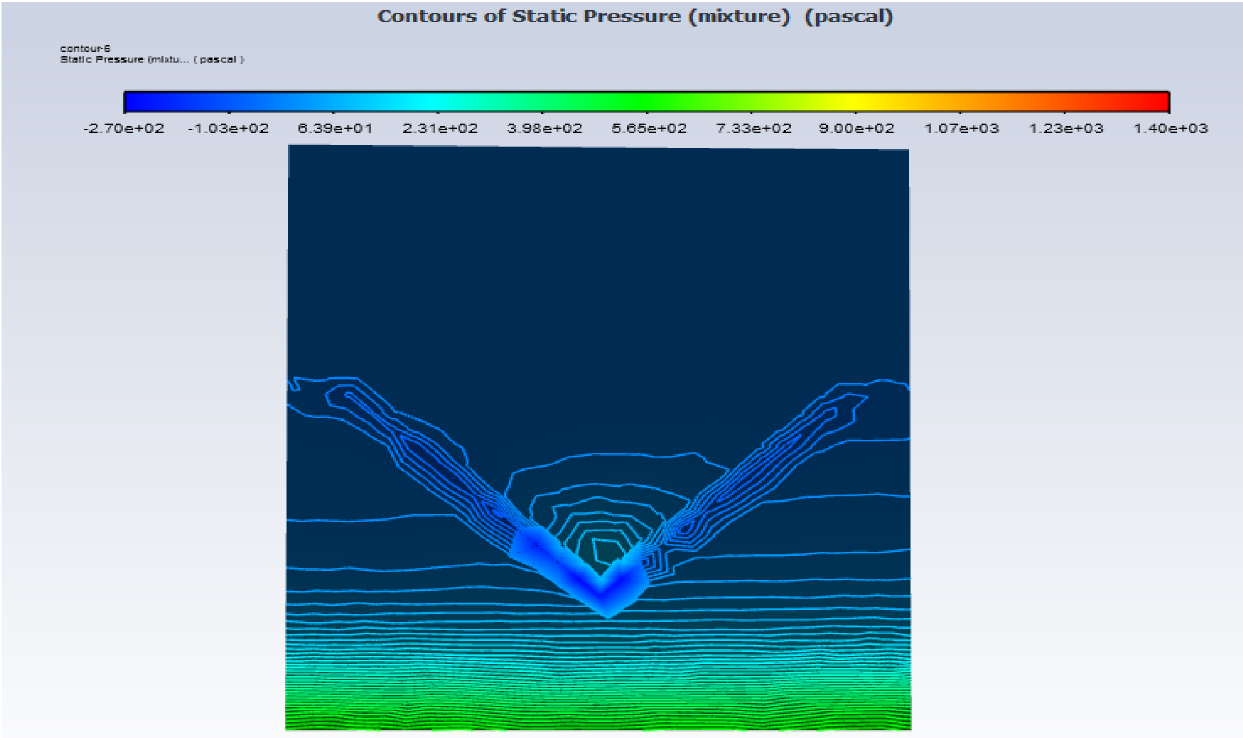


Figure 5.1.7 Variation of Cd (Coefficient of discharge) for the triangular weir.

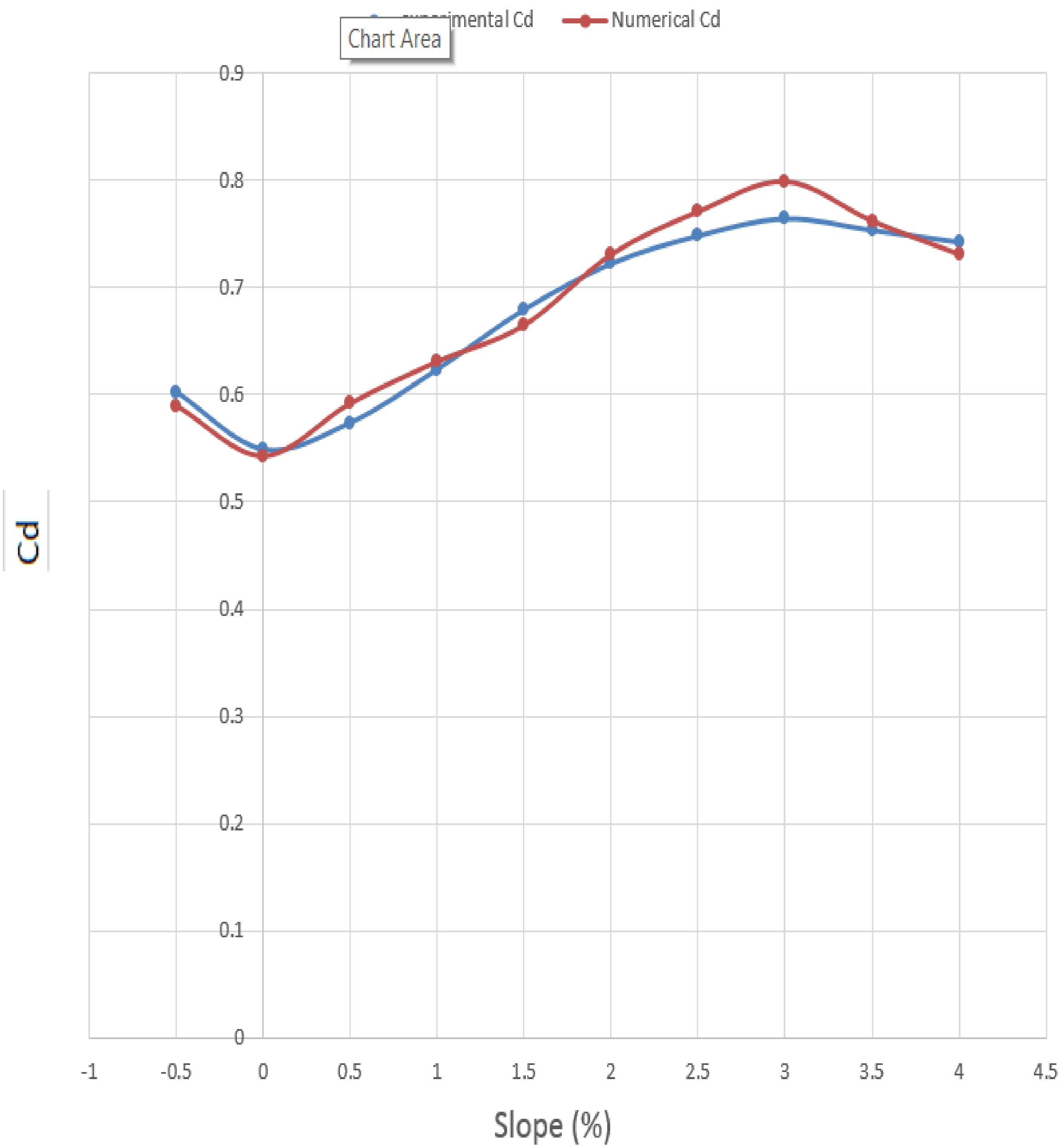


Figure 5.1.8 Variation of point Velocities just weir Upstream for triangular weir for different slopes for clear flow.

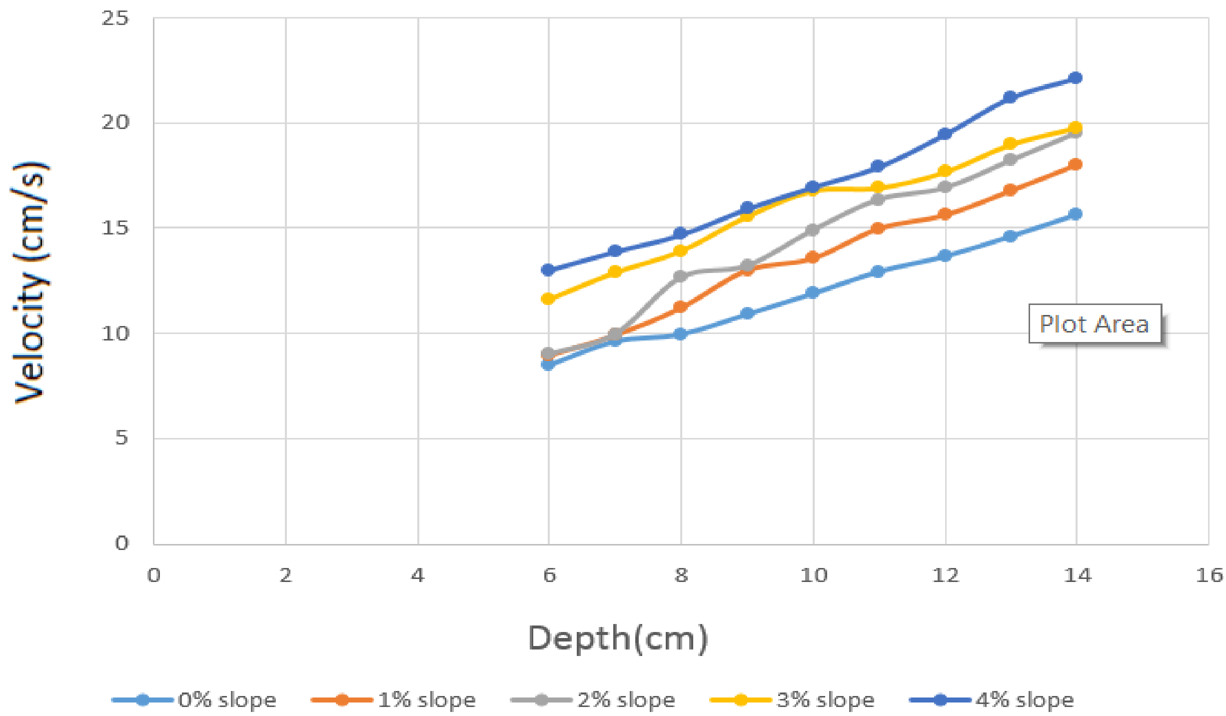


Figure. 5.1.9 Variation of point Velocities at mid channel for triangular weir for different slopes

