HYDRAULIC CHARACTERISTICS OF MODIFIED TYROLEAN TYPE INTAKES

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submitted by **KUTAY YILMAZ** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Civil Engineering Department, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences** ________________

Prof. Dr. Ahmet Türer
Head of Department, **Civil Engineering** ________________

Prof. Dr. Mustafa Göğüş
Supervisor, **Civil Engineering, METU** ________________

Prof. Dr. Mete Köken
Co-Supervisor, **Civil Engineering, METU** ________________

Examining Committee Members:

Prof. Dr. Ayşe Burcu Altan Sakarya
Civil Engineering, METU ________________

Prof. Dr. Mustafa Göğüş
Civil Engineering, METU ________________

Prof. Dr. Mehmet Ali Kökpınar
Civil Engineering, TED University ________________

Asst. Prof. Dr. Aslı Numanoğlu Genç
Civil Engineering, TED University ________________

Asst. Prof. Dr. Elif Oğuz
Civil Engineering, METU ________________

Date: 13.12.2019

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Surname: Kutay Yılmaz

Signature:

ABSTRACT

HYDRAULIC CHARACTERISTICS OF MODIFIED TYROLEAN TYPE INTAKES

Yılmaz, Kutay
Doctor of Philosophy, Civil Engineering
Supervisor: Prof. Dr. Mustafa Göğüş
Co-Supervisor: Prof. Dr. Mete Köken

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Today, besides the dams, construction of runoff-river type hydroelectric power plants are also important for producing the required electricity. Among the runoff-river hydroelectric power plants, Tyrolean type intakes are very popular as they do not need reservoirs. These intakes are mostly constructed on rivers which carry sediment and have large slopes. The inclination angle of the rack, θ, rack length, L, and the rack spacing, e, are the most important parameters that determine the amount of sediment that will enter into the collection channel. Although there are empirical equations in the literature to determine these parameters, they are not sufficient to make an economical design. There are no methods to decrease the amount of sediment that enters into the collection channel and the amount of material that deposits in the settling basin. The aim of this study is to make an arrangement inside the collection channel of the Tyrolean intake having optimum rack slope so that sediment entering here will be given back to the downstream part of the river without being sent to the settling basin. By doing this, the requirement of a large settling basin will be eliminated and it will be possible to supply water containing very fine sediment or no sediment to the turbines. For this reason, a large series of experiments were conducted in a modified Tyrolean type intake model having a rack slope of θ= 23°, at the laboratory with and without sediment. The primary dimensions of the "Collection Channels" located just underneath the rack for collecting water and sediment were changed and investigated. Eventually, the relevant dimensionless parameters of the collection channels resulting in minimum amount of sediment passage to the intake channel were determined.

An attempt was also made to verify the results of the experimental study by modeling the modified Tyrolean intake numerically. The software of Flow-3D was used in the analysis and it was shown that the results of the numerical analysis are compatible with those of experimental studies when the tests were conducted with only water. Due to the constraints of the software, real physical conditions of the experiments with sediment can not be represented in the numerical simulations.

Keywords: Open Channel Flow, Tyrolean Weir, Bottom Intake Structure, Computational Fluid Dynamics, Sediment Transport, Settling Basin.

ÖZ

MODİFİYE EDİLMİŞ TİROL TİPİ SAVAKLARIN HİDROLİK KARAKTERİSTİKLERİ

Yılmaz, Kutay
Doktora, İnşaat Mühendisliği
Tez Danışmanı: Prof. Dr. Mustafa Göğüş
Ortak Tez Danışmanı: Prof. Dr. Mete Köken

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Günümüzde büyük gereksinim duyulan elektrik enerjisi üretimi için barajların yanı sıra nehir tipi santralların yapımı da önem arz etmektedir. Nehir tipi santrallar arasında en çok ilgi görenler, su biriktirme yapısı gerektirmeyen ve daha çok eğimi fazla olan ve katı madde taşıyan nehirler üzerine inşa edilen "Tirol tipi" su alma yapısına sahip olanlardır."Tirol tipi su alma yapısı" nın en önemli elamanı, sedde boyunca yer alan demir ızgaralardır. Bu ızgaraların yatayla yaptığı açı, θ, ızgaraların boyu, L, ve ızgara aralıkları, e, nehirden alınacak olan su ve katı madde miktarını belirleyen en önemli parametrelerdir. Literatürde bu parametrelerin hesaplanmalarında kullanılabilecek ampirik bağıntılar ve diyagramlar bulunmakla beraber bunlar ekonomik boyutlandırmaların yapılabilmesi için yeterli değildir. Bilhassa ızgaranın altında yer alan toplama kanalına gelecek olan katı madde miktarını ve buradan çökeltme havuzuna geçecek olan katı madde miktarını azaltacak metodlar mevcut değildir. Bu çalışmanın amacı, en ideal eğime sahip Tirol tipi savağın " su ve katı madde toplama kanalı" içinde yeni bir düzenleme yaparak, savağın içine giren katı maddeleri çökeltim havuzuna göndermeden tekrar savaktan nehrin mansap kısmına iletebilmektir. Bu durumda, sisteme büyük ölçekli bir çökeltim havuzunun yapılmasına gereksinim olmayacak ve enerji hattına içinde katı madde olmayan, sadece kabul edilebilir

boyutlarda askı halinde az miktarda katı madde bulunan suyun iletilmesi mümkün olacaktır.

Bu sebeple ızgaranın yatayla yaptığı açı, θ= 23°, olan modifiye edilmiş bir Tirol tipi savak kullanılarak laboratuvarda bir dizi deney yapılmıştır. Deneyler esnasında, ızgaranın hemen altında yer alan ve su ile sedimentin toplanmasını sağlayan "Toplama Kanalının" temel boyutları değiştirilerek incelemiştir. Deneyler sonucunda su alma kanalına minimum miktarda sediment ve maksimum miktarda su alınmasına olanak sağlayan boyutsuz parametreler belirlenmiştir.

Ayrıca yapılan deneyler nümerik olarak simüle edilmiş ve modifiye edilmiş Tirol tipi savağın nümerik sonuçları deneysel sonuçlar ile karşılaştırılmıştır. Nümerik çalışmada Flow-3D paket programı kullanılmıştır. Sadece su ile yapılan deneylerin sonuçları nümerik model ile uyuşmaktadır fakat sediment kullanılarak yapılan deneylerin gerçek fiziksel koşulları, programda mevcut olan sınırlamalardan dolayı simülasyonlarda yansıtılamamıştır.

Anahtar Kelimeler: Açık Kanal Akımı,Tirol Tipi Savak, Dip Su Alma Yapısı, Hesaplamalı Akışkanlar Mekaniği, Sediment Taşınımı, Çökeltim Havuzu.

To beloved family and my lovely wife

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LIST OF ABBREVIATIONS

ABBREVIATIONS

CFD	: Computational Fluid Dynamics
DPH	: Dividing Plate Height
GPL	: Guide Plate Length

LIST OF SYMBOLS

SYMBOLS

a	: Distance between two neighbour bars
B	: Width of collection channels
B_{mc}	: Width of the main channel
C_d	: Coefficient of discharge
d_{50}	: Median diameter of sediment
e_i	: Clear bar spacing (i=1,2,3,4)
F_H	: Froude number of approaching flow
$(F_r)_e$	: Modified froude number
g	: Gravitational accelaration
h_c	: Critical water depth
H	: Approaching flow depth
L	: Rack length
L_1	: Wetted rack length 1
L_2	: Wetted rack length 2
$(q_w)_{ic}$	: Unit discharge that reaches to the "Intake Channel"
$(q_w)_T$	: Unit discharge present within the main channel
$(Q_w)_{ic}$	: Discharge passing through racks
$(Q_w)_{sc}$	: Discharge within the "Sediment Collection Channel"
$(Q_w)_t$	: Main channel discharge
$(S_{cc})_1$	: Bottom slope of collection channel 1
$(S_{cc})_2$	: Bottom slope of collection channel 2
t	: Thickness of the bars
T	: Gate opening
U	: Approaching flow velocity
$(w_s)_{sc}$	: Weight of sediment per unit width of the main channel that reaches to the "Intake Channel"
$(W_s)_T$	: Total weight of the sediment placed upstream of the main channel
$(W_s)_o$	: Weight of the seidment passed over the rack and remained at the downstream of the main channel
$(W_s)_{rack}$	: weight of the sediment that passes through the rack inside the "Intake Structure"
$(W_s)_{cc}$	: Weight of the sediment retained in the "Collection Channel-1"
$(W_s)_{ic}$	: Weight of the sediment retained in the "Intake Channel"
$(W_s)_{sc}$	: Weight of the sediment retained in the "Sediment Discharge Channel"
$[(W_s)_{cc}]_R$	: Ratio of sediment within sediment "Collection Channel" to the weight

		the sediment present in main channel
$[(W_s)_{ic}]_R$	:	Ratio of sediment within "Intake Channel" to the weight of the sediment present in the main channel
$[(W_s)_{sc}]_R$	:	Ratio of sediment within "Sediment Collection Channel" to the weight of the sediment present in main channel
y_i	:	Water depth of the "Intake Channel"
y_0	:	Water depth of the main channel
y_{sc}	:	Water depth of the "Sediment Discharge Channel"
Z_1	:	Height of dividing plate
Z_2	:	Length of guide plate
α	:	Angle between guide plate and horizontal
μ	:	Viscosity of water
θ	:	Angle between rack and horizontal
ρ_s	:	Density of sediment
ρ_w	:	Density of water
ω	:	Rack porosity

CHAPTER 1

INTRODUCTION

1.1. General Remarks

Energy is the key for social, economic and industrial development. After the industrial revolution, energy demand all over the world has increased day by day. Increasing population and industrialization resulted in increasing energy demand. Energy production can be divided into two main categories in terms of resources used for production; renewable and non-renewable.

Renewable energy source potential depends on geographic location. For example, energy production efficiency from solar power is lower than the efficiency from the hydropower in British Columbia, Canada. On the other hand, Energy production efficiency from solar power is higher than the hydropower in Algeria. According to the report by World Energy Council (2016), hydropower is the only renewable that generates a significant portion of world's electricity compared to other renewable energy resources.

Energy demand of British Columbia is 2141 TWH and 85 % of this demand is fulfilled by hydropower (Helston & Farris, 2017). According to TEİAŞ report (2017) total installed energy capacity is 841 TWH in 2017 and 31.1 % of it is fulfilled by hydropower. In addition, Norway fulfilled nearly whole energy demand by hydropower (International Hydropower Association, 2019).

After the construction of the first hydropower project in Northumberland, England in 1878, hydropower has gained importance (International Hydropower Association, 2018). Due to the importance of clean energy production and potential, governments aim to increase installed capacity of hydropower. Hydropower capacity have been extended all over the world by constructing large hydropower plants and small hydropower plants throughout the decades. Due to the long period of construction, high capital costs, difficult operating conditions and non-significant environmental effects of large hydropower plants, small hydropower plants have been propelled into the energy scene.

Operating principle of run off river hydropower plants is diverting sufficient amount of water from river and conveying discharge to a channel or penstock, which leads to a powerhouse where energy of the flowing water spins the turbines that drive energy generator. Due to the running water in the nature, sediment can be present in the diverted water and can damage the turbines.

Bottom rack intakes are commonly used structures in hydraulic engineering to divert sufficient amount of water from mountains, streams and torrents for electricity and supply purposes. Due to the nature of mountains and rivers discharge contains solid materials that can be prevented from diverted water. In order to prevent solid materials from diverted water and provide enough water for electricity purposes bottom racks are used (Brunella & Hager, 2003).

In this study, it was aimed to increase the diverted amount of water while minimizing sediment in the diverted discharge by configuring collection channel placed below the bottom of racks and to determine the parameters that affect the hydraulic performance of the bottom racks. Moreover, a numerical model was constructed and some of the experiments were simulated. By validating the numerical model with the experimental results, the design parameters that have not been tested could be determined and optimized.

1.2. Objective of the Study

Objective of this study is to design a Tyrolean Weir which can be named as "Modified-Tyrolean Weir" to accomplish a more efficient energy production chamber. In order to accomplish a new design, a new bottom rack with its components was designed and the parameters within the design were optimized so that a general formula for designing a Tyrolean Weir was determined.

Due to common use of the bottom intakes, lots of studies have been conducted to investigate and comprehend hydraulic behavior of bottom intakes throughout the history. However, there are few studies considering the effect of sediment in the design of bottom intakes and rack behavior. In this study, a large series of experiments were conducted under sediment load to determine the hydraulic behavior of the specific Tyrolean weir modelled at the laboratory with several parameters.

1.3. Outline of the Thesis

The outline of the thesis is given as follows. Chapter 2 covers the literature review with the reviews of the studies conducted experimentally and numerically related to bottom intake design. Experimental setup and procedure are explained in Chapter 3. Dimensionless parameters related to newly designed bottom intake are given in Chapter 4. Results of the experiments are presented and discussed in Chapter 5. Numerical modelling procedure and its results are presented in Chapter 6 and Chapter 7, respectively. Finally, results of the study are discussed in Chapter 8.

CHAPTER 2

LITERATURE REVIEW

2.1. General Remarks

The aim of this study is to determine design considerations to improve performance of bottom intakes by increasing diverted amount of discharge and removing sediment from diverted discharge as far as possible. A series of experiments have been conducted to investigate and to comprehend hydraulic behavior of bottom intakes throughout the history. Therefore, previous studies both experimental and numerical ones are examined and brief summary of those are given in this chapter.

2.2. Investigation of Previous Studies of Bottom Intake Design

One of the earliest studies was conducted by Orth (1954) who first defined the bottom racks. The study has focused on investigating the effect of rack angle and rack shape on diverted discharge. Moreover, racks with five different geometry such as basic T-profile, T-profile with a triangular top, circular profile, semi-circular profile and ovoid profile on a channel with a 20 % of bottom slope have been tested within the scope of the study and it was concluded that T-profile bars requires longer bar length to divert the same amount of discharge compared to ovoid profile bars. In addition, effect of rack angle on clogging was negligible (Brunella & Hager, 2003).

Kuntzmann and Bouvard (1954) conducted a study to determine water surface profile over bottom racks. An approach was developed by assuming a constant energy head over bottom racks and by considering orifice equation. Therefore, the study had ended up with sixth order differential equation for determining water surface profile over bottom racks.

Various projects were conducted around the Savoy region of French Alps by Ract-Madoux (1955) and generalized design considerations for bottom racks were presented. According to the study some important items of the design considerations are as follows;

- Discharges of water and sediment are important,
- To divert maximum amount of discharge, bars should be in rounded profiles along the streamwise direction.
- To reduce the risk of clogging due to sediment, bottom slope of the rack should be greater than 20 % (Brunella & Hager, 2003).

A study conducted by Frank (1956) shows that calculation of wetted rack length is essential for predicting diverted discharge correctly. They proposed equations for wetted rack length and coefficient of discharge depending on the following assumptions;

- There is no head loss along the rack,
- Flow is critical at the upstream of the racks,
- Diverted discharge equals to the total discharge on the main channel.

Frank (1956) proposed the following equation for rack length;

$$L = 2.561\frac{(q_w)_T}{\lambda\sqrt{h_0}} \tag{2.1}$$

Where;

$\lambda = \varphi\mu_s\sqrt{2gcos\theta}$

φ=e/a, is the coefficient of discharge,

e is the net distance between rack bars,

a is the distance measured from the center of a bar to the central of the neighbor bar,

$\mu_s = 0.8052\varphi^{-0.16}(a/h_0)^{0.13}$ contraction coefficient, g is the gravitational acceleration,

h_0 is the water depth at the upstream of the racks.

$h_0 = \chi h_c$

χ is the reduction coefficient and it can be calculated as follows;

$$2\cos\theta\,\chi^3 - 3\chi^2 + 1 = 0 \tag{2.2}$$

Where;

θ is the slope of the screen or rack,

h_c is the critical depth and it can be expressed as follow;

$$h_c = \sqrt[3]{\frac{(q_w)_T^2}{g}} \tag{2.3}$$

$(q_w)_T$ is the unit discharge of the main channel.

Noseda (1956) conducted a series of experiments to determine the wetted rack length and suggested the following equation by assuming constant head over the bottom rack.

$$L = 1.185\frac{h_c}{\mu_m \varphi} \tag{2.4}$$

Where;

$\mu_m = 1.22\mu$ and

μ is the viscosity of water.

These equations are valid only for horizontal racks due the assumption made by Noseda.

Drobir et al. (1999) conducted a series of experiments on a laboratory model with a scale of 1:10 in University of Technology of Vienna. Main channel width is 5 m and bottom racks are made of circular bars that are 10 cm in diameter. The parameters that were tested under different discharge conditions are; clear bar spacing of 10 cm and 15 cm, slope of the rack varying between 10 % - 30 %. Wetted rack lengths, L_1 and L_2 which are shown in Figure 2.1, were obtained as a result of the experiments and these lengths were compared to those of Frank (1956) and Noseda (1956). According to the study, there is a significant difference between the measured rack lengths and the rack length predicted by Noseda and Frank under low discharge conditions. On the other hand, the difference decreases with increasing discharge.

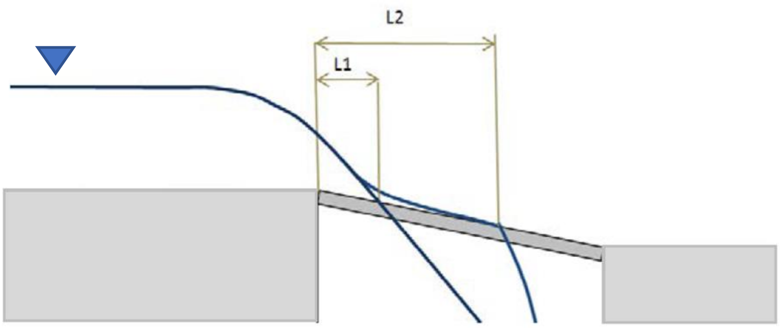

Figure 2.1. Scheme of Wetted Rack Lengths L_1 and L_2 and Shape of Nappe (Drobir et al., 1999)

Brunella and Hager (2003) conducted a series of experiments on a 7 m long and 0.5 m wide laboratory model to determine effect of clear bar spacing, rack angle and geometry of racks on a diverted discharge. Wide variety of values for the parameters were tested throughout the study such as two different clear bar spacings (3 mm, 6 mm), two different rack lengths (0.45 m and 0.6 m) and eight different rack angles (0°, 7°, 19° ,28°, 35°, 39°,44° and 51°). A new equation was provided for diverting whole discharge from the main channel in a dimensionless form.

$$C_d \omega \left(\frac{L_2}{h_c}\right) = 0.83 \quad (2.5)$$

Where;

C_d is the coefficient of discharge,

h_c is the critical water depth,

ω is the rack porosity defined as ratio of net effective area between bars to channel width.

$\omega = A_n/w$

C_d is the coefficient of discharge and it varies between 0.87 and 1.10 and depends on ω .

An experimental study was conducted by Ghosn and Ahmad (2006) to investigate discharge characteristics of bottom intakes with flat bars. In order to calculate discharge coefficient, following equation was proposed by assuming constant head over the racks;

$$C_d = 0.1296\left(\frac{t}{e}\right) - 0.4284(tan\theta)^2 + 0.1764 \qquad (2.6)$$

Where; t is thickness of the bars.

