Cape Peninsula University of Technology

# NON-NEWTONIAN FLUID FLOW MEASUREMENT USING SHARP CRESTED NOTCHES

**by**

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## DECLARATION

I, Morakane Charlotte Khahledi, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

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## ABSTRACT

Notches, particularly rectangular and V shaped are the cheapest and most common devices used to measure the flow rate of water in open channels. However, they have not been used to measure the flow rate of non-Newtonian fluids. These viscous fluids behave differently from water. It is difficult to predict the flow rate of such fluids during transportation in open channels due to their complex viscous properties. The aim of this work was to explore the possibility of extending the application of especially rectangular and V-shaped notches to non-Newtonian fluids. The tests reported in this document were carried out in the Flow Process and Rheology Centre laboratory. Notches fitted to the entrance of a 10 m flume and an in-line tube viscometer were calibrated using water. The in-line tube viscometer with 13 and 28 mm diameter tubes was used to determine the fluid rheology. Flow depth was determined using digital depth gauges and flow rate measurements using magnetic flow meters. Three different non-Newtonian fluids, namely, aqueous solutions of Carboxymethyl Cellulose (CMC) and water-based suspensions of kaolin and bentonite were used as model non-Newtonian test fluids. From these the coefficient of discharge ($C_d$) values and appropriate non-Newtonian Reynolds numbers for each fluid and concentration were calculated. The experimental values of the coefficient of discharge ($C_d$) were plotted against three different definitions of the Reynolds number. Under laminar flow conditions, the discharge coefficient exhibited a typical dependence on the Reynolds number with slopes of ~0.43-0.44 for rectangular and V notches respectively. The discharge coefficient was nearly constant in the turbulent flow regime. Single composite power-law functions were used to correlate the $C_d$-Re relationship for each of the two notch shapes used. Using these correlations, the $C_d$ values could be predicted to within ±5% for the rectangular and V notches. This is the first time that such a prediction has been done for a range of non-Newtonian fluids through sharp crested notches. The research will benefit the mining and food processing industries where high concentrations of non-Newtonian fluids are transported to either disposal sites or during processing.

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## DEDICATION

To my family – For their love and faith.

**"**Truly 'thoughts are things', and powerful things at that, when mixed with purpose, persistence and a burning desire for their translation into riches or other material objects" **Edwin C, Barnes**

**"**One of the most common causes of failure is the habit of quitting when one is overtaken by temporary defeat." **R.U Darby**

## GLOSSARY

# Constants

| Symbol | Meaning (units) |
|---|---|
| A | area ($m^2$) |
| B | channel width (m) |
| b | notch width (m) |
| C | Coefficient of discharge Lenz (1943) Eq 2.23 |
| $C_d$ | coefficient of discharge |
| $C_{dpre}$ | predicted coefficient of discharge |
| $C_e$ | Shen's coefficient of discharge |
| $C_v$ | concentration by volume |
| D | pipe diameter (m) |
| $D_h$ | hydraulic diameter (m) |
| $D_{shear}$ | diameter of the sheared part of fluid in pipe (m) |
| F | force (N) |
| $f$ | Darcy friction factor |
| g | acceleration due to gravity ($m/s^2$) |
| H | flow height at intermediate position measured from notch crest to water level (m) |
| h | fluid height (m) |
| $h_e$ | effective energy head |
| $H_{max}$ | maximum fluid height (m) |
| k | fluid consistency index ($Pa.s^n$) |
| k′ | apparent fluid consistency index ($Pa.s^n$) |
| $K_b$ | factor which caters for the effect of viscosity and surface tension |
| $K_h$ | factor which caters for the effect of viscosity and surface tension (0.001 m) |
| $k_s$ | roughness height |
| LSE | log standard error |
| M | Mass flow rate (kg/s) |
| n | flow behaviour index |
| n′ | apparent flow behaviour index |
| P | height between the notch crest and the channel floor (m) |
| P | Pressure (Pa) |
| Pw | Wetted Perimeter (m) |
| Q | flow rate ($m^3/s$) |
| $Q_{plug}$ | flow rate of plug ($m^3/s$) |
| $Q_{pre}$ | predicted flow rate ($m^3/s$) |
| R | pipe radius (m) |
| $R_{plug}$ | plug radius (m) |

| | |
|---|---|
| $R^2$ | coefficient of determination |
| Rd | relative density |
| Re | Reynolds number (Eq. 2.39) |
| $Re_b$ | Reynolds number based on L=b, where b is the top width of the flow area at the notch setion for different heads h in the case of multi-slit V-notch (Eq. 2.35) |
| $Re_H$ | Haldenwang et al. (2002) Reynolds number (Eq. 2.38) |
| $Re_{MR}$ | Metzner and Reed Reynolds number (Eq. 2.40) |
| $Re_R$ | Ramamurthy et al. (2013) notch Reynolds number (Eq. 2.34) |
| $Re_3$ | Slatter Reynolds number (Eq. 2.47) |
| $R_h$ | hydraulic radius (m) |
| V | velocity (m/s) |
| $V_{ann}$ | velocity in the annular region (m/s) |
| We | Weber number |

## Greek letters

| Symbol | Meaning (units) |
|---|---|
| $\rho$ | density (kg/m$^3$) |
| $\tau_w$ | wall shear stress (Pa) |
| $\sigma$ | surface tension (N/m) |
| $\theta$ | V notch inclusive angle (degrees) |
| $\phi$ | coefficient of discharge |
| $\tau_y$ | yield stress (Pa) |
| $\dot{\gamma}$ | shear rate (1/s) |
| $\mu$ | viscosity (Pa.s) |

# Terms and concepts

| **Term** | **Explanation** |
|---|---|
| Coefficient of discharge | The ratio of the actual discharge to the theoretical discharge |
| Crest | The edge or surface over which the liquid passes |
| Flume | Artificial open channel that carries liquids, slurries or tailings |
| Head | Height above the crest of the notch |
| Laminar flow | Viscous fluids dominate the flow behaviour and the fluid particles are moving in smooth paths |
| Nappe | The curved jet of water, which falls over a notch |
| Newtonian fluid | A fluid whose flow curve ( $\tau_w$ vs $\dot{\gamma}$ ) is linear and passes through the origin (Chhabra and Richardson, 2008) |

| | |
|---|---|
| Non-Newtonian fluid | A fluid whose flow curve ( $\tau_w$ vs $\dot{\gamma}$ ) is not linear and does not pass through the origin |
| Orifice | A thin plate with a hole in it that is used to measure the flow rate of fluids |
| Reynolds Number | The ratio of inertial to viscous forces |
| Rheology | The science of deformation and flow of materials |
| Transition | Region between laminar and turbulent flow |
| Turbulent flow | Region where inertial forces are more dominant than viscous forces and fluid particles move in irregular paths |
| Viscosity | The resistance of fluids to flow |
| Weber number | Ratio between fluid inertia and surface tension |
| Weir or Notch | An obstruction that is used to measure the flow rate by means of overflow |
| Yield stress | Stress at which a material begins to deform plastically |

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# CHAPTER ONE
# INTRODUCTION

## 1.1 Introduction

The study of notches using water has been explored for a long time and references include the work done by Torricelli in 1643 (Horton, 1907). Since then notches have been used to measure the flow rate of water and other Newtonian fluids. Nonetheless, there has not been much research done on the flow measurement of non-Newtonian fluids using notches. It could be because of the complexity of these fluids' viscous characteristics. This makes it difficult to predict their flow rate during transportation in open channels. Therefore, there was a need to determine the accuracy of notches in measuring the flow rate of non-Newtonian fluids.

## 1.2 Background to the problem

Weirs are hydraulic structures placed across open channels and rivers, with an opening to regulate and measure the flow rate of a liquid (Replogle, 2006). There is no difference between a notch and weir except that the former is a small structure which has sharp edges. Notches are normally used in laboratories, water-supply systems and test wells to gauge small compensation flows and effluents of clean water or water containing only dissolved pollutants (Douglas et al, 1985; Ackers et al, 1978). The parameters obtained in flow rate measurements of water using notches are used to calculate the coefficient of discharge ($C_d$), which is a constant for water.

Lenz (1943) provided proof that notches can be used for fluids other than water when studying the flow of oil through V-notches. However, both water and oil are Newtonian fluids.

The flow behaviour of non-Newtonian fluids is very different from that of Newtonian fluids. Except for limited work published by Haldenwang et al. (2007) establishing the relationship between $C_d$ and total head for different concentrations of kaolin and bentonite suspensions for rectangular and V-notches, notches have not been used to measure the flow of non-Newtonian fluids.

## 1.3 The research problem

Various hydraulic structures such as orifices and notches are used to measure the flow rate of Newtonian fluids in open channels and overflow from tanks. Very little research has been done on the use of notches to measure the flow rate of non-Newtonian fluids. It is difficult to predict the flow rate of these fluids due to their complex viscous properties. Therefore, there is a need to determine the accuracy of notches in measuring the flow rate of non-Newtonian fluids and this work aims to fill this gap in the literature.

### 1.4 Research question

Can sharp crested notches be used to accurately measure the flow rate of non-Newtonian fluids?

### 1.5 The specific need

This research is needed in the mining industry for flow rate measurement of highly concentrated mine tailings during their transportation from a tank and in an open channel. This work will also benefit the chemical, food processing, and civil engineering industries where non-Newtonian solutions and suspensions are regularly transported in open channels and where flow measurements are required.

### 1.6 Aims and objectives

The aim of this work was to establish the possibility of flow rate measurement of non-Newtonian fluids through rectangular and V-shaped notches.

In order to achieve this, the following objectives were met:

- Determine the $C_d$ values of V and rectangular notches using water for calibration
- Calculate the $C_d$ values for concentrations of  4.15%, 5.14% and 7% bentonite suspensions
- Calculate the $C_d$ values for concentrations of 1.73% , 4.63%, 6.2%,7.3% and 8.35% CMC solutions
- Calculate the $C_d$ values for concentrations of 5.48%, 6.71%, 8.23%, 10.91%, 12.62%, 14.64%, 15.31%  and 16% kaolin suspensions
- Establish a correlation between $C_d$ values and Reynolds number for the non-Newtonian fluids
- Obtain a logistic dose response model for each notch shape.

### 1.7 Delineation

This study does not cover the flow rate measurement through trapezoidal notch and circular notch nor will it deal with time dependent fluids.

## 1.8 Context of the research

This research is within the Civil Engineering (Water Engineering) discipline.

## 1.9 Methodology

Fluid flow rate measurements were carried out using rectangular and V-notches. The information obtained was used to calculate $C_d$ values of Newtonian and non-Newtonian fluids using equations provided by Ackers et al. (1978) for Newtonian fluids.

Rheology measurements for non-Newtonian fluids were conducted using an in-line tube viscometer. The rheological characteristics obtained were used to calculate the Haldenwang et al, (2002) Reynolds number $Re_H$ for all non-Newtonian fluids which were used in this research. The $C_d$ values versus $Re_H$ numbers for each fluid and concentration were plotted for each notch. The Metzner and Reed Reynolds ($Re_{MR}$) number was used for comparison with the $Re_H$ Reynolds number for CMC solutions. The relationship between $Re_H$ and $C_d$ values was established and a predictive model for each notch shape was obtained using a double power law correlation.

## 1.10 Organisation of dissertation

### 1.10.1 Literature review – Chapter 2

Literature pertaining to flow rate measurement of Newtonian fluids using notches has been extensively discussed in this chapter. However, little has been written on the flow rate measurement of non-Newtonian fluids using notches accept Haldenwang et al., (2007) research due to limited studies done. Horton (1907) indicated that the use of notches to measure the flow is similar to the flow rate measurement using partially filled orifices. Therefore the flow of Newtonian and non-Newtonian fluids over orifices has been considered. This chapter includes the research done for rheological characterisation of these fluids, which were used to calculate the Reynolds number (Re). The Reynolds number used was one developed for non-Newtonian open channel flow.

### 1.10.2 Research Method – Chapter 3

The detail of each component of the equipment which has been used to carry out relative density, flow rate and rheology measurements is described in this chapter. The calibration procedures for tube viscometer and notches with the results obtained are also outlined.

Testing procedures for flow rate measurement using notches and rheology measurement using an inline tube viscometer are explained.

### 1.10.3 Results and Analysis – Chapter 4

The results obtained from the measurements done are presented in this chapter. The rheology and flow rate measurement results for each notch and each concentration are discussed.

### 1.10.4 Model Prediction – Chapter 5

This chapter explains the prediction of single composite equations for rectangular and V-notches. Error margins of the predicted compared to the measured values of the flow rates are presented.

### 1.10.5 Discussion – Chapter 6

The results obtained are discussed with reference to the available literature. The focus starts from the calibration of the equipment, the influence of the notch geometry on the $C_d$ values obtained and the effect of rheological parameters on the Reynolds number used ($Re_H$). These analysis and results helped to develop a new model for flow rate measurement of non-Newtonian fluids using notches.

### 1.10.6 Conclusions and Recommendations – Chapter 7

This chapter summarises the findings obtained from this research and describe how the research question has been answered. The conclusions are drawn and recommendations for future studies are made.

# CHAPTER TWO
## LITERATURE REVIEW

### 2.1 Introduction

Weirs and notches are the cheapest and most common devices which have been successfully used to measure the flow rate of water in open channels. The fully contracted rectangular and V-notches are frequently used in open channels and overflow tanks, but other types such as circular, parabolic and compound notches are mostly used for special applications (Ackers et al., 1978). There has not been much research done on flow measurement of fluids using notches other than water and oil (Ackers et al., 1978; Lenz, 1943) and for non-Newtonian suspensions by Haldenwang et al., 2007. This research can benefit mining industries as they generally transport non-Newtonian fluids and fine particle slurries to disposal sites in open channels (Guang et al., 2009). The food processing, chemical and waste water industries also transport concentrated suspensions (Haldenwang, 2003).

While there is extensive literature available for flow measurement of water using sharp crested notches done by researchers such as, Chow, 1959; Chaudhry 1993; Borghei et al., 1999 and Finnermore & Frannzini, 2002 there has not been much done for non-Newtonian fluids.

### 2.2 Notches

The notch crest is a sharp metal plate surface over which the liquid passes. The edges of the notch plates in contact with the flowing medium should be sharp and cut so as to form an angle of 45° to the direction of flow. Notches are mounted accurately at right angles to the direction of flow and with the upper edge horizontal. The mounting can be carried out by one of the following methods, care being taken to ensure tight seals against the walls and the bed of the channel (Bouveng, 1969):

- The notch is mounted between rails or bolts. For temporary installations it will often suffice to bolt strong strips to each channel wall (the water pressure will normally be great enough to keep the notch in position), and to seal with machine felt, foam rubber or foam plastic. The sealing material is chosen with regard to the properties of the flowing medium. This alternative is to be preferred.
- The notch, which shall be made slightly wider than the channel, is forced into position, care being taken to avoid damaging the edges.

- The notch can be secured with wooden wedges, but this method entails problems in sealing.

The fully contracted notches have a number of features in common which are outlined by Replogle 2006; ASTM 1993; Douglass 1985 & Bouveng, 1969.

The water surface must be far enough below the notch crest to allow for aeration and that stream of water is called a nappe. When the nappe is aerated the flow is referred to as free or critical. When the downstream water level rises to the point where air does not flow freely beneath the nappe, it is not ventilated and the discharge rate may be inaccurate because of the low pressure beneath the nappe. The relationship between the discharge over the notch and water level towards the notch crest is known. This means that the discharge may be found by observing the approach channel water level and this depth is referred to as the head. The head measurements must be at a minimum distance of 3-4 times the expected maximum flow height. To ensure an adequate steady flow at the notch, the upstream part of the channel should have a straight portion with a length that is at least 10 times its width. To reduce turbulence, a grating or guide baffles can be inserted before the notch. The notch should be easily accessible for cleaning.

**2.3 Bernoulli equation**

The flow of an incompressible liquid depends on pressure, velocity, acceleration due to gravity and density. Ackers et al. (1978) derived equations for flow measurement of water over notches based on the Bernoulli equation (Eq. 2.1).

$$\frac{v_1^2}{2g} + \frac{p_1}{\rho g} + h_1 = \frac{v_2^2}{2g} + \frac{p_1}{\rho g} + h_2 \qquad (2.1)$$

Figure 2.1 shows installation, flow requirements and Bernoulli's parameters for a fully contracted sharp crested notch.

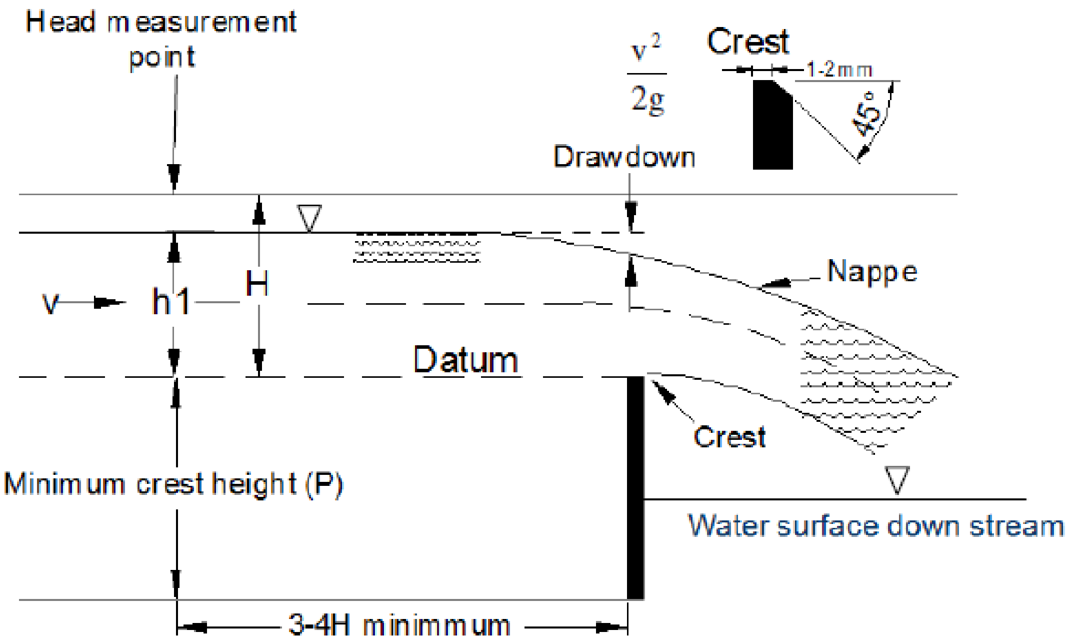



Figure 2.1: Flow over thin-plate notch (Replogle 2006; Chadwick et al., 2004 and Chow, 1959)

Consider a particle of fluid moving from a position 1 some distance away from the notch to a position on top of the notch crest in Fig. 2.1. Assuming that there is no energy loss and the cross-sectional area of the approach channel is much larger than the notch, the fluid in the vertical plane will be relatively at rest. Therefore the total head (H) of all the points relative to the datum will be the same. Pressure at points 1 and on top of the notch crest is assumed to be 0 because the fluid is exposed to atmospheric pressure. Therefore Eq. 2.1 becomes

$$H = h_1 + \frac{v_1^2}{2g} \tag{2.2}$$

and

$$H - h_1 = h \tag{2.3}$$

Thus

$$h = \frac{v_1^2}{2g} \tag{2.4}$$

The Bernoulli equation is used to derive flow rate equations for notches where the coefficient of discharge ($C_d$) is part of the equation. The $C_d$ value is normally defined as a function of the applicable dimensionless factors based on experimental data from a laboratory (Aydin et al., 2011). Ackers et al. (1978) showed that $C_d$ is reliant on total head (H), Reynolds number

(Re) and Weber number (We). Kindsvater and Carter (1957) illustrated that the flow over notches depends on the width of the notch; width of approach channel; crest height of the notch above the head; measured head related to notch crest; specific weight; density; dynamic viscosity and surface tension of the fluid. Furthermore, Barr (1910) and Mitra & Mazudar (2004) experimentally confirmed that $C_d$ depends on total head. Lenz (1943) mentioned that for water, surface tension and velocity of approach have an impact on the relationship between $C_d$ values and the head, which confirms the dependence of $C_d$ values on Reynolds and Weber numbers. The surface tension effects are of the same order for rectangular and V notches. However, the cross sectional area of a V-notch is small when compared to the channel cross section. As a result, the velocity of approach effect for the V-notch is much smaller than for the rectangular notch. On the other hand, Afzalimehr & Bagheri (2009) suggested that the effects of viscosity, surface tension, relative boundary roughness and crest geometry are insignificant for sharp crested notches when the boundary material is smooth, the crest has a standard geometry, the overflow depth is at least 50 to 70 mm and the channel width is at least 300 mm.

### 2.4 Velocity of approach

Horton (1907) extensively discussed the effect of velocity of approach for flow rate measurement of water using notches. The equations derived for notch discharge have to accommodate the velocity of approach, hence the introduction of $C_d$ values to the formulae Fig. 2.2 shows the threads of the water in the cross section of the channel of approach to a notch with different velocities. When the velocity of the water in the leading channel is nearly uniform, the $C_d$ in the discharge formula will be smaller. The fitting of stilling racks or baffles inside the approaching channel calms the velocity to be nearly uniform.

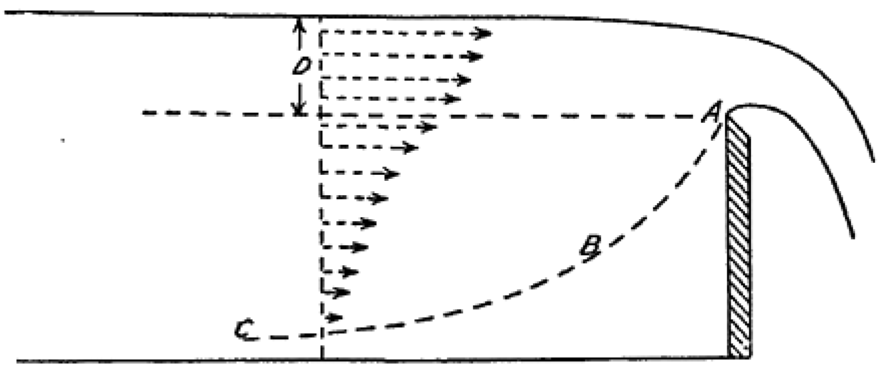



Figure 2.2 Distribution of velocities boundary (Horton, 1907)

The velocity distribution is the same for any kind of sharp crested notch.

### 2.5 Rectangular notch

The rectangular notch is the oldest type of notch in use and is useful in measurement of high flow rates (Ackers et al., 1978). It is a cut that is perpendicular to the direction of flow of a channel, with the notch having a horizontal base and vertical sides (Fig. 2.3). According to Replogle (2006) Fig. 2.3 illustrates configuration of contracted sharp crested notch and it has been previously published by Thomson (1876). During the flow of water through a rectangular notch the cross-section of the stream changes as the depth increases and that causes the $C_d$ value to vary (Ackers et al., 1978). The equations for computing the flow rate are discussed in the following sections.

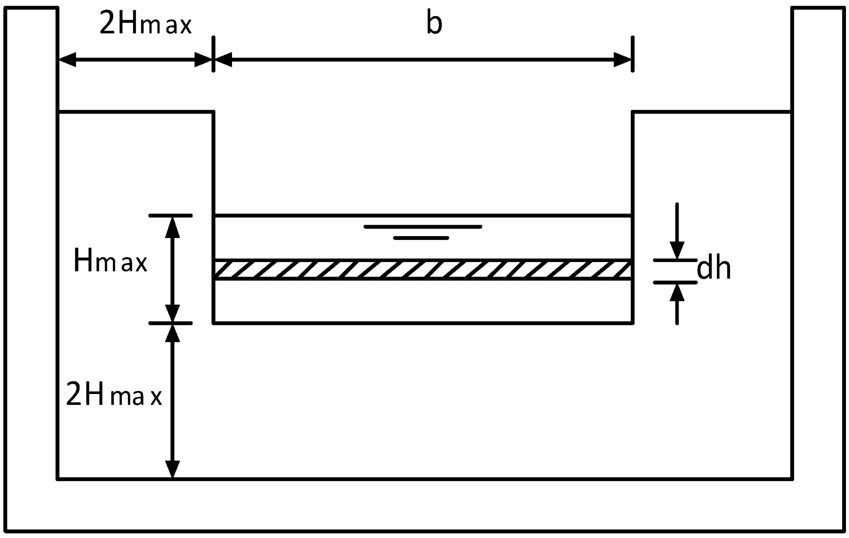



Figure 2.3 Rectangular Sharp Crested Weir Design (Replogle, 2006; Aydin, 2011)

#### 2.5.1 Rectangular notch Equation

There are several formulae developed for calculating the discharge over rectangular notches by different researchers (Kindsvater & Carter, 1957 and Rehbock, 1929). However, the Kindsvater & Carter (1957) equation is highly recommended in ASTM 1993, USBR 1997 and ISO 1980 documents and by Acker et al., 1978. It has the ability to cover much small notches down to 0.03 m wide, with heads ranging from 0.05 to 0.2 m (ASTM 1993; USBR 1997; ISO, 1980 and Ackers et al., 1978).

The $C_d$ value for a rectangular notch is determined from the discharge equation derived by Kindsvater and Carter (Ackers et al., 1978; Bos, 1989 and USBR, 1997):

$$Q = \int_0^H \sqrt{2gh}\, b\, dh \qquad (2.5)$$

After integration, Eq. 2.5 becomes

$$Q = \frac{2}{3}\sqrt{2g}bh^{3/2} \tag{2.6}$$

The $C_d$ value is introduced in Eq. 2.7, when taking into account the contraction of the stream as it passes through the notch.

$$Q = C_d \frac{2}{3}\sqrt{2g}bh^{3/2} \tag{2.7}$$

$$Q = C_d \frac{2}{3}\sqrt{2g}(b + K_b)(h + K_h)^{3/2} \tag{2.8}$$

Catering for the dimensionless variables, such as viscosity and surface tension Eq. 2.7 gives the following limits of applications (ASTM, 1993)

$H/P \le 2$, $H \ge 0.003$ m, $B \ge 0.15$ m and $P \ge 0.1$ m, $K_b$ and $K_h$ are factors which cater for the effect of viscosity and surface tension. Kindsvater and Carter (1957) provided the information shown in Fig. 2.4 (ISO 1980) where from the $K_b$ values can be read off for ratios of b/B.

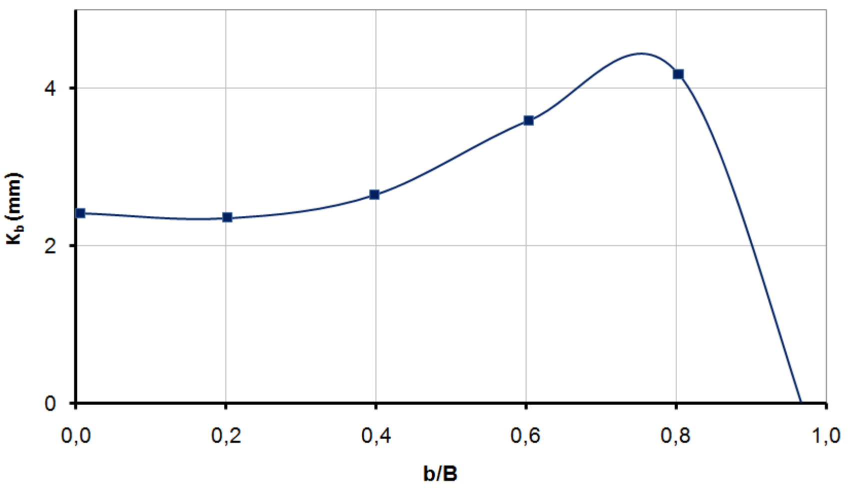



Figure 2.4 $K_b$ values for a rectangular notch (after Georgia Institute of Technology) (LMNO Engineering, 1999-2007; ISO, 1980)

Figure 2.5 shows the coefficient of discharge ($C_d$) values for ratios h/P and b/B, also derived by Kindsvater & Carter (1959) with LMNO fit (LMNO Engineering, 1999-2007) which indicates the fit accuracy of the equation.

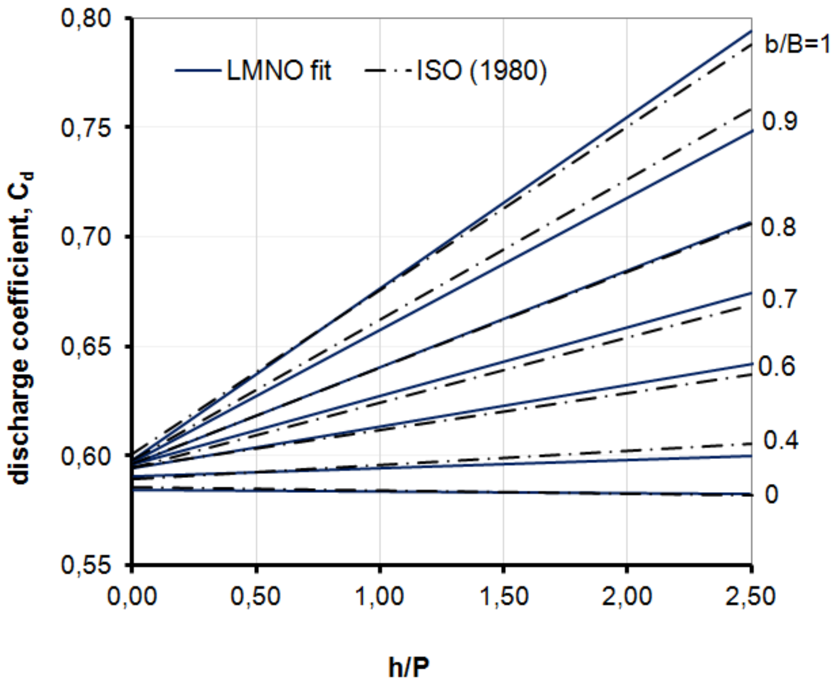



Figure 2.5 $C_d$ as a function of the ratios b/B and h/P, (after Georgia Institute of Technology) (LMNO Engineering,1999-2007; ISO 1980)

### 2.5.2 Design and Installation

The installation guidelines and applicability of the rectangular notch equation are as follows (Replogle, 2006; ASTM, 1993; USBR, 1997 and ISO, 1980):

- The value of (b-B) must be greater than $4H_{max}$
- The opening of the notch should be between 1 and 2 mm thick. If the thickness of the notch is more than 2 mm, the downstream verge of the crest should be bevelled at an angle greater than $45^0$ so that the water does not adhere to the downstream face of the notch
- The notch width should be at least 0.15 m
- The measured head should be greater than 0.03 m and
- The water surface downstream of the notch should be at least 0.06 m below the notch crest.

### 2.6 V-Notch

A V-notch is a symmetrical triangular excision from a thin-plate with top downwards as shown in Fig. 2.6 (Replogle 2006). Its advantage lies in the ability to measure low discharge accurately and to cover a wide range of flows, even small ones. The popular angle sizes of the notch are 90, 60 and 45 degrees. According to Ackers et al. (1978) the following researchers studied the flow rate measurement of water using a V-notch (Numachi et al., 1940; Greve, 1932; Cone, 1916; Yarnall, 1912; Barr, 1910; Shen, 1960 and Thomson, 1876 & 1861).

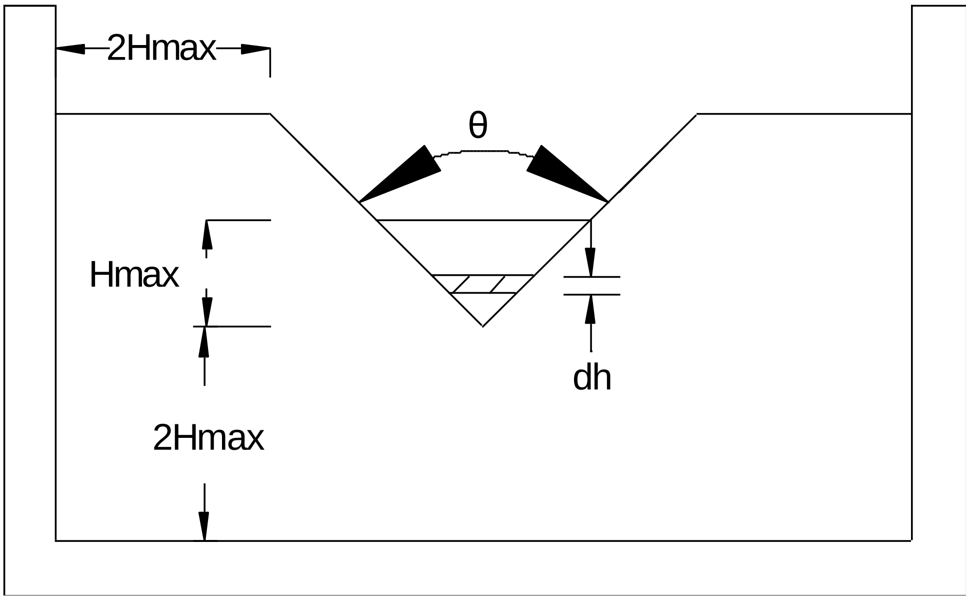



Figure 2.6 geometry of V-notch (Replogle, 2006, Ackers et al., 1978)

The basic principle of V-notch is that the water level above the bottom of the V; referred to as head (h) is directly related to the discharge (Bergmann, 1963).

#### 2.6.1 V-notch equation

The basic equation used to analyse the V-notch experimental data is as follows (Shen, 1960):

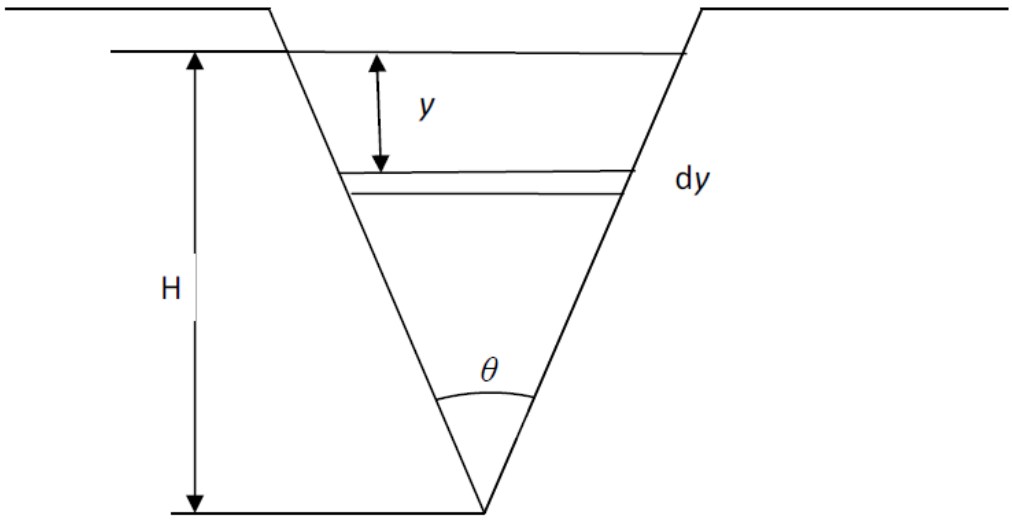



Figure 2.7 V-notch basic equation ( Ackers et al., 1978)

$$dQ = C_d \times \sqrt{(2gy)} \times 2(H - y)\tan\left(\theta/2\right)dy \tag{2.9}$$

Therefore

$$Q = C_d \times \sqrt{2g} \times \tan\left(\theta/2\right) \int_0^H \left(H\sqrt{y} - y^{2/3}\right)dy \tag{2.10}$$

After integration, Eq. 2.10 yields:

$$Q = C_d \frac{8}{15}\tan\frac{\theta}{2}\sqrt{2g}\,H^{5/2} \tag{2.11}$$

However, the flow of water over the V-notch should be defined by the following quantities: the mass flow rate; the elevation of the upstream water surface relative to the vertex of the notch, acceleration due to gravity; fluid viscosity; surface tension of fluid; angle of notch and mass density of fluid (Ackers et al., 1978).

The Buckingham π-theorem can be used to articulate the above variables to dimensionless ratios which explains their functional relationship:

$$\frac{M}{h^2\rho\sqrt{gh}} = \phi_1\left(\theta; \frac{M}{h\mu}; \frac{M\sqrt{g}}{\sigma\sqrt{h}}\right) \tag{2.12}$$

Reverting to the conventional volumetric flow rate Q, the above may be converted to

$$Q = \sqrt{g}h^{5/2}\varphi_1 \quad \theta; \frac{h\sqrt{gh}}{\mu/\rho}; \frac{h^2 g}{\sigma/\rho} \tag{2.13}$$

Where

$$C_d = \phi_1(\text{Re}; \text{We}) \tag{2.14}$$

The Weber number was not incorporated in this work.

Taking note of the limitations on the proximity of bed and walls, the present state of knowledge on the flow of water through V-notches can be expressed by Shen's equation which was used by Kindsvater and Carter (1957), and has been standardised by USBR (1997), ASTM (1993) and ISO (1980) to be.

$$Q = \frac{8}{15}\sqrt{2}C_e \tan\left(\frac{\theta}{2}\right)\sqrt{g}(h_1 + k_h)^{5/2} \tag{2.15}$$

Where $K_h$ is a theoretical vertical displacement of the vertex which is given as:

$$h_e = h_1 + k_h \tag{2.16}$$

$K_h$ may be read from Fig. 2.7 which represents the head correction factor and verifies Shen's conclusion regarding the variation of Ce with θ.

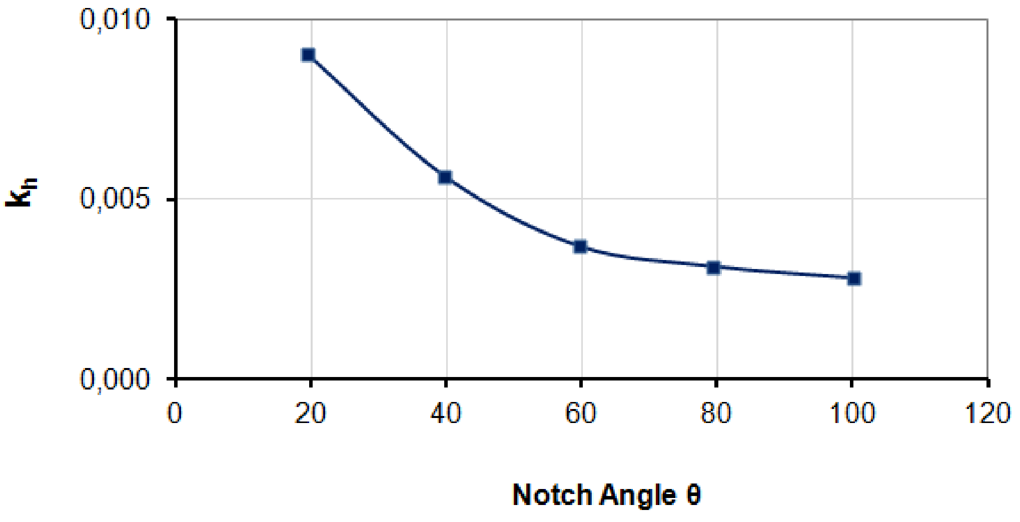



Figure 2.8 V-notch: values of $K_h$ vs notch angle (LMNO Engineering,1999-2007; ASTM, 1993; USBR, 1997; BSI, 1966)

For water at temperatures from 5 to 30° C the effective coefficient of discharge (Ce) for a fully contracted V-notch as a function of the notch angle θ is illustrated in Fig. 2.9.

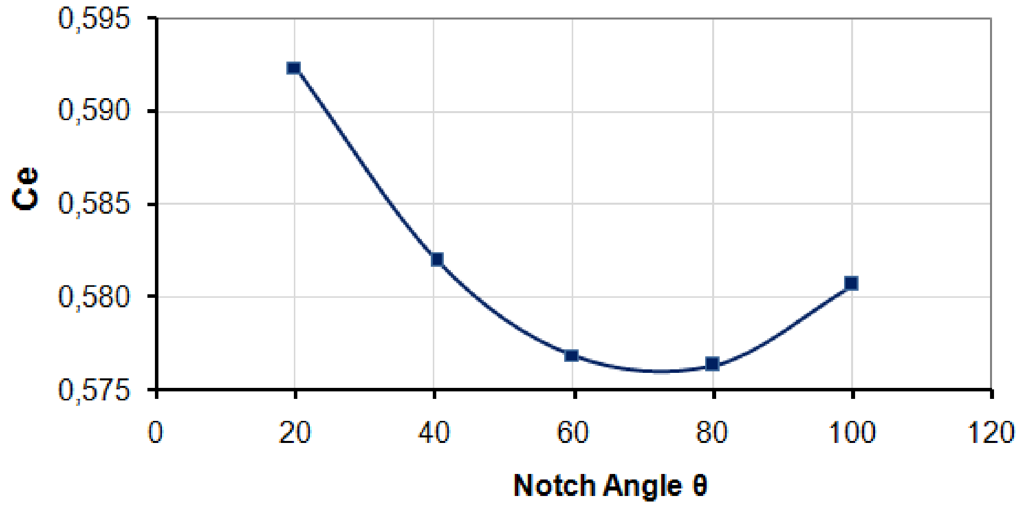



Figure 2.9 V-notch: Relationship of Ce and notch angle (LMNO Engineering, 1999-2007; ASTM, 1993; USBR, 1997; BSI, 1966)

### 2.6.2 Design and Installation

The explanation of design, installation and conditions for using V-notches is outlined below (Replogle, 2006; USBR, 1997; Ackers et al., 1978):

- The minimum distance of the sides of the notch from the channel banks and the minimum distance from the crest of the pool bottom should be at least twice the maximum expected head on the notch.
- The notch should be between 0.8 to 2 mm thick or if it is not then the downstream edge of the notch should be chamfered at a recommended angle of 60° so that the water does not cling to the downstream side of the notch.
- The water depth should be gauged at a distance of at least 4H upstream of the notch.

The conditions for full contraction of V-notches are as follows (ASTM, 1993): $H/P \leq 0.4$; $P \geq 0.45$ m; $B \geq 0.9$ m and $0.05 \text{ m} \leq H \leq 0.38$ m

The limiting conditions are (ASTM, 1993; ISO, 1980; BSI, 1965): $H/P \leq 1.2$; $H/B \leq 0.4$; $P \geq 0.1$ m; $B \geq 0.6$ m and $0.05 \text{ m} \leq H \leq 0.6$ m.

## 2.7 Fluid properties

Fluids can generally be classified as Newtonian and Non-Newtonian which can be rheologically classified. This is discussed in the following sections.

### 2.7.1 Measurement of rheological parameters of the fluids

Rheology is the study of the deformation and flow of matter. The Rheogram (relationship between shear stress and shear rate) of these fluids are shown in Fig. 2.10.

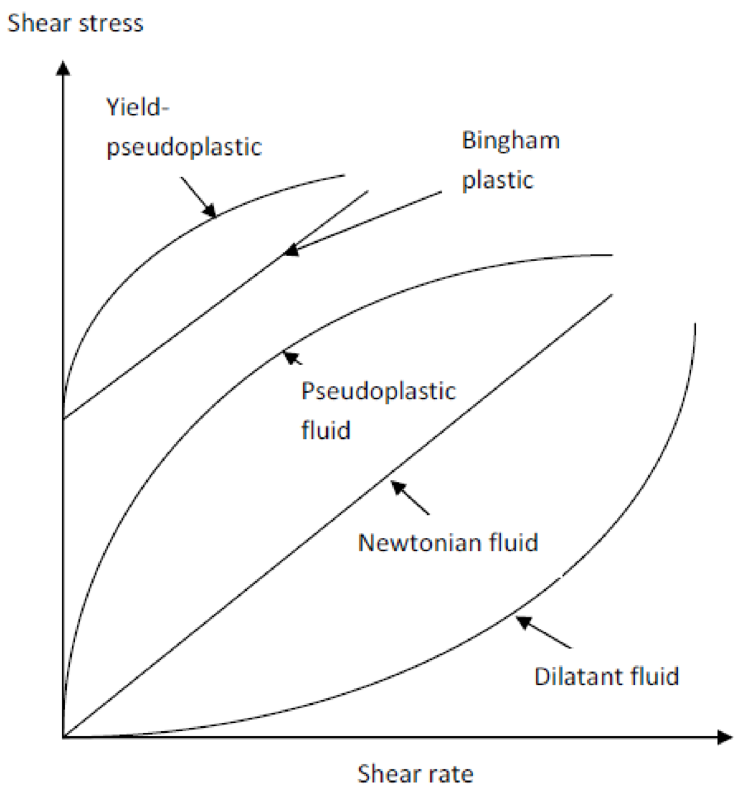



Figure 2.10 Qualitative flow curves for different types of non-Newtonian fluids (Chhabra and Richardson 2008)

A viscometer is a device for measuring the viscous properties or rheology of fluids. The following viscometers can be used to carry out viscosity measurements: capillary viscometers (Cai et al., 2005), rotating viscometers (Madan & Mazumdar, 2004), and falling ball or needle viscometers (Caetano et al., 2004 and Wilhelm et al., 1998).

The capillary or tube viscometer has been used for decades and remains the most commonly used device for measuring rheological properties for Newtonian and non-Newtonian fluids. This is because of its simplicity and accuracy (Macosko, 1993; Mezger

2006; and Chhabra & Richardson 2008). Steffe (1996) stated that data obtained from a tube viscometer are pressure drop and volumetric flow rate which have to be transformed into shear stress and shear rate. The results obtained are used to form a flow curve and the fluid parameters can be determined.

### 2.7.2 Viscosity

Fluid flow has internal friction that opposes any dynamic change in its motion, and is referred to viscosity. Furthermore, viscosity is described as the ratio of the shearing stress to the shearing rate in steady-state flow according to Newton's law which is defined by Eq. 2.17 (Bird, 2002 and Kestin, 1988).

Viscous fluids are characterised either as Newtonian or non-Newtonian.

The apparent viscosity of fluids is expressed as:

$$\mu = \frac{\tau}{\left(\frac{dv}{dz}\right)} \tag{2.17}$$

and for pseudoplastic and dilitant fluids, it is given by:

$$\mu = \frac{k\left[-\frac{dv}{dz}\right]^{n}}{\left[\frac{dv}{dz}\right]} = k\left[-\frac{dv}{dz}\right]^{n-1} \tag{2.18}$$

### 2.7.3 Yield Stress

The yield stress is considered as a true material property by many researchers (Nguyen and Boger, 1983, Kelessidis et al., 2006), even though its existence has been debated over many years (Barnes 1999 and 1985). It is the measure of the strength of a structure formed by dispersed solid particles which causes the material to flow. According to Stokes & Telford (2004) and Cheng (1986) the yield stress is characterised as a time dependent property (Kelessidis et al., 2007).

### 2.7.4 Newtonian fluids

Classification of fluids is based on the relationship between shear stress and shear rate. Myles (2003), Chhabra and Richardson (2008) and Kobo (2009) define a Newtonian fluid as a liquid which has a linear relationship between the applied shear stress and shear rate, such as water and cooking oil. Figure 2.11 illustrates a fluid between two parallel plates under steady state conditions. Force F is applied to the fluid as shown, so the fluid is subjected to shear, which is balanced by an equal and opposite internal frictional force in the fluid.

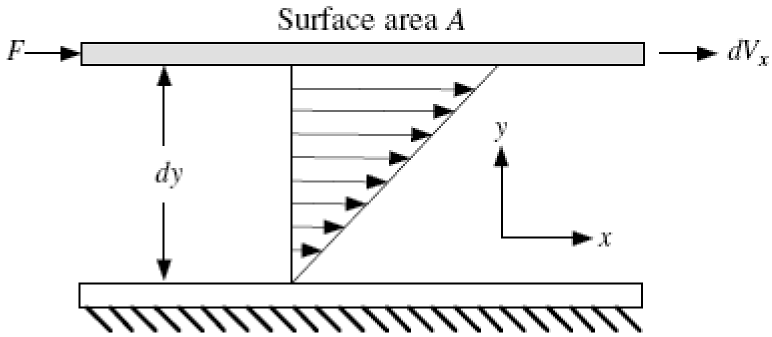



Figure 2.11 Schematic representation of unidirectional shearing flow (Chhabra and Richardson, 2008)

For flow of a Newtonian fluid in laminar and incompressible conditions, the shear stress will be equivalent to the product of the shear rate and the viscosity of the fluid medium. Therefore, the shear rate may be articulated as the velocity gradient in the direction at right angles to that of the shear force as given in Eq. 2.19 (Chhabra & Richardson, 2008).

$$\frac{F}{A} = \tau_{yx} = \mu\left(-\frac{dV_x}{dy}\right) = \mu\dot{\gamma}_{yx} \qquad (2.19)$$

### 2.7.5 Non-Newtonian fluids

Non-Newtonian fluids have a complex behaviour, which does not result in a linear relationship between shear stress and shear rate (Metzner & Reed, 1955; Malkin & Isayev, 2006; Chhabra & Richardson, 2008) and therefore they do not obey Newton's law of viscosity. They are categorised into three groups which are time-independent, time dependent and visco-elastic fluids (Rashaida, 2005; Chhabra & Richardson, 2008). Non-Newtonian fluids are characterised by different rheological models (Myles, 2003; Malkin & Isayev, 2006), some of which are the Bingham plastic, pseudoplastic and yield-pseudoplastic or Herschel-Bulkely models. For this work only time independent fluids were considered.

### 2.7.6 Time-Independent fluids

According to Skelland (1967), the nominal viscosity of a time-independent non-Newtonian fluid is reliant on the shear rate. The flow behaviour is characterised as shear thinning, shear thickening, or viscoplastic depending on the apparent viscosity fluctuations with shear rate.

### 2.7.7 Shear thinning fluids

Chhabra and Richardson (2008) define pseudoplastic behaviour of a fluid as that which does not need a yield stress for it to start shearing. Shear stress and shear rate can be plotted on double logarithmic scale in order to depict more easily their relationship. For a shear-thinning fluid the correlation is estimated by a straight line which is a power law relationship (Chhabra & Richardson, 2008 and de Waele, 1923). Shear stress is expressed as follows:

$$\tau = k\left[-\frac{dv}{dz}\right]^n \tag{2.20}$$

When $n < 1$, the fluid is pseudoplastic (shear thinning) or when $n > 1$, the fluid is known as dilatant (shear thickening) and when $n = 1$, the fluid is Newtonian and $k = \mu$.

The Herschel–Bulkley model (Herschel & Bulkley, 1926) for the yield-pseudoplastic behaviour (Slatter, 1994) can be formulated as:

$$\tau = \tau_y + K\left[-\frac{du}{dy}\right]^n \tag{2.21}$$

### 2.7.8 Viscoplastic fluids

Viscoplastic fluids require initial stress to initiate shearing. This means the fluid behaves like a solid below a certain critical shear stress. However, the material flows like a fluid once that shear stress value is exceeded. Bingham plastics are classified as viscoplastic fluids and once they start to flow they exhibit a linear relationship between shear stress and shear rate (Rashaida, 2005). The Bingham plastic model is expressed in Eq. 2.22 as:

$$\tau = \tau_y + K\left[-\frac{du}{dy}\right] \tag{2.22}$$

### 2.8 Research on sharp crested notches

The research on notches started prior to 1850 for water. According to Horton (1907) the East Indian engineers developed an equation for sharp crested notches. The maximum $C_d$ value obtained was 0.654 and decreased slowly as the head increased.

The V-notches with angles not exceeding 90° were used to measure the flow rate of fuel oil (oil A) and dustproofing oil (oil G) at room temperature (Lenz, 1943). A tank used was 1.1 m wide with the notch vertex about 1 m above the floor and the crest thickness was 0.8 mm. The following empirical equation was used to compute the experimental coefficients (C). This was proof that notches could be used to measure the flow rate of viscous liquids.

$$C = 0.56 + \frac{B}{Re^n We^m} \tag{2.23}$$

The values B, n, and m are functions of the angle of notch and may be calculated from the following equations

$$B = 0.475 + \frac{0.225}{\left(\tan\frac{\theta}{2}\right)^{0.80}} \tag{2.24}$$

$$n = 0.165\left(\tan\frac{\theta}{2}\right)^{-8.80} \tag{2.25}$$

$$m = \frac{0.170}{\left(\tan\frac{\theta}{2}\right)^{0.035}} \tag{2.26}$$

$$Re = \frac{h_1\sqrt{gh_1}}{\mu/\rho} \tag{2. 27}$$

$$We = \frac{\rho g h_1^2}{\sigma} \tag{2.28}$$

Limitations to be observed are:

$We > 300$

$Re > 300\left(\tan\frac{\theta}{2}\right)^{-0.75}$

$28^o < \theta < 90^o$

$\mu/\rho = V < 1.4\ cm^2/s$

$\sigma < 73\ dynes/cm^2$

If values of Re and We are large, the term α/Re, We becomes small; if this term is less than 0.21, Eq. 2.23 should be replaced by the limiting value, $C_d = 0.438$.

Lenz (1943) discovered that there was an increase in the $C_d$ value with an increase in viscosity as shown in Fig 2.12. The broken line at low heads of oil A at 70° indicates the extension of Eq. 2.23 beyond its range of usefulness. The dots represent Yarnall (1912) data.

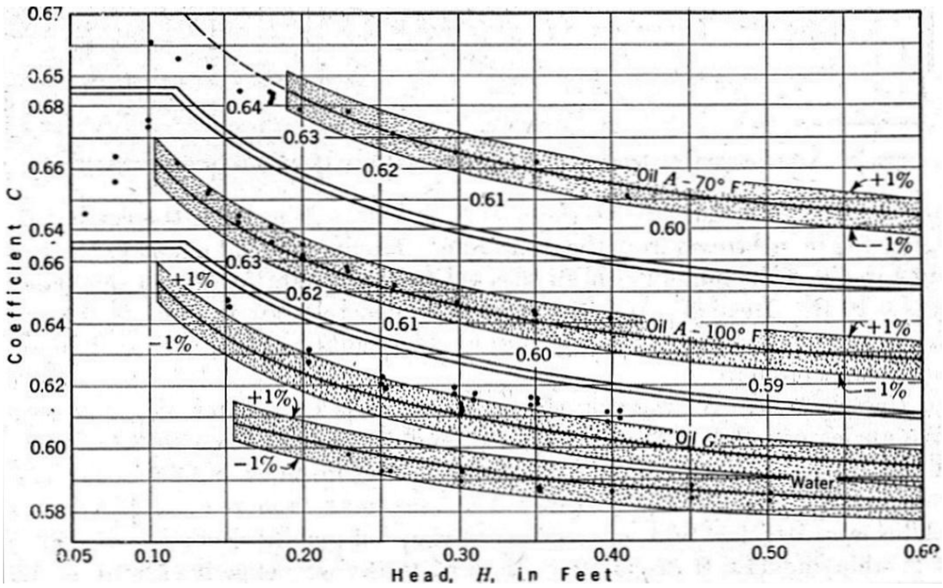



Figure 2.12 The effect of surface tension and viscosity of a V-notch coeficient C values(Lenz,1943)

Haldenwang et al. (2007) investigated the relationship between $C_d$ and total head for different concentrations of kaolin and bentonite suspensions for rectangular and V-notches. The results presented in Figs 2.13, 2.14 2.15 and 2.16 show that there was a significant increase in $C_d$ values with increase in concentration for rectangular and V notches. It was also mentioned that the curvatures from the data exist because of laminar conditions at low flow rates and the linear behaviour indicates the fully turbulent conditions.

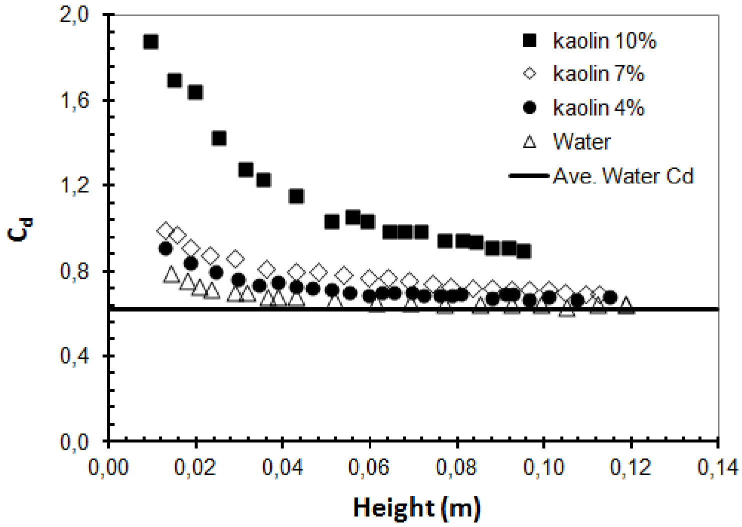



Figure 2.13 $C_d$ values for kaolin suspension in a rectangular notch (Haldenwang et al., 2007)

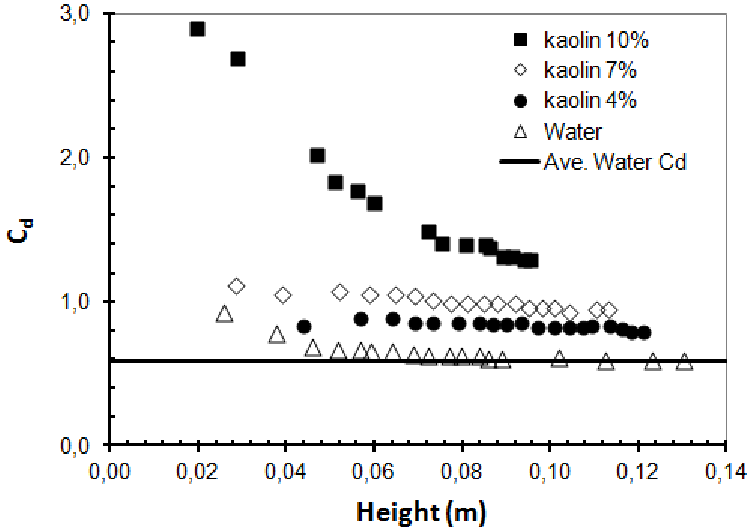



Figure 2.14 $C_d$ values for kaolin suspension in a V-notch (Haldenwang et al., 2007)

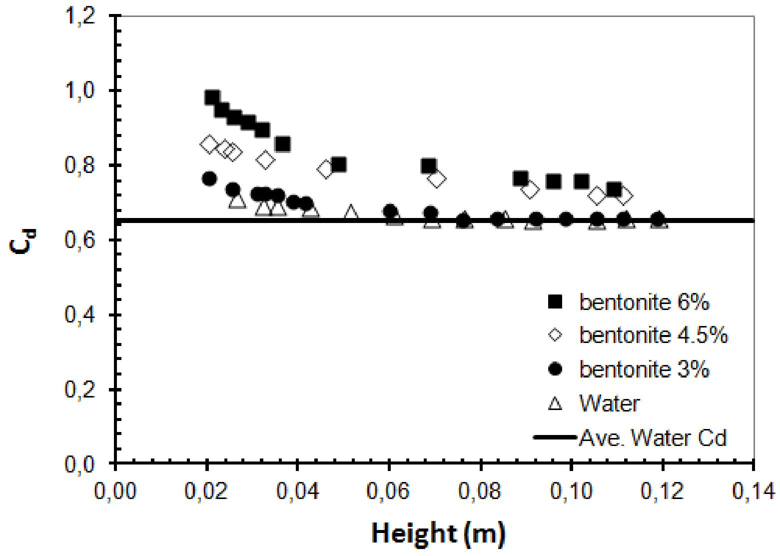



Figure 2.15 $C_d$ values for bentonite suspension in rectangular notch (Haldenwang et al., 2007)

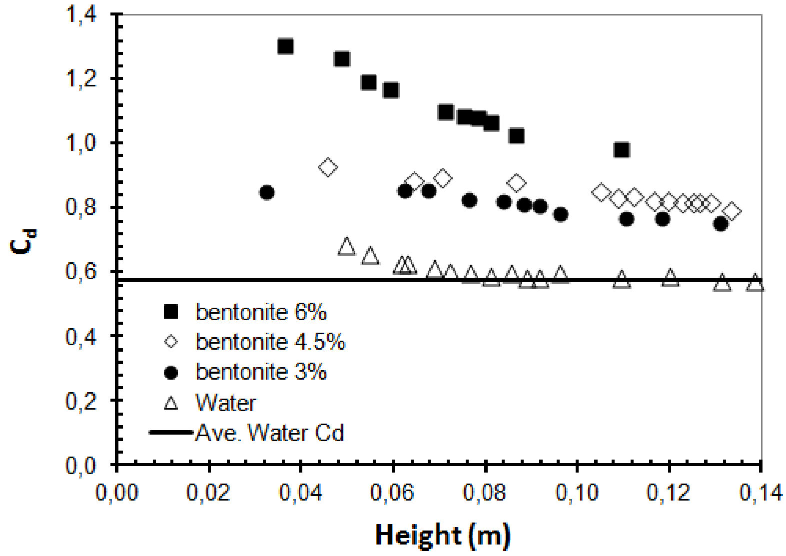



Figure 2.16 $C_d$ values for bentonite suspension in V-notch (Haldenwang et al., 2007)

Haldenwang et al. (2007) attempted to determine a relationship between the discharge coefficients and yield stress for non-Newtonian fluids as shown in Fig 2.17. Results showed that with an increase in concentration and yield stress, there was an increase in $C_d$ values.