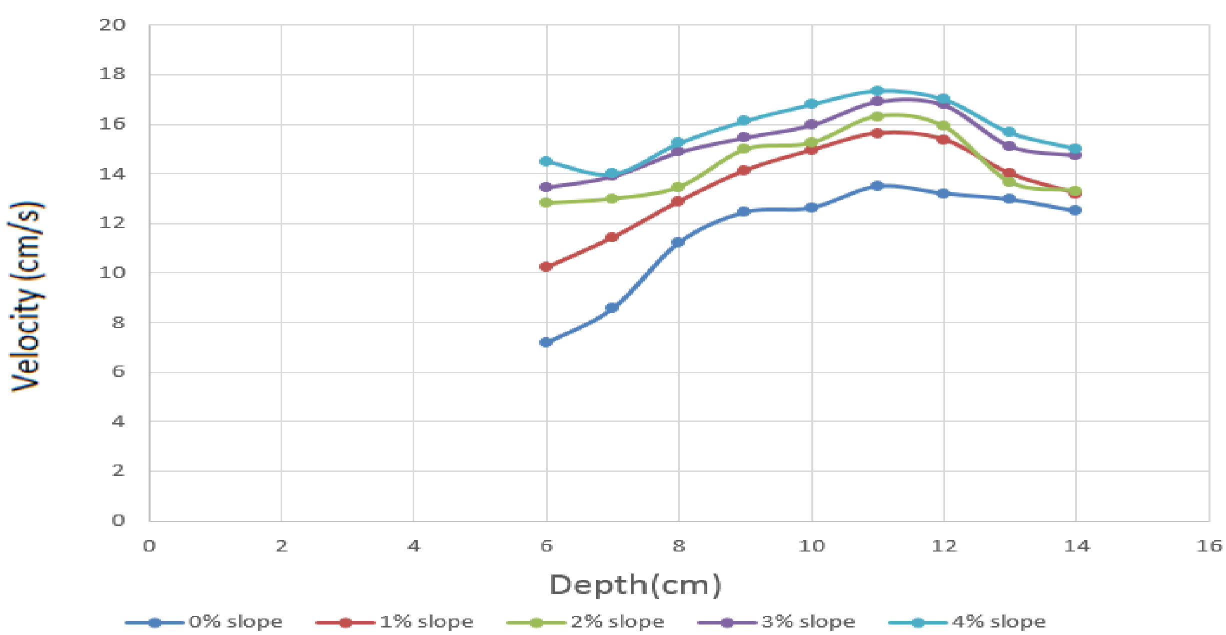


Figure 5.1.10 Variation of Cd (Coefficient of discharge) for the triangular weir with plane gravel bed.

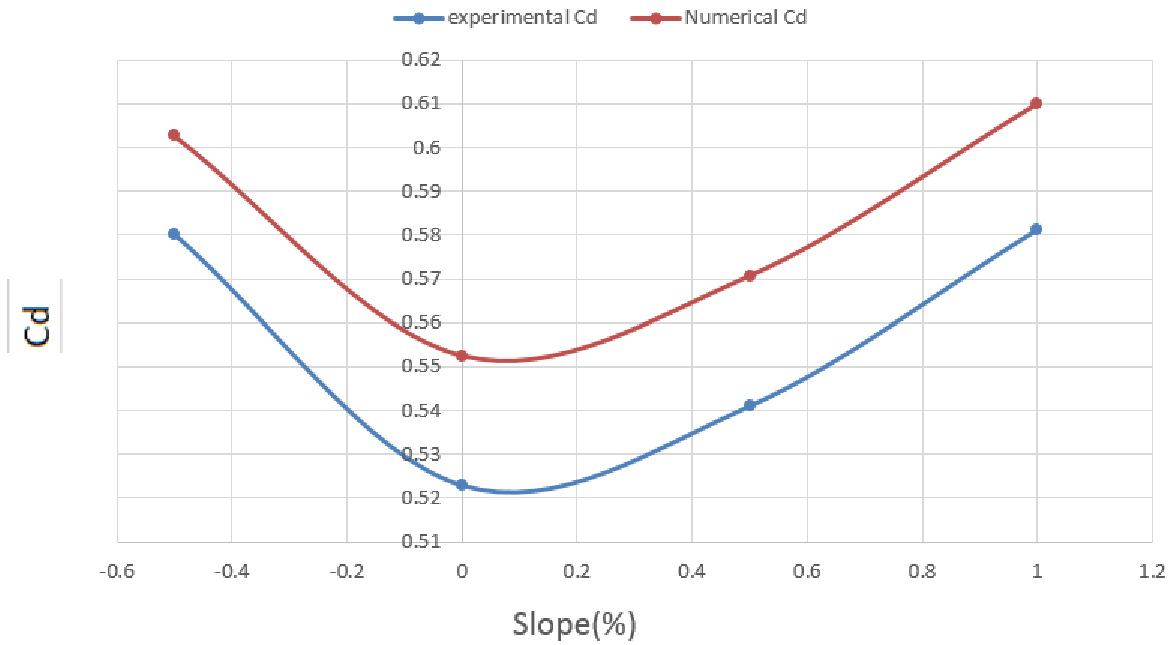


Figure 5.1.11 Variation of point Velocities just weir Upstream for triangular weir for 0% slope in a plane gravel bed.

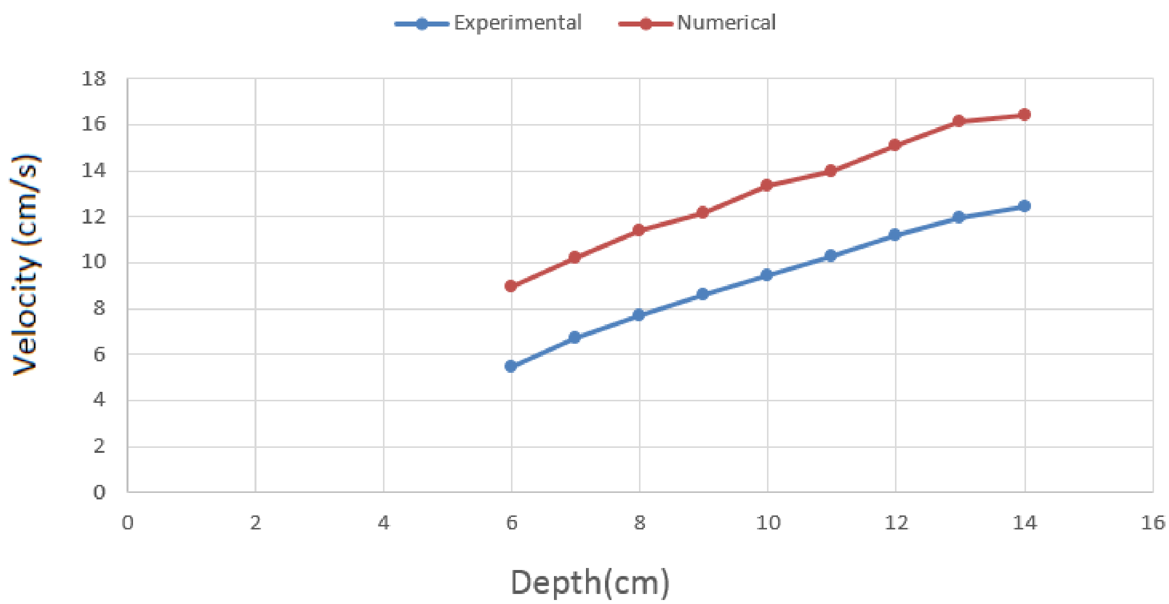


Figure. 5.1.12 Variation of point Velocities at mid channel for triangular weir for 0% slope with plane gravel bed.

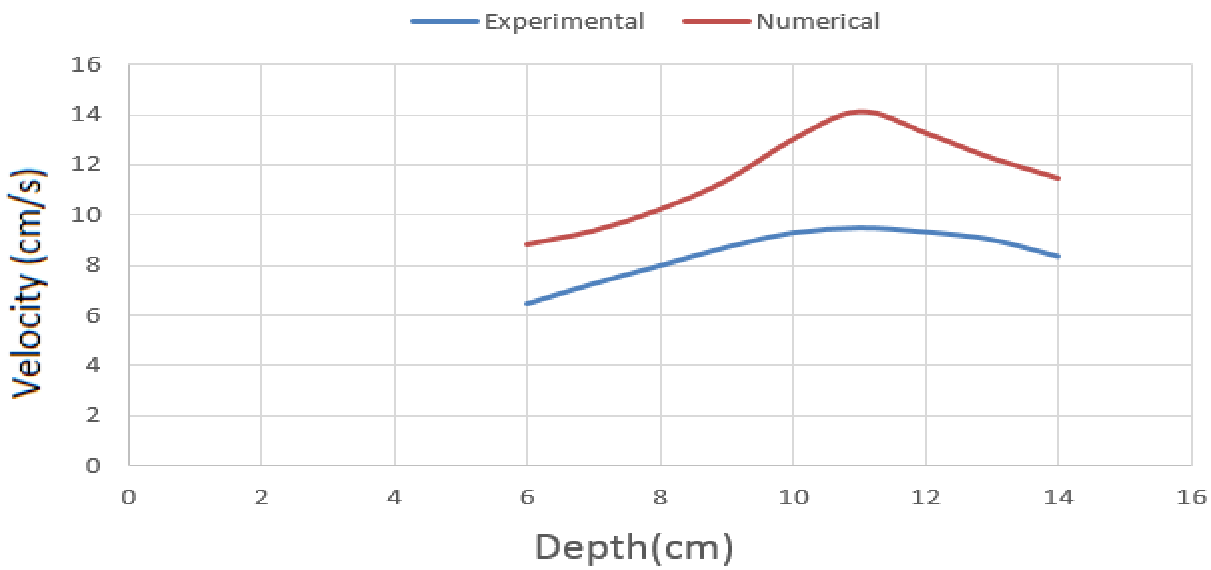


Figure. 5.1.13 Variation of point Velocities just weir Upstream for triangular weir for 1% slope in a plane gravel bed.