The equation is valid for screens with flat bars and it predicts coefficient of discharge by 10 % error. In addition, it was noted that equation was derived by limited number of experiments and a lot of experiments were needed for determining coefficient of discharge more correctly (Ahmad and Mittal, 2006).

Righetti and Lanzoni (2008) conducted a study to investigate variation of diverted discharge with rack length, coefficient of discharge and modified Froude number. In this context, a laboratory flume of 12 m in length, 0.25 m in width and varying slope was constructed. Slope of the Tyrolen weir was the same as the channel slope, rack length was 0.45 m and void ratio was 0.2. Furthermore, total discharge within the system and velocity profile over the racks were measured by using laser doppler aneometer. As a result, Righetti and Lanzoni proposed the following equation;

$$(q_w)_i = C_d \cdot \omega \cdot w \cdot L\sqrt{2gH}\left(\frac{\gamma}{2}\frac{L}{H}F_H + 1\right)tanh\left[b_0(\sqrt{2} - F_H)^{b_1}\right] \tag{2.7}$$

Where;

C_d is the coefficient of discharge for longitudal racks varies between 0.95 to 1.

w is the channel width,

H is the approaching flow depth,

F_H is modified Froude number,

$$F_H = \frac{U}{\sqrt{gH}}$$

Where;

U is the velocity of approaching flow within the main channel,

Other empirical constants are;

γ = 0.1056, b_0 = 1.5 and b_1 = 0.6093

The above equation provided by Righetti and Lanzoni gives similar results to those of Noseda's (1956). Difference between diverted discharges is about 15 % which is caused by the horizontal rack assumption that was made by Noseda.

Kamandebast and Bejestan (2008) conducted a series of experiments to investigate the effect of rack inclination and net effective void ratio on a diverted discharge. The experiments were conducted on a laboratory flume which is 8 m in length, 60 cm in width and 60 cm in height. Void ratio has been varied between 30 % and 40 % whereas the bar diameters were selected as 6 mm and 8 mm. In addition, four different rack inclinations (10 %, 20 %, 30 % and 40 %) have been tested under the different discharge conditions. It was concluded that the diverted discharge is only affected by rack inclination and void ratio. Moreover, increment in rack angle causes diverted discharge to increase to a certain point which was the maximum discharge that could be diverted. After having reached to the maximum, there was a sharp decrease in a diverted discharge. Moreover, best hydraulic performance in terms of diverting discharge can be obtained if the rack slope is about 30 % which is consistent with the results of the study of Ract-Madoux (1955). In addition, there exist experiments with sediment but results were not explained except for reduction of diverted discharge by 10 % due to clogging of screens by sediment.

Aghmandji & Heydari (2014) conducted experimental and numerical study to develop relationship between coefficient of discharge and other physical parameters for optimum design of bottom racks. In this context, a laboratory flume of 60 cm width and 8 m length was constructed and experiments were conducted under different rack sizes, area openings and discharge conditions. It was concluded that, best hydraulic performance in terms of diverting discharge can be achieved by selecting rack slope as 30 % and rack opening as 40 %.

Castillo et al. (2013) carried out a numerical study and compared the results with the those of Noseda's (1956) and Drobir's (1981) experimental results under the clear water conditions by using FLOW-3D. According to Castillo, more and more experimental study was needed to improve the knowledge about bottom intake structures but numerical results are close to experimental one with an error of 15 %.

Castillo et al. (2016) conducted experimental and numerical study to investigate optimal rack slope and effective void ratio as well. The experiments were conducted on a 5 m long, 0.5 m wide and 0.3 m height channel with bar spacings of 5.7 mm, 8.5 mm and 11.7 mm. Bars are in T-shape and 0.9 m in length. Experimental results were compared with the numerical ones obtained by ANSYS CFX. Therefore, optimal longitudinal rack slope was determined as 30 % and numerical results were found compatible with the experimental one even if the flow conditions and slopes were changed.

Yılmaz (2010), Şahiner (2012) and Melek (2017) conducted experiments with and without sediment in the Hydraulic Laboratory of Civil Engineering Department of Middle East Technical University in order to determine hydraulic characteristics of Tyrolean weirs. The experiments were conducted on a flume which has a length of 7 m and width of 1.98 m for a wide range of discharges. The screen made of aluminum bars of circular cross-section which is 1 cm in diameter and clear distances between two adjacent bars are 3 mm, 6mm and 10 mm. The same experimental setup was used within the scope of the all three studies except the rack inclinations. Yılmaz (2010) tested rack inclinations of 4.8°, 9.6° and 14.5° whereas Şahiner (2012) tested 27.8°, 32° and 37° In the latest study, Melek (2017) tested rack inclinations of 19° and 23° to cover the gap between these rack inclinations stated above. Moreover, variation of discharge coefficient, wetted rack length and diverted discharge with respect to main channel discharge were investigated for diverting maximum amount of discharge with minimum sediment. The most important design parameter was the rack angle. Melek (2017) determined a range for rack angle to divert maximum amount of water with minimum sediment by comparing his results with those of Yılmaz (2010) and Şahiner (2012). According to Melek's study (2017) all these three studies suggest that the rack angle should be between 22° and 25° to obtain maximum performance from Tyrolean weir setup in terms of diverting maximum amount of water. In addition, Melek (2017) conducted numerical simulations by using FLOW-3D to validate the numerical results with the experimental ones and it was stated that results of the both studies were consistent.

CHAPTER 3

EXPERIMENTAL SETUP AND PROCEDURE

3.1. Introduction

The experiments were conducted at a laboratory flume in the Hydromechanics Laboratory of the Civil Engineering Department at Middle East Technical University. Information about the experimental procedure, laboratory flume, sediment characteristics, and measurement techniques were presented in the following sections.

3.2. Overview

Yılmaz (2010), Şahiner (2012) and Melek (2017) conducted series of experiments in a laboratory flume to determine the optimum angle of the rack of Tyrolean intake to provide maximum amount of water to the transmission line. The optimum angle range of the rack for capturing maximum amount of water was determined as $22° \leq \theta \leq 25°$. For a given range of rack angle, water capture efficiency increased considerably. However, sediment amount conveyed by the discharge could not be minimized. In order to increase water capture efficiency further and to decrease the sediment amount captured by the racks, modifications were implemented in the existing experimental setup. As a result, the experimental setup shown in Figure 3.1 comes up.

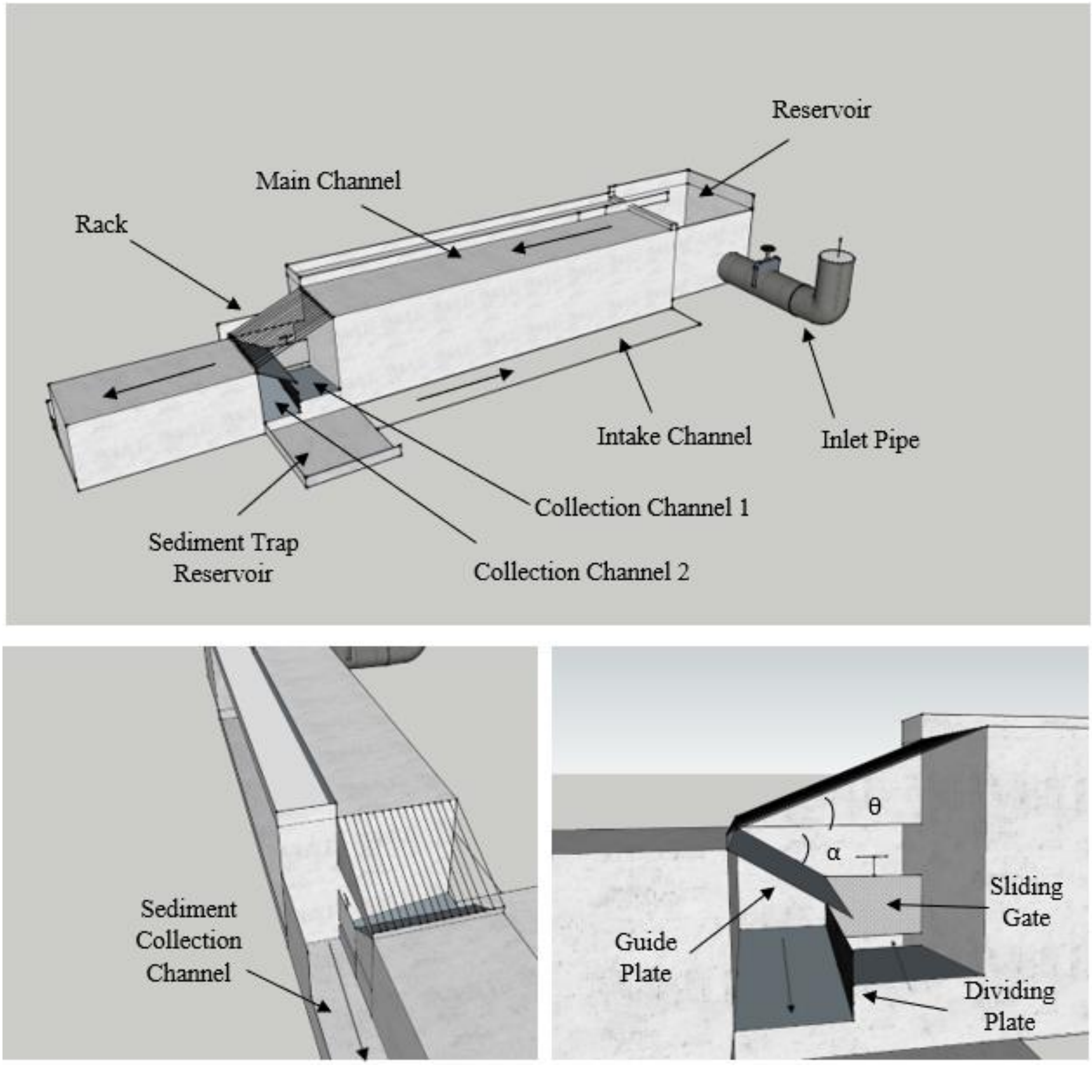

Figure 3.1. Schematic representation of the experimental setup

The experimental setup consists of “Main Channel”, “Rack”, “Collection Channel-1”, “Collection Channel-2”, “Sediment Collection Channel” and “Intake Channel”. The main Channel is 1.30 m in width and approximately 7.0 m in length. At the upstream of the main channel, there is a reservoir that supplies water to the main channel. At the downstream of the main channel, there exists a rack which is made of aluminum bars of circular cross-section. Aluminum bars are 1.0 cm in diameter and 70.0 cm in length. Throughout the experiments, the rack length was kept constant as 70.0 cm and the angle between the rack and horizontal direction was selected as 23° as a result of the previous studies.

The channel below the rack is divided into two parts by placing a “Dividing Plate” just at the middle of the channel. The first part is named as “Collection Channel-1” and it mainly diverts sediment to the “Sediment Collection Channel” while the “Collection Channel-2” diverts mainly water to the “Intake Channel”. Upstream of the “Collection Channel-1” is completely closed and a vertical “Sliding Gate” is placed at the downstream part of the “Collection Channel-1”. By opening the gate at a certain height, the sediment and some of the discharge are allowed to pass through the opening and move along the “Sediment Collection Channel”. Upstream of the “Collection Channel-2” is completely closed while downstream of it is completely open to convey the flow to the “Intake Channel”. “Collection Channel-1” and “Collection Channel-2” are 45.0 cm in width and 1.30 m in length. Both of the channels have a slope of 4° in reverse directions. In addition, there is a metal plate named as “Guide Plate” which is placed just downstream of the screen. Its length and angle with horizontal direction can be adjusted. Therefore, it diverts the flow and sediment particles coming from the main channel and passing through the rack to “Collection Channel-1”.

The working principle of the system described above can be summarized as follows: a part of the water and sediment particles coming from the main channel will be conveyed to the collection channel placed under the rack according to the type of rack being used and the remaining part will continue to move in the main channel from the downstream of the rack.

Considerable portion of the sediment particles moving together with the water in the main channel will be poured into the "Collection Channel-1" via the rack. A major part of this sediment will move through “Collection Channel-1” along with water and reaches the “Sediment Collection Channel” after passing through the opening of the “Sliding Gate”.

As the flow rate in the "Collection Channel-1" increases, the water level in this channel increases and the excess water will pass over the "Dividing Plate" to the "Collection Channel-2" and from there it will continue to flow into the “Intake Channel”. Since the height of the “Dividing Plate” is higher than the base floors of the both channels, sediment particles moving at the bottom of the "Collection Channel-1" are prevented from passing into the “Collection Channel 2”. Only some of the suspended sediment particles in the “Collection Channel-1” may pass to the "Collection Channel-2".

The water and sediment particles passing from the rack are also directed into the "Collection Channel-1" by means of the “Guide Plate”. As a result, considerable portion of the sediment particles passing from the rack throughout rack length is taken into the "Collection Channel-1", from which it is directed to the “Sediment Collection Channel” and then to the downstream of the main channel. The flow with relatively small amount of solids moves towards the “Intake Channel” and will reach to the turbines leaving the solids contained in the sediment trap reservoir.

As it can be understood from the above explanations, the purpose of the current study is to separate considerable amount of sediment particles that passes under the rack and direct it to the downstream of the main channel, and to convey the smallest amount of suspended sediment particles to the sediment trap reservoir. As a result, it can be stated that sedimentation reservoirs of Tyrolean Intakes can be constructed at a small scale and they can be cleaned in a short time due to the presence of small and fine-grained solid materials.

3.3. Experimental Setup

Figures 3.2-3.11 show the sketches and some photos of the experimental setup taken from different angles.

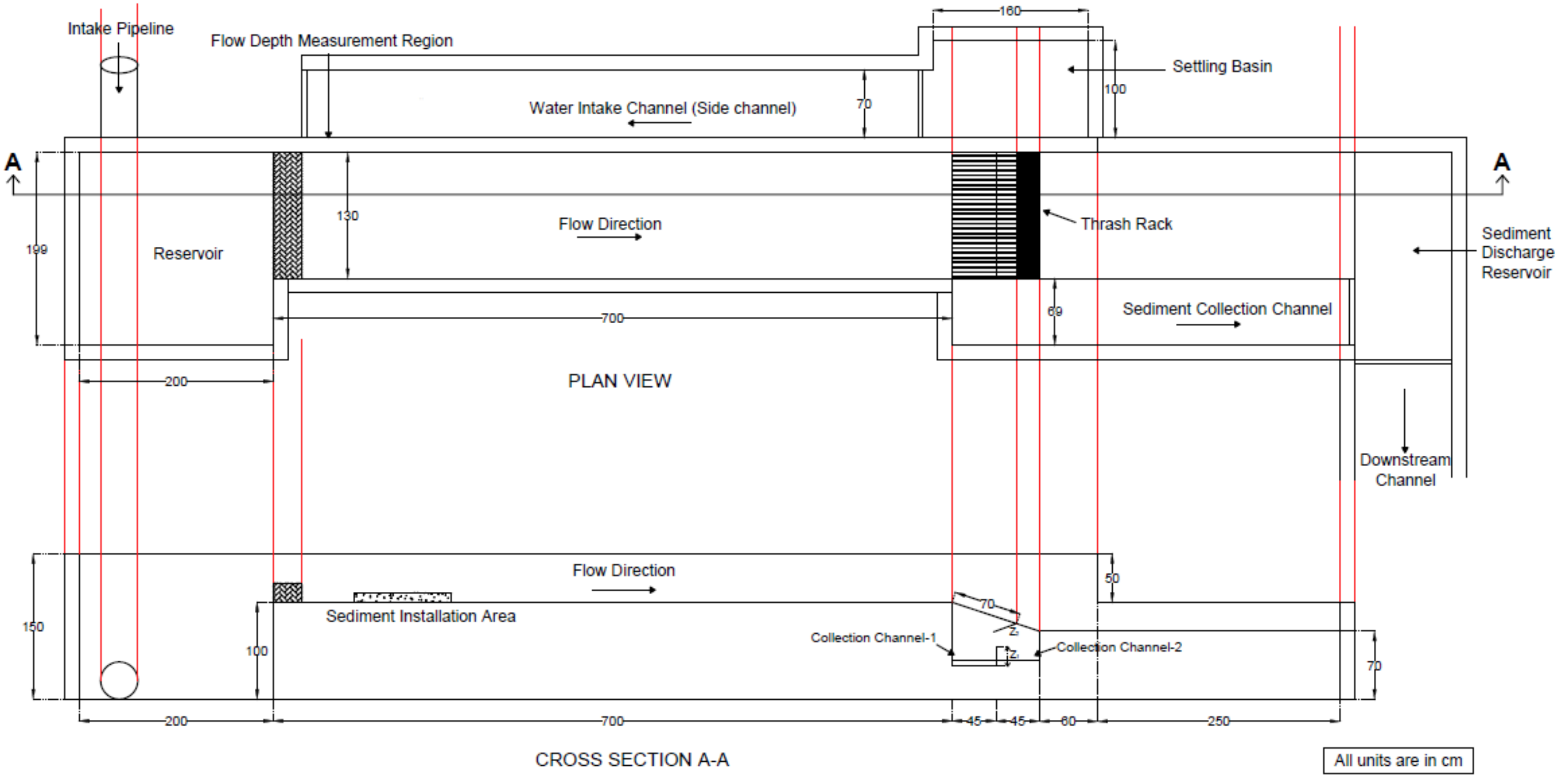

Figure 3.2. Plan view and longitudinal profile of the experimental setup (Dimensions are in centimeters)

The width of the main channel is 1.30 m (Figure 3.2). A "Dividing Plate" was placed in the center of the collection channel at the bottom of the rack to obtain "Collection Channel-1" and "Collection Channel-2", each 45 cm wide. These two channels have a bottom slope of 4° in the opposite directions (Figure 3.3). The upstream part of the “Collection Channel-1” is completely closed as it can be seen from the detailed drawing shown in Figure 3.3 and the downstream part is connected to the “Sediment Collection Chanel” with a vertical “Sliding Gate”. The amount of flow and sediment which will come to the “Sediment Collection Channel” can be controlled by adjusting the “Sliding Gate”. The upstream part of the “Collection Channel-2” is completely closed and the downstream part is connected to the "Intake Channel" which carries flow to the turbines. The water and sediment coming to the "Collection Channel-2" are first directed to the sediment trap reservoir. A barrier with a height of 0.2 m at the downstream of the sediment trap reservoir keeps sediment particles in the reservoir and prevent the particles to reach intake channel which is 0.7 m in width and 6.5 m in length. Detailed photos taken from different aspects of the experimental setup are shown in Figures 3.4 - 3.7.