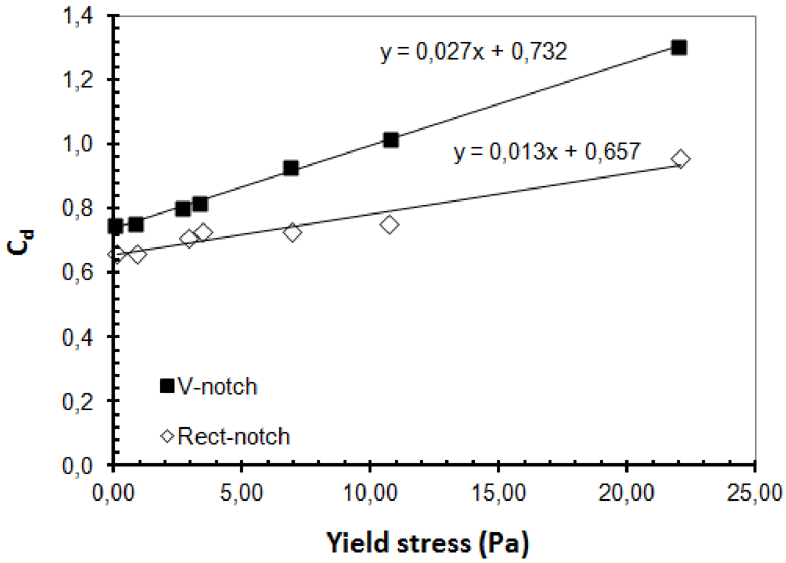



Figure 2.17 Relationship between $C_d$ and yield stress for rectangular and V notches and all concentrations (Haldenwang et al., 2007)

The $C_d$ values of non-Newtonian fluids were compared to constant $C_d$ value for water for both rectangular and V-notches in order to predict discharge coefficient of non-Newtonian fluids. Equations 2.29 and 2.30 for rectangular and V notches were formulated.

Rectangular notch $C_{d(yield\ stress)}$ prediction equation

$$C_{d(yield stress fluid)} = C_{d(water)} + 0.0267\tau_y \quad (2.29)$$

V-notch $C_{d(yield\ stress)}$ prediction equation

$$C_{d(yield stress fluid)} = C_{d(water)} + 0.0127\tau_y \quad (2.30)$$

**2.9 Reynolds number: Previous work**

Research has been done on flow rate measurement of water using notches but there is little research available on the flow rate measurement of non-Newtonian fluids using the same devices. Therefore the work done in open channels and orifices establishing coefficient of discharge and Reynolds number relationships was considered.

### 2.9.1 Previous research using notches

Arvanaghi and Oskuei (2013) investigated the effect of Reynolds number on notch discharge coefficients for water using experimental data as shown in Fig. 2.18. However the notches used were without end contractions. The results obtained show that the $C_d$ values were at a fixed value of 0.7 when Re > 20000.

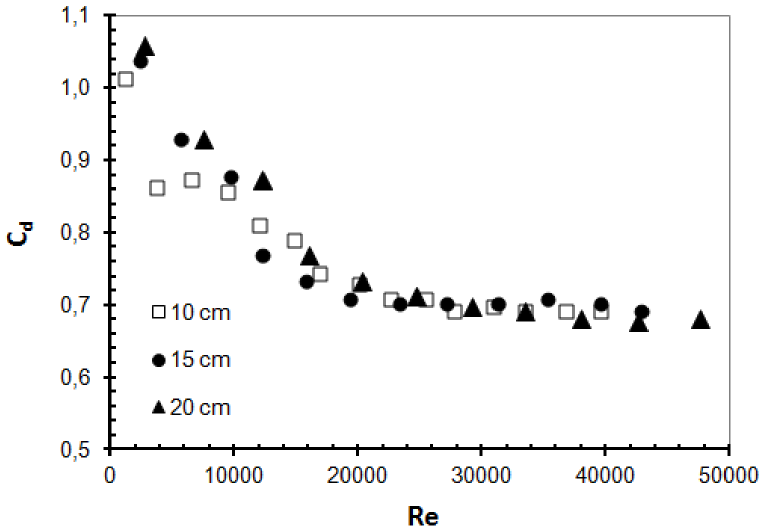



Figure 2.18 Experimental $C_d$ vs. Re (Arvanaghi and Oskuei, 2013)

Ramamurthy et al. (2013) conducted a study on the flow rate measurement of water through multi-slit rectangular and V-notches. They analysed their results based on the Reynolds number-$C_d$ relationship and concluded that at large Reynolds number, $C_d$ attains the value of 0.61 as shown in Fig. 2.19. They used the following equation to calculate the $C_d$ values:

$$C_d = 0.575 + \frac{9.71}{Re_R^{\ 0.12}} \tag{2.31}$$

Where

$$Re_R = \frac{V(2R_h)}{\nu} \tag{2.32}$$

and

$$Re_b = \frac{VL}{\nu} \tag{2.33}$$

$$L = 2R_h \tag{2.34}$$

and

$$R_h = \frac{P_w}{A} \tag{2.35}$$

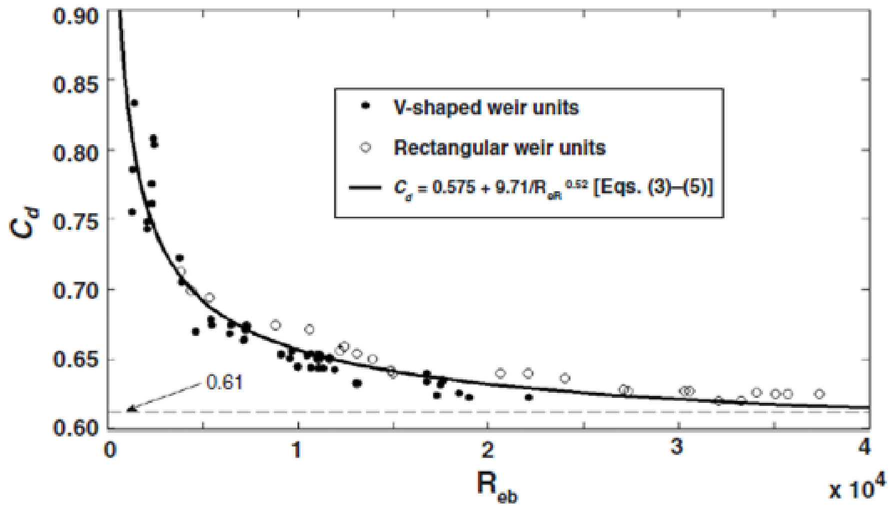



Figure 2.19 $C_d$ versus $R_{eR}$ for rectangular and V-shaped multislit notches (Ramamurthy et al., 2013)

### 2.9.2 Previous research in open channels

In a study done by Burger et al. (2010) the effect of open channel (rectangular, semi-circular, triangular and trapezoidal) shape on the friction factor-Reynolds number relationship for laminar flow of non-Newtonian fluids was determined. They concluded that for open channel flow of non-Newtonian fluids the laminar flow friction factor versus Reynolds number can be expressed as $f$ = K/Re. This conclusion corresponds with findings of Straub et al. (1958), Lansford and Robertson (1958) and Chow (1959) for laminar flow of Newtonian fluids in open channels with different cross-sections.

Haldenwang et al. (2002) developed an equation to define the Reynolds number ($Re_H$) in an open channel based on the yield-pseudoplastic or Herschel-Bulkley theoretical model adapted from the work done by Slatter (1994) for the pipe flow. This is given in Eq. 2.36.

$$Re_H = \frac{\rho 8 v^2}{\tau_y + k\left(\frac{2v}{R_h}\right)^n} \tag{2.36}$$

For Newtonian Reynolds number, Eq. 2.36 reverts to

$$\mathrm{Re} = \frac{4R_h \rho v}{\mu} \tag{2.37}$$

### 2.9.3 Previous research using orifices

Torricelli (1643) developed the theorem that stated that an orifice becomes a notch when it is not at its full capacity (Horton, 1907). Therefore the research on the discharge measurement of Newtonian and non-Newtonian fluids using orifices was considered for comparison purpose in this work.

Dziubiński and Marcinkowski (2006) carried out research on the discharge of water, ethylene glycol and water solutions of starch syrup (Newtonian fluids), and CMC solution (non-Newtonian fluid) from tanks using an orifice. They used an equation developed by Metzner and Reed (1955) to compute Re for CMC solution as per Eq. 2.38.

$$\mathrm{Re}_{MR} = \frac{v^{2\ \ n} d^n \rho}{k\left((3n+1)/4n\right)^n 8^{n\ \ 1}} \tag{2.38}$$

For open channel flow equation 2.38 would be

$$\mathrm{Re}_{MR} = \frac{8v^2\rho}{k'\left(\frac{2v}{R_h}\right)^{n'}} \tag{2.39}$$

with

$$k' = k\left(\frac{3n+1}{4n}\right)^n \text{ and } n=n'$$

The discharge coefficient of Newtonian fluids and CMC solutions were plotted against Reynolds number as shown in Figs. 2.20 and 2.21. It was found that the discharge coefficient ($\phi$) of both Newtonian fluids and CMC solutions increased with an increasing Reynolds number for the laminar flow region and became constant in the turbulent flow region. The discharge coefficient of Newtonian fluids was 0.62 and became constant at Re > 100. The experimental points at Re < 10 were approximated by the curves that are described by the power equation:

$$\phi = b\mathrm{Re}^C \tag{2.40}$$

The constants b and c depend on the orifice geometry and for this study c is close to 0.5. Therefore the coefficient of discharge becomes

$$\phi = B^{'}\sqrt{Re} \tag{2.41}$$

Coefficient $B^{'}$ depends on the ratio of orifice length to diameter L/d. As a result $B^{'}$ is approximated by:

$$B^{'} = A_1 + A_2\left(\frac{L}{d}\right)^{A_3} \tag{2.42}$$

The coefficients $A_1$, $A_2$, and $A_3$ were obtained by correlating experimental data from Fig. 2.20. Thus the coefficient of discharge correlation equation at the flow for Newtonian fluids from tanks through a small cylindrical orifice was established to be:

$$\phi = \left[0.186 - 0.0756\left(\frac{L}{d}\right)^{0.333}\right]\sqrt{Re} \tag{2.43}$$

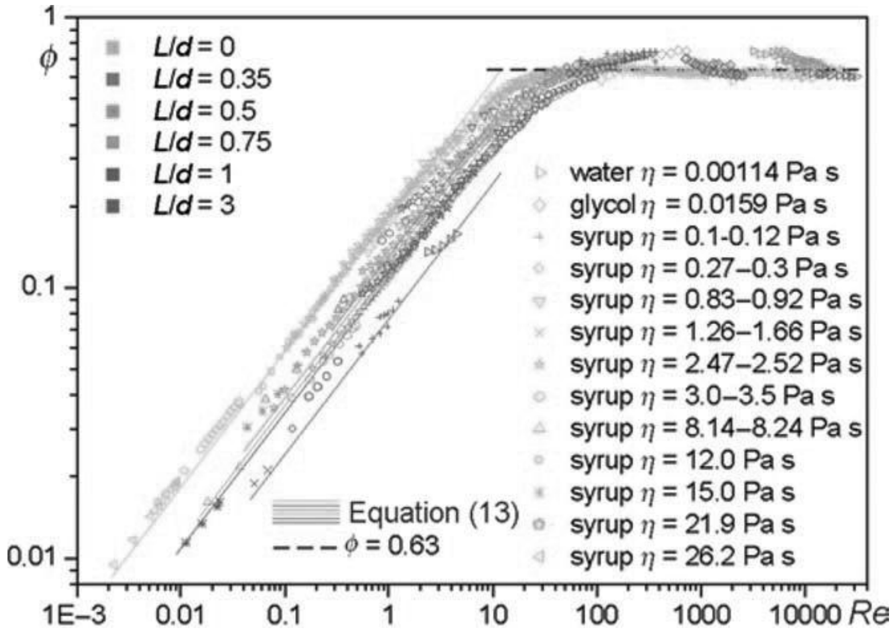



Figure 2.20 Dependence of discharge coefficient on Reynolds number for Newtonian fluids (Dziubiński and Marcinkowiski 2006)

The discharge coefficient values obtained experimentally and those calculated from Eq. 2.43 were compared and the mean relative error of the description of experimental data was equal to 7.1% as shown in Fig. 2.21.

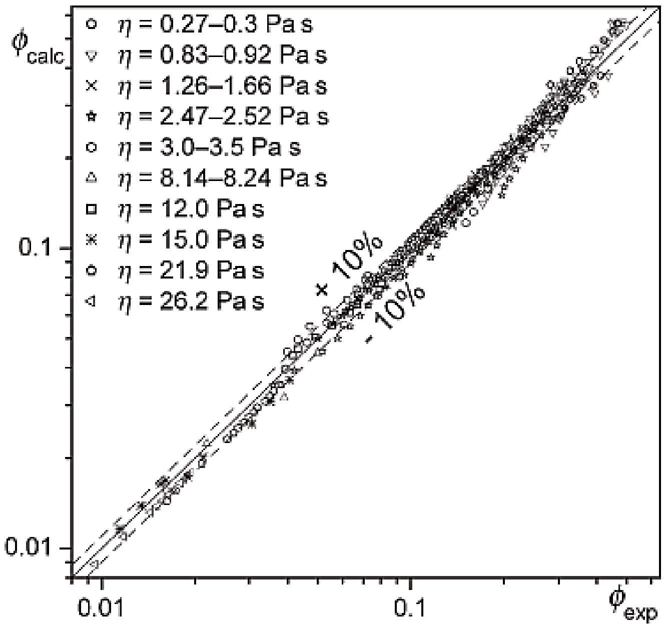



Figure 2.21 Comparison of Discharge coefficient of Newtonian liquids obtained experimentally and calculated from Eq. 2.45 (Dziubiński and Marcinkowiski 2006)

The discharge coefficient for non-Newtonian fluids was calculated as a function of the generalised Metzner-Reed Reynolds number $Re_{MR}$ (Eq. 2.38). The discharge coefficient increases with increasing Reynolds number and becomes constant at $Re_{MR}$ > 100. The average coefficient of discharge obtained is 0.67 (Fig 2.22). For the Reynolds number $Re_{MR}$ < 100, the experimental data are described as in the case of discharge of Newtonian liquids from tanks. The equation obtained for the discharge coefficient is as follows:

$$\phi = \left[0.101 - 0.0164\left(\frac{L}{d}\right)^{0.48}\right] Re_{MR}^{0.426} \tag{2.44}$$

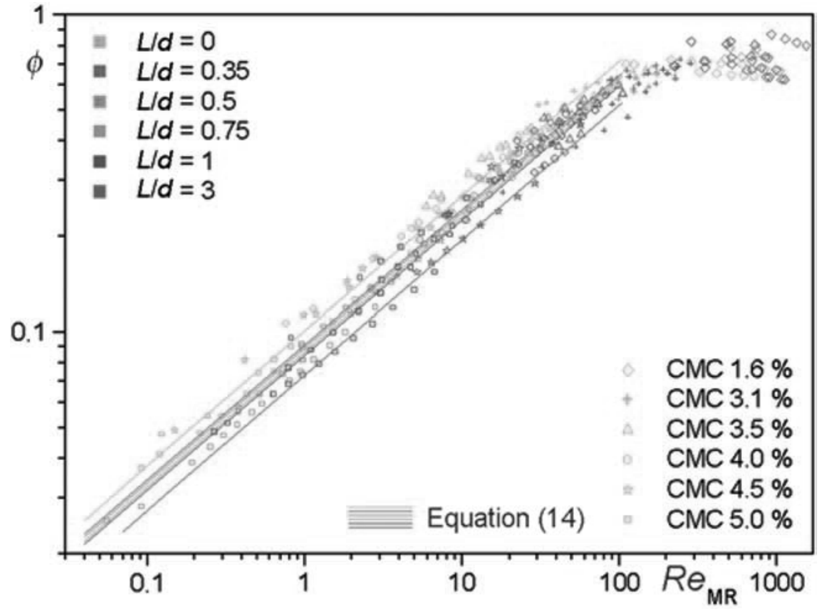



Figure 2.22 Discharge coefficient versus generalised Reynolds number $Re_{MR}$ for selected L/d values for CMC solutions (Dziubiński and Marcinkowiski 2006)

Figure 2.23 presents a comparison of discharge coefficient obtained experimentally and that calculated from Eq. 2.44. The mean relative error was equal to 5.7%.

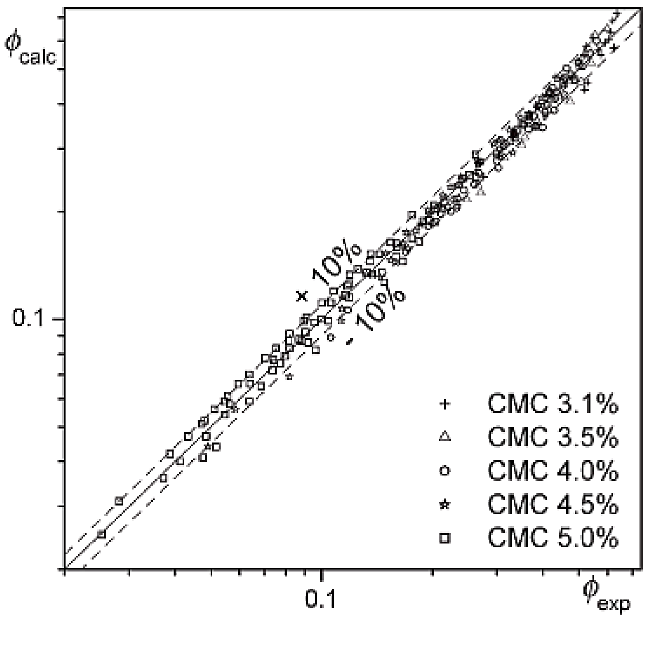



Figure 2.23 Comparison of discharge coefficient of non-Newtonian liquids obtained experimentally and calculated from Eq. 2.44 (Dziubiński and Marcinkowiski 2006)

Ntamba (2011) conducted similar research using short square-edged orifice plates for water (Newtonian fluid), CMC solution, kaolin and bentonite suspensions (non-Newtonian fluids). Similar behaviour of the fluids is observed when comparing Ntamba (2011) results with the Dziubiński and Marcinkowski (2006) results. The transition zone occurs at Reynolds number 1000, and the average coefficient of discharge in the turbulent region is constant at a value of about 0.64.

Figure 2.24 shows results of flow rate measurement obtained by Ntamba (2011) for the flow rate measurement of water, CMC solution, kaolin and bentonite suspensions through short square-edged orifice plates. He used the Slatter (1994) Reynolds number denoted as $Re_3$.

$$Re_3 = \frac{8\rho\left(V_{ann}\right)^2}{\tau_y\left(\frac{8V_{ann}}{D_{shear}}\right)^n} \qquad (2.\ 45)$$

With velocity in the annular region $V_{ann}$ and diameter of sheared part of fluid in pipe $D_{shear}$

$$V_{ann} = \frac{Q - Q_{plug}}{\pi\left(R^2 - R_{plug}^2\right)} \qquad (2.46)$$

$$D_{shear} = 2\left(R - R_{plug}\right) \qquad (2.\ 47)$$

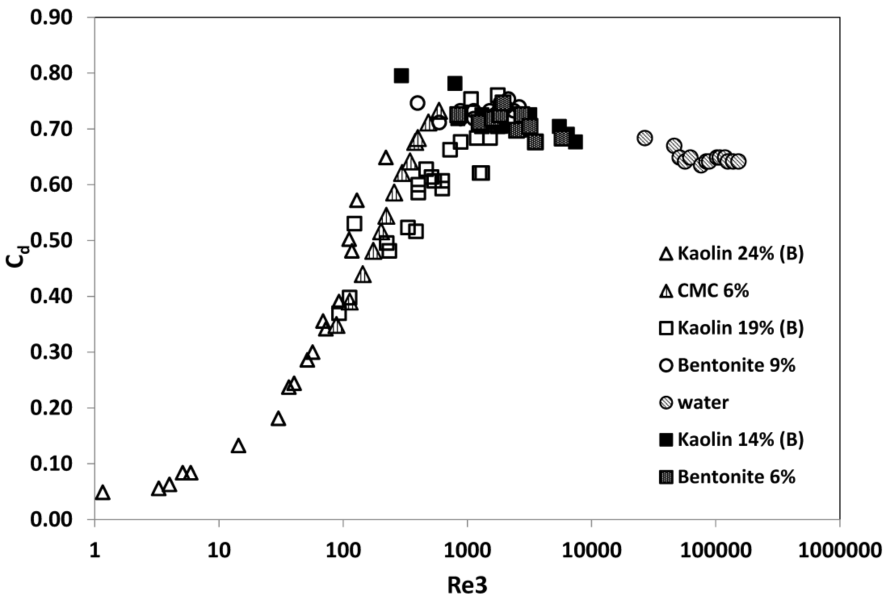



Figure 2.24 Discharge coefficient data for square-edged orifice plate with equivalent diameter ratio β = 0.7 (Ntamba, 2011)

This finding confirmed results of similar studies carried out by Troskolanski (1954), Prosnak (1970) and Kiljanski (1993) for Newtonian fluids. More studies were done by Merrit (1967) where he established the relationship between the discharge coefficient and the square root of the Reynolds number. It was observed that $C_d$ is a non-linear function of the Reynolds number and is constant at a value of 0.61 for large values of Reynolds number. Borutzky et al. (2002) used the Merrit (1967) correlation to develop an orifice flow model for energy losses in laminar and turbulent flow conditions (Fig 2.25).

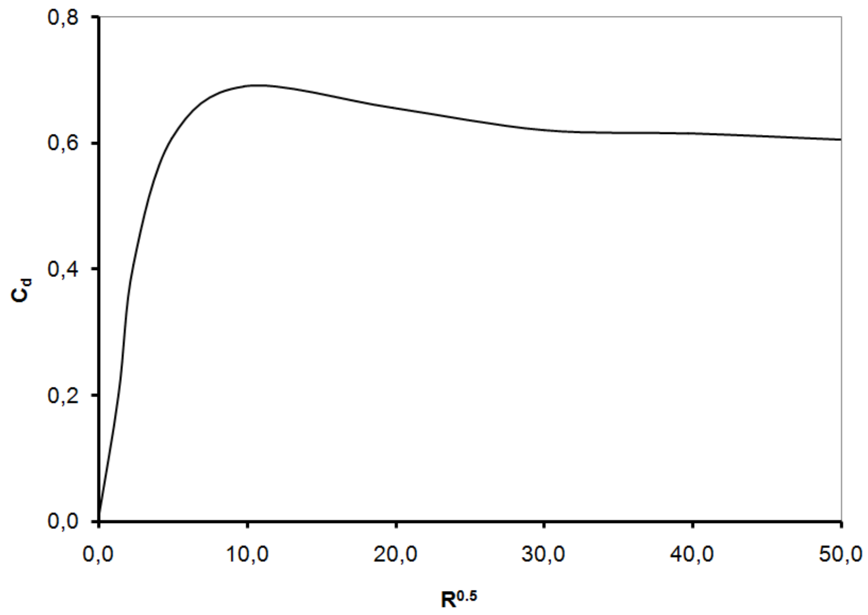



Figure 2.25 Discharge coefficient versus the square root of the Reynolds number (Merritt, 1967)

Ackers et al. (1978) theoretically illustrated that $C_d$ is a function of Reynolds number. The relationship between Reynolds number and discharge coefficient was used to analyse the flow of both Newtonian and non-Newtonian fluids in open channels and orifices. No research has been done for full contracted notches using the Reynolds number and $C_d$ relationship.

## 2.10 Data analysis

A single composite equation could be derived to predict the range of friction factors for liquid flow rates using the method described by Patankar et al. (2002). Equation 2.48 can be obtained by fitting data with a logistic dose response curve to a data set.

$$Cd = f_2 + \frac{(f_1 - f_2)}{\left(1 + \left(\frac{Re}{t}\right)^c\right)^d} \tag{2.48}$$

Where $f_1$ and $f_2$ are power laws defined as

$$f_1 = a_1 Re^{b_1} \tag{2.49}$$

**and**

$$f_2 = a_2 Re^{b_2} \tag{2.50}$$

The data can be fitted with power law correlations in the laminar and turbulent regions in order to obtain the parameters $a_1$, $a_2$, $b_1$ and $b_2$. Equation 2.48 is then fitted to all the data points to obtain parameters c, d and t using the non-linear optimisation method of Microsoft Excel solver minimising the residual mean square values. According to Patankar et al. (2002), a single composite equation infers that correlations in the entire range could be represented by power laws connected by transitions. Authors such as Garcia et al. (2003) used this technique to find the correlations for power law and composite power law friction factor for laminar and turbulent gas-liquid flow in horizontal pipelines. Haldenwang et al. (2012) used this to predict sludge pipe flow pressure drop friction factor-Reynolds number correlations based on different non-Newtonian Reynolds numbers.

## 2.11 Conclusion

The literature shows that the study of notches as flow measuring devices for Newtonian fluids has been much researched and little has been done for non-Newtonian fluids. Rectangular and V-notches are considered the simplest and most common hydraulic devices used for flow rate measurement. For each of these two types of sharp-crested notches, Kindsvater and Carter (1957) equations are presented and are used in this study. The $C_d$ graphs needed for use with these equations are also discussed. ASTM (1993) outlined the set of conditions under which the equations can be used for rectangular and V notches. Most studies report on a correlation between $C_d$ and h, but there is no explicit recognition that the correlation is evidence of the combined effects of viscosity and surface tension.

On the other hand, Lenz (1943) isolated the effects of viscosity and surface tension for flow of oil over V-notches. He found that the $C_d$ values increased with increasing viscosity. Haldenwang et al, (2007) attempted to isolate and evaluate the influence of rheological properties of non-Newtonian fluids through rectangular and V-notches and proposed a relationship between $C_d$ and yield stress. But the relationship does not include all rheological parameters of the tested fluids. It was concluded that as the concentration and yield stress increased the $C_d$ values also increased.

Since there is not much research done on the flow rate measurement of non-Newtonian fluids over notches, other flow measuring devices are considered for comparison purpose and to obtain the formulae used. The Reynolds numbers used are $Re_H$ for open channels developed by Haldenwang et al. (2002) and the $Re_{MR}$ Metzner and Reed (1955) for pipe flow but adapted for open channel flow. In the studies of orifices $C_d$ values are correlated to Reynolds number (Merrit, 1967; Dziubiński & Marcinkowski, 2006 and Ntamba, 2011). In order to obtain the Reynolds number for non-Newtonian fluids, rheological parameters of the fluids must be known. The models used to characterise non-Newtonian fluids for this study are Bingham plastic, pseodoplastic and yield-pseudoplastic or Herschel-Bulkly.

The data analysis method described by Patankar et al. (2002) where a single composite equation is used is discussed. The method entails fitting of data to a logistic dose response curve to predict the range of friction factors for liquid flow rates. This technique was used by authors such as Garcia et al. (2003) and Haldenwang et al. (2012).

From the above it is clear that there is no model available to predict the $C_d$ values for non-Newtonian fluids. As a result it is necessary to study the flow rate measurement of non-Newtonian fluids through notches and develop the model that can be used to predict the $C_d$ values.

# CHAPTER THREE
## RESEARCH METHOD

### 3.1 Introduction

This chapter describes the equipment used and practical procedures followed to obtain data and methods used to process the data. The facilities in the Flow Process Research Centre slurry laboratory were used to conduct all experiments. A flume rig was used to conduct all the tests. It comprised of a mixing tank, positive displacement pump, centrifugal pump, in-line tube viscometer, 900 by 900 mm square tank, and a 10 m long flume. Flow meters were fitted to the tube viscometer. V and rectangular notches, and three depth gauges were assembled at the inlet tank. A data acquisition unit and a computer were used to capture and process data. Water was used for in-line tube viscometer and notch calibration. Different concentrations of kaolin suspensions (yield pseudo-plastic behaviour), CMC solutions (power law behaviour) and bentonite suspensions (Bingham plastic behaviour) were prepared and tested.

### 3.2 Equipment

#### 3.2.1 Mixing tank and an electric mixer

The mixing tank had a capacity of 2000 litres. It was used as a main storage unit for all fluids. It was connected to the rest of the rig by pipe fittings and valves. An electric mixer was attached to the tank which could be controlled to produce varying mixing speeds (Fig. 3.1). This mixer was mainly used to mix water with the powdery materials to form a suspension or slurry and to avoid settlement of suspensions. The fluids were pumped from the mixing tank using a progressive cavity positive displacement pump.

#### 3.2.2 Pump

The progressive cavity positive displacement pump was a 100 mm 30 bar pump driven by a 17 kW motor and regulated by a variable speed drive capable of delivering approximately 25 l/s of water. The pump was used to circulate the fluids from the mixing tank through the in-line tube viscometer to the flume.

#### 3.2.3 An in-line tube viscometer and flow meters

The fluid was pumped from the mixing tank to an in-line tube viscometer (Fig 3.1). The in-line tube viscometer was used because it enabled the real time properties of the measured fluids. The system consisted of a heat exchanger to regulate the fluid temperature before entering an in-line tube viscometer. The tube viscometer comprised of 13, 28 and 80 mm diameter tubes and was used to determine the rheological properties of the test fluids. The entry length to the differential pressure transducers was at least 50 mm pipe diameters to ensure that flow was fully developed. Flushing pods were connected at the centre of each pipe by means of two pressure tapping points. The flushing pods were connected to high (0-30 kPa and low (0-4 kPa differential Fuji pressure transducers cells (DPT's). They established the differential change in pressure between tapping points along each pipe. The temperature, density and flow rate were measured by a mass flow meter connected to the 13 mm diameter pipe. Each pipe had a Krohne magnetic flow meter to measure the flow rate of the fluids pumped through the rig. From the in-line tube viscometer the fluid was pumped to a 900 by 900 mm square tank at the entrance to the flume. The test rig and calibration procedure is described in detail by Haldenwang (2003). Haldenwang (2003) designed and assembled this flume rig to be used for research purposes.

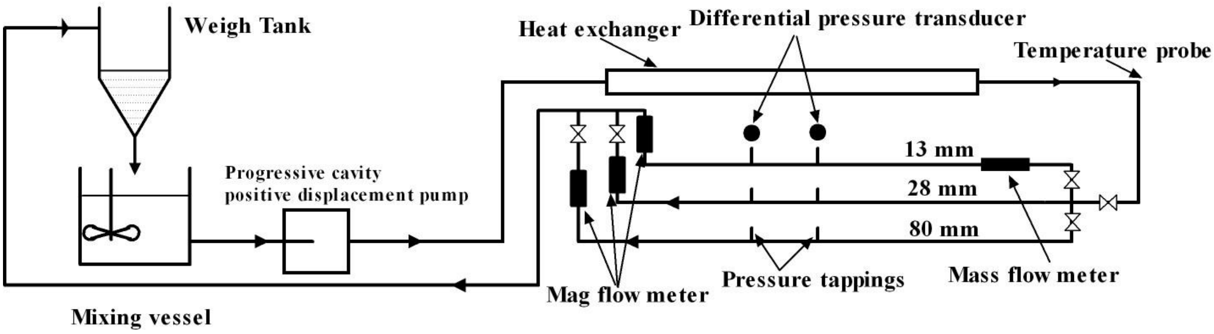



Figure 3.1 Mixing tank, pump and tube viscometer (Haldenwang 2003)

### 3.2.4 Inlet tank, depth gauges and notches

The fluid flowed from an in-line tube viscometer through a pipe to a 900 by 900 by 1500 mm high tank. The tank had baffles inside to calm the velocity of approach of the test fluids. A 10 m long by 300 mm wide flume connected the outlet of the tank and the mixing tank (Fig. 3.2).

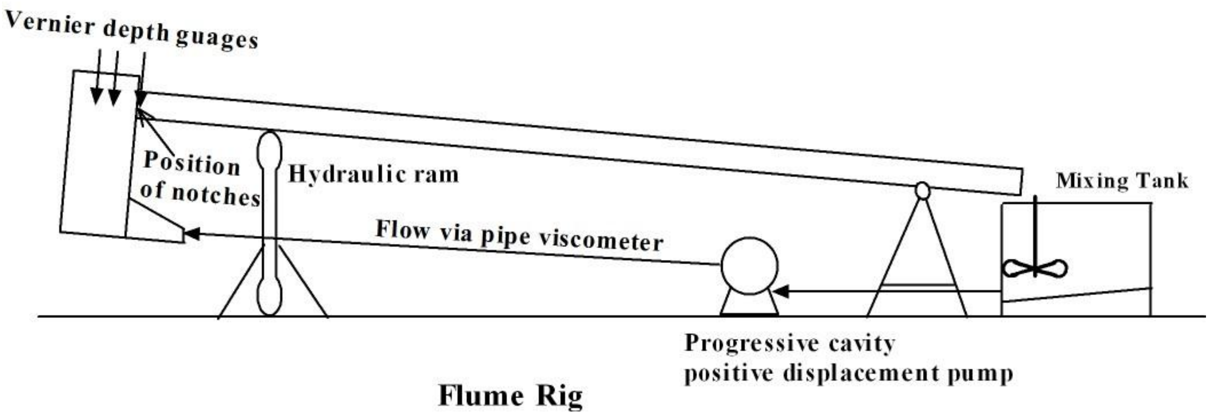



Figure 3.2 Inlet tank (Haldenwang, 2003)

There were three vernier electronic depth gauges fitted to the tank. Two digital depth gauges were fitted to the tank to measure the height above the notch in order to establish the head and $C_d$ values. The gauges were fitted 300 and 600 mm away from the notch crest respectively. Those recorded depths were used to compute $C_d$ values. The third gauge was fitted on top of the notch crest and the height recorded was used to calculate Reynolds number (see Fig 3.2). The digital depth gauges were connected electronically to the PC via an RS232 interface.

All notches were constructed from thin brass plate and are fully contracted. The edges of the notch plates are sharp and chamfered at an angle of $45^o$ to the direction of flow. The notches were temporarily mounted at the outlet of the tank between bolts with foam rubber sealing. The notches used comprised of the following dimensions: a rectangular notch with the crest width of 0.1234 m (b) and 0.150 m height above the notch crest and a 45° V notch with 0.130 m width and 0.150 m height above the crest. Table 3.1 shows a comparison of the ASTM (1993) limitations to the notches used.

**Table 3.1 Limitations of the rectangular and V-notches geometry**

| Rectangular notch | | V-notch | |
|---|---|---|---|
| ASTM (1993) conditions | Rect. Notch | ASTM (1993) conditions | V-Notch |
| H/P ≤ 2 | 0.1 < 0.2 | H/P ≤ 0.4, | 0.1 < 0.4 |
| H ≥ 0.03 m | 0.15 m > 0.03 m | P ≥ 0.45 m | 1.5 m > 0.45 m |
| b ≥ 0.15 m | 0.1234 m < 0.15 m | B ≥ 0.9 m | 0.130 m < 0.9 m |
| P ≥ 0.1 m | 1.5 m > 0.1 m | 0.05 m ≤ H ≤ 0.38 m | 0.05 m < 0.15 m < 0.38 m |
| | | With the following limitations | |
| | | H/P ≤ 1.2 | 0.1 < 1.2 |
| | | H/B ≤ 0.4, P ≥ 0.1 m | 1.15 < 0.4, 1.5 m > 0.1 m |
| | | B ≥ 0.6 m | 0.13 > 0.6 m |
| | | 0.05 m ≤ H ≤ 0.6 m | 0.05 m < 0.15 m < 0.6 m |

Most of the notches geometric design parameters are within the design limits stated by ASTM (1993) except the widths of rectangular and V-notches. A 10 m long by 300 mm wide flume was connected to the outlet of the tank and the mixing tank.

### 3.2.5 Data acquisition unit and computer

An HP data acquisition unit and a standard computer were used to capture data from DPT's, flow meters and depth gauges.

## 3.3 Materials used

Water tests were carried out for calibration of the notches. Different concentrations of Carboxymethyl Cellullose (CMC) solutions and kaolin and bentonite suspensions were tested. CMC is a white powder which when mixed with water produces a polymer solution used as an industrial coagulating agent. Kaolin is a dry white powder which is mixed with tap water to obtain a suspension at a desired concentration. Bentonite is natural clay which is mixed with water to form a bentonite suspension. As these materials exhibit some time dependent behaviour they had to be pre-sheared for a considerable time.

## 3.4 Experimental procedures

This section explains experimental procedures used to obtain data. It describes the methods followed to calibrate an in line tube viscometer and notches. Materials used had to be prepared before being test and that preparation procedure is outlined. In order to obtain $C_d$ values and Reynolds numbers for all test fluids the flow rate and flow depth had to be measured. Therefore the gauging procedure for these variables is also discussed.

### 3.4.1 Calibration of in line tube viscometer

Clear water test were conducted for calibration purpose for the 13 and 28 mm diameter pipes.

The pressure drop readings were recorded for each pipe over a fixed straight length (1 m). From the data obtained, the Darcy-Weisbach expression for friction head was used to determine shear stress (Haldenwang, 2003) as

$$h_f = \frac{4 f l v^2}{2gd} \qquad (3.1)$$

Therefore

$$\tau_w = \frac{D \Delta P}{4L} = \frac{\rho D g h_f}{4L} \qquad (3.2)$$

By substituting equation 3.1 to 3.2, equation 3.2 becomes

$$\tau_w = \frac{v^2 f \rho}{2} \qquad (3.3)$$

The shear stress was plotted against velocity and compared to the Colebrook and White (1937) Eq. 3.4. According to Chadwick et al. (2004) the Colebrook and White (1937) equation conglomerates experimental results of studies of turbulent flow in smooth and rough pipes. As a result it has been used for flow through turbulent region for commercial pipes and an effective roughness could be experimentally established for a specific pipe.

$$\frac{1}{\sqrt{4f}} = -2\log\left(\frac{k_s}{3.7d} + \frac{2.51}{Re\sqrt{4f}}\right) \qquad (3.4)$$

Below is the procedure used to carry out an in-line tube viscometer calibration.

- Pump clear water through 13, 28 and 80 mm diameter pipes.
- Leave water running through 13 mm pipe and close 28 and 80 mm pipes
- Connect the pipe to differential pressure transducers via two pressure tappings which are connected to two flushing pods.
- Flush the pods to ensure that there is no entrapped air on the connection pipes between transducers and 13 mm pipe.
- Open the tappings from the 13 mm pipe.

- Open the rheology Excel program on the personal computer
- Choose 13 mm pipe and type of material being tested (water)
- Capture data starting with low flow rates and compare the data with the Colebrook and White (1937) (Eq. 3.4).
- Repeat the same procedure for the 28 mm diameter pipe.

Figures 3.3 and 3.4 show the comparison of the experimentally acquired shear stress with that of the calculated shear stress using the Colebrook and White (1937) Eq. 3.4 for 13 mm and 28 mm tubes used in this work. Water data for all the pipes collapse within ±10% from Colebrook and White (1937) prediction. This indicated that both flow rate and pressure drop measurements were within accepted values. The k-values for 13 and 28 mm diameter tubes were 1 µm and 3 µm for 80 mm diameter tube.

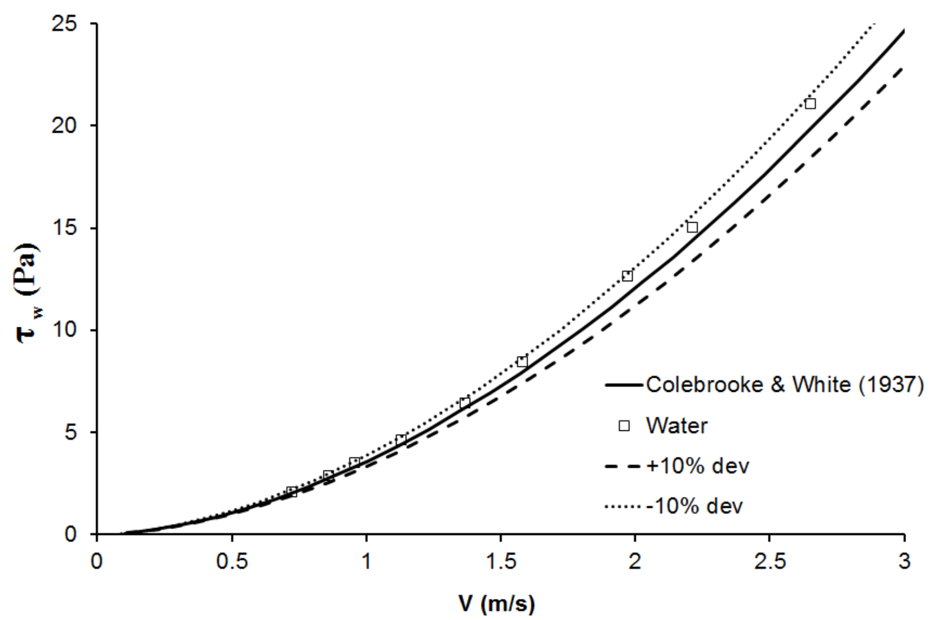



Figure 3.3 Clear water data vs Colebrook-White (1937) prediction, 13 mm diameter pipe

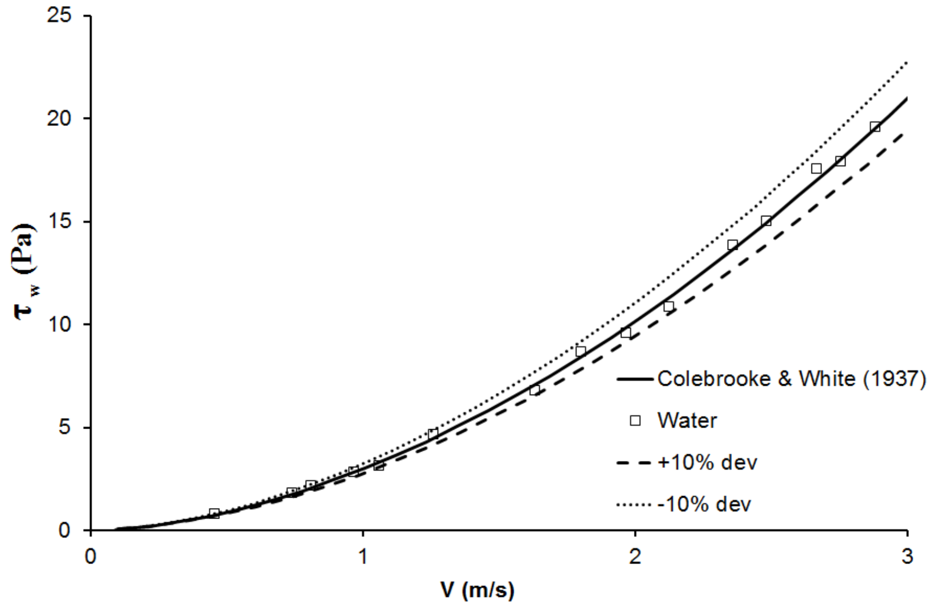



Figure 3.4 Clear water data vs Colebrook-White (1937) prediction, 28 mm diameter pipe

### 3.4.2 Calibration of notches

Rectangular and V-notches were calibrated and data obtained was graphically presented and compared to Replogle (2006) data. The following procedure explains the how the notches were calibrated.

- Lower the flume to the level position
- Pump water and allow it to flow over the notch
- Switch off the pump, close the valve that feeds the water to the inlet tank and allow water to overflow through the notch until it is level with the notch crest
- Open flume Excel programme on the personal computer
- Choose relevant material, type of notch, and dimensions
- Adjust depth gauges to the level of the water and zero them
- Increase the flow rate for the water to form a nape
- Adjust the depth gauges to the level of the water
- Capture data using computer
- Increase the flow rate to a predetermined value and readjust the depth gauges to the water level and capture data
- Repeat the same procedure until the flow reaches the highest level of the notch crest

The $C_d$ values were calculated using Eqs. 2.7 and 2.11 for rectangular and V-notches respectively. The results obtained for rectangular notch are presented in Appendix D. The $C_d$ values obtained were plotted against the head and compared to the existing data (Replogle 2006) to verify the validity of the calibration results as shown in Fig. 3.5. The present data fall within ±5% of his values.

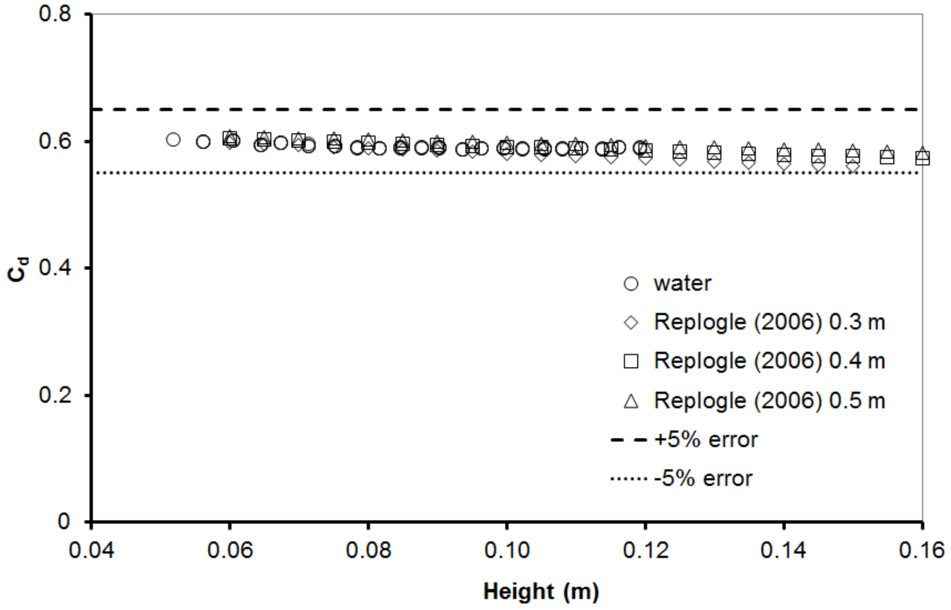
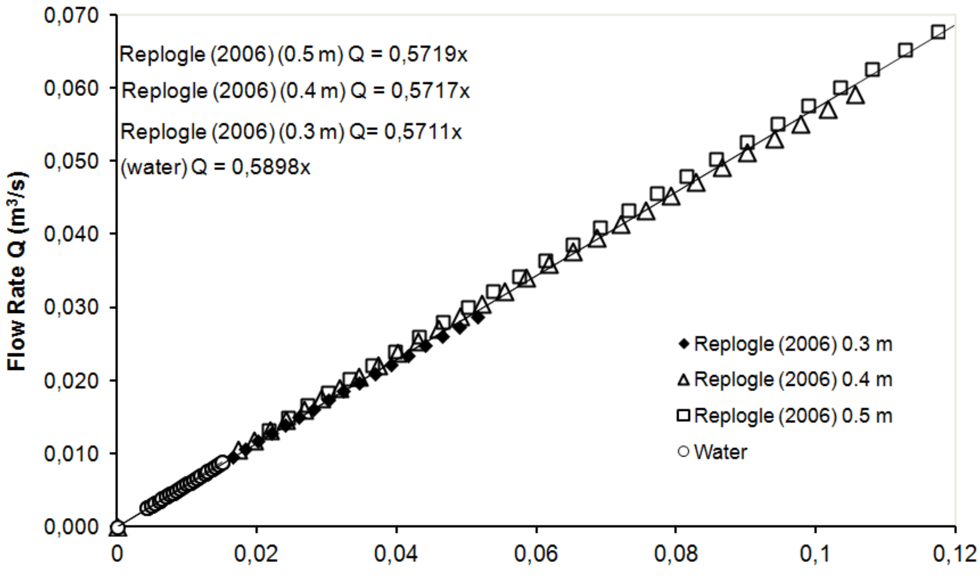



Figure 3.5 Rectangular notch water test results compared to Replogle (2006) experimental data

Figure 3.6 indicates relationship between the flow rate and Eq. 2.6 to obtain the mean representative $C_d$ values for the notch. The mean representative $C_d$ value of 0.59 is in agreement with the value of 0.57 reported by Replogle (2006).




$$\frac{2}{3}\sqrt{2g}\,bh^{\frac{3}{2}}$$

Figure 3.6 Rectangular notch average $C_d$ values as compared to Replogle (2006) experimental data

V-notch results are presented in appendix H and were compared to 45° V-notch data obtained from Replogle (2006), as shown in Fig. 3.7. In this case 82% of the present data falls within +5% of that reported by Replogle (2006). However the average $C_d$ values differ significantly, these being 0.58 (Replongle, 2006) and 0.62 in the present case, Fig 3.8. The Replogle (2006) coefficient of discharge is similar to the one given in Fig. 2.7 for 45° V-notch (ASTM, 2002; USBR, 1997; BSI, 1966).

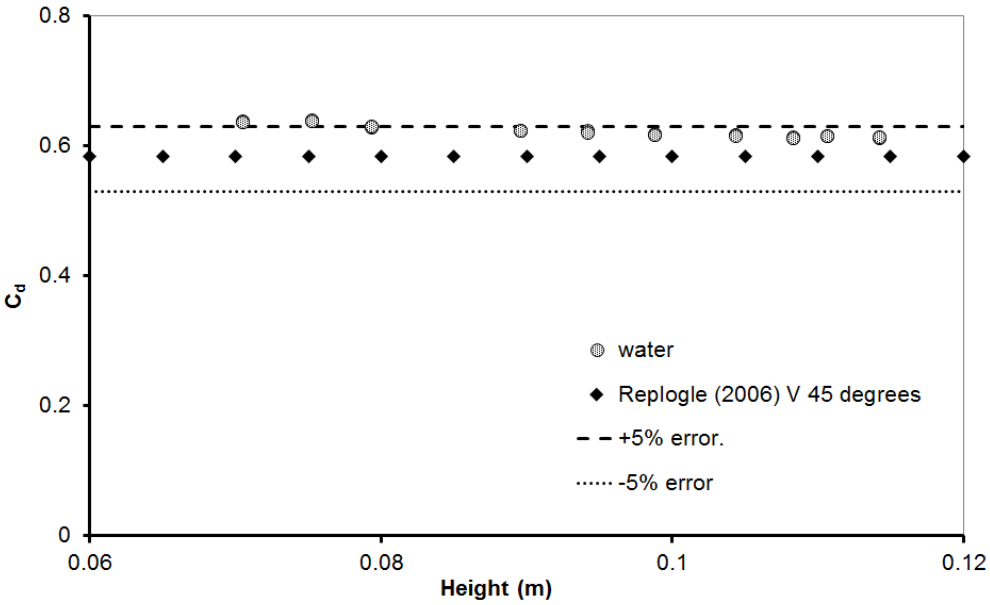
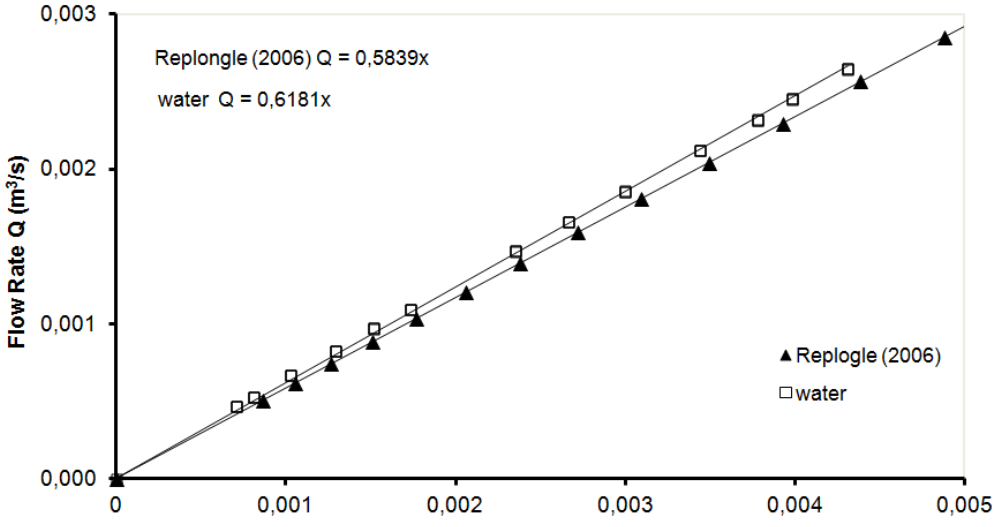



Figure 3.7 V-notch water test results compared to Replogle (2006) experimental data




$$\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{5/2}$$

Figure 3.8 V-notch average $C_d$ value as compared to Replogle (2006) experimental data

### 3.5 Preparation of slurries

The slurries tested needed to be prepared before carrying out rheology, flow rate and depth measurements. This was because materials used were in a solid (powder) form. The slurries preparation method is explained below:

- Calculate the total volume of the flume rig system.
- For kaolin calculate the amount of powder based on percentage volume/volume

$$\%v/v = \frac{\text{volume dry solids}}{\text{volume total mix}} \times 2.65 \times 100 \quad (3.5)$$

- For bentonite and CMC calculate the amount of powder to be used using percentage of weight/weight

$$\%w/w = \frac{\text{mass dry solids}}{\text{mass total mix}} \times 100 \quad (3.6)$$

- Gradually add powder to the water in the mixing tank.
- Ensure that an electric mixer is switched on.
- Leave the mixture for 5 days to thoroughly mix.
- Circulate the mixture on the system.

- Read off the relative density on the mass flow meter and carry out the relative density test to verify the mass flow meter readings. Use those results to find the percentage of the slurry obtained.
- Carry out rheology test and flow rate measurement using notches.
- Dilute the material to obtain the desired concentration and repeat all the tests.
- After completing the test for one material, discharge the material and thoroughly clean the rig.
- Mix another material and repeat the testing procedure

**3.6 Rheology test**

After material preparation the mixtures would be ready for testing. Similar to calibration of the in-line tube viscometer, pressure drop and flow rate readings were measured. Velocity was calculated and the true shear rate at the wall of tube viscometer obtained. For Newtonian fluids true shear rate is expressed in Eq. 3.7 and is used as the apparent shear rate at the wall for non-Newtonian fluids.

$$\dot{\gamma} = \frac{8V}{D} \tag{3.7}$$

Eq. 3.8 illustrates how true shear rate could be obtained using Rabinowitsch-Mooney relation where n' is expressed as:

$$n' = \frac{d(\log \tau_0)}{d\left(\log \frac{8v}{D}\right)} \tag{3.8}$$

Therefore the true shear rate at the wall for a non-Newtonian fluid is expressed as follows

$$\dot{\gamma} = \left(\frac{8V}{D}\right)\left(\frac{3n' + 1}{4n'}\right) \tag{3.9}$$

Where the slope n' may differ with the apparent shear rate. For shear-thinning fluid (n' < 1), the nominal shear rate at the wall is lower than the true shear rate, with the contrary applying near the centre of the tube (Laun, 1983).

When the rheological parameters are known, then k' and n' which are used for pseudoplastic fluids can be calculated, the relation could be calculated using the following equation:

$$k' = k\left(\frac{3n+1}{4n}\right)^n \qquad (3.10)$$

and

$$n' = n$$

The following procedure was used to carry out the rheology characterisation for CMC solution, kaolin and bentonite suspensions.

- Pump the slurry through 13, 28 and 80 mm diameter pipes.
- Leave the fluid running through 13 mm pipe and close 28 and 80 mm pipe.
- Connect the pipe to differential pressure transducers via two pressure tapings which are connected to two flushing pods.
- Flush the pods to ensure that there is no entrapped air on the connection pipes between transducers and 13 mm pipe.
- Open the tapings from the 13 mm pipe.
- Open the Rheology Excel program on the personal computer.
- Choose 13 mm pipe and insert type and percentage of material being tested.
- Capture data starting with low flow rates.
- Repeat this procedure for 28 mm pipe.
- Process data using Rabinowitsch-Mooney relation.

### 3.7 Flow rate and depth measurement

The information obtained from the Rabinowitsch-Mooney relation is recorded in the flow rate and flow depth measurements Excel sheet, as it was part of variables used to calculate the Reynolds number. Thereafter the flow rate and depth measurements were gauged as explained below:

- Immediately after completing rheology test start the flow rate measurement test.
- Ensure that the right notch is fitted to the outlet tank.
- Allow the slurry to pump through the rig for 30 minutes.
- Open the flume program and insert the type, concentration and relative density of material, notch type, and open an excel sheet to capture data.
- Close 28 mm and 80 mm pipe and adjust the flow rate to be just at the crest of the notch.
- Switch off the pump and close the valve leading to the inlet tank.
- Allow the slurry to flow over the notch until there is not more flow.
- Adjust the depth gauges to be at the surface of the medium and zero them.

- Re-open the closed valve and switch on the pump.
- Adjust the flow rate to a predetermined value.
- Adjust the flow electronic depth gauges to the surface of the slurry.
- Capture the readings in the computer, preferably two iterations for reading verification.
- Adjust the rate of flow to the next predetermined increment and capture data until the maximum allowable flow rate for specific pipe is reached.
- Repeat the above procedures for 28 mm and 80 mm pipes.
- Change the notch and repeat the above procedure for all notches.
- Dilute the slurry to the lower percentage and repeat the testing procedure until all concentrations are tested.

## 3.8 Processing of data

This section explains how the data obtained was processed and analysed. It outlines the interpretation of calibration results for the in-line tube viscometer and notches. The processing of flow rate and depth data is also illustrated. Error analysis for the equipment and the results obtained is explained.

### 3.8.1 In-line tube viscometer calibration

Clear water tests were conducted in all three pipes of the tube viscometer. The pressure drop readings were alternatively taken for each pipe over a fixed straight length and plotted against the Colebrook and White equation (Eq. 3.4).

### 3.8.2 Rheology

The programme used the average flow rate to automatically calculate the pseudo shear rate and the differential pressure to obtain the wall shear stress. This data was automatically exported to graphically display wall shear stress against shear rate. The graphical illustrations of pseudo shear diagrams are presented in Chapter 4. The pseudo shear rates were first changed to true shear rates using the Rabinowitsch-Mooney relation. The shear stresses and shear rates were used to calculate yield stress, consistency indices and consistency coefficient. These parameters were used to calculate the appropriate Reynolds number of the fluids. Figures 3.7, 3.8 and 3.9 show pseudo shear diagrams for 8.35% CMC solution, 6.71% kaolin and 4.15% bentonite suspensions respectively. The pseudo shear diagrams of all concentrations of CMC solution, kaolin and bentonite suspensions are presented in chapter 4.