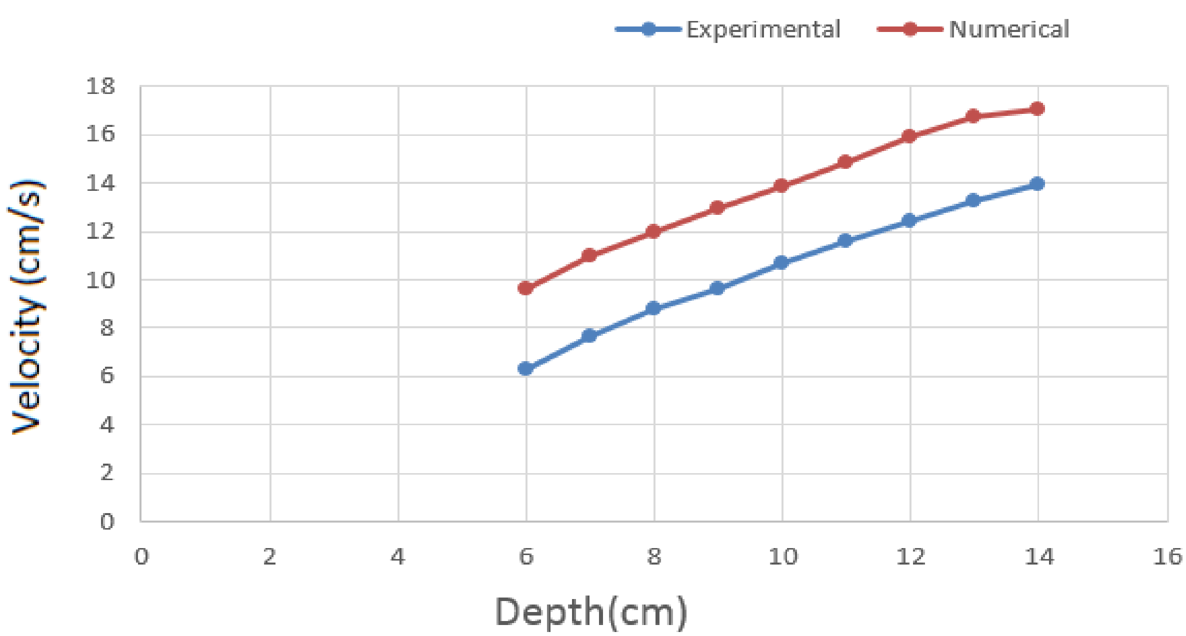


Figure 5.1.14 Variation of point Velocities at mid channel for triangular weir for 1% slope with plane gravel bed

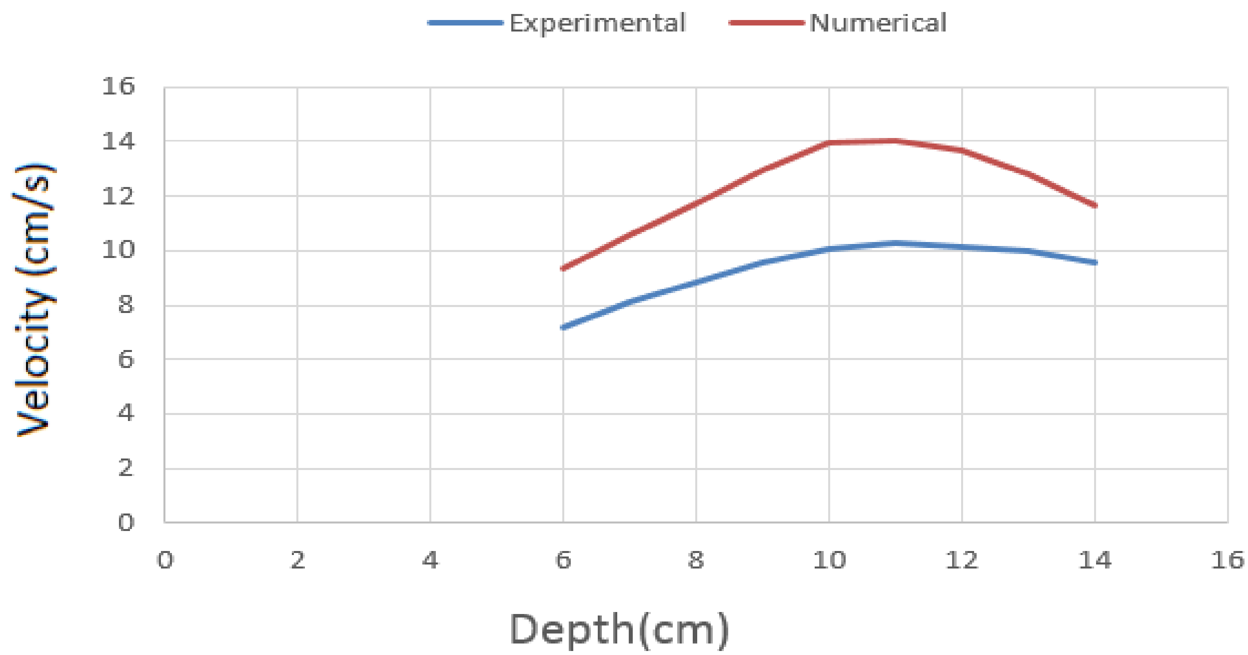


Figure 5.1.15 Contours of wall shear stress just downstream of the weir.

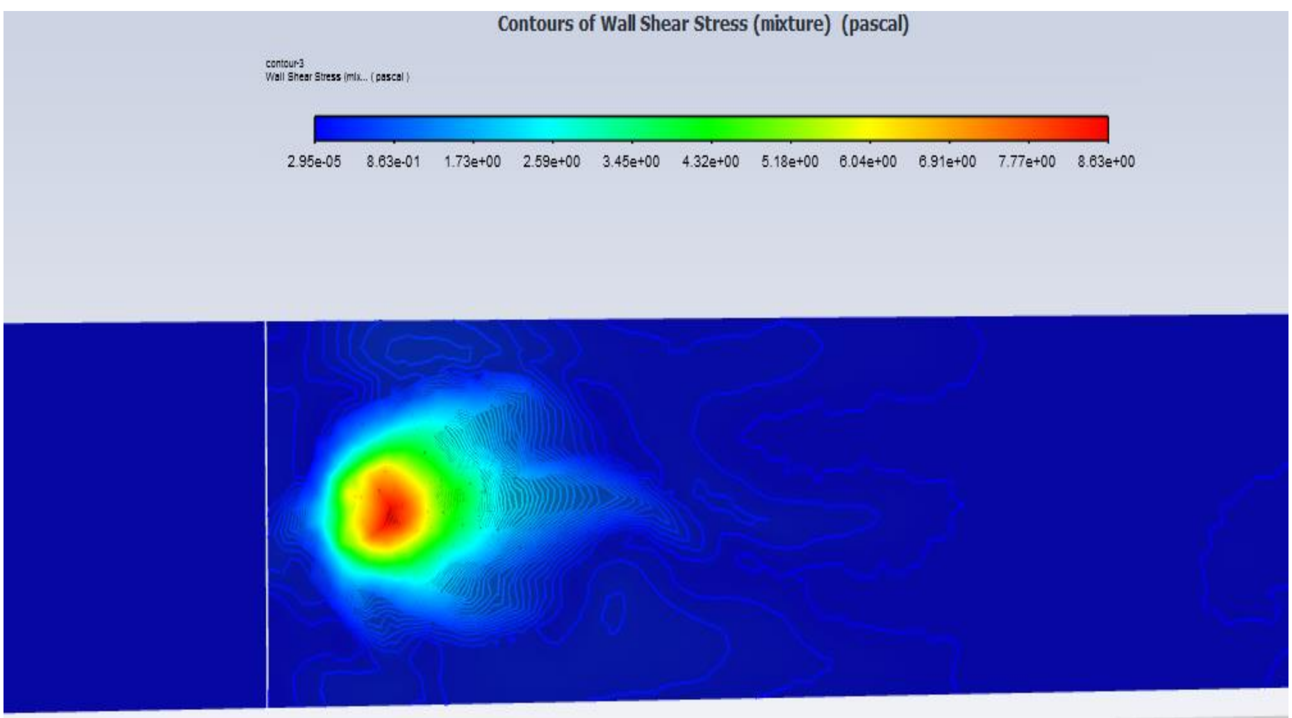


Figure 5.1.16 Contours of Molecular viscosity at the notch.

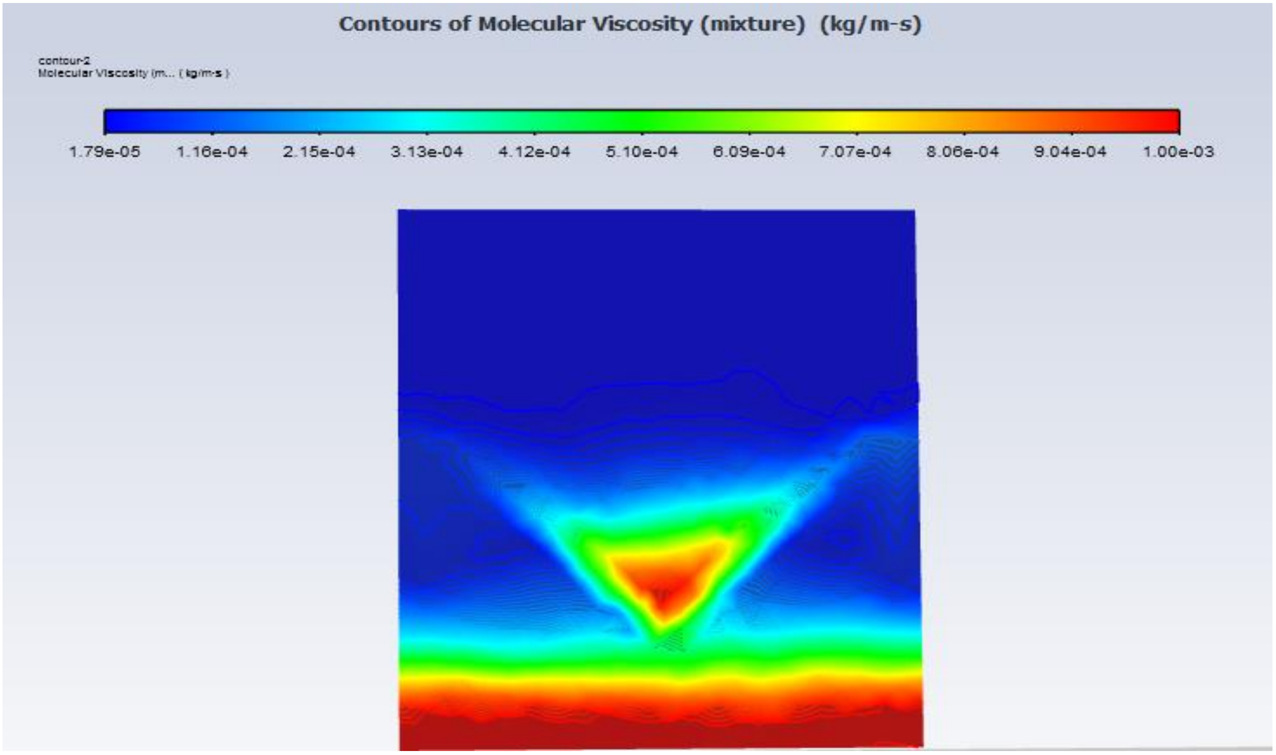


Figure 5.1.17 Discrete phase modelling (Erosion on the bottom bed)