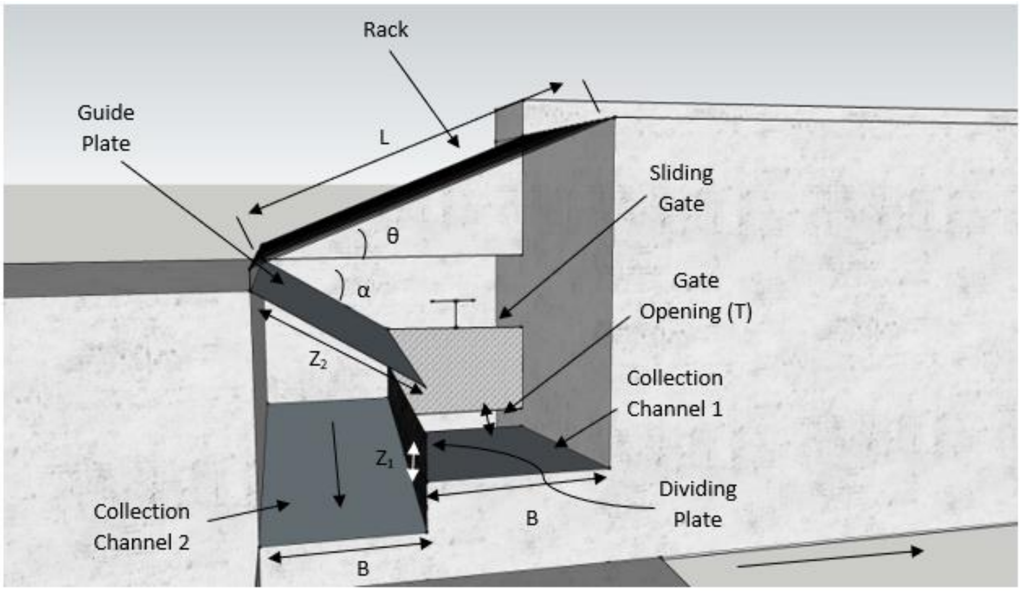

Figure 3.3. A detailed sketch of the intake structure

Figure 3.4. Downstream view of the main channel

Figure 3.5. Side view of the "Collection Channel", "Dividing Plate" and "Guide Plate"

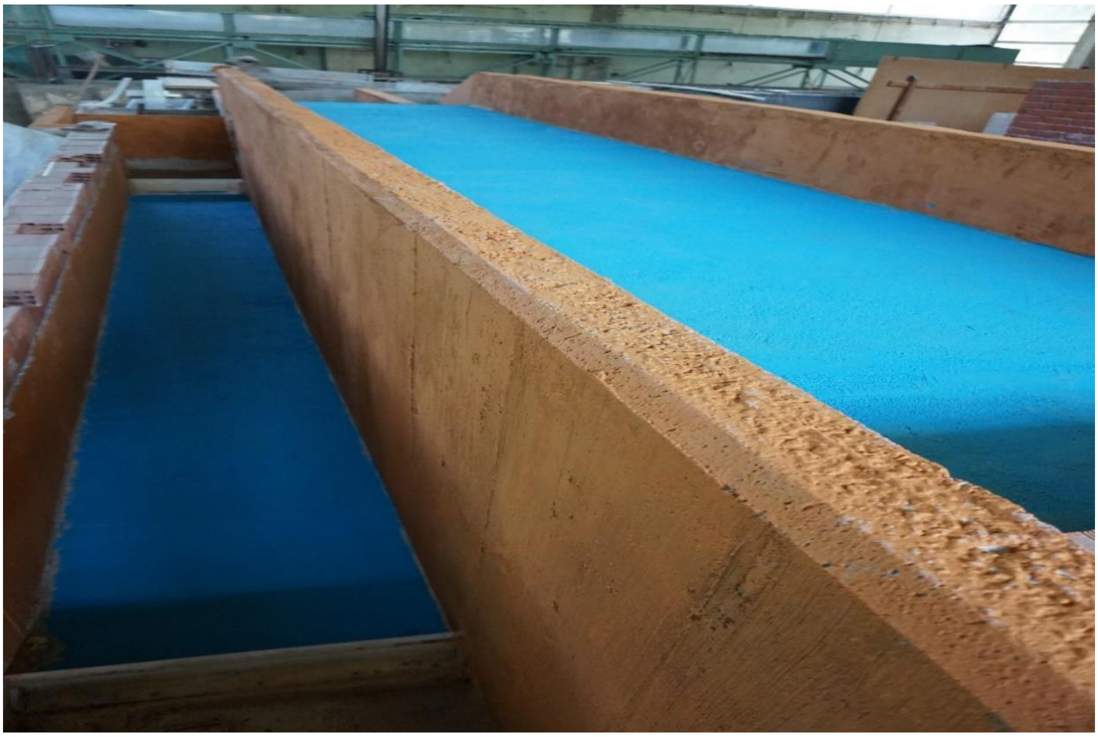

Figure 3.6. Downstream view of the “Intake Channel”

Figure 3.7. Top view of the “Main Channel” and “Sediment Discharge Channel”

The water coming from the main channel and containing solid matter is conveyed to the "Collection Channel-1" via the adjustable "Guide Plate" with the length of Z_2 and the angle of α (Figure 3.3). Large portion of the sediment coming from the main channel to the collection channel is conveyed to the "Collection Channel-1" and moves towards the “Sliding Gate”. As the flow depth in the “Collection Channel-1” rises and exceeds the height of the “Dividing plate”, the excess water spills over the “Dividing Plate” into the “Collection Channel-2” along with some fine sediment particles in suspension.

Within the scope of the study, 3 different “Dividing Plate” heights (Z_1=5 cm, 10 cm and 15 cm), 2 different "Guide Plate" lengths (Z_2=20 cm and 25 cm), 4 different "Guide Plate” angles (α=10°, 20°, 30° and 40°) were tested for a wide range of flow rates for 4 different (e= 3 mm, 6mm, 10mm and 15mm) clear bar spacings of the racks (Figures 3.8-3.11). A series of experiments with and without sediment were conducted first. All of the experiments in this group are called as "A-Group Experiments".

Figure 3.8. View of the rack with clear bar spacing of e_1=3 mm

Figure 3.9. View of the rack with clear bar spacing of e_2=6 mm

Figure 3.10. View of the rack with clear bar spacing of e_3=10 mm

Figure 3.11. View of the rack with clear bar spacing of e_4=15 mm

The results of "A-group experiments" were analyzed and it was concluded that it would be appropriate to make some changes at the bottom slope of the "Collection Channel-1" to obtain more positive results for the system. Bottom slope of the "Collection Channel-1" was changed three times. After having the bottom slope changed, a series of experiments were conducted for each case and named as "B-Group", "C-Group" and "D-Group" experiments, respectively.

The "B-Group Experiments" were carried out by increasing bottom slope of the “Collection Channel-1” from 4° to 6 ° in the flow direction. (Figure 3.12).

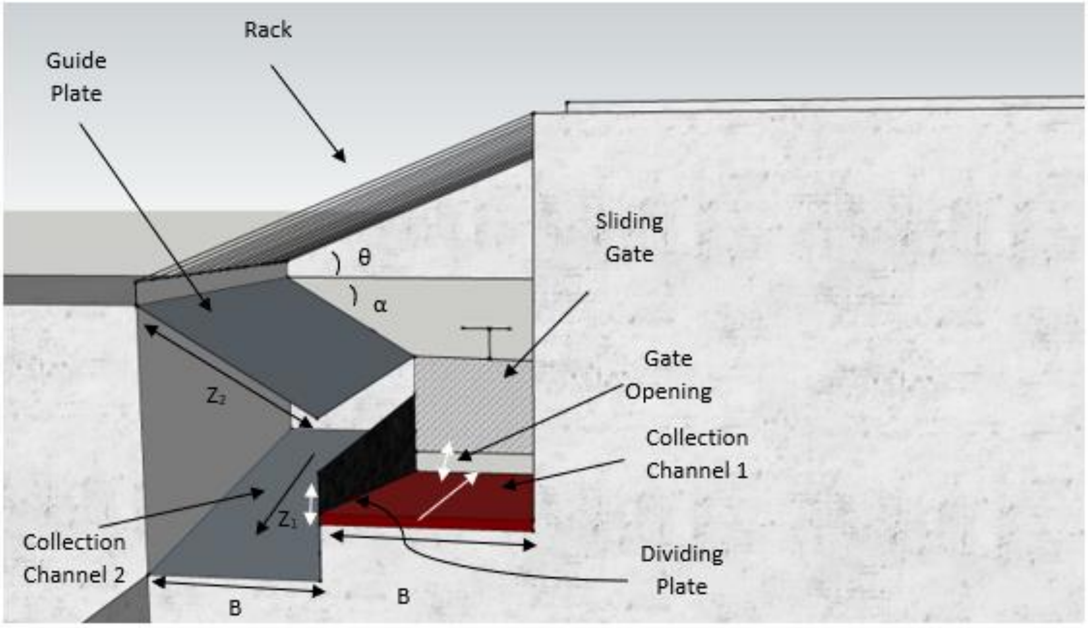

Figure 3.12. A detailed sketch of the intake structure for B-Group experiments

The "C-Group Experiments" were carried out by reorganizing "Collection Channel-1"to carry the obtained results to a better point.

In this new arrangement, the bottom of the “Collection Channel-1” along the upstream length was raised by about 5 cm and then was connected to the base of the “Dividing Plate” to form a constant lateral slope of 6° (Figure 3.13).

Therefore, the "Collection Channel-1" had a 6 ° of slope in the direction of the flow and a 6° of slope in the lateral direction towards the "Dividing Plate". The aim of this arrangement is to move sediment towards the "Dividing Plate" and have it reached to the "Sediment Collection Channel" through the gate opening.

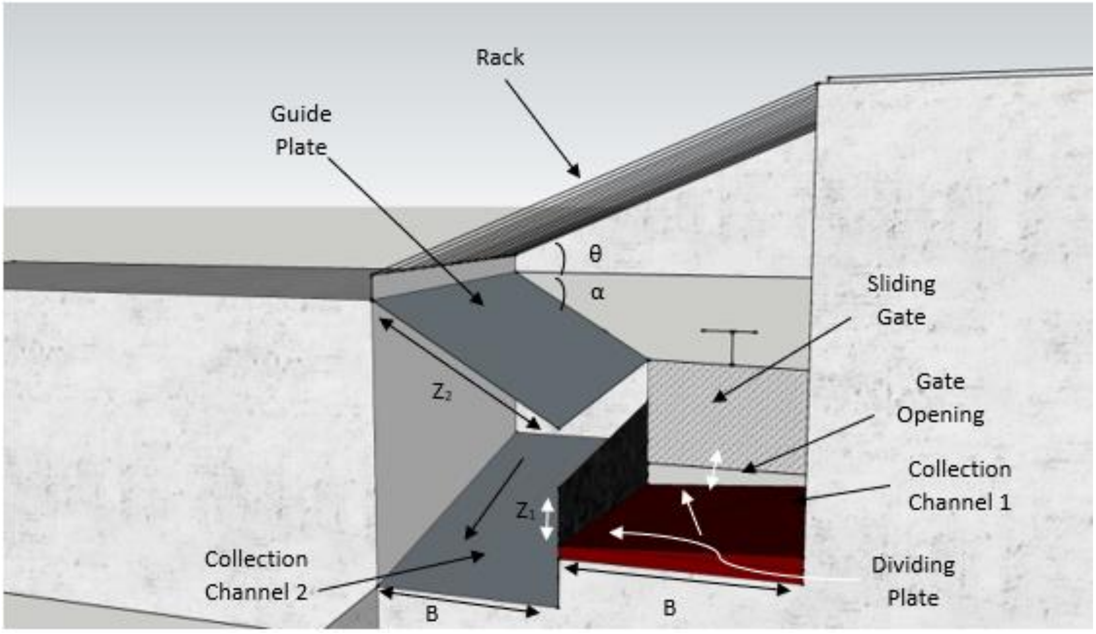

Figure 3.13. A detailed sketch of the intake structure for C-Group experiments

After having the changes in the base of the "Collection Channel-1" implemented, the similar experiments were repeated for some selected cases and their results were compared with the experimental results obtained in the previous cases. Eventually, it was observed that sediment accumulated locally at the bottom of the “Collection Channel-1” depending on discharge, length and position of the parameters of the system. Therefore, it was decided to make a final modification on the bottom slope of the "Collection Channel-1". Within this scope, the base of the “Collection Channel-1” was excavated along the channel by 5 cm at the edge of the “Dividing Plate” and by 10 cm at the opposite edge. As a result, a lateral slope of 6° along the channel width was provided in the reverse direction compared to the case described above (Figure. 3.14). For this new situation, the related experiments were repeated under the name of "D-group experiments" and it was observed that the best results within the study were obtained.

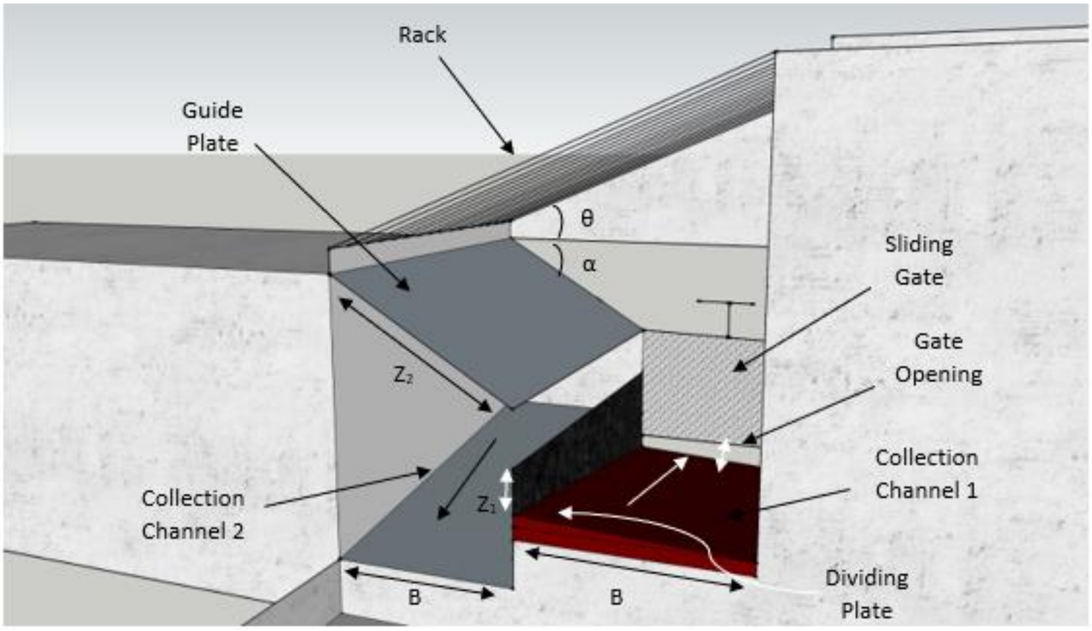

Figure 3.14. A detailed sketch of the intake structure for D-Group experiments

The values of the parameters used in the experiments performed under the four groups; the distance between the bars of the racks, e, the "Dividing Plate" height, Z_1, the "Guide Plate" length, Z_2, and the angle, α, are given in Table 3.1 for each test group. In this table, the reason why the experiments for a limited number of α values were made in some experimental groups is that, based on some preliminary experiments, the untested α values did not give good results regarding the deposition and motion of sediment through the "Collection Channel-1".

Table 3.1. *Values of the parameters used in A,B,C and D-Group experiments*

Groups of the Experiments	e=3 mm			e=6 mm			e=10 mm			e=15 mm		
	Z_1 (cm)	Z_2 (cm)	α (º)	Z_1 (cm)	Z_2 (cm)	α (º)	Z_1 (cm)	Z_2 (cm)	α (º)	Z_1 (cm)	Z_2 (cm)	α (º)
A-1 Group (Without Sediment)	5	20 25	10 20 40	5	20 25	10 20 40	5	20 25	10 20 40	5	20 25	10 20 40
	10	20 25	10 20 20	10	20 25	10 20 20	10	20 25	10 20 20	10	20 25	10 20 20
	15	20 25	10 20	15	20 25	10 20	15	20 25	10 20	15	20 25	10 20
A-2 Group (With Sediment)	5	20 25	10 20 10 20	5	20 25	10 40 30 40	5	20 25	40 40	5	20 25	40 40
	10	20 25	10 20 10 20	10	20 25	10 20 10 20	10	20 25	20 30 40	10	20 25	20 30 40
	15	20 25	10 20 10 20	15	20 25	10 20 10 20	15	20 25	20 30 40	15	20 25	20 30 40
B- Group (With Sediment)	5	20 25		5	20 25		5	20 25		5	20 25	
	10	20 25	30 40	10	20 25	30 40	10	20 25	30 40	10	20 25	10 20 40
	15	20 25	30 40	15	20 25	30 40	15	20 25	30 40	15	20 25	20 30 40
C- Group (With Sediment)	5	20 25		5	20 25		5	20 25		5	20 25	
	10	20 25	40	10	20 25		10	20 25		10	20 25	
	15	20 25	30	15	20 25		15	20 25		15	20 25	
D-Group (With Sediment)	5	20 25		5	20 25		5	20 25		5	20 25	
	10	20 25	30 40	10	20 25	30 40	10	20 25	30 40	10	20 25	30 40
	15	20 25	30 40	15	20 25	30 40	15	20 25	30 40	15	20 25	30 40

3.4. Experimental Procedure

3.4.1. Discharge Measurement

To obtain the calibration curves of the main channel, sediment and intake channels, first, the flow depths in these channels were recorded by using the manometer readings located at appropriate locations on these channels; upstream of the main channel and downstream of the sediment and intake channels, respectively, after having the flow reached the steady state case for a given discharge.

The discharge passing through the main channel was measured with the help of an ultrasonic flowmeter installed on the intake pipe with an accuracy of ± 2%. The discharge of the main channel was diverted to the “Collection Channel-2” and from there to the “Intake Channel”. By recording the flow depth over the sharp-crested weir located at the end of the “Intake Channel”, the calibration curve of the “Intake Channel” was obtained for a wide range of discharges. The same procedure was applied to the “Collection Channel-1” by completely closing the downstream part of the “Collection Channel-2”. In this case, the incoming flow from the main channel was diverted to the “Collection Channel-1” and from there to the “Sediment Collection Channel” and finally its calibration curve was obtained.

3.4.2. Experiments Conducted with only Water

The experiments in this section were carried out with 4 different clear bar spacings, two different guide plate lengths and three different dividing plate heights and named as A-1 Group experiments.

The minimum discharge to the main channel was supplied in such a way that the water level of the manometer at the upstream of the main channel was about 5 cm. After having the system reached to the steady state case, water depth values were read from the manometers at the upstream of the main channel and downstream of the "Water Intake and Sediment Collection Channels" and corresponding discharges in these channels were determined using their calibration curves. This process was repeated by increasing the water level in the main channel 1 cm for each test and completed after having the water level in the main channel reached to 17 cm which was the maximum flow depth to be provided.

Each experiment without sediment was completed within about one and a half hours. The water capture efficiency of the system for each case was calculated by using the experimental results. The measured and calculated parameters are presented in Appendix A in Tables A.1 - A.4.

3.5. Experiments Conducted with Sediment

3.5.1. Characteristics of Sediment used in the Experiments

Four sediment mixture groups were prepared by combining five different sediment groups of which sediment diameters varying between; 1-3 mm, 3-6 mm, 6-9 mm, 9-15 mm and 15-25 mm (Figure 3.15) as shown in Table 3.2. The amounts of each sediment group stated in Table 3.2 were weighted and mixed with each other to get the total weights of the sediment mixtures listed in the last column. For the selected clear bar spacings to be tested the total amounts of the sediment mixtures were used in the experiment groups of A, B, C and D as listed in Table 3.2.