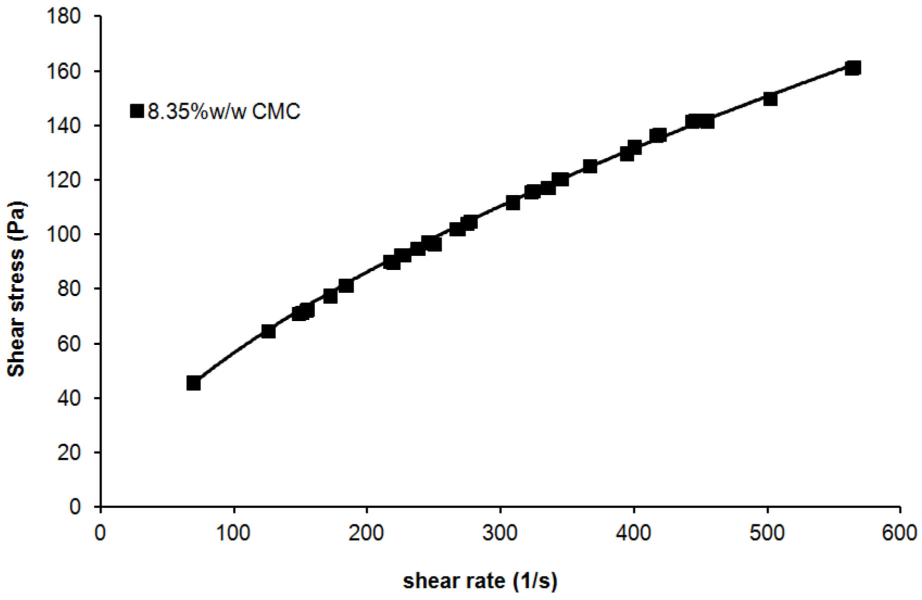



Figure 3.9 pseudo shear diagram for 8.35%w/w CMC solution

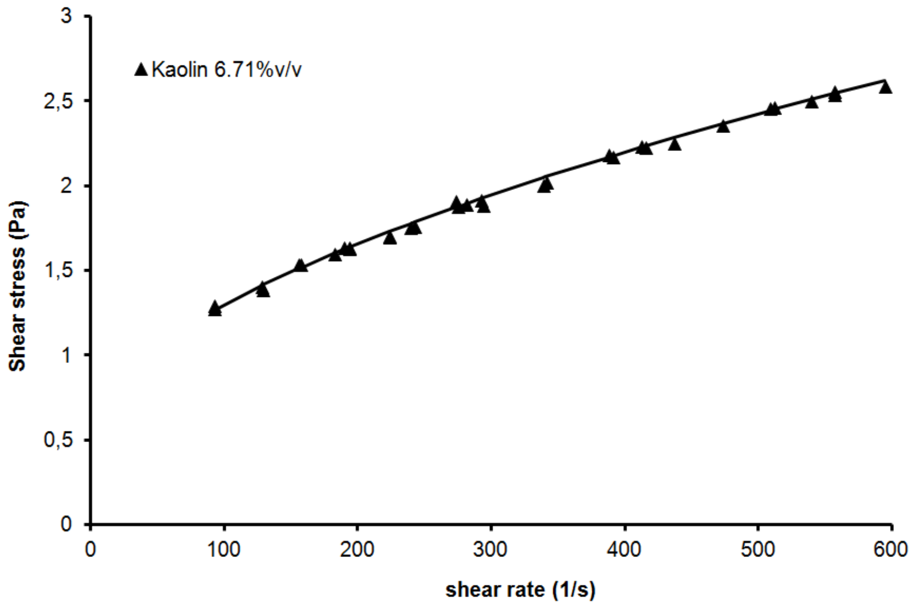



Figure 3.10 pseudo shear diagram for 6.71% kaolin suspension

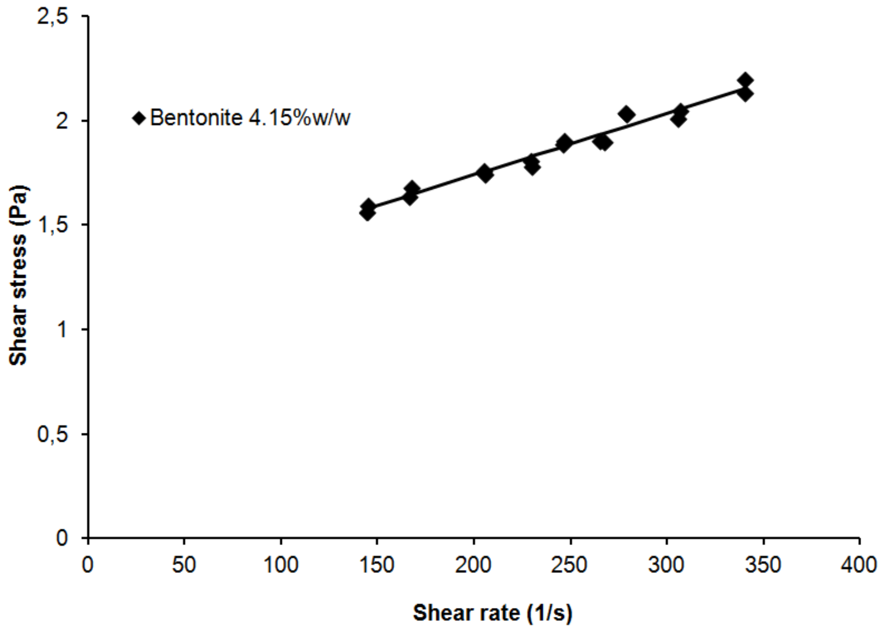



Figure 3.11 pseudo shear diagram for 4.15% bentonite suspension

### 3.8.3 Notches calibration and non-Newtonian fluids flow rate measurement

For calibration of the notches and flow rate measurement of all fluids, flow height (h) in meter above the notch crest from each depth gauge and flow rate (Q) readings in l/s were captured. The flow heights read from depth gauges situated upstream of the notch were used to calculate $C_d$ values using Eqs. 2.7 for the rectangular notch and 2.11 for the V-notch. The depths recorded at the notch crest were used to calculate the Reynolds numbers. For notch calibration $C_d$ values and corresponding flow heights were exported to a spreadsheet where the $C_d$ values were plotted against the height of flow above the notch crest. These data was compared to data obtained from Replogle (2006). The $C_d$ values were plotted against the Reynolds numbers obtained above the notch crest.

The similarity of $C_d$ values at the same Reynolds numbers of all fluids for each notch was established. This was achieved by determining the slope and interception of each fluid and concentration data. The accuracy of sharp crested notches in measuring the flow rate of non-Newtonian fluids depended on the comparison of the results obtained. Thereafter a predictive model for each notch shape was obtained.

### 3.8.4 Predictive model

The predictive model for each notch shape was established using a method explained by Patankar et al. (2002).

- Obtain parameters $a_1$, $b_1$, $a_2$ and $b_2$ from $C_d$ and Re power law relation. $a_1$ and $b_1$ are acquired from laminar flow data and $a_2$ and $b_2$ from turbulent
- Compute $f_1$ and $f_2$ (equations 2.49 and 2.50) for each data point
- Fit all the data points to Eq. 2.48 to get parameters c, d and t as explained by Patankar et al. (2002) and attain the predictive $C_d$ values for each data point
- Plot the $C_d$ values and predicted $C_d$ values against Re
- Establish a single composite equation for each notch

## 3.9 Error Analysis

There are different kinds of errors in experimental work such as gross errors, systematic errors; random errors and computational errors (Benziger and Aksay, 1999). Some quantities like Reynolds numbers and discharge coefficients are calculated from different variables such as discharge velocity with their subsequent errors. Procedure for calculating such errors uses a root mean square approach, Eq. 3.11.

$$\left(\frac{\Delta X}{X}\right) = \Sigma\left(\frac{\partial X}{\partial n}\right)^2\left(\frac{n}{X}\right)^2\left(\frac{\Delta n}{n}\right)^2 \tag{3.11}$$

The flow velocity encountered within the notch is calculated from the flow rate measured by the magnetic flow meters and the cross-sectional area of the notch. For the rectangular and V-notch:

$$V = \frac{Q}{Bh} \tag{3.12}$$

and

$$V = \frac{Q}{\frac{1}{2}Bh} \tag{3.13}$$

The highest expected error for rectangular notch is calculated from Eq 3.14

$$\left(\frac{\Delta V}{V}\right)^2 = \left(\frac{1}{Bh}\frac{Q}{V}\frac{\Delta Q}{Q}\right)^2 + \left(\frac{Q}{B^2h}\frac{B}{V}\frac{\Delta B}{B}\right)^2 + \left(\frac{Q}{Bh^2}\frac{h}{V}\frac{\Delta h}{h}\right)^2 \tag{3. 14}$$

And the highest expected error for V-notch is calculated from Eq 3.15

$$\left(\frac{\Delta V}{V}\right)^2 = \left(\frac{1}{2Bh}\frac{Q}{V}\frac{\Delta Q}{Q}\right)^2 + \left(\frac{Q}{2B^2h}\frac{B}{V}\frac{\Delta B}{B}\right)^2 + \left(\frac{Q}{2Bh^2}\frac{h}{V}\frac{\Delta h}{h}\right)^2 \quad (3.15)$$

The results obtained are shown graphically in figs 3.12 and 3.13 for rectangular and V notches respectively.

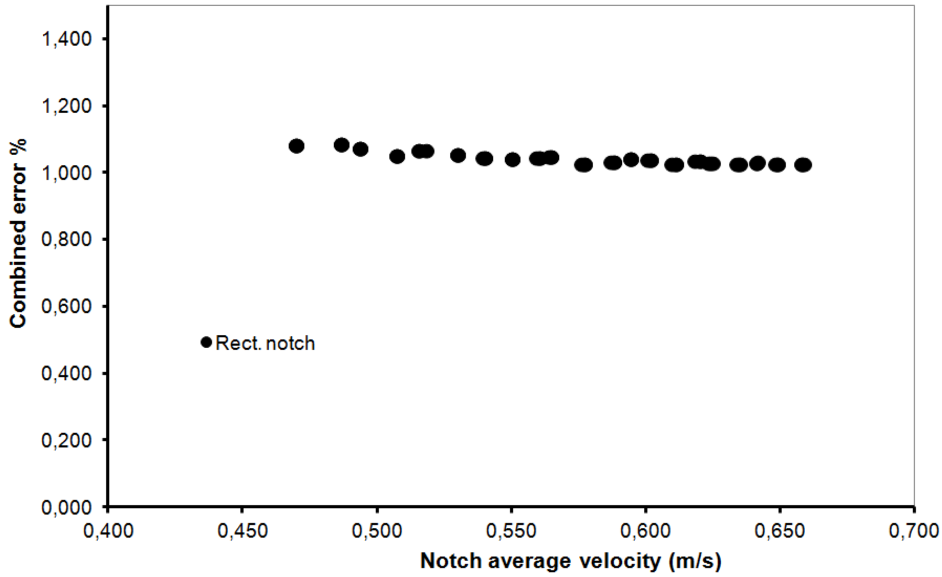



Figure 3.12 Combined errors for rectangular notch average velocity

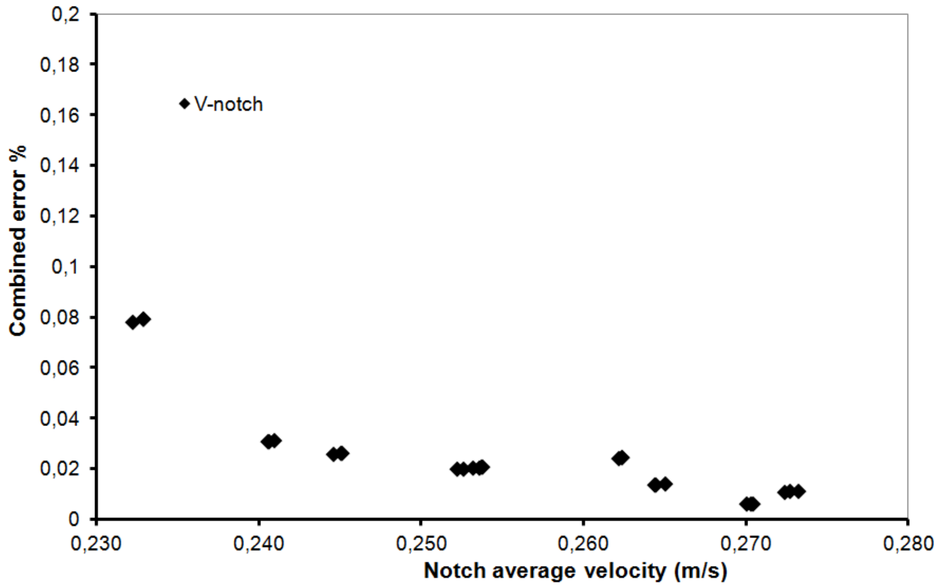



Figure 3.13 Combined errors for V-notch average velocity

The summary of the combined errors for the notches' average velocity are as follow:

| Notch type | Measurement errors $\frac{\Delta V}{V}\%$ |
|---|---|
| Rectangular notch | 0.043% |
| V-notch | 0.026% |

Haldenwang (2012) referred to the Lazarus and Nielson (1978) explanation of assessing the accuracy of variables such as Reynolds number, and discharge coefficients by computing coefficient of determination ($R^2$) and log standard error (LES). These are essential for comparing the performance of the different Reynolds numbers correlations in predicting discharge coefficients.

$$R^2 = \frac{\sum\left(f_{pred} - avef_{exp}\right)^2}{\sum\left(f_{exp} - f_{pred}\right)^2 + \sum\left(f_{pred} - avef_{exp}\right)^2} \tag{3.16}$$

$$LSE = \frac{\sqrt{\sum\left(\log\left(f_{exp}\right) - \log\left(f_{pred}\right)\right)^2}}{N-1} \tag{3.17}$$

Bouveng (1969) stated that under practical conditions flow measurement using notches can be carried out to an accuracy of ±10%. The assumption would be that the turbulence can be reduced; the notch and the depth gauges are kept free from sediment and there is a free fall. These conditions require the speed of water immediately upstream of the notch to be close to zero. The error due to speed of the water would be:

$$h1 = h2 + D2/2g \tag{3.18}$$

### 3.9.1 Error in tube viscometer

More than one diameter tubes must be used to account for wall slip errors. The apparent slip occurs when the viscosity near the wall reduces because of the diluted layer of particles at that section of the wall as compared to the bulk flow. If there is no wall slip the data on the laminar flow regions of the tube will coincide. If they do not coincide the slip velocity must be computed for each tube and deducted from the measured mean velocity (Chhabra & Richardson, 1999).

### 3.9.2 Accuracy of the equipment used

The flow meters and differential pressure transducers were calibrated and the accuracy of the flow rate measurements was thoroughly investigated by Haldenwang (2003).

**Flow meters**

According to Haldenwang (2003), Heywood et al. (1993) evaluated numerous magnetic flow meters. They recommended that the output should be influenced by the velocity profile since the magnetic flux lines can never be exactly parallel.

The calibration of flow meters were carried out using a 500 litre weigh tank suspended over the mixing tank with one end swivelling while the other end was connected to the roof with a load cell. The materials tested differed in concentration and chemical composition. Therefore each material and concentration was tested for a range of flow rates by diverting the flow into the weigh tank. The flow rate was divided into about 12 different flow rates for each flow meter. The flow rate was measured with time in the weigh tank while the data logger continuously sampled the change in weight with time. The average flow rate was calculated from the readings obtained. The sampling period ranged from 120 seconds for low flow rates to 12 seconds for the high flow rates. The relationship between the flow rate and volts obtained were expressed graphically on Fig 3.14. This is a typical test results for 28 mm magnetic flow meter calibrations.

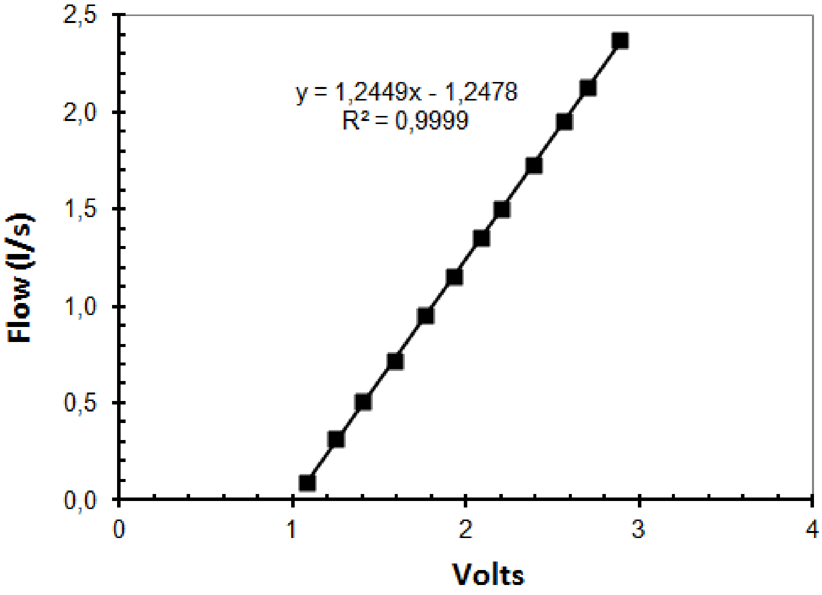



Figure 3.14 28 mm magnetic flow meter calibration for 6% kaolin (Haldenwang, 2003)

Haldenwang (2003) experienced difficulty for 80 mm magnetic flow meter calibration because the higher flow rates filled the tank in a short time. There were also vibrations due to the high impact of the inflow on the tank and frame which caused inaccurate results. Therefore the calibration results obtained for various concentrations of kaolin suspension (3%, 4.5%, 6%, and 10%) for 80 mm flow meter were compared to the water calibration results. It was found that at the very low flow rates the voltage was low and the deviations were significant. The flow rates resulted in less than 2% deviation. It was concluded that there was no increase in deviation with increase in concentration. Therefore the accuracy of the magnetic flow meters was not influenced by the effect of density and higher viscosity of the slurries.

The following results were obtained from the manufacturers for 80 mm flow meter calibration. It was calibrated at a flow rate of 8.33 l/s.

| | | |
|---|---|---|
| At 98% of the range | -0.08% deviation | 0.0065 l/s |
| At 45% of the range | -0.06% deviation | 0.0022 l/s |
| At 21% of the range | +0.32% deviation | 0.0056 l/s |

The maximum error was concluded to be 4% provided that the 80 mm flow meter was not used below 2 l/s and the 28 mm not less than 0.4 l/s.

**Digital depth gauges**

The standard vernier was used to calibrate the depth gauges. It was held against the depth electronic gauge and depths over the range of measurements were checked. The digital depth readings were directly transmitted to the PC in mm. The depth gauges were accurate to 0.0001 m (Haldenwang, 2003).

### 3.9.3 Repeatability of measurements

There were measures taken to minimise random errors during the experiments. In order to ensure that the depth gauges were at the same datum, the valve fitted between the feeding pipes and the inlet tank was closed. The fluid was allowed to flow over the notch until it was at the same level with the notch crest. When there was no more fluid flowing over the notch the depth gauges were adjusted to the top of the fluid and zeroed. Measurements were also repeated. Two readings were recorded when conducting rheology tests and two flow rate measurements were taken at the same flow height when carrying out flow rate measurement tests. The relative density tests were carried out and compared to the relative density value read from the mass flow meter.

Correlation coefficient was computed in order to compare the performance of Re correlation in predicting $C_d$ values (Eqs. 3.16).

### 3.10 Conclusion

This chapter has introduced and discussed the facility, equipment and materials as suitable methodology for this study. The procedures which have been followed to obtain rheology parameters, $C_d$ values and Reynolds numbers are also discussed. The literature has been used for comparison of calibration results obtained for in line tube viscometer and notches. The methods used for analysis of the results and the prediction of the model are outlined including discussion on error analysis.

The Flow Process Research Centre laboratory was used to conduct all the experiments. The testing equipment was the flume rig and it comprised of various instruments. Mixing tank was used as storage and an electric mixer was fitted to it to mix the powder with water. The positive displacement pump was used to initiate the flow through the system. The fluids were pumped to an in-line tube viscometer which was used to measure rheology. The DPT cells were fitted to the in-line tube viscometer to measure pressure between the two tappings. Mass flow and magnetic flow meters were attached to the in-line tube viscometer. The mass flow meter measured temperature, density and flow rate of the fluids while magnetic flow meters measured flow rate. The tube viscometer was connected to the inlet tank by a pipe. The notches and electronic depth gauges were attached to the tank. The two depth gauges measured the head and one measured the height above the notch crest. Rectangular and V notches were used and their geometric design and installation parameters were compared to the limits stated by ASTM (1993). The parameters were within the limits.

Materials tested were various concentrations of CMC solution, kaolin and bentonite suspensions.

The in-line tube viscometer was calibrated and the data obtained was compared to Colebrook and White (1937) equation. The results were within $\pm$10% from Colebrook and white prediction. Notches were also calibrated and their $C_d$ values were compared to Replogle (2006) results. The results were within $\pm$5% from Replogle (2006) values. The average $C_d$ values obtained for rectangular and V-notches were 0.59 and 0.62 respectively while the average $C_d$ values for Replogle (2006) were 0.57 and 0.58.

The procedure for obtaining rheological parameters was explained and Rabinowitsch-Mooney relation was used to process the data. The procedure for carrying out the flow rate measurement test was also explained. The method used to process the data in order to obtain $C_d$ values and Reynolds number was illustrated as well as method explained by Patankar et al. (2002) to predict the model.

The chapter also discussed error calculations. Measurement errors for flow velocity for rectangular and V-notches amounted to 0.043% and 0.026% respectively by using the root mean square approach. The maximum errors for flow meters were concluded to be 4% (Haldenwang, 2003).

# CHAPTER FOUR
## RESULTS AND ANALYSIS

### 4.1 Introduction

The results obtained during the experimental work are illustrated in this chapter. The tests were carried out for all percentage volume concentrations of kaolin suspensions, percentage mass concentrations of bentonite suspensions and CMC solution. The results entail density, rheology and flow rate measurement data.

### 4.2 Rheology and relative density results

The tube viscometer was used to perform rheology tests using both the 13 mm and 28 mm pipes. Data obtained for each fluid and concentration is presented graphically. The rheological fitting parameters were obtained from the interpretation of data using the Rabinowitsch-Mooney relation to change the apparent shear rate to true shear rate and then determining the most relevant rheological parameter for the different fluids. For power law fluids (Eq. 2.20), yield pseudoplastic (Eq. 2.21) and Bingham (Eq. 2.22)

#### 4.2.1 Kaolin

Eight concentrations of kaolin suspensions were prepared and tested separately. Figure 4.1 is the flow curve for 5.5% by volume kaolin suspension. The data for 6.7; 8.2; 10.9; 12.6; 14.6; 15.3; and 16% are shown in appendix A.

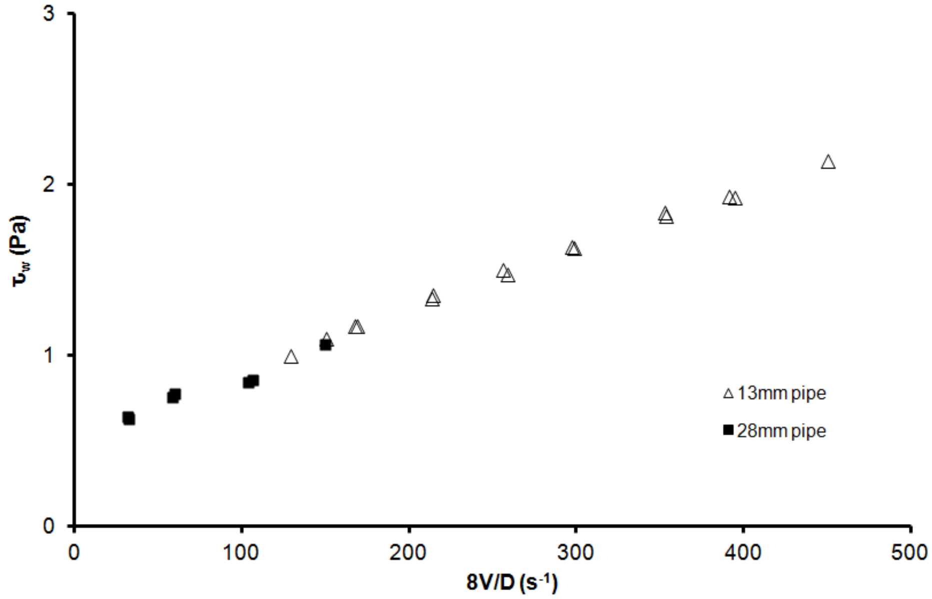



Figure 4.1 Flow curve for 5.5% v/v kaolin suspension

Rheological parameters of the test fluids were obtained from the in-line viscometer data. The yield-pseudoplastic model was used to characterise the fluids, (See Eq. 2.21)

$$\tau_w = \tau_y + k(\dot{\gamma})^n \qquad (2.21)$$

The equation reverts to the Bingham equation with n=1 and to the power-law equation when the yield stress $\tau_y = 0$

Figure 4.2 displays the rheological results of all kaolin suspensions after application of the Rabinowitsch-Mooney relationship using yield-pseudoplastic (YYP) model fitting, Eq. 2.21.

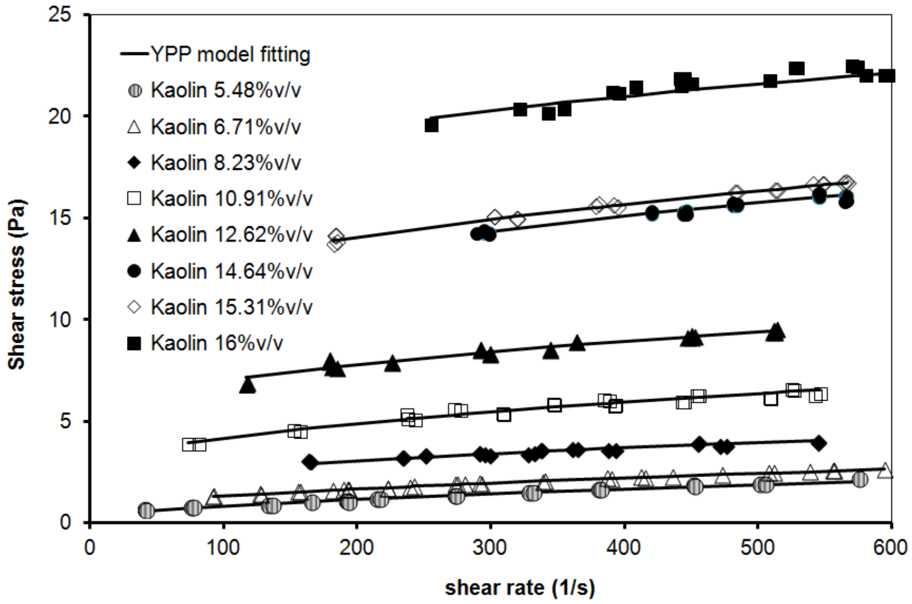



Figure 4.2 Kaolin suspensions flow curves characterised by yield-pseudoplastic model

### 4.2.2 Bentonite

Figure. 4.3 depicts the pseudo shear diagram computed for 4.2% by mass bentonite suspension. Appendix B shows the diagrams for 5.2% and 6% bentonite suspensions.

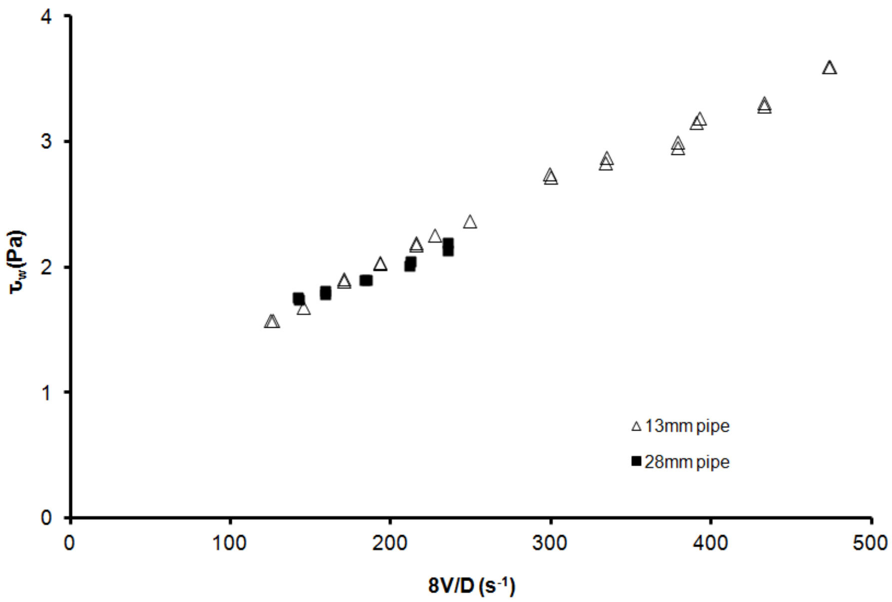



Figure 4.3 bentonite 4.2%w/w rheology results

Bingham plastic model fitting was used to characterise the rheology results for bentonite, Eq. 2.22. Fig. 4.4 displays the flow curves for the three concentrations of bentonite tested.

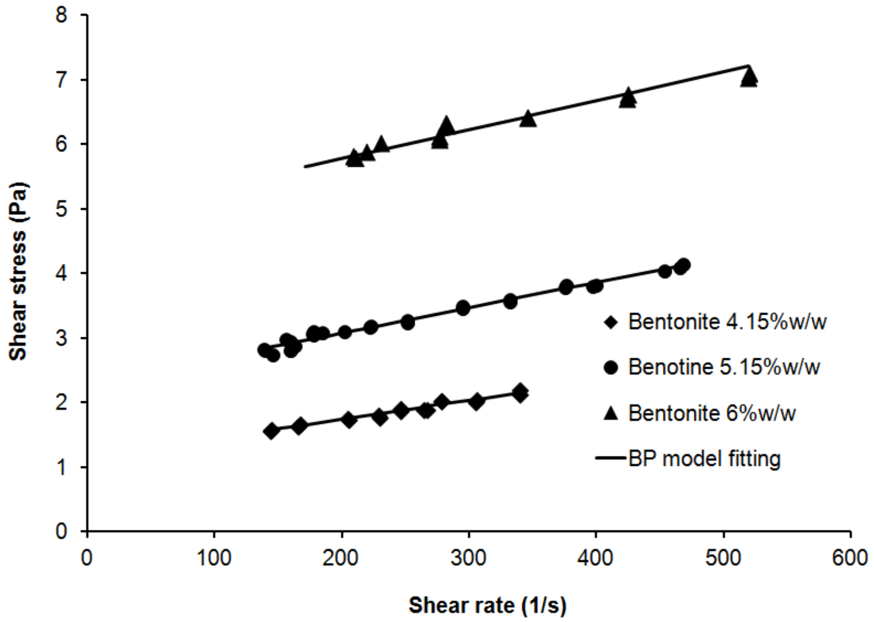



Figure 4.4 Bentonite suspensions flow curves characterised by Bingham plastic model fitting

### 4.2.3 CMC

The pseudo shear diagram for 1.7% by mass CMC solution are given in Fig. 4.5 while the graphs for 4.2%, 6.2%, 7.3% and 8.4% are shown in appendix C.

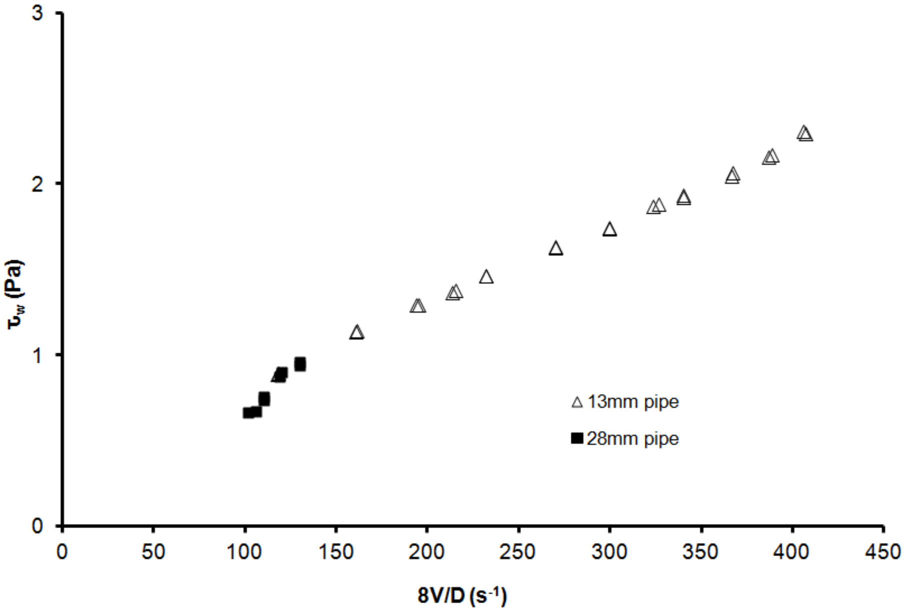



Figure 4.5 CMC 1.7%w/w rheology results

Power law model fitting was used to characterise the solutions and the flow curves are shown in Fig. 4.6.

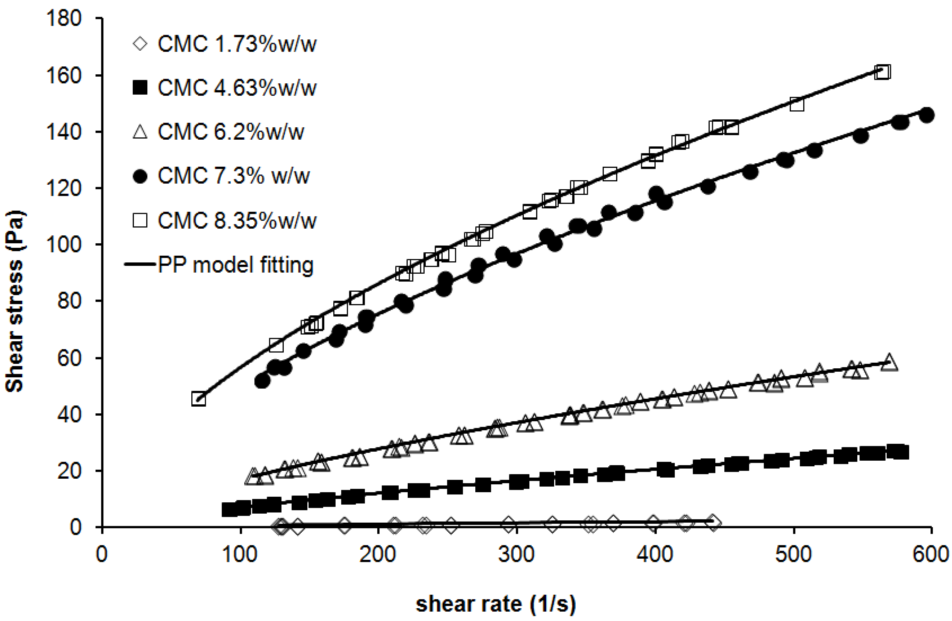



Figure 4.6 CMC solutions characterised by pseudo plastic model fitting

Rheological characteristics of the non-Newtonian fluids tested are presented in Table 4.1. Kaolin and bentonite yield stresses and consistency indexes increased with increasing concentration of the fluids. Fluid consistency indexes for CMC also increased with the increase in concentration. The information in the table has been used to calculate the Reynolds numbers.

**Table 4.1 Rheology parameters obtained from tube viscometer**

| Sample | Concentration (%) | Density ($kg/m^3$) | $\tau_y$ (Pa.) | K ($Pa.s^n$) | n |
|---|---|---|---|---|---|
| CMC (%w/w) | 1,7 | 1010,4 | - | 0,024 | 0,747 |
| | 4,6 | 1026,2 | - | 0,213 | 0,763 |
| | 6,2 | 1034,9 | - | 0,646 | 0,710 |
| | 7,3 | 1041,3 | - | 2,974 | 0,611 |
| | 8,4 | 1048,1 | - | 3,423 | 0,609 |
| Bentonite (%w/w) | 4,2 | 1025,2 | 1,15 | 0,003 | 1,000 |
| | 5,2 | 1031,2 | 2,29 | 0,004 | 1,000 |
| | 6,0 | 1036,5 | 4,88 | 0.004 | 1,000 |
| Kaolin (%v/v) | 5,5 | 1090,4 | 0,25 | 0,029 | 0,645 |
| | 6,7 | 1110,7 | 0,60 | 0,045 | 0,596 |
| | 8,2 | 1135,7 | 1,50 | 0,099 | 0,517 |
| | 10,9 | 1180,1 | 2,60 | 0,129 | 0,542 |
| | 12,6 | 1208,2 | 5,20 | 0,158 | 0,527 |
| | 14,6 | 1241,6 | 9,90 | 0,209 | 0,536 |
| | 15,3 | 1252,6 | 10,40 | 0,219 | 0,531 |
| | 16,0 | 1264,3 | 15,80 | 0,259 | 0,500 |

## 4.3 Flow rate measurement over notches

The flow rate and depth measurements through rectangular and V-notches were done after completion of the rheological characterisation. To ensure that the rheology did not change during testing the characterisation was repeated at the end of each test.

### 4.3.1 Relationship between $C_d$ and yield stress

Available literature shows an extensive research done on the flow rate measurement of water using notches and results analysis are based on the relationship between $C_d$ and head. Similarly Haldenwang et al. (2007) investigated the relationship between $C_d$ and head for various concentrations of kaolin and bentonite suspensions for rectangular and V notches. Therefore the same has been done for this research and Figs 4.7, 4.8, 4.9 and 4.10 illustrate the relationship between $C_d$ and head. Only fluids that exhibited yield stress (kaolin and bentonite suspensions) and concentrations that are in the turbulent region are analysed.

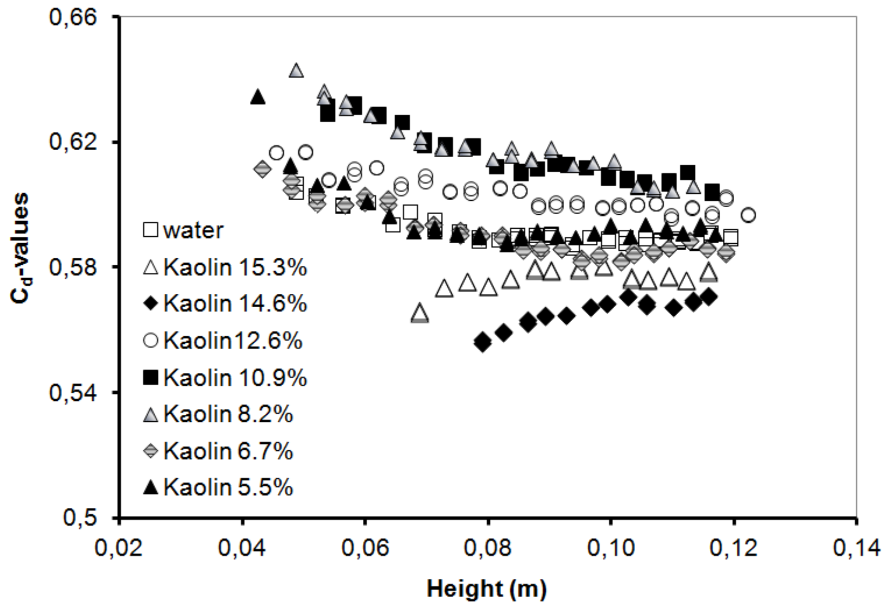



Figure 4.7 Relationship for $C_d$ values vs head for kaolin suspension in rectangular notch

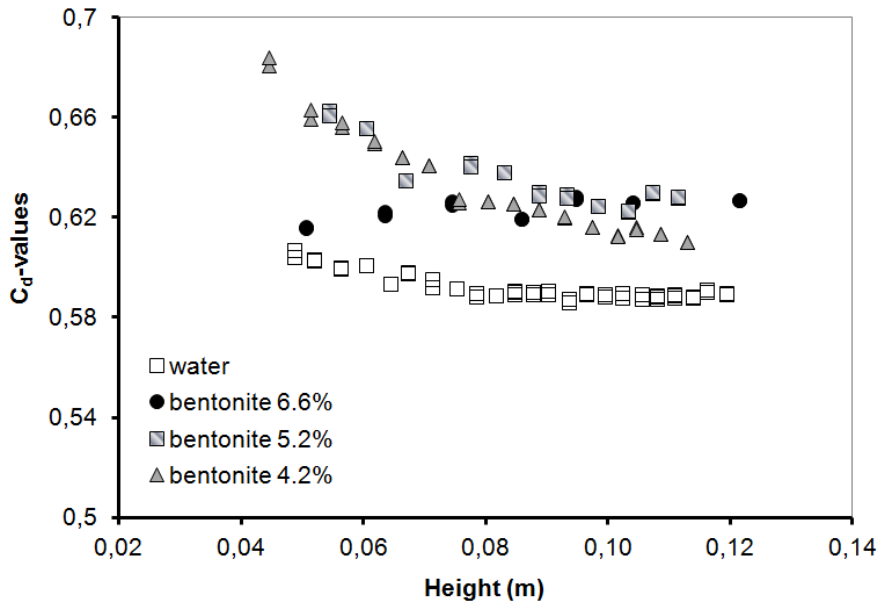



Figure 4.8 Relationship for $C_d$ values vs head for bentonite suspension in rectangular notch

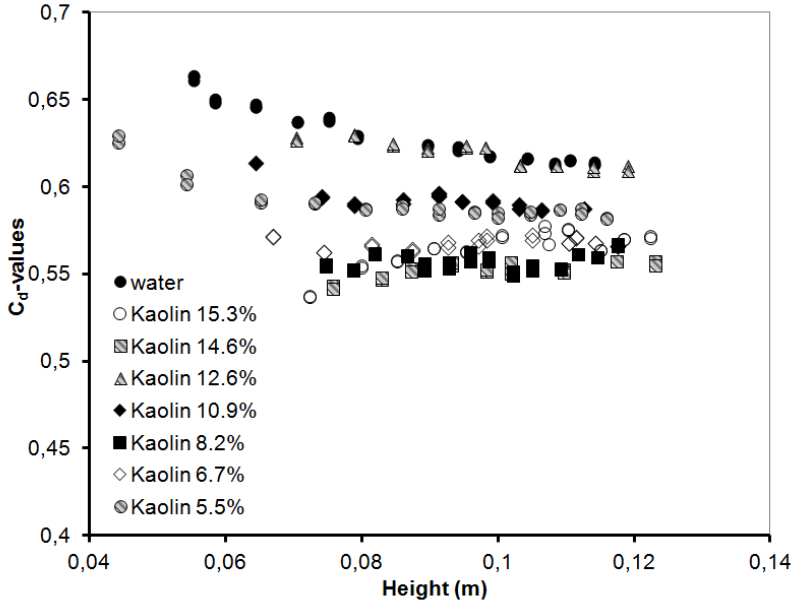



Figure 4.9 Relationship for $C_d$ values vs head for kaolin suspension in V-notch

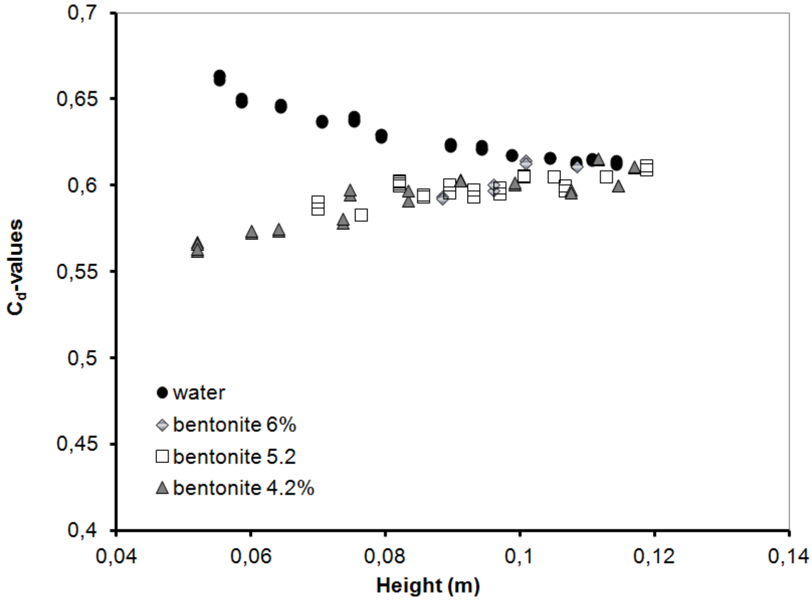



Figure 4.10 Relationship for $C_d$ values vs head for bentonite suspension for V-notch

According to Haldenwang et al. (2007) results there was an increase in $C_d$ values with increase in concentration for rectangular and V notches. The maximum concentration10%v/v kaolin and the yield stress obtained was +20 Pa. However the same behaviour could not be obtained with the current results. This could be because of change of material properties. The maximum concentration tested was 15%v/v kaolin at yield stress of +10 Pa. In order to investigate the relationship between the $C_d$ and yield stress, representative $C_d$ values for the whole range of data had to be established using eq. 2.7 for the rectangular notch and 2.11

for V-notch. For the rectangular notch flow rate (Q) and $\frac{2}{3}\sqrt{2g}bh^{\frac{3}{2}}$ were plotted on co-ordinate axes (Figs 4.11 and 4.12) for a series of slurry concentrations. The slope of the best-fit line through the each data set was taken as the representative $C_d$ value for that concentration.

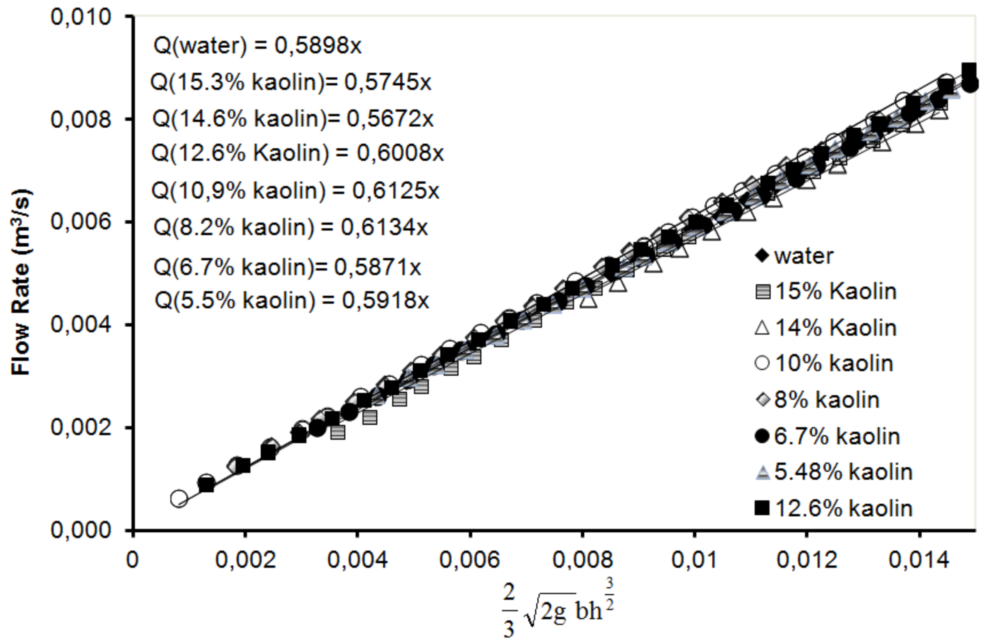



Figure 4.11 kaolin suspensions' average $C_d$ values for rectangular notch

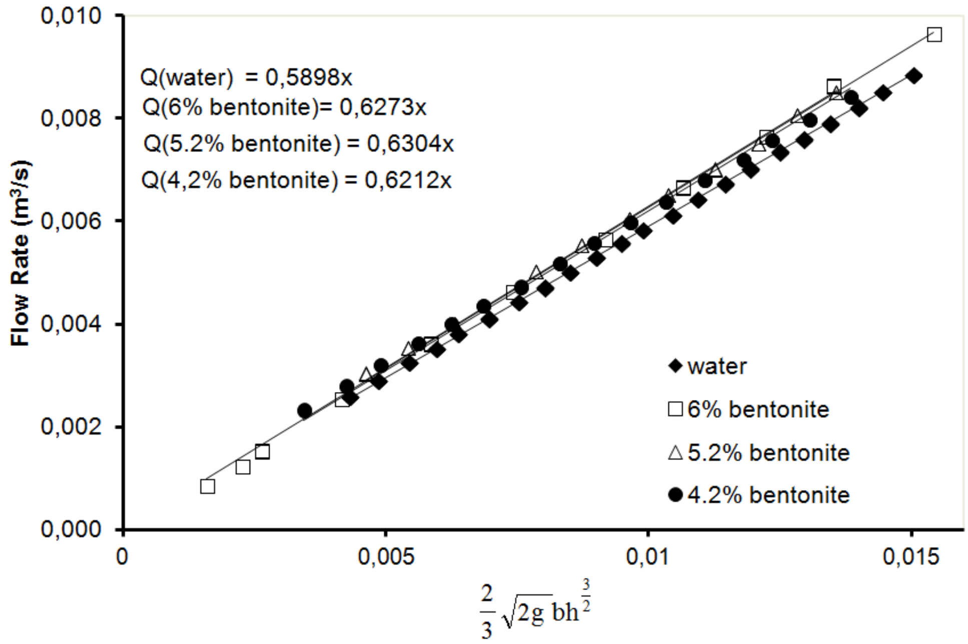



Figure 4.12 bentonite suspensions' average $C_d$ values for rectangular notch

For the V-notch, a similar derivation was used, the horizontal axis in this case being $\frac{8}{15}\tan\left(\frac{\theta}{2}\right)\sqrt{2g}H^{\frac{5}{2}}$.

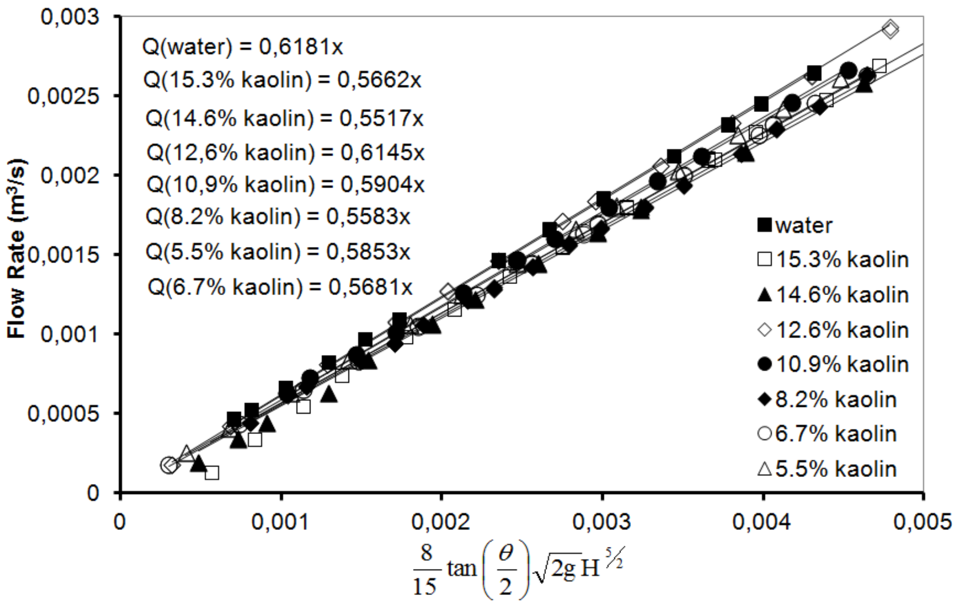



Figure 4.13 kaolin suspensions' average $C_d$ values for V-notch

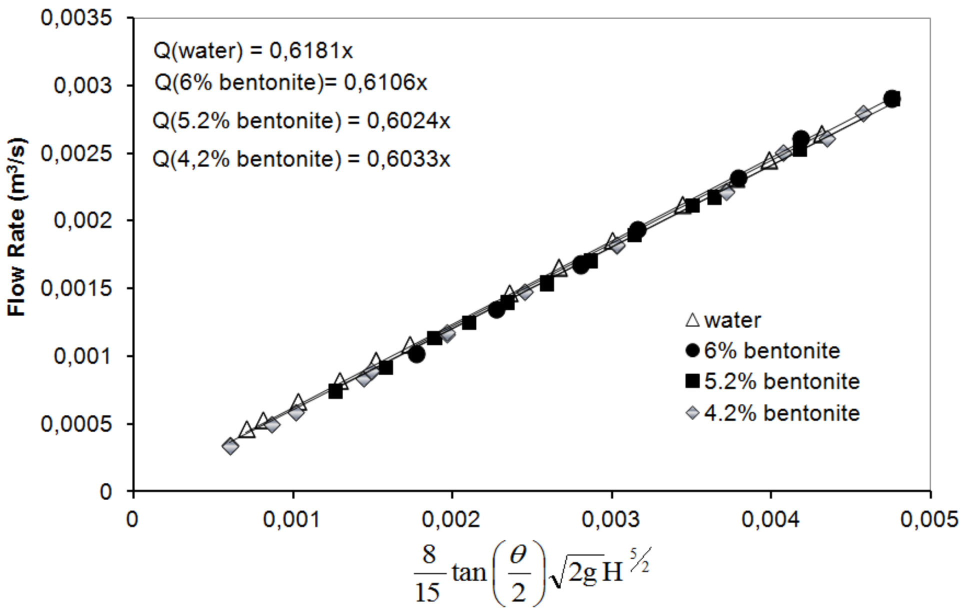



Figure 4.14 bentonite suspensions' average $C_d$ values for V-notch

Haldenwang et al. (2007) determined the relationship between the $C_d$ values and yield stress values for the non-Newtonian fluids tested. Their results showed that with an increase in concentration and yield stress, there was an increase in $C_d$ values but the same cannot be said for this research as shown in Fig 4.15.

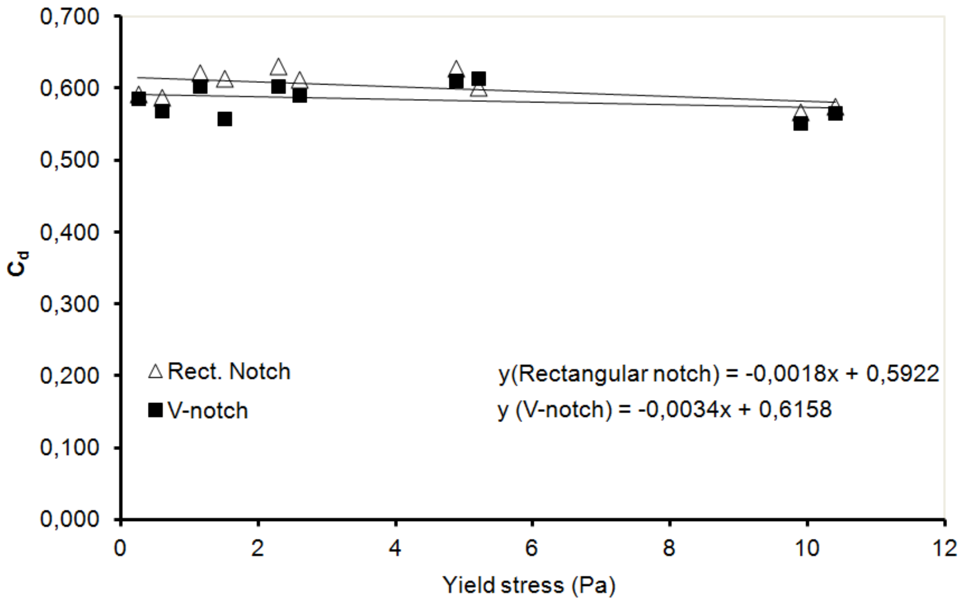



Figure 4.15 Relationship between $C_d$ and yield stress for rectangular and V notches for concentrations in the turbulent region

Haldenwang et al. (2007) compared the $C_d$ values for non-Newtonian fluids to constant $C_d$ value of water for both rectangular and V-notches in order to predict discharge coefficient of non-Newtonian fluids. The same was done for this research and equations 4.1 and 4.2 were determined for rectangular and V-notches. The similarity between Haldenwang et al. (2007) equations with this study $C_d$ equations is that the water $C_d$ values for rectangular and V notches coincide with the ones in the equations.

Rectangular notch $C_{d(\text{yield stress})}$ prediction equation

$$C_{d(\text{yieldstress fluid})} = C_{d(\text{water})} - 0.0018\tau_y \tag{4.1}$$

V-notch $C_{d(\text{yield stress})}$ prediction equation

$$C_{d(\text{yeildstress fluid})} = C_{d(\text{water})} - 0.0034\tau_y \tag{4.2}$$

### 4.3.2 Reynolds number

The Reynolds number obtained for all non-Newtonain fluids was calculated from Haldenwang et al. (2002) equation 2.36. For the sake of comparison, the Metzner and Reed (1955) Reynolds number was also used (Eq. 2.38) for the CMC solutions.

### 4.3.3 Rectangular notch

Appendices E and F show the results obtained for flow rate measurement of each concentration of kaolin and bentonite suspensions through the rectangular notch. CMC solution results are presented in Appendix G. The results obtained for the rectangular notch indicate that high concentrations of kaolin suspensions and CMC solutions are in the laminar regime with an average slope of 0.42 (Fig. 4.16). The $C_d$ values increased with increasing Reynolds number. The lower concentrations have an average $C_d$ of 0.60, aligning with the water results which are in the turbulent region. The transition point is at a Re of approximately 280. The difference between the plots obtained using the $Re_H$ and $Re_{MR}$ for the CMC solutions is not very explicit and can hardly be seen on Fig 4.16. The $Re_{MR}$ data points were not included for obtaining the correlations.

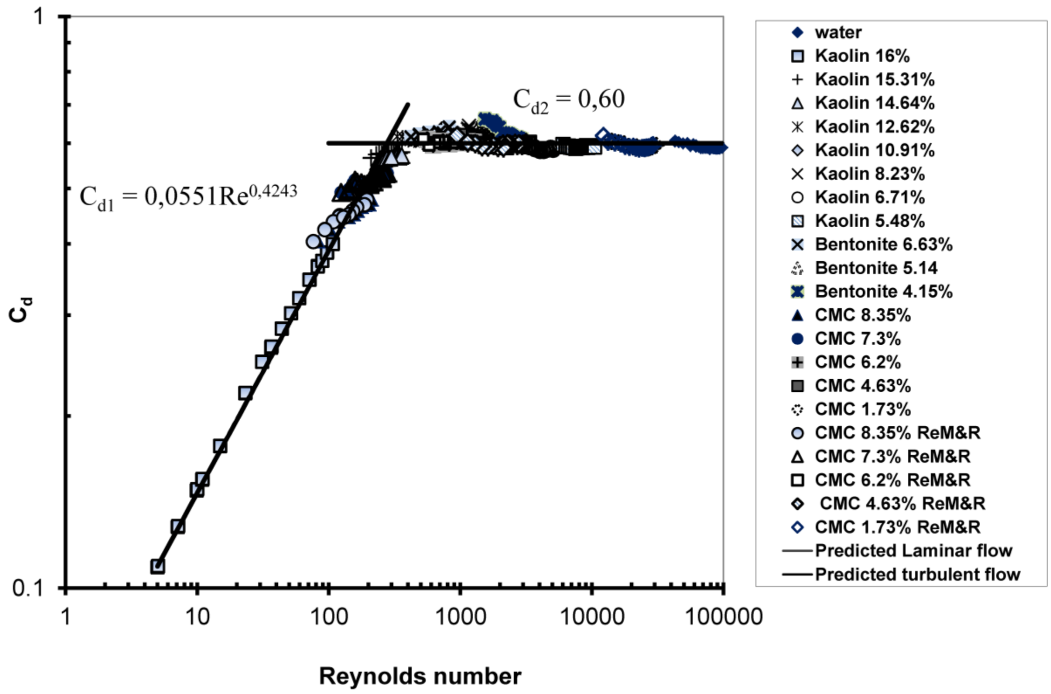



Figure 4.16 $C_d$ values for rectangular notch (CMC solution, kaolin and bentonite suspensions)

### 4.3.4 V-notch

V-notch results for kaolin and bentonite suspensions are given in appendices I and J respectively while the CMC solution results are in appendix K. Similar behaviour was observed for the V-notch with an average slope of 0.439 in the laminar flow region and an average $C_d$ value of 0.61 aligning with water $C_d$ values in the turbulent region. The transition occurred at a Re value of approximately 100 (Fig 4.17). Similar to rectangular notch there is very little difference between $Re_H$ and $Re_{MR}$ (Fig 4.17). The $Re_{MR}$ data points were not included for obtaining the correlations.

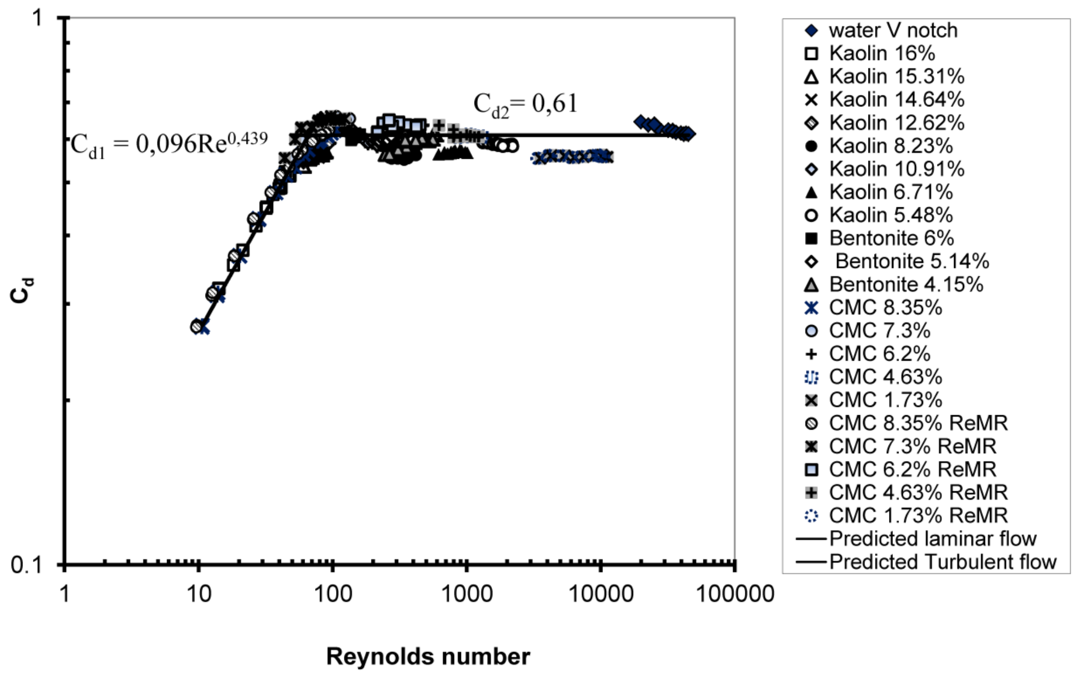



Figure 4.17 $C_d$ values for V notch (CMC solution, kaolin and bentonite suspensions)

## 4.4 Conclusion

Rheological parameters of the test fluids obtained from the in-line tube viscometer data have been presented in this chapter. Bingham Plastic, pseudoplastic and yield-pseudoplastic models were used to characterise the fluids. The parameters obtained were used to determine the $C_d$-yield stress relationship and Reynolds numbers. The results showed that the $C_d$ values did not increase with increasing concentration of the fluids nor yield stress. The average $C_d$ values of the fluids are equal to the water $C_d$ value. The Haldenwang et al. (2002) Reynolds number was used for all non-Newtonian fluids and Metzner and Reed (1955) Reynolds number was used for the CMC solution for comparison purpose. The $C_d$ values for all fluids were calculated using equations that are normally used for Newtonian fluids. The Reynolds number and $C_d$ values have been presented graphically. They indicate that the data obtained with the relatively high concentrations of kaolin suspensions and CMC solutions are in the laminar flow regime. The $C_d$-Re plot exhibited an average slope of 0.42 and 0.44 for rectangular and V notches respectively. The turbulent region is encountered with low concentrations and for bentonite suspensions and, under these conditions; the $C_d$ values become constant aligning with the water results. In this regime, the representative $C_d$ value for the rectangular notch is 0.60 and the transition region is at an Re of approximately 280 while for the V notch the representative $C_d$ value was 0.61 and transition occurred at a Re value of 100. Furthermore, there is no significant difference between the plots obtained using the $Re_H$ and $Re_{MR}$ for the CMC solutions considering that the log-log scale has been used.