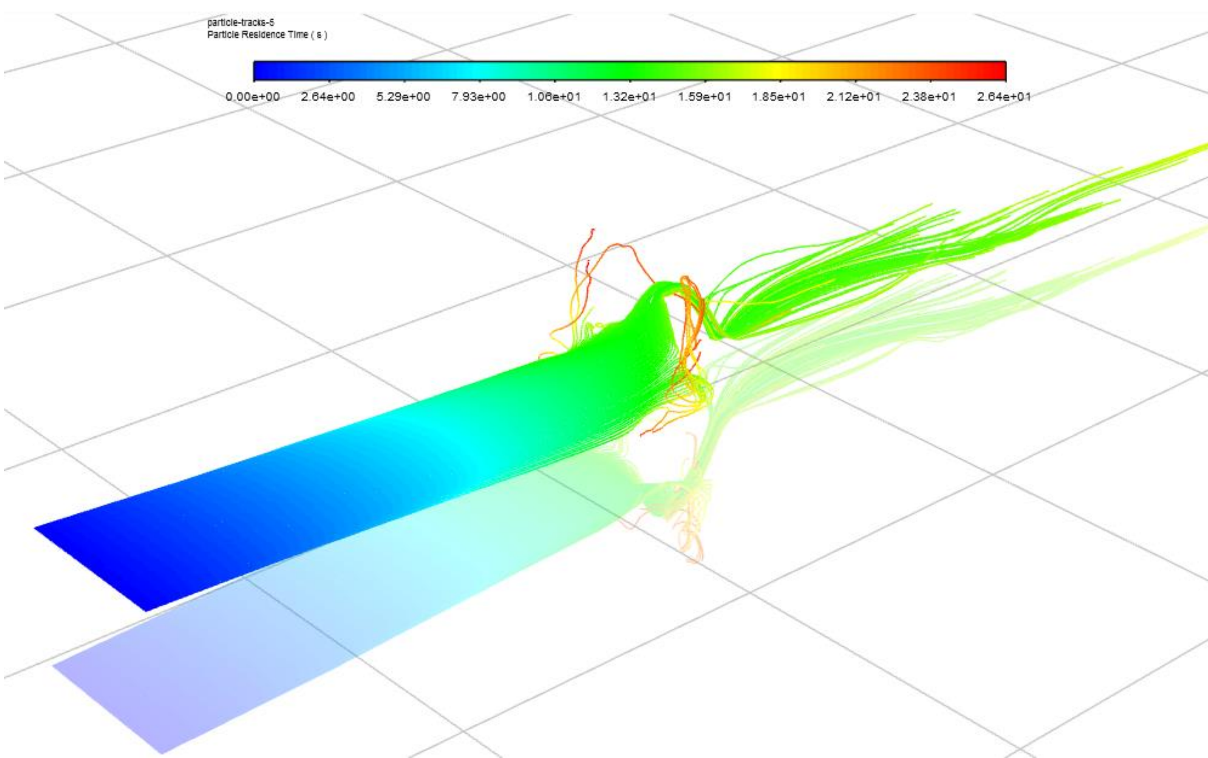


Figure 5.1.18 Discrete phase modelling (Particles residence coming from inlet surface)

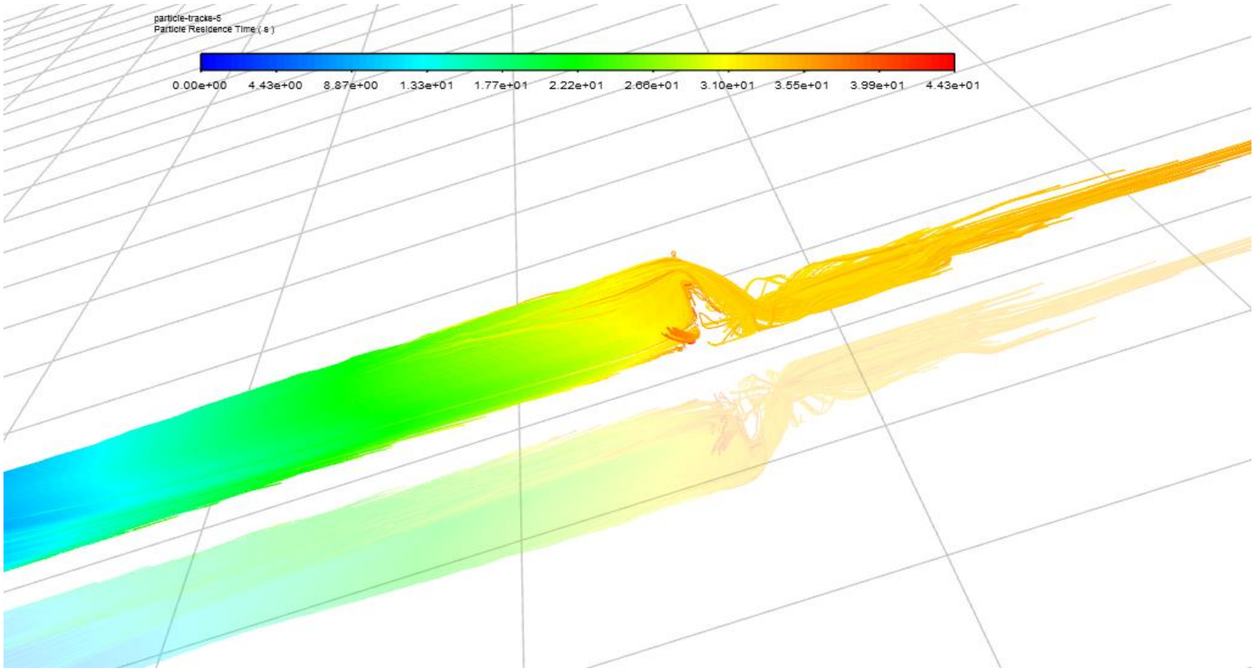
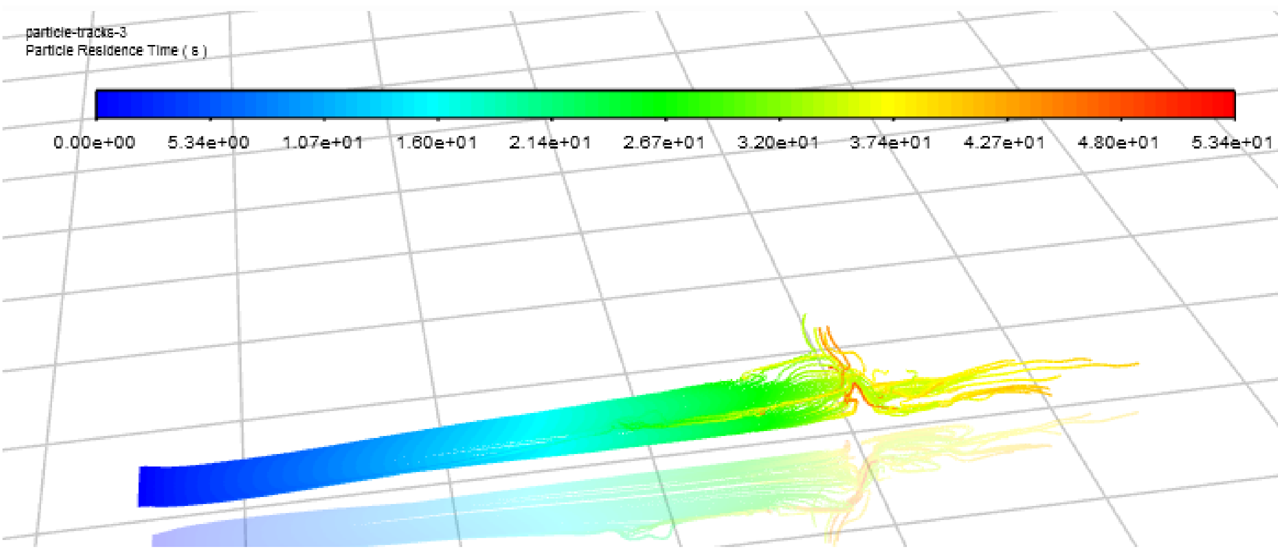
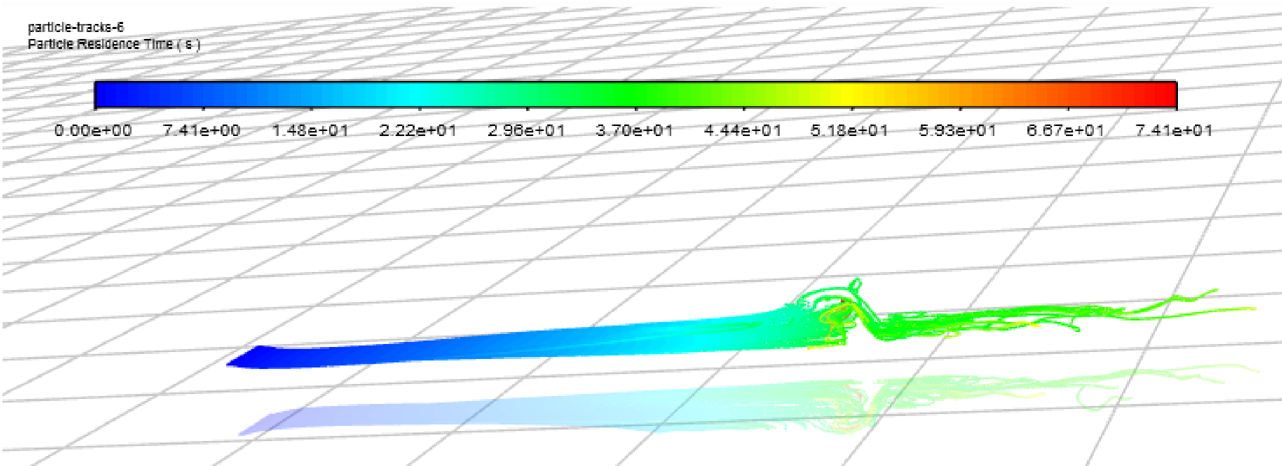


Figure 5.1.19 Discrete phase modelling (particle residence time track) for particles size 20 microns, 50 microns, 100 microns, 150 microns and 200 microns.