Table 3.2. *Composition of the sediment mixtures and bar spacings of the racks used in the tests*

Sediment Mixture Group	Experiment Group	Tested Clear Bar Spacing, e (mm)	Size Ranges of the Sediment Forming the Mixtures and Their Weights (kgf)					Total Weight of the Sediment Mixture (kgf)
			Size, d_s (mm)					
			1-3	3-6	6-9	9-15	15-25	
1	A-B-C-D	3	50	25	25	-	-	100
2	A-B-D	6	30	30	30	30	-	120
3	A-B-D	10	20	20	20	30	30	120
4	A-B-D	15	20	20	20	20	40	120

Figure 3.15. Sediment mixture groups used in the experiments

3.5.2. Procedure of the Experiments with Sediment

After selecting the experiment group and clear bar spacing to be tested, the corresponding sediment mixture group at the amount given in Table 3.2 was spreaded to main channel uniformly (Figure 3.16). A flow rate of 10 lt /s was supplied to the system for 4 minutes and the water depths were measured from the manometers on the main channel, water and sediment collection channels for every 1 minute within 4 minutes interval. At the end of 4 minutes, the flow rate was slowly increased to 30 l / s and flow rate was maintained in the main channel for 4 minutes as done before. In this process, the manometer readings from the main channel, water and sediment discharge channels were provided at 1-minute intervals and the motion of sediment along the main channel was observed. This procedure was repeated to create an artificial flood condition until the maximum discharge of the system was reached.

Figure 3.16. A view of the spreaded sediment at the upstream of the main channel before experiments started

Experiments were terminated when all of the sediment particles in the main canal were washed away. After the tests were stopped, the amount of sediment remaining in the downstream of the collection channels, water intake and sediment collection channels and downstream of the main canal was dried out and weighed and the ratio of the sediment distribution in the specified channels to the total sediment amount was calculated. Each experiment in these groups took an average of four hours to complete.

All experiments were repeated for 4 different clear bar spacings (e_1 = 3 mm, e_2 = 6 mm, e_3 = 10 mm, e_4 = 15 mm). Figures 3.17-3.24 show some of the photographs taken during the experiments.

Figure 3.17. Accumulation of sediment (A-2 Group Experiments) at the upstream of the "Intake Channel" (e_1=3 mm, Z_1= 10 cm, Z_2= 25 cm, α=20°)

Figure 3.18. Accumulation of sediment (A-2 Group Experiments) within the "Collection Channel-1" (e_1=3 mm, Z_1= 10 cm, Z_2= 25 cm, α=20°)

Figure 3.19. Accumulation of sediment (A-2 Group Experiments) at the downstream of the main channel (e_1=3 mm, Z_1= 10 cm, Z_2= 25 cm, α=20°)

Figure 3.20. Accumulation of sediment (A-2 Group Experiments) within the “Sediment Collection Channel” (e_1=3 mm, Z_1= 10 cm, Z_2= 25 cm, α=20°)

Figure 3.21. Accumulation of sediment (D Group Experiments) within the rack (e_4=15 mm, Z_1= 10 cm, Z_2= 20 cm, α=30°)

Figure 3.22. Accumulation of sediment (D Group Experiments) at the upstream of the "Intake Channel" (e_4=15 mm, Z_1= 10 cm, Z_2= 20 cm, α=30°)

Figure 3.23. Accumulation of sediment (D Group Experiments) within the "Sediment Collection Channel" (e_4=15 mm, Z_1= 10 cm, Z_2= 20 cm, α=30°)

Figure 3.24. Accumulation of sediment (D Group Experiments) within the "Collection Channel-1" (e_4=15 mm, Z_1= 10 cm, Z_2= 20 cm, α=30°)

The values obtained from the measurements and the calculated parameters are presented in Appendices B, C, D and E (Tables B.1-E.4).

CHAPTER 4

THEORETICAL ANALYSIS

4.1. Introduction

In order to obtain the general equations to be used in the design of modified Tyrolean weirs, important dimensionless parameters related to the topic should be determined and the relations between them should be found out based on the experimental results. Therefore, dimensional analysis is to be applied to the parameters of the system under consideration.

4.2. Dimensional Analysis

By considering Figure 4.1 given below, the following relations related to the unit discharge $(q_w)_i$ that reaches to the "Intake Channel" from the main channel after passing through the rack [$(q_w)_{ic} = {(Q_w)_{ic}}/{B_{mc}}$ where $(Q_w)_{ic}$ is the total discharge of the "Intake Channel" and B_{mc} is the width of the main channel.] and the amount of sediment per unit width of the main channel, $(w_s)_{sc}$, that reaches to the "Sediment Collection Channel" [$(w_s)_{sc} = {(W_s)_{sc}}/{B_{mc}}$ where $(W_s)_{sc}$ is the total weight of the sediment coming into the "Sediment Collection Channel"] can be stated as follows;

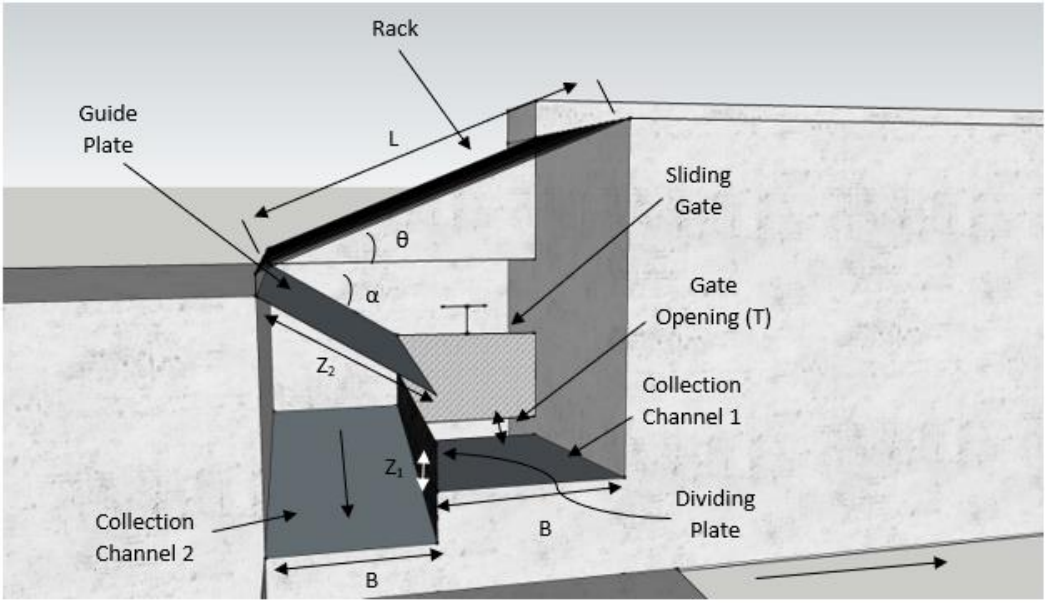

Figure 4.1. Sketch of the experimental setup showing all the important parameters involved

$$(q_i)_{ic} = f_1[(q_w)_T, L, \theta, e, a, t, Z_1, Z_2, \alpha, B, (S_{cc})_2, T, g, \rho_w, \rho_w, \mu_w] \quad (4.1)$$

$$(w_s)_{sc} = f_2[(w_s)_T, \rho_s, d_{50}, (Q_w)_T, L, \theta, e, a, B, (S_{cc})_1, t, Z_1, Z_2, \alpha, T, g, \rho_w, \mu_w] \quad (4.2)$$

Where;

$(q_w)_{ic}$ is the unit discharge passing through the racks,

$(q_w)_T$ is the unit discharge of the main channel discharge,

L is the rack length (constant throughout the study and measured as L=70 cm,

θ is the angle between rack and horizontal axis (constant throughout the study and measured as θ=23°),

e is the clear bar spacing measured between two neighbor bars,

a is the distance between the center of the two neighbor bars,

t is the diameter of the rack bar (constant and t= 1 cm, a=e+t),

Z_1 is the height of the "Dividing Plate",

Z_2 is the length of the "Guide Plate",

α is the angle between "Guide plate" and horizontal axis,

B is the width of the "Collection Channel-1" and "Collection Channel-2",

$(S_{cc})_2$ is the bottom slope of the "Collection Channel-2",

T is the opening height of the "Sliding Gate" (Kept constant throughout A-1 group experiments as 4 mm and kept constant throughout B-C and D group experiments as 2 cm)

g is the gravitational acceleration,

ρ_w is the density of water,

μ_w is the dynamic viscosity of water,

$(w_s)_{sc}$ is the weight of the sediment coming into the "Sediment Collection Channel" from unit width of the main channel,

$(w_s)_T$ is the weight of the sediment present in the main channel per unit width [$(w_s)_T = {(W_s)_T}/{B_{mc}}$] before experiments start,

$(S_{cc})_1$ is the bottom slope of the "Collection Channel-1",

ρ_s is the density of the sediment and,

d_{50} is the median diameter of the sediment.

Due the nature of the experiments, turbulence intensity is high within the whole system so that viscosity of water has a negligible effect on the depended parameters given in Equations 4.1 and 4.2. Width of the main channel B_{mc}, width of the collection channels B, diameter of the bars t, rack length L, rack angle θ, opening of the sliding gate T and ρ_w are constant throughout the experiments.

Sediment mixtures were prepared according to the rack types so that for every clear bar spacing “e”, different sediment mixture groups were tested within the experiments. Since the same sediment mixture groups were used for the specified clear bar spacing, “d_{50}” and “ρ_s" values are the same, therefore, these parameters can be dropped out from the above equations.

Experiments were classified under four different groups. While the bottom slope of the “Collection Channel-2” ,$(S_{cc})_2$, is 4° and constant, bottom slope of the “Collection Channel-1” , $(S_{cc})_1$, is varied depending on the experiment group but kept constant throughout the specified group of experiment. Therefore, those slope values can be treated as constant within the analysis.

Consequently, Equations 4.1 and 4.2 can be expressed as;

$$(q_w)_{ic} = f_3[(q_w)_T, e, Z_1, Z_2, \alpha, g] \tag{4.3}$$

$$(w_s)_{sc} = f_4[(w_s)_T, (q_w)_T, e, Z_1, Z_2, \alpha, g] \tag{4.4}$$

By applying Buckinghams π Theorem to Equation 4.3, Equation 4.5 can be written as;

$$\frac{(q_w)_{ic}}{(q_w)_T} = \frac{(Q_w)_{ic}}{(Q_w)_T} = f_5\left[[(F_r)_e]^2, \frac{Z_1}{e}, \frac{Z_2}{e}, \alpha\right] \tag{4.5}$$

$(F_r)_e = \left[\frac{{(q_w)_T}^2}{e^3 g}\right]^{1/2}$ Froude Number based on clear bar spacing “e”.

The discharge $(Q_w)_{sc}$, coming from the “Collection Channel-1” to the “Sediment Collection Channel” underneath of the “Sliding Gate” becomes negligible at larger values of $(Q_w)_T$, compared to the discharge $(Q_w)_{ic}$, within the intake channel. Therefore, a dimensionless parameter related to $(Q_w)_{sc}$ was not derived. Variation of $(Q_w)_{sc}$ with respect to flow conditions and “Sliding Gate” opening T were presented in tabular forms in Appendices A, B, C, D and E, $[\frac{(Q_w)_{sc}}{(Q_w)_T} = 1 - \frac{(Q_w)_{ic}}{(Q_w)_T}]$.

Similarly, by applying Buckinghams π Theorem to Equation 4.4, Equation 4.6 is obtained;

$$\frac{(w_s)_{sc}}{(w_s)_T} = \frac{(W_s)_{sc}}{(W_s)_T} = f_6\left[[(F_r)_e]^2, \frac{Z_1}{e}, \frac{Z_2}{e}, \alpha\right] \qquad (4.6)$$

To investigate what percent of the sediment passing through the rack, $(W_s)_{rack}$, is diverted towards the "Sediment Collection Channel" in the following analysis instead of $\frac{(W_s)_{sc}}{(W_s)_T}$ given in Equation 4.6, $\frac{(W_s)_{sc}}{(W_s)_{Rack}}$ is to be used to be in safe side in the determination of efficiency of the intake structure. Because there is no direct effect of modified intake structure on the amount of sediment passing over the rack which is equal to $(W_s)_0 = (W_s)_T - (W_s)_{rack}$.

$$[(W_s)_{sc}]_R = \frac{(W_s)_{sc}}{(W_s)_{Rack}} = f_7\left[[(F_r)_e]^2, \frac{Z_1}{e}, \frac{Z_2}{e}, \alpha\right] \qquad (4.7)$$

The results of the experiments were evaluated according to Equation 4.5 and Equation 4.7 in the following sections.

CHAPTER 5

EXPERIMENTAL ANALYSIS

5.1. Introduction

After having the experiments conducted under four different experimental groups, results of each group have been investigated within each other by considering the equation derived in Chapter 4. In this chapter, optimized values of the dimensionless parameters for the predefined Tyrolen weir were determined to maximize the discharge in the intake channel and minimize the sediment within the intake channel.

5.2. Results and Analysis of A-1 Group Experiments (Without Sediment)

In order to determine hydraulic characteristics and working principles of the predefined bottom intake, a series of experiments without sediment were conducted and measured data were evaluated to assess the effect of parameters such as Z_1, Z_2 and α on the diverted discharge. Throughout the experiments, the gate opening at the downstream part of the "Collection Channel-1" was set to 4 mm to let the sediment pass through this gate opening in the cases of experiments to be conducted with sediment. In this part of the study the aim is to observe the behavior of the diverted water from the bottom rack within the collection channel, the effect of the "Dividing Plate" on the flow and amount of water moving towards the transmission line.

Figures 5.1-5.12 show the variation of water capture efficiency with $(F_r)_e$ and α for the clear bar spacings of e_1=3 mm, e_2=6 mm, e_3=10 mm and e_4=15 mm and the parameters of Z_1 and Z_2. These figures clearly show that the water capture efficiency increases rapidly for the constant values of Z_1/e, Z_2/e and α with increasing modified Froude Number, $(F_r)_e$, up to the value of about; 40 for e_1=3 mm, 15 for e_2= 6 mm, 10 for e_3=10mm, and 4 e_4=15 mm, respectively. At the larger values of the Froude numbers than those stated above, the water capture efficiency continues to increase at a decreasing rate.

Almost the whole amount of discharge coming from the main channel through the bottom rack is diverted first into the “Collection Channel – 1” depending on the length of the “Guide Plate” and then moves towards the vertical “Sliding Gate”. While a small amount of this discharge in the “Collection Channel-1” flows into the “Sediment Collection Channel” through the bottom opening of the “Sliding Gate”, the rest of the discharge passes to the “Collection Channel-2” over the “Dividing Plate”. Increasing the main channel discharge results in an increment in the discharge present in the “Collection Channel-1” and “Collection Channel-2”. Therefore, the water depth within the “Collection Channel – 2” increases rapidly and results in an increased discharge through the turbines. That is the reason why the water capture efficiency increases with increasing $(F_r)_e$.

From figures 5.1-5.12 it is clearly seen that for a model of known e, L, Z_1, Z_2 and $(F_r)_e$, variation of α does not significantly affect the value of water capture efficiency. An increment on the value of e, while the other parameters are being kept constant, results in an increase in the water capture efficiency.

As the value of Z_1 gets larger, the vertical distance between the “Dividing Plate” and “Guide Plate” decreases. This situation prevents the passage of more discharge from “Collection Channel-1” to “Collection Channel-2”, which results in a decrease on the value of water capture efficiency. Therefore, the models of Z_2=15 cm yield slightly low water capture efficiencies than those models of Z_2=5 cm and Z_2=10 cm.

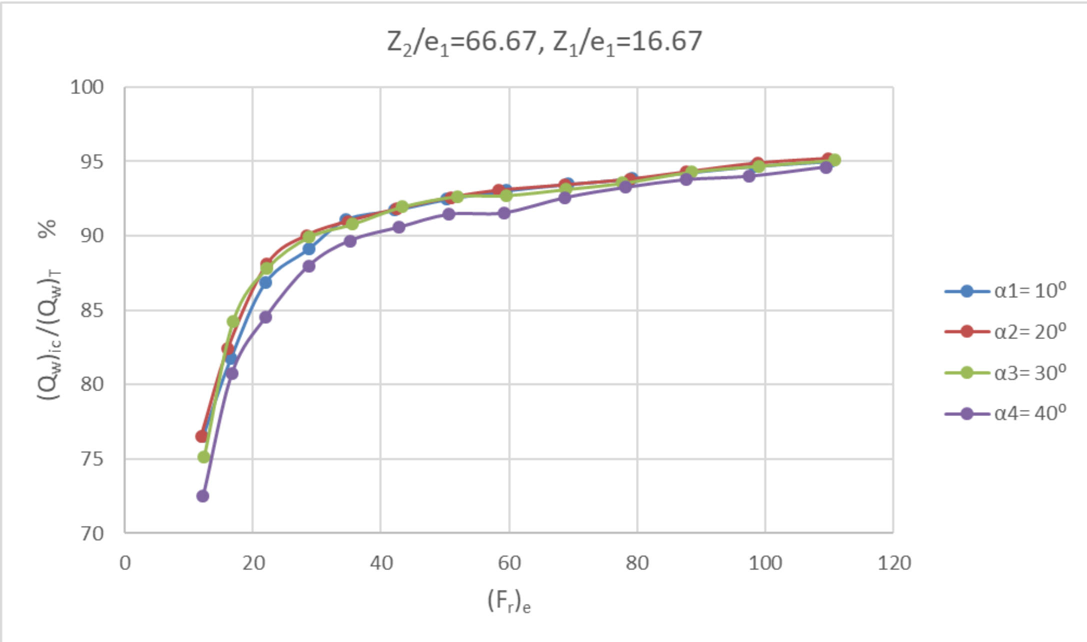

Figure 5.1. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1= 5 cm, Z_2=20 cm)

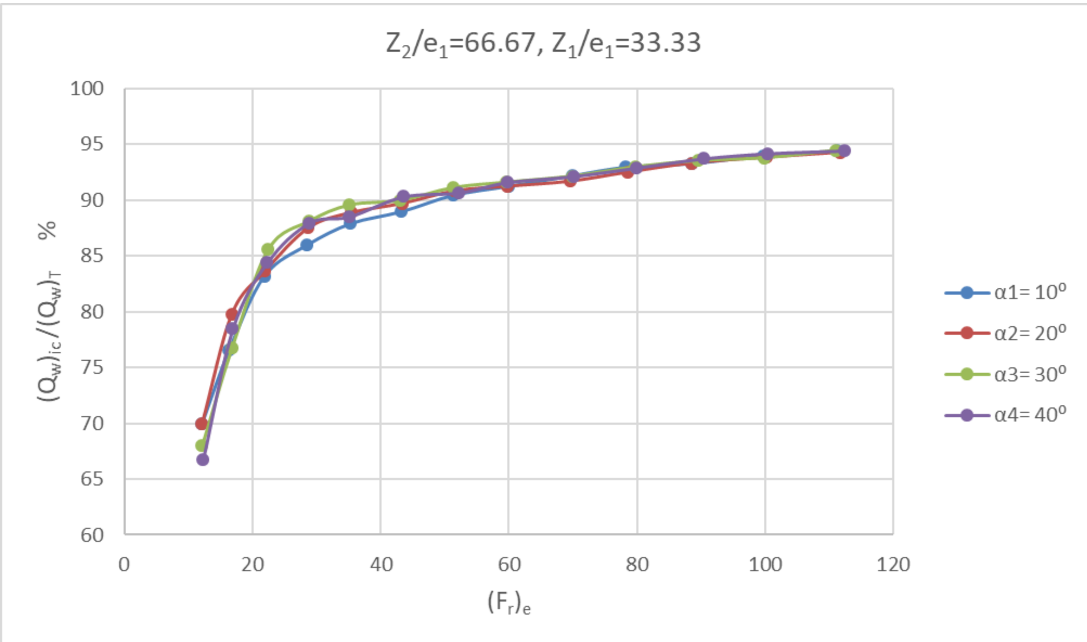

Figure 5.2. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1= 10 cm, Z_2=20 cm)