# CHAPTER FIVE
## MODEL PREDICTION FOR $C_d$

### 5.1 Introduction

This chapter includes the prediction of a single composite equation for the rectangular and V-notches. This is done by fitting data with a logistic dose response curve to a set of data for each notch. The model has been explained by Patankar et al. (2002). The Haldenwang et. al (2002) version of the Reynolds number ($Re_H$) has been used.

### 5.2 Single composite equation

Applying a single composite equation (Eq. 2.48) to the data obtained for the rectangular notch $f_1$ becomes $0.055Re^{0.4243}$ and $f_2$ is 0.60. After minimising the sum of squares of the residuals, Eq. 2.48 takes the form of Eq. 5.1.

$$C_{dpre} = 0.590\left[\frac{0.056Re^{0.396} - 0.590}{\left(1+\left(\frac{Re}{280}\right)^{1.299}\right)^{1.293}}\right] \qquad (5.1)$$

Figure 5.1 shows the adequacy of the fit of the present results via Eq. 5.1.

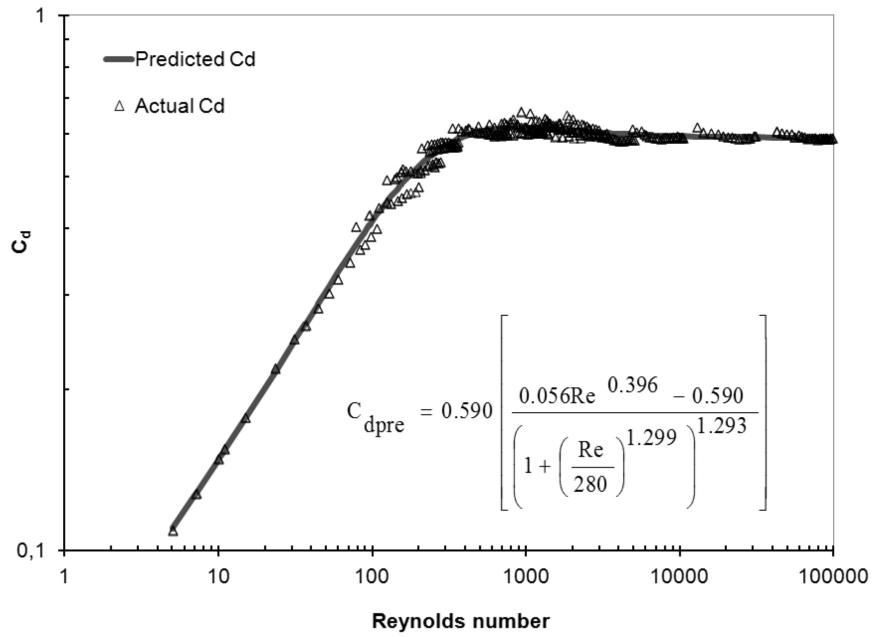



Figure 5.1 Logistic dose response curve for rectangular notch results

Transition for the rectangular notch occurred at Re = 280. Equation 5.1 was used to calculate the predicted $C_d$ values in order to determine the predicted flow rate using Eq.5.2.

$$Q_{Pre} = C_{dpre} \frac{2}{3} \sqrt{2g} b h^{3/2} \tag{5.2}$$

The correlation coefficient approach was used to calculate the deviation between the predicted discharge and the actual discharge. The flow rates could be predicted to within +/- 5% when compared to the actual flow rate (Fig. 5.2).

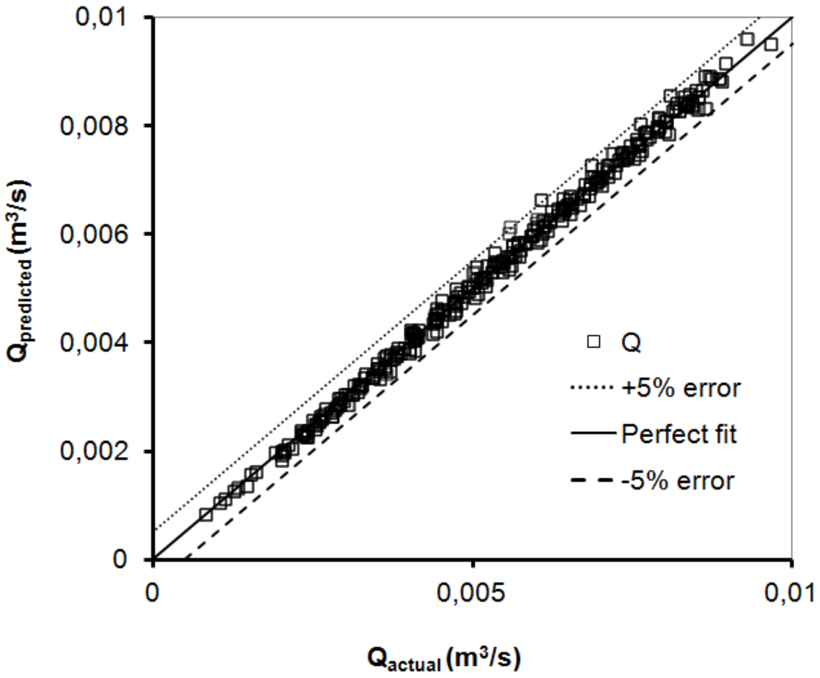



Figure 5.2 Comparison between the actual and predicted flow rates through rectangular notch

A single composite equation was also derived for the V-notch using the same procedure as for the rectangular notch. The fitting parameters $f_1$ and $f_2$ were $0.096Re^{0.439}$ and 0.61 respectively. Figure 5.3 shows the relationship between the predicted $C_d$ values and Reynolds number. Equation 5.3 was established and transition is at Re = 100.

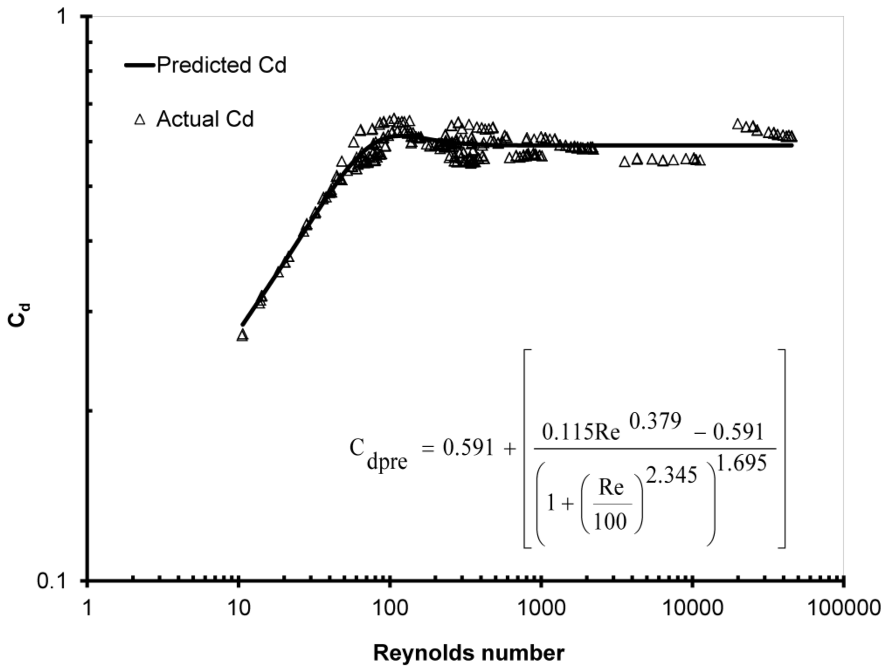



Figure 5.3 Logistic dose response curve for V notch results

$$C_{dpre} = 0.591 + \left[ \frac{0.115\mathrm{Re}^{0.379} - 0.591}{\left(1 + \left(\frac{\mathrm{Re}}{100}\right)^{2.345}\right)^{1.695}} \right] \qquad (5.3)$$

The V-notch predicted flow rate values were calculated using Eq. 5.4 and plotted against the actual flow rates. Similar to the rectangular notch the error margin is 5% as shown in Fig. 5.4.

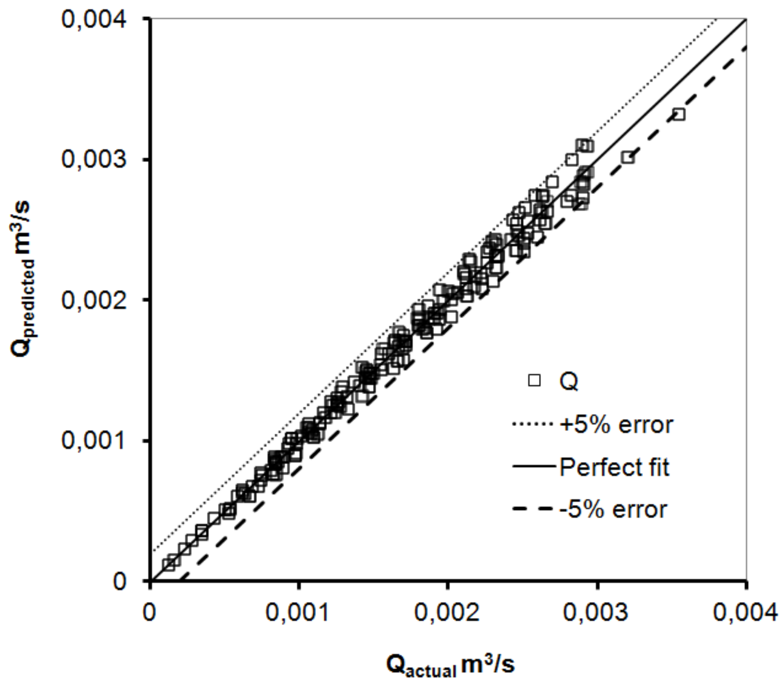



Figure 5.4 Comparison between the actual and predicted flow rates through V notch

$$Q_{pre} = C_{pre} \frac{8}{15} \tan\left(\frac{\theta}{2}\right) \sqrt{2g} h^{5/2} \tag{5.4}$$

### 5.3 Conclusion

The single composite equation was applied to the data obtained for the notches and predicted $C_d$ values and flow rates obtained. After an application of the single composite equation the laminar flow relationship between $C_d$–Re for rectangular notch became $0.56Re^{0.40}$ and $0.12Re^{0.38}$ for the V-notch. The transition for rectangular and V-notches occurred at Re = 280 and 100 respectively. The $C_d$ values were independent of Reynolds number in the turbulent flow. They maintained an average constant value of 0.59 for rectangular and V notches. The log standard error approach was used to calculate errors for discharge velocity values because they depend on other variables (Eq. 3.16). The error margins for rectangular and V-notches were 5%.

# CHAPTER SIX
## DISCUSSION

### 6.1 Introduction

In this chapter the results are discussed and compared to the literature. Since there is not much work found on the flow rate measurement of non-Newtonian fluids using notches the discussion is supported by the literature on flow rate measurement of Newtonian fluids through notches, and discharge through orifices for both Newtonian and non-Newtonian fluids.

### 6.2 Calibration

The experimental shear stress obtained from calibration of an in-line tube viscometer for 13 and 28 mm diameter pipes were found to be within ±10% deviation compared to calculated shear stress from the Colebrook and White (1937) prediction. This is in line with work done by researchers in the same research group.

The mean representative $C_d$ values obtained for the rectangular notch was 0.59. The data is within ±5% when compared to Replogle (2006) data. The mean representative $C_d$ value presented by Replogle (2006) is 0.57. On the other hand V-notch mean best-fit experimental $C_d$ value is 0.62 while Replogle (2006) obtained mean representative $C_d$ value of 0.58. Thus only 82% of the results are inside +5% margins. This could be because of potential measurement error at the small heads.

### 6.3 Notch Design

The literature shows that the Kindsvater and Carter (1957) equation can be applied to smaller notches down to 0.03 m wide, with heads ranging from 0.05 to 0.2 m (ASTM 1993, USBR 1993; ISO, 1980 and Ackers et al., 1978). The data published by Replogle (2006) have a minimum head of 0.06 m and the smallest width of the notch used was 0.3 m wide. In this study rectangular notch was 0.1234 m wide and the measured heights ranged from +0.01 to +0.1 m when considering flow rate measurements for all tested fluids. The minimum and maximum heads measured for the V-notch were +0.03 and +0.1 m respectively. The minimum head measurements achieved in this work for both rectangular and V notches was lower than the limits specified in the literature. Ackers et al. (1978) commented that the V-notch has the ability to cover a wide range of flows, even small ones. However, the rectangular notch covered much smaller flow rates than V-notch in this study.

### 6.4 $C_d$-yield stress relationship

Haldenwang et al. (2007) determined the relationship for the $C_d$ and yield stress as shown in Fig. 2.16. They concluded that the $C_d$ values increased with increasing concentration and yield stress. Equations were established for rectangular and V-notch as given in Eqs. 2.31 and 2.32. However, those equations did not incorporate all rheological parameters of the tested fluids. The same concept was used to analysis the present data. The $C_d$ values were found to be almost constant regardless the concentration or yield stress. But the maximum concentration tested and yield stress found by Haldenwang et al. (2007) were 10%v/v kaolin at +20 Pa while for this research it was 15%v/v kaolin at +10 Pa. Therefore the difference could be due to the variance in material rheological properties which has been observed with different batches by various researches conducted in the unit.

### 6.5 $C_d$-Re relationship

It has been stated that the flow of liquids depends on velocity; flow rate; width of the notch; crest height of the notch above mean bed level; measured head related to notch crest; dynamic viscosity of fluid and the density. Thus the $C_d$ depends on Reynolds number. This statement was based on theoretical and experimental analysis by the following authors: Barr (1910); Lenz (1943); Kindsvater & Carter (1957); Ackers et al. (1978); Mitra & Mazudar (2004); Afzalimehr & Bagheri (2009) and Aydin et al. (2011). In order to determine Reynolds numbers, geometric parameters of the notches had to be known, density of fluids and rheological parameters were measured. This confirms the dependence of fluid flow behaviour of fluids through notches on Reynolds number.

One of the findings of this work is that high concentrations of kaolin suspension and CMC solutions are in laminar flow region and the low concentration, bentonite suspension and water are at turbulent condition for rectangular and V notches. This confirms an observation of the results obtained by Dziubiński and Marcinkowski (2006) where high concentrations of starch syrup (Fig. 2.20) and CMC solution (Fig 2.22) are found in the laminar section while turbulent region consists of low concentrations of both fluids, ethylene glycol and water. Ntamba's (2011) results also show similar behaviour where high concentrations of kaolin suspension and CMC solution are at laminar area and low concentrations of kaolin, bentonite and water are found in turbulent region.

The data published by Dziubiński and Marcinkowski (2006) for CMC solution and Newtonian fluids data indicates that at Re < 10 (laminar region). The results were described by the power law equation:

$$\phi = b\mathrm{Re}^{C} \tag{2.43}$$

This is in agreement with the expression used by Patankar et al. (2002) model prediction where

$$f_1 = a_1\mathrm{Re}^{b_1} \tag{2.51}$$

And $f_1$ is found to be $0.055\mathrm{Re}^{0.4243}$ and $0.096\mathrm{Re}^{0.439}$ for rectangular and V notches respectively before applying a single composite equation.

Dziubiński and Marcinkowski's (2006) average $C_d$ values in the turbulent regions are 0.62 and 0.67 for Newtonian fluids and CMC solution. The research done by Ntamba (2011) on flow rate measurement of non-Newtonian fluids through short square-edged orifice plates confirms Dziubiński and Marcinkowski's (2006) work and the average $C_d$ value obtained in turbulent region is 0.64. Furthermore, Merrit (1967) achieved an average $C_d$ value of 0.61 at turbulent flow when establishing the relationship between the discharge coefficient and the square root of the Reynolds number. The average $C_d$ values attained in the turbulent region for rectangular notch before application of single composite equation are 0.60 and 0.61 for rectangular and V-notches. These studies all had constant $C_d$ values in the turbulent region.

The transition zones are encountered at different Reynolds number for different researches. The effect of the type and geometry of hydraulic equipment used could influence the transition region. Rectangular notch transition occurred at an Re of 280 while for the V-notch at an Re value of 100.

For comparison purposes $\mathrm{Re}_{MR}$ was used to calculate the Reynolds number for the CMC solutions. There was very little difference between $\mathrm{Re}_{MR}$ and $\mathrm{Re}_{H}$.

**6.6 Model prediction**

The literature indicates that Borutzky et al. (2002) developed an orifice model for energy losses in laminar and turbulent flow conditions using the Merrit (1967) data. The observed behaviour of that model (Fig. 2.25) shows similarity with predicted models for rectangular and V-notches (Figs 5.1 and 5.3).

After an application of a single composite equation the slopes in laminar flow for rectangular and V-notches are 0.40 and 0.38 respectively. The difference between the two slopes is very little. The average $C_d$ value is 0.59 for rectangular notch and transition occurred at Re 280 while V notch average $C_d$ value is 0.59 and transition happened at Re 100.

## 6.7 Error Analysis

The error margins have been evaluated using the correlation coefficient for flow rate measurement results of rectangular and V-notches. The comparison was between the actual and predicted discharges and the error was within ±5%. This error margin is in agreement with the mean relative errors obtained by Dziubiński and Marcinkowski (2006) for flow of Newtonian fluids and CMC solution through orifices and they were 7.1% and 5.7% respectively. It also confirms Bouveng (1969) statement that flow rate measurement using notches can be carried out to an accuracy of +10%.

## 6.8 Conclusion

Water tests were conducted in the in-line tube viscometer for the different pipes for calibration purposes. When comparing the data with the Colebrook and white (1937) prediction, they were found to be within ±10% deviation.

Rectangular and V notches calibration results were compared to Replogle (2006) data. The data for rectangular notch was within ±5% while for V-notch, 18% of the data was outside the ±5% margins. The minimum measured heads for both rectangular and V notches in this work were lower than the specified limits from the literature.

The $C_d$-yield stress relationship was established for rectangular and V notches. The mean representative $C_d$ values were almost constant at all concentrations and yield stresses. In the work published by Haldenwang et al. (2007) $C_d$ values increased with increasing concentration and yield stress which could be due to the variation in rheological properties for different material batches.

The results obtained for flow rate measurement of Newtonian and non-Newtonian fluids through orifices indicate the dependence of $C_d$ on Re in laminar flow. The $C_d$ values increased with an increasing Reynolds number. They become constant in the turbulent region and are independent of Reynolds number. Similar behaviour has been observed for flow rate measurement of non-Newtonian fluids through rectangular and V-notches. This confirms the statement made by Horton (1907) that orifices behave similar to notches when they are not at full capacity.

Transition zones were different for research on notches. Reynolds numbers ($Re_{MR}$ and $Re_H$) for CMC solution did not differ much. The predicted discharge is within 5% of the actual discharge for rectangular and V-notches.

# CHAPTER SEVEN
## CONCLUSION AND RECOMMENDATIONS

### 7.1 Introduction

This chapter presents a summary of work done to accomplish the research on flow rate measurement of non-Newtonian fluids through rectangular and V notches. It restates the objective and outlines the literature used. The findings are summarised with their implications and significance. It also entails recommendations for further work.

### 7.2 Summary

This study shows the possibility of using notches to measure the flow rate of non-Newtonian fluids provided that rheological behaviour and parameters of these fluids are known. This was achieved by establishing the relationship between the coefficient of discharge ($C_d$) and an appropriate Reynolds number values for all the fluids using both a rectangular and a V-notch. Equations used to calculate $C_d$ values were obtained from the studies done for flow rate measurement of water over notches proposed by Kindsvater and Carter (1957). The Reynolds numbers used were those proposed by Haldenwang et al., (2002) and Metzner and Reed (1955) for open channel flow. Literature pertaining to orifices was used for comparison purposes. This is because there is very limited literature found on the flow of non-Newtonian fluids through notches. Bingham plastic, pseudoplastic and yield-pseudoplastic models were used to determine rheological parameters of the test fluids. The non-Newtonian fluids tested were Carboxymethyl Cellulose (CMC) solutions and kaolin and bentonite suspensions. A modified flume rig was used to conduct all the experiments. An in-line tube viscometer was used to measure the rheological parameters of the fluids. Those parameters were used to calculate the appropriate Reynolds number $Re_H$ and $Re_{MR.}$ The $C_d$ values were plotted against the Reynolds numbers. Results obtained indicate that the $C_d$ values were totally dependent of Reynolds number in the laminar region and independent of Reynolds number and maintaining constant $C_d$ values in the turbulent flow region similar to that of water. A single composite power-law model was used to correlate the $C_d$ and Reynolds number relationship for rectangular and V-notches of the whole flow regime from laminar to turbulent. The discussion of the results was based on flow measurement of Newtonian fluids using notches, open channel flow and flow of non-Newtonian fluids through orifices.

## 7.3 Findings

After an application of the single composite equation the laminar flow relationship between $C_d$–Re for rectangular notch became $0.056Re^{0.40}$ and $0.12Re^{0.38}$ for the V-notch. The transition for rectangular and V-notches occurred at Re = 280 and 100 respectively. The $C_d$ values were independent of Reynolds number in the turbulent flow. They maintained a mean representative constant value of 0.59 for both rectangular and V-notches. The error margins were within 5% for both notches.

The relationship between $C_d$ values and yield stress for non-Newtonian fluids was carried out. The analysis was based on fluids that were on the turbulent region. The $C_d$ values did not increase with increasing concentration or yield stress but they were somewhat constant, while in the work published by Haldenwang et al. (2007), $C_d$ values increased with increasing concentration and yield stress. This method did not include all rheological parameters. As a result $C_d$-Re relationship was found to be a more appropriate approach.

The results of this research are supported by the literature on the flow rate measurement of fluids through orifices. Similar behaviour of flow rate measurement of non-Newtonian fluids through notches was observed by Ntamba (2011) and Dziubiński and Marcinkowiski (2006) for flow of Newtonian and non-Newtonian fluids through orifices. The model developed by Borutzky et al. (2002) also showed similar behaviour to the single composite model used in this work. There is no obvious difference for the $Re_H$ and $Re_{MR}$ numbers for flow of the CMC solutions for rectangular and V-notches. An implication of this is the possibility that rectangular and V-notches can be used to measure the flow rate of non-Newtonian fluids. For the first time an attempt has been made to predict the flow rate of non-Newtonian fluids using a rectangular and a V-notch.

This research will benefit mining, food processing, waste water treatment and chemical processing industries to opt for notches as a simple flow rate measuring device in tanks and open channels during transportation and processing of non-Newtonian fluids.

The findings of this work have been published in the ASCE journal of Hydraulic Engineering. Khahledi M, Haldenwang R and Chhabra R (2015). Flow rate measurement of non-Newtonian fluids through sharp crested notches. *J.Hydraul.Eng.,*141(1,04014067).

## 7.4 Recommendations

The database for flow rate measurement of non-Newtonian fluids using notches can be extended by using shapes other than rectangular and V-notches i.e. half-round or trapezoid. It is also recommended that other non-Newtonian fluids be tested. This will extend an opportunity to develop more predictions for $C_d$ in terms of an appropriate Reynolds number as obtained for rectangular and V notches in this work. The effect of scale up is also a possible area for future research as only one size each of the V and rectangular notches were tested in this work.

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# APPENDICES

## APPENDIX A: Kaolin rheology results

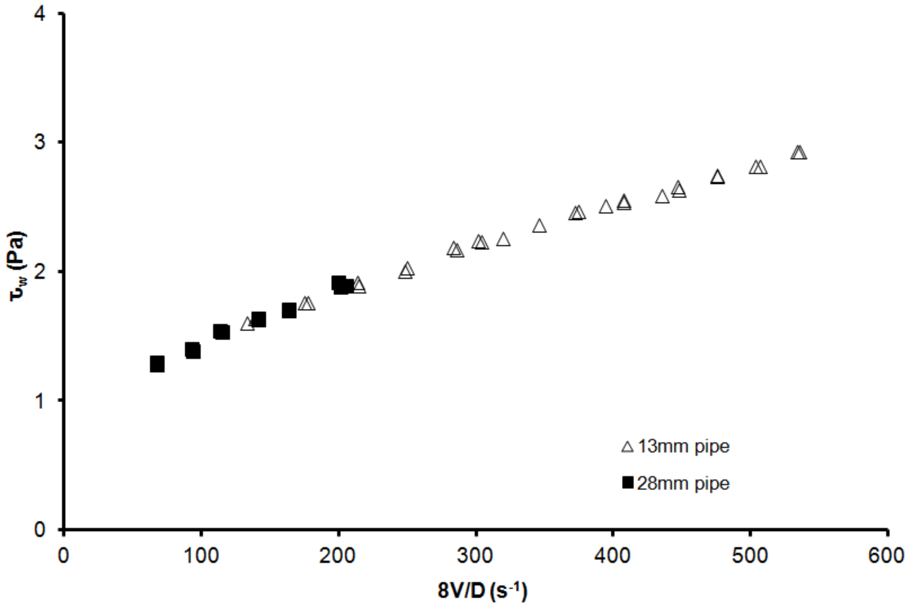


Figure 4.18 kaolin 6.7%v/v rheology result

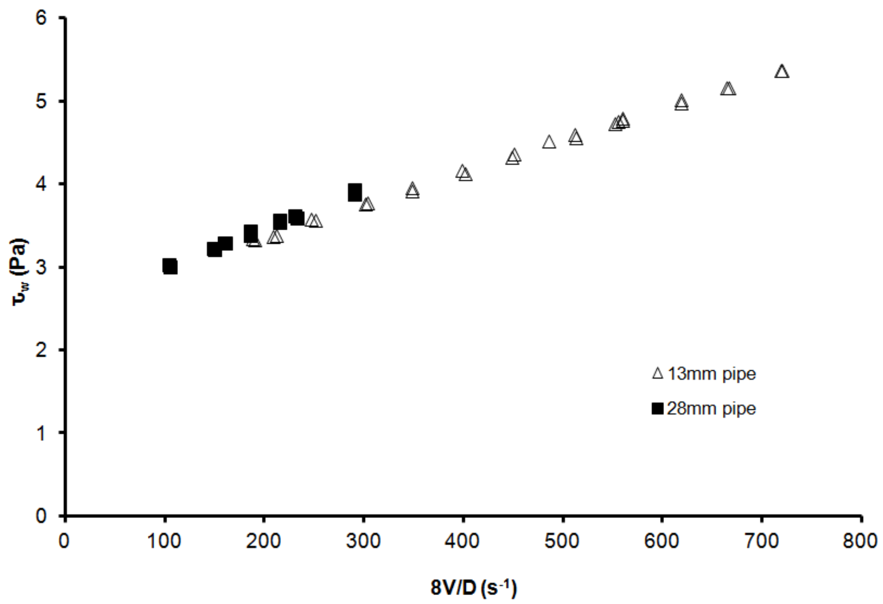


Figure 4.19 kaolin 8.2%v/v rheology results

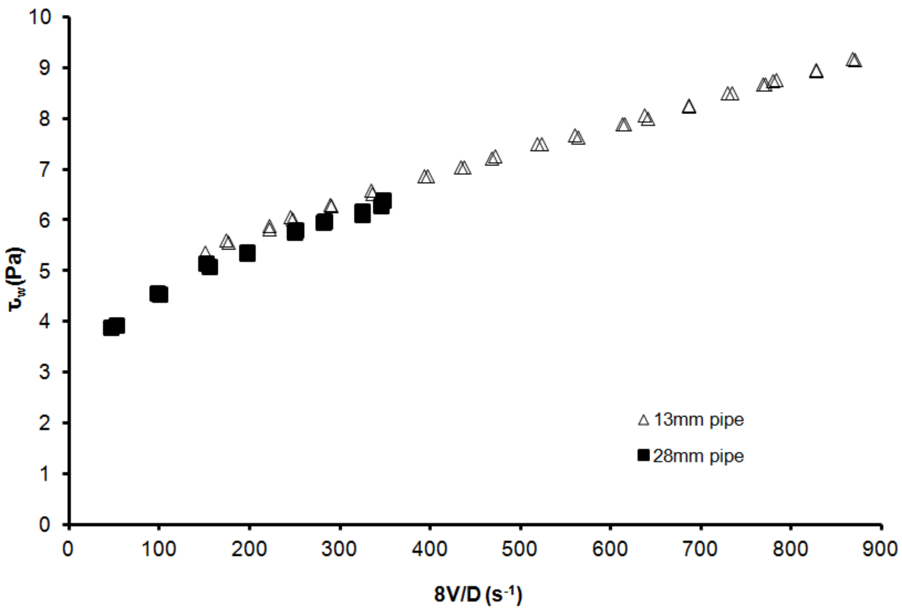


Figure 4.20 kaolin 10.9%v/v rheology results

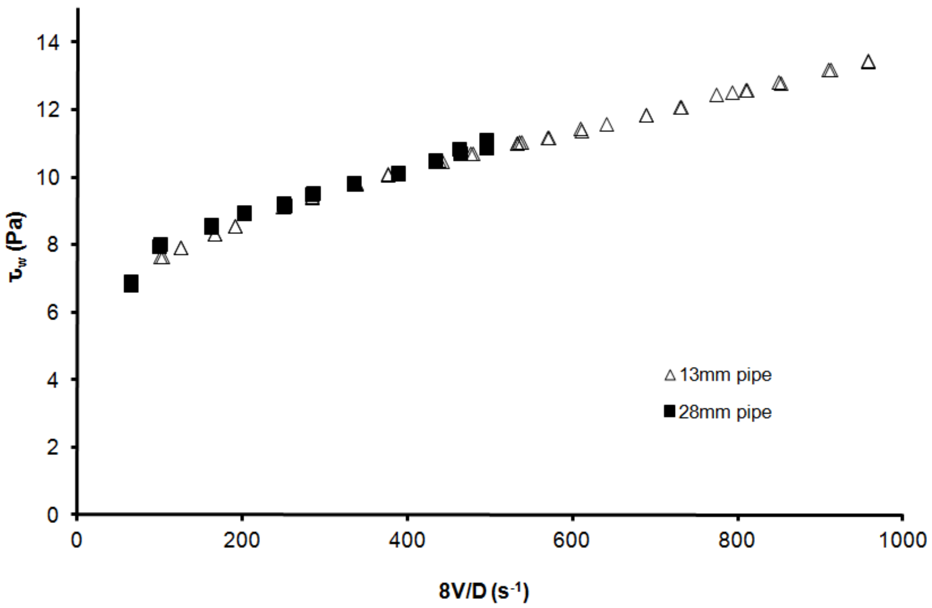


Figure 4.21 kaolin 12.6%v/v rheology results

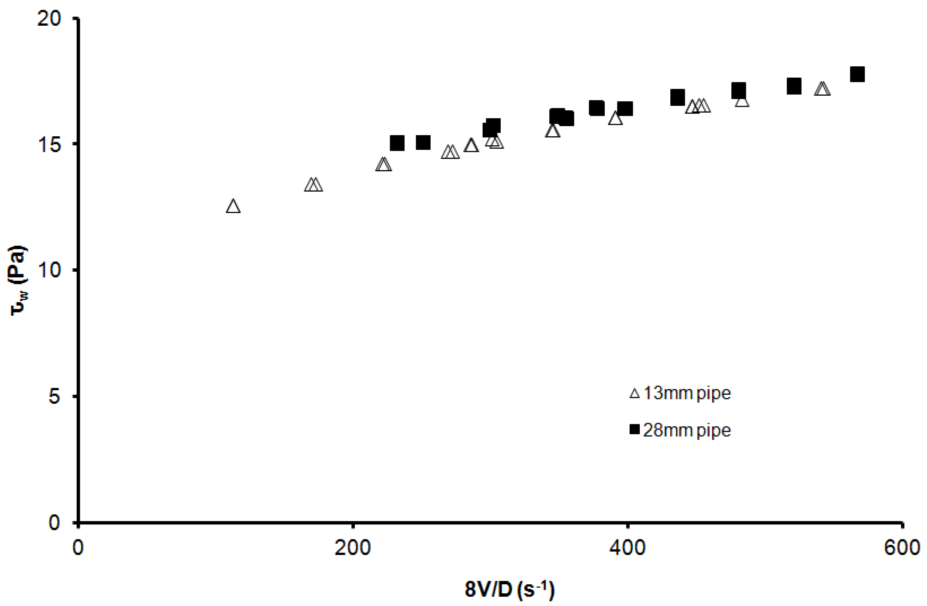


Figure 4.22 kaolin 14.6%v/v rheology results

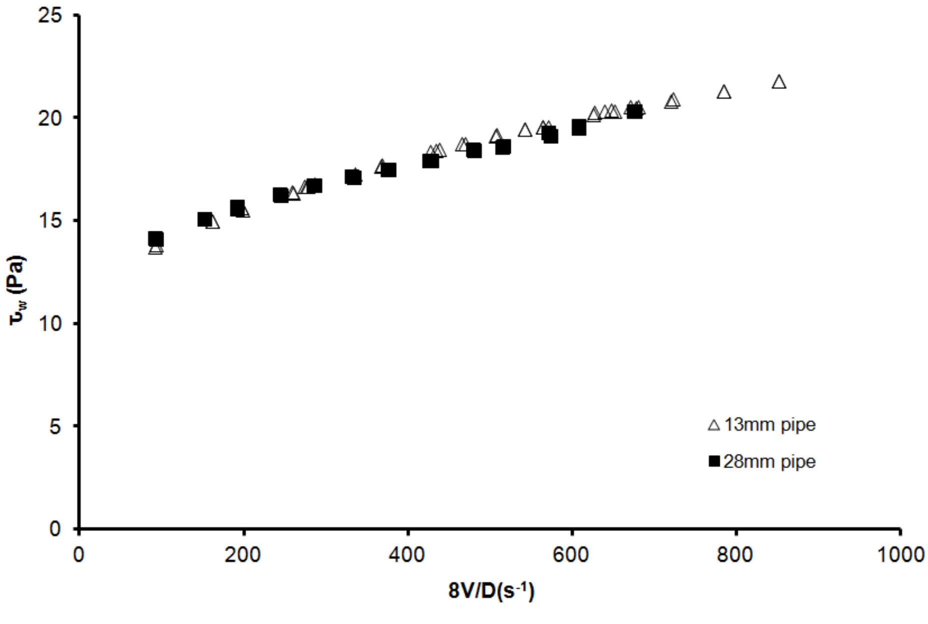


Figure 4.23 kaolin 15.3%v/v rheology results

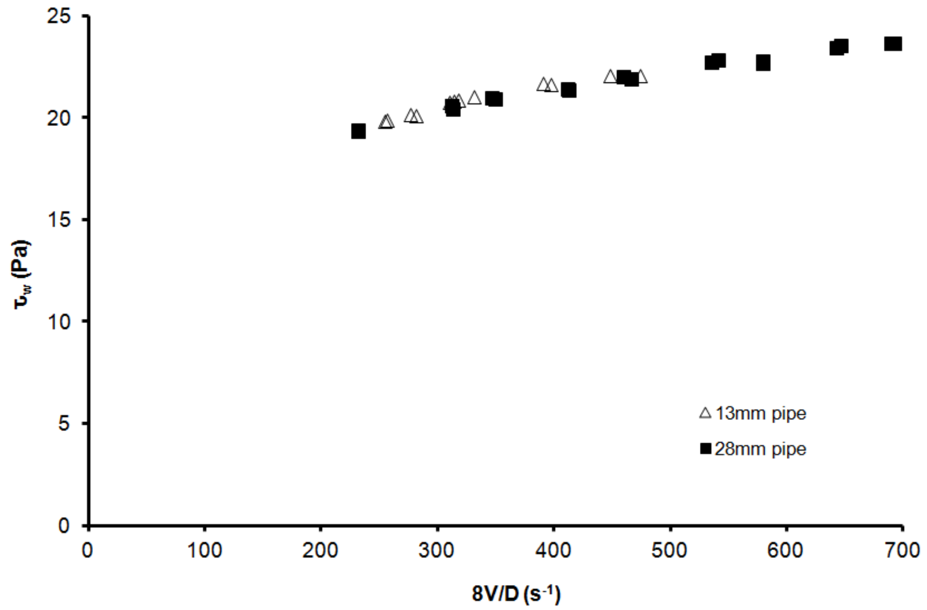


Figure 4.24 kaolin 16%v/v rheology results

## APPENDIX B: Bentonite rheology results

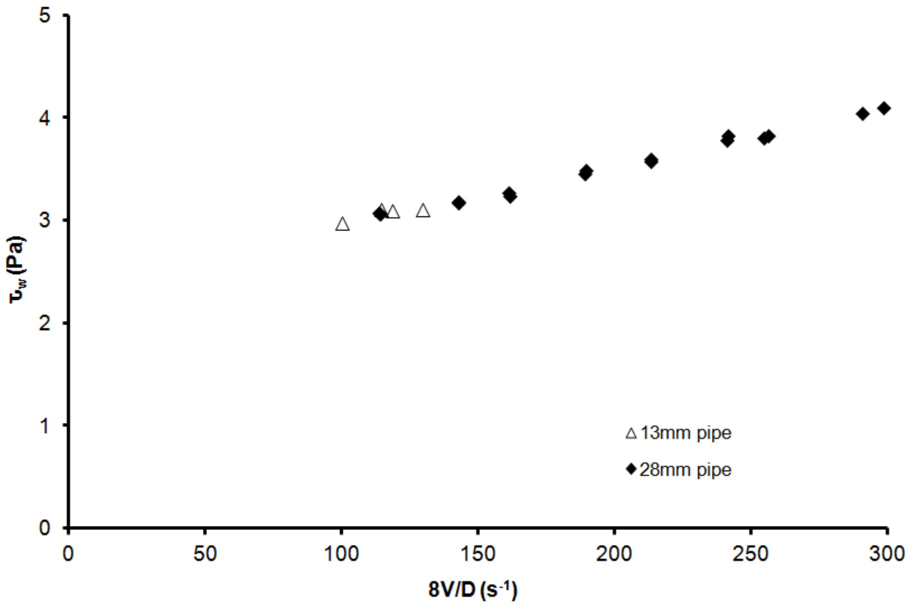


Figure 4.25 bentonite 5.1%w/w rheology results

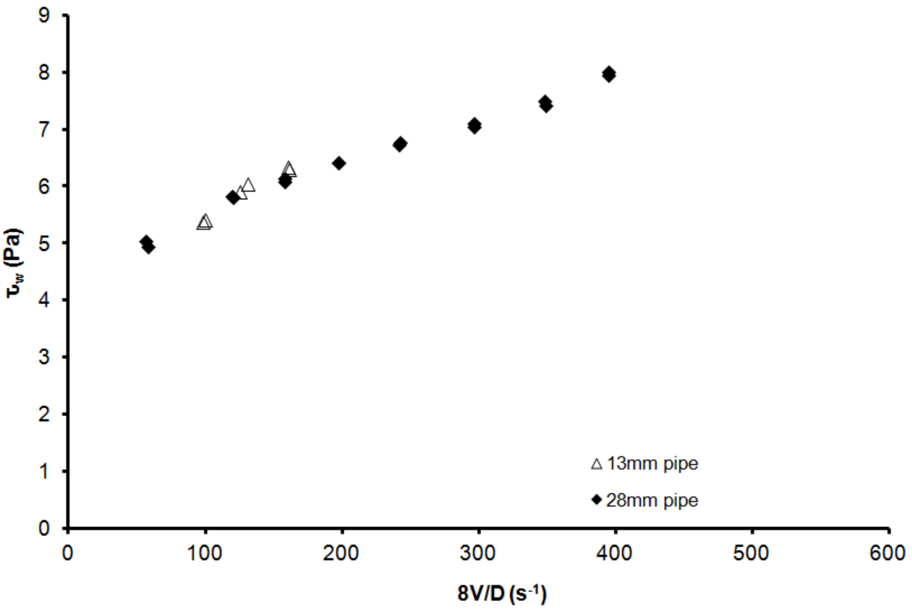


Figure 4.26 bentonite 6%w/w rheology results

## APPENDIX C: CMC rheology results

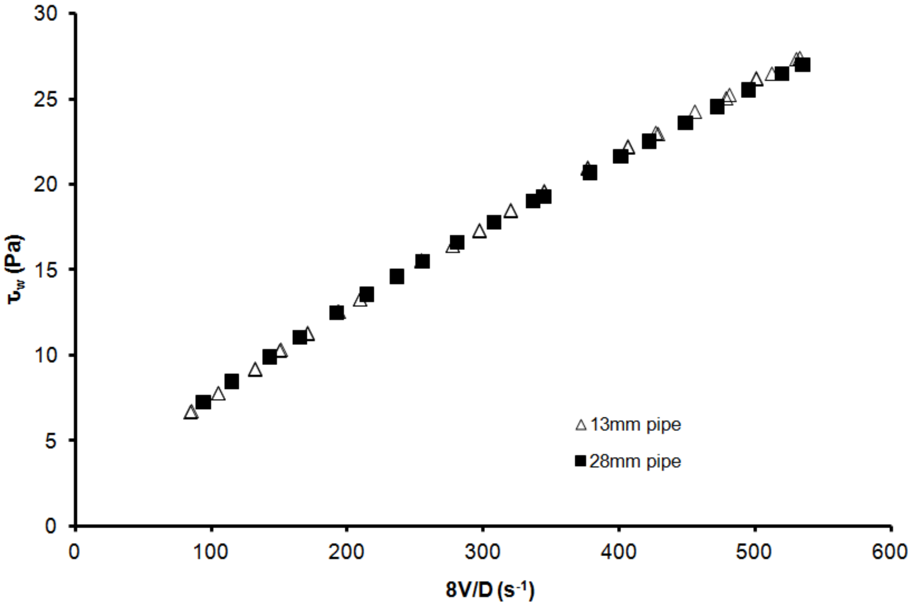


Figure 4.27 CMC 4.6%w/w rheology results

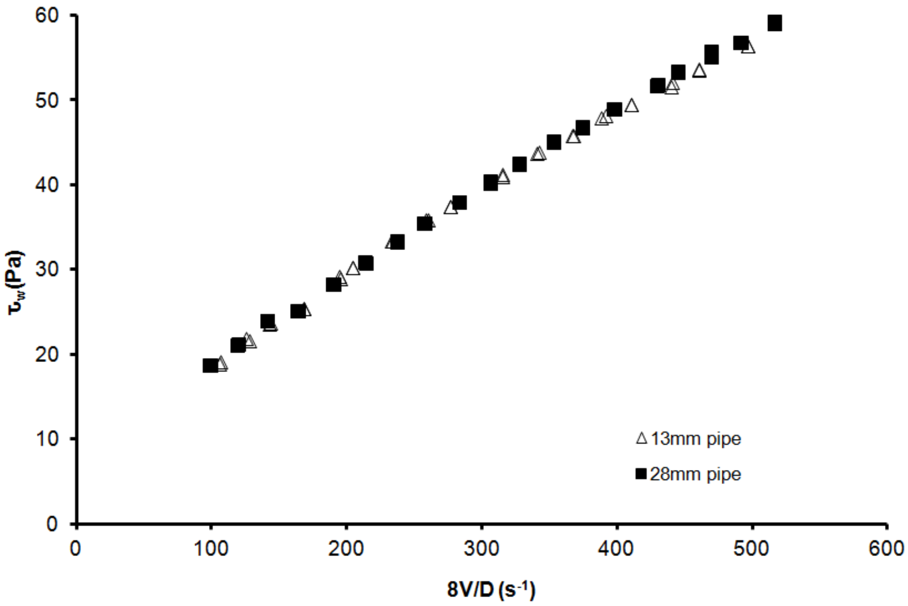


Figure 4.28 CMC 6.2%w/w rheology results

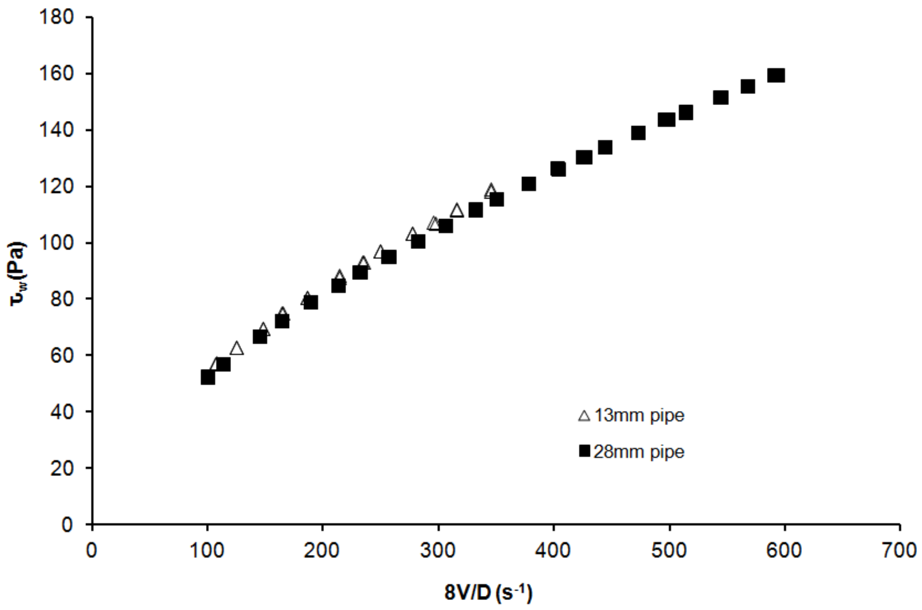


Figure 4.29 CMC 7.3%w/w rheology results

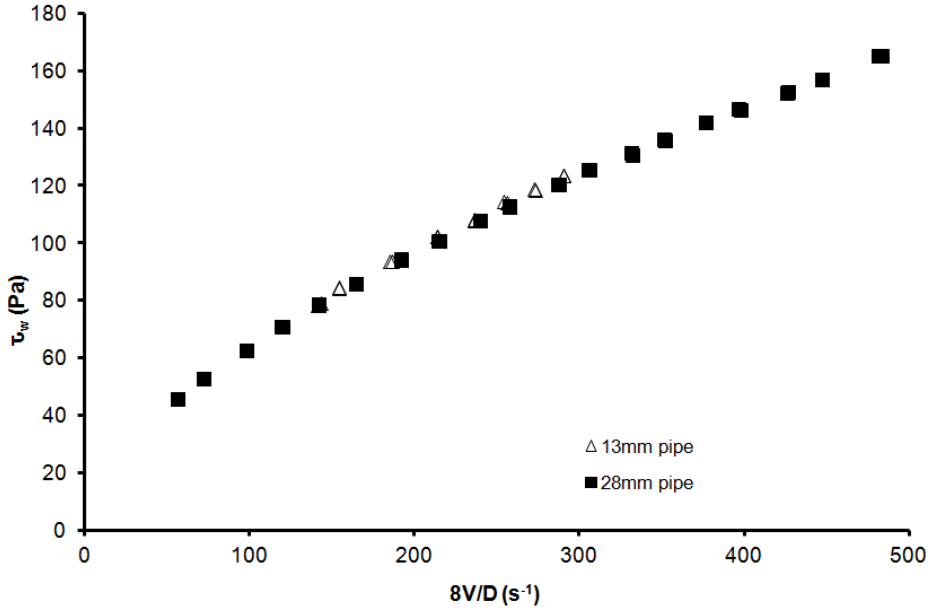


Figure 4.30 CMC 8.4%w/w rheology results

## APPENDIX D: Rectangular notch water calibration results (Water)

**Table 3.2 Water calibration results (Rectangular notch)**

Rectangular Notch (Water)

B(m)= 0,1234 g(m/s$^2$)= 9,81 9,813 Viscosity (Pa.s)= 0,001

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge4 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic radius m | Velocity m/s | Reynolds Number Re | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,60 | 0,0518 | 0,0520 | 0,0467 | 0,0000 | 0,0519 | 0,00260 | 0,217 | 0,00577 | 0,106 | 0,451 | 47942 | 0,604 | 0,602 | 0,603 |
| 2,60 | 0,0518 | 0,0520 | 0,0467 | 0,0000 | 0,0519 | 0,00260 | 0,217 | 0,00577 | 0,106 | 0,451 | 47925 | 0,604 | 0,602 | 0,603 |
| 2,91 | 0,0562 | 0,0561 | 0,0502 | 0,0000 | 0,0562 | 0,00291 | 0,224 | 0,00619 | 0,111 | 0,470 | 52021 | 0,599 | 0,601 | 0,600 |
| 2,91 | 0,0562 | 0,0561 | 0,0502 | 0,0000 | 0,0562 | 0,00291 | 0,224 | 0,00619 | 0,111 | 0,470 | 52044 | 0,599 | 0,601 | 0,600 |
| 2,91 | 0,0562 | 0,0561 | 0,0502 | 0,0000 | 0,0562 | 0,00291 | 0,224 | 0,00619 | 0,111 | 0,470 | 52045 | 0,599 | 0,601 | 0,600 |
| 3,26 | 0,0604 | 0,0605 | 0,0542 | 0,0000 | 0,0605 | 0,00326 | 0,232 | 0,00669 | 0,115 | 0,487 | 56177 | 0,601 | 0,600 | 0,601 |
| 3,25 | 0,0604 | 0,0605 | 0,0542 | 0,0000 | 0,0605 | 0,00325 | 0,232 | 0,00669 | 0,115 | 0,487 | 56167 | 0,601 | 0,600 | 0,601 |
| 3,26 | 0,0604 | 0,0605 | 0,0542 | 0,0000 | 0,0605 | 0,00326 | 0,232 | 0,00669 | 0,115 | 0,487 | 56171 | 0,601 | 0,600 | 0,601 |
| 3,54 | 0,0644 | 0,0644 | 0,0580 | 0,0000 | 0,0644 | 0,00354 | 0,239 | 0,00716 | 0,120 | 0,494 | 59070 | 0,594 | 0,593 | 0,594 |
| 3,54 | 0,0644 | 0,0644 | 0,0580 | 0,0000 | 0,0644 | 0,00354 | 0,239 | 0,00716 | 0,120 | 0,494 | 59075 | 0,594 | 0,593 | 0,594 |
| 3,54 | 0,0644 | 0,0644 | 0,0580 | 0,0000 | 0,0644 | 0,00354 | 0,239 | 0,00716 | 0,120 | 0,494 | 59072 | 0,594 | 0,593 | 0,594 |
| 3,81 | 0,0674 | 0,0673 | 0,0608 | 0,0000 | 0,0673 | 0,00381 | 0,245 | 0,00750 | 0,122 | 0,508 | 62163 | 0,597 | 0,598 | 0,598 |
| 3,81 | 0,0674 | 0,0673 | 0,0608 | 0,0000 | 0,0673 | 0,00381 | 0,245 | 0,00750 | 0,122 | 0,508 | 62164 | 0,597 | 0,598 | 0,598 |
| 3,81 | 0,0674 | 0,0673 | 0,0608 | 0,0000 | 0,0673 | 0,00381 | 0,245 | 0,00750 | 0,122 | 0,508 | 62160 | 0,597 | 0,598 | 0,598 |
| 4,11 | 0,0714 | 0,0713 | 0,0646 | 0,0000 | 0,0713 | 0,00411 | 0,253 | 0,00797 | 0,126 | 0,516 | 65103 | 0,592 | 0,593 | 0,592 |
| 4,11 | 0,0714 | 0,0713 | 0,0646 | 0,0000 | 0,0713 | 0,00411 | 0,253 | 0,00797 | 0,126 | 0,516 | 65089 | 0,592 | 0,593 | 0,592 |
| 4,13 | 0,0714 | 0,0713 | 0,0646 | 0,0000 | 0,0713 | 0,00413 | 0,253 | 0,00797 | 0,126 | 0,518 | 65417 | 0,595 | 0,596 | 0,595 |

Rectangular Notch (Water)

B(m)= 0,1234 $g(m/s^2)$= 9,81 9,813 Viscosity (Pa.s)= 0,001

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge4 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic radius m | Velocity m/s | Reynolds Number Re | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4,44 | 0,0752 | 0,0751 | 0,0679 | 0,0000 | 0,0752 | 0,00444 | 0,259 | 0,00838 | 0,129 | 0,530 | 68562 | 0,591 | 0,592 | 0,592 |
| 4,44 | 0,0752 | 0,0751 | 0,0679 | 0,0000 | 0,0752 | 0,00444 | 0,259 | 0,00838 | 0,129 | 0,530 | 68555 | 0,591 | 0,592 | 0,592 |
| 4,44 | 0,0752 | 0,0751 | 0,0679 | 0,0000 | 0,0752 | 0,00444 | 0,259 | 0,00838 | 0,129 | 0,530 | 68553 | 0,591 | 0,592 | 0,591 |
| 4,72 | 0,0785 | 0,0784 | 0,0708 | 0,0000 | 0,0785 | 0,00472 | 0,265 | 0,00874 | 0,132 | 0,540 | 71286 | 0,589 | 0,590 | 0,590 |
| 4,71 | 0,0785 | 0,0784 | 0,0708 | 0,0000 | 0,0785 | 0,00471 | 0,265 | 0,00874 | 0,132 | 0,539 | 71143 | 0,588 | 0,589 | 0,589 |
| 4,72 | 0,0785 | 0,0784 | 0,0708 | 0,0000 | 0,0785 | 0,00472 | 0,265 | 0,00874 | 0,132 | 0,540 | 71281 | 0,589 | 0,590 | 0,590 |
| 5,01 | 0,0816 | 0,0817 | 0,0737 | 0,0000 | 0,0816 | 0,00501 | 0,271 | 0,00909 | 0,134 | 0,551 | 73946 | 0,590 | 0,588 | 0,589 |
| 5,00 | 0,0816 | 0,0817 | 0,0737 | 0,0000 | 0,0816 | 0,00500 | 0,271 | 0,00909 | 0,134 | 0,551 | 73942 | 0,590 | 0,588 | 0,589 |
| 5,00 | 0,0816 | 0,0817 | 0,0737 | 0,0000 | 0,0816 | 0,00500 | 0,271 | 0,00909 | 0,134 | 0,551 | 73945 | 0,590 | 0,588 | 0,589 |
| 5,30 | 0,0847 | 0,0848 | 0,0767 | 0,0000 | 0,0847 | 0,00530 | 0,277 | 0,00946 | 0,137 | 0,559 | 76520 | 0,589 | 0,589 | 0,589 |
| 5,31 | 0,0847 | 0,0848 | 0,0767 | 0,0000 | 0,0847 | 0,00531 | 0,277 | 0,00946 | 0,137 | 0,561 | 76687 | 0,591 | 0,590 | 0,590 |
| 5,31 | 0,0847 | 0,0848 | 0,0767 | 0,0000 | 0,0847 | 0,00531 | 0,277 | 0,00946 | 0,137 | 0,561 | 76694 | 0,591 | 0,590 | 0,590 |
| 5,59 | 0,0877 | 0,0878 | 0,0801 | 0,0000 | 0,0877 | 0,00559 | 0,284 | 0,00989 | 0,139 | 0,565 | 78794 | 0,591 | 0,590 | 0,590 |
| 5,58 | 0,0877 | 0,0878 | 0,0801 | 0,0000 | 0,0877 | 0,00558 | 0,284 | 0,00989 | 0,139 | 0,564 | 78655 | 0,590 | 0,589 | 0,589 |
| 5,59 | 0,0877 | 0,0878 | 0,0801 | 0,0000 | 0,0877 | 0,00559 | 0,284 | 0,00989 | 0,139 | 0,565 | 78785 | 0,591 | 0,590 | 0,590 |
| 5,84 | 0,0902 | 0,0903 | 0,0819 | 0,0000 | 0,0903 | 0,00584 | 0,287 | 0,01011 | 0,141 | 0,577 | 81301 | 0,591 | 0,590 | 0,591 |
| 5,84 | 0,0902 | 0,0903 | 0,0819 | 0,0000 | 0,0903 | 0,00584 | 0,287 | 0,01011 | 0,141 | 0,577 | 81280 | 0,591 | 0,590 | 0,590 |
| 5,83 | 0,0902 | 0,0903 | 0,0819 | 0,0000 | 0,0903 | 0,00583 | 0,287 | 0,01011 | 0,141 | 0,576 | 81140 | 0,590 | 0,589 | 0,589 |

Rectangular Notch (Water)

B(m)= 0,1234 g(m/s$^2$)= 9,81 9,813 Viscosity (Pa.s)= 0,001

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge4 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic radius m | Velocity m/s | Reynolds Number Re | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6,13 | 0,0936 | 0,0936 | 0,0844 | 0,0000 | 0,0936 | 0,00613 | 0,292 | 0,01042 | 0,143 | 0,588 | 83891 | 0,588 | 0,587 | 0,587 |
| 6,13 | 0,0936 | 0,0936 | 0,0844 | 0,0000 | 0,0936 | 0,00613 | 0,292 | 0,01042 | 0,143 | 0,588 | 83891 | 0,588 | 0,587 | 0,587 |
| 6,12 | 0,0936 | 0,0936 | 0,0844 | 0,0000 | 0,0936 | 0,00612 | 0,292 | 0,01042 | 0,143 | 0,587 | 83731 | 0,586 | 0,586 | 0,586 |
| 6,43 | 0,0963 | 0,0966 | 0,0876 | 0,0000 | 0,0964 | 0,00643 | 0,299 | 0,01081 | 0,145 | 0,595 | 86136 | 0,591 | 0,588 | 0,589 |
| 6,43 | 0,0963 | 0,0966 | 0,0876 | 0,0000 | 0,0964 | 0,00643 | 0,299 | 0,01081 | 0,145 | 0,595 | 86125 | 0,591 | 0,588 | 0,589 |
| 6,43 | 0,0963 | 0,0966 | 0,0876 | 0,0000 | 0,0964 | 0,00643 | 0,299 | 0,01081 | 0,145 | 0,595 | 86138 | 0,591 | 0,588 | 0,590 |
| 6,74 | 0,0994 | 0,0997 | 0,0908 | 0,0000 | 0,0995 | 0,00674 | 0,305 | 0,01120 | 0,147 | 0,602 | 88446 | 0,590 | 0,588 | 0,589 |
| 6,73 | 0,0994 | 0,0997 | 0,0908 | 0,0000 | 0,0995 | 0,00673 | 0,305 | 0,01120 | 0,147 | 0,601 | 88306 | 0,589 | 0,587 | 0,588 |
| 6,74 | 0,0994 | 0,0997 | 0,0908 | 0,0000 | 0,0995 | 0,00674 | 0,305 | 0,01120 | 0,147 | 0,602 | 88441 | 0,590 | 0,588 | 0,589 |
| 7,00 | 0,1022 | 0,1023 | 0,0931 | 0,0000 | 0,1022 | 0,00700 | 0,310 | 0,01149 | 0,148 | 0,610 | 90495 | 0,588 | 0,587 | 0,588 |
| 7,02 | 0,1022 | 0,1023 | 0,0931 | 0,0000 | 0,1022 | 0,00702 | 0,310 | 0,01149 | 0,148 | 0,612 | 90763 | 0,590 | 0,589 | 0,590 |
| 7,02 | 0,1022 | 0,1023 | 0,0931 | 0,0000 | 0,1022 | 0,00702 | 0,310 | 0,01149 | 0,148 | 0,612 | 90763 | 0,590 | 0,589 | 0,590 |
| 7,34 | 0,1054 | 0,1056 | 0,0961 | 0,0000 | 0,1055 | 0,00734 | 0,316 | 0,01186 | 0,150 | 0,618 | 92970 | 0,588 | 0,587 | 0,588 |
| 7,36 | 0,1054 | 0,1056 | 0,0961 | 0,0000 | 0,1055 | 0,00736 | 0,316 | 0,01186 | 0,150 | 0,620 | 93235 | 0,590 | 0,588 | 0,589 |
| 7,36 | 0,1054 | 0,1056 | 0,0961 | 0,0000 | 0,1055 | 0,00736 | 0,316 | 0,01186 | 0,150 | 0,620 | 93252 | 0,590 | 0,588 | 0,589 |
| 7,61 | 0,1079 | 0,1081 | 0,0987 | 0,0000 | 0,1080 | 0,00761 | 0,321 | 0,01218 | 0,152 | 0,624 | 94843 | 0,589 | 0,588 | 0,588 |
| 7,61 | 0,1079 | 0,1081 | 0,0987 | 0,0000 | 0,1080 | 0,00761 | 0,321 | 0,01218 | 0,152 | 0,625 | 94909 | 0,589 | 0,588 | 0,589 |
| 7,60 | 0,1079 | 0,1081 | 0,0987 | 0,0000 | 0,1080 | 0,00760 | 0,321 | 0,01218 | 0,152 | 0,624 | 94711 | 0,588 | 0,587 | 0,587 |