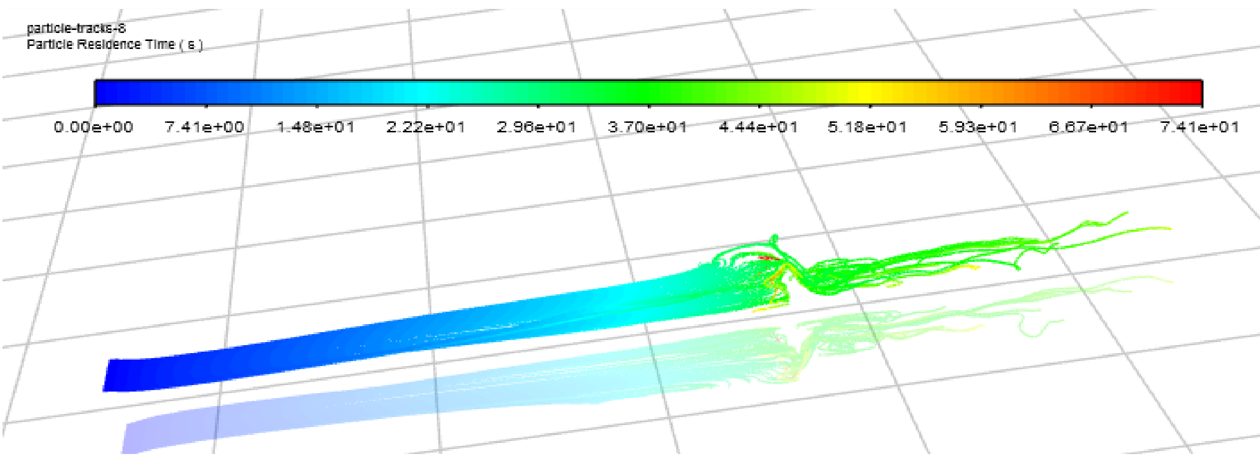
-*20 Microns*



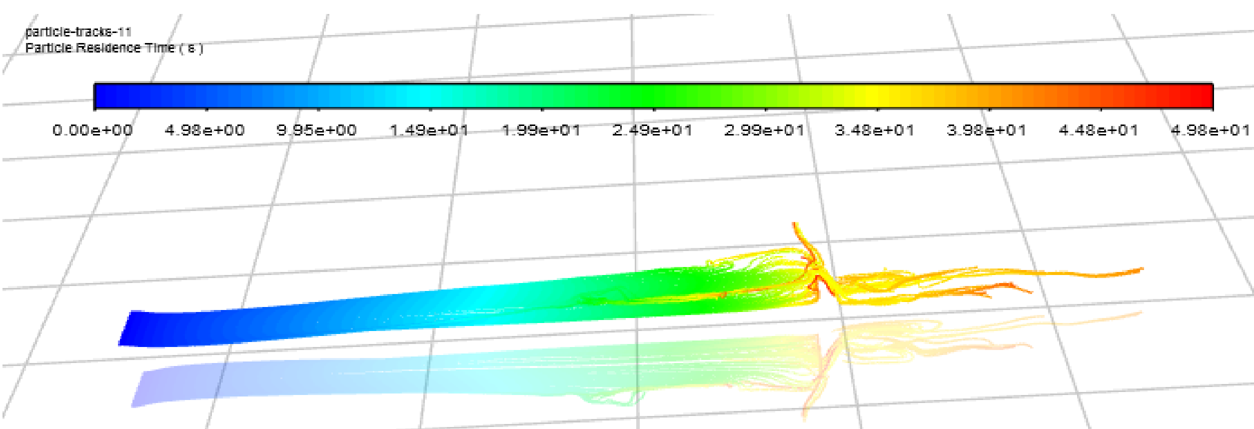
-50 Microns



-100 Microns



-150 Microns



-200 Microns

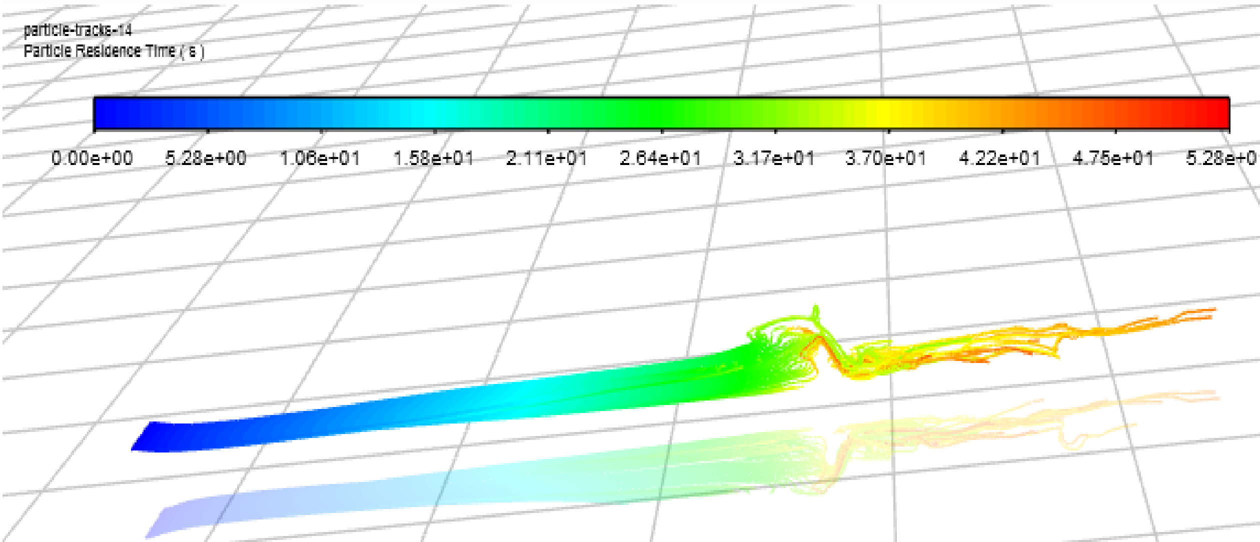


Figure 5.1.20 Plot of erosion rate for the impact particle against particle diameter.

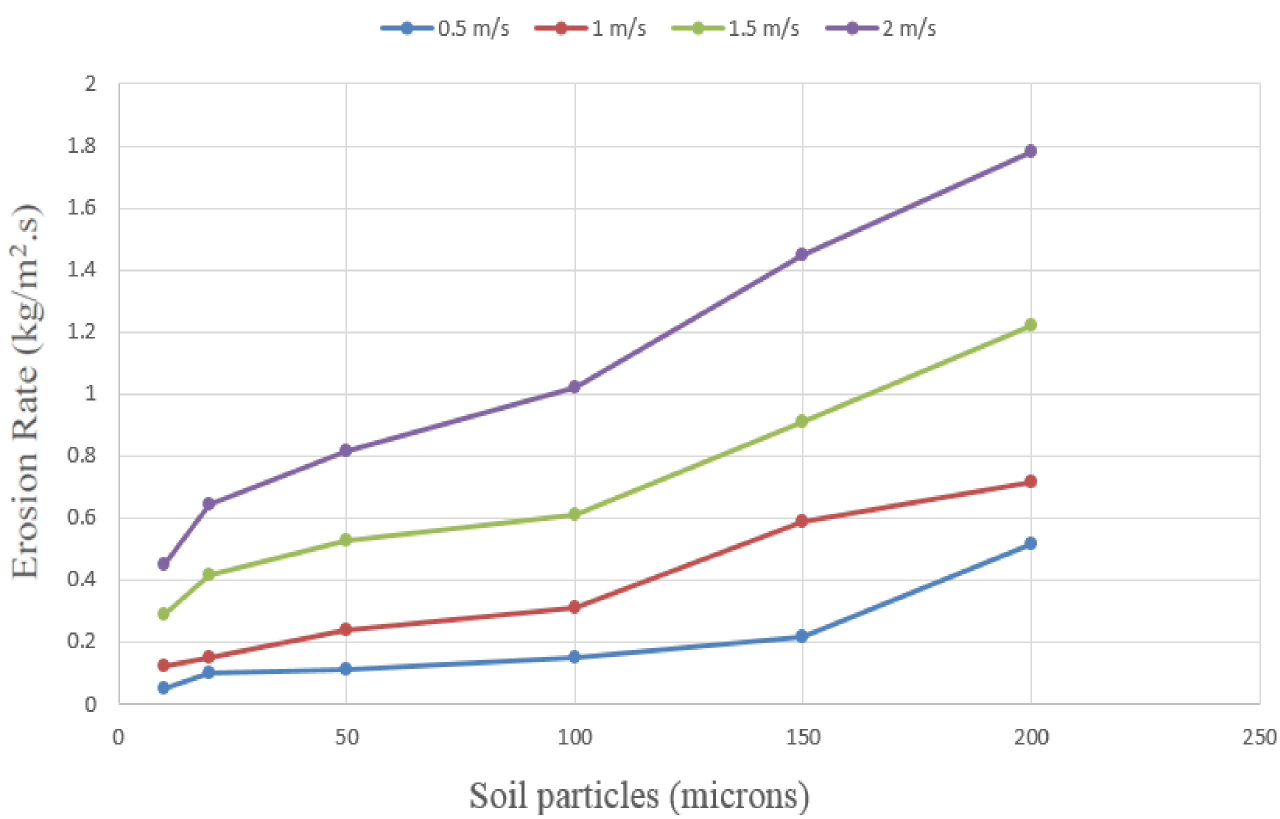


Figure 5.1.21 Plot between three different equation turbulence models for the particle size of 200 (μm).