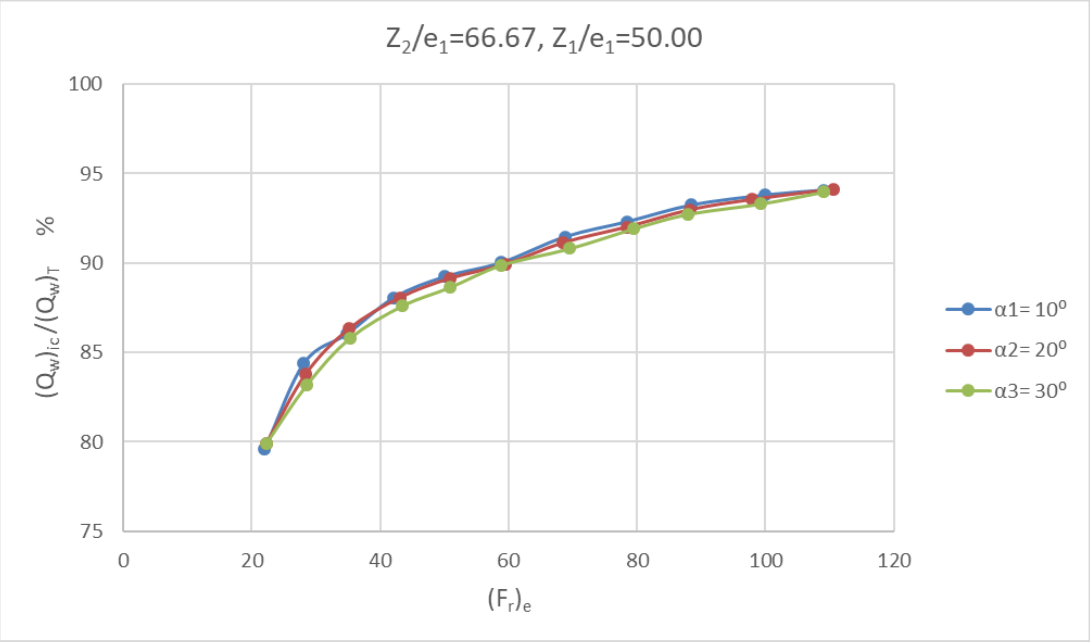

Figure 5.3. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1= 15 cm, Z_2=20 cm)

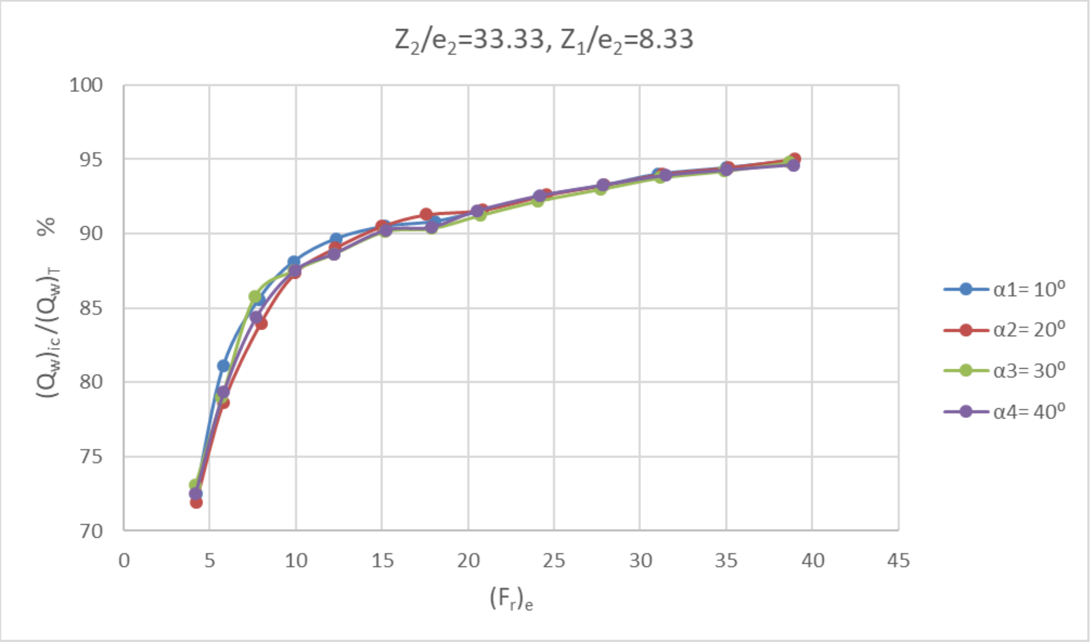

Figure 5.4. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1= 5 cm, Z_2=20 cm)

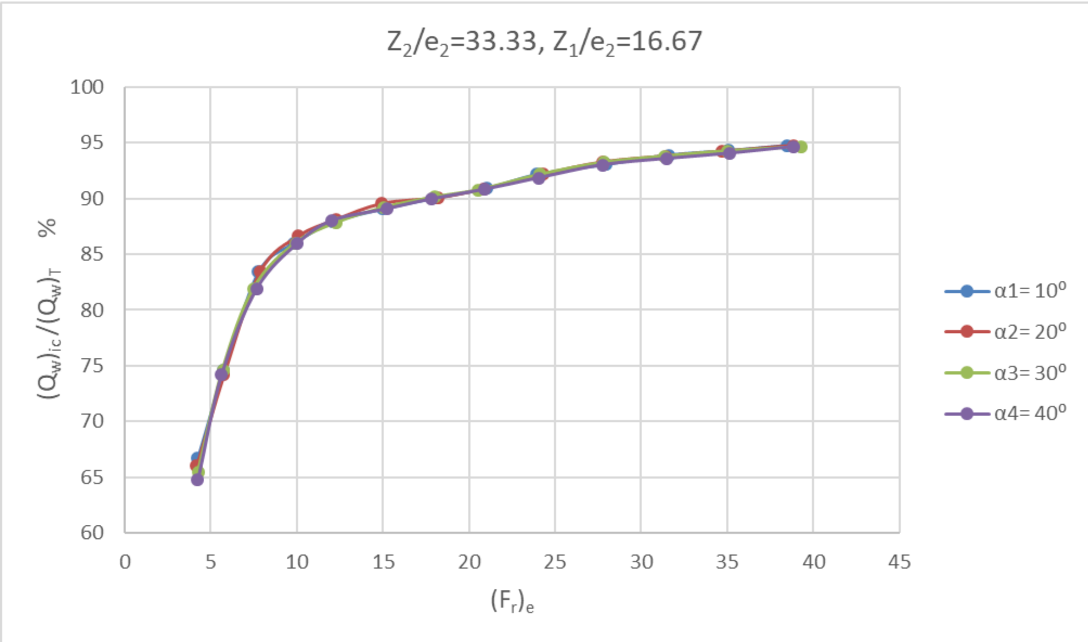

Figure 5.5. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1= 10 cm, Z_2=20 cm)

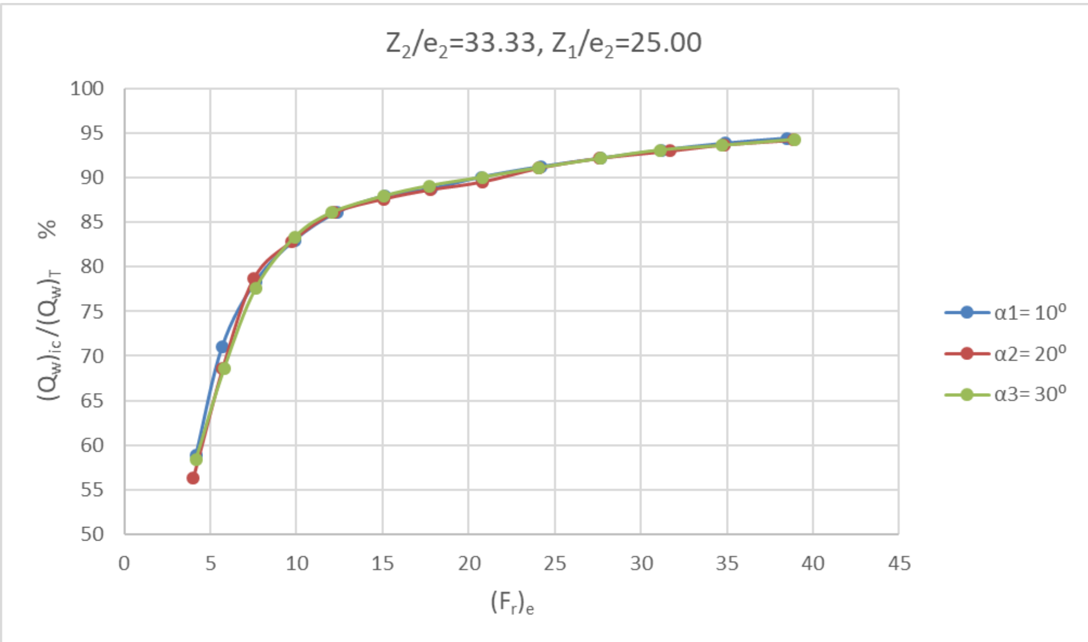

Figure 5.6. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1= 15 cm, Z_2=20 cm)

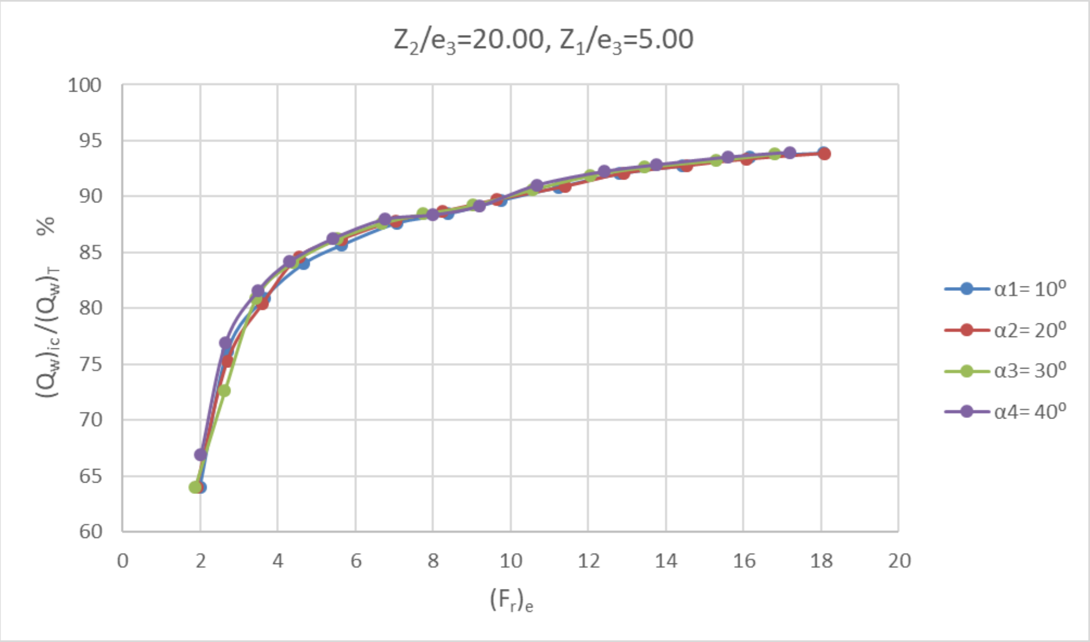

Figure 5.7. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_3=10 mm, L=70 cm, Z_1= 5 cm, Z_2=20 cm)

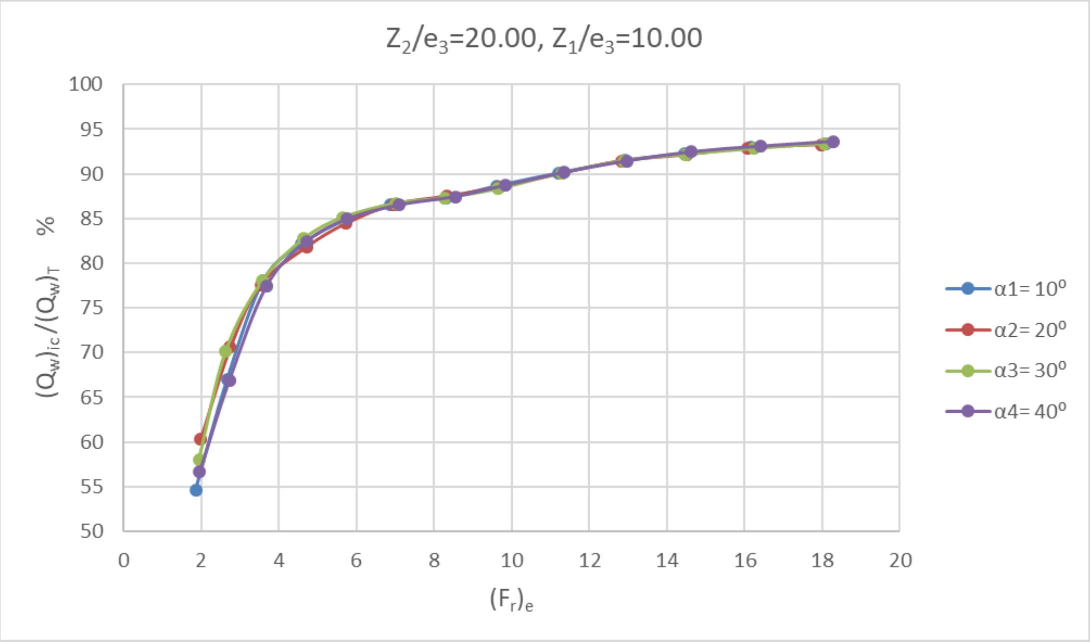

Figure 5.8. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_3=10 mm, L=70 cm, Z_1= 10 cm, Z_2=20 cm)

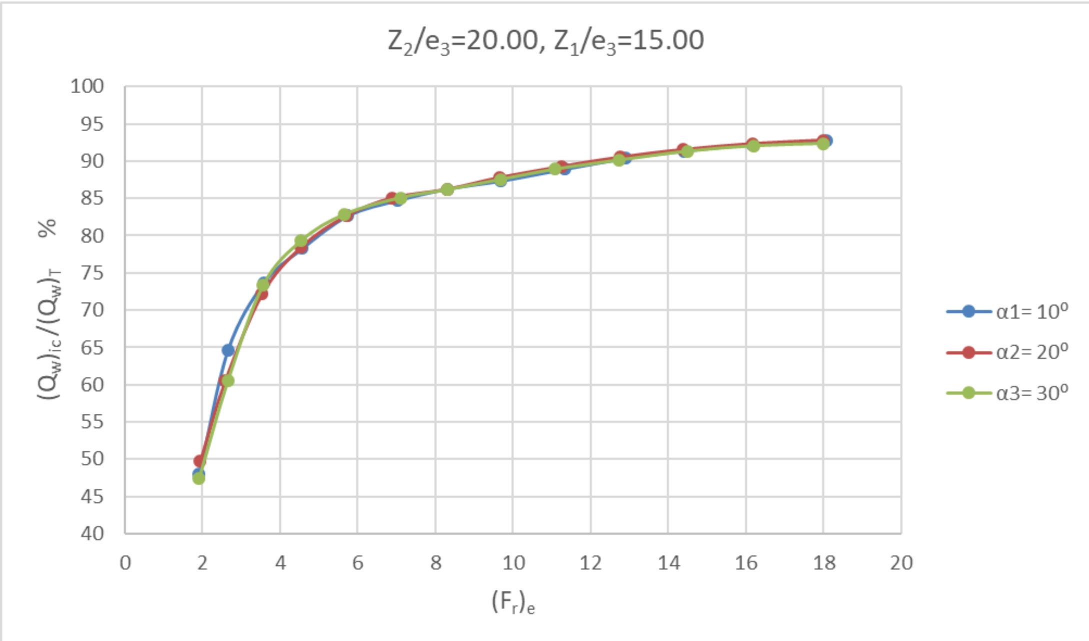

Figure 5.9. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_3=10 mm, L=70 cm, Z_1= 15 cm, Z_2=20 cm)

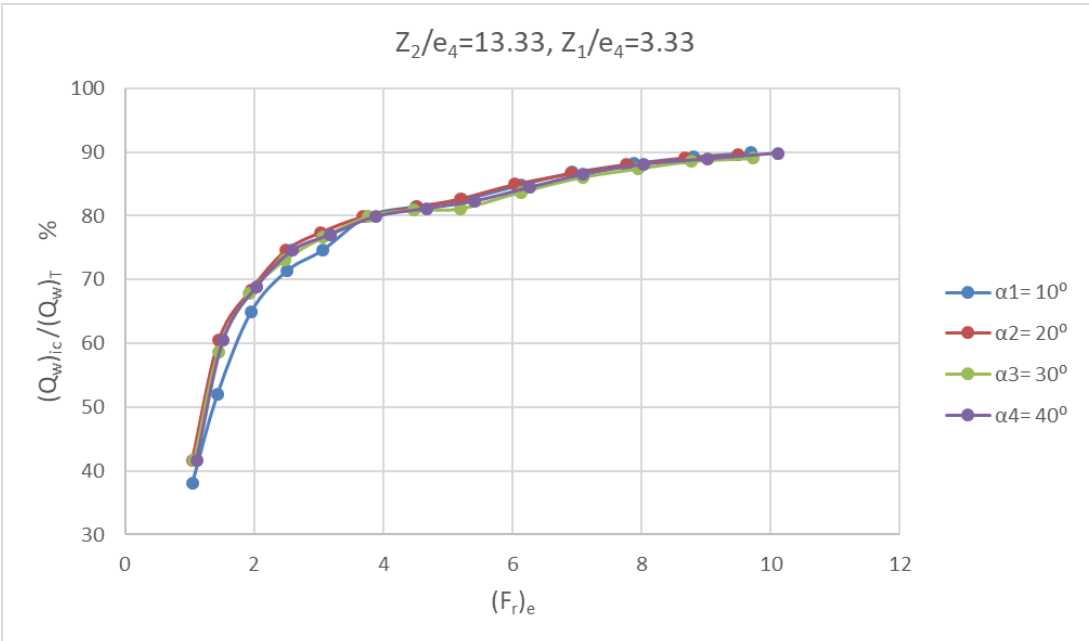

Figure 5.10. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_4=15 mm, L=70 cm, Z_1= 5 cm, Z_2=20 cm)