Rectangular Notch (Water)

B(m)= 0,1234 g($m/s^2$)= 9,81 9,813 Viscosity (Pa.s)= 0,001

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge4 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic radius m | Velocity m/s | Reynolds Number Re | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7,91 | 0,1106 | 0,1109 | 0,1010 | 0,0000 | 0,1108 | 0,00791 | 0,325 | 0,01246 | 0,153 | 0,635 | 97240 | 0,590 | 0,587 | 0,589 |
| 7,90 | 0,1106 | 0,1109 | 0,1010 | 0,0000 | 0,1108 | 0,00790 | 0,325 | 0,01246 | 0,153 | 0,634 | 97128 | 0,589 | 0,587 | 0,588 |
| 7,91 | 0,1106 | 0,1109 | 0,1010 | 0,0000 | 0,1108 | 0,00791 | 0,325 | 0,01246 | 0,153 | 0,635 | 97319 | 0,590 | 0,588 | 0,589 |
| 8,23 | 0,1138 | 0,1138 | 0,1039 | 1,0000 | 0,1138 | 0,00823 | 0,331 | 0,01282 | 0,155 | 0,642 | 99386 | 0,588 | 0,588 | 0,588 |
| 8,22 | 0,1138 | 0,1138 | 0,1039 | 2,0000 | 0,1138 | 0,00822 | 0,331 | 0,01282 | 0,155 | 0,641 | 99319 | 0,588 | 0,587 | 0,588 |
| 8,22 | 0,1138 | 0,1138 | 0,1039 | 3,0000 | 0,1138 | 0,00822 | 0,331 | 0,01282 | 0,155 | 0,641 | 99318 | 0,588 | 0,587 | 0,588 |
| 8,52 | 0,1162 | 0,1162 | 0,1065 | 4,0000 | 0,1162 | 0,00852 | 0,336 | 0,01314 | 0,156 | 0,649 | 101350 | 0,590 | 0,590 | 0,590 |
| 8,53 | 0,1162 | 0,1162 | 0,1065 | 5,0000 | 0,1162 | 0,00853 | 0,336 | 0,01314 | 0,156 | 0,649 | 101478 | 0,591 | 0,591 | 0,591 |
| 8,53 | 0,1162 | 0,1162 | 0,1065 | 6,0000 | 0,1162 | 0,00853 | 0,336 | 0,01314 | 0,156 | 0,649 | 101479 | 0,591 | 0,591 | 0,591 |
| 8,85 | 0,1191 | 0,1195 | 0,1089 | 7,0000 | 0,1193 | 0,00885 | 0,341 | 0,01344 | 0,158 | 0,658 | 103729 | 0,591 | 0,588 | 0,589 |
| 8,86 | 0,1191 | 0,1195 | 0,1089 | 8,0000 | 0,1193 | 0,00886 | 0,341 | 0,01344 | 0,158 | 0,659 | 103830 | 0,591 | 0,588 | 0,590 |
| 8,85 | 0,1191 | 0,1195 | 0,1089 | 9,0000 | 0,1193 | 0,00885 | 0,341 | 0,01344 | 0,158 | 0,658 | 103713 | 0,591 | 0,588 | 0,589 |

**APPENDIX E: Rectangular notch flow rate measurement results (Kaolin suspension)**

**Table 4.2 Flow rate measurement of kaolin 5.48% through rectangular notch**

Rectangular Notch (Kaolin 5.48%)

Yield stress (Pa)= 0,246

Density (kg/m$^3$)= 1090

n = 0,645

B(m)= 0,1234    g(m/s$^2$)= 9,813    k (Pa.s$^n$)= 0,0294

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,02 | 0,0423 | 0,0424 | 0,0368 | 0,0424 | 0,00202 | 0,197 | 0,00454 | 0,0922 | 0,444 | 4607 | 0,635 | 0,634 | 0,635 |
| 2,02 | 0,0423 | 0,0424 | 0,0368 | 0,0424 | 0,00202 | 0,197 | 0,00454 | 0,0922 | 0,444 | 4602 | 0,635 | 0,634 | 0,634 |
| 2,34 | 0,0478 | 0,0478 | 0,0413 | 0,0478 | 0,00234 | 0,206 | 0,00510 | 0,0990 | 0,458 | 4951 | 0,613 | 0,613 | 0,613 |
| 2,33 | 0,0478 | 0,0478 | 0,0413 | 0,0478 | 0,00233 | 0,206 | 0,00510 | 0,0990 | 0,458 | 4938 | 0,612 | 0,612 | 0,612 |
| 2,63 | 0,0521 | 0,0521 | 0,0453 | 0,0521 | 0,00263 | 0,214 | 0,00559 | 0,105 | 0,470 | 5241 | 0,606 | 0,607 | 0,606 |
| 2,63 | 0,0521 | 0,0521 | 0,0453 | 0,0521 | 0,00263 | 0,214 | 0,00559 | 0,105 | 0,470 | 5240 | 0,606 | 0,607 | 0,606 |
| 2,97 | 0,0566 | 0,0565 | 0,0494 | 0,0565 | 0,00297 | 0,222 | 0,00610 | 0,110 | 0,488 | 5651 | 0,606 | 0,608 | 0,607 |
| 2,97 | 0,0566 | 0,0565 | 0,0494 | 0,0565 | 0,00297 | 0,222 | 0,00610 | 0,110 | 0,487 | 5650 | 0,606 | 0,608 | 0,607 |
| 3,23 | 0,0602 | 0,0601 | 0,0529 | 0,0602 | 0,00323 | 0,229 | 0,00653 | 0,114 | 0,495 | 5863 | 0,600 | 0,602 | 0,601 |
| 3,23 | 0,0602 | 0,0601 | 0,0529 | 0,0602 | 0,00323 | 0,229 | 0,00653 | 0,114 | 0,496 | 5866 | 0,600 | 0,602 | 0,601 |
| 3,51 | 0,0640 | 0,0639 | 0,0567 | 0,0639 | 0,00351 | 0,237 | 0,00700 | 0,118 | 0,502 | 6050 | 0,596 | 0,597 | 0,596 |
| 3,51 | 0,0640 | 0,0639 | 0,0567 | 0,0639 | 0,00351 | 0,237 | 0,00700 | 0,118 | 0,502 | 6046 | 0,596 | 0,597 | 0,596 |
| 3,81 | 0,0678 | 0,0678 | 0,0599 | 0,0678 | 0,00381 | 0,243 | 0,00739 | 0,122 | 0,515 | 6373 | 0,591 | 0,592 | 0,591 |
| 3,81 | 0,0678 | 0,0678 | 0,0599 | 0,0678 | 0,00381 | 0,243 | 0,00739 | 0,122 | 0,515 | 6373 | 0,591 | 0,592 | 0,591 |

Rectangular Notch (Kaolin 5.48%)

Yield stress (Pa)= 0,246

Density (kg/$m^3$)= 1090

n = 0,645

B(m)= 0,1234 g(m/$s^2$)= 9,813 k (Pa.$s^n$)= 0,0294

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3$/s | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4,11 | 0,0713 | 0,0712 | 0,0633 | 0,0712 | 0,00411 | 0,250 | 0,00781 | 0,125 | 0,526 | 6648 | 0,592 | 0,594 | 0,593 |
| 4,10 | 0,0713 | 0,0712 | 0,0633 | 0,0712 | 0,00410 | 0,250 | 0,00781 | 0,125 | 0,525 | 6620 | 0,591 | 0,592 | 0,592 |
| 4,40 | 0,0748 | 0,0748 | 0,0668 | 0,0748 | 0,00440 | 0,257 | 0,00824 | 0,128 | 0,535 | 6885 | 0,590 | 0,590 | 0,590 |
| 4,41 | 0,0748 | 0,0748 | 0,0668 | 0,0748 | 0,00441 | 0,257 | 0,00824 | 0,128 | 0,535 | 6903 | 0,591 | 0,591 | 0,591 |
| 4,72 | 0,0784 | 0,0783 | 0,0699 | 0,0784 | 0,00472 | 0,263 | 0,00863 | 0,131 | 0,547 | 7214 | 0,590 | 0,591 | 0,591 |
| 4,71 | 0,0784 | 0,0783 | 0,0699 | 0,0784 | 0,00471 | 0,263 | 0,00863 | 0,131 | 0,546 | 7185 | 0,589 | 0,590 | 0,589 |
| 5,13 | 0,0830 | 0,0829 | 0,0740 | 0,0830 | 0,00513 | 0,271 | 0,00914 | 0,135 | 0,561 | 7592 | 0,588 | 0,589 | 0,589 |
| 5,12 | 0,0830 | 0,0829 | 0,0740 | 0,0830 | 0,00512 | 0,271 | 0,00914 | 0,135 | 0,560 | 7566 | 0,587 | 0,588 | 0,588 |
| 5,36 | 0,0853 | 0,0853 | 0,0762 | 0,0853 | 0,00536 | 0,276 | 0,00940 | 0,136 | 0,570 | 7824 | 0,590 | 0,591 | 0,590 |
| 5,35 | 0,0853 | 0,0853 | 0,0762 | 0,0853 | 0,00535 | 0,276 | 0,00940 | 0,136 | 0,569 | 7792 | 0,589 | 0,589 | 0,589 |
| 5,62 | 0,0880 | 0,0880 | 0,0786 | 0,0880 | 0,00562 | 0,281 | 0,00970 | 0,138 | 0,580 | 8083 | 0,591 | 0,591 | 0,591 |
| 5,63 | 0,0880 | 0,0880 | 0,0786 | 0,0880 | 0,00563 | 0,281 | 0,00970 | 0,138 | 0,580 | 8102 | 0,592 | 0,592 | 0,592 |
| 5,91 | 0,0911 | 0,0911 | 0,0817 | 0,0911 | 0,00591 | 0,287 | 0,0101 | 0,141 | 0,586 | 8277 | 0,590 | 0,590 | 0,590 |
| 5,91 | 0,0911 | 0,0911 | 0,0817 | 0,0911 | 0,00591 | 0,287 | 0,0101 | 0,141 | 0,586 | 8280 | 0,590 | 0,590 | 0,590 |
| 6,21 | 0,0942 | 0,0941 | 0,0843 | 0,0942 | 0,00621 | 0,292 | 0,0104 | 0,142 | 0,597 | 8588 | 0,589 | 0,590 | 0,590 |
| 6,21 | 0,0942 | 0,0941 | 0,0843 | 0,0942 | 0,00621 | 0,292 | 0,0104 | 0,142 | 0,597 | 8582 | 0,589 | 0,590 | 0,590 |

Rectangular Notch (Kaolin 5.48%)

Yield stress (Pa)= 0,246

Density ($kg/m^3$)= 1090

n = 0,645

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,0294

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6,53 | 0,0972 | 0,0972 | 0,0871 | 0,0972 | 0,00653 | 0,298 | 0,0108 | 0,144 | 0,607 | 8861 | 0,591 | 0,591 | 0,591 |
| 6,52 | 0,0972 | 0,0972 | 0,0871 | 0,0972 | 0,00652 | 0,298 | 0,0108 | 0,144 | 0,607 | 8858 | 0,591 | 0,591 | 0,591 |
| 6,83 | 0,1000 | 0,0999 | 0,0899 | 0,0999 | 0,00683 | 0,303 | 0,0111 | 0,146 | 0,616 | 9115 | 0,593 | 0,594 | 0,593 |
| 6,84 | 0,1000 | 0,0999 | 0,0899 | 0,0999 | 0,00684 | 0,303 | 0,0111 | 0,146 | 0,616 | 9127 | 0,593 | 0,594 | 0,594 |
| 7,11 | 0,1029 | 0,1031 | 0,0921 | 0,1030 | 0,00711 | 0,308 | 0,0114 | 0,148 | 0,625 | 9386 | 0,590 | 0,589 | 0,590 |
| 7,11 | 0,1029 | 0,1031 | 0,0921 | 0,1030 | 0,00711 | 0,308 | 0,0114 | 0,148 | 0,625 | 9390 | 0,591 | 0,590 | 0,590 |
| 7,42 | 0,1054 | 0,1056 | 0,0950 | 0,1055 | 0,00742 | 0,313 | 0,0117 | 0,150 | 0,633 | 9615 | 0,595 | 0,593 | 0,594 |
| 7,42 | 0,1054 | 0,1056 | 0,0950 | 0,1055 | 0,00742 | 0,313 | 0,0117 | 0,150 | 0,633 | 9614 | 0,595 | 0,593 | 0,594 |
| 7,77 | 0,1088 | 0,1092 | 0,0981 | 0,1090 | 0,00777 | 0,320 | 0,0121 | 0,151 | 0,642 | 9904 | 0,594 | 0,591 | 0,593 |
| 7,76 | 0,1088 | 0,1092 | 0,0981 | 0,1090 | 0,00776 | 0,320 | 0,0121 | 0,151 | 0,641 | 9870 | 0,593 | 0,590 | 0,592 |
| 8,03 | 0,1115 | 0,1117 | 0,1000 | 0,1116 | 0,00803 | 0,323 | 0,0123 | 0,153 | 0,651 | 10162 | 0,592 | 0,590 | 0,591 |
| 8,03 | 0,1115 | 0,1117 | 0,1000 | 0,1116 | 0,00803 | 0,323 | 0,0123 | 0,153 | 0,651 | 10170 | 0,592 | 0,590 | 0,591 |
| 8,37 | 0,1143 | 0,1144 | 0,1030 | 0,1144 | 0,00837 | 0,329 | 0,0127 | 0,154 | 0,658 | 10389 | 0,594 | 0,593 | 0,594 |
| 8,36 | 0,1143 | 0,1144 | 0,1030 | 0,1144 | 0,00836 | 0,329 | 0,0127 | 0,154 | 0,657 | 10365 | 0,593 | 0,593 | 0,593 |
| 8,60 | 0,1166 | 0,1170 | 0,1054 | 0,1168 | 0,00860 | 0,334 | 0,0130 | 0,156 | 0,661 | 10486 | 0,592 | 0,589 | 0,591 |
| 8,60 | 0,1166 | 0,1170 | 0,1054 | 0,1168 | 0,00860 | 0,334 | 0,0130 | 0,156 | 0,661 | 10486 | 0,592 | 0,589 | 0,591 |

**Table 4.3 Flow rate measurement of kaolin 6.71% through rectangular notch**

Rectangular Notch (Kaolin 6,71%)

Yield stress (Pa)= 0,601

Density ($kg/m^3$)= 1111

n = 0,596

B(m)= 0,1234 $g(m/s^2)$= 9,813 k ($Pa.s^n$)= 0,0449

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,00 | 0,0432 | 0,0433 | 0,0374 | 0,0433 | 0,00200 | 0,198 | 0,00462 | 0,0932 | 0,434 | 2175 | 0,612 | 0,611 | 0,611 |
| 2,01 | 0,0432 | 0,0433 | 0,0374 | 0,0433 | 0,00201 | 0,198 | 0,00462 | 0,0932 | 0,434 | 2176 | 0,612 | 0,611 | 0,612 |
| 2,61 | 0,0522 | 0,0522 | 0,0455 | 0,0522 | 0,00261 | 0,214 | 0,00561 | 0,105 | 0,465 | 2511 | 0,600 | 0,600 | 0,600 |
| 2,62 | 0,0522 | 0,0522 | 0,0455 | 0,0522 | 0,00262 | 0,214 | 0,00561 | 0,105 | 0,467 | 2530 | 0,603 | 0,603 | 0,603 |
| 3,21 | 0,0599 | 0,0600 | 0,0527 | 0,0599 | 0,00321 | 0,229 | 0,00650 | 0,114 | 0,494 | 2843 | 0,601 | 0,600 | 0,601 |
| 3,22 | 0,0599 | 0,0600 | 0,0527 | 0,0599 | 0,00322 | 0,229 | 0,00650 | 0,114 | 0,496 | 2861 | 0,604 | 0,602 | 0,603 |
| 3,83 | 0,0680 | 0,0680 | 0,0601 | 0,0680 | 0,00383 | 0,244 | 0,00742 | 0,122 | 0,516 | 3108 | 0,593 | 0,593 | 0,593 |
| 3,83 | 0,0680 | 0,0680 | 0,0601 | 0,0680 | 0,00383 | 0,244 | 0,00742 | 0,122 | 0,516 | 3107 | 0,593 | 0,593 | 0,593 |
| 4,10 | 0,0711 | 0,0711 | 0,0632 | 0,0711 | 0,00410 | 0,250 | 0,00780 | 0,125 | 0,526 | 3231 | 0,594 | 0,594 | 0,594 |
| 4,10 | 0,0711 | 0,0711 | 0,0632 | 0,0711 | 0,00410 | 0,250 | 0,00780 | 0,125 | 0,526 | 3230 | 0,594 | 0,594 | 0,594 |
| 5,36 | 0,0855 | 0,0857 | 0,0769 | 0,0856 | 0,00536 | 0,277 | 0,00948 | 0,137 | 0,565 | 3738 | 0,588 | 0,586 | 0,587 |
| 5,35 | 0,0855 | 0,0857 | 0,0769 | 0,0856 | 0,00535 | 0,277 | 0,00948 | 0,137 | 0,564 | 3726 | 0,587 | 0,585 | 0,586 |
| 5,62 | 0,0884 | 0,0887 | 0,0798 | 0,0885 | 0,00562 | 0,283 | 0,00984 | 0,139 | 0,571 | 3822 | 0,587 | 0,584 | 0,585 |
| 5,63 | 0,0884 | 0,0887 | 0,0798 | 0,0885 | 0,00563 | 0,283 | 0,00984 | 0,139 | 0,572 | 3835 | 0,588 | 0,585 | 0,586 |

Rectangular Notch (Kaolin 6,71%)

Yield stress (Pa)= 0,601

Density (kg/m$^3$)= 1111

n = 0,596

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,0449

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5,94 | 0,0918 | 0,0919 | 0,0828 | 0,0918 | 0,00594 | 0,289 | 0,0102 | 0,141 | 0,581 | 3962 | 0,587 | 0,585 | 0,586 |
| 5,94 | 0,0918 | 0,0919 | 0,0828 | 0,0918 | 0,00594 | 0,289 | 0,0102 | 0,141 | 0,581 | 3962 | 0,587 | 0,585 | 0,586 |
| 6,23 | 0,0949 | 0,0951 | 0,0858 | 0,0950 | 0,00623 | 0,295 | 0,0106 | 0,144 | 0,589 | 4064 | 0,583 | 0,583 | 0,583 |
| 6,22 | 0,0949 | 0,0951 | 0,0858 | 0,0950 | 0,00622 | 0,295 | 0,0106 | 0,144 | 0,588 | 4051 | 0,582 | 0,582 | 0,582 |
| 6,51 | 0,0979 | 0,0980 | 0,0883 | 0,0980 | 0,00651 | 0,300 | 0,0109 | 0,145 | 0,598 | 4192 | 0,583 | 0,582 | 0,583 |
| 6,52 | 0,0979 | 0,0980 | 0,0883 | 0,0980 | 0,00652 | 0,300 | 0,0109 | 0,145 | 0,599 | 4205 | 0,584 | 0,583 | 0,584 |
| 6,86 | 0,1013 | 0,1017 | 0,0917 | 0,1015 | 0,00686 | 0,307 | 0,0113 | 0,148 | 0,606 | 4311 | 0,584 | 0,581 | 0,582 |
| 6,86 | 0,1013 | 0,1017 | 0,0917 | 0,1015 | 0,00686 | 0,307 | 0,0113 | 0,148 | 0,606 | 4305 | 0,584 | 0,580 | 0,582 |
| 7,11 | 0,1034 | 0,1038 | 0,0935 | 0,1036 | 0,00711 | 0,310 | 0,0115 | 0,149 | 0,617 | 4451 | 0,587 | 0,584 | 0,585 |
| 7,10 | 0,1034 | 0,1038 | 0,0935 | 0,1036 | 0,00710 | 0,310 | 0,0115 | 0,149 | 0,615 | 4431 | 0,585 | 0,582 | 0,584 |
| 7,45 | 0,1068 | 0,1071 | 0,0969 | 0,1070 | 0,00745 | 0,317 | 0,0120 | 0,151 | 0,623 | 4551 | 0,586 | 0,583 | 0,585 |
| 7,46 | 0,1068 | 0,1071 | 0,0969 | 0,1070 | 0,00746 | 0,317 | 0,0120 | 0,151 | 0,624 | 4557 | 0,586 | 0,584 | 0,585 |
| 7,73 | 0,1091 | 0,1097 | 0,0988 | 0,1094 | 0,00773 | 0,321 | 0,0122 | 0,152 | 0,634 | 4708 | 0,589 | 0,584 | 0,586 |
| 7,73 | 0,1091 | 0,1097 | 0,0988 | 0,1094 | 0,00773 | 0,321 | 0,0122 | 0,152 | 0,634 | 4708 | 0,589 | 0,584 | 0,586 |
| 8,13 | 0,1126 | 0,1131 | 0,1020 | 0,1128 | 0,00813 | 0,327 | 0,0126 | 0,154 | 0,646 | 4877 | 0,590 | 0,587 | 0,588 |
| 8,13 | 0,1126 | 0,1131 | 0,1020 | 0,1128 | 0,00813 | 0,327 | 0,0126 | 0,154 | 0,646 | 4877 | 0,590 | 0,587 | 0,588 |

Rectangular Notch (Kaolin 6,71%)

Yield stress (Pa)= 0,601

Density (kg/m$^3$)= 1111

n = 0,596

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,0449

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8,40 | 0,1153 | 0,1159 | 0,1046 | 0,1156 | 0,00840 | 0,333 | 0,0129 | 0,155 | 0,651 | 4952 | 0,588 | 0,584 | 0,586 |
| 8,40 | 0,1153 | 0,1159 | 0,1046 | 0,1156 | 0,00840 | 0,333 | 0,0129 | 0,155 | 0,651 | 4950 | 0,588 | 0,584 | 0,586 |
| 8,70 | 0,1183 | 0,1189 | 0,1069 | 0,1186 | 0,00870 | 0,337 | 0,0132 | 0,157 | 0,659 | 5079 | 0,587 | 0,582 | 0,584 |
| 8,71 | 0,1183 | 0,1189 | 0,1069 | 0,1186 | 0,00871 | 0,337 | 0,0132 | 0,157 | 0,660 | 5091 | 0,587 | 0,583 | 0,585 |
| 5,07 | 0,0821 | 0,0823 | 0,0736 | 0,0822 | 0,00507 | 0,271 | 0,00908 | 0,134 | 0,558 | 3646 | 0,591 | 0,589 | 0,590 |
| 5,06 | 0,0821 | 0,0823 | 0,0736 | 0,0822 | 0,00506 | 0,271 | 0,00908 | 0,134 | 0,557 | 3633 | 0,590 | 0,588 | 0,589 |
| 4,75 | 0,0787 | 0,0789 | 0,0704 | 0,0788 | 0,00475 | 0,264 | 0,00869 | 0,132 | 0,547 | 3503 | 0,591 | 0,589 | 0,590 |
| 4,75 | 0,0787 | 0,0789 | 0,0704 | 0,0788 | 0,00475 | 0,264 | 0,00869 | 0,132 | 0,547 | 3503 | 0,591 | 0,589 | 0,590 |
| 4,47 | 0,0754 | 0,0755 | 0,0672 | 0,0755 | 0,00447 | 0,258 | 0,00829 | 0,129 | 0,539 | 3400 | 0,592 | 0,591 | 0,592 |
| 4,46 | 0,0754 | 0,0755 | 0,0672 | 0,0755 | 0,00446 | 0,258 | 0,00829 | 0,129 | 0,538 | 3386 | 0,591 | 0,590 | 0,590 |
| 3,50 | 0,0634 | 0,0638 | 0,0562 | 0,0636 | 0,00350 | 0,236 | 0,00694 | 0,118 | 0,505 | 2976 | 0,603 | 0,597 | 0,600 |
| 3,51 | 0,0634 | 0,0638 | 0,0562 | 0,0636 | 0,00351 | 0,236 | 0,00694 | 0,118 | 0,507 | 2991 | 0,604 | 0,599 | 0,602 |
| 2,94 | 0,0565 | 0,0566 | 0,0495 | 0,0566 | 0,00294 | 0,222 | 0,00611 | 0,110 | 0,482 | 2698 | 0,601 | 0,599 | 0,600 |
| 2,94 | 0,0565 | 0,0566 | 0,0495 | 0,0566 | 0,00294 | 0,222 | 0,00611 | 0,110 | 0,482 | 2698 | 0,601 | 0,599 | 0,600 |
| 2,32 | 0,0479 | 0,0481 | 0,0418 | 0,0480 | 0,00232 | 0,207 | 0,00516 | 0,0996 | 0,449 | 2340 | 0,607 | 0,603 | 0,605 |
| 2,33 | 0,0479 | 0,0481 | 0,0418 | 0,0480 | 0,00233 | 0,207 | 0,00516 | 0,0996 | 0,452 | 2360 | 0,610 | 0,606 | 0,608 |

**Table 4.4 Flow rate measurement of kaolin 8.23% through rectangular notch**

Rectangular Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,50

Density ($kg/m^3$)= 1136

n = 0,517

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,0993

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,44 | 0,0118 | 0,0119 | 0,0111 | 0,0119 | 0,000442 | 0,146 | 0,00136 | 0,0375 | 0,324 | 493 | 0,944 | 0,930 | 0,937 |
| 0,44 | 0,0118 | 0,0119 | 0,0111 | 0,0119 | 0,000442 | 0,146 | 0,00136 | 0,0375 | 0,324 | 493 | 0,944 | 0,930 | 0,937 |
| 0,88 | 0,0220 | 0,0221 | 0,0204 | 0,0221 | 0,000882 | 0,164 | 0,00252 | 0,0613 | 0,350 | 602 | 0,741 | 0,736 | 0,739 |
| 0,89 | 0,0220 | 0,0221 | 0,0204 | 0,0221 | 0,000889 | 0,164 | 0,00252 | 0,0613 | 0,353 | 611 | 0,747 | 0,742 | 0,744 |
| 1,27 | 0,0293 | 0,0291 | 0,0266 | 0,0292 | 0,00127 | 0,177 | 0,00328 | 0,0743 | 0,386 | 738 | 0,694 | 0,699 | 0,696 |
| 1,27 | 0,0293 | 0,0291 | 0,0266 | 0,0292 | 0,00127 | 0,177 | 0,00328 | 0,0743 | 0,388 | 745 | 0,698 | 0,702 | 0,700 |
| 1,65 | 0,0357 | 0,0359 | 0,0325 | 0,0358 | 0,00165 | 0,188 | 0,00401 | 0,0852 | 0,411 | 842 | 0,670 | 0,666 | 0,668 |
| 1,65 | 0,0357 | 0,0359 | 0,0325 | 0,0358 | 0,00165 | 0,188 | 0,00401 | 0,0852 | 0,411 | 843 | 0,671 | 0,667 | 0,669 |
| 1,93 | 0,0401 | 0,0403 | 0,0365 | 0,0402 | 0,00193 | 0,196 | 0,00450 | 0,0917 | 0,429 | 919 | 0,658 | 0,653 | 0,656 |
| 1,93 | 0,0401 | 0,0403 | 0,0365 | 0,0402 | 0,00193 | 0,196 | 0,00450 | 0,0917 | 0,429 | 920 | 0,659 | 0,653 | 0,656 |
| 2,17 | 0,0435 | 0,0436 | 0,0393 | 0,0435 | 0,00217 | 0,202 | 0,00485 | 0,0960 | 0,448 | 1001 | 0,658 | 0,655 | 0,656 |
| 2,18 | 0,0435 | 0,0436 | 0,0393 | 0,0435 | 0,00218 | 0,202 | 0,00485 | 0,0960 | 0,450 | 1012 | 0,661 | 0,659 | 0,660 |

Rectangular Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,50

Density (kg/m$^3$)= 1136

n = 0,517

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,0993

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,53 | 0,0487 | 0,0488 | 0,0423 | 0,0488 | 0,00253 | 0,208 | 0,00522 | 0,100 | 0,484 | 1168 | 0,644 | 0,642 | 0,643 |
| 2,53 | 0,0487 | 0,0488 | 0,0423 | 0,0488 | 0,00253 | 0,208 | 0,00522 | 0,100 | 0,484 | 1167 | 0,644 | 0,642 | 0,643 |
| 2,85 | 0,0533 | 0,0531 | 0,0482 | 0,0532 | 0,00285 | 0,220 | 0,00595 | 0,108 | 0,479 | 1152 | 0,635 | 0,638 | 0,637 |
| 2,84 | 0,0533 | 0,0531 | 0,0482 | 0,0532 | 0,00284 | 0,220 | 0,00595 | 0,108 | 0,477 | 1144 | 0,633 | 0,636 | 0,634 |
| 3,12 | 0,0569 | 0,0569 | 0,0517 | 0,0569 | 0,00312 | 0,227 | 0,00637 | 0,112 | 0,489 | 1204 | 0,631 | 0,631 | 0,631 |
| 3,13 | 0,0569 | 0,0569 | 0,0517 | 0,0569 | 0,00313 | 0,227 | 0,00637 | 0,112 | 0,491 | 1212 | 0,633 | 0,633 | 0,633 |
| 3,44 | 0,0608 | 0,0609 | 0,0553 | 0,0609 | 0,00344 | 0,234 | 0,00682 | 0,117 | 0,505 | 1281 | 0,630 | 0,628 | 0,629 |
| 3,44 | 0,0608 | 0,0609 | 0,0553 | 0,0609 | 0,00344 | 0,234 | 0,00682 | 0,117 | 0,504 | 1280 | 0,629 | 0,628 | 0,629 |
| 3,78 | 0,0652 | 0,0651 | 0,0593 | 0,0651 | 0,00378 | 0,242 | 0,00732 | 0,121 | 0,516 | 1339 | 0,622 | 0,624 | 0,623 |
| 3,78 | 0,0652 | 0,0651 | 0,0593 | 0,0651 | 0,00378 | 0,242 | 0,00732 | 0,121 | 0,516 | 1339 | 0,622 | 0,624 | 0,623 |
| 4,09 | 0,0689 | 0,0690 | 0,0626 | 0,0689 | 0,00409 | 0,249 | 0,00772 | 0,124 | 0,530 | 1413 | 0,621 | 0,619 | 0,620 |
| 4,10 | 0,0689 | 0,0690 | 0,0626 | 0,0689 | 0,00410 | 0,249 | 0,00772 | 0,124 | 0,531 | 1421 | 0,622 | 0,621 | 0,622 |
| 4,38 | 0,0723 | 0,0723 | 0,0657 | 0,0723 | 0,00438 | 0,255 | 0,00811 | 0,127 | 0,541 | 1474 | 0,618 | 0,618 | 0,618 |
| 4,38 | 0,0723 | 0,0723 | 0,0657 | 0,0723 | 0,00438 | 0,255 | 0,00811 | 0,127 | 0,540 | 1471 | 0,618 | 0,618 | 0,618 |

Rectangular Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,50

Density (kg/m$^3$)= 1136

n = 0,517

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,0993

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4,72 | 0,0761 | 0,0761 | 0,0697 | 0,0761 | 0,00472 | 0,263 | 0,00860 | 0,131 | 0,549 | 1521 | 0,618 | 0,618 | 0,618 |
| 4,73 | 0,0761 | 0,0761 | 0,0697 | 0,0761 | 0,00473 | 0,263 | 0,00860 | 0,131 | 0,550 | 1528 | 0,619 | 0,619 | 0,619 |
| 5,14 | 0,0805 | 0,0808 | 0,0737 | 0,0806 | 0,00514 | 0,271 | 0,00909 | 0,134 | 0,565 | 1611 | 0,614 | 0,614 | 0,614 |
| 5,14 | 0,0805 | 0,0808 | 0,0737 | 0,0806 | 0,00514 | 0,271 | 0,00909 | 0,134 | 0,565 | 1611 | 0,614 | 0,614 | 0,614 |
| 5,45 | 0,0838 | 0,0836 | 0,0771 | 0,0837 | 0,00545 | 0,278 | 0,00951 | 0,137 | 0,573 | 1658 | 0,617 | 0,619 | 0,618 |
| 5,43 | 0,0838 | 0,0836 | 0,0771 | 0,0837 | 0,00543 | 0,278 | 0,00951 | 0,137 | 0,571 | 1646 | 0,615 | 0,617 | 0,616 |
| 5,75 | 0,0870 | 0,0871 | 0,0802 | 0,0870 | 0,00575 | 0,284 | 0,00989 | 0,139 | 0,582 | 1708 | 0,615 | 0,615 | 0,615 |
| 5,75 | 0,0870 | 0,0871 | 0,0802 | 0,0870 | 0,00575 | 0,284 | 0,00989 | 0,139 | 0,581 | 1703 | 0,614 | 0,614 | 0,614 |
| 6,09 | 0,0901 | 0,0902 | 0,0829 | 0,0901 | 0,00609 | 0,289 | 0,0102 | 0,141 | 0,595 | 1786 | 0,617 | 0,617 | 0,617 |
| 6,10 | 0,0901 | 0,0902 | 0,0829 | 0,0901 | 0,00610 | 0,289 | 0,0102 | 0,141 | 0,596 | 1792 | 0,619 | 0,618 | 0,618 |
| 6,42 | 0,0941 | 0,0936 | 0,0868 | 0,0939 | 0,00642 | 0,297 | 0,0107 | 0,144 | 0,599 | 1814 | 0,611 | 0,615 | 0,613 |
| 6,42 | 0,0941 | 0,0936 | 0,0868 | 0,0939 | 0,00642 | 0,297 | 0,0107 | 0,144 | 0,600 | 1815 | 0,611 | 0,615 | 0,613 |
| 6,74 | 0,0969 | 0,0969 | 0,0892 | 0,0969 | 0,00674 | 0,302 | 0,0110 | 0,146 | 0,613 | 1892 | 0,613 | 0,614 | 0,613 |
| 6,74 | 0,0969 | 0,0969 | 0,0892 | 0,0969 | 0,00674 | 0,302 | 0,0110 | 0,146 | 0,612 | 1892 | 0,613 | 0,614 | 0,613 |

Rectangular Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,50

Density ($kg/m^3$)= 1136

n = 0,517

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,0993

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7,12 | 0,1006 | 0,1003 | 0,0930 | 0,1005 | 0,00712 | 0,309 | 0,0115 | 0,148 | 0,620 | 1939 | 0,612 | 0,615 | 0,613 |
| 7,13 | 0,1006 | 0,1003 | 0,0930 | 0,1005 | 0,00713 | 0,309 | 0,0115 | 0,148 | 0,621 | 1945 | 0,613 | 0,616 | 0,614 |
| 7,42 | 0,1041 | 0,1042 | 0,0964 | 0,1042 | 0,00742 | 0,316 | 0,0119 | 0,150 | 0,624 | 1965 | 0,606 | 0,606 | 0,606 |
| 7,42 | 0,1041 | 0,1042 | 0,0964 | 0,1042 | 0,00742 | 0,316 | 0,0119 | 0,150 | 0,624 | 1966 | 0,606 | 0,606 | 0,606 |
| 7,71 | 0,1071 | 0,1069 | 0,0989 | 0,1070 | 0,00771 | 0,321 | 0,0122 | 0,152 | 0,632 | 2014 | 0,604 | 0,606 | 0,605 |
| 7,72 | 0,1071 | 0,1069 | 0,0989 | 0,1070 | 0,00772 | 0,321 | 0,0122 | 0,152 | 0,633 | 2020 | 0,605 | 0,607 | 0,606 |
| 8,02 | 0,1098 | 0,1099 | 0,1019 | 0,1099 | 0,00802 | 0,327 | 0,0126 | 0,154 | 0,638 | 2057 | 0,605 | 0,604 | 0,604 |
| 8,02 | 0,1098 | 0,1099 | 0,1019 | 0,1099 | 0,00802 | 0,327 | 0,0126 | 0,154 | 0,638 | 2057 | 0,605 | 0,604 | 0,605 |
| 8,43 | 0,1135 | 0,1132 | 0,1054 | 0,1134 | 0,00843 | 0,334 | 0,0130 | 0,156 | 0,648 | 2122 | 0,605 | 0,607 | 0,606 |
| 8,43 | 0,1135 | 0,1132 | 0,1054 | 0,1134 | 0,00843 | 0,334 | 0,0130 | 0,156 | 0,648 | 2122 | 0,605 | 0,607 | 0,606 |

**Table 4.5 Flow rate measurement of kaolin 10.91% through rectangular notch**

Rectangular Notch (Kaolin 10,91%)

Yield stress (Pa)= 2,60

Density (kg/m$^3$)= 1180

n = 0,542

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,129

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 0,63 | 0,0171 | 0,0172 | 0,0156 | 0,0171 | 0,000629 | 0,155 | 0,00193 | 0,0498 | 0,327 | 323 | 0,770 | 0,767 | 0,769 |
| 0,63 | 0,0171 | 0,0172 | 0,0156 | 0,0171 | 0,000629 | 0,155 | 0,00193 | 0,0498 | 0,327 | 323 | 0,770 | 0,767 | 0,769 |
| 0,95 | 0,0233 | 0,0234 | 0,0209 | 0,0233 | 0,000954 | 0,165 | 0,00258 | 0,0625 | 0,370 | 417 | 0,738 | 0,731 | 0,735 |
| 0,96 | 0,0233 | 0,0234 | 0,0209 | 0,0233 | 0,000957 | 0,165 | 0,00258 | 0,0625 | 0,371 | 420 | 0,741 | 0,734 | 0,737 |
| 1,27 | 0,0293 | 0,0294 | 0,0264 | 0,0294 | 0,00127 | 0,176 | 0,00326 | 0,0740 | 0,391 | 471 | 0,695 | 0,692 | 0,693 |
| 1,28 | 0,0293 | 0,0294 | 0,0264 | 0,0294 | 0,00128 | 0,176 | 0,00326 | 0,0740 | 0,394 | 477 | 0,700 | 0,696 | 0,698 |
| 1,63 | 0,0355 | 0,0355 | 0,0319 | 0,0355 | 0,00163 | 0,187 | 0,00394 | 0,0841 | 0,415 | 534 | 0,669 | 0,669 | 0,669 |
| 1,62 | 0,0355 | 0,0355 | 0,0319 | 0,0355 | 0,00162 | 0,187 | 0,00394 | 0,0841 | 0,411 | 523 | 0,662 | 0,662 | 0,662 |
| 1,99 | 0,0409 | 0,0409 | 0,0368 | 0,0409 | 0,00199 | 0,197 | 0,00454 | 0,0922 | 0,439 | 600 | 0,661 | 0,661 | 0,661 |
| 1,98 | 0,0409 | 0,0409 | 0,0368 | 0,0409 | 0,00198 | 0,197 | 0,00454 | 0,0922 | 0,436 | 591 | 0,656 | 0,656 | 0,656 |
| 2,23 | 0,0449 | 0,0447 | 0,0400 | 0,0448 | 0,00223 | 0,203 | 0,00494 | 0,0971 | 0,451 | 634 | 0,643 | 0,647 | 0,645 |
| 2,22 | 0,0449 | 0,0447 | 0,0400 | 0,0448 | 0,00222 | 0,203 | 0,00494 | 0,0971 | 0,450 | 629 | 0,640 | 0,644 | 0,642 |

Rectangular Notch (Kaolin 10,91%)

Yield stress (Pa)= 2,60

Density ($kg/m^3$)= 1180

n = 0,542

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,129

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,61 | 0,0499 | 0,0497 | 0,0447 | 0,0498 | 0,00261 | 0,213 | 0,00552 | 0,104 | 0,473 | 698 | 0,642 | 0,646 | 0,644 |
| 2,61 | 0,0499 | 0,0497 | 0,0447 | 0,0498 | 0,00261 | 0,213 | 0,00552 | 0,104 | 0,473 | 697 | 0,641 | 0,646 | 0,644 |
| 2,87 | 0,0538 | 0,0538 | 0,0484 | 0,0538 | 0,00287 | 0,220 | 0,00597 | 0,108 | 0,481 | 724 | 0,632 | 0,631 | 0,632 |
| 2,86 | 0,0538 | 0,0538 | 0,0484 | 0,0538 | 0,00286 | 0,220 | 0,00597 | 0,108 | 0,479 | 718 | 0,629 | 0,629 | 0,629 |
| 3,23 | 0,0582 | 0,0583 | 0,0524 | 0,0583 | 0,00323 | 0,228 | 0,00646 | 0,113 | 0,501 | 783 | 0,632 | 0,630 | 0,631 |
| 3,24 | 0,0582 | 0,0583 | 0,0524 | 0,0583 | 0,00324 | 0,228 | 0,00646 | 0,113 | 0,501 | 786 | 0,633 | 0,631 | 0,632 |
| 3,55 | 0,0621 | 0,0621 | 0,0561 | 0,0621 | 0,00355 | 0,236 | 0,00693 | 0,118 | 0,512 | 820 | 0,629 | 0,629 | 0,629 |
| 3,54 | 0,0621 | 0,0621 | 0,0561 | 0,0621 | 0,00354 | 0,236 | 0,00693 | 0,118 | 0,511 | 819 | 0,629 | 0,628 | 0,628 |
| 3,87 | 0,0659 | 0,0660 | 0,0594 | 0,0660 | 0,00387 | 0,242 | 0,00732 | 0,121 | 0,528 | 873 | 0,627 | 0,626 | 0,626 |
| 3,87 | 0,0659 | 0,0660 | 0,0594 | 0,0660 | 0,00387 | 0,242 | 0,00732 | 0,121 | 0,528 | 873 | 0,627 | 0,626 | 0,627 |
| 4,14 | 0,0696 | 0,0696 | 0,0630 | 0,0696 | 0,00414 | 0,249 | 0,00778 | 0,125 | 0,532 | 888 | 0,619 | 0,619 | 0,619 |
| 4,15 | 0,0696 | 0,0696 | 0,0630 | 0,0696 | 0,00415 | 0,249 | 0,00778 | 0,125 | 0,534 | 893 | 0,621 | 0,621 | 0,621 |
| 4,43 | 0,0730 | 0,0728 | 0,0661 | 0,0729 | 0,00443 | 0,256 | 0,00815 | 0,128 | 0,544 | 927 | 0,617 | 0,619 | 0,618 |
| 4,44 | 0,0730 | 0,0728 | 0,0661 | 0,0729 | 0,00444 | 0,256 | 0,00815 | 0,128 | 0,545 | 931 | 0,618 | 0,621 | 0,619 |

Rectangular Notch (Kaolin 10,91%)

Yield stress (Pa)= 2,60

Density (kg/m$^3$)= 1180

n = 0,542

B(m)= 0,1234    g(m/s$^2$)= 9,813    k (Pa.s$^n$)= 0,129

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4,87 | 0,0775 | 0,0775 | 0,0706 | 0,0775 | 0,00487 | 0,265 | 0,00871 | 0,132 | 0,559 | 978 | 0,618 | 0,619 | 0,619 |
| 4,86 | 0,0775 | 0,0775 | 0,0706 | 0,0775 | 0,00486 | 0,265 | 0,00871 | 0,132 | 0,558 | 976 | 0,618 | 0,619 | 0,618 |
| 5,18 | 0,0813 | 0,0814 | 0,0739 | 0,0814 | 0,00518 | 0,271 | 0,00912 | 0,135 | 0,568 | 1012 | 0,612 | 0,612 | 0,612 |
| 5,18 | 0,0813 | 0,0814 | 0,0739 | 0,0814 | 0,00518 | 0,271 | 0,00912 | 0,135 | 0,568 | 1012 | 0,612 | 0,612 | 0,612 |
| 5,55 | 0,0853 | 0,0853 | 0,0780 | 0,0853 | 0,00555 | 0,279 | 0,00962 | 0,138 | 0,577 | 1043 | 0,611 | 0,610 | 0,611 |
| 5,54 | 0,0853 | 0,0853 | 0,0780 | 0,0853 | 0,00554 | 0,279 | 0,00962 | 0,138 | 0,576 | 1041 | 0,610 | 0,610 | 0,610 |
| 5,82 | 0,0880 | 0,0880 | 0,0803 | 0,0880 | 0,00582 | 0,284 | 0,00991 | 0,140 | 0,587 | 1080 | 0,611 | 0,612 | 0,612 |
| 5,82 | 0,0880 | 0,0880 | 0,0803 | 0,0880 | 0,00582 | 0,284 | 0,00991 | 0,140 | 0,587 | 1080 | 0,611 | 0,612 | 0,612 |
| 6,11 | 0,0907 | 0,0906 | 0,0831 | 0,0907 | 0,00611 | 0,290 | 0,0103 | 0,142 | 0,595 | 1112 | 0,613 | 0,615 | 0,614 |
| 6,10 | 0,0907 | 0,0906 | 0,0831 | 0,0907 | 0,00610 | 0,290 | 0,0103 | 0,142 | 0,594 | 1109 | 0,612 | 0,614 | 0,613 |
| 6,33 | 0,0929 | 0,0929 | 0,0853 | 0,0929 | 0,00633 | 0,294 | 0,0105 | 0,143 | 0,601 | 1133 | 0,613 | 0,613 | 0,613 |
| 6,33 | 0,0929 | 0,0929 | 0,0853 | 0,0929 | 0,00633 | 0,294 | 0,0105 | 0,143 | 0,601 | 1133 | 0,613 | 0,613 | 0,613 |
| 6,63 | 0,0960 | 0,0959 | 0,0882 | 0,0960 | 0,00663 | 0,300 | 0,0109 | 0,145 | 0,609 | 1163 | 0,612 | 0,612 | 0,612 |
| 6,63 | 0,0960 | 0,0959 | 0,0882 | 0,0960 | 0,00663 | 0,300 | 0,0109 | 0,145 | 0,609 | 1164 | 0,612 | 0,612 | 0,612 |

Rectangular Notch (Kaolin 10,91%)

Yield stress (Pa)= 2,60

Density ($kg/m^3$)= 1180

n = 0,542

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,129

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6,96 | 0,0995 | 0,0993 | 0,0914 | 0,0994 | 0,00696 | 0,306 | 0,0113 | 0,147 | 0,617 | 1196 | 0,608 | 0,611 | 0,610 |
| 6,95 | 0,0995 | 0,0993 | 0,0914 | 0,0994 | 0,00695 | 0,306 | 0,0113 | 0,147 | 0,616 | 1192 | 0,608 | 0,610 | 0,609 |
| 7,27 | 0,1027 | 0,1024 | 0,0946 | 0,1026 | 0,00727 | 0,313 | 0,0117 | 0,149 | 0,623 | 1220 | 0,607 | 0,609 | 0,608 |
| 7,28 | 0,1027 | 0,1024 | 0,0946 | 0,1026 | 0,00728 | 0,313 | 0,0117 | 0,149 | 0,624 | 1223 | 0,607 | 0,610 | 0,609 |
| 7,57 | 0,1055 | 0,1053 | 0,0971 | 0,1054 | 0,00757 | 0,318 | 0,0120 | 0,151 | 0,632 | 1252 | 0,606 | 0,608 | 0,607 |
| 7,58 | 0,1055 | 0,1053 | 0,0971 | 0,1054 | 0,00758 | 0,318 | 0,0120 | 0,151 | 0,632 | 1255 | 0,606 | 0,608 | 0,607 |
| 8,00 | 0,1094 | 0,1093 | 0,1012 | 0,1093 | 0,00800 | 0,326 | 0,0125 | 0,153 | 0,641 | 1289 | 0,607 | 0,608 | 0,608 |
| 7,99 | 0,1094 | 0,1093 | 0,1012 | 0,1093 | 0,00799 | 0,326 | 0,0125 | 0,153 | 0,640 | 1285 | 0,606 | 0,607 | 0,607 |
| 8,37 | 0,1123 | 0,1123 | 0,1039 | 0,1123 | 0,00837 | 0,331 | 0,0128 | 0,155 | 0,653 | 1337 | 0,610 | 0,610 | 0,610 |
| 8,37 | 0,1123 | 0,1123 | 0,1039 | 0,1123 | 0,00837 | 0,331 | 0,0128 | 0,155 | 0,653 | 1337 | 0,610 | 0,610 | 0,610 |
| 8,73 | 0,1164 | 0,1163 | 0,1076 | 0,1163 | 0,00873 | 0,339 | 0,0133 | 0,157 | 0,658 | 1358 | 0,603 | 0,605 | 0,604 |
| 8,74 | 0,1164 | 0,1163 | 0,1076 | 0,1163 | 0,00874 | 0,339 | 0,0133 | 0,157 | 0,659 | 1361 | 0,604 | 0,605 | 0,605 |

**Table 4.6 Flow rate measurement of kaolin 14.64% through rectangular notch**

Rectangular Notch (Kaolin 14.64%)

Yield stress (Pa)= 9,90

Density ($kg/m^3$)= 1242

n = 0,536

B(m)= 0,1234  g($m/s^2$)= 9,813  k ($Pa.s^n$)= 0,208

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,55 | 0,0492 | 0,0496 | 0,0488 | 0,0494 | 0,00155 | 0,221 | 0,00602 | 0,109 | 0,257 | 63,4 | 0,389 | 0,385 | 0,387 |
| 1,54 | 0,0492 | 0,0496 | 0,0488 | 0,0494 | 0,00154 | 0,221 | 0,00602 | 0,109 | 0,256 | 62,9 | 0,388 | 0,383 | 0,385 |
| 1,20 | 0,0446 | 0,0447 | 0,0445 | 0,0447 | 0,00120 | 0,212 | 0,00549 | 0,103 | 0,219 | 46,0 | 0,350 | 0,349 | 0,349 |
| 1,20 | 0,0446 | 0,0447 | 0,0445 | 0,0447 | 0,00120 | 0,212 | 0,00549 | 0,103 | 0,218 | 45,6 | 0,348 | 0,348 | 0,348 |
| 1,81 | 0,0506 | 0,0508 | 0,0488 | 0,0507 | 0,00181 | 0,221 | 0,00603 | 0,109 | 0,300 | 85,6 | 0,436 | 0,433 | 0,434 |
| 1,81 | 0,0506 | 0,0508 | 0,0488 | 0,0507 | 0,00181 | 0,221 | 0,00603 | 0,109 | 0,301 | 86,3 | 0,438 | 0,435 | 0,436 |
| 2,21 | 0,0540 | 0,0539 | 0,0516 | 0,0539 | 0,00221 | 0,227 | 0,00637 | 0,112 | 0,347 | 115 | 0,484 | 0,484 | 0,484 |
| 2,19 | 0,0540 | 0,0539 | 0,0516 | 0,0539 | 0,00219 | 0,227 | 0,00637 | 0,112 | 0,344 | 113 | 0,480 | 0,480 | 0,480 |
| 2,51 | 0,0578 | 0,0579 | 0,0545 | 0,0579 | 0,00251 | 0,232 | 0,00672 | 0,116 | 0,373 | 132 | 0,494 | 0,493 | 0,494 |
| 2,50 | 0,0578 | 0,0579 | 0,0545 | 0,0579 | 0,00250 | 0,232 | 0,00672 | 0,116 | 0,373 | 132 | 0,494 | 0,493 | 0,494 |
| 2,87 | 0,0624 | 0,0626 | 0,0581 | 0,0625 | 0,00287 | 0,240 | 0,00717 | 0,120 | 0,401 | 152 | 0,506 | 0,503 | 0,504 |
| 2,88 | 0,0624 | 0,0626 | 0,0581 | 0,0625 | 0,00288 | 0,240 | 0,00717 | 0,120 | 0,402 | 153 | 0,507 | 0,504 | 0,506 |

Rectangular Notch (Kaolin 14.64%)

Yield stress (Pa)= 9,90

Density ($kg/m^3$)= 1242

n = 0,536

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,208

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,22 | 0,0660 | 0,0662 | 0,0616 | 0,0661 | 0,00322 | 0,247 | 0,00760 | 0,123 | 0,424 | 170 | 0,522 | 0,519 | 0,521 |
| 3,21 | 0,0660 | 0,0662 | 0,0616 | 0,0661 | 0,00321 | 0,247 | 0,00760 | 0,123 | 0,423 | 169 | 0,520 | 0,518 | 0,519 |
| 3,49 | 0,0686 | 0,0689 | 0,0636 | 0,0687 | 0,00349 | 0,251 | 0,00785 | 0,125 | 0,445 | 187 | 0,534 | 0,531 | 0,532 |
| 3,48 | 0,0686 | 0,0689 | 0,0636 | 0,0687 | 0,00348 | 0,251 | 0,00785 | 0,125 | 0,444 | 186 | 0,532 | 0,529 | 0,531 |
| 3,87 | 0,0722 | 0,0726 | 0,0671 | 0,0724 | 0,00387 | 0,258 | 0,00828 | 0,129 | 0,467 | 207 | 0,548 | 0,543 | 0,545 |
| 3,87 | 0,0722 | 0,0726 | 0,0671 | 0,0724 | 0,00387 | 0,258 | 0,00828 | 0,129 | 0,467 | 207 | 0,548 | 0,543 | 0,545 |
| 4,20 | 0,0764 | 0,0766 | 0,0711 | 0,0765 | 0,00420 | 0,266 | 0,00878 | 0,132 | 0,479 | 217 | 0,546 | 0,544 | 0,545 |
| 4,20 | 0,0764 | 0,0766 | 0,0711 | 0,0765 | 0,00420 | 0,266 | 0,00878 | 0,132 | 0,479 | 217 | 0,546 | 0,544 | 0,545 |
| 4,52 | 0,0789 | 0,0793 | 0,0732 | 0,0791 | 0,00452 | 0,270 | 0,00903 | 0,134 | 0,500 | 236 | 0,559 | 0,555 | 0,557 |
| 4,51 | 0,0789 | 0,0793 | 0,0732 | 0,0791 | 0,00451 | 0,270 | 0,00903 | 0,134 | 0,499 | 235 | 0,558 | 0,553 | 0,556 |
| 4,83 | 0,0822 | 0,0827 | 0,0764 | 0,0825 | 0,00483 | 0,276 | 0,00942 | 0,137 | 0,512 | 248 | 0,562 | 0,557 | 0,559 |
| 4,83 | 0,0822 | 0,0827 | 0,0764 | 0,0825 | 0,00483 | 0,276 | 0,00942 | 0,137 | 0,512 | 248 | 0,562 | 0,557 | 0,559 |
| 5,20 | 0,0861 | 0,0866 | 0,0797 | 0,0864 | 0,00520 | 0,283 | 0,00983 | 0,139 | 0,529 | 264 | 0,565 | 0,560 | 0,562 |
| 5,21 | 0,0861 | 0,0866 | 0,0797 | 0,0864 | 0,00521 | 0,283 | 0,00983 | 0,139 | 0,530 | 266 | 0,566 | 0,561 | 0,563 |

Rectangular Notch (Kaolin 14.64%)

Yield stress (Pa)= 9,90

Density (kg/m$^3$)= 1242

n = 0,536

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,208

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5,49 | 0,0891 | 0,0895 | 0,0823 | 0,0893 | 0,00549 | 0,288 | 0,0102 | 0,141 | 0,541 | 276 | 0,566 | 0,563 | 0,564 |
| 5,49 | 0,0891 | 0,0895 | 0,0823 | 0,0893 | 0,00549 | 0,288 | 0,0102 | 0,141 | 0,541 | 277 | 0,567 | 0,563 | 0,565 |
| 5,83 | 0,0925 | 0,0929 | 0,0853 | 0,0927 | 0,00583 | 0,294 | 0,0105 | 0,143 | 0,554 | 289 | 0,565 | 0,565 | 0,565 |
| 5,83 | 0,0925 | 0,0929 | 0,0853 | 0,0927 | 0,00583 | 0,294 | 0,0105 | 0,143 | 0,554 | 289 | 0,565 | 0,565 | 0,565 |
| 6,47 | 0,0991 | 0,0993 | 0,0913 | 0,0992 | 0,00647 | 0,306 | 0,0113 | 0,147 | 0,574 | 311 | 0,569 | 0,568 | 0,568 |
| 6,47 | 0,0991 | 0,0993 | 0,0913 | 0,0992 | 0,00647 | 0,306 | 0,0113 | 0,147 | 0,574 | 311 | 0,569 | 0,568 | 0,568 |
| 6,84 | 0,1025 | 0,1028 | 0,0950 | 0,1026 | 0,00684 | 0,313 | 0,0117 | 0,150 | 0,583 | 321 | 0,572 | 0,569 | 0,571 |
| 6,84 | 0,1025 | 0,1028 | 0,0950 | 0,1026 | 0,00684 | 0,313 | 0,0117 | 0,150 | 0,583 | 321 | 0,572 | 0,569 | 0,571 |
| 7,13 | 0,1056 | 0,1059 | 0,0978 | 0,1058 | 0,00713 | 0,319 | 0,0121 | 0,151 | 0,591 | 330 | 0,570 | 0,567 | 0,569 |
| 7,12 | 0,1056 | 0,1059 | 0,0978 | 0,1058 | 0,00712 | 0,319 | 0,0121 | 0,151 | 0,590 | 328 | 0,569 | 0,566 | 0,568 |
| 7,56 | 0,1100 | 0,1103 | 0,1020 | 0,1101 | 0,00756 | 0,327 | 0,0126 | 0,154 | 0,601 | 340 | 0,569 | 0,566 | 0,567 |
| 7,56 | 0,1100 | 0,1103 | 0,1020 | 0,1101 | 0,00756 | 0,327 | 0,0126 | 0,154 | 0,601 | 340 | 0,569 | 0,566 | 0,567 |
| 7,91 | 0,1131 | 0,1136 | 0,1053 | 0,1134 | 0,00791 | 0,334 | 0,0130 | 0,156 | 0,609 | 350 | 0,570 | 0,567 | 0,569 |
| 7,92 | 0,1131 | 0,1136 | 0,1053 | 0,1134 | 0,00792 | 0,334 | 0,0130 | 0,156 | 0,610 | 351 | 0,571 | 0,568 | 0,569 |

Rectangular Notch (Kaolin 14.64%)

Yield stress (Pa)= 9,90

Density ($kg/m^3$)= 1242

n = 0,536

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,208

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8,19 | 0,1156 | 0,1159 | 0,1076 | 0,1157 | 0,00819 | 0,339 | 0,0133 | 0,157 | 0,617 | 359 | 0,572 | 0,570 | 0,571 |
| 8,19 | 0,1156 | 0,1159 | 0,1076 | 0,1157 | 0,00819 | 0,339 | 0,0133 | 0,157 | 0,617 | 359 | 0,572 | 0,570 | 0,571 |
| 6,20 | 0,0964 | 0,0967 | 0,0893 | 0,0965 | 0,00620 | 0,302 | 0,0110 | 0,146 | 0,563 | 299 | 0,569 | 0,566 | 0,567 |
| 6,20 | 0,0964 | 0,0967 | 0,0893 | 0,0965 | 0,00620 | 0,302 | 0,0110 | 0,146 | 0,563 | 299 | 0,569 | 0,566 | 0,567 |

**Table 4.7 Flow rate measurement of kaolin 15.31% through rectangular notch**

Rectangular Notch (Kaolin 15.31%)