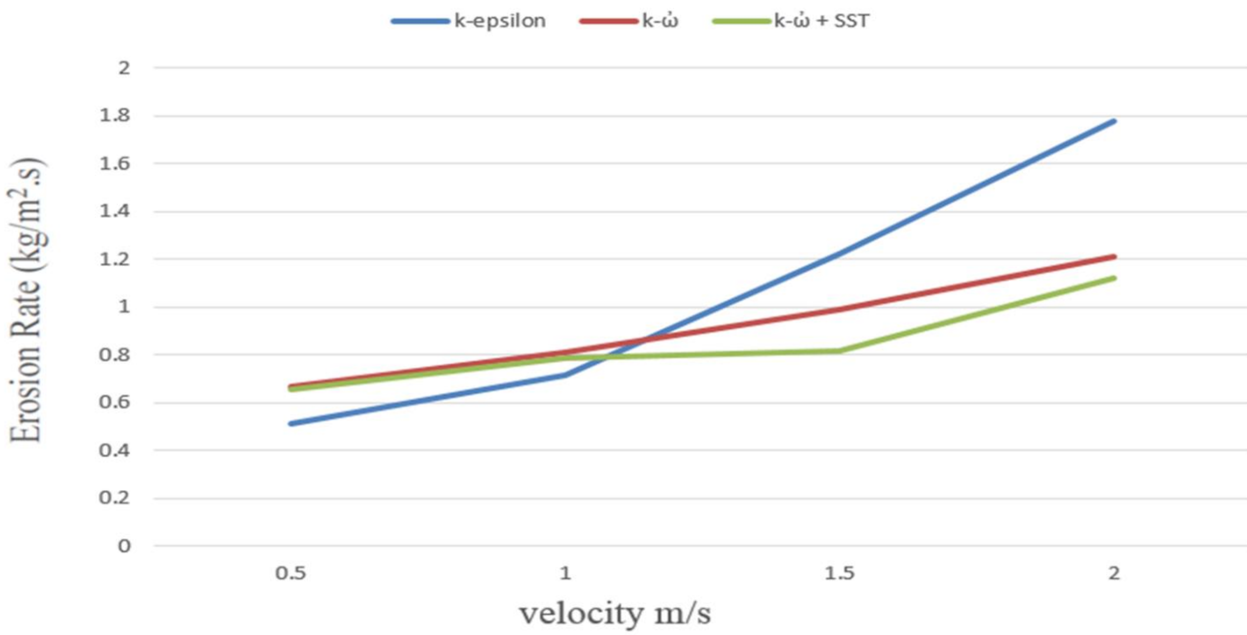


Figure 5.1.22 For the 2 m/s supplied velocity, plot of mean residence time of soil particles

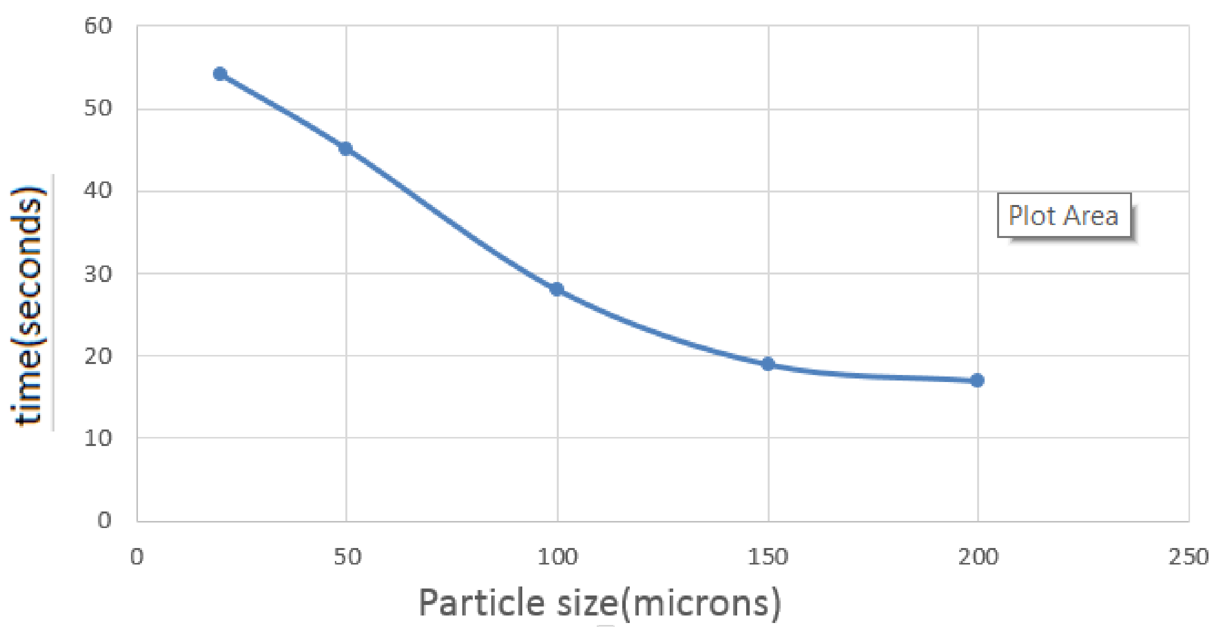
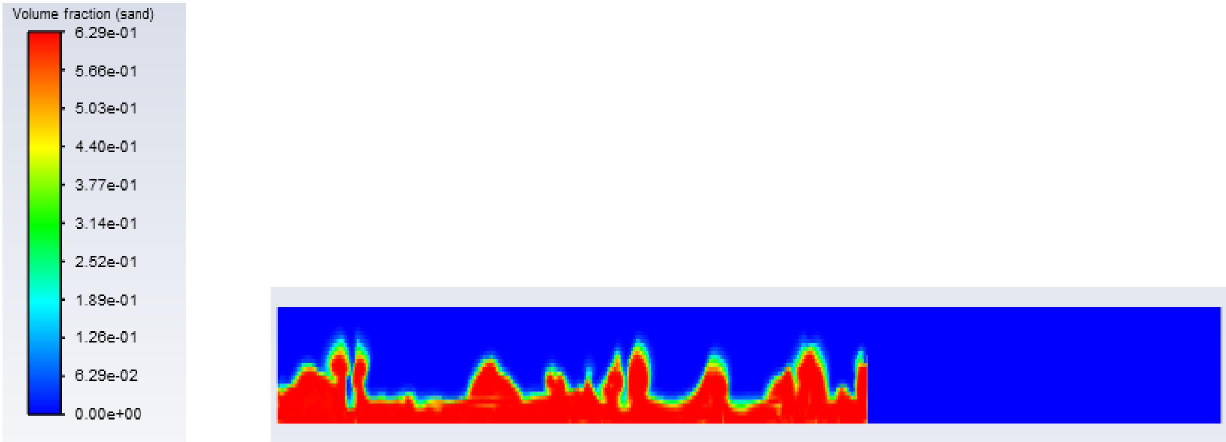
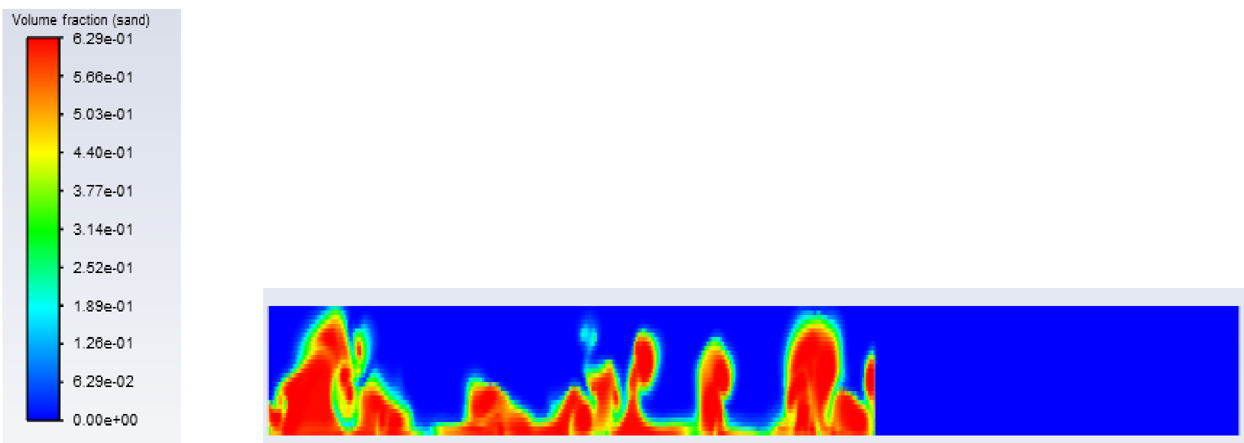
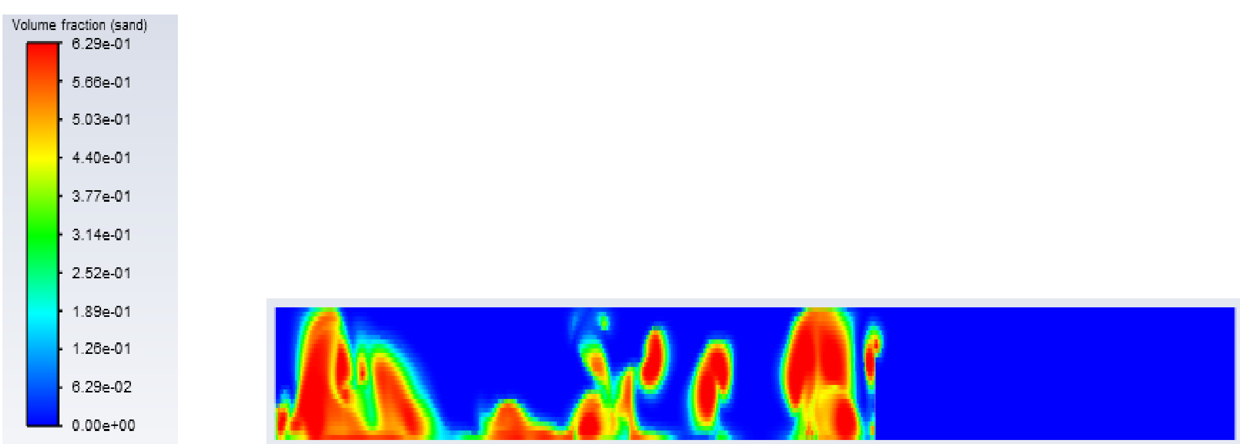
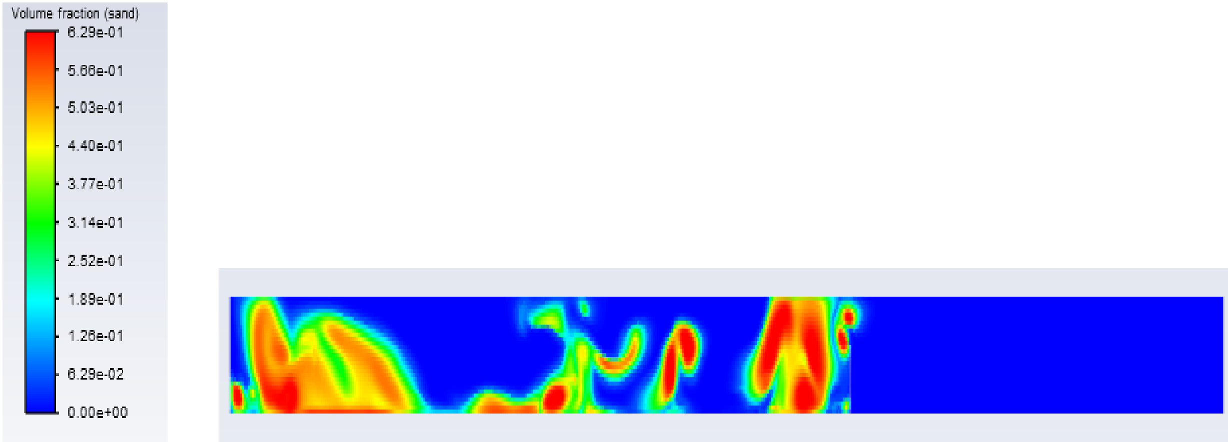