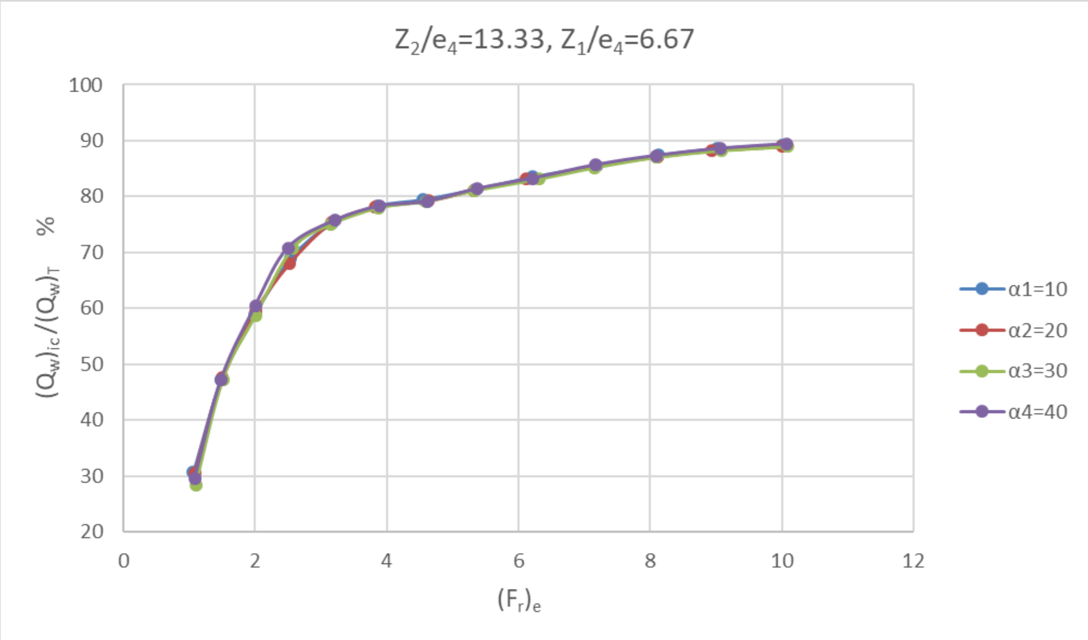

Figure 5.11. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_4=15 mm, L=70 cm, Z_1= 10 cm, Z_2=20 cm)

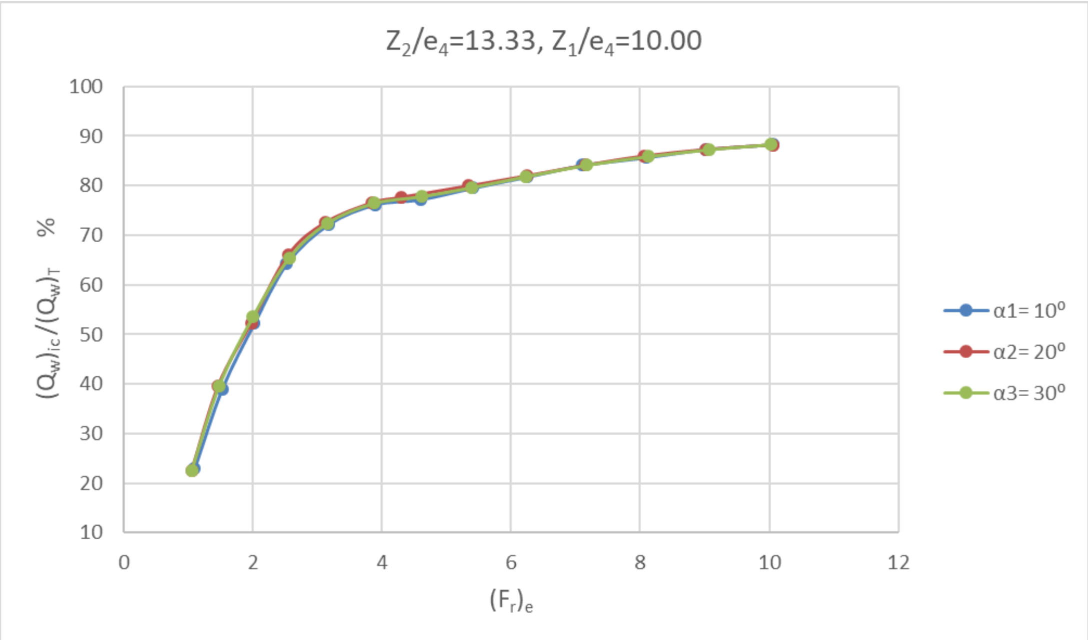

Figure 5.12. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_4=15 mm, L=70 cm, Z_1= 15 cm, Z_2=20 cm)

5.3. Results and Analysis of A-2 Group Experiments (With Sediment)

The experiments defined under A-2 Group were conducted for the variables of Z_1/e_1, Z_2/e_1 and α, and the related measured and the calculated parameters were presented in Appendix B (Tables B.1-B.4). The opening of the “Sliding Gate” was kept constant as 2 cm based on the knowledge of pre-experiments (Preliminary A-2 Group experiments conducted with different “Sliding Gate” openings) from which it was observed that gate opening less than 2 cm results in clogging in front of the gate and larger than 2 cm increases loss of water from the “Collection Channel-1”.

Throughout the experiments the discharges within the “Intake Channel” the “Sediment Collection Channel” and the main channel were defined as $(Q_w)_{ic}$, $(Q_w)_{sc}$ and $(Q_w)_T$, respectively. The ratio of the discharge within a specified channel to the main channel discharge was calculated and presented in Appendix B (Tables B.1-B.4). The most important parameter is the “Water Capture Efficiency” which is defined as $(Q_w)_{ic}/(Q_w)_T$. Figures 5.13-5.26 show the variation of water capture efficiency with $(F_r)_e$ and α for each of the clear bar spacing tested (e_1=3 mm, e_2=6 mm, e_3=10 mm and e_4=15 mm) and various values of Z_1 and Z_2.

These figures clearly show that the general trends of the curves given for the water capture efficiency as a function of $(F_r)_e$ and α are very similar and the effect of α on the water capture efficiency is almost negligible. At small $(F_r)_e$ values water capture efficiency is small but increasing $(F_r)_e$ causes water capture efficiency to increase and attain values of over about 80 % at maximum $(F_r)_e$ tested. Small main channel discharges come directly into the “Collection Channel-1” and move towards the “Sediment Collection Channel” without having a chance to rise within the “Collection Channel-1” and pass over the “Dividing Plate”. Therefore, the values of $(Q_w)_{sc}$ is higher in these specific cases than those of at large $(F_r)_e$.

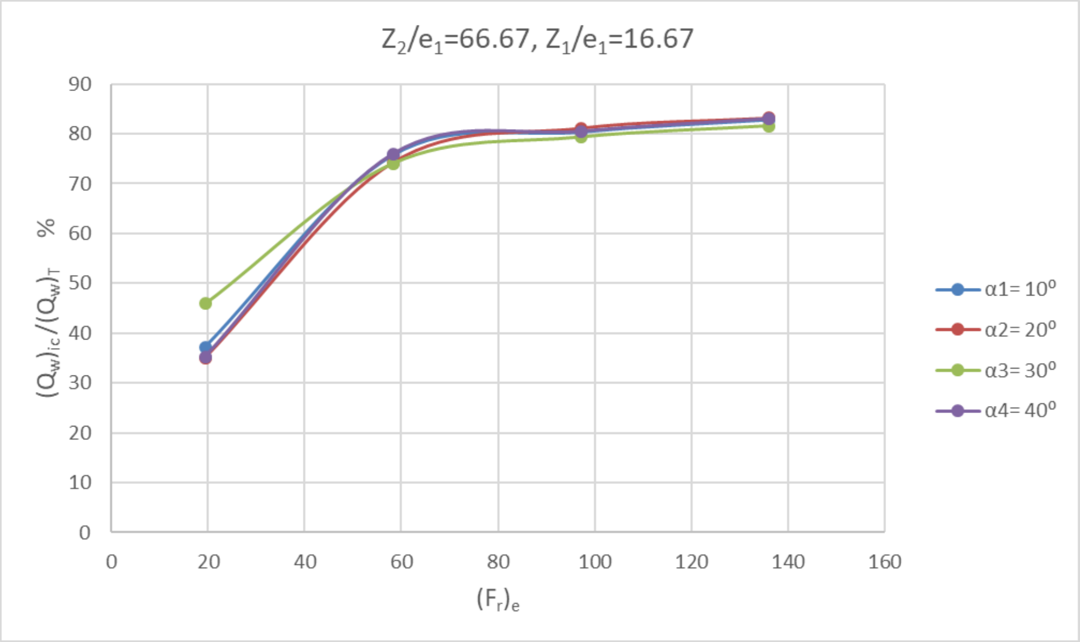

Figure 5.13. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1= 5 cm, Z_2=20 cm)

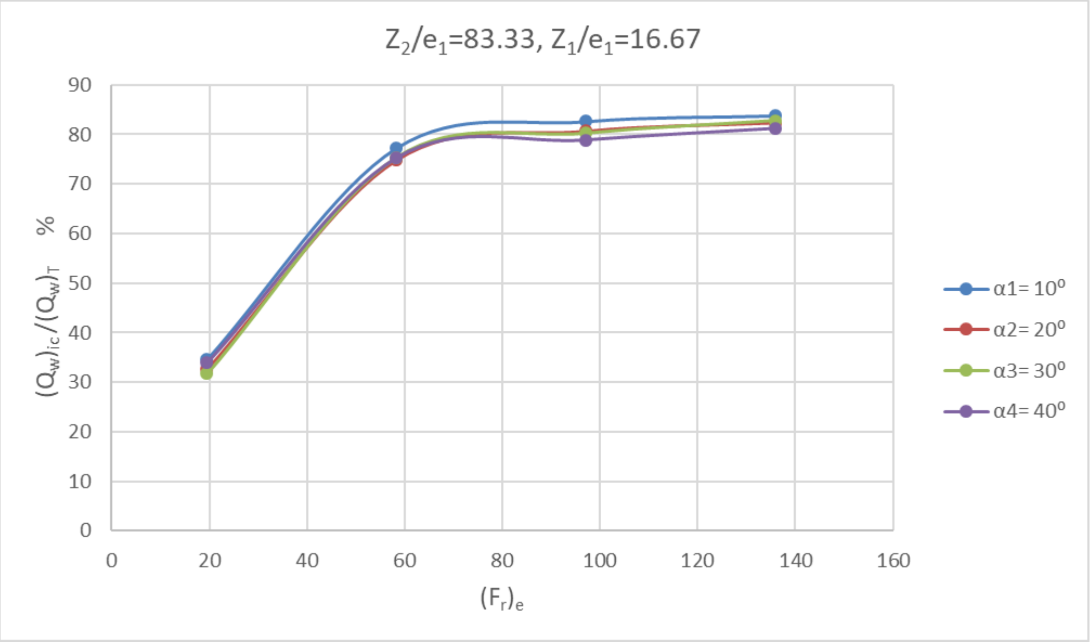

Figure 5.14. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1=5 cm, Z_2=25 cm)

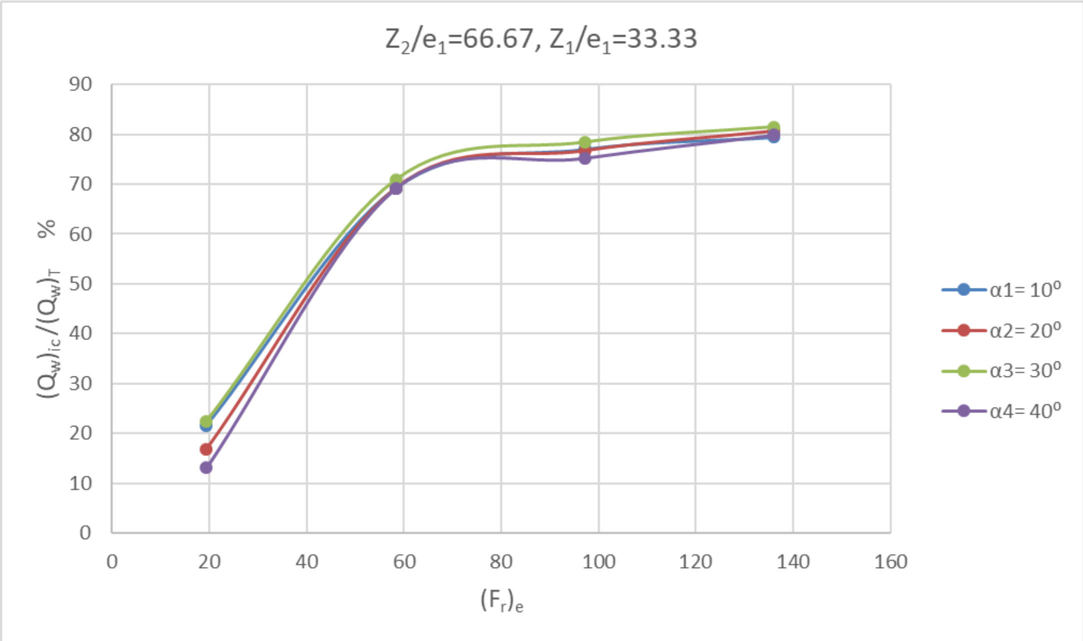

Figure 5.15. Variation of Water Capture Efficiency $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1=10 cm, Z_2=20 cm)

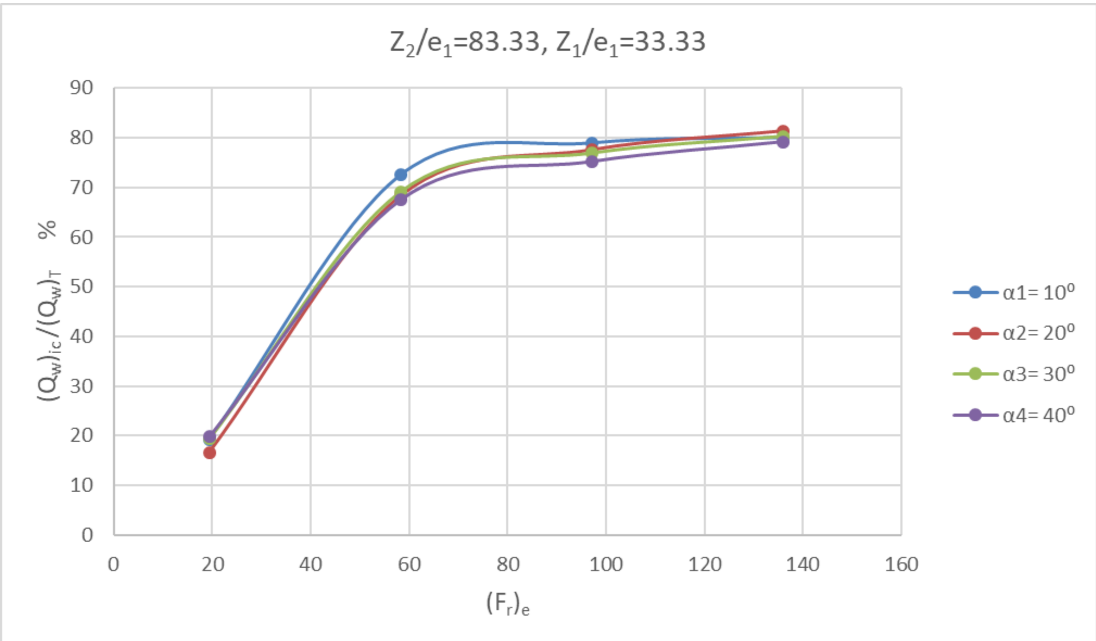

Figure 5.16. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1=10 cm, Z_2=25 cm)

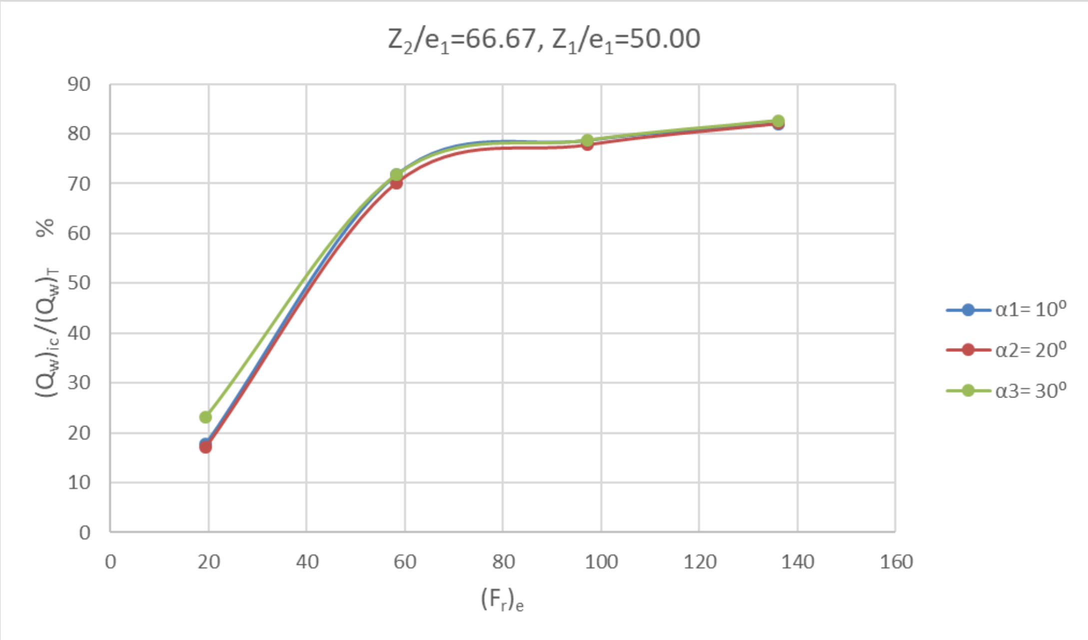

Figure 5.17. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1=15 cm, Z_2=20 cm)

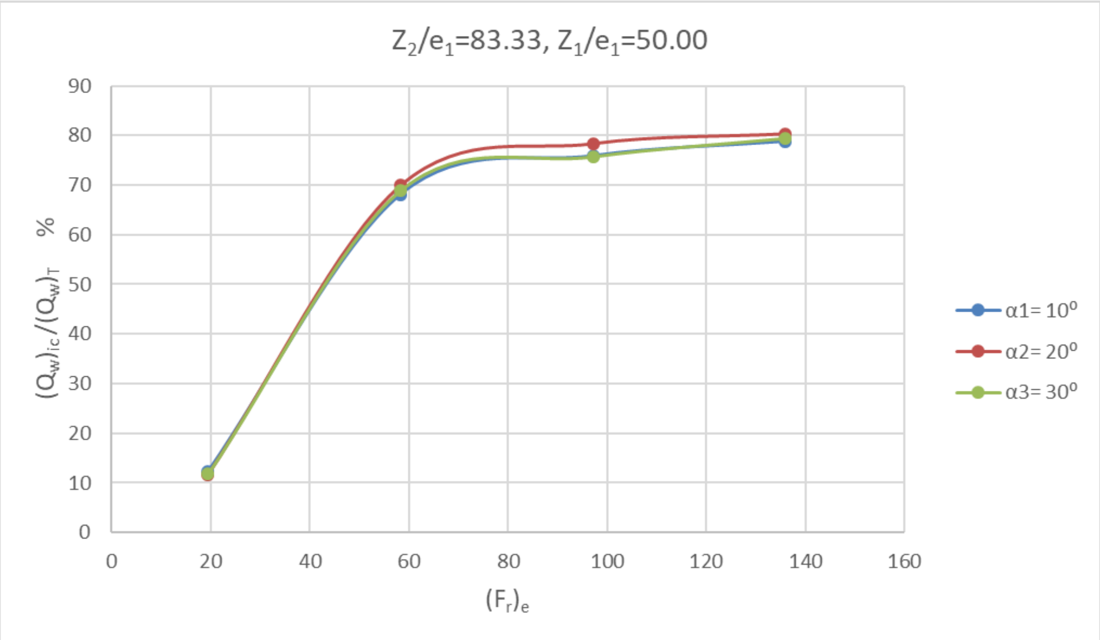

Figure 5.18. Variation of Water Capture Efficiency with respect to $(F_r)_e$ and α (e_1=3 mm, L=70 cm, Z_1=15 cm, Z_2=25 cm)