Yield stress (Pa)= 10,4

Density (kg/m$^3$)= 1253

n = 0,531

B(m)= 0,1234  g(m/s$^2$)= 9,813  k (Pa.s$^n$)= 0,219

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | Cdavg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 0,60 | 0,0299 | 0,0301 | 0,0296 | 0,0300 | 0,000602 | 0,183 | 0,00365 | 0,0800 | 0,165 | 25,1 | 0,321 | 0,316 | 0,318 |
| 0,60 | 0,0299 | 0,0301 | 0,0296 | 0,0300 | 0,000603 | 0,183 | 0,00365 | 0,0800 | 0,165 | 25,1 | 0,321 | 0,316 | 0,318 |
| 0,92 | 0,0353 | 0,0358 | 0,0337 | 0,0355 | 0,000924 | 0,191 | 0,00416 | 0,0872 | 0,222 | 45,2 | 0,383 | 0,374 | 0,379 |
| 0,93 | 0,0353 | 0,0358 | 0,0337 | 0,0355 | 0,000926 | 0,191 | 0,00416 | 0,0872 | 0,222 | 45,4 | 0,384 | 0,375 | 0,379 |
| 1,26 | 0,0393 | 0,0399 | 0,0374 | 0,0396 | 0,00126 | 0,198 | 0,00461 | 0,0931 | 0,273 | 68,1 | 0,443 | 0,434 | 0,439 |
| 1,26 | 0,0393 | 0,0399 | 0,0374 | 0,0396 | 0,00126 | 0,198 | 0,00461 | 0,0931 | 0,273 | 68,3 | 0,444 | 0,435 | 0,439 |
| 1,56 | 0,0429 | 0,0432 | 0,0403 | 0,0431 | 0,00156 | 0,204 | 0,00498 | 0,0976 | 0,314 | 89,9 | 0,483 | 0,477 | 0,480 |
| 1,55 | 0,0429 | 0,0432 | 0,0403 | 0,0431 | 0,00155 | 0,204 | 0,00498 | 0,0976 | 0,312 | 88,9 | 0,480 | 0,474 | 0,477 |
| 1,92 | 0,0463 | 0,0465 | 0,0431 | 0,0464 | 0,00192 | 0,210 | 0,00532 | 0,102 | 0,360 | 118 | 0,528 | 0,524 | 0,526 |
| 1,91 | 0,0463 | 0,0465 | 0,0431 | 0,0464 | 0,00191 | 0,210 | 0,00532 | 0,102 | 0,359 | 117 | 0,527 | 0,522 | 0,524 |
| 2,20 | 0,0511 | 0,0512 | 0,0472 | 0,0512 | 0,00220 | 0,218 | 0,00582 | 0,107 | 0,378 | 130 | 0,522 | 0,520 | 0,521 |
| 2,21 | 0,0511 | 0,0512 | 0,0472 | 0,0512 | 0,00221 | 0,218 | 0,00582 | 0,107 | 0,380 | 131 | 0,526 | 0,523 | 0,524 |
| 2,56 | 0,0551 | 0,0554 | 0,0505 | 0,0553 | 0,00256 | 0,224 | 0,00623 | 0,111 | 0,411 | 153 | 0,542 | 0,537 | 0,540 |
| 2,56 | 0,0551 | 0,0554 | 0,0505 | 0,0553 | 0,00256 | 0,224 | 0,00623 | 0,111 | 0,411 | 154 | 0,543 | 0,538 | 0,541 |

Rectangular Notch (Kaolin 15.31%)

Yield stress (Pa)= 10,4

Density ($kg/m^3$)= 1253

n = 0,531

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,219

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d1$ | $C_d2$ | Cdavg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 2,81 | 0,0582 | 0,0585 | 0,0531 | 0,0583 | 0,00281 | 0,230 | 0,00656 | 0,114 | 0,428 | 166 | 0,549 | 0,545 | 0,547 |
| 2,81 | 0,0582 | 0,0585 | 0,0531 | 0,0583 | 0,00281 | 0,230 | 0,00656 | 0,114 | 0,428 | 166 | 0,549 | 0,545 | 0,547 |
| 3,15 | 0,0621 | 0,0624 | 0,0567 | 0,0623 | 0,00315 | 0,237 | 0,00700 | 0,118 | 0,450 | 184 | 0,558 | 0,554 | 0,556 |
| 3,16 | 0,0621 | 0,0624 | 0,0567 | 0,0623 | 0,00316 | 0,237 | 0,00700 | 0,118 | 0,452 | 185 | 0,560 | 0,556 | 0,558 |
| 3,39 | 0,0651 | 0,0653 | 0,0590 | 0,0652 | 0,00339 | 0,241 | 0,00728 | 0,121 | 0,466 | 197 | 0,560 | 0,558 | 0,559 |
| 3,39 | 0,0651 | 0,0653 | 0,0590 | 0,0652 | 0,00339 | 0,241 | 0,00728 | 0,121 | 0,466 | 197 | 0,560 | 0,558 | 0,559 |
| 3,71 | 0,0686 | 0,0687 | 0,0626 | 0,0687 | 0,00371 | 0,249 | 0,00772 | 0,124 | 0,481 | 210 | 0,567 | 0,565 | 0,566 |
| 3,71 | 0,0686 | 0,0687 | 0,0626 | 0,0687 | 0,00371 | 0,249 | 0,00772 | 0,124 | 0,480 | 209 | 0,566 | 0,565 | 0,565 |
| 4,10 | 0,0726 | 0,0728 | 0,0659 | 0,0727 | 0,00410 | 0,255 | 0,00814 | 0,127 | 0,504 | 230 | 0,574 | 0,572 | 0,573 |
| 4,10 | 0,0726 | 0,0728 | 0,0659 | 0,0727 | 0,00410 | 0,255 | 0,00814 | 0,127 | 0,504 | 230 | 0,575 | 0,573 | 0,574 |
| 4,44 | 0,0764 | 0,0767 | 0,0697 | 0,0766 | 0,00444 | 0,263 | 0,00860 | 0,131 | 0,516 | 242 | 0,577 | 0,573 | 0,575 |
| 4,44 | 0,0764 | 0,0767 | 0,0697 | 0,0766 | 0,00444 | 0,263 | 0,00860 | 0,131 | 0,516 | 242 | 0,577 | 0,574 | 0,576 |
| 4,72 | 0,0796 | 0,0801 | 0,0725 | 0,0799 | 0,00472 | 0,268 | 0,00895 | 0,133 | 0,528 | 253 | 0,577 | 0,571 | 0,574 |
| 4,72 | 0,0796 | 0,0801 | 0,0725 | 0,0799 | 0,00472 | 0,268 | 0,00895 | 0,133 | 0,528 | 253 | 0,577 | 0,571 | 0,574 |

Rectangular Notch (Kaolin 15.31%)

Yield stress (Pa)= 10,4

Density ($kg/m^3$)= 1253

n = 0,531

B(m)= 0,1234  g($m/s^2$)= 9,813  k ($Pa.s^n$)= 0,219

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d1$ | $C_d2$ | Cdavg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 5,08 | 0,0833 | 0,0836 | 0,0762 | 0,0835 | 0,00508 | 0,276 | 0,00940 | 0,136 | 0,540 | 264 | 0,576 | 0,576 | 0,576 |
| 5,08 | 0,0833 | 0,0836 | 0,0762 | 0,0835 | 0,00508 | 0,276 | 0,00940 | 0,136 | 0,540 | 265 | 0,576 | 0,576 | 0,576 |
| 5,47 | 0,0874 | 0,0877 | 0,0801 | 0,0875 | 0,00547 | 0,284 | 0,00989 | 0,139 | 0,554 | 278 | 0,581 | 0,578 | 0,580 |
| 5,47 | 0,0874 | 0,0877 | 0,0801 | 0,0875 | 0,00547 | 0,284 | 0,00989 | 0,139 | 0,553 | 277 | 0,581 | 0,578 | 0,579 |
| 5,72 | 0,0901 | 0,0904 | 0,0826 | 0,0903 | 0,00572 | 0,289 | 0,0102 | 0,141 | 0,561 | 285 | 0,580 | 0,578 | 0,579 |
| 5,72 | 0,0901 | 0,0904 | 0,0826 | 0,0903 | 0,00572 | 0,289 | 0,0102 | 0,141 | 0,561 | 285 | 0,580 | 0,578 | 0,579 |
| 6,16 | 0,0947 | 0,0949 | 0,0870 | 0,0948 | 0,00616 | 0,297 | 0,0107 | 0,144 | 0,574 | 299 | 0,580 | 0,578 | 0,579 |
| 6,17 | 0,0947 | 0,0949 | 0,0870 | 0,0948 | 0,00617 | 0,297 | 0,0107 | 0,144 | 0,575 | 300 | 0,581 | 0,579 | 0,580 |
| 6,56 | 0,0986 | 0,0987 | 0,0907 | 0,0987 | 0,00656 | 0,305 | 0,0112 | 0,147 | 0,586 | 311 | 0,581 | 0,580 | 0,580 |
| 6,56 | 0,0986 | 0,0987 | 0,0907 | 0,0987 | 0,00656 | 0,305 | 0,0112 | 0,147 | 0,586 | 311 | 0,581 | 0,580 | 0,581 |
| 6,98 | 0,1032 | 0,1034 | 0,0948 | 0,1033 | 0,00698 | 0,313 | 0,0117 | 0,150 | 0,597 | 323 | 0,578 | 0,576 | 0,577 |
| 6,97 | 0,1032 | 0,1034 | 0,0948 | 0,1033 | 0,00697 | 0,313 | 0,0117 | 0,150 | 0,596 | 322 | 0,577 | 0,576 | 0,576 |
| 7,24 | 0,1059 | 0,1060 | 0,0972 | 0,1060 | 0,00724 | 0,318 | 0,0120 | 0,151 | 0,603 | 330 | 0,576 | 0,576 | 0,576 |
| 7,24 | 0,1059 | 0,1060 | 0,0972 | 0,1060 | 0,00724 | 0,318 | 0,0120 | 0,151 | 0,604 | 330 | 0,576 | 0,576 | 0,576 |

Rectangular Notch (Kaolin 15.31%)

Yield stress (Pa)= 10,4

Density ($kg/m^3$)= 1253

n = 0,531

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,219

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d1$ | $C_d2$ | Cdavg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 7,60 | 0,1091 | 0,1094 | 0,1005 | 0,1093 | 0,00760 | 0,324 | 0,0124 | 0,153 | 0,613 | 340 | 0,578 | 0,576 | 0,577 |
| 7,59 | 0,1091 | 0,1094 | 0,1005 | 0,1093 | 0,00759 | 0,324 | 0,0124 | 0,153 | 0,612 | 340 | 0,578 | 0,576 | 0,577 |
| 7,89 | 0,1122 | 0,1122 | 0,1035 | 0,1122 | 0,00789 | 0,330 | 0,0128 | 0,155 | 0,618 | 346 | 0,576 | 0,576 | 0,576 |
| 7,89 | 0,1122 | 0,1122 | 0,1035 | 0,1122 | 0,00789 | 0,330 | 0,0128 | 0,155 | 0,618 | 346 | 0,576 | 0,576 | 0,576 |
| 8,31 | 0,1157 | 0,1159 | 0,1068 | 0,1158 | 0,00831 | 0,337 | 0,0132 | 0,156 | 0,630 | 360 | 0,579 | 0,578 | 0,578 |
| 8,32 | 0,1157 | 0,1159 | 0,1068 | 0,1158 | 0,00832 | 0,337 | 0,0132 | 0,156 | 0,631 | 360 | 0,580 | 0,579 | 0,579 |
| 2,30 | 0,0538 | 0,0539 | 0,0495 | 0,0538 | 0,00230 | 0,222 | 0,00611 | 0,110 | 0,376 | 128 | 0,506 | 0,503 | 0,504 |
| 2,30 | 0,0538 | 0,0539 | 0,0495 | 0,0538 | 0,00230 | 0,222 | 0,00611 | 0,110 | 0,376 | 128 | 0,506 | 0,503 | 0,504 |

**Table 4.8 Flow rate measurement of kaolin 16% through rectangular notch**

Rectangular Notch (Kaolin 16%)

Yield stress (Pa)= 15,8

Density ($kg/m^3$)= 1264

n = 0,500

B(m)= 0,1234 g($m/s^2$)= 9,813 k ($Pa.s^n$)= 0,259

k'= 0,290

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,82 | 0,0754 | 0,0754 | 0,0743 | 0,0754 | 0,000820 | 0,272 | 0,00917 | 0,135 | 0,0894 | 5,02 | 0,109 | 0,109 | 0,109 |
| 0,82 | 0,0754 | 0,0754 | 0,0743 | 0,0754 | 0,000823 | 0,272 | 0,00917 | 0,135 | 0,0898 | 5,07 | 0,109 | 0,109 | 0,109 |
| 1,05 | 0,0796 | 0,0796 | 0,0795 | 0,0796 | 0,00105 | 0,282 | 0,00981 | 0,139 | 0,107 | 7,14 | 0,128 | 0,128 | 0,128 |
| 1,05 | 0,0796 | 0,0796 | 0,0795 | 0,0796 | 0,00105 | 0,282 | 0,00981 | 0,139 | 0,107 | 7,18 | 0,128 | 0,128 | 0,128 |
| 1,27 | 0,0820 | 0,0819 | 0,0814 | 0,0819 | 0,00127 | 0,286 | 0,0100 | 0,140 | 0,126 | 9,95 | 0,148 | 0,148 | 0,148 |
| 1,27 | 0,0820 | 0,0819 | 0,0814 | 0,0819 | 0,00127 | 0,286 | 0,0100 | 0,140 | 0,127 | 10,0 | 0,149 | 0,149 | 0,149 |
| 2,41 | 0,0891 | 0,0891 | 0,0872 | 0,0891 | 0,00241 | 0,298 | 0,0108 | 0,145 | 0,224 | 31,2 | 0,249 | 0,249 | 0,249 |
| 2,41 | 0,0891 | 0,0891 | 0,0872 | 0,0891 | 0,00241 | 0,298 | 0,0108 | 0,145 | 0,224 | 31,2 | 0,249 | 0,249 | 0,249 |
| 2,66 | 0,0916 | 0,0916 | 0,0889 | 0,0916 | 0,00266 | 0,301 | 0,0110 | 0,146 | 0,243 | 36,6 | 0,263 | 0,263 | 0,263 |
| 2,67 | 0,0916 | 0,0916 | 0,0889 | 0,0916 | 0,00267 | 0,301 | 0,0110 | 0,146 | 0,244 | 36,9 | 0,264 | 0,264 | 0,264 |
| 3,01 | 0,0945 | 0,0945 | 0,0914 | 0,0945 | 0,00301 | 0,306 | 0,0113 | 0,147 | 0,267 | 44,1 | 0,284 | 0,284 | 0,284 |
| 3,01 | 0,0945 | 0,0945 | 0,0914 | 0,0945 | 0,00301 | 0,306 | 0,0113 | 0,147 | 0,267 | 44,1 | 0,284 | 0,284 | 0,284 |

Rectangular Notch (Kaolin 16%)

Yield stress (Pa)= 15,8

Density (kg/m$^3$)= 1264

n = 0,500

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,259

k'= 0,290

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,33 | 0,0971 | 0,0970 | 0,0932 | 0,0970 | 0,00333 | 0,310 | 0,0115 | 0,149 | 0,289 | 51,9 | 0,302 | 0,302 | 0,302 |
| 3,33 | 0,0971 | 0,0970 | 0,0932 | 0,0970 | 0,00333 | 0,310 | 0,0115 | 0,149 | 0,289 | 51,9 | 0,302 | 0,302 | 0,302 |
| 3,65 | 0,0991 | 0,0991 | 0,0953 | 0,0991 | 0,00365 | 0,314 | 0,0118 | 0,150 | 0,311 | 59,8 | 0,321 | 0,321 | 0,321 |
| 3,65 | 0,0991 | 0,0991 | 0,0953 | 0,0991 | 0,00365 | 0,314 | 0,0118 | 0,150 | 0,311 | 59,8 | 0,321 | 0,321 | 0,321 |
| 4,05 | 0,1009 | 0,1011 | 0,0965 | 0,1010 | 0,00405 | 0,316 | 0,0119 | 0,151 | 0,340 | 71,6 | 0,346 | 0,346 | 0,346 |
| 4,05 | 0,1009 | 0,1011 | 0,0965 | 0,1010 | 0,00405 | 0,316 | 0,0119 | 0,151 | 0,340 | 71,5 | 0,346 | 0,345 | 0,346 |
| 4,44 | 0,1035 | 0,1036 | 0,0982 | 0,1036 | 0,00444 | 0,320 | 0,0121 | 0,152 | 0,366 | 83,0 | 0,366 | 0,365 | 0,366 |
| 4,43 | 0,1035 | 0,1036 | 0,0982 | 0,1036 | 0,00443 | 0,320 | 0,0121 | 0,152 | 0,366 | 82,7 | 0,365 | 0,365 | 0,365 |
| 4,73 | 0,1064 | 0,1068 | 0,1008 | 0,1066 | 0,00473 | 0,325 | 0,0124 | 0,153 | 0,381 | 89,5 | 0,374 | 0,372 | 0,373 |
| 4,73 | 0,1064 | 0,1068 | 0,1008 | 0,1066 | 0,00473 | 0,325 | 0,0124 | 0,153 | 0,381 | 89,5 | 0,374 | 0,372 | 0,373 |
| 5,02 | 0,1083 | 0,1083 | 0,1023 | 0,1083 | 0,00502 | 0,328 | 0,0126 | 0,154 | 0,397 | 97,5 | 0,386 | 0,386 | 0,386 |
| 5,01 | 0,1083 | 0,1083 | 0,1023 | 0,1083 | 0,00501 | 0,328 | 0,0126 | 0,154 | 0,397 | 97,2 | 0,386 | 0,386 | 0,386 |
| 5,34 | 0,1104 | 0,1104 | 0,1036 | 0,1104 | 0,00534 | 0,331 | 0,0128 | 0,155 | 0,418 | 108 | 0,400 | 0,399 | 0,399 |
| 5,34 | 0,1104 | 0,1104 | 0,1036 | 0,1104 | 0,00534 | 0,331 | 0,0128 | 0,155 | 0,418 | 108 | 0,400 | 0,399 | 0,399 |

Rectangular Notch (Kaolin 16%)

Yield stress (Pa)= 15,8

Density (kg/m$^3$)= 1264

n = 0,500

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,259

k'= 0,290

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 2,05 | 0,0870 | 0,0872 | 0,0861 | 0,0871 | 0,00205 | 0,296 | 0,0106 | 0,144 | 0,193 | 23,3 | 0,219 | 0,219 | 0,219 |
| 2,06 | 0,0870 | 0,0872 | 0,0861 | 0,0871 | 0,00206 | 0,296 | 0,0106 | 0,144 | 0,194 | 23,4 | 0,220 | 0,219 | 0,219 |
| 1,61 | 0,0855 | 0,0856 | 0,0845 | 0,0856 | 0,00161 | 0,292 | 0,0104 | 0,143 | 0,155 | 15,0 | 0,177 | 0,177 | 0,177 |
| 1,62 | 0,0855 | 0,0856 | 0,0845 | 0,0856 | 0,00162 | 0,292 | 0,0104 | 0,143 | 0,155 | 15,0 | 0,177 | 0,177 | 0,177 |
| 1,33 | 0,0823 | 0,0822 | 0,0815 | 0,0822 | 0,00133 | 0,286 | 0,0101 | 0,140 | 0,132 | 10,9 | 0,154 | 0,155 | 0,155 |
| 1,33 | 0,0823 | 0,0822 | 0,0815 | 0,0822 | 0,00133 | 0,286 | 0,0101 | 0,140 | 0,133 | 11,0 | 0,155 | 0,155 | 0,155 |

**APPENDIX F: Rectangular notch flow rate measurement results (Bentonite suspension)**

**Table 4.9 Flow rate measurement of bentonite 4.15% through rectangular notch**

Rectangular Notch (Bentonite 4.15%)

Yield stress (Pa)= 1,15

Density (kg/m$^3$)= 1025

n = 1

B(m)= 0,1234 g (m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,00294

| Flow | Gauge 1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 8,44 | 0,1127 | 0,1132 | 0,1052 | 0,1129 | 0,00844 | 0,334 | 0,0130 | 0,156 | 0,650 | 2944 | 0,612 | 0,608 | 0,610 |
| 8,44 | 0,1127 | 0,1132 | 0,1052 | 0,1129 | 0,00844 | 0,334 | 0,0130 | 0,156 | 0,650 | 2945 | 0,612 | 0,608 | 0,610 |
| 8,00 | 0,1086 | 0,1087 | 0,1016 | 0,1086 | 0,00800 | 0,327 | 0,0125 | 0,154 | 0,638 | 2842 | 0,614 | 0,613 | 0,613 |
| 8,00 | 0,1086 | 0,1087 | 0,1016 | 0,1086 | 0,00800 | 0,327 | 0,0125 | 0,154 | 0,638 | 2842 | 0,614 | 0,613 | 0,613 |
| 7,60 | 0,1044 | 0,1049 | 0,0986 | 0,1047 | 0,00760 | 0,321 | 0,0122 | 0,152 | 0,625 | 2723 | 0,618 | 0,614 | 0,616 |
| 7,60 | 0,1044 | 0,1049 | 0,0986 | 0,1047 | 0,00760 | 0,321 | 0,0122 | 0,152 | 0,624 | 2718 | 0,618 | 0,613 | 0,615 |
| 7,22 | 0,1014 | 0,1017 | 0,0961 | 0,1015 | 0,00722 | 0,316 | 0,0119 | 0,150 | 0,609 | 2585 | 0,614 | 0,611 | 0,613 |
| 7,22 | 0,1014 | 0,1017 | 0,0961 | 0,1015 | 0,00722 | 0,316 | 0,0119 | 0,150 | 0,609 | 2585 | 0,614 | 0,611 | 0,613 |
| 6,82 | 0,0968 | 0,0978 | 0,0914 | 0,0973 | 0,00682 | 0,306 | 0,0113 | 0,147 | 0,604 | 2545 | 0,621 | 0,612 | 0,616 |
| 6,82 | 0,0968 | 0,0978 | 0,0914 | 0,0973 | 0,00682 | 0,306 | 0,0113 | 0,147 | 0,604 | 2544 | 0,621 | 0,612 | 0,616 |
| 6,40 | 0,0929 | 0,0929 | 0,0872 | 0,0929 | 0,00640 | 0,298 | 0,0108 | 0,145 | 0,594 | 2465 | 0,620 | 0,620 | 0,620 |
| 6,40 | 0,0929 | 0,0929 | 0,0872 | 0,0929 | 0,00640 | 0,298 | 0,0108 | 0,145 | 0,595 | 2466 | 0,620 | 0,620 | 0,620 |
| 6,00 | 0,0886 | 0,0888 | 0,0834 | 0,0887 | 0,00600 | 0,290 | 0,0103 | 0,142 | 0,583 | 2373 | 0,624 | 0,622 | 0,623 |
| 6,00 | 0,0886 | 0,0888 | 0,0834 | 0,0887 | 0,00600 | 0,290 | 0,0103 | 0,142 | 0,583 | 2373 | 0,624 | 0,622 | 0,623 |

Rectangular Notch (Bentonite 4.15%)

Yield stress (Pa)= 1,15

Density (kg/m$^3$)= 1025

n = 1

B(m)= 0,1234 g (m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,00294

| Flow | Gauge 1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 5,60 | 0,0842 | 0,0848 | 0,0789 | 0,0845 | 0,00560 | 0,281 | 0,00973 | 0,138 | 0,575 | 2307 | 0,629 | 0,622 | 0,626 |
| 5,60 | 0,0842 | 0,0848 | 0,0789 | 0,0845 | 0,00560 | 0,281 | 0,00973 | 0,138 | 0,575 | 2308 | 0,629 | 0,622 | 0,626 |
| 5,20 | 0,0803 | 0,0804 | 0,0754 | 0,0804 | 0,00520 | 0,274 | 0,00931 | 0,136 | 0,559 | 2179 | 0,627 | 0,626 | 0,626 |
| 5,20 | 0,0803 | 0,0804 | 0,0754 | 0,0804 | 0,00520 | 0,274 | 0,00931 | 0,136 | 0,559 | 2179 | 0,627 | 0,626 | 0,626 |
| 4,73 | 0,0752 | 0,0759 | 0,0705 | 0,0755 | 0,00473 | 0,264 | 0,00870 | 0,132 | 0,544 | 2065 | 0,630 | 0,621 | 0,626 |
| 4,74 | 0,0752 | 0,0759 | 0,0705 | 0,0755 | 0,00474 | 0,264 | 0,00870 | 0,132 | 0,545 | 2075 | 0,632 | 0,623 | 0,627 |
| 4,38 | 0,0705 | 0,0707 | 0,0663 | 0,0706 | 0,00438 | 0,256 | 0,00818 | 0,128 | 0,536 | 2000 | 0,642 | 0,640 | 0,641 |
| 4,38 | 0,0705 | 0,0707 | 0,0663 | 0,0706 | 0,00438 | 0,256 | 0,00818 | 0,128 | 0,536 | 2000 | 0,642 | 0,640 | 0,641 |
| 4,01 | 0,0663 | 0,0665 | 0,0623 | 0,0664 | 0,00401 | 0,248 | 0,00769 | 0,124 | 0,522 | 1901 | 0,646 | 0,642 | 0,644 |
| 4,01 | 0,0663 | 0,0665 | 0,0623 | 0,0664 | 0,00401 | 0,248 | 0,00769 | 0,124 | 0,522 | 1901 | 0,646 | 0,642 | 0,644 |
| 3,64 | 0,0618 | 0,0618 | 0,0574 | 0,0618 | 0,00364 | 0,238 | 0,00708 | 0,119 | 0,514 | 1841 | 0,650 | 0,649 | 0,650 |
| 3,65 | 0,0618 | 0,0618 | 0,0574 | 0,0618 | 0,00365 | 0,238 | 0,00708 | 0,119 | 0,515 | 1847 | 0,651 | 0,650 | 0,651 |
| 3,21 | 0,0564 | 0,0567 | 0,0519 | 0,0565 | 0,00321 | 0,227 | 0,00641 | 0,113 | 0,501 | 1749 | 0,658 | 0,653 | 0,656 |
| 3,22 | 0,0564 | 0,0567 | 0,0519 | 0,0565 | 0,00322 | 0,227 | 0,00641 | 0,113 | 0,503 | 1760 | 0,661 | 0,655 | 0,658 |
| 2,80 | 0,0512 | 0,0515 | 0,0484 | 0,0513 | 0,00280 | 0,220 | 0,00597 | 0,108 | 0,468 | 1527 | 0,663 | 0,656 | 0,659 |
| 2,81 | 0,0512 | 0,0515 | 0,0484 | 0,0513 | 0,00281 | 0,220 | 0,00597 | 0,108 | 0,471 | 1543 | 0,666 | 0,660 | 0,663 |

Rectangular Notch (Bentonite 4.15%)

Yield stress (Pa)= 1,15

Density (kg/$m^3$)= 1025

n = 1

B(m)= 0,1234 g (m/$s^2$)= 9,813 k (Pa.$s^n$)= 0,00294

| Flow | Gauge 1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3$/s | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 2,34 | 0,0445 | 0,0447 | 0,0419 | 0,0446 | 0,00234 | 0,207 | 0,00517 | 0,0999 | 0,452 | 1420 | 0,683 | 0,679 | 0,681 |
| 2,35 | 0,0445 | 0,0447 | 0,0419 | 0,0446 | 0,00235 | 0,207 | 0,00517 | 0,0999 | 0,454 | 1433 | 0,686 | 0,682 | 0,684 |

**Table 4.10 Flow rate measurement of bentonite 5.14% through rectangular notch**

Rectangular Notch (Bentonite 5,14%)

Yield stress (Pa)= 2,29

Density (kg/m$^3$)= 1031

n = 1

B(m)= 0,1234 g (m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,00394

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 8,51 | 0,1113 | 0,1116 | 0,1013 | 0,1115 | 0,00851 | 0,326 | 0,0125 | 0,153 | 0,681 | 1648 | 0,629 | 0,626 | 0,628 |
| 8,52 | 0,1113 | 0,1116 | 0,1013 | 0,1115 | 0,00852 | 0,326 | 0,0125 | 0,153 | 0,682 | 1652 | 0,630 | 0,627 | 0,628 |
| 8,07 | 0,1070 | 0,1077 | 0,0968 | 0,1073 | 0,00807 | 0,317 | 0,0119 | 0,151 | 0,675 | 1622 | 0,633 | 0,626 | 0,630 |
| 8,07 | 0,1070 | 0,1077 | 0,0968 | 0,1073 | 0,00807 | 0,317 | 0,0119 | 0,151 | 0,676 | 1624 | 0,633 | 0,627 | 0,630 |
| 7,51 | 0,1030 | 0,1034 | 0,0918 | 0,1032 | 0,00751 | 0,307 | 0,0113 | 0,148 | 0,663 | 1564 | 0,624 | 0,620 | 0,622 |
| 7,52 | 0,1030 | 0,1034 | 0,0918 | 0,1032 | 0,00752 | 0,307 | 0,0113 | 0,148 | 0,664 | 1569 | 0,625 | 0,621 | 0,623 |
| 7,02 | 0,0982 | 0,0986 | 0,0879 | 0,0984 | 0,00702 | 0,299 | 0,0108 | 0,145 | 0,647 | 1490 | 0,627 | 0,622 | 0,624 |
| 7,03 | 0,0981 | 0,0986 | 0,0879 | 0,0984 | 0,00703 | 0,299 | 0,0108 | 0,145 | 0,648 | 1491 | 0,627 | 0,622 | 0,625 |
| 6,52 | 0,0931 | 0,0933 | 0,0831 | 0,0932 | 0,00652 | 0,290 | 0,0103 | 0,142 | 0,636 | 1439 | 0,630 | 0,628 | 0,629 |
| 6,51 | 0,0931 | 0,0933 | 0,0831 | 0,0932 | 0,00651 | 0,290 | 0,0103 | 0,142 | 0,635 | 1434 | 0,629 | 0,627 | 0,628 |
| 6,07 | 0,0884 | 0,0890 | 0,0783 | 0,0887 | 0,00607 | 0,280 | 0,00966 | 0,138 | 0,628 | 1401 | 0,633 | 0,626 | 0,630 |
| 6,06 | 0,0884 | 0,0890 | 0,0783 | 0,0887 | 0,00606 | 0,280 | 0,00966 | 0,138 | 0,627 | 1396 | 0,632 | 0,625 | 0,629 |

Rectangular Notch (Bentonite 5,14%)

Yield stress (Pa)= 2,29

Density (kg/m$^3$)= 1031

n = 1

B(m)= 0,1234 g (m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,00394

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 5,56 | 0,0826 | 0,0833 | 0,0725 | 0,0830 | 0,00556 | 0,268 | 0,00895 | 0,133 | 0,621 | 1369 | 0,642 | 0,634 | 0,638 |
| 5,56 | 0,0826 | 0,0833 | 0,0725 | 0,0830 | 0,00556 | 0,268 | 0,00895 | 0,133 | 0,621 | 1369 | 0,642 | 0,634 | 0,638 |
| 5,04 | 0,0771 | 0,0777 | 0,0668 | 0,0774 | 0,00504 | 0,257 | 0,00824 | 0,128 | 0,611 | 1326 | 0,645 | 0,638 | 0,642 |
| 5,03 | 0,0771 | 0,0777 | 0,0668 | 0,0774 | 0,00503 | 0,257 | 0,00824 | 0,128 | 0,610 | 1321 | 0,644 | 0,637 | 0,640 |
| 4,00 | 0,0668 | 0,0670 | 0,0588 | 0,0669 | 0,00400 | 0,241 | 0,00725 | 0,120 | 0,552 | 1083 | 0,636 | 0,633 | 0,635 |
| 4,00 | 0,0668 | 0,0670 | 0,0588 | 0,0669 | 0,00400 | 0,241 | 0,00725 | 0,120 | 0,552 | 1083 | 0,636 | 0,633 | 0,635 |
| 3,55 | 0,0603 | 0,0605 | 0,0526 | 0,0604 | 0,00355 | 0,229 | 0,00650 | 0,114 | 0,546 | 1058 | 0,657 | 0,654 | 0,656 |
| 3,55 | 0,0603 | 0,0605 | 0,0526 | 0,0604 | 0,00355 | 0,229 | 0,00650 | 0,114 | 0,546 | 1058 | 0,658 | 0,654 | 0,656 |
| 3,06 | 0,0538 | 0,0549 | 0,0483 | 0,0543 | 0,00306 | 0,220 | 0,00596 | 0,108 | 0,513 | 933 | 0,673 | 0,653 | 0,663 |
| 3,05 | 0,0538 | 0,0549 | 0,0483 | 0,0543 | 0,00305 | 0,220 | 0,00596 | 0,108 | 0,511 | 927 | 0,671 | 0,650 | 0,661 |

**Table 4.11 Flow rate measurement of bentonite 6% through rectangular notch**

Rectangular Notch (Bentonite 6%)

Yield stress (Pa)= 4,88

Density (kg/m$^3$)= 1037

n = 1

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,00437

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9,66 | 0,1209 | 0,1219 | 0,1088 | 0,1214 | 0,00966 | 0,341 | 0,0134 | 0,157 | 0,719 | 872 | 0,630 | 0,623 | 0,627 |
| 9,66 | 0,1209 | 0,1219 | 0,1088 | 0,1214 | 0,00966 | 0,341 | 0,0134 | 0,157 | 0,719 | 872 | 0,630 | 0,623 | 0,627 |
| 8,64 | 0,1106 | 0,1116 | 0,1002 | 0,1111 | 0,00864 | 0,324 | 0,0124 | 0,153 | 0,699 | 823 | 0,645 | 0,635 | 0,640 |
| 8,65 | 0,1106 | 0,1116 | 0,1002 | 0,1111 | 0,00865 | 0,324 | 0,0124 | 0,153 | 0,700 | 825 | 0,645 | 0,636 | 0,641 |
| 7,65 | 0,1042 | 0,1037 | 0,0935 | 0,1040 | 0,00765 | 0,310 | 0,0115 | 0,149 | 0,663 | 742 | 0,624 | 0,628 | 0,626 |
| 7,65 | 0,1042 | 0,1037 | 0,0935 | 0,1040 | 0,00765 | 0,310 | 0,0115 | 0,149 | 0,663 | 742 | 0,624 | 0,628 | 0,626 |
| 6,67 | 0,0940 | 0,0956 | 0,0845 | 0,0948 | 0,00667 | 0,292 | 0,0104 | 0,143 | 0,640 | 690 | 0,635 | 0,619 | 0,627 |
| 6,68 | 0,0940 | 0,0956 | 0,0845 | 0,0948 | 0,00668 | 0,292 | 0,0104 | 0,143 | 0,641 | 693 | 0,636 | 0,620 | 0,628 |
| 5,67 | 0,0851 | 0,0864 | 0,0759 | 0,0858 | 0,00567 | 0,275 | 0,0094 | 0,136 | 0,605 | 617 | 0,627 | 0,613 | 0,620 |
| 5,67 | 0,0851 | 0,0864 | 0,0759 | 0,0858 | 0,00567 | 0,275 | 0,0094 | 0,136 | 0,605 | 617 | 0,627 | 0,613 | 0,620 |
| 4,63 | 0,0738 | 0,0751 | 0,0642 | 0,0745 | 0,00463 | 0,252 | 0,0079 | 0,126 | 0,585 | 576 | 0,633 | 0,617 | 0,625 |
| 4,64 | 0,0738 | 0,0751 | 0,0642 | 0,0745 | 0,00464 | 0,252 | 0,0079 | 0,126 | 0,586 | 579 | 0,635 | 0,618 | 0,627 |

Rectangular Notch (Bentonite 6%)

Yield stress (Pa)= 4,88

Density (kg/m$^3$)= 1037

n = 1

B(m)= 0,1234 g(m/s$^2$)= 9,813 k (Pa.s$^n$)= 0,00437

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 3,63 | 0,0626 | 0,0644 | 0,0545 | 0,0635 | 0,00363 | 0,232 | 0,0067 | 0,116 | 0,539 | 490 | 0,635 | 0,609 | 0,622 |
| 3,62 | 0,0626 | 0,0644 | 0,0545 | 0,0635 | 0,00362 | 0,232 | 0,0067 | 0,116 | 0,538 | 488 | 0,633 | 0,608 | 0,621 |
| 2,56 | 0,0499 | 0,0514 | 0,0414 | 0,0506 | 0,00256 | 0,206 | 0,0051 | 0,0991 | 0,501 | 423 | 0,630 | 0,602 | 0,616 |
| 2,56 | 0,0499 | 0,0514 | 0,0414 | 0,0506 | 0,00256 | 0,206 | 0,0051 | 0,0991 | 0,501 | 422 | 0,630 | 0,602 | 0,616 |
| 1,53 | 0,0363 | 0,0385 | 0,0292 | 0,0374 | 0,00153 | 0,182 | 0,0036 | 0,0793 | 0,423 | 302 | 0,605 | 0,555 | 0,580 |
| 1,54 | 0,0363 | 0,0385 | 0,0292 | 0,0374 | 0,00154 | 0,182 | 0,0036 | 0,0793 | 0,428 | 308 | 0,611 | 0,561 | 0,586 |
| 1,24 | 0,0334 | 0,0343 | 0,0247 | 0,0338 | 0,00124 | 0,173 | 0,0030 | 0,0706 | 0,406 | 278 | 0,557 | 0,535 | 0,546 |
| 1,23 | 0,0334 | 0,0343 | 0,0247 | 0,0338 | 0,00123 | 0,173 | 0,0030 | 0,0706 | 0,405 | 275 | 0,555 | 0,533 | 0,544 |
| 0,86 | 0,0261 | 0,0272 | 0,0183 | 0,0266 | 0,000858 | 0,160 | 0,0023 | 0,0565 | 0,380 | 242 | 0,559 | 0,525 | 0,542 |
| 0,86 | 0,0261 | 0,0272 | 0,0183 | 0,0266 | 0,000863 | 0,160 | 0,0023 | 0,0565 | 0,382 | 245 | 0,562 | 0,528 | 0,545 |

**APPENDIX G: Rectangular notch flow rate measurement results (CMC solution)**

**Table 4.12 Flow rate measurement of CMC 1.73% through rectangular notch**

Rectangular Notch (CMC 1,73%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1010

n'=n = 0,747

k (Pa.s$^n$)= 0,0235

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 0,0250

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 8,90 | 0,1186 | 0,1190 | 0,1078 | 0,1188 | 0,00890 | 0,339 | 0,0133 | 0,157 | 0,669 | 30985 | 29162 | 0,598 | 0,595 | 0,596 |
| 8,89 | 0,1186 | 0,1190 | 0,1078 | 0,1188 | 0,00889 | 0,339 | 0,0133 | 0,157 | 0,668 | 30939 | 29119 | 0,597 | 0,594 | 0,596 |
| 8,44 | 0,1145 | 0,1154 | 0,1035 | 0,1149 | 0,00844 | 0,330 | 0,0128 | 0,155 | 0,661 | 30177 | 28402 | 0,598 | 0,591 | 0,594 |
| 8,44 | 0,1145 | 0,1154 | 0,1035 | 0,1149 | 0,00844 | 0,330 | 0,0128 | 0,155 | 0,661 | 30179 | 28404 | 0,598 | 0,591 | 0,594 |
| 7,89 | 0,1103 | 0,1103 | 0,0999 | 0,1103 | 0,00789 | 0,323 | 0,0123 | 0,153 | 0,640 | 28693 | 27005 | 0,591 | 0,591 | 0,591 |
| 7,89 | 0,1103 | 0,1103 | 0,0999 | 0,1103 | 0,00789 | 0,323 | 0,0123 | 0,153 | 0,640 | 28697 | 27009 | 0,591 | 0,591 | 0,591 |
| 7,41 | 0,1056 | 0,1060 | 0,0959 | 0,1058 | 0,00741 | 0,315 | 0,0118 | 0,150 | 0,626 | 27597 | 25973 | 0,592 | 0,589 | 0,591 |
| 7,40 | 0,1056 | 0,1060 | 0,0959 | 0,1058 | 0,00740 | 0,315 | 0,0118 | 0,150 | 0,625 | 27551 | 25930 | 0,591 | 0,588 | 0,590 |
| 6,93 | 0,1013 | 0,1013 | 0,0917 | 0,1013 | 0,00693 | 0,307 | 0,0113 | 0,148 | 0,613 | 26488 | 24930 | 0,590 | 0,590 | 0,590 |
| 6,93 | 0,1013 | 0,1013 | 0,0917 | 0,1013 | 0,00693 | 0,307 | 0,0113 | 0,148 | 0,613 | 26492 | 24933 | 0,590 | 0,590 | 0,590 |
| 6,43 | 0,0963 | 0,0966 | 0,0862 | 0,0964 | 0,00643 | 0,296 | 0,0106 | 0,144 | 0,605 | 25574 | 24069 | 0,590 | 0,588 | 0,589 |
| 6,42 | 0,0963 | 0,0966 | 0,0862 | 0,0964 | 0,00642 | 0,287 | 0,0101 | 0,141 | 0,636 | 26784 | 25208 | 0,589 | 0,587 | 0,588 |
| 5,93 | 0,0914 | 0,0917 | 0,0819 | 0,0916 | 0,00593 | 0,287 | 0,0101 | 0,141 | 0,587 | 24250 | 22823 | 0,588 | 0,586 | 0,587 |
| 5,93 | 0,0914 | 0,0917 | 0,0819 | 0,0916 | 0,00593 | 0,287 | 0,0101 | 0,141 | 0,587 | 24250 | 22823 | 0,588 | 0,586 | 0,587 |

Rectangular Notch (CMC 1,73%)

Yield stress (Pa)= 0

Density ($kg/m^3$)= 1010

n'=n = 0,747

k ($Pa.s^n$)= 0,0235

B(m)= 0,1234 g ($m/s^2$)= 9,813 k'(Pa.sn)= 0,0250

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 5,45 | 0,0863 | 0,0865 | 0,0775 | 0,0864 | 0,00545 | 0,278 | 0,00957 | 0,137 | 0,570 | 22959 | 21608 | 0,590 | 0,589 | 0,589 |
| 5,45 | 0,0863 | 0,0865 | 0,0775 | 0,0864 | 0,00545 | 0,278 | 0,00957 | 0,137 | 0,570 | 22955 | 21604 | 0,590 | 0,588 | 0,589 |
| 4,94 | 0,0805 | 0,0807 | 0,0712 | 0,0806 | 0,00494 | 0,266 | 0,00878 | 0,132 | 0,563 | 21945 | 20654 | 0,594 | 0,592 | 0,593 |
| 4,94 | 0,0805 | 0,0807 | 0,0712 | 0,0806 | 0,00494 | 0,266 | 0,00878 | 0,132 | 0,563 | 21947 | 20656 | 0,594 | 0,592 | 0,593 |
| 4,41 | 0,0746 | 0,0750 | 0,0656 | 0,0748 | 0,00441 | 0,255 | 0,00810 | 0,127 | 0,545 | 20462 | 19258 | 0,594 | 0,590 | 0,592 |
| 4,41 | 0,0746 | 0,0750 | 0,0656 | 0,0748 | 0,00441 | 0,255 | 0,00810 | 0,127 | 0,544 | 20462 | 19258 | 0,594 | 0,590 | 0,592 |
| 3,92 | 0,0689 | 0,0690 | 0,0604 | 0,0690 | 0,00392 | 0,244 | 0,00745 | 0,122 | 0,526 | 19016 | 17898 | 0,595 | 0,593 | 0,594 |
| 3,92 | 0,0689 | 0,0690 | 0,0604 | 0,0690 | 0,00392 | 0,244 | 0,00745 | 0,122 | 0,526 | 19017 | 17898 | 0,595 | 0,593 | 0,594 |
| 3,45 | 0,0629 | 0,0630 | 0,0549 | 0,0629 | 0,00345 | 0,233 | 0,00677 | 0,116 | 0,510 | 17605 | 16569 | 0,601 | 0,599 | 0,600 |
| 3,45 | 0,0629 | 0,0630 | 0,0549 | 0,0629 | 0,00345 | 0,233 | 0,00677 | 0,116 | 0,510 | 17600 | 16564 | 0,601 | 0,599 | 0,600 |
| 2,92 | 0,0560 | 0,0563 | 0,0483 | 0,0562 | 0,00292 | 0,220 | 0,00596 | 0,108 | 0,490 | 15909 | 14973 | 0,605 | 0,600 | 0,602 |
| 2,92 | 0,0560 | 0,0563 | 0,0483 | 0,0562 | 0,00292 | 0,220 | 0,00596 | 0,108 | 0,490 | 15899 | 14964 | 0,604 | 0,600 | 0,602 |
| 2,41 | 0,0492 | 0,0494 | 0,0418 | 0,0493 | 0,00241 | 0,207 | 0,00516 | 0,0996 | 0,467 | 14082 | 13253 | 0,605 | 0,602 | 0,604 |
| 2,42 | 0,0492 | 0,0494 | 0,0418 | 0,0493 | 0,00242 | 0,207 | 0,00516 | 0,0996 | 0,470 | 14163 | 13329 | 0,608 | 0,605 | 0,606 |

Rectangular Notch (CMC 1,73%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1010

n'=n = 0,747

k (Pa.s$^n$)= 0,0235

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 0,0250

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 2,06 | 0,0436 | 0,0437 | 0,0359 | 0,0437 | 0,00206 | 0,195 | 0,00443 | 0,0908 | 0,464 | 13005 | 12240 | 0,619 | 0,617 | 0,618 |
| 2,06 | 0,0436 | 0,0437 | 0,0359 | 0,0437 | 0,00206 | 0,195 | 0,00443 | 0,0908 | 0,464 | 13021 | 12255 | 0,620 | 0,618 | 0,619 |

**Table 4.13 Flow rate measurement of CMC 4.63% through rectangular notch**

Rectangular Notch (CMC 4,63%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1026

n'=n = 0,7631

k (Pa.s$^n$)= 0,2129

B(m)= 0,1234 g (m/s$^2$)= 9,813 (Pa.sn)= 0,2254

| Flow (l/s) | Gauge 1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | Reynolds Number $Re_{MR}$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8,35 | 0,1131 | 0,1132 | 0,0994 | 0,1132 | 0,00835 | 0,322 | 0,0123 | 0,152 | 0,681 | 3358 | 3172 | 0,602 | 0,601 | 0,602 |
| 8,32 | 0,1131 | 0,1132 | 0,0994 | 0,1132 | 0,00832 | 0,322 | 0,0123 | 0,152 | 0,678 | 3342 | 3156 | 0,600 | 0,599 | 0,599 |
| 7,91 | 0,1096 | 0,1098 | 0,0957 | 0,1097 | 0,00791 | 0,315 | 0,0118 | 0,150 | 0,670 | 3256 | 3076 | 0,598 | 0,597 | 0,597 |
| 7,92 | 0,1096 | 0,1098 | 0,0957 | 0,1097 | 0,00792 | 0,315 | 0,0118 | 0,150 | 0,671 | 3261 | 3081 | 0,599 | 0,598 | 0,598 |
| 7,44 | 0,1054 | 0,1054 | 0,0921 | 0,1054 | 0,00744 | 0,308 | 0,0114 | 0,148 | 0,655 | 3128 | 2955 | 0,597 | 0,596 | 0,597 |
| 7,43 | 0,1054 | 0,1054 | 0,0921 | 0,1054 | 0,00743 | 0,308 | 0,0114 | 0,148 | 0,653 | 3120 | 2947 | 0,596 | 0,595 | 0,595 |
| 6,92 | 0,1001 | 0,1002 | 0,0874 | 0,1002 | 0,00692 | 0,298 | 0,0108 | 0,145 | 0,641 | 3000 | 2834 | 0,599 | 0,598 | 0,599 |
| 6,91 | 0,1001 | 0,1002 | 0,0874 | 0,1002 | 0,00691 | 0,298 | 0,0108 | 0,145 | 0,641 | 2995 | 2829 | 0,599 | 0,598 | 0,598 |
| 6,40 | 0,0954 | 0,0956 | 0,0827 | 0,0955 | 0,00640 | 0,289 | 0,0102 | 0,141 | 0,627 | 2867 | 2708 | 0,596 | 0,594 | 0,595 |
| 6,40 | 0,0954 | 0,0956 | 0,0827 | 0,0955 | 0,00640 | 0,289 | 0,0102 | 0,141 | 0,627 | 2867 | 2708 | 0,596 | 0,594 | 0,595 |
| 5,94 | 0,0903 | 0,0904 | 0,0777 | 0,0904 | 0,00594 | 0,279 | 0,00959 | 0,138 | 0,620 | 2766 | 2613 | 0,601 | 0,600 | 0,600 |
| 5,93 | 0,0903 | 0,0904 | 0,0777 | 0,0904 | 0,00593 | 0,268 | 0,00892 | 0,133 | 0,665 | 2944 | 2781 | 0,600 | 0,598 | 0,599 |

Rectangular Notch (CMC 4,63%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1026

n'=n = 0,7631

k (Pa.s$^n$)= 0,2129

B(m)= 0,1234 g (m/s$^2$)= 9,813 (Pa.sn)= 0,2254

| Flow (l/s) | Gauge 1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | Reynolds Number $Re_{MR}$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5,38 | 0,0850 | 0,0852 | 0,0723 | 0,0851 | 0,00538 | 0,268 | 0,00892 | 0,133 | 0,603 | 2609 | 2465 | 0,596 | 0,594 | 0,595 |
| 5,38 | 0,0850 | 0,0852 | 0,0723 | 0,0851 | 0,00538 | 0,268 | 0,00892 | 0,133 | 0,603 | 2610 | 2465 | 0,596 | 0,594 | 0,595 |
| 4,94 | 0,0801 | 0,0802 | 0,0670 | 0,0801 | 0,00494 | 0,257 | 0,00826 | 0,128 | 0,598 | 2515 | 2375 | 0,599 | 0,597 | 0,598 |
| 4,94 | 0,0801 | 0,0802 | 0,0670 | 0,0801 | 0,00494 | 0,257 | 0,00826 | 0,128 | 0,598 | 2512 | 2373 | 0,598 | 0,597 | 0,598 |
| 4,54 | 0,0756 | 0,0758 | 0,0623 | 0,0757 | 0,00454 | 0,248 | 0,00769 | 0,124 | 0,591 | 2411 | 2278 | 0,600 | 0,598 | 0,599 |
| 4,55 | 0,0756 | 0,0758 | 0,0623 | 0,0757 | 0,00455 | 0,248 | 0,00769 | 0,124 | 0,592 | 2413 | 2279 | 0,600 | 0,598 | 0,599 |
| 4,16 | 0,0714 | 0,0715 | 0,0598 | 0,0714 | 0,00416 | 0,243 | 0,00738 | 0,121 | 0,564 | 2240 | 2116 | 0,599 | 0,597 | 0,598 |
| 4,16 | 0,0714 | 0,0715 | 0,0598 | 0,0714 | 0,00416 | 0,243 | 0,00738 | 0,121 | 0,564 | 2239 | 2115 | 0,599 | 0,597 | 0,598 |
| 3,62 | 0,0656 | 0,0657 | 0,0541 | 0,0656 | 0,00362 | 0,232 | 0,00668 | 0,115 | 0,542 | 2048 | 1934 | 0,592 | 0,589 | 0,590 |
| 3,61 | 0,0656 | 0,0657 | 0,0541 | 0,0656 | 0,00361 | 0,219 | 0,00592 | 0,108 | 0,610 | 2256 | 2131 | 0,591 | 0,588 | 0,589 |
| 3,14 | 0,0592 | 0,0596 | 0,0480 | 0,0594 | 0,00314 | 0,219 | 0,00592 | 0,108 | 0,530 | 1896 | 1791 | 0,598 | 0,592 | 0,595 |
| 3,14 | 0,0592 | 0,0596 | 0,0480 | 0,0594 | 0,00314 | 0,219 | 0,00592 | 0,108 | 0,530 | 1896 | 1791 | 0,598 | 0,592 | 0,595 |
| 2,70 | 0,0537 | 0,0539 | 0,0428 | 0,0538 | 0,00270 | 0,209 | 0,00528 | 0,101 | 0,511 | 1724 | 1629 | 0,595 | 0,592 | 0,594 |
| 2,69 | 0,0537 | 0,0539 | 0,0428 | 0,0538 | 0,00269 | 0,209 | 0,00528 | 0,101 | 0,509 | 1717 | 1621 | 0,593 | 0,590 | 0,591 |

Rectangular Notch (CMC 4,63%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1026

n'=n = 0,7631

k (Pa.s$^n$)= 0,2129

B(m)= 0,1234 g (m/s$^2$)= 9,813 (Pa.sn)= 0,2254

| Flow (l/s) | Gauge 1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | Reynolds Number $Re_{MR}$ | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,32 | 0,0485 | 0,0486 | 0,0382 | 0,0485 | 0,00232 | 0,200 | 0,00471 | 0,0943 | 0,492 | 1558 | 1472 | 0,596 | 0,594 | 0,595 |
| 2,31 | 0,0485 | 0,0486 | 0,0382 | 0,0485 | 0,00231 | 0,200 | 0,00471 | 0,0943 | 0,490 | 1550 | 1464 | 0,593 | 0,591 | 0,592 |
| 1,92 | 0,0425 | 0,0427 | 0,0330 | 0,0426 | 0,00192 | 0,189 | 0,00408 | 0,0861 | 0,471 | 1378 | 1302 | 0,601 | 0,598 | 0,599 |
| 1,92 | 0,0425 | 0,0427 | 0,0330 | 0,0426 | 0,00192 | 0,189 | 0,00408 | 0,0861 | 0,471 | 1379 | 1302 | 0,601 | 0,598 | 0,599 |
| 1,54 | 0,0365 | 0,0367 | 0,0271 | 0,0366 | 0,00154 | 0,178 | 0,00335 | 0,0753 | 0,459 | 1206 | 1139 | 0,604 | 0,600 | 0,602 |
| 1,54 | 0,0365 | 0,0367 | 0,0271 | 0,0366 | 0,00154 | 0,178 | 0,00335 | 0,0753 | 0,459 | 1206 | 1139 | 0,604 | 0,600 | 0,602 |
| 1,12 | 0,0290 | 0,0292 | 0,0202 | 0,0291 | 0,00112 | 0,164 | 0,00249 | 0,0608 | 0,450 | 998 | 942 | 0,621 | 0,616 | 0,619 |
| 1,12 | 0,0290 | 0,0292 | 0,0202 | 0,0291 | 0,00112 | 0,164 | 0,00249 | 0,0608 | 0,450 | 998 | 942 | 0,621 | 0,616 | 0,619 |

**Table 4.14 Flow rate measurement of CMC 6.2% through rectangular notch**

Rectangular Notch (CMC 6,2%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1035

n'=n = 0,710

k (Pa.s$^n$)= 0,646

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 0,692

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 8,49 | 0,1138 | 0,1148 | 0,1008 | 0,1143 | 0,00849 | 0,325 | 0,0124 | 0,153 | 0,683 | 1263 | 1179 | 0,606 | 0,599 | 0,603 |
| 8,49 | 0,1138 | 0,1148 | 0,1008 | 0,1143 | 0,00849 | 0,325 | 0,0124 | 0,153 | 0,683 | 1263 | 1179 | 0,607 | 0,599 | 0,603 |
| 8,16 | 0,1108 | 0,1118 | 0,0972 | 0,1113 | 0,00816 | 0,318 | 0,0120 | 0,151 | 0,680 | 1244 | 1161 | 0,607 | 0,599 | 0,603 |
| 8,16 | 0,1108 | 0,1118 | 0,0972 | 0,1113 | 0,00816 | 0,318 | 0,0120 | 0,151 | 0,680 | 1244 | 1161 | 0,607 | 0,599 | 0,603 |
| 7,71 | 0,1066 | 0,1077 | 0,0936 | 0,1071 | 0,00771 | 0,311 | 0,0115 | 0,149 | 0,668 | 1203 | 1123 | 0,608 | 0,599 | 0,604 |
| 7,71 | 0,1066 | 0,1077 | 0,0936 | 0,1071 | 0,00771 | 0,311 | 0,0115 | 0,149 | 0,668 | 1203 | 1123 | 0,608 | 0,599 | 0,604 |
| 7,32 | 0,1031 | 0,1042 | 0,0904 | 0,1036 | 0,00732 | 0,304 | 0,0112 | 0,147 | 0,656 | 1163 | 1085 | 0,606 | 0,597 | 0,602 |
| 7,32 | 0,1031 | 0,1042 | 0,0904 | 0,1036 | 0,00732 | 0,304 | 0,0112 | 0,147 | 0,656 | 1163 | 1085 | 0,606 | 0,597 | 0,602 |
| 6,90 | 0,0990 | 0,1001 | 0,0867 | 0,0996 | 0,00690 | 0,297 | 0,0107 | 0,144 | 0,645 | 1125 | 1050 | 0,607 | 0,597 | 0,602 |
| 6,90 | 0,0990 | 0,1001 | 0,0867 | 0,0996 | 0,00690 | 0,297 | 0,0107 | 0,144 | 0,645 | 1125 | 1050 | 0,608 | 0,598 | 0,603 |
| 6,51 | 0,0951 | 0,0962 | 0,0829 | 0,0957 | 0,00651 | 0,289 | 0,0102 | 0,141 | 0,637 | 1092 | 1019 | 0,609 | 0,599 | 0,604 |
| 6,51 | 0,0951 | 0,0962 | 0,0829 | 0,0957 | 0,00651 | 0,282 | 0,00979 | 0,139 | 0,665 | 1139 | 1063 | 0,609 | 0,599 | 0,604 |
| 6,10 | 0,0914 | 0,0925 | 0,0794 | 0,0919 | 0,00610 | 0,282 | 0,00979 | 0,139 | 0,623 | 1047 | 977 | 0,606 | 0,595 | 0,601 |
| 6,11 | 0,0914 | 0,0925 | 0,0794 | 0,0919 | 0,00611 | 0,282 | 0,00979 | 0,139 | 0,624 | 1049 | 979 | 0,607 | 0,596 | 0,601 |

Rectangular Notch (CMC 6,2%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1035

n'=n = 0,710

k (Pa.s$^n$)= 0,646

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 0,692

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 5,70 | 0,0873 | 0,0883 | 0,0755 | 0,0878 | 0,00570 | 0,274 | 0,00931 | 0,136 | 0,612 | 1008 | 941 | 0,606 | 0,596 | 0,601 |
| 5,70 | 0,0873 | 0,0883 | 0,0755 | 0,0878 | 0,00570 | 0,274 | 0,00931 | 0,136 | 0,612 | 1008 | 941 | 0,606 | 0,596 | 0,601 |
| 5,32 | 0,0831 | 0,0841 | 0,0713 | 0,0836 | 0,00532 | 0,266 | 0,00880 | 0,132 | 0,604 | 973 | 908 | 0,609 | 0,598 | 0,603 |
| 5,32 | 0,0831 | 0,0841 | 0,0713 | 0,0836 | 0,00532 | 0,266 | 0,00880 | 0,132 | 0,604 | 973 | 908 | 0,609 | 0,598 | 0,603 |
| 4,93 | 0,0790 | 0,0799 | 0,0674 | 0,0794 | 0,00493 | 0,258 | 0,00832 | 0,129 | 0,593 | 931 | 869 | 0,610 | 0,599 | 0,604 |
| 4,92 | 0,0790 | 0,0799 | 0,0674 | 0,0794 | 0,00492 | 0,258 | 0,00832 | 0,129 | 0,592 | 929 | 867 | 0,608 | 0,598 | 0,603 |
| 4,51 | 0,0745 | 0,0755 | 0,0634 | 0,0750 | 0,00451 | 0,250 | 0,00782 | 0,125 | 0,577 | 881 | 822 | 0,609 | 0,597 | 0,603 |
| 4,51 | 0,0745 | 0,0755 | 0,0634 | 0,0750 | 0,00451 | 0,241 | 0,00728 | 0,121 | 0,619 | 940 | 877 | 0,608 | 0,596 | 0,602 |
| 4,07 | 0,0699 | 0,0708 | 0,0590 | 0,0704 | 0,00407 | 0,241 | 0,00728 | 0,121 | 0,559 | 823 | 768 | 0,604 | 0,592 | 0,598 |
| 4,07 | 0,0699 | 0,0708 | 0,0590 | 0,0704 | 0,00407 | 0,241 | 0,00728 | 0,121 | 0,559 | 823 | 769 | 0,604 | 0,592 | 0,598 |
| 3,70 | 0,0652 | 0,0662 | 0,0539 | 0,0657 | 0,00370 | 0,231 | 0,00665 | 0,115 | 0,557 | 793 | 740 | 0,611 | 0,597 | 0,604 |
| 3,70 | 0,0652 | 0,0662 | 0,0539 | 0,0657 | 0,00370 | 0,231 | 0,00665 | 0,115 | 0,557 | 793 | 740 | 0,611 | 0,597 | 0,604 |
| 3,31 | 0,0603 | 0,0613 | 0,0497 | 0,0608 | 0,00331 | 0,223 | 0,00613 | 0,110 | 0,539 | 737 | 688 | 0,612 | 0,598 | 0,605 |
| 3,30 | 0,0603 | 0,0613 | 0,0497 | 0,0608 | 0,00330 | 0,223 | 0,00613 | 0,110 | 0,538 | 734 | 685 | 0,610 | 0,596 | 0,603 |