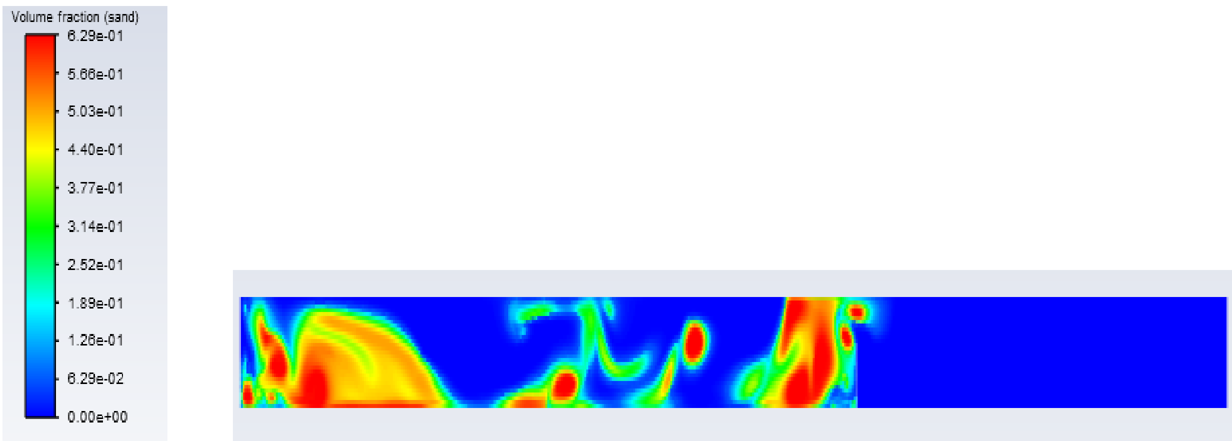
Figure 5.1.23 Contours of volume fraction of Sand by Two phase Eulerian method on the 2 dimensional model of the channel with weir -