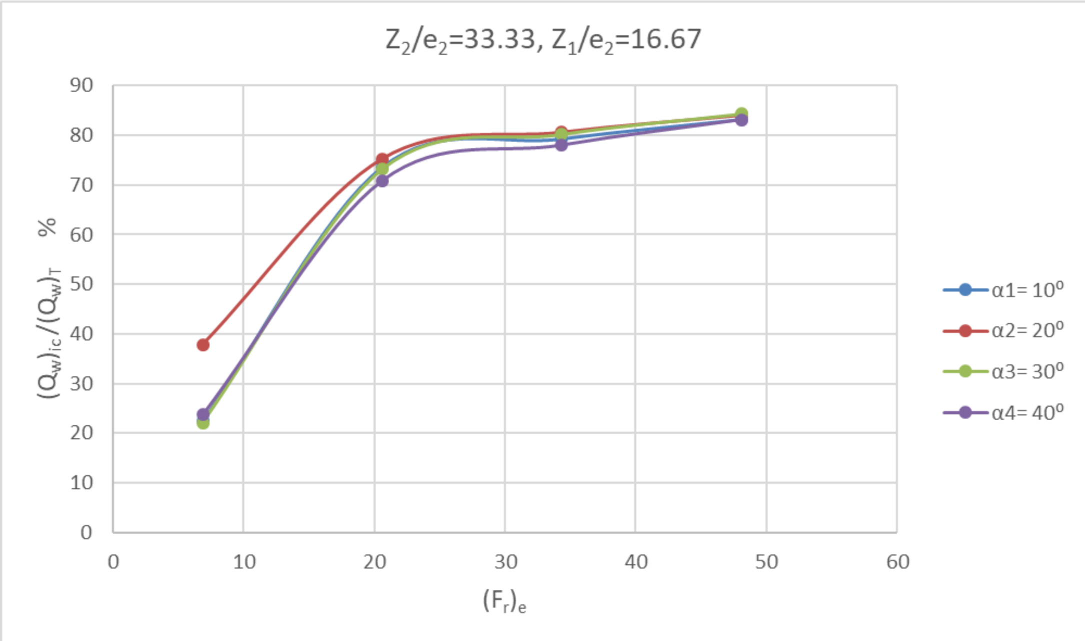

Figure 5.19. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1=10 cm, Z_2=20 cm)

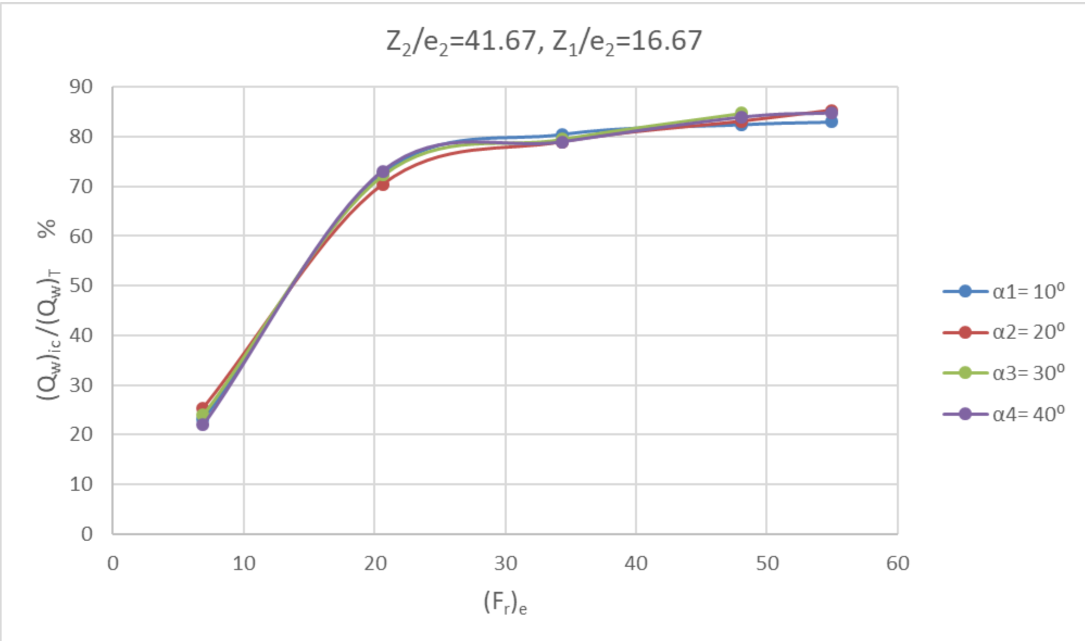

Figure 5.20. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1=10 cm, Z_2=25 cm)

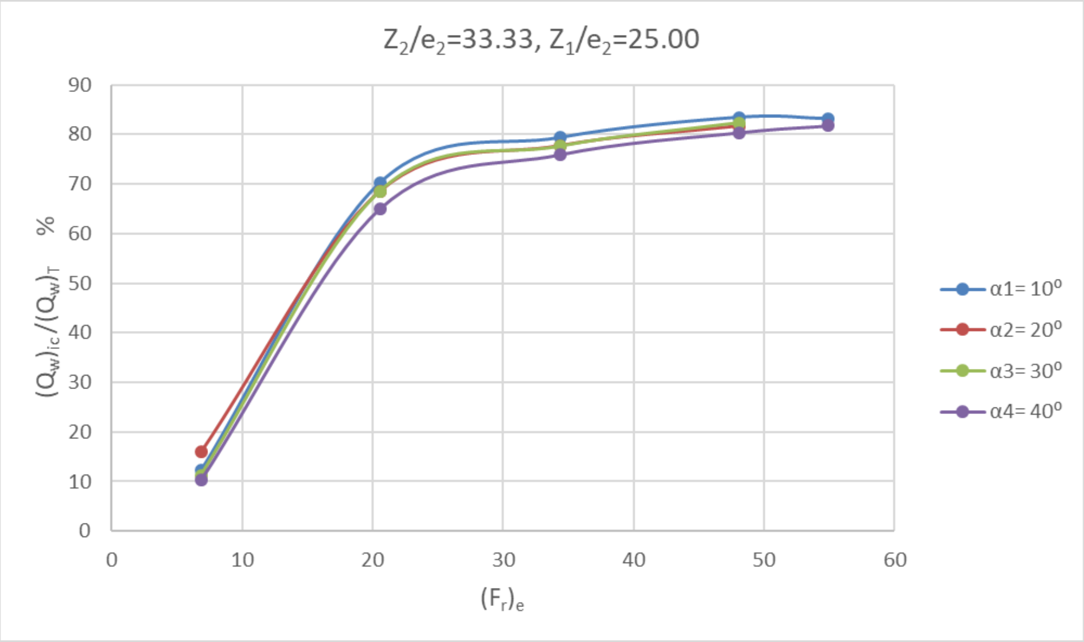

Figure 5.21. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1=15 cm, Z_2=20 cm)

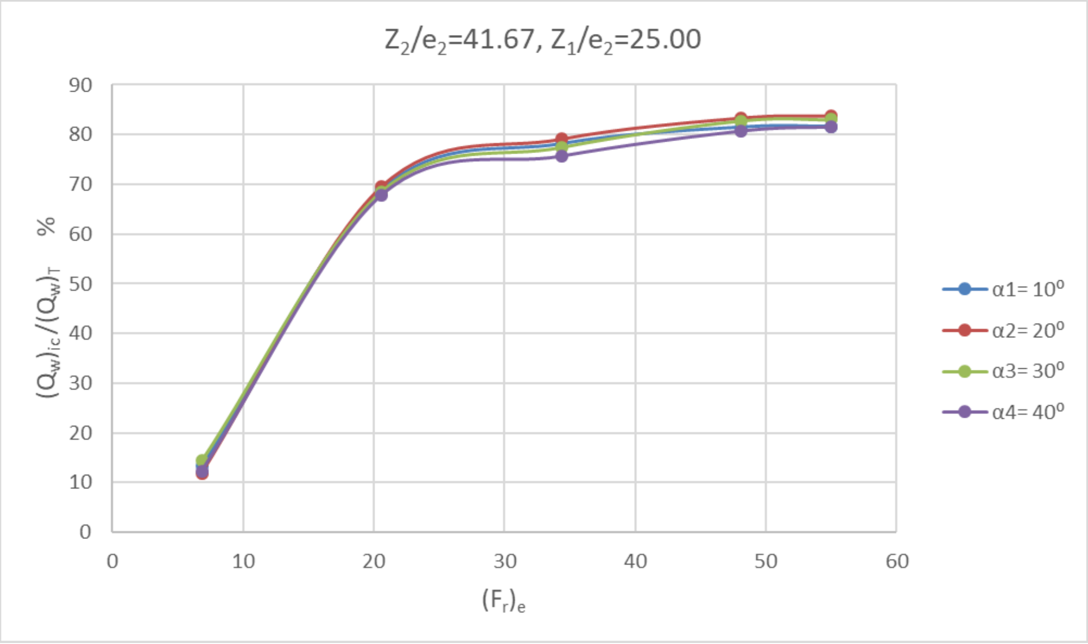

Figure 5.22. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_2=6 mm, L=70 cm, Z_1=15 cm, Z_2=25 cm)

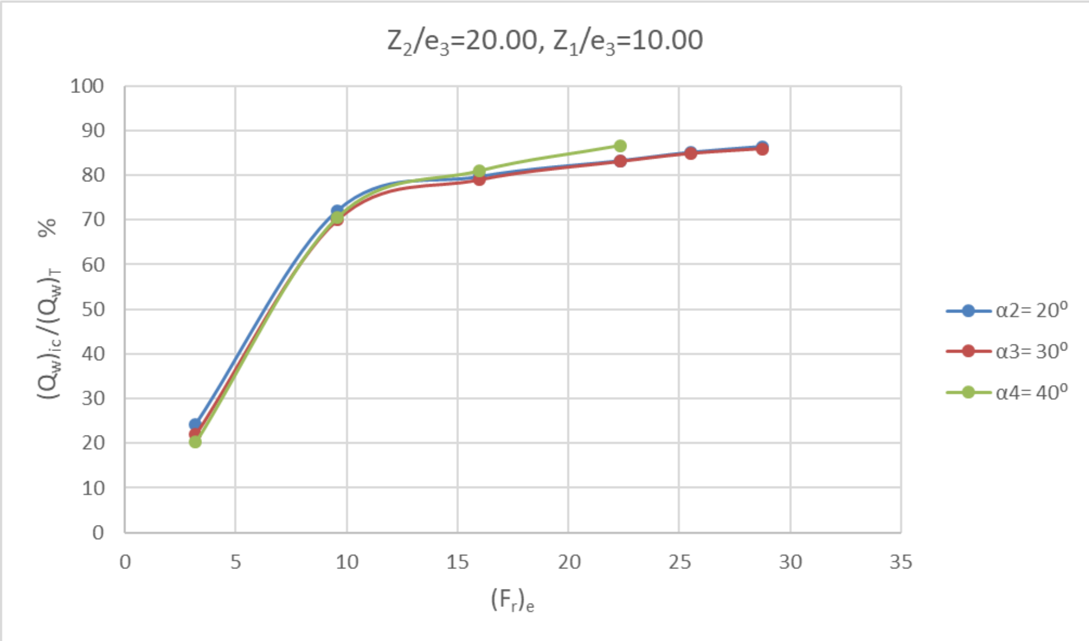

Figure 5.23. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_3=10 mm, L=70 cm, Z_1=10 cm, Z_2=20 cm)

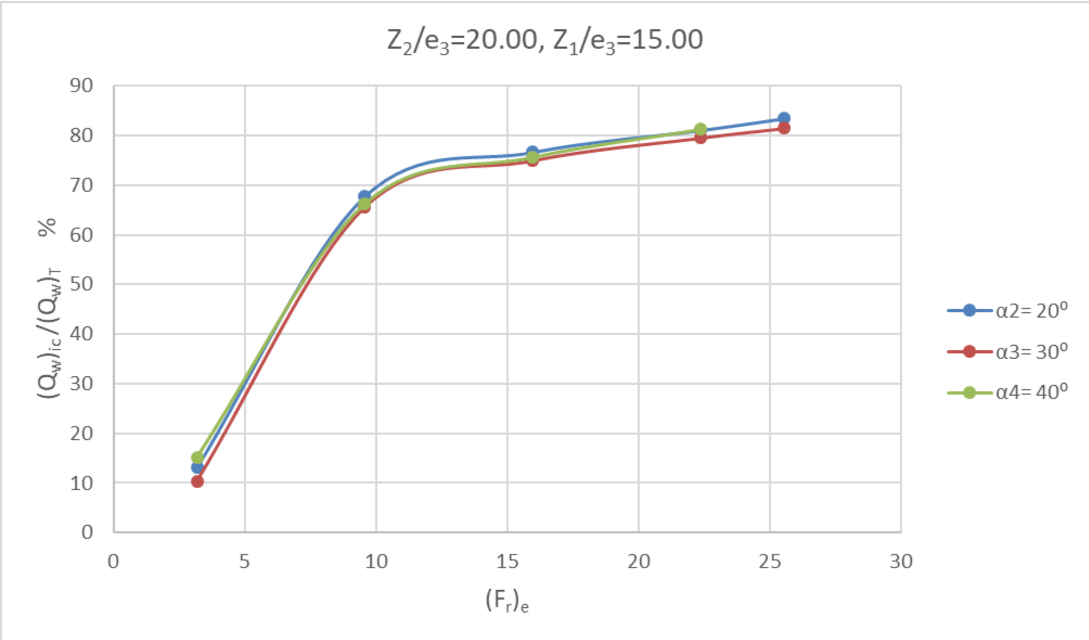

Figure 5.24. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_3=10 mm, L=70 cm, Z_1=15 cm, Z_2=20 cm)

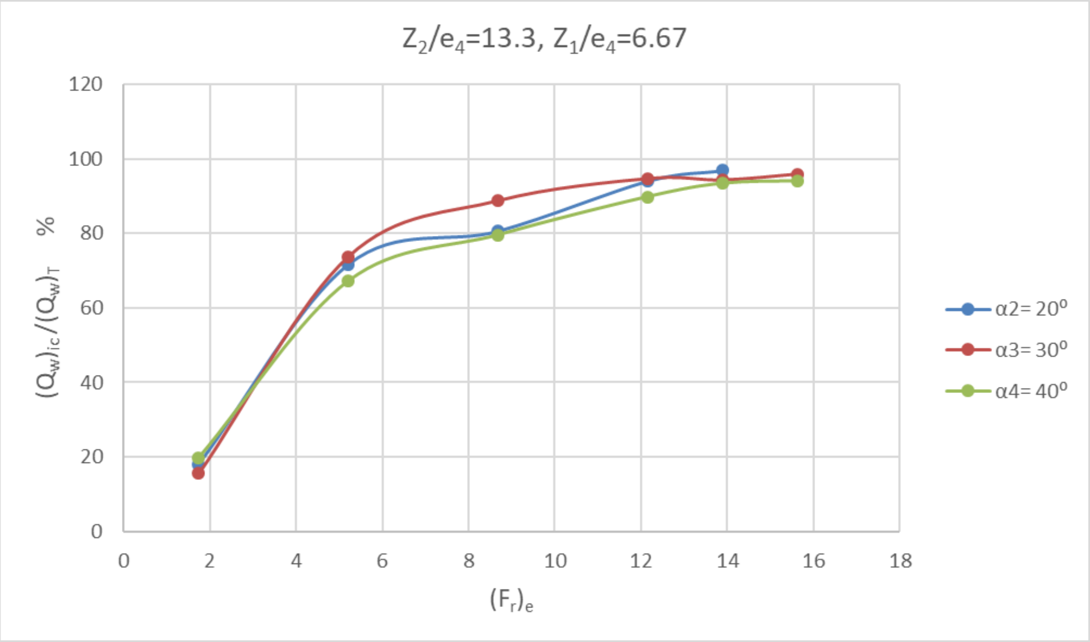

Figure 5.25. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_4=15 mm, L=70 cm, Z_1=10 cm, Z_2=20 cm)

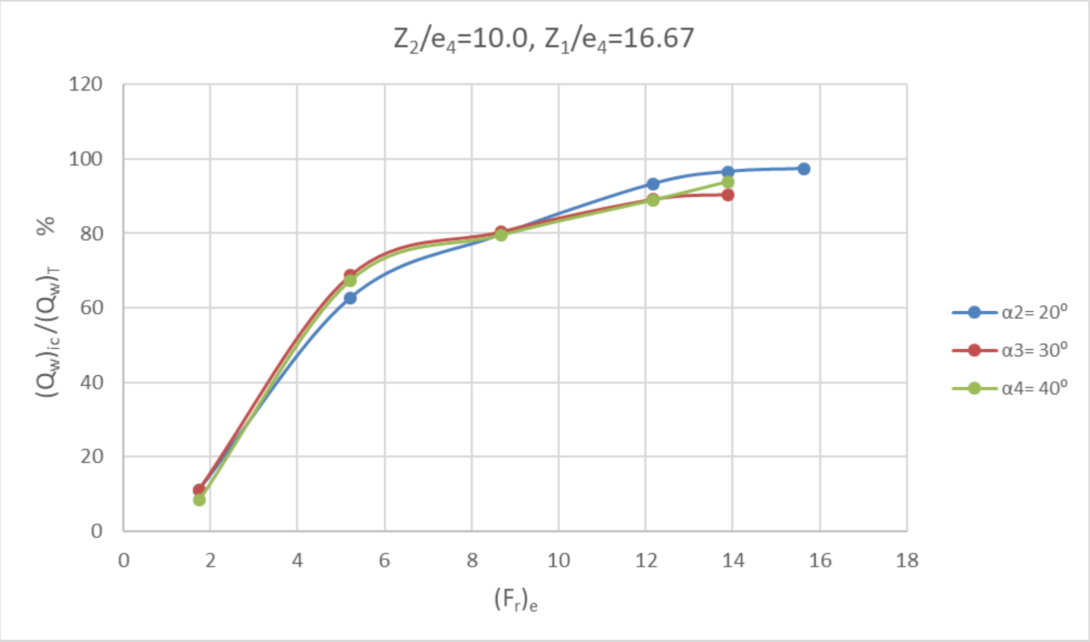

Figure 5.26. Variation of Water Capture Efficiency with $(F_r)_e$ and α (e_4=15 mm, L=70 cm, Z_1=15 cm, Z_2=20 cm)

In A-2 Group experiments, weight of the sediment within the “Collection Channel-1”, “Intake Channel” and “Sediment Collection Channel” as well as water capture efficiency were measured the related dimensionless parameters were determined and presented in Appendix-B (Tables B.1-B.4). The aim of this part of the study is to determine the configuration of the experimental setup which maximize the parameter of $[(W_s)_{sc}]_R$ Figures 5.27-5.30 show the variation of $[(W_s)_{sc}]_R$ with α for constant values of Z_1/e, Z_2/e and clear bar spacing e.