Rectangular Notch (CMC 6,2%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1035

n'=n = 0,710

k (Pa.s$^n$)= 0,646

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 0,692

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 2,90 | 0,0555 | 0,0564 | 0,0444 | 0,0560 | 0,00290 | 0,212 | 0,00548 | 0,103 | 0,529 | 688 | 642 | 0,609 | 0,594 | 0,601 |
| 2,90 | 0,0555 | 0,0564 | 0,0444 | 0,0560 | 0,00290 | 0,212 | 0,00548 | 0,103 | 0,529 | 688 | 642 | 0,609 | 0,594 | 0,601 |
| 2,49 | 0,0505 | 0,0513 | 0,0399 | 0,0509 | 0,00249 | 0,203 | 0,00492 | 0,0969 | 0,507 | 621 | 580 | 0,602 | 0,589 | 0,595 |
| 2,49 | 0,0505 | 0,0513 | 0,0399 | 0,0509 | 0,00249 | 0,203 | 0,00492 | 0,0969 | 0,507 | 621 | 580 | 0,602 | 0,589 | 0,595 |
| 2,12 | 0,0445 | 0,0455 | 0,0352 | 0,0450 | 0,00212 | 0,194 | 0,00434 | 0,0896 | 0,488 | 560 | 523 | 0,620 | 0,600 | 0,610 |
| 2,12 | 0,0445 | 0,0455 | 0,0352 | 0,0450 | 0,00212 | 0,194 | 0,00434 | 0,0896 | 0,488 | 560 | 523 | 0,620 | 0,600 | 0,610 |

**Table 4.15 Flow rate measurement of CMC 7.3% through rectangular notch**

Rectangular Notch (CMC 7,3%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1041

n'=n = 0,611

k (Pa.s$^n$)= 2,97

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 3,25

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 7,19 | 0,1108 | 0,1113 | 0,0971 | 0,1110 | 0,00719 | 0,318 | 0,0120 | 0,151 | 0,600 | 260 | 260 | 0,535 | 0,531 | 0,533 |
| 7,18 | 0,1108 | 0,1113 | 0,0971 | 0,1110 | 0,00718 | 0,318 | 0,0120 | 0,151 | 0,599 | 259 | 259 | 0,534 | 0,531 | 0,532 |
| 6,85 | 0,1089 | 0,1096 | 0,0936 | 0,1092 | 0,00685 | 0,311 | 0,0116 | 0,149 | 0,593 | 253 | 253 | 0,523 | 0,518 | 0,520 |
| 6,86 | 0,1089 | 0,1096 | 0,0936 | 0,1092 | 0,00686 | 0,311 | 0,0116 | 0,149 | 0,594 | 254 | 254 | 0,524 | 0,519 | 0,521 |
| 8,09 | 0,1202 | 0,1204 | 0,1051 | 0,1203 | 0,00809 | 0,334 | 0,0130 | 0,156 | 0,624 | 279 | 279 | 0,532 | 0,531 | 0,532 |
| 8,09 | 0,1202 | 0,1204 | 0,1051 | 0,1203 | 0,00809 | 0,334 | 0,0130 | 0,156 | 0,624 | 279 | 279 | 0,532 | 0,531 | 0,532 |
| 7,62 | 0,1158 | 0,1159 | 0,1007 | 0,1158 | 0,00762 | 0,325 | 0,0124 | 0,153 | 0,613 | 270 | 270 | 0,531 | 0,530 | 0,530 |
| 7,62 | 0,1158 | 0,1159 | 0,1007 | 0,1158 | 0,00762 | 0,325 | 0,0124 | 0,153 | 0,613 | 270 | 270 | 0,531 | 0,530 | 0,530 |
| 6,41 | 0,1034 | 0,1035 | 0,0887 | 0,1035 | 0,00641 | 0,301 | 0,0110 | 0,146 | 0,585 | 246 | 246 | 0,529 | 0,528 | 0,529 |
| 6,41 | 0,1034 | 0,1035 | 0,0887 | 0,1035 | 0,00641 | 0,301 | 0,0110 | 0,146 | 0,585 | 246 | 246 | 0,529 | 0,528 | 0,529 |
| 5,99 | 0,0993 | 0,0994 | 0,0844 | 0,0994 | 0,00599 | 0,292 | 0,0104 | 0,143 | 0,575 | 237 | 237 | 0,525 | 0,525 | 0,525 |
| 6,00 | 0,0993 | 0,0994 | 0,0844 | 0,0994 | 0,00600 | 0,285 | 0,00995 | 0,140 | 0,603 | 250 | 250 | 0,526 | 0,526 | 0,526 |
| 5,62 | 0,0954 | 0,0954 | 0,0806 | 0,0954 | 0,00562 | 0,285 | 0,00995 | 0,140 | 0,565 | 228 | 228 | 0,524 | 0,523 | 0,523 |
| 5,63 | 0,0954 | 0,0954 | 0,0806 | 0,0954 | 0,00563 | 0,285 | 0,00995 | 0,140 | 0,566 | 229 | 229 | 0,524 | 0,524 | 0,524 |

Rectangular Notch (CMC 7,3%)

Yield stress (Pa)= 0

Density ($kg/m^3$)= 1041

n'=n = 0,611

k ($Pa.s^n$)= 2,97

B(m)= 0,1234 g ($m/s^2$)= 9,813 k'(Pa.sn)= 3,25

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 5,22 | 0,0918 | 0,0922 | 0,0762 | 0,0920 | 0,00522 | 0,276 | 0,00941 | 0,136 | 0,555 | 219 | 219 | 0,515 | 0,512 | 0,513 |
| 5,22 | 0,0918 | 0,0922 | 0,0762 | 0,0920 | 0,00522 | 0,276 | 0,00941 | 0,136 | 0,555 | 219 | 219 | 0,515 | 0,512 | 0,514 |
| 4,82 | 0,0871 | 0,0872 | 0,0727 | 0,0871 | 0,00482 | 0,269 | 0,00897 | 0,133 | 0,537 | 207 | 207 | 0,514 | 0,514 | 0,514 |
| 4,81 | 0,0871 | 0,0872 | 0,0727 | 0,0871 | 0,00481 | 0,269 | 0,00897 | 0,133 | 0,536 | 206 | 206 | 0,513 | 0,512 | 0,513 |
| 4,43 | 0,0829 | 0,0829 | 0,0683 | 0,0829 | 0,00443 | 0,260 | 0,00843 | 0,130 | 0,525 | 197 | 197 | 0,509 | 0,509 | 0,509 |
| 4,42 | 0,0829 | 0,0829 | 0,0683 | 0,0829 | 0,00442 | 0,260 | 0,00843 | 0,130 | 0,524 | 196 | 196 | 0,508 | 0,508 | 0,508 |
| 4,02 | 0,0778 | 0,0779 | 0,0633 | 0,0779 | 0,00402 | 0,250 | 0,00781 | 0,125 | 0,515 | 187 | 187 | 0,509 | 0,507 | 0,508 |
| 4,02 | 0,0778 | 0,0779 | 0,0633 | 0,0779 | 0,00402 | 0,240 | 0,00720 | 0,120 | 0,559 | 205 | 205 | 0,509 | 0,507 | 0,508 |
| 3,63 | 0,0723 | 0,0724 | 0,0584 | 0,0724 | 0,00363 | 0,240 | 0,00720 | 0,120 | 0,504 | 177 | 177 | 0,512 | 0,511 | 0,511 |
| 3,63 | 0,0723 | 0,0724 | 0,0584 | 0,0724 | 0,00363 | 0,240 | 0,00720 | 0,120 | 0,504 | 177 | 177 | 0,512 | 0,511 | 0,511 |
| 3,21 | 0,0665 | 0,0667 | 0,0535 | 0,0666 | 0,00321 | 0,230 | 0,00660 | 0,115 | 0,487 | 164 | 164 | 0,514 | 0,512 | 0,513 |
| 3,21 | 0,0665 | 0,0667 | 0,0535 | 0,0666 | 0,00321 | 0,230 | 0,00660 | 0,115 | 0,487 | 164 | 164 | 0,514 | 0,512 | 0,513 |
| 2,81 | 0,0609 | 0,0612 | 0,0476 | 0,0610 | 0,00281 | 0,219 | 0,00587 | 0,107 | 0,478 | 154 | 154 | 0,513 | 0,509 | 0,511 |
| 2,81 | 0,0609 | 0,0612 | 0,0476 | 0,0610 | 0,00281 | 0,219 | 0,00587 | 0,107 | 0,478 | 154 | 154 | 0,512 | 0,509 | 0,511 |
| 2,41 | 0,0563 | 0,0565 | 0,0429 | 0,0564 | 0,00241 | 0,209 | 0,00529 | 0,101 | 0,456 | 139 | 139 | 0,495 | 0,493 | 0,494 |
| 2,41 | 0,0563 | 0,0565 | 0,0429 | 0,0564 | 0,00241 | 0,209 | 0,00529 | 0,101 | 0,456 | 139 | 139 | 0,495 | 0,493 | 0,494 |

Rectangular Notch (CMC 7,3%)

Yield stress (Pa)= 0

Density ($kg/m^3$)= 1041

n'=n = 0,611

k ($Pa.s^n$)= 2,97

B(m)= 0,1234 g ($m/s^2$)= 9,813 k'(Pa.sn)= 3,25

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 2,01 | 0,0500 | 0,0504 | 0,0375 | 0,0502 | 0,00201 | 0,198 | 0,00463 | 0,0933 | 0,435 | 124 | 124 | 0,495 | 0,489 | 0,492 |
| 2,01 | 0,0500 | 0,0504 | 0,0375 | 0,0502 | 0,00201 | 0,198 | 0,00463 | 0,0933 | 0,435 | 124 | 124 | 0,495 | 0,489 | 0,492 |
| 2,40 | 0,0558 | 0,0560 | 0,0413 | 0,0559 | 0,00240 | 0,206 | 0,00510 | 0,0990 | 0,471 | 143 | 143 | 0,500 | 0,497 | 0,498 |
| 2,40 | 0,0558 | 0,0560 | 0,0413 | 0,0559 | 0,00240 | 0,206 | 0,00510 | 0,0990 | 0,471 | 143 | 143 | 0,500 | 0,497 | 0,499 |
| 2,81 | 0,0605 | 0,0606 | 0,0463 | 0,0606 | 0,00281 | 0,216 | 0,00571 | 0,106 | 0,491 | 158 | 158 | 0,518 | 0,516 | 0,517 |
| 2,81 | 0,0605 | 0,0606 | 0,0463 | 0,0606 | 0,00281 | 0,216 | 0,00571 | 0,106 | 0,491 | 158 | 158 | 0,518 | 0,516 | 0,517 |

**Table 4.16 Flow rate measurement of CMC 8.35% through rectangular notch**

Rectangular Notch (CMC 8,35%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1048

n'=n = 0,609

k (Pa.s$^n$)= 3,42

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 3,75

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow m$^3$/s | Wetted Perimeter m | Area m$^2$ | Hydraulic Radius m | Velocity m/s | Reynolds Number $Re_H$ | Reynolds Number $Re_{MR}$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,06 | 0,0703 | 0,0707 | 0,0588 | 0,0705 | 0,00306 | 0,241 | 0,00725 | 0,120 | 0,421 | 133 | 121 | 0,450 | 0,446 | 0,448 |
| 3,05 | 0,0703 | 0,0707 | 0,0588 | 0,0705 | 0,00305 | 0,241 | 0,00725 | 0,120 | 0,420 | 132 | 121 | 0,448 | 0,444 | 0,446 |
| 2,55 | 0,0634 | 0,0635 | 0,0514 | 0,0635 | 0,00255 | 0,226 | 0,00634 | 0,112 | 0,401 | 119 | 109 | 0,437 | 0,437 | 0,437 |
| 2,55 | 0,0634 | 0,0635 | 0,0514 | 0,0635 | 0,00255 | 0,226 | 0,00634 | 0,112 | 0,401 | 119 | 109 | 0,437 | 0,436 | 0,437 |
| 2,01 | 0,0552 | 0,0557 | 0,0434 | 0,0554 | 0,00201 | 0,210 | 0,00535 | 0,102 | 0,376 | 103 | 93,8 | 0,427 | 0,420 | 0,424 |
| 2,01 | 0,0552 | 0,0557 | 0,0434 | 0,0554 | 0,00201 | 0,210 | 0,00535 | 0,102 | 0,376 | 103 | 93,7 | 0,427 | 0,420 | 0,423 |
| 1,47 | 0,0462 | 0,0467 | 0,0345 | 0,0465 | 0,00147 | 0,192 | 0,00426 | 0,0885 | 0,346 | 83,8 | 76,5 | 0,407 | 0,400 | 0,404 |
| 1,47 | 0,0462 | 0,0467 | 0,0345 | 0,0465 | 0,00147 | 0,192 | 0,00426 | 0,0885 | 0,346 | 83,7 | 76,5 | 0,407 | 0,400 | 0,403 |
| 6,08 | 0,1060 | 0,1076 | 0,0907 | 0,1068 | 0,00608 | 0,305 | 0,0112 | 0,147 | 0,543 | 214 | 195 | 0,483 | 0,472 | 0,478 |
| 6,08 | 0,1060 | 0,1076 | 0,0907 | 0,1068 | 0,00608 | 0,305 | 0,0112 | 0,147 | 0,543 | 214 | 195 | 0,483 | 0,472 | 0,478 |
| 5,57 | 0,1017 | 0,1028 | 0,0900 | 0,1023 | 0,00557 | 0,303 | 0,0111 | 0,146 | 0,501 | 191 | 174 | 0,471 | 0,463 | 0,467 |
| 5,58 | 0,1017 | 0,1028 | 0,0900 | 0,1023 | 0,00558 | 0,293 | 0,0104 | 0,143 | 0,534 | 205 | 187 | 0,472 | 0,464 | 0,468 |
| 5,06 | 0,0960 | 0,0968 | 0,0846 | 0,0964 | 0,00506 | 0,293 | 0,0104 | 0,143 | 0,484 | 179 | 163 | 0,466 | 0,461 | 0,464 |
| 5,05 | 0,0960 | 0,0968 | 0,0846 | 0,0964 | 0,00505 | 0,293 | 0,0104 | 0,143 | 0,484 | 179 | 163 | 0,466 | 0,461 | 0,463 |

Rectangular Notch (CMC 8,35%)

Yield stress (Pa)= 0

Density (kg/m$^3$)= 1048

n'=n = 0,609

k (Pa.s$^n$)= 3,42

B(m)= 0,1234 g (m/s$^2$)= 9,813 k'(Pa.sn)= 3,75

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds Number | Reynolds Number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 4,51 | 0,0898 | 0,0907 | 0,0783 | 0,0903 | 0,00451 | 0,280 | 0,00966 | 0,138 | 0,467 | 167 | 152 | 0,459 | 0,453 | 0,456 |
| 4,51 | 0,0898 | 0,0907 | 0,0783 | 0,0903 | 0,00451 | 0,280 | 0,00966 | 0,138 | 0,467 | 167 | 152 | 0,460 | 0,454 | 0,457 |
| 4,03 | 0,0842 | 0,0847 | 0,0721 | 0,0845 | 0,00403 | 0,268 | 0,00890 | 0,133 | 0,452 | 156 | 142 | 0,452 | 0,448 | 0,450 |
| 4,03 | 0,0842 | 0,0847 | 0,0721 | 0,0845 | 0,00403 | 0,268 | 0,00890 | 0,133 | 0,452 | 156 | 142 | 0,452 | 0,448 | 0,450 |
| 3,52 | 0,0776 | 0,0779 | 0,0660 | 0,0778 | 0,00352 | 0,255 | 0,00814 | 0,128 | 0,432 | 142 | 130 | 0,446 | 0,443 | 0,445 |
| 3,52 | 0,0776 | 0,0779 | 0,0660 | 0,0778 | 0,00352 | 0,255 | 0,00814 | 0,128 | 0,432 | 143 | 130 | 0,446 | 0,443 | 0,445 |

## APPENDIX H: V-notch water calibration results

**Table 3.3 V-notch calibration results (Water)**

V-Notch (Water)

Tan(ϑ/2)= 0,414  g ($m/s^2$)= 9,813  Cosθ= 0,924  Viscosity (Pa.s)= 0,001  Density ($kg/m^3$)= 1000

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number Re | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,82 | 0,0704 | 0,0706 | 0,0672 | 0,0705 | 0,000824 | 0,146 | 0,00374 | 0,103 | 0,220 | 22635 | 0,640 | 0,635 | 0,638 |
| 0,82 | 0,0704 | 0,0706 | 0,0672 | 0,0705 | 0,000823 | 0,146 | 0,00374 | 0,103 | 0,220 | 22608 | 0,639 | 0,634 | 0,637 |
| 0,82 | 0,0704 | 0,0706 | 0,0672 | 0,0705 | 0,000823 | 0,146 | 0,00374 | 0,103 | 0,220 | 22619 | 0,639 | 0,635 | 0,637 |
| 1,09 | 0,0793 | 0,0793 | 0,0752 | 0,0793 | 0,00109 | 0,163 | 0,00469 | 0,115 | 0,232 | 26743 | 0,628 | 0,628 | 0,628 |
| 1,09 | 0,0793 | 0,0793 | 0,0752 | 0,0793 | 0,00109 | 0,163 | 0,00469 | 0,115 | 0,233 | 26819 | 0,630 | 0,629 | 0,630 |
| 1,09 | 0,0793 | 0,0793 | 0,0752 | 0,0793 | 0,00109 | 0,163 | 0,00469 | 0,115 | 0,233 | 26818 | 0,630 | 0,629 | 0,630 |
| 1,28 | 0,0845 | 0,0846 | 0,0801 | 0,0846 | 0,00128 | 0,173 | 0,00531 | 0,123 | 0,241 | 29539 | 0,630 | 0,628 | 0,629 |
| 1,28 | 0,0845 | 0,0846 | 0,0801 | 0,0846 | 0,00128 | 0,173 | 0,00531 | 0,123 | 0,241 | 29489 | 0,629 | 0,627 | 0,628 |
| 1,28 | 0,0845 | 0,0846 | 0,0801 | 0,0846 | 0,00128 | 0,173 | 0,00531 | 0,123 | 0,241 | 29499 | 0,629 | 0,627 | 0,628 |
| 1,47 | 0,0896 | 0,0896 | 0,0850 | 0,0896 | 0,00147 | 0,184 | 0,00599 | 0,130 | 0,245 | 31841 | 0,623 | 0,623 | 0,623 |
| 1,47 | 0,0896 | 0,0896 | 0,0850 | 0,0896 | 0,00147 | 0,184 | 0,00599 | 0,130 | 0,245 | 31907 | 0,624 | 0,624 | 0,624 |
| 1,47 | 0,0896 | 0,0896 | 0,0850 | 0,0896 | 0,00147 | 0,184 | 0,00599 | 0,130 | 0,245 | 31900 | 0,624 | 0,624 | 0,624 |
| 1,66 | 0,0942 | 0,0942 | 0,0890 | 0,0942 | 0,00166 | 0,193 | 0,00656 | 0,136 | 0,253 | 34399 | 0,622 | 0,621 | 0,622 |
| 1,66 | 0,0942 | 0,0942 | 0,0890 | 0,0942 | 0,00166 | 0,193 | 0,00656 | 0,136 | 0,253 | 34483 | 0,624 | 0,623 | 0,623 |
| 1,65 | 0,0942 | 0,0942 | 0,0890 | 0,0942 | 0,00165 | 0,193 | 0,00656 | 0,136 | 0,252 | 34351 | 0,621 | 0,620 | 0,621 |
| 1,86 | 0,0988 | 0,0988 | 0,0939 | 0,0988 | 0,00186 | 0,203 | 0,00731 | 0,144 | 0,254 | 36492 | 0,618 | 0,618 | 0,618 |
| 1,85 | 0,0988 | 0,0988 | 0,0939 | 0,0988 | 0,00185 | 0,203 | 0,00731 | 0,144 | 0,254 | 36476 | 0,618 | 0,618 | 0,618 |
| 1,85 | 0,0988 | 0,0988 | 0,0939 | 0,0988 | 0,00185 | 0,203 | 0,00731 | 0,144 | 0,254 | 36462 | 0,617 | 0,617 | 0,617 |

V-Notch (Water)

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cosθ= 0,924 Viscosity (Pa.s)= 0,001 Density ($kg/m^3$)= 1000

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number Re | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,12 | 0,1042 | 0,1045 | 0,0988 | 0,1043 | 0,00212 | 0,214 | 0,00809 | 0,151 | 0,262 | 39671 | 0,619 | 0,614 | 0,616 |
| 2,12 | 0,1042 | 0,1045 | 0,0988 | 0,1043 | 0,00212 | 0,214 | 0,00809 | 0,151 | 0,262 | 39680 | 0,619 | 0,614 | 0,616 |
| 2,12 | 0,1042 | 0,1045 | 0,0988 | 0,1043 | 0,00212 | 0,214 | 0,00809 | 0,151 | 0,262 | 39643 | 0,618 | 0,613 | 0,616 |
| 2,31 | 0,1084 | 0,1083 | 0,1028 | 0,1083 | 0,00231 | 0,223 | 0,00875 | 0,157 | 0,264 | 41595 | 0,612 | 0,613 | 0,612 |
| 2,32 | 0,1084 | 0,1083 | 0,1028 | 0,1083 | 0,00232 | 0,223 | 0,00875 | 0,157 | 0,265 | 41705 | 0,613 | 0,614 | 0,614 |
| 2,31 | 0,1084 | 0,1083 | 0,1028 | 0,1083 | 0,00231 | 0,223 | 0,00875 | 0,157 | 0,264 | 41610 | 0,612 | 0,613 | 0,612 |
| 2,45 | 0,1106 | 0,1107 | 0,1046 | 0,1106 | 0,00245 | 0,227 | 0,00907 | 0,160 | 0,270 | 43292 | 0,616 | 0,615 | 0,615 |
| 2,45 | 0,1106 | 0,1107 | 0,1046 | 0,1106 | 0,00245 | 0,227 | 0,00907 | 0,160 | 0,270 | 43254 | 0,615 | 0,614 | 0,615 |
| 2,45 | 0,1106 | 0,1107 | 0,1046 | 0,1106 | 0,00245 | 0,227 | 0,00907 | 0,160 | 0,270 | 43315 | 0,616 | 0,615 | 0,615 |
| 2,65 | 0,1141 | 0,1143 | 0,1082 | 0,1142 | 0,00265 | 0,234 | 0,00970 | 0,166 | 0,273 | 45173 | 0,614 | 0,612 | 0,613 |
| 2,64 | 0,1141 | 0,1143 | 0,1082 | 0,1142 | 0,00264 | 0,234 | 0,00970 | 0,166 | 0,272 | 45113 | 0,613 | 0,612 | 0,612 |
| 2,65 | 0,1141 | 0,1143 | 0,1082 | 0,1142 | 0,00265 | 0,234 | 0,00970 | 0,166 | 0,273 | 45254 | 0,615 | 0,613 | 0,614 |

**APPENDIX I: V-notch flow rate measurement results (Kaolin suspension)**

**Table 4.17 Flow rate measurement of kaolin 5.48% through V-notch**

V-Notch (Kaolin 5,48%)

Yield stress (Pa)= 0,246

k (Pa.$s^n$)= 0,0294

n= 0,645

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1090

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,25 | 0,0444 | 0,0443 | 0,0396 | 0,0443 | 0,000254 | 0,0856 | 0,00130 | 0,0605 | 0,196 | 969 | 0,625 | 0,626 | 0,626 |
| 0,26 | 0,0444 | 0,0443 | 0,0396 | 0,0443 | 0,000255 | 0,0856 | 0,00130 | 0,0605 | 0,197 | 980 | 0,629 | 0,630 | 0,630 |
| 0,41 | 0,0543 | 0,0544 | 0,0488 | 0,0544 | 0,000409 | 0,106 | 0,00197 | 0,0747 | 0,207 | 1117 | 0,608 | 0,606 | 0,607 |
| 0,41 | 0,0543 | 0,0544 | 0,0488 | 0,0544 | 0,000406 | 0,106 | 0,00197 | 0,0747 | 0,205 | 1100 | 0,602 | 0,601 | 0,602 |
| 0,63 | 0,0651 | 0,0652 | 0,0582 | 0,0652 | 0,000628 | 0,126 | 0,00280 | 0,0890 | 0,224 | 1326 | 0,592 | 0,590 | 0,591 |
| 0,63 | 0,0651 | 0,0652 | 0,0582 | 0,0652 | 0,000629 | 0,126 | 0,00280 | 0,0890 | 0,224 | 1332 | 0,594 | 0,592 | 0,593 |
| 0,84 | 0,0732 | 0,0730 | 0,0659 | 0,0731 | 0,000835 | 0,143 | 0,00360 | 0,101 | 0,232 | 1446 | 0,589 | 0,592 | 0,590 |
| 0,84 | 0,0732 | 0,0730 | 0,0659 | 0,0731 | 0,000836 | 0,143 | 0,00360 | 0,101 | 0,233 | 1450 | 0,590 | 0,592 | 0,591 |
| 1,06 | 0,0806 | 0,0805 | 0,0728 | 0,0806 | 0,00106 | 0,158 | 0,00439 | 0,111 | 0,241 | 1574 | 0,586 | 0,588 | 0,587 |
| 1,06 | 0,0806 | 0,0805 | 0,0728 | 0,0806 | 0,00106 | 0,158 | 0,00439 | 0,111 | 0,241 | 1571 | 0,586 | 0,588 | 0,587 |
| 1,25 | 0,0860 | 0,0860 | 0,0782 | 0,0860 | 0,00125 | 0,169 | 0,00506 | 0,120 | 0,247 | 1664 | 0,589 | 0,589 | 0,589 |
| 1,25 | 0,0860 | 0,0860 | 0,0782 | 0,0860 | 0,00125 | 0,169 | 0,00506 | 0,120 | 0,246 | 1655 | 0,587 | 0,588 | 0,588 |

V-Notch (Kaolin 5,48%)

Yield stress (Pa)= 0,246

k (Pa.s$^n$)= 0,0294

n= 0,645

Tan(ϑ/2)= 0,414 g (m/s$^2$)= 9,813 Cos(ϑ/2)= 0,924 Density (kg/m$^3$)= 1090

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 1,66 | 0,0966 | 0,0966 | 0,0883 | 0,0966 | 0,00166 | 0,191 | 0,00645 | 0,135 | 0,257 | 1826 | 0,586 | 0,585 | 0,586 |
| 1,66 | 0,0966 | 0,0966 | 0,0883 | 0,0966 | 0,00166 | 0,191 | 0,00645 | 0,135 | 0,257 | 1824 | 0,585 | 0,585 | 0,585 |
| 1,44 | 0,0913 | 0,0914 | 0,0834 | 0,0914 | 0,00144 | 0,180 | 0,00576 | 0,128 | 0,250 | 1722 | 0,585 | 0,584 | 0,584 |
| 1,45 | 0,0913 | 0,0914 | 0,0834 | 0,0914 | 0,00145 | 0,180 | 0,00576 | 0,128 | 0,252 | 1741 | 0,588 | 0,587 | 0,588 |
| 2,03 | 0,1046 | 0,1048 | 0,0952 | 0,1047 | 0,00203 | 0,206 | 0,00750 | 0,146 | 0,270 | 2019 | 0,585 | 0,583 | 0,584 |
| 2,03 | 0,1046 | 0,1048 | 0,0952 | 0,1047 | 0,00203 | 0,206 | 0,00750 | 0,146 | 0,271 | 2034 | 0,587 | 0,585 | 0,586 |
| 2,25 | 0,1089 | 0,1091 | 0,0992 | 0,1090 | 0,00225 | 0,215 | 0,00815 | 0,152 | 0,277 | 2125 | 0,588 | 0,585 | 0,587 |
| 2,25 | 0,1089 | 0,1091 | 0,0992 | 0,1090 | 0,00225 | 0,215 | 0,00815 | 0,152 | 0,277 | 2125 | 0,588 | 0,585 | 0,587 |
| 2,42 | 0,1122 | 0,1122 | 0,1021 | 0,1122 | 0,00242 | 0,221 | 0,00863 | 0,156 | 0,280 | 2188 | 0,587 | 0,587 | 0,587 |
| 2,41 | 0,1122 | 0,1122 | 0,1021 | 0,1122 | 0,00241 | 0,221 | 0,00863 | 0,156 | 0,279 | 2170 | 0,585 | 0,585 | 0,585 |
| 2,61 | 0,1159 | 0,1160 | 0,1058 | 0,1160 | 0,00261 | 0,229 | 0,00927 | 0,162 | 0,281 | 2210 | 0,582 | 0,582 | 0,582 |
| 2,61 | 0,1159 | 0,1160 | 0,1058 | 0,1160 | 0,00261 | 0,229 | 0,00927 | 0,162 | 0,281 | 2210 | 0,582 | 0,582 | 0,582 |
| 1,81 | 0,0999 | 0,1000 | 0,0914 | 0,0999 | 0,00181 | 0,198 | 0,00692 | 0,140 | 0,261 | 1886 | 0,585 | 0,584 | 0,585 |
| 1,80 | 0,0999 | 0,1000 | 0,0914 | 0,0999 | 0,00180 | 0,198 | 0,00692 | 0,140 | 0,260 | 1870 | 0,583 | 0,582 | 0,582 |

**Table 4.18 Flow rate measurement of kaolin 6.71% through V-notch**

V-Notch (Kaolin 6,71%)

Yield stress (Pa)= 0,601

k (Pa.$s^n$)= 0,0449

n= 0,596

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1111

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,18 | 0,0392 | 0,0395 | 0,0350 | 0,0393 | 0,000177 | 0,0758 | 0,00102 | 0,0536 | 0,174 | 365 | 0,594 | 0,584 | 0,589 |
| 0,18 | 0,0392 | 0,0395 | 0,0350 | 0,0393 | 0,000177 | 0,0758 | 0,00102 | 0,0536 | 0,174 | 364 | 0,593 | 0,584 | 0,588 |
| 0,44 | 0,0563 | 0,0563 | 0,0503 | 0,0563 | 0,000435 | 0,109 | 0,00209 | 0,0770 | 0,208 | 531 | 0,591 | 0,592 | 0,591 |
| 0,43 | 0,0563 | 0,0563 | 0,0503 | 0,0563 | 0,000434 | 0,109 | 0,00209 | 0,0770 | 0,207 | 527 | 0,588 | 0,590 | 0,589 |
| 0,65 | 0,0669 | 0,0671 | 0,0600 | 0,0670 | 0,000650 | 0,130 | 0,00298 | 0,0918 | 0,218 | 593 | 0,574 | 0,569 | 0,571 |
| 0,65 | 0,0669 | 0,0671 | 0,0600 | 0,0670 | 0,000651 | 0,130 | 0,00298 | 0,0918 | 0,218 | 594 | 0,574 | 0,569 | 0,572 |
| 0,83 | 0,0744 | 0,0744 | 0,0673 | 0,0744 | 0,000831 | 0,146 | 0,00375 | 0,103 | 0,222 | 617 | 0,562 | 0,562 | 0,562 |
| 0,83 | 0,0744 | 0,0744 | 0,0673 | 0,0744 | 0,000832 | 0,146 | 0,00375 | 0,103 | 0,222 | 618 | 0,563 | 0,562 | 0,562 |
| 1,05 | 0,0813 | 0,0815 | 0,0738 | 0,0814 | 0,00105 | 0,160 | 0,00451 | 0,113 | 0,232 | 681 | 0,567 | 0,565 | 0,566 |
| 1,05 | 0,0813 | 0,0815 | 0,0738 | 0,0814 | 0,00105 | 0,160 | 0,00451 | 0,113 | 0,233 | 684 | 0,569 | 0,566 | 0,567 |
| 1,25 | 0,0875 | 0,0875 | 0,0794 | 0,0875 | 0,00125 | 0,172 | 0,00523 | 0,122 | 0,239 | 721 | 0,563 | 0,563 | 0,563 |
| 1,25 | 0,0875 | 0,0875 | 0,0794 | 0,0875 | 0,00125 | 0,172 | 0,00523 | 0,122 | 0,239 | 723 | 0,564 | 0,564 | 0,564 |

V-Notch (Kaolin 6,71%)

Yield stress (Pa)= 0,601

k ($Pa.s^n$)= 0,0449

n= 0,596

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1111

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,45 | 0,0926 | 0,0927 | 0,0845 | 0,0926 | 0,00145 | 0,183 | 0,00591 | 0,129 | 0,246 | 766 | 0,569 | 0,567 | 0,568 |
| 1,44 | 0,0926 | 0,0927 | 0,0845 | 0,0926 | 0,00144 | 0,183 | 0,00591 | 0,129 | 0,244 | 759 | 0,566 | 0,564 | 0,565 |
| 1,70 | 0,0982 | 0,0986 | 0,0899 | 0,0984 | 0,00170 | 0,195 | 0,00669 | 0,138 | 0,254 | 821 | 0,574 | 0,569 | 0,572 |
| 1,69 | 0,0982 | 0,0986 | 0,0899 | 0,0984 | 0,00169 | 0,195 | 0,00669 | 0,138 | 0,253 | 816 | 0,572 | 0,567 | 0,570 |
| 2,32 | 0,1114 | 0,1116 | 0,1023 | 0,1115 | 0,00232 | 0,221 | 0,00867 | 0,157 | 0,268 | 917 | 0,572 | 0,570 | 0,571 |
| 2,32 | 0,1114 | 0,1116 | 0,1023 | 0,1115 | 0,00232 | 0,221 | 0,00867 | 0,157 | 0,267 | 914 | 0,572 | 0,569 | 0,570 |
| 2,63 | 0,1175 | 0,1178 | 0,1062 | 0,1177 | 0,00263 | 0,230 | 0,00935 | 0,163 | 0,281 | 1013 | 0,568 | 0,564 | 0,566 |
| 2,63 | 0,1175 | 0,1178 | 0,1062 | 0,1177 | 0,00263 | 0,230 | 0,00935 | 0,163 | 0,281 | 1013 | 0,568 | 0,564 | 0,566 |
| 1,64 | 0,0972 | 0,0971 | 0,0888 | 0,0972 | 0,00164 | 0,192 | 0,00653 | 0,136 | 0,251 | 803 | 0,568 | 0,570 | 0,569 |
| 1,63 | 0,0972 | 0,0971 | 0,0888 | 0,0972 | 0,00163 | 0,192 | 0,00653 | 0,136 | 0,250 | 795 | 0,565 | 0,567 | 0,566 |
| 2,45 | 0,1143 | 0,1142 | 0,1035 | 0,1143 | 0,00245 | 0,224 | 0,00888 | 0,158 | 0,276 | 976 | 0,567 | 0,568 | 0,568 |
| 2,45 | 0,1143 | 0,1142 | 0,1035 | 0,1143 | 0,00245 | 0,224 | 0,00888 | 0,158 | 0,276 | 977 | 0,567 | 0,568 | 0,568 |
| 2,25 | 0,1105 | 0,1104 | 0,1005 | 0,1105 | 0,00225 | 0,218 | 0,00837 | 0,154 | 0,269 | 926 | 0,567 | 0,568 | 0,568 |
| 2,25 | 0,1105 | 0,1104 | 0,1005 | 0,1105 | 0,00225 | 0,218 | 0,00837 | 0,154 | 0,269 | 927 | 0,567 | 0,569 | 0,568 |

V-Notch (Kaolin 6,71%)

Yield stress (Pa)= 0,601

k ($Pa.s^n$)= 0,0449

n= 0,596

Tan($\vartheta$/2)= 0,414 g ($m/s^2$)= 9,813 Cos($\vartheta$/2)= 0,924 Density ($kg/m^3$)= 1111

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 1,99 | 0,1051 | 0,1051 | 0,0957 | 0,1051 | 0,00199 | 0,207 | 0,00759 | 0,146 | 0,263 | 881 | 0,569 | 0,569 | 0,569 |
| 2,00 | 0,1051 | 0,1051 | 0,0957 | 0,1051 | 0,00200 | 0,207 | 0,00759 | 0,146 | 0,264 | 890 | 0,572 | 0,572 | 0,572 |

**Table 4.19 Flow rate measurement of kaolin 8.32% through V-notch**

V-Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,503

k (Pa.s$^n$)= 0,0993

n= 0,517

Tan(ϑ/2)= 0,414 g (m/s$^2$)= 9,813 Cos(ϑ/2)= 0,924 Density (kg/m$^3$)= 1136

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | | | |
| 0,44 | 0,0582 | 0,0584 | 0,0510 | 0,0583 | 0,000443 | 0,110 | 0,00215 | 0,0780 | 0,206 | 222 | 0,554 | 0,549 | 0,551 |
| 0,45 | 0,0582 | 0,0584 | 0,0510 | 0,0583 | 0,000445 | 0,110 | 0,00215 | 0,0780 | 0,207 | 224 | 0,557 | 0,551 | 0,554 |
| 0,67 | 0,0675 | 0,0674 | 0,0588 | 0,0675 | 0,000673 | 0,127 | 0,00287 | 0,0901 | 0,235 | 288 | 0,581 | 0,582 | 0,582 |
| 0,67 | 0,0675 | 0,0674 | 0,0588 | 0,0675 | 0,000674 | 0,127 | 0,00287 | 0,0901 | 0,235 | 289 | 0,582 | 0,583 | 0,583 |
| 0,83 | 0,0749 | 0,0746 | 0,0668 | 0,0747 | 0,000830 | 0,145 | 0,00369 | 0,102 | 0,225 | 267 | 0,552 | 0,558 | 0,555 |
| 0,83 | 0,0749 | 0,0746 | 0,0668 | 0,0747 | 0,000828 | 0,145 | 0,00369 | 0,102 | 0,224 | 266 | 0,551 | 0,557 | 0,554 |
| 0,94 | 0,0789 | 0,0788 | 0,0706 | 0,0788 | 0,000943 | 0,153 | 0,00413 | 0,108 | 0,228 | 277 | 0,552 | 0,553 | 0,553 |
| 0,94 | 0,0789 | 0,0788 | 0,0706 | 0,0788 | 0,000943 | 0,153 | 0,00413 | 0,108 | 0,228 | 276 | 0,552 | 0,552 | 0,552 |
| 1,06 | 0,0820 | 0,0819 | 0,0736 | 0,0820 | 0,00106 | 0,159 | 0,00449 | 0,113 | 0,236 | 295 | 0,560 | 0,563 | 0,561 |
| 1,06 | 0,0820 | 0,0819 | 0,0736 | 0,0820 | 0,00106 | 0,159 | 0,00449 | 0,113 | 0,236 | 295 | 0,561 | 0,563 | 0,562 |
| 1,21 | 0,0868 | 0,0865 | 0,0719 | 0,0866 | 0,00121 | 0,156 | 0,00428 | 0,110 | 0,283 | 419 | 0,558 | 0,562 | 0,560 |
| 1,21 | 0,0868 | 0,0865 | 0,0719 | 0,0866 | 0,00121 | 0,156 | 0,00428 | 0,110 | 0,283 | 420 | 0,559 | 0,563 | 0,561 |

V-Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,503

k (Pa.$s^n$)= 0,0993

n= 0,517

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1136

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,28 | 0,0893 | 0,0891 | 0,0805 | 0,0892 | 0,00128 | 0,174 | 0,00536 | 0,123 | 0,239 | 306 | 0,550 | 0,554 | 0,552 |
| 1,29 | 0,0893 | 0,0891 | 0,0805 | 0,0892 | 0,00129 | 0,174 | 0,00536 | 0,123 | 0,241 | 310 | 0,554 | 0,558 | 0,556 |
| 1,42 | 0,0928 | 0,0927 | 0,0840 | 0,0928 | 0,00142 | 0,182 | 0,00584 | 0,129 | 0,243 | 315 | 0,552 | 0,554 | 0,553 |
| 1,43 | 0,0928 | 0,0927 | 0,0840 | 0,0928 | 0,00143 | 0,182 | 0,00584 | 0,129 | 0,244 | 318 | 0,555 | 0,558 | 0,556 |
| 1,56 | 0,0960 | 0,0959 | 0,0867 | 0,0960 | 0,00156 | 0,188 | 0,00622 | 0,133 | 0,250 | 334 | 0,557 | 0,558 | 0,557 |
| 1,57 | 0,0960 | 0,0959 | 0,0867 | 0,0960 | 0,00157 | 0,188 | 0,00622 | 0,133 | 0,252 | 340 | 0,562 | 0,563 | 0,562 |
| 1,67 | 0,0986 | 0,0987 | 0,0893 | 0,0986 | 0,00167 | 0,193 | 0,00661 | 0,137 | 0,252 | 339 | 0,558 | 0,556 | 0,557 |
| 1,67 | 0,0986 | 0,0987 | 0,0893 | 0,0986 | 0,00167 | 0,193 | 0,00661 | 0,137 | 0,253 | 342 | 0,560 | 0,559 | 0,559 |
| 1,79 | 0,1022 | 0,1021 | 0,0926 | 0,1022 | 0,00179 | 0,200 | 0,00710 | 0,142 | 0,253 | 342 | 0,548 | 0,550 | 0,549 |
| 1,80 | 0,1022 | 0,1021 | 0,0926 | 0,1022 | 0,00180 | 0,200 | 0,00710 | 0,142 | 0,254 | 345 | 0,551 | 0,553 | 0,552 |
| 1,94 | 0,1051 | 0,1051 | 0,0954 | 0,1051 | 0,00194 | 0,207 | 0,00755 | 0,146 | 0,258 | 356 | 0,554 | 0,555 | 0,555 |
| 1,94 | 0,1051 | 0,1051 | 0,0954 | 0,1051 | 0,00194 | 0,207 | 0,00755 | 0,146 | 0,256 | 353 | 0,552 | 0,553 | 0,552 |
| 2,14 | 0,1094 | 0,1092 | 0,0995 | 0,1093 | 0,00214 | 0,215 | 0,00819 | 0,152 | 0,261 | 366 | 0,552 | 0,555 | 0,553 |
| 2,14 | 0,1094 | 0,1092 | 0,0995 | 0,1093 | 0,00214 | 0,215 | 0,00819 | 0,152 | 0,261 | 365 | 0,551 | 0,554 | 0,553 |

V-Notch (Kaolin 8,23%)

Yield stress (Pa)= 1,503

k ($Pa.s^n$)= 0,0993

n= 0,517

$Tan(\vartheta/2)$= 0,414 g ($m/s^2$)= 9,813 $Cos(\vartheta/2)$= 0,924 Density ($kg/m^3$)= 1136

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,29 | 0,1117 | 0,1117 | 0,1018 | 0,1117 | 0,00229 | 0,220 | 0,00858 | 0,156 | 0,267 | 383 | 0,561 | 0,562 | 0,562 |
| 2,29 | 0,1117 | 0,1117 | 0,1018 | 0,1117 | 0,00229 | 0,220 | 0,00858 | 0,156 | 0,267 | 382 | 0,561 | 0,561 | 0,561 |
| 2,43 | 0,1145 | 0,1146 | 0,1045 | 0,1146 | 0,00243 | 0,226 | 0,00904 | 0,160 | 0,269 | 389 | 0,560 | 0,559 | 0,559 |
| 2,43 | 0,1145 | 0,1146 | 0,1045 | 0,1146 | 0,00243 | 0,226 | 0,00904 | 0,160 | 0,269 | 389 | 0,560 | 0,559 | 0,559 |
| 2,64 | 0,1176 | 0,1177 | 0,1074 | 0,1177 | 0,00264 | 0,232 | 0,00955 | 0,164 | 0,276 | 410 | 0,568 | 0,567 | 0,567 |
| 2,63 | 0,1176 | 0,1177 | 0,1074 | 0,1177 | 0,00263 | 0,232 | 0,00955 | 0,164 | 0,275 | 408 | 0,566 | 0,565 | 0,566 |
| 0,94 | 0,0789 | 0,0788 | 0,0706 | 0,0788 | 0,00094 | 0,153 | 0,00413 | 0,108 | 0,228 | 277 | 0,552 | 0,553 | 0,553 |
| 0,94 | 0,0789 | 0,0788 | 0,0706 | 0,0788 | 0,00094 | 0,153 | 0,00413 | 0,108 | 0,228 | 276 | 0,552 | 0,552 | 0,552 |

**Table 4.20 Flow rate measurement of kaolin 10.91% through V-notch**

V-Notch (Kaolin 10,91%)

Yield stress (Pa)= 2,60

k (Pa.s$^n$)= 0,129

n= 0,542

Tan($\vartheta$/2)= 0,414 g (m/s$^2$)= 9,813 Cos($\vartheta$/2)= 0,924 Density (kg/m$^3$)= 1180

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | m$^3$/s | m | m$^2$ | m | m/s | $Re_H$ | | | |
| 0,63 | 0,0641 | 0,0647 | 0,0578 | 0,0644 | 0,000632 | 0,125 | 0,00277 | 0,0885 | 0,228 | 169 | 0,620 | 0,606 | 0,613 |
| 0,63 | 0,0641 | 0,0647 | 0,0578 | 0,0644 | 0,000633 | 0,125 | 0,00277 | 0,0885 | 0,229 | 169 | 0,621 | 0,606 | 0,614 |
| 0,73 | 0,0677 | 0,0681 | 0,0613 | 0,0679 | 0,000727 | 0,133 | 0,00311 | 0,0938 | 0,233 | 177 | 0,623 | 0,614 | 0,618 |
| 0,73 | 0,0677 | 0,0681 | 0,0613 | 0,0679 | 0,000729 | 0,133 | 0,00311 | 0,0938 | 0,234 | 178 | 0,624 | 0,615 | 0,620 |
| 0,87 | 0,0740 | 0,0744 | 0,0675 | 0,0742 | 0,000872 | 0,146 | 0,00377 | 0,103 | 0,231 | 175 | 0,597 | 0,591 | 0,594 |
| 0,87 | 0,0740 | 0,0744 | 0,0675 | 0,0742 | 0,000872 | 0,146 | 0,00377 | 0,103 | 0,231 | 175 | 0,597 | 0,591 | 0,594 |
| 1,01 | 0,0787 | 0,0791 | 0,0717 | 0,0789 | 0,00101 | 0,155 | 0,00426 | 0,110 | 0,237 | 183 | 0,593 | 0,586 | 0,589 |
| 1,01 | 0,0787 | 0,0791 | 0,0717 | 0,0789 | 0,00101 | 0,155 | 0,00426 | 0,110 | 0,237 | 184 | 0,594 | 0,587 | 0,590 |
| 1,26 | 0,0860 | 0,0862 | 0,0787 | 0,0861 | 0,00126 | 0,170 | 0,00513 | 0,120 | 0,245 | 197 | 0,592 | 0,589 | 0,591 |
| 1,26 | 0,0860 | 0,0862 | 0,0787 | 0,0861 | 0,00126 | 0,170 | 0,00513 | 0,120 | 0,246 | 199 | 0,594 | 0,591 | 0,593 |
| 1,47 | 0,0910 | 0,0916 | 0,0837 | 0,0913 | 0,00147 | 0,181 | 0,00581 | 0,128 | 0,252 | 209 | 0,599 | 0,590 | 0,595 |
| 1,47 | 0,0910 | 0,0916 | 0,0837 | 0,0913 | 0,00147 | 0,181 | 0,00581 | 0,128 | 0,252 | 210 | 0,599 | 0,591 | 0,595 |

V-Notch (Kaolin 10,91%)

Yield stress (Pa)= 2,60

k ($Pa.s^n$)= 0,129

n= 0,542

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1180

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,47 | 0,0913 | 0,0915 | 0,0836 | 0,0914 | 0,00147 | 0,181 | 0,00579 | 0,128 | 0,254 | 212 | 0,598 | 0,594 | 0,596 |
| 1,47 | 0,0913 | 0,0915 | 0,0836 | 0,0914 | 0,00147 | 0,181 | 0,00579 | 0,128 | 0,254 | 212 | 0,598 | 0,594 | 0,596 |
| 1,60 | 0,0945 | 0,0950 | 0,0870 | 0,0947 | 0,00160 | 0,188 | 0,00627 | 0,133 | 0,255 | 214 | 0,595 | 0,588 | 0,592 |
| 1,60 | 0,0945 | 0,0950 | 0,0870 | 0,0947 | 0,00160 | 0,188 | 0,00627 | 0,133 | 0,255 | 214 | 0,595 | 0,588 | 0,592 |
| 1,80 | 0,0991 | 0,0995 | 0,0913 | 0,0993 | 0,00180 | 0,198 | 0,00691 | 0,140 | 0,260 | 223 | 0,594 | 0,588 | 0,591 |
| 1,80 | 0,0991 | 0,0995 | 0,0913 | 0,0993 | 0,00180 | 0,198 | 0,00691 | 0,140 | 0,261 | 224 | 0,595 | 0,589 | 0,592 |
| 1,96 | 0,1029 | 0,1032 | 0,0946 | 0,1031 | 0,00196 | 0,205 | 0,00741 | 0,145 | 0,265 | 231 | 0,590 | 0,586 | 0,588 |
| 1,97 | 0,1029 | 0,1032 | 0,0946 | 0,1031 | 0,00197 | 0,205 | 0,00741 | 0,145 | 0,266 | 233 | 0,591 | 0,588 | 0,590 |
| 2,12 | 0,1063 | 0,1064 | 0,0983 | 0,1064 | 0,00212 | 0,213 | 0,00800 | 0,150 | 0,265 | 232 | 0,587 | 0,586 | 0,587 |
| 2,12 | 0,1063 | 0,1064 | 0,0983 | 0,1064 | 0,00212 | 0,213 | 0,00800 | 0,150 | 0,265 | 232 | 0,587 | 0,586 | 0,587 |
| 2,45 | 0,1127 | 0,1128 | 0,1039 | 0,1127 | 0,00245 | 0,225 | 0,00894 | 0,159 | 0,274 | 249 | 0,587 | 0,587 | 0,587 |
| 2,46 | 0,1127 | 0,1128 | 0,1039 | 0,1127 | 0,00246 | 0,225 | 0,00894 | 0,159 | 0,276 | 251 | 0,590 | 0,589 | 0,590 |
| 2,66 | 0,1162 | 0,1167 | 0,1070 | 0,1164 | 0,00266 | 0,232 | 0,00949 | 0,164 | 0,280 | 260 | 0,591 | 0,585 | 0,588 |
| 2,66 | 0,1162 | 0,1167 | 0,1070 | 0,1164 | 0,00266 | 0,232 | 0,00949 | 0,164 | 0,280 | 261 | 0,591 | 0,585 | 0,588 |

**Table 4.21 Flow rate measurement of kaolin 12.62% through V-notch**

V-Notch (Kaolin 12,62%)

Yield stress (Pa)= 5,20

k ($Pa.s^n$)= 0,158

n= 0,527

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1208

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,18 | 0,0402 | 0,0406 | 0,0333 | 0,0404 | 0,000176 | 0,0720 | 0,000916 | 0,0509 | 0,192 | 62,8 | 0,553 | 0,539 | 0,546 |
| 0,18 | 0,0402 | 0,0406 | 0,0333 | 0,0404 | 0,000176 | 0,0720 | 0,000916 | 0,0509 | 0,192 | 62,7 | 0,553 | 0,539 | 0,546 |
| 0,42 | 0,0544 | 0,0548 | 0,0466 | 0,0546 | 0,000419 | 0,101 | 0,00180 | 0,0713 | 0,234 | 93,7 | 0,620 | 0,609 | 0,615 |
| 0,42 | 0,0544 | 0,0548 | 0,0466 | 0,0546 | 0,000420 | 0,101 | 0,00180 | 0,0713 | 0,234 | 94,0 | 0,621 | 0,610 | 0,616 |
| 0,61 | 0,0646 | 0,0649 | 0,0565 | 0,0647 | 0,000614 | 0,122 | 0,00264 | 0,0865 | 0,232 | 93,2 | 0,592 | 0,585 | 0,589 |
| 0,62 | 0,0646 | 0,0649 | 0,0565 | 0,0647 | 0,000615 | 0,122 | 0,00264 | 0,0865 | 0,233 | 93,8 | 0,594 | 0,587 | 0,590 |
| 0,81 | 0,0703 | 0,0706 | 0,0619 | 0,0704 | 0,000810 | 0,134 | 0,00317 | 0,0947 | 0,255 | 113 | 0,631 | 0,625 | 0,628 |
| 0,81 | 0,0703 | 0,0706 | 0,0619 | 0,0704 | 0,000807 | 0,134 | 0,00317 | 0,0947 | 0,254 | 112 | 0,629 | 0,623 | 0,626 |
| 1,08 | 0,0787 | 0,0791 | 0,0700 | 0,0789 | 0,00108 | 0,152 | 0,00406 | 0,107 | 0,265 | 122 | 0,633 | 0,626 | 0,630 |
| 1,08 | 0,0787 | 0,0791 | 0,0700 | 0,0789 | 0,00108 | 0,152 | 0,00406 | 0,107 | 0,265 | 122 | 0,632 | 0,626 | 0,629 |
| 1,27 | 0,0843 | 0,0849 | 0,0756 | 0,0846 | 0,00127 | 0,164 | 0,00473 | 0,116 | 0,269 | 125 | 0,629 | 0,618 | 0,624 |
| 1,27 | 0,0843 | 0,0849 | 0,0756 | 0,0846 | 0,00127 | 0,164 | 0,00473 | 0,116 | 0,269 | 126 | 0,630 | 0,619 | 0,624 |

V-Notch (Kaolin 12,62%)

Yield stress (Pa)= 5,20

k ($Pa.s^n$)= 0,158

n= 0,527

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1208

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,46 | 0,08941 | 0,08980 | 0,08026 | 0,08961 | 0,00146 | 0,174 | 0,00534 | 0,123 | 0,274 | 131 | 0,626 | 0,619 | 0,622 |
| 1,46 | 0,08941 | 0,08980 | 0,08026 | 0,08961 | 0,00146 | 0,174 | 0,00534 | 0,123 | 0,274 | 130 | 0,624 | 0,617 | 0,621 |
| 1,71 | 0,09525 | 0,09553 | 0,08594 | 0,09539 | 0,00171 | 0,186 | 0,00612 | 0,132 | 0,280 | 137 | 0,625 | 0,620 | 0,622 |
| 1,71 | 0,09525 | 0,09553 | 0,08594 | 0,09539 | 0,00171 | 0,186 | 0,00612 | 0,132 | 0,280 | 137 | 0,626 | 0,621 | 0,623 |
| 1,84 | 0,09809 | 0,09818 | 0,08810 | 0,09813 | 0,00184 | 0,191 | 0,00643 | 0,135 | 0,286 | 143 | 0,623 | 0,622 | 0,622 |
| 1,84 | 0,09809 | 0,09818 | 0,08810 | 0,09813 | 0,00184 | 0,191 | 0,00643 | 0,135 | 0,286 | 142 | 0,623 | 0,621 | 0,622 |
| 2,06 | 0,1033 | 0,1034 | 0,09331 | 0,1033 | 0,00206 | 0,202 | 0,00721 | 0,143 | 0,285 | 142 | 0,613 | 0,611 | 0,612 |
| 2,06 | 0,1033 | 0,1034 | 0,09331 | 0,1033 | 0,00206 | 0,202 | 0,00721 | 0,143 | 0,285 | 142 | 0,613 | 0,611 | 0,612 |
| 2,33 | 0,1083 | 0,1089 | 0,09816 | 0,1086 | 0,00233 | 0,212 | 0,00798 | 0,150 | 0,292 | 149 | 0,616 | 0,608 | 0,612 |
| 2,33 | 0,1083 | 0,1089 | 0,09816 | 0,1086 | 0,00233 | 0,212 | 0,00798 | 0,150 | 0,292 | 149 | 0,616 | 0,608 | 0,612 |
| 2,62 | 0,1139 | 0,1142 | 0,1034 | 0,1141 | 0,00262 | 0,224 | 0,00885 | 0,158 | 0,296 | 153 | 0,611 | 0,607 | 0,609 |
| 2,63 | 0,1139 | 0,1142 | 0,1034 | 0,1141 | 0,00263 | 0,224 | 0,00885 | 0,158 | 0,297 | 155 | 0,613 | 0,609 | 0,611 |
| 2,93 | 0,1191 | 0,1191 | 0,1081 | 0,1191 | 0,00293 | 0,234 | 0,00968 | 0,165 | 0,303 | 161 | 0,612 | 0,612 | 0,612 |
| 2,92 | 0,1191 | 0,1191 | 0,1081 | 0,1191 | 0,00292 | 0,234 | 0,00968 | 0,165 | 0,301 | 159 | 0,609 | 0,609 | 0,609 |

**Table 4.22 Flow rate measurement of kaolin 14.64% through V-notch**

V-Notch (Kaolin 14,64%)

Yield stress (Pa)= 9,900

k ($Pa.s^n$)= 0,208

n= 0,536

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1242

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,19 | 0,0476 | 0,0477 | 0,0357 | 0,0477 | 0,000193 | 0,0772 | 0,00105 | 0,0546 | 0,183 | 31,8 | 0,398 | 0,397 | 0,397 |
| 0,19 | 0,0476 | 0,0477 | 0,0357 | 0,0477 | 0,000192 | 0,0772 | 0,00105 | 0,0546 | 0,182 | 31,4 | 0,396 | 0,395 | 0,395 |
| 0,44 | 0,0613 | 0,0614 | 0,0494 | 0,0613 | 0,000440 | 0,107 | 0,00202 | 0,0755 | 0,218 | 45,4 | 0,484 | 0,482 | 0,483 |
| 0,44 | 0,0613 | 0,0614 | 0,0494 | 0,0613 | 0,000444 | 0,107 | 0,00202 | 0,0755 | 0,220 | 46,0 | 0,488 | 0,485 | 0,486 |
| 0,34 | 0,0561 | 0,0562 | 0,0436 | 0,0562 | 0,000343 | 0,0944 | 0,00158 | 0,0668 | 0,218 | 44,9 | 0,470 | 0,468 | 0,469 |
| 0,34 | 0,0561 | 0,0562 | 0,0436 | 0,0562 | 0,000337 | 0,0944 | 0,00158 | 0,0668 | 0,214 | 43,4 | 0,462 | 0,459 | 0,461 |
| 0,63 | 0,0704 | 0,0708 | 0,0573 | 0,0706 | 0,000627 | 0,124 | 0,00272 | 0,0877 | 0,230 | 50,6 | 0,487 | 0,480 | 0,484 |
| 0,63 | 0,0704 | 0,0708 | 0,0573 | 0,0706 | 0,000632 | 0,124 | 0,00272 | 0,0877 | 0,232 | 51,5 | 0,491 | 0,484 | 0,488 |
| 0,84 | 0,0758 | 0,0757 | 0,0645 | 0,0757 | 0,000838 | 0,140 | 0,00345 | 0,0987 | 0,243 | 56,6 | 0,542 | 0,544 | 0,543 |
| 0,84 | 0,0758 | 0,0757 | 0,0645 | 0,0757 | 0,000836 | 0,140 | 0,00345 | 0,0987 | 0,243 | 56,3 | 0,541 | 0,542 | 0,542 |
| 1,06 | 0,0830 | 0,0830 | 0,0712 | 0,0830 | 0,00106 | 0,154 | 0,00420 | 0,109 | 0,253 | 61,3 | 0,547 | 0,547 | 0,547 |
| 1,06 | 0,0830 | 0,0830 | 0,0712 | 0,0830 | 0,00106 | 0,154 | 0,00420 | 0,109 | 0,253 | 61,5 | 0,548 | 0,548 | 0,548 |
| 1,22 | 0,0873 | 0,0875 | 0,0757 | 0,0874 | 0,00122 | 0,164 | 0,00475 | 0,116 | 0,257 | 63,3 | 0,555 | 0,551 | 0,553 |
| 1,22 | 0,0873 | 0,0875 | 0,0757 | 0,0874 | 0,00122 | 0,164 | 0,00475 | 0,116 | 0,256 | 62,9 | 0,553 | 0,549 | 0,551 |

V-Notch (Kaolin 14,64%)