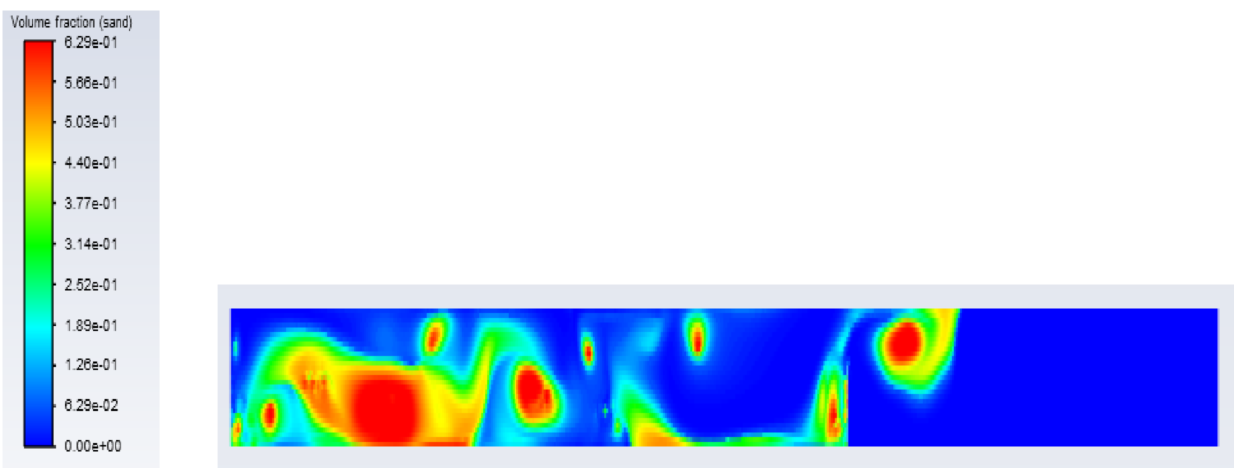


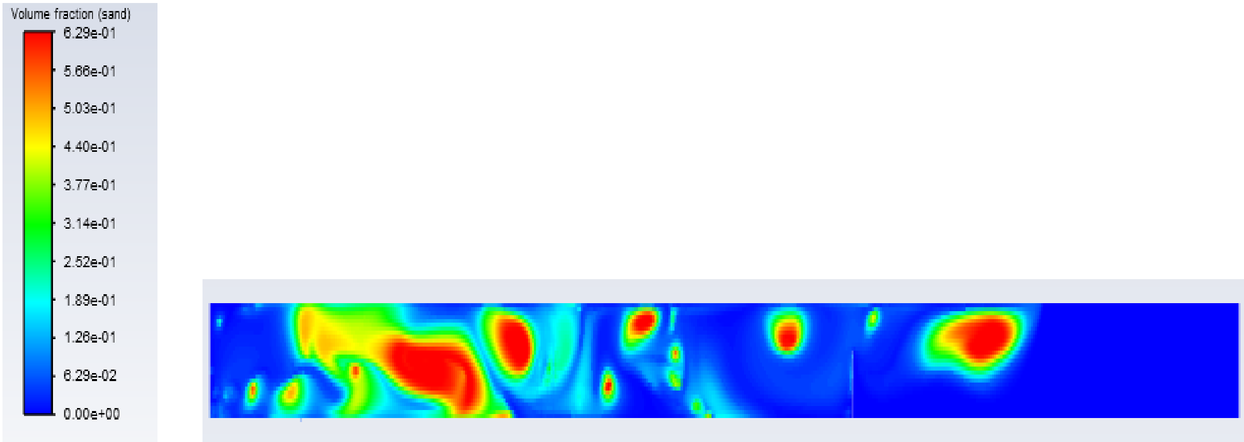


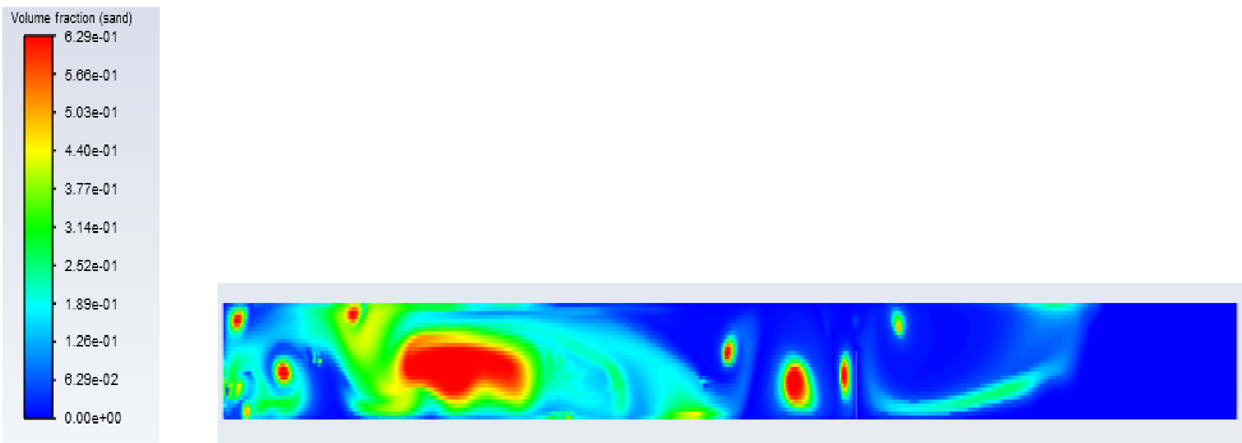


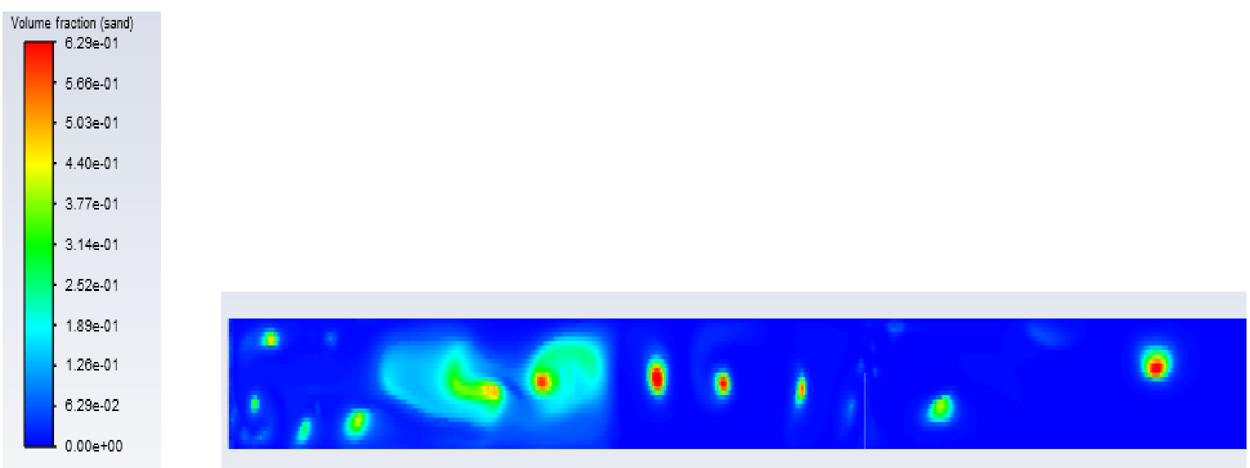

Volume fraction (sand)
6.29e-01
5.66e-01
5.03e-01
4.40e-01
3.77e-01
3.14e-01
2.52e-01
1.89e-01
1.26e-01
6.29e-02
0.00e+00


Volume fraction (sand)
6.29e-01
5.66e-01
5.03e-01
4.40e-01
3.77e-01
3.14e-01
2.52e-01
1.89e-01
1.26e-01
6.29e-02
0.00e+00


Volume fraction (sand)
6.29e-01
5.66e-01
5.03e-01
4.40e-01
3.77e-01
3.14e-01
2.52e-01
1.89e-01
1.26e-01
6.29e-02
0.00e+00


Volume fraction (sand)
6.29e-01
5.66e-01
5.03e-01
4.40e-01
3.77e-01
3.14e-01
2.52e-01
1.89e-01
1.26e-01
6.29e-02
0.00e+00


Volume fraction (sand)
6.29e-01
5.66e-01
5.03e-01
4.40e-01
3.77e-01
3.14e-01
2.52e-01
1.89e-01
1.26e-01
6.29e-02
0.00e+00


Volume fraction (sand)
6.29e-01
5.66e-01
5.03e-01
4.40e-01
3.77e-01
3.14e-01
2.52e-01
1.89e-01
1.26e-01
6.29e-02
0.00e+00

5.2 Conclusions-

1. The effect of channel slope on the discharge coefficient for sharp-crested triangular weir was found to decrease from channel slope -0.5 to 0.0 percent, increase from channel slope 0.0 percent to 3.0 percent and decrease at a small rate from channel slope 3.0 percent to 4.0 percent, respectively for the clear flow
2. The coefficient of discharge for the sharp crested triangular weir was found to be 0.50-0.65 on an average for the experimental setup in mild slope and upto 0.75 for slope equals to 3%.
3. The coefficient of discharge for the same weir was in the range of 0.50-0.70 for the mild slope (adverse and positive) and upto 0.80 for the 3% slope when the simulations were done numerically.
4. For the simulations on a plane gravel bed, Coefficient of discharge ranged from 0.55 to 0.61 in the numerical analysis
5. With the comparison to experimental available data, the error went upto approximately 6%. This is generally due to the difference in gravel stability in the bed.
6. The conclusion that can be drawn from the data obtained from numerical simulation in clear flow is that the error range was from -5.0% to +5.0% depending upon the slope of the channel. Hence this numerical analysis validates the experiment done for the clear flow over the triangular channel.
7. The point velocities obtained for the weir just upstream from numerical simulation on clear flow showed range upto 22.14 cm/s for 4% slope. The error was within limits (upto 10%) for the depth of the channel.
8. Similarly for the simulation in plane gravel bed, the error ranged upto 8-10% for the point velocities.
9. The point velocities obtained for the weir at the mid channel had minute variation with good accuracy (-3% to +5% of error) for clear flow.
10. The variation of velocity with the depth of flow at mid channel from weir invert shows slight dip after 11 cm of depth upto 14cm for both the simulations. This is generally due to shear resistance offered by the walls of the channel.

11. The DPM injection of 1000 particles for the erosion at bottom of the channel tracked 946 particles passing over the channel while 54 particles lost their track within the upstream face and travelled back.
12. On figure 5.1.20 Comparison for erosion rate on soil particles of different size with their erosion rate was found for velocities 0.5m/s- 2m/s. As the velocity and particle size of soil increased, the soil erosion also found to increase.
13. On Figure 5.1.21 Plot for the three different equation turbulence models for the particle size of 200 (μm) with the varied velocity, linear variation was observed for the k-omega turbulence model towards erosion rate. And for the k-omega+SST model and k-epsilon model, erosion rate increased with increase in velocity.
14. For the 2 m/s supplied velocity, mean residence time of soil particles were found and as the particle size increased, the mean cell residence time of the soil particles found to decrease.
15. From the two dimensional analysis of the sand patch in the open channel. 20% of the sand particles started dispersing with the velocity of 0.02 m/s and 100% of the particles dispersed and went into suspension within 1600 seconds of inlet velocity of 0.02m/s.

References-

1. Subhojit Kadia, Binit Kumar and Zulfequar Ahmad Discharge Characteristics of Triangular Weir with Upstream Ramp and Its CFD Modelling Using Ansys CFX Module, Recent Trends in Environmental, Hydraulics, geoplanet: Earth and Planetary Sciences, 2020

2. B. R. Samaga, “Velocity distribution in alluvial channel flow,” Journal of Hydraulic Research, vol. 24, no. 4, 1986.

3. C. Bautista-Capetillo, O. Robles, H. Júnez-Ferreira, and E. Playán,; Discharge Coefficient(Cd) Analysis for Triangular SharpCrested Weir using Low Speed Photographics Technique,; Journal of Irrigation and Drainage Engineering, vol. 140, no. 3, p. 06013005, 2014.

4. Dargahi, B., Experimental Study and 3D Numerical Simulations for a Free- Overflow Spillway, Journal of Hydraulic Engineering, 2006, ASCE, Vol. 132, pp. 899-907.

5. Hirt, C.W.,, Nichols, B.D., Methods for the Dynamic of Free Boundaries; Journal of Computational Physics.; 1981; Vol. 3; pp. 201-225.

6. Shen, Discharge characteristics of triangular-notch thin-plate weirs. Geological Survey water-supply paper 1617-B, Department of the interior, United States Geological Survey, 1981.

7. K. Subramanya, Flow in open channels. New Delhi: mcgraw Hill Education (India), 2015.

8. Alfatlawi T. J. And Alshaikhli H. I., Prediction the Coefficient of Discharge for Stepped Morning Glory Spillway Using ANN and MNLR Approaches, International Journal of Civil and Environmental Engineering, 2015, ISSN: pp. 1701-8285, Vol.37, Issue.2.

9. Bremerf,oertelm(2017)Numerical investigation of wallthickness influence on Piano Key Weir discharge coefficients: A preliminary study In: Proceedings of the Third International Workshop on Labyrinth and Piano Key Weirs 2017.Taylor & Francis Group , London,pp101–108

10. Rajab, H. ,, Elgizawy, A.:; Design of SpillTube with Feature for Controlling Air Bubble Generated on Aircraft Application’s. ASME, ECTC; November 2-3, 2012: Atlanta, Georgia USA. Chanel, P.G..

11. Madadi, M.R.; Dalir, A.H. and Farsadizadeh, D.; Control of undular weir flow by the changing of weir's geometry. Flow Meas. Instrum.. 2013, 34, 160–167.

12. Hakim, S.S.; Azimi,; A.H. Hydraulics of Submerged triangular weirs, Weirs of Finite-depth Length with Upstream & Downstream Ramps;. J. Irrig. Drain.: Eng. 2017, 143, 06017008.

13. Sarker, M.A.;; Rhodes, D.G,; Calculation of freesurface profile on a rectangular broadcrested weir.; Flow Measurement,, 2004, 15, 215–219.

14. WMO (World Meteorological Organization), Manual on Sediment Management and Measurement. Operational Hydrology Report No. 47, Geneva, Switzerland, 2003.

15. WMO (World Meteorological Organization), Use of weirs and flumes in stream gauging. Technical Note No. 117, Geneva, Switzerland, 1971.

16. X. Zhang, L. Yuan, R. Peng, and Z. Chen, "Hydraulic Relations for Clinging Flow of Sharp-Crested Weir," Journal of Hydraulic Engineering, vol. 136, no. 6, pp. 385–390, 2010.

17. Hoseini, S. H. Jahromi, S. H. M. & Vahid, M. S. R. (2013). Determination of Discharge Coefficient of Rectangular Broad-Crested Side Weir in Trapezoidal Channel by CFD. International Journal of Hydraulic Engineering, 2(4), 64-70. DOI: 10.5923/j.ijhe.20130204.02

18. Lodomez, M., Erpicum, S., Dewals, B., Pirotton, M. & Archambeau, P;. (2014). Comparison between Exp. and SPH Models on a Sharpcrested Weir; the 5th International Junior Researcher and Engineer Workshop, on Hydraulic Structures; Spa, Belgium.

19. Naghavi, B., Esmaili, K., Yazdi, J, and Vahid, F.K. 2011.: An experimental and numerical study on hydraulic characteristics and theoretical equations over circular weirs. Canadian Journal of Civil Engineering,; 38(12).