Yield stress (Pa)= 9,900

k ($Pa.s^n$)= 0,208

n= 0,536

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1242

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,44 | 0,0932 | 0,0934 | 0,0814 | 0,0933 | 0,00144 | 0,176 | 0,00549 | 0,125 | 0,263 | 66,3 | 0,556 | 0,553 | 0,555 |
| 1,45 | 0,0932 | 0,0934 | 0,0814 | 0,0933 | 0,00145 | 0,176 | 0,00549 | 0,125 | 0,264 | 66,8 | 0,558 | 0,555 | 0,557 |
| 1,64 | 0,0983 | 0,0984 | 0,0860 | 0,0983 | 0,00164 | 0,186 | 0,00613 | 0,132 | 0,267 | 68,5 | 0,553 | 0,550 | 0,552 |
| 1,64 | 0,0983 | 0,0984 | 0,0860 | 0,0983 | 0,00164 | 0,186 | 0,00613 | 0,132 | 0,268 | 68,8 | 0,554 | 0,551 | 0,552 |
| 1,80 | 0,1019 | 0,1018 | 0,0900 | 0,1019 | 0,00180 | 0,195 | 0,00672 | 0,138 | 0,269 | 69,4 | 0,556 | 0,557 | 0,557 |
| 1,78 | 0,1019 | 0,1018 | 0,0900 | 0,1019 | 0,00178 | 0,195 | 0,00672 | 0,138 | 0,266 | 67,8 | 0,550 | 0,551 | 0,550 |
| 2,15 | 0,1095 | 0,1097 | 0,0975 | 0,1096 | 0,00215 | 0,211 | 0,00788 | 0,149 | 0,273 | 71,8 | 0,554 | 0,551 | 0,553 |
| 2,14 | 0,1095 | 0,1097 | 0,0975 | 0,1096 | 0,00214 | 0,211 | 0,00788 | 0,149 | 0,272 | 71,3 | 0,552 | 0,550 | 0,551 |
| 2,58 | 0,1173 | 0,1175 | 0,1047 | 0,1174 | 0,00258 | 0,227 | 0,00908 | 0,160 | 0,284 | 77,6 | 0,558 | 0,556 | 0,557 |
| 2,58 | 0,1173 | 0,1175 | 0,1047 | 0,1174 | 0,00258 | 0,227 | 0,00908 | 0,160 | 0,284 | 77,6 | 0,558 | 0,556 | 0,557 |
| 2,90 | 0,1231 | 0,1232 | 0,1102 | 0,1231 | 0,00290 | 0,239 | 0,0101 | 0,169 | 0,288 | 80,1 | 0,557 | 0,557 | 0,557 |
| 2,89 | 0,1231 | 0,1232 | 0,1102 | 0,1231 | 0,00289 | 0,239 | 0,0101 | 0,169 | 0,287 | 79,5 | 0,555 | 0,554 | 0,555 |

**Table 4.23 Flow rate measurement of kaolin 15.31% through V-notch**

V-Notch (Kaolin 15,31%)

Yield stress (Pa)= 10,4

k ($Pa.s^n$)= 0,219

n= 0,531

Tan($\vartheta$/2)= 0,414 g ($m/s^2$)= 9,813 Cos($\vartheta$/2)= 0,924 Density ($kg/m^3$)= 1252,6

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,13 | 0,0504 | 0,0508 | 0,0377 | 0,0506 | 0,000130 | 0,0817 | 0,00118 | 0,0578 | 0,111 | 11,3 | 0,234 | 0,229 | 0,231 |
| 0,13 | 0,0504 | 0,0508 | 0,0377 | 0,0506 | 0,000131 | 0,0817 | 0,00118 | 0,0578 | 0,111 | 11,4 | 0,235 | 0,230 | 0,233 |
| 0,34 | 0,0590 | 0,0595 | 0,0464 | 0,0592 | 0,000339 | 0,100 | 0,00178 | 0,0710 | 0,190 | 33,2 | 0,411 | 0,401 | 0,406 |
| 0,34 | 0,0590 | 0,0595 | 0,0464 | 0,0592 | 0,000339 | 0,100 | 0,00178 | 0,0710 | 0,190 | 33,1 | 0,410 | 0,400 | 0,405 |
| 0,55 | 0,0670 | 0,0671 | 0,0539 | 0,0670 | 0,000548 | 0,117 | 0,00241 | 0,0825 | 0,227 | 47,4 | 0,481 | 0,480 | 0,481 |
| 0,55 | 0,0670 | 0,0671 | 0,0539 | 0,0670 | 0,000549 | 0,117 | 0,00241 | 0,0825 | 0,228 | 47,5 | 0,482 | 0,481 | 0,482 |
| 0,74 | 0,0721 | 0,0725 | 0,0590 | 0,0723 | 0,000738 | 0,128 | 0,00288 | 0,0902 | 0,256 | 60,2 | 0,540 | 0,533 | 0,537 |
| 0,74 | 0,0721 | 0,0725 | 0,0590 | 0,0723 | 0,000739 | 0,128 | 0,00288 | 0,0902 | 0,257 | 60,3 | 0,541 | 0,534 | 0,537 |
| 0,98 | 0,0798 | 0,0802 | 0,0665 | 0,0800 | 0,000984 | 0,144 | 0,00366 | 0,102 | 0,269 | 66,3 | 0,558 | 0,552 | 0,555 |
| 0,98 | 0,0798 | 0,0802 | 0,0665 | 0,0800 | 0,000981 | 0,144 | 0,00366 | 0,102 | 0,268 | 65,9 | 0,556 | 0,550 | 0,553 |
| 1,16 | 0,0850 | 0,0855 | 0,0713 | 0,0852 | 0,00116 | 0,154 | 0,00422 | 0,109 | 0,274 | 69,1 | 0,561 | 0,554 | 0,557 |
| 1,16 | 0,0850 | 0,0855 | 0,0713 | 0,0852 | 0,00116 | 0,154 | 0,00422 | 0,109 | 0,274 | 69,1 | 0,561 | 0,554 | 0,557 |

V-Notch (Kaolin 15,31%)

Yield stress (Pa)= 10,4

k ($Pa.s^n$)= 0,219

n= 0,531

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1252,6

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,37 | 0,0903 | 0,0909 | 0,0766 | 0,0906 | 0,00137 | 0,166 | 0,00486 | 0,117 | 0,281 | 72,6 | 0,570 | 0,560 | 0,565 |
| 1,37 | 0,0903 | 0,0909 | 0,0766 | 0,0906 | 0,00137 | 0,166 | 0,00486 | 0,117 | 0,281 | 72,6 | 0,570 | 0,560 | 0,565 |
| 1,55 | 0,0951 | 0,0957 | 0,0812 | 0,0954 | 0,00155 | 0,176 | 0,00547 | 0,124 | 0,284 | 74,0 | 0,567 | 0,559 | 0,563 |
| 1,55 | 0,0951 | 0,0957 | 0,0812 | 0,0954 | 0,00155 | 0,176 | 0,00547 | 0,124 | 0,283 | 73,8 | 0,566 | 0,558 | 0,562 |
| 1,80 | 0,1005 | 0,1008 | 0,0866 | 0,1007 | 0,00180 | 0,187 | 0,00621 | 0,133 | 0,290 | 77,3 | 0,575 | 0,570 | 0,572 |
| 1,80 | 0,1005 | 0,1008 | 0,0866 | 0,1007 | 0,00180 | 0,187 | 0,00621 | 0,133 | 0,289 | 77,0 | 0,574 | 0,569 | 0,571 |
| 2,11 | 0,1066 | 0,1071 | 0,0922 | 0,1069 | 0,00211 | 0,200 | 0,00704 | 0,141 | 0,300 | 82,8 | 0,581 | 0,574 | 0,578 |
| 2,10 | 0,1066 | 0,1071 | 0,0922 | 0,1069 | 0,00210 | 0,200 | 0,00704 | 0,141 | 0,298 | 81,7 | 0,577 | 0,570 | 0,574 |
| 2,28 | 0,1101 | 0,1104 | 0,0956 | 0,1103 | 0,00228 | 0,207 | 0,00757 | 0,146 | 0,301 | 83,4 | 0,578 | 0,573 | 0,575 |
| 2,28 | 0,1101 | 0,1104 | 0,0956 | 0,1103 | 0,00228 | 0,207 | 0,00757 | 0,146 | 0,301 | 83,4 | 0,578 | 0,573 | 0,576 |
| 2,47 | 0,1148 | 0,1152 | 0,1000 | 0,1150 | 0,00247 | 0,217 | 0,00829 | 0,153 | 0,298 | 82,3 | 0,566 | 0,561 | 0,563 |
| 2,47 | 0,1148 | 0,1152 | 0,1000 | 0,1150 | 0,00247 | 0,217 | 0,00829 | 0,153 | 0,299 | 82,3 | 0,566 | 0,561 | 0,563 |
| 2,69 | 0,1181 | 0,1187 | 0,1032 | 0,1184 | 0,00269 | 0,223 | 0,00883 | 0,158 | 0,305 | 85,8 | 0,574 | 0,566 | 0,570 |
| 2,69 | 0,1181 | 0,1187 | 0,1032 | 0,1184 | 0,00269 | 0,223 | 0,00883 | 0,158 | 0,305 | 85,8 | 0,573 | 0,566 | 0,570 |

V-Notch (Kaolin 15,31%)

Yield stress (Pa)= 10,4

k ($Pa.s^n$)= 0,219

n= 0,531

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1252,6

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,93 | 0,1221 | 0,1227 | 0,1071 | 0,1224 | 0,00293 | 0,232 | 0,00950 | 0,164 | 0,308 | 87,9 | 0,575 | 0,568 | 0,571 |
| 2,93 | 0,1221 | 0,1227 | 0,1071 | 0,1224 | 0,00293 | 0,232 | 0,00950 | 0,164 | 0,308 | 87,6 | 0,574 | 0,567 | 0,571 |
| 2,10 | 0,1071 | 0,1077 | 0,0928 | 0,1074 | 0,00210 | 0,201 | 0,00714 | 0,142 | 0,294 | 79,7 | 0,571 | 0,564 | 0,567 |
| 2,10 | 0,1071 | 0,1077 | 0,0928 | 0,1074 | 0,00210 | 0,201 | 0,00714 | 0,142 | 0,294 | 79,7 | 0,571 | 0,564 | 0,567 |

**Table 4.24 Flow rate measurement of kaolin 16% through V-notch**

V-Notch (Kaolin 16%)

Yield stress (Pa)= 15,8

k (Pa.s$^n$)= 0,259

n= 0,500

Tan(ϑ/2)= 0,41421 g (m/s$^2$)= 9,813 Cos(ϑ/2)= 0,92388 Density (kg/m$^3$)= 1264

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_davg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,41 | 0,0571 | 0,0570 | 0,0419 | 0,0570 | 0,000407 | 0,0907 | 0,00145 | 0,0641 | 0,280 | 48,0 | 0,534 | 0,537 | 0,536 |
| 0,41 | 0,0571 | 0,0570 | 0,0419 | 0,0570 | 0,000407 | 0,0907 | 0,00145 | 0,0160 | 0,280 | 45,9 | 0,534 | 0,537 | 0,536 |
| 0,68 | 0,0860 | 0,0862 | 0,0733 | 0,0861 | 0,000682 | 0,159 | 0,00445 | 0,0281 | 0,153 | 14,2 | 0,321 | 0,319 | 0,320 |
| 0,68 | 0,0860 | 0,0862 | 0,0733 | 0,0861 | 0,000680 | 0,159 | 0,00445 | 0,0281 | 0,153 | 14,2 | 0,320 | 0,319 | 0,319 |
| 0,85 | 0,0904 | 0,0905 | 0,0768 | 0,0904 | 0,000849 | 0,166 | 0,00489 | 0,0294 | 0,174 | 18,3 | 0,353 | 0,352 | 0,353 |
| 0,85 | 0,0904 | 0,0905 | 0,0768 | 0,0904 | 0,000849 | 0,166 | 0,00489 | 0,0294 | 0,174 | 18,3 | 0,353 | 0,352 | 0,353 |
| 0,98 | 0,0932 | 0,0935 | 0,0792 | 0,0933 | 0,000979 | 0,172 | 0,00520 | 0,0303 | 0,188 | 21,4 | 0,377 | 0,375 | 0,376 |
| 0,98 | 0,0932 | 0,0935 | 0,0792 | 0,0933 | 0,000978 | 0,172 | 0,00520 | 0,0303 | 0,188 | 21,4 | 0,377 | 0,375 | 0,376 |
| 1,21 | 0,0974 | 0,0977 | 0,0832 | 0,0975 | 0,00121 | 0,180 | 0,00574 | 0,0318 | 0,211 | 26,9 | 0,418 | 0,415 | 0,416 |
| 1,21 | 0,0974 | 0,0977 | 0,0832 | 0,0975 | 0,00121 | 0,180 | 0,00574 | 0,0318 | 0,211 | 26,9 | 0,418 | 0,415 | 0,416 |
| 2,47 | 0,1189 | 0,1190 | 0,1033 | 0,1189 | 0,00247 | 0,224 | 0,00884 | 0,0395 | 0,279 | 47,0 | 0,517 | 0,517 | 0,517 |
| 2,46 | 0,1189 | 0,1190 | 0,1033 | 0,1189 | 0,00246 | 0,224 | 0,00884 | 0,0395 | 0,279 | 46,8 | 0,517 | 0,516 | 0,516 |

V-Notch (Kaolin 16%)

Yield stress (Pa)= 15,8

k ($Pa.s^n$)= 0,259

n= 0,500

Tan($\vartheta$/2)= 0,41421 g ($m/s^2$)= 9,813 Cos($\vartheta$/2)= 0,92388 Density ($kg/m^3$)= 1264

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,53 | 0,1202 | 0,1206 | 0,1039 | 0,1204 | 0,00253 | 0,225 | 0,00894 | 0,0397 | 0,283 | 48,2 | 0,516 | 0,511 | 0,514 |
| 2,53 | 0,1202 | 0,1206 | 0,1039 | 0,1204 | 0,00253 | 0,225 | 0,00894 | 0,0397 | 0,283 | 48,2 | 0,516 | 0,511 | 0,513 |
| 2,16 | 0,1125 | 0,1126 | 0,0982 | 0,1125 | 0,00216 | 0,213 | 0,00799 | 0,0376 | 0,271 | 44,2 | 0,521 | 0,520 | 0,520 |
| 2,17 | 0,1125 | 0,1126 | 0,0982 | 0,1125 | 0,00217 | 0,213 | 0,00799 | 0,0376 | 0,272 | 44,6 | 0,523 | 0,522 | 0,523 |
| 1,90 | 0,1096 | 0,1096 | 0,0937 | 0,1096 | 0,00190 | 0,203 | 0,00727 | 0,0358 | 0,261 | 41,2 | 0,488 | 0,488 | 0,488 |
| 1,90 | 0,1096 | 0,1096 | 0,0937 | 0,1096 | 0,00190 | 0,203 | 0,00727 | 0,0358 | 0,262 | 41,2 | 0,488 | 0,489 | 0,489 |
| 1,87 | 0,1090 | 0,1091 | 0,0937 | 0,1090 | 0,00187 | 0,203 | 0,00727 | 0,0359 | 0,257 | 39,9 | 0,488 | 0,487 | 0,487 |
| 1,89 | 0,1090 | 0,1091 | 0,0937 | 0,1090 | 0,00189 | 0,203 | 0,00727 | 0,0359 | 0,259 | 40,5 | 0,491 | 0,490 | 0,491 |
| 1,92 | 0,1094 | 0,1100 | 0,0945 | 0,1097 | 0,00192 | 0,205 | 0,00740 | 0,0362 | 0,260 | 40,6 | 0,495 | 0,489 | 0,492 |
| 1,93 | 0,1094 | 0,1100 | 0,0945 | 0,1097 | 0,00193 | 0,205 | 0,00740 | 0,0362 | 0,261 | 40,9 | 0,497 | 0,491 | 0,494 |
| 1,69 | 0,1055 | 0,1058 | 0,0913 | 0,1057 | 0,00169 | 0,198 | 0,00691 | 0,0350 | 0,244 | 36,0 | 0,477 | 0,473 | 0,475 |
| 1,70 | 0,1055 | 0,1058 | 0,0913 | 0,1057 | 0,00170 | 0,198 | 0,00691 | 0,0350 | 0,246 | 36,4 | 0,480 | 0,476 | 0,478 |
| 1,49 | 0,1029 | 0,1030 | 0,0885 | 0,1029 | 0,00149 | 0,192 | 0,00648 | 0,0339 | 0,230 | 31,9 | 0,449 | 0,448 | 0,448 |
| 1,50 | 0,1029 | 0,1030 | 0,0885 | 0,1029 | 0,00150 | 0,192 | 0,00648 | 0,0339 | 0,231 | 32,3 | 0,451 | 0,450 | 0,451 |

**APPENDIX J: V-notch flow rate measurement results (Bentonite suspension)**

**Table 4.25 Flow rate measurement of bentonite 4.14% through V-notch**

V-Notch (Benotnite 4,15%)

Yield stress (Pa)= 1,15

k ($Pa.s^n$)= 0,00294

n= 1

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1025

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,80 | 0,1169 | 0,1170 | 0,1079 | 0,1170 | 0,00280 | 0,234 | 0,00964 | 0,165 | 0,290 | 593 | 0,611 | 0,610 | 0,611 |
| 2,80 | 0,1169 | 0,1170 | 0,1079 | 0,1170 | 0,00280 | 0,234 | 0,00964 | 0,165 | 0,290 | 593 | 0,611 | 0,611 | 0,611 |
| 2,50 | 0,1116 | 0,1116 | 0,1029 | 0,1116 | 0,00250 | 0,223 | 0,00878 | 0,158 | 0,285 | 574 | 0,615 | 0,615 | 0,615 |
| 2,51 | 0,1116 | 0,1116 | 0,1029 | 0,1116 | 0,00251 | 0,223 | 0,00878 | 0,158 | 0,285 | 575 | 0,616 | 0,615 | 0,615 |
| 2,22 | 0,1077 | 0,1075 | 0,0993 | 0,1076 | 0,00222 | 0,215 | 0,00817 | 0,152 | 0,272 | 521 | 0,596 | 0,599 | 0,597 |
| 2,21 | 0,1077 | 0,1075 | 0,0993 | 0,1076 | 0,00221 | 0,215 | 0,00817 | 0,152 | 0,271 | 518 | 0,594 | 0,597 | 0,596 |
| 2,61 | 0,1145 | 0,1147 | 0,1058 | 0,1146 | 0,00261 | 0,229 | 0,00927 | 0,162 | 0,282 | 560 | 0,601 | 0,599 | 0,600 |
| 2,61 | 0,1145 | 0,1147 | 0,1058 | 0,1146 | 0,00261 | 0,229 | 0,00927 | 0,162 | 0,282 | 560 | 0,601 | 0,599 | 0,600 |
| 1,82 | 0,0991 | 0,0992 | 0,0915 | 0,0992 | 0,00182 | 0,198 | 0,00694 | 0,140 | 0,262 | 485 | 0,601 | 0,599 | 0,600 |
| 1,82 | 0,0991 | 0,0992 | 0,0915 | 0,0992 | 0,00182 | 0,198 | 0,00694 | 0,140 | 0,263 | 488 | 0,603 | 0,601 | 0,602 |
| 1,48 | 0,0909 | 0,0912 | 0,0833 | 0,0911 | 0,00148 | 0,180 | 0,00575 | 0,128 | 0,257 | 465 | 0,605 | 0,601 | 0,603 |
| 1,48 | 0,0909 | 0,0912 | 0,0833 | 0,0911 | 0,00148 | 0,180 | 0,00575 | 0,128 | 0,257 | 465 | 0,605 | 0,601 | 0,603 |
| 1,16 | 0,0833 | 0,0835 | 0,0764 | 0,0834 | 0,00116 | 0,165 | 0,00483 | 0,117 | 0,241 | 409 | 0,593 | 0,590 | 0,591 |
| 1,17 | 0,0833 | 0,0835 | 0,0764 | 0,0834 | 0,00117 | 0,165 | 0,00483 | 0,117 | 0,243 | 417 | 0,599 | 0,596 | 0,597 |
| 0,84 | 0,0736 | 0,0738 | 0,0671 | 0,0737 | 0,000835 | 0,145 | 0,00373 | 0,103 | 0,224 | 354 | 0,580 | 0,577 | 0,579 |
| 0,84 | 0,0736 | 0,0738 | 0,0671 | 0,0737 | 0,000838 | 0,145 | 0,00373 | 0,103 | 0,225 | 356 | 0,582 | 0,579 | 0,581 |

V-Notch (Benotnite 4,15%)

Yield stress (Pa)= 1,15

k ($Pa.s^n$)= 0,00294

n= 1

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1025

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,50 | 0,0597 | 0,0604 | 0,0543 | 0,0601 | 0,000495 | 0,118 | 0,00244 | 0,0831 | 0,203 | 289 | 0,581 | 0,564 | 0,572 |
| 0,50 | 0,0597 | 0,0604 | 0,0543 | 0,0601 | 0,000496 | 0,118 | 0,00244 | 0,0831 | 0,203 | 290 | 0,582 | 0,565 | 0,574 |
| 0,34 | 0,0518 | 0,0522 | 0,0467 | 0,0520 | 0,000342 | 0,101 | 0,00181 | 0,0715 | 0,189 | 251 | 0,572 | 0,563 | 0,567 |
| 0,34 | 0,0518 | 0,0522 | 0,0467 | 0,0520 | 0,000339 | 0,101 | 0,00181 | 0,0715 | 0,187 | 247 | 0,567 | 0,558 | 0,562 |
| 0,58 | 0,0642 | 0,0639 | 0,0581 | 0,0641 | 0,000584 | 0,126 | 0,00280 | 0,0889 | 0,209 | 307 | 0,570 | 0,577 | 0,574 |
| 0,58 | 0,0642 | 0,0639 | 0,0581 | 0,0641 | 0,000585 | 0,126 | 0,00280 | 0,0889 | 0,209 | 308 | 0,571 | 0,579 | 0,575 |
| 0,89 | 0,0748 | 0,0746 | 0,0696 | 0,0747 | 0,000889 | 0,151 | 0,00401 | 0,107 | 0,221 | 345 | 0,593 | 0,596 | 0,595 |
| 0,89 | 0,0748 | 0,0746 | 0,0696 | 0,0747 | 0,000893 | 0,151 | 0,00401 | 0,107 | 0,222 | 348 | 0,596 | 0,599 | 0,598 |
| 0,34 | 0,0518 | 0,0521 | 0,0458 | 0,0520 | 0,000341 | 0,0992 | 0,00174 | 0,0702 | 0,196 | 269 | 0,569 | 0,563 | 0,566 |
| 0,34 | 0,0518 | 0,0521 | 0,0458 | 0,0520 | 0,000339 | 0,0992 | 0,00174 | 0,0702 | 0,195 | 266 | 0,566 | 0,560 | 0,563 |

**Table 4.26 Flow rate measurement of bentonite 5.14% through V-notch**

V-Notch (Benotnite 5,14%)

Yield stress (Pa)= 2,285

k (Pa.$s^n$)= 0,00394

n= 1

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1031

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,90 | 0,1189 | 0,1187 | 0,1062 | 0,1188 | 0,00290 | 0,230 | 0,00934 | 0,163 | 0,310 | 346 | 0,608 | 0,611 | 0,609 |
| 2,91 | 0,1189 | 0,1187 | 0,1062 | 0,1188 | 0,00291 | 0,230 | 0,00934 | 0,163 | 0,311 | 348 | 0,610 | 0,613 | 0,611 |
| 2,53 | 0,1127 | 0,1127 | 0,1012 | 0,1127 | 0,00253 | 0,219 | 0,00848 | 0,155 | 0,298 | 318 | 0,605 | 0,605 | 0,605 |
| 2,53 | 0,1127 | 0,1127 | 0,1012 | 0,1127 | 0,00253 | 0,219 | 0,00848 | 0,155 | 0,298 | 318 | 0,605 | 0,605 | 0,605 |
| 2,12 | 0,1049 | 0,1053 | 0,0945 | 0,1051 | 0,00212 | 0,205 | 0,00740 | 0,145 | 0,287 | 294 | 0,608 | 0,603 | 0,605 |
| 2,12 | 0,1049 | 0,1053 | 0,0945 | 0,1051 | 0,00212 | 0,205 | 0,00740 | 0,145 | 0,286 | 294 | 0,608 | 0,602 | 0,605 |
| 1,71 | 0,0966 | 0,0972 | 0,0861 | 0,0969 | 0,00171 | 0,186 | 0,00614 | 0,132 | 0,279 | 279 | 0,604 | 0,593 | 0,599 |
| 1,70 | 0,0966 | 0,0972 | 0,0861 | 0,0969 | 0,00170 | 0,186 | 0,00614 | 0,132 | 0,277 | 276 | 0,601 | 0,590 | 0,595 |
| 1,40 | 0,0895 | 0,0894 | 0,0785 | 0,0895 | 0,00140 | 0,170 | 0,00510 | 0,120 | 0,273 | 268 | 0,595 | 0,596 | 0,596 |
| 1,41 | 0,0895 | 0,0894 | 0,0785 | 0,0895 | 0,00141 | 0,170 | 0,00510 | 0,120 | 0,276 | 272 | 0,600 | 0,601 | 0,600 |
| 0,92 | 0,0762 | 0,0766 | 0,0674 | 0,0764 | 0,000921 | 0,146 | 0,00376 | 0,103 | 0,245 | 215 | 0,587 | 0,579 | 0,583 |
| 0,92 | 0,0762 | 0,0766 | 0,0674 | 0,0764 | 0,000920 | 0,146 | 0,00376 | 0,103 | 0,245 | 215 | 0,587 | 0,579 | 0,583 |
| 0,74 | 0,0700 | 0,0698 | 0,0595 | 0,0699 | 0,000743 | 0,129 | 0,00294 | 0,091 | 0,253 | 229 | 0,584 | 0,588 | 0,586 |
| 0,75 | 0,0700 | 0,0698 | 0,0595 | 0,0699 | 0,000748 | 0,129 | 0,00294 | 0,091 | 0,255 | 232 | 0,589 | 0,593 | 0,591 |

V-Notch (Benotnite 5,14%)

Yield stress (Pa)= 2,285

k (Pa.$s^n$)= 0,00394

n= 1

Tan(ϑ/2)= 0,414 g (m/$s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density (kg/$m^3$)= 1031

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3$/s | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,25 | 0,0858 | 0,0855 | 0,0778 | 0,0856 | 0,00125 | 0,168 | 0,00501 | 0,119 | 0,249 | 223 | 0,592 | 0,598 | 0,595 |
| 1,25 | 0,0858 | 0,0855 | 0,0778 | 0,0856 | 0,00125 | 0,168 | 0,00501 | 0,119 | 0,249 | 222 | 0,591 | 0,597 | 0,594 |
| 1,13 | 0,0820 | 0,0819 | 0,0732 | 0,0820 | 0,00113 | 0,158 | 0,00444 | 0,112 | 0,256 | 234 | 0,602 | 0,603 | 0,603 |
| 1,13 | 0,0820 | 0,0819 | 0,0732 | 0,0820 | 0,00113 | 0,158 | 0,00444 | 0,112 | 0,255 | 234 | 0,601 | 0,603 | 0,602 |
| 1,14 | 0,0821 | 0,0821 | 0,0732 | 0,0821 | 0,00114 | 0,158 | 0,00444 | 0,112 | 0,256 | 235 | 0,601 | 0,601 | 0,601 |
| 1,13 | 0,0821 | 0,0821 | 0,0732 | 0,0821 | 0,00113 | 0,158 | 0,00444 | 0,112 | 0,256 | 234 | 0,600 | 0,601 | 0,600 |
| 1,55 | 0,0932 | 0,0930 | 0,0835 | 0,0931 | 0,00155 | 0,181 | 0,00578 | 0,128 | 0,268 | 257 | 0,596 | 0,599 | 0,598 |
| 1,54 | 0,0932 | 0,0930 | 0,0835 | 0,0931 | 0,00154 | 0,181 | 0,00578 | 0,128 | 0,266 | 253 | 0,592 | 0,595 | 0,594 |
| 2,18 | 0,1071 | 0,1063 | 0,0991 | 0,1067 | 0,00218 | 0,215 | 0,00814 | 0,152 | 0,268 | 258 | 0,594 | 0,605 | 0,600 |
| 2,17 | 0,1071 | 0,1063 | 0,0991 | 0,1067 | 0,00217 | 0,215 | 0,00814 | 0,152 | 0,267 | 256 | 0,591 | 0,602 | 0,597 |
| 1,90 | 0,1008 | 0,1004 | 0,0911 | 0,1006 | 0,00190 | 0,197 | 0,00687 | 0,139 | 0,277 | 275 | 0,603 | 0,609 | 0,606 |
| 1,90 | 0,1008 | 0,1004 | 0,0911 | 0,1006 | 0,00190 | 0,197 | 0,00687 | 0,139 | 0,277 | 274 | 0,602 | 0,608 | 0,605 |

**Table 4.27 Flow rate measurement of bentonite 6% through V-notch**

V-Notch (Benotnite 6%)

Yield stress (Pa)= 4,88
k (Pa.$s^n$)= 0,00437
n= 1
Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1037

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,61 | 0,1121 | 0,1134 | 0,1024 | 0,1128 | 0,00261 | 0,222 | 0,00868 | 0,157 | 0,301 | 153 | 0,635 | 0,616 | 0,625 |
| 2,61 | 0,1121 | 0,1134 | 0,1024 | 0,1128 | 0,00261 | 0,222 | 0,00868 | 0,157 | 0,300 | 153 | 0,633 | 0,615 | 0,624 |
| 2,90 | 0,1181 | 0,1193 | 0,1068 | 0,1187 | 0,00290 | 0,231 | 0,00945 | 0,163 | 0,307 | 160 | 0,619 | 0,603 | 0,611 |
| 2,91 | 0,1181 | 0,1193 | 0,1068 | 0,1187 | 0,00291 | 0,231 | 0,00945 | 0,163 | 0,308 | 161 | 0,620 | 0,605 | 0,612 |
| 2,32 | 0,1081 | 0,1089 | 0,0971 | 0,1085 | 0,00232 | 0,210 | 0,00781 | 0,149 | 0,297 | 149 | 0,616 | 0,605 | 0,611 |
| 2,32 | 0,1081 | 0,1089 | 0,0971 | 0,1085 | 0,00232 | 0,210 | 0,00781 | 0,149 | 0,297 | 149 | 0,616 | 0,605 | 0,611 |
| 1,94 | 0,1006 | 0,1010 | 0,0904 | 0,1008 | 0,00194 | 0,196 | 0,00677 | 0,138 | 0,287 | 139 | 0,618 | 0,611 | 0,614 |
| 1,94 | 0,1006 | 0,1010 | 0,0904 | 0,1008 | 0,00194 | 0,196 | 0,00677 | 0,138 | 0,286 | 138 | 0,616 | 0,609 | 0,613 |
| 1,67 | 0,0960 | 0,0962 | 0,0841 | 0,0961 | 0,00167 | 0,182 | 0,00586 | 0,129 | 0,285 | 138 | 0,599 | 0,595 | 0,597 |
| 1,68 | 0,0960 | 0,0962 | 0,0841 | 0,0961 | 0,00168 | 0,182 | 0,00586 | 0,129 | 0,287 | 140 | 0,602 | 0,599 | 0,601 |
| 1,35 | 0,0879 | 0,0889 | 0,0764 | 0,0884 | 0,00135 | 0,165 | 0,00484 | 0,117 | 0,279 | 131 | 0,602 | 0,585 | 0,594 |
| 1,35 | 0,0879 | 0,0889 | 0,0764 | 0,0884 | 0,00135 | 0,165 | 0,00484 | 0,117 | 0,278 | 131 | 0,601 | 0,584 | 0,592 |

V-Notch (Benotnite 6%)

Yield stress (Pa)= 4,88

k ($Pa.s^n$)= 0,00437

n= 1

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1037

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,02 | 0,0793 | 0,0808 | 0,0676 | 0,0801 | 0,00102 | 0,146 | 0,00379 | 0,104 | 0,269 | 122 | 0,589 | 0,560 | 0,575 |
| 1,02 | 0,0793 | 0,0808 | 0,0676 | 0,0801 | 0,00102 | 0,146 | 0,00379 | 0,104 | 0,268 | 122 | 0,587 | 0,559 | 0,573 |

**APPENDIX K: V-notch flow rate measurement results (CMC solution)**

**Table 4.28 Flow rate measurement of CMC 1.73% through V-notch**

V-Notch (CMC 1,73%)

Yield stress (Pa)= 0
k (Pa.$s^n$)= 0,0235
k'(Pa.$s^n$)= 0,0250
n=n'= 0,747
Density (kg/$m^3$)= 1010

Tan(ϑ/2)= 0,414 g (m/$s^2$)= 9,813 Cos(ϑ/2)= 0,924

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3$/s | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,93 | 0,0782 | 0,0782 | 0,0681 | 0,0782 | 0,000930 | 0,147 | 0,00384 | 0,104 | 0,242 | 6394 | 6018 | 0,557 | 0,556 | 0,556 |
| 0,93 | 0,0782 | 0,0782 | 0,0681 | 0,0782 | 0,000927 | 0,147 | 0,00384 | 0,104 | 0,242 | 6371 | 5997 | 0,555 | 0,554 | 0,555 |
| 2,83 | 0,1218 | 0,1220 | 0,1091 | 0,1219 | 0,00283 | 0,236 | 0,00986 | 0,167 | 0,287 | 11230 | 10570 | 0,557 | 0,556 | 0,557 |
| 2,83 | 0,1218 | 0,1220 | 0,1091 | 0,1219 | 0,00283 | 0,236 | 0,00986 | 0,167 | 0,287 | 11230 | 10569 | 0,557 | 0,556 | 0,556 |
| 2,51 | 0,1164 | 0,1162 | 0,1039 | 0,1163 | 0,00251 | 0,225 | 0,00894 | 0,159 | 0,281 | 10569 | 9947 | 0,556 | 0,559 | 0,558 |
| 2,51 | 0,1164 | 0,1162 | 0,1039 | 0,1163 | 0,00251 | 0,225 | 0,00894 | 0,159 | 0,281 | 10570 | 9949 | 0,556 | 0,559 | 0,558 |
| 2,31 | 0,1120 | 0,1124 | 0,0998 | 0,1122 | 0,00231 | 0,216 | 0,00825 | 0,153 | 0,280 | 10177 | 9578 | 0,561 | 0,557 | 0,559 |
| 2,32 | 0,1120 | 0,1124 | 0,0998 | 0,1122 | 0,00232 | 0,216 | 0,00825 | 0,153 | 0,281 | 10235 | 9632 | 0,564 | 0,559 | 0,561 |
| 1,86 | 0,1026 | 0,1032 | 0,0916 | 0,1029 | 0,00186 | 0,198 | 0,00694 | 0,140 | 0,268 | 9051 | 8519 | 0,564 | 0,555 | 0,559 |
| 1,86 | 0,1026 | 0,1032 | 0,0916 | 0,1029 | 0,00186 | 0,198 | 0,00694 | 0,140 | 0,268 | 9062 | 8529 | 0,564 | 0,556 | 0,560 |
| 1,28 | 0,0886 | 0,0888 | 0,0780 | 0,0887 | 0,00128 | 0,169 | 0,00505 | 0,119 | 0,253 | 7490 | 7049 | 0,559 | 0,556 | 0,557 |
| 1,28 | 0,0886 | 0,0888 | 0,0780 | 0,0887 | 0,00128 | 0,169 | 0,00505 | 0,119 | 0,253 | 7487 | 7047 | 0,559 | 0,555 | 0,557 |

V-Notch (CMC 1,73%)

Yield stress (Pa)= 0

k (Pa.$s^n$)= 0,0235

k'(Pa.$s^n$)= 0,0250

n=n'= 0,747

Tan(ϑ/2)= 0,414 g (m/$s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density (kg/$m^3$)= 1010

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3$/s | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d$1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,43 | 0,0571 | 0,0572 | 0,0490 | 0,0571 | 0,000428 | 0,106 | 0,00199 | 0,0750 | 0,215 | 4313 | 4059 | 0,561 | 0,560 | 0,561 |
| 0,43 | 0,0571 | 0,0572 | 0,0490 | 0,0571 | 0,000426 | 0,106 | 0,00199 | 0,0750 | 0,215 | 4291 | 4039 | 0,559 | 0,558 | 0,558 |
| 0,62 | 0,0660 | 0,0663 | 0,0559 | 0,0662 | 0,000616 | 0,121 | 0,00259 | 0,0855 | 0,238 | 5400 | 5082 | 0,562 | 0,555 | 0,559 |
| 0,62 | 0,0660 | 0,0664 | 0,0559 | 0,0662 | 0,000617 | 0,121 | 0,00259 | 0,0855 | 0,239 | 5411 | 5093 | 0,563 | 0,556 | 0,560 |
| 0,28 | 0,0482 | 0,0483 | 0,0400 | 0,0482 | 0,000276 | 0,0867 | 0,00133 | 0,0613 | 0,208 | 3555 | 3346 | 0,554 | 0,552 | 0,553 |
| 0,28 | 0,0482 | 0,0483 | 0,0400 | 0,0482 | 0,000277 | 0,0867 | 0,00133 | 0,0613 | 0,208 | 3560 | 3351 | 0,554 | 0,553 | 0,554 |

**Table 4.29 Flow rate measurement of CMC 4.63% through V-notch**

V-Notch ( CMC 4,63%)

Yield stress (Pa)= 0

k (Pa.s$^n$)= 0,213

k' (Pa.s$^n$)= 0,225

n=n'= 0,763

Tan(ϑ/2)= 0,414 g (m/s$^2$)= 9,813 Cos(ϑ/2)= 0,924 Density (kg/m$^3$)= 1026

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,82 | 0,1175 | 0,1180 | 0,1058 | 0,1178 | 0,00282 | 0,229 | 0,00928 | 0,162 | 0,304 | 1297 | 1225 | 0,608 | 0,602 | 0,605 |
| 2,83 | 0,1175 | 0,1180 | 0,1058 | 0,1178 | 0,00283 | 0,229 | 0,00928 | 0,162 | 0,305 | 1302 | 1230 | 0,610 | 0,604 | 0,607 |
| 2,50 | 0,1122 | 0,1124 | 0,1013 | 0,1123 | 0,00250 | 0,219 | 0,00851 | 0,155 | 0,294 | 1208 | 1141 | 0,607 | 0,605 | 0,606 |
| 2,50 | 0,1122 | 0,1124 | 0,1013 | 0,1123 | 0,00250 | 0,219 | 0,00851 | 0,155 | 0,294 | 1208 | 1141 | 0,607 | 0,605 | 0,606 |
| 2,22 | 0,1068 | 0,1068 | 0,0967 | 0,1068 | 0,00222 | 0,209 | 0,00775 | 0,148 | 0,287 | 1128 | 1066 | 0,610 | 0,609 | 0,609 |
| 2,21 | 0,1068 | 0,1068 | 0,0967 | 0,1068 | 0,00221 | 0,209 | 0,00775 | 0,148 | 0,285 | 1122 | 1060 | 0,607 | 0,606 | 0,607 |
| 1,93 | 0,1009 | 0,1009 | 0,0909 | 0,1009 | 0,00193 | 0,197 | 0,00685 | 0,139 | 0,282 | 1056 | 997 | 0,612 | 0,610 | 0,611 |
| 1,94 | 0,1009 | 0,1009 | 0,0909 | 0,1009 | 0,00194 | 0,197 | 0,00685 | 0,139 | 0,283 | 1058 | 999 | 0,612 | 0,611 | 0,612 |
| 1,55 | 0,0925 | 0,0927 | 0,0822 | 0,0926 | 0,00155 | 0,178 | 0,00560 | 0,126 | 0,276 | 951 | 898 | 0,607 | 0,604 | 0,606 |
| 1,55 | 0,0925 | 0,0927 | 0,0822 | 0,0926 | 0,00155 | 0,178 | 0,00560 | 0,126 | 0,276 | 951 | 898 | 0,608 | 0,604 | 0,606 |
| 1,23 | 0,0844 | 0,0850 | 0,0749 | 0,0847 | 0,00123 | 0,162 | 0,00465 | 0,115 | 0,266 | 844 | 797 | 0,610 | 0,599 | 0,604 |
| 1,24 | 0,0844 | 0,0850 | 0,0749 | 0,0847 | 0,00124 | 0,162 | 0,00465 | 0,115 | 0,268 | 853 | 805 | 0,615 | 0,604 | 0,609 |
| 0,96 | 0,0754 | 0,0759 | 0,0626 | 0,0757 | 0,000963 | 0,135 | 0,00324 | 0,0958 | 0,297 | 844 | 798 | 0,629 | 0,620 | 0,625 |
| 0,96 | 0,0754 | 0,0759 | 0,0626 | 0,0757 | 0,000962 | 0,135 | 0,00324 | 0,0958 | 0,297 | 844 | 797 | 0,629 | 0,620 | 0,624 |

V-Notch ( CMC 4,63%)

Yield stress (Pa)= 0

k ($Pa.s^n$)= 0,213

k' ($Pa.s^n$)= 0,225

n=n'= 0,763

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1026

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,63 | 0,0632 | 0,0633 | 0,0531 | 0,0633 | 0,000627 | 0,115 | 0,00233 | 0,0812 | 0,269 | 659 | 622 | 0,637 | 0,634 | 0,635 |
| 0,63 | 0,0632 | 0,0633 | 0,0531 | 0,0633 | 0,000628 | 0,115 | 0,00233 | 0,0812 | 0,269 | 660 | 624 | 0,638 | 0,635 | 0,637 |

**Table 4.30 Flow rate measurement of CMC 6.2% through V-notch**

V-Notch ( CMC 6,2%)

Yield stress (Pa)= 0
$k$ (Pa.s$^n$)= 0,646
$k'$ (Pa.s$^n$)= 0,692
$n=n'$= 0,710
Tan(ϑ/2)= 0,414    g (m/s$^2$)= 9,813    Cos(ϑ/2)= 0,924    Density (kg/m$^3$)= 1035

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,88 | 0,1161 | 0,1170 | 0,1055 | 0,1165 | 0,00288 | 0,228 | 0,00922 | 0,161 | 0,312 | 479 | 447 | 0,641 | 0,628 | 0,635 |
| 2,89 | 0,1161 | 0,1170 | 0,1055 | 0,1165 | 0,00289 | 0,228 | 0,00922 | 0,161 | 0,314 | 481 | 449 | 0,643 | 0,630 | 0,637 |
| 0,72 | 0,0666 | 0,0671 | 0,0569 | 0,0669 | 0,000724 | 0,123 | 0,00269 | 0,0872 | 0,270 | 255 | 238 | 0,646 | 0,634 | 0,640 |
| 0,73 | 0,0666 | 0,0671 | 0,0569 | 0,0669 | 0,000725 | 0,123 | 0,00269 | 0,0872 | 0,270 | 256 | 239 | 0,647 | 0,635 | 0,641 |
| 2,22 | 0,1050 | 0,1056 | 0,0939 | 0,1053 | 0,00222 | 0,203 | 0,00731 | 0,144 | 0,304 | 426 | 397 | 0,635 | 0,627 | 0,631 |
| 2,22 | 0,1050 | 0,1056 | 0,0939 | 0,1053 | 0,00222 | 0,203 | 0,00731 | 0,144 | 0,304 | 426 | 398 | 0,635 | 0,627 | 0,631 |
| 1,92 | 0,0988 | 0,0994 | 0,0872 | 0,0991 | 0,00192 | 0,189 | 0,00630 | 0,133 | 0,305 | 405 | 378 | 0,639 | 0,631 | 0,635 |
| 1,92 | 0,0988 | 0,0994 | 0,0872 | 0,0991 | 0,00192 | 0,189 | 0,00630 | 0,133 | 0,305 | 405 | 378 | 0,639 | 0,631 | 0,635 |
| 1,63 | 0,0925 | 0,0929 | 0,0810 | 0,0927 | 0,00163 | 0,175 | 0,00544 | 0,124 | 0,300 | 376 | 351 | 0,640 | 0,633 | 0,636 |
| 1,63 | 0,0925 | 0,0929 | 0,0810 | 0,0927 | 0,00163 | 0,175 | 0,00544 | 0,124 | 0,300 | 376 | 351 | 0,640 | 0,633 | 0,637 |
| 1,33 | 0,0848 | 0,0852 | 0,0749 | 0,0850 | 0,00133 | 0,162 | 0,00465 | 0,115 | 0,285 | 334 | 312 | 0,648 | 0,640 | 0,644 |
| 1,33 | 0,0848 | 0,0852 | 0,0749 | 0,0850 | 0,00133 | 0,162 | 0,00465 | 0,115 | 0,285 | 334 | 312 | 0,647 | 0,640 | 0,644 |
| 0,97 | 0,0752 | 0,0759 | 0,0641 | 0,0756 | 0,000973 | 0,139 | 0,00340 | 0,0981 | 0,286 | 300 | 280 | 0,640 | 0,626 | 0,633 |
| 0,97 | 0,0752 | 0,0759 | 0,0641 | 0,0756 | 0,000973 | 0,139 | 0,00340 | 0,0981 | 0,286 | 300 | 280 | 0,641 | 0,626 | 0,633 |

V-Notch ( CMC 6,2%)

Yield stress (Pa)= 0

k ($Pa.s^n$)= 0,646

k' ($Pa.s^n$)= 0,692

n=n'= 0,710

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1035

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | Reynolds number | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 2,51 | 0,1100 | 0,1108 | 0,0989 | 0,1104 | 0,00251 | 0,214 | 0,00810 | 0,151 | 0,309 | 451 | 421 | 0,638 | 0,627 | 0,632 |
| 2,50 | 0,1100 | 0,1108 | 0,0989 | 0,1104 | 0,00250 | 0,214 | 0,00810 | 0,151 | 0,309 | 451 | 421 | 0,638 | 0,627 | 0,632 |
| 0,88 | 0,0720 | 0,0721 | 0,0619 | 0,0721 | 0,000884 | 0,134 | 0,00317 | 0,0947 | 0,279 | 283 | 264 | 0,650 | 0,646 | 0,648 |
| 0,89 | 0,0720 | 0,0721 | 0,0619 | 0,0721 | 0,000886 | 0,134 | 0,00317 | 0,0947 | 0,279 | 284 | 265 | 0,652 | 0,648 | 0,650 |
| 0,53 | 0,0593 | 0,0602 | 0,0481 | 0,0598 | 0,000528 | 0,104 | 0,00191 | 0,0736 | 0,276 | 233 | 218 | 0,631 | 0,606 | 0,618 |
| 0,53 | 0,0593 | 0,0602 | 0,0481 | 0,0598 | 0,000526 | 0,104 | 0,00191 | 0,0736 | 0,275 | 232 | 217 | 0,628 | 0,603 | 0,616 |

**Table 4.31 Flow rate measurement of CMC 7.3% through V-notch**

V-Notch ( CMC 7,3%)

Yield stress (Pa)= 0

k (Pa.$s^n$)= 2,97

k' (Pa.$s^n$)= 3,25

n=n'= 0,611

$Tan(\vartheta/2)$= 0,414 g ($m/s^2$)= 9,813 $Cos(\vartheta/2)$= 0,924 Density ($kg/m^3$)= 1041

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | Reynolds number | $C_d1$ | $C_d2$ | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 3,55 | 0,1249 | 0,1254 | 0,1141 | 0,1252 | 0,00355 | 0,247 | 0,0108 | 0,175 | 0,329 | 135 | 123 | 0,657 | 0,650 | 0,654 |
| 3,55 | 0,1249 | 0,1254 | 0,1141 | 0,1252 | 0,00355 | 0,247 | 0,0108 | 0,175 | 0,329 | 135 | 123 | 0,657 | 0,650 | 0,654 |
| 3,20 | 0,1200 | 0,1208 | 0,1108 | 0,1204 | 0,00320 | 0,240 | 0,0102 | 0,170 | 0,315 | 125 | 114 | 0,656 | 0,646 | 0,651 |
| 3,20 | 0,1200 | 0,1208 | 0,1108 | 0,1204 | 0,00320 | 0,240 | 0,0102 | 0,170 | 0,315 | 125 | 114 | 0,655 | 0,646 | 0,650 |
| 2,90 | 0,1153 | 0,1160 | 0,1058 | 0,1157 | 0,00290 | 0,229 | 0,00928 | 0,162 | 0,313 | 120 | 110 | 0,656 | 0,646 | 0,651 |
| 2,90 | 0,1153 | 0,1160 | 0,1058 | 0,1157 | 0,00290 | 0,229 | 0,00928 | 0,162 | 0,313 | 120 | 110 | 0,656 | 0,646 | 0,651 |
| 2,60 | 0,1103 | 0,1112 | 0,1009 | 0,1108 | 0,00260 | 0,218 | 0,00844 | 0,154 | 0,308 | 114 | 104 | 0,656 | 0,644 | 0,650 |
| 2,60 | 0,1103 | 0,1112 | 0,1009 | 0,1108 | 0,00260 | 0,218 | 0,00844 | 0,154 | 0,308 | 114 | 104 | 0,656 | 0,644 | 0,650 |
| 2,30 | 0,1043 | 0,1053 | 0,0962 | 0,1048 | 0,00230 | 0,208 | 0,00767 | 0,147 | 0,299 | 107 | 97,4 | 0,668 | 0,651 | 0,660 |
| 2,30 | 0,1043 | 0,1053 | 0,0962 | 0,1048 | 0,00230 | 0,208 | 0,00767 | 0,147 | 0,299 | 107 | 97,4 | 0,668 | 0,652 | 0,660 |
| 2,01 | 0,0998 | 0,1000 | 0,0912 | 0,0999 | 0,00201 | 0,198 | 0,00690 | 0,140 | 0,292 | 99,8 | 91,1 | 0,655 | 0,651 | 0,653 |
| 2,01 | 0,0998 | 0,1000 | 0,0912 | 0,0999 | 0,00201 | 0,198 | 0,00690 | 0,140 | 0,292 | 99,8 | 91,2 | 0,655 | 0,651 | 0,653 |
| 1,69 | 0,0932 | 0,0936 | 0,0852 | 0,0934 | 0,00169 | 0,184 | 0,00602 | 0,130 | 0,281 | 90,8 | 82,9 | 0,652 | 0,645 | 0,649 |
| 1,70 | 0,0932 | 0,0936 | 0,0852 | 0,0934 | 0,00170 | 0,184 | 0,00602 | 0,130 | 0,282 | 91,2 | 83,3 | 0,655 | 0,648 | 0,651 |

V-Notch ( CMC 7,3%)

Yield stress (Pa)= 0

k ($Pa.s^n$)= 2,97

k' ($Pa.s^n$)= 3,25

n=n'= 0,611

Tan(ϑ/2)= 0,414 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,924 Density ($kg/m^3$)= 1041

| Flow | Gauge1 | Gauge2 | Gauge3 | Gauge Avg. | Flow | Wetted Perimeter | Area | Hydraulic Radius | Velocity | Reynolds number | Reynolds number | $C_d1$ | $C_d2$ | $C_d avg$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (l/s) | m | m | m | m | $m^3/s$ | m | $m^2$ | m | m/s | $Re_H$ | $Re_{MR}$ | | | |
| 1,41 | 0,0868 | 0,0873 | 0,0781 | 0,0871 | 0,00141 | 0,169 | 0,00505 | 0,120 | 0,279 | 85,2 | 77,8 | 0,648 | 0,639 | 0,644 |
| 1,42 | 0,0868 | 0,0873 | 0,0781 | 0,0871 | 0,00142 | 0,169 | 0,00505 | 0,120 | 0,281 | 86,0 | 78,6 | 0,653 | 0,644 | 0,648 |
| 1,12 | 0,0799 | 0,0802 | 0,0708 | 0,0800 | 0,00112 | 0,153 | 0,00415 | 0,108 | 0,270 | 76,7 | 70,1 | 0,636 | 0,630 | 0,633 |
| 1,12 | 0,0799 | 0,0802 | 0,0708 | 0,0800 | 0,00112 | 0,153 | 0,00415 | 0,108 | 0,269 | 76,2 | 69,6 | 0,633 | 0,627 | 0,630 |
| 0,84 | 0,0712 | 0,0717 | 0,0640 | 0,0715 | 0,000838 | 0,138 | 0,00339 | 0,0979 | 0,247 | 63,7 | 58,2 | 0,632 | 0,623 | 0,628 |
| 0,84 | 0,0712 | 0,0717 | 0,0640 | 0,0715 | 0,000842 | 0,138 | 0,00339 | 0,0979 | 0,248 | 64,1 | 58,6 | 0,635 | 0,625 | 0,630 |
| 0,52 | 0,0618 | 0,0622 | 0,0536 | 0,0620 | 0,000519 | 0,116 | 0,00238 | 0,0820 | 0,219 | 48,1 | 44,0 | 0,558 | 0,550 | 0,554 |
| 0,52 | 0,0618 | 0,0622 | 0,0536 | 0,0620 | 0,000519 | 0,116 | 0,00238 | 0,0820 | 0,219 | 48,2 | 44,0 | 0,558 | 0,550 | 0,554 |
| 0,66 | 0,0660 | 0,0664 | 0,0576 | 0,0662 | 0,000662 | 0,125 | 0,00275 | 0,0882 | 0,241 | 57,6 | 52,6 | 0,603 | 0,594 | 0,599 |
| 0,66 | 0,0660 | 0,0664 | 0,0576 | 0,0662 | 0,000662 | 0,125 | 0,00275 | 0,0882 | 0,241 | 57,6 | 52,7 | 0,604 | 0,595 | 0,599 |

**Table 4.32 Flow rate measurement of CMC 8.35% through V-notch**

V-Notch ( CMC 8,35%)

Yield stress (Pa)= 0

k ($Pa.s^n$)= 3,42

k' ($Pa.s^n$)= 3,75

n=n'= 0,609

Tan(ϑ/2)= 0,41421 g ($m/s^2$)= 9,813 Cos(ϑ/2)= 0,92388 Density ($kg/m^3$)= 1048

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,90 | 0,1173 | 0,1179 | 0,1065 | 0,1176 | 0,00290 | 0,449 | 0,00940 | 0,0837 | 0,309 | 69,2 | 63,2 | 0,629 | 0,622 | 0,625 |
| 2,89 | 0,1173 | 0,1179 | 0,1065 | 0,1176 | 0,00289 | 0,231 | 0,00940 | 0,163 | 0,307 | 103 | 94,2 | 0,626 | 0,618 | 0,622 |
| 2,66 | 0,1138 | 0,1148 | 0,1037 | 0,1143 | 0,00266 | 0,224 | 0,00891 | 0,159 | 0,299 | 97,5 | 89,0 | 0,622 | 0,609 | 0,616 |
| 2,66 | 0,1138 | 0,1148 | 0,1037 | 0,1143 | 0,00266 | 0,224 | 0,00891 | 0,159 | 0,299 | 97,5 | 89,1 | 0,622 | 0,609 | 0,616 |
| 2,32 | 0,1082 | 0,1091 | 0,0984 | 0,1087 | 0,00232 | 0,213 | 0,00802 | 0,151 | 0,289 | 90,2 | 82,4 | 0,615 | 0,602 | 0,608 |
| 2,33 | 0,1082 | 0,1091 | 0,0984 | 0,1087 | 0,00233 | 0,213 | 0,00802 | 0,151 | 0,290 | 90,8 | 82,9 | 0,618 | 0,604 | 0,611 |
| 2,02 | 0,1029 | 0,1038 | 0,0947 | 0,1034 | 0,00202 | 0,205 | 0,00743 | 0,145 | 0,271 | 80,7 | 73,7 | 0,606 | 0,593 | 0,599 |
| 2,01 | 0,1029 | 0,1038 | 0,0947 | 0,1034 | 0,00201 | 0,205 | 0,00743 | 0,145 | 0,271 | 80,6 | 73,6 | 0,605 | 0,592 | 0,599 |
| 1,72 | 0,0968 | 0,0976 | 0,0868 | 0,0972 | 0,00172 | 0,188 | 0,00625 | 0,133 | 0,275 | 77,9 | 71,1 | 0,601 | 0,590 | 0,595 |
| 1,71 | 0,0968 | 0,0976 | 0,0868 | 0,0972 | 0,00171 | 0,188 | 0,00625 | 0,133 | 0,274 | 77,5 | 70,8 | 0,599 | 0,588 | 0,594 |
| 1,32 | 0,0885 | 0,0889 | 0,0795 | 0,0887 | 0,00132 | 0,172 | 0,00523 | 0,122 | 0,252 | 65,5 | 59,8 | 0,578 | 0,571 | 0,575 |
| 1,32 | 0,0885 | 0,0889 | 0,0795 | 0,0887 | 0,00132 | 0,172 | 0,00523 | 0,122 | 0,252 | 65,3 | 59,6 | 0,577 | 0,570 | 0,574 |
| 1,09 | 0,0828 | 0,0828 | 0,0730 | 0,0828 | 0,00109 | 0,158 | 0,00441 | 0,112 | 0,247 | 60,3 | 55,1 | 0,563 | 0,563 | 0,563 |
| 1,09 | 0,0828 | 0,0828 | 0,0730 | 0,0828 | 0,00109 | 0,158 | 0,00441 | 0,112 | 0,247 | 60,3 | 55,1 | 0,563 | 0,563 | 0,563 |

V-Notch ( CMC 8,35%)

Yield stress (Pa)= 0

k (Pa.s$^n$)= 3,42

k' (Pa.s$^n$)= 3,75

n=n'= 0,609

Tan(ϑ/2)= 0,41421  g (m/s$^2$)= 9,813  Cos(ϑ/2)= 0,92388  Density (kg/m$^3$)= 1048

| Flow (l/s) | Gauge1 m | Gauge2 m | Gauge3 m | Gauge Avg. m | Flow $m^3/s$ | Wetted Perimeter m | Area $m^2$ | Hydraulic Radius m | Velocity m/s | Reynolds number $Re_H$ | Reynolds number $Re_{MR}$ | $C_d$ 1 | $C_d$2 | $C_d$avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,74 | 0,0732 | 0,0735 | 0,0651 | 0,0734 | 0,000736 | 0,141 | 0,00351 | 0,0997 | 0,210 | 44,9 | 41,0 | 0,519 | 0,513 | 0,516 |
| 0,74 | 0,0732 | 0,0735 | 0,0651 | 0,0734 | 0,000736 | 0,141 | 0,00351 | 0,0997 | 0,209 | 44,8 | 40,9 | 0,519 | 0,513 | 0,516 |
| 0,88 | 0,0775 | 0,0780 | 0,0681 | 0,0778 | 0,000881 | 0,147 | 0,00384 | 0,1042 | 0,229 | 52,3 | 47,7 | 0,537 | 0,530 | 0,534 |
| 0,88 | 0,0775 | 0,0780 | 0,0681 | 0,0778 | 0,000881 | 0,147 | 0,00384 | 0,1042 | 0,229 | 52,3 | 47,7 | 0,537 | 0,530 | 0,534 |
| 0,53 | 0,0656 | 0,0667 | 0,0569 | 0,0662 | 0,000528 | 0,123 | 0,00268 | 0,0871 | 0,197 | 37,8 | 34,6 | 0,489 | 0,469 | 0,479 |
| 0,53 | 0,0656 | 0,0667 | 0,0569 | 0,0662 | 0,000528 | 0,123 | 0,00268 | 0,0871 | 0,197 | 37,8 | 34,6 | 0,489 | 0,469 | 0,479 |
| 0,34 | 0,0576 | 0,0587 | 0,0494 | 0,0581 | 0,000341 | 0,107 | 0,00202 | 0,0756 | 0,169 | 28,0 | 25,6 | 0,437 | 0,418 | 0,428 |
| 0,34 | 0,0576 | 0,0587 | 0,0494 | 0,0581 | 0,000342 | 0,107 | 0,00202 | 0,0756 | 0,169 | 28,2 | 25,8 | 0,439 | 0,420 | 0,429 |
| 0,12 | 0,0453 | 0,0457 | 0,0391 | 0,0455 | 0,000118 | 0,0846 | 0,00127 | 0,0599 | 0,0933 | 10,7 | 9,7 | 0,277 | 0,271 | 0,274 |
| 0,12 | 0,0453 | 0,0457 | 0,0391 | 0,0455 | 0,000117 | 0,0846 | 0,00127 | 0,0599 | 0,0926 | 10,6 | 9,6 | 0,275 | 0,269 | 0,272 |
| 0,23 | 0,0519 | 0,0532 | 0,0443 | 0,0526 | 0,000228 | 0,0958 | 0,00162 | 0,0678 | 0,140 | 20,3 | 18,5 | 0,379 | 0,356 | 0,367 |
| 0,23 | 0,0519 | 0,0532 | 0,0443 | 0,0526 | 0,000227 | 0,0958 | 0,00162 | 0,0678 | 0,140 | 20,2 | 18,5 | 0,378 | 0,355 | 0,367 |
| 0,15 | 0,0474 | 0,0488 | 0,0412 | 0,0481 | 0,000154 | 0,0893 | 0,00141 | 0,0631 | 0,109 | 13,7 | 12,5 | 0,322 | 0,300 | 0,311 |
| 0,16 | 0,0474 | 0,0488 | 0,0412 | 0,0481 | 0,000156 | 0,0893 | 0,00141 | 0,0631 | 0,111 | 14,0 | 12,8 | 0,325 | 0,303 | 0,314 |