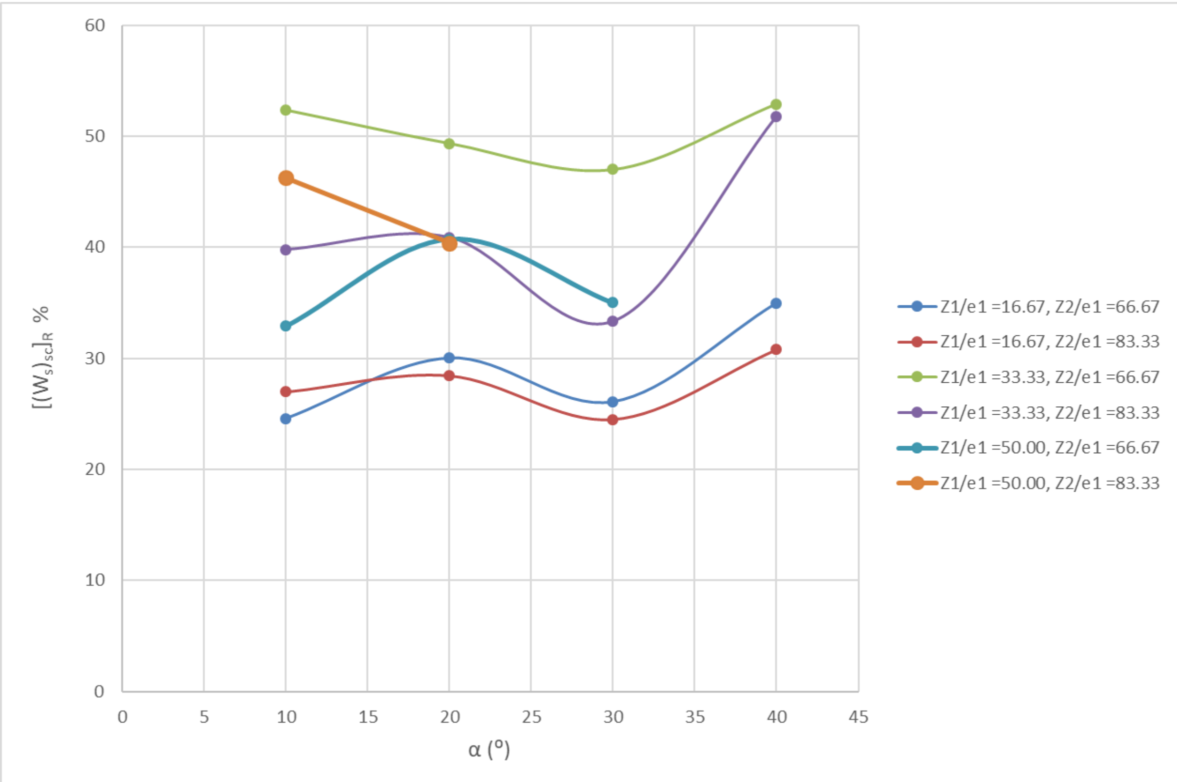

Figure 5.27. Variation of $[(W_s)_{sc}]_R$ with α, Z_1/e and Z_2/e for the rack of e_1= 3 mm

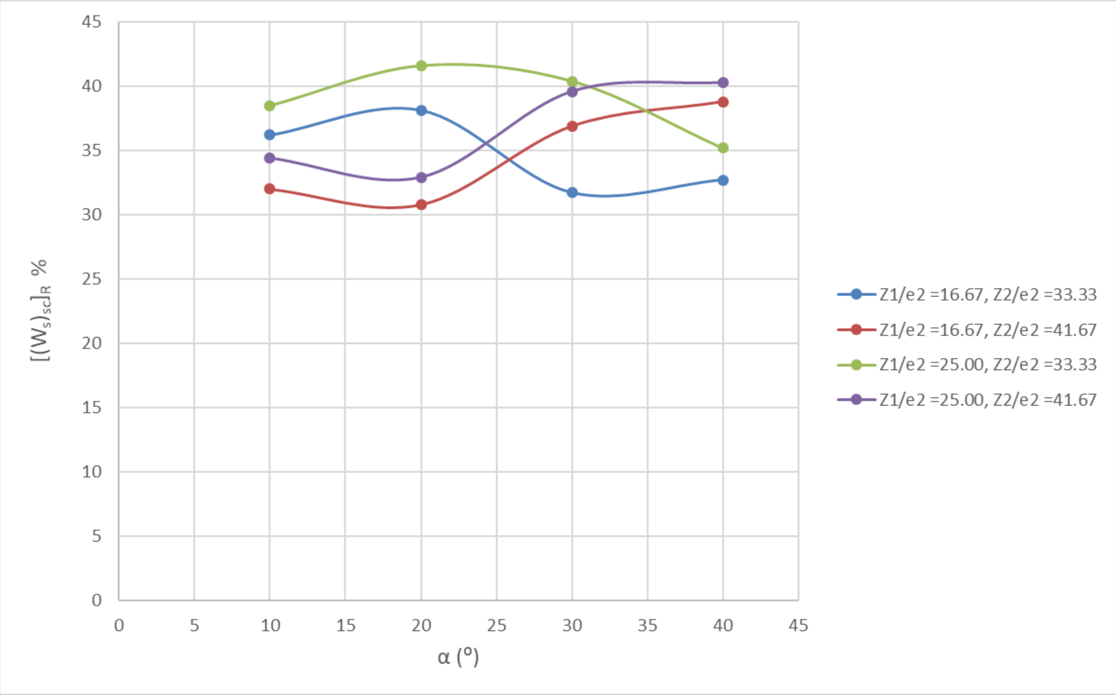

Figure 5.28. Variation of $[(W_s)_{sc}]_R$ with α, Z_1/e and Z_2/e for the rack of e_2=6 mm

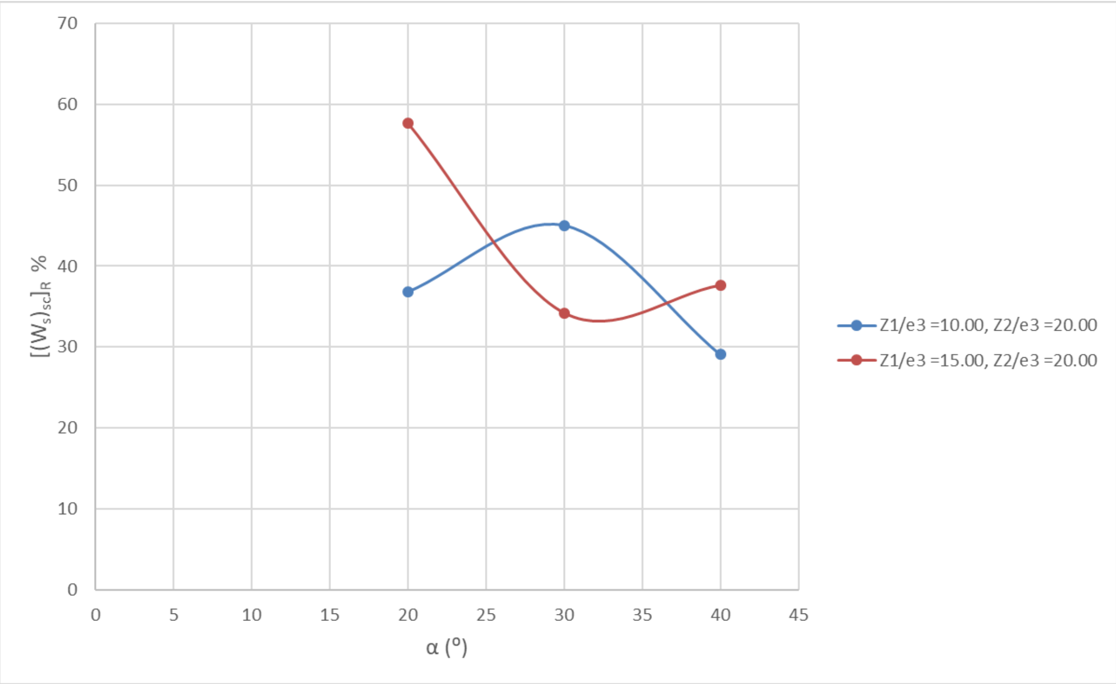

Figure 5.29. Variation of $[(W_s)_{sc}]_R$ with α, Z_1/e and Z_2/e for the rack of e_3=10 mm

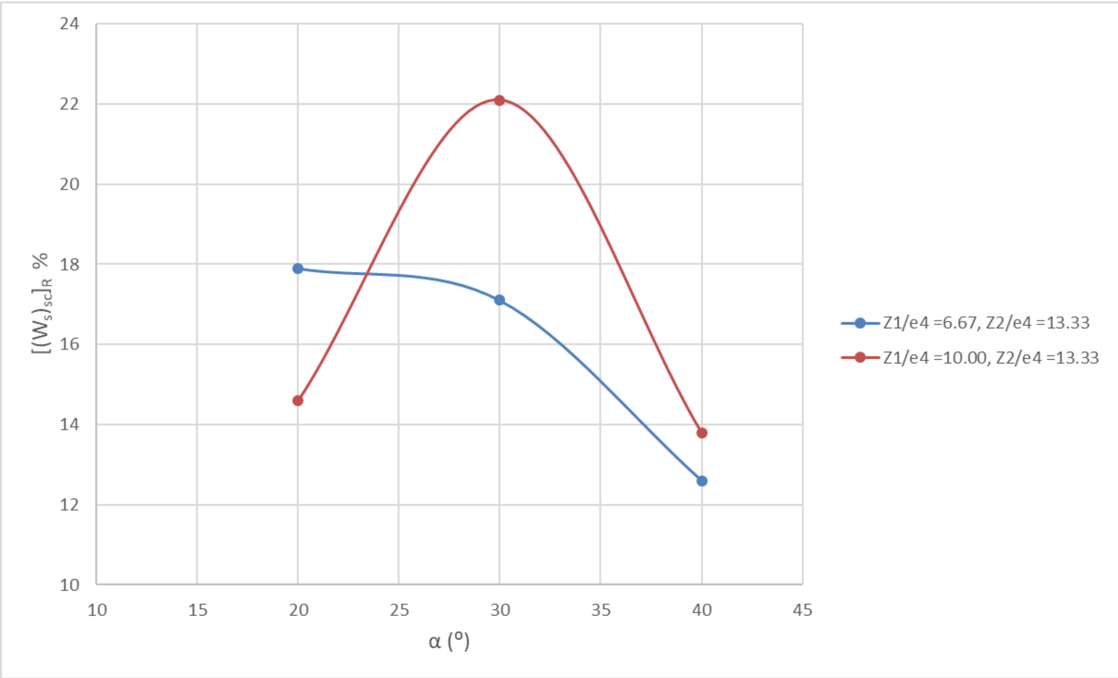

Figure 5.30. Variation of $[(W_s)_{sc}]_R$ with α, Z_1/e and Z_2/e for the rack of e_4=15 mm

Figure 5.27 shows the variation of $[(W_s)_{sc}]_R$ with α for clear bar spacing of e_1=3 mm. The highest value of $[(W_s)_{sc}]_R$ is determined as 52.9 % for the parameters of α=40°, Z_1= 10 cm and Z_2=20 cm. Experiment for the parameters Z_1=15 cm and α=40° were not conducted because of the lack of space between the "Dividing Plate" and "Guide Plate" which prevents the passage of flow from "Collection Channel-1" to "Collection Channel-2".

From Figures 5.28, 5.29 and 5.30 it is seen that the largest values of the parameter $[(W_s)_{sc}]_R$ measured are 41.6 %, 57.7 % and 22.1 % for the clear bar spacings of e_2=6, e_3=10 mm and e_4=15 mm, and for the parameters of α=20°, Z_1= 15 cm and Z_2=20 cm, α=20°, Z_1= 15 cm and Z_2=20 cm and α=30°, Z_1= 15 cm and Z_2=20 cm, respectively.

Largest values determined for the parameter of $[(W_s)_{sc}]_R$ stated above are listed in Table 5.1 along with the other related parameters.

Table 5.1. *Values of the Parameters that Convey Maximum Amount of Sediment to the "Sediment Collection Channel" for A-2 Group Experiments*

e (mm)	*3*	*6*	*10*	*15*
α (°)	40	20	20	30
Z_1 (cm)	10	15	15	15
Z_2 (cm)	20	20	20	20
$[(W_s)_{ic}]_R$ (%)	37.0	31.4	20.4	24.4
$[(W_s)_{sc}]_R$ (%)	52.9	41.6	57.7	22.1
$[(W_s)_{cc}]_R$ (%)	10.2	27.0	21.9	53.5

By examining the table above and the results of the experiments, it can be stated that the values of the parameters α, Z_1 and Z_2 for a specified clear bar spacing are different and in most of the cases given in the table sediment is accumulated at the bottom of the "Collection Channel-1". Therefore, it was concluded that the results of the A-2 Group Experiments cannot fulfill the expectations so that the base slope of the "Collection Channel-1"was increased to 6° from 4° and a series of experiments, named as B-Group Experiments, were conducted under the predefined conditions.

5.4. Results and Analysis of B-Group Experiments

All of the experiments under A-2 Group were repeated within the scope of B- Group Experiments. Measured and calculated data were provided in Appendix C (Tables C.1-C.4).

"Sliding Gate" opening was set to T=2 cm for the clear bar spacings of e_1=3 mm, e_2=6 mm and e_3=10 mm while the "Sliding Gate" opening was set to T=3 cm for clear bar spacing of e_4=15 mm to prevent the gate opening area from sediment accumulation. The accumulation of sediment around the gate opening was caused by the coarser sediment particles that pass through the bottom rack.

The guide plate angles of α=30° and 40° provided the highest sediment ratios within the "Sediment Collection Channel" so that these two guide plate angles were used for the clear bar spacings of e=3, 6, 10 and 15 mm throughout the B-Group experiments. Within the scope of B-Group experiments the related figures were not given here but the analyses of the experimental results were made to determine the optimum values of the parameters α, Z_1, Z_2. Best system configurations for obtaining the maximum amount of sediment within the “Sediment Collection Channel” are provided in Table 5.2 as a function of the clear bar spacings tested.

Table 5.2. *Values of the Parameters that Convey Maximum Amount of Sediment to the “Sediment Collection Channel” for B-Group Experiments*

e (mm)	*3*	*6*	*10*	*15*
α (°)	40	30	30	40
Z_1 (cm)	15	15	10	15
Z_2 (cm)	20	20	20	20
$[(W_s)_{ic}]_R$ (%)	34.0	30.5	31.8	18.7
$[(W_s)_{sc}]_R$ (%)	63.8	58.7	52.8	69.0
$[(W_s)_{cc}]_R$ (%)	2.1	10.8	15.5	12.3

The largest value of the parameter $[(W_s)_{sc}]_R$ is 63.8 % for the clear bar spacing of e_1=3 mm while the value of $[(W_s)_{cc}]_R$ = 2.1 %. These are the best results for the clear bar spacing of e_1= 3 mm and obtained by setting α=40°, Z_1=15 cm and Z_2=20.

The largest value of the parameter $[(W_s)_{sc}]_R$ is 58.7 % for the clear bar spacing of e_2 = 6 mm while the value of $[(W_s)_{cc}]_R$ = 10.8 %. These are the best results for the clear bar spacing of e_1= 6 mm and obtained by setting α=30°, Z_1=15 cm and Z_2=20.

For the clear bar spacing of e_3= 10 mm, the largest value of the parameter $[(W_s)_{sc}]_R$ is 52.8 % while $[(W_s)_{cc}]_R$ = 15.5 %. These results were obtained by setting; α=30°, Z_1=10 cm and Z_2=20.

For the clear bar spacing of e_4= 15 mm, the largest value of the parameter $[(W_s)_{sc}]_R$ is 69 % while $[(W_s)_{cc}]_R$ = 12.3 %. These results were obtained by setting; α=40°, Z_1=15 cm and Z_2=20.

Throughout the B-Group and A-2 Group Experiments, the largest values obtained for the parameter of $[(W_s)_{cc}]_R$ are; 15.5 % for the model of e_3= 10 mm, α=30°, Z_1=10 cm and Z_2= 20 cm and 53.5 % for the model of e_4=15 mm, α=30°, Z_1=15 cm and Z_2=20 cm respectively.

From the comparison of these two cases it is clearly seen that increasing the bottom slope of the "Collection Channel -1" from 4° to 6° prevent accumulation of sediment and clogging at the channel bottom.

In order to improve the diverted sediment ratio and the captured discharge, further modifications were implemented to the experimental setup by keeping the initial bottom slope of the "Collection Channel-1" and providing a lateral slope of 6° at the channel bottom from upstream wall of the "Collection Channel-1" towards the "Dividing Plate" . A series of experiments, which is called as C-Group Experiments, were conducted after implementing the modifications stated above.

5.5. Results and Analysis of C-Group Experiments

Experiments with clear bar spacing of e_1= 3 mm and guide plate angles of α=30° and 40° were conducted to observe the effect of lateral slope of 6° at the "Collection Channel-1" on sediment movement within the C-Group Experiments.

By considering A-2 and B-Group Experiments, it was observed that "Guide Plate" angles of α= 30° and α= 40° have a tendency to cause higher amount of sediment within the "Sediment Collection Channel" than those of other α values tested, which was the ultimate aim of the study. Due to the lack of number of experiments, the results were analyzed by comparing the raw data, which are presented in Appendix D (Table D.1), instead of constructing graphs of related parameters.

By choosing the same; guide plate angle, length and dividing plate height, clear bar spacing and the total sediment amount of $(W_s)_T$=100 kgf in the main channel, the experimental results of C-Group Experiments and B-Group Experiments were compared in terms of sediment amount diverted into the “Sediment Collection Channel”. It was concluded that;

- For e_1=3 mm and α=30° in B-Group Experiments, 34.9 % of the main channel sediment amount passes through the bottom racks and 64.4 % of that is diverted to the “Sediment Collection Channel” of which 0.8 % is accumulated within the “Collection Channel-1”.
- For e_1=3 mm and α=30° in C-Group Experiments, 41.18 % of the main channel sediment amount passes through the bottom racks and 50.33 % of that is diverted to the “Sediment Collection Channel” of which 0.7 % is accumulated within the “Collection Channel-1”.

The results of the experiments conducted with guide plate angle of α=40° were presented in Appendix D (Table D.1). Based on the comparison of the results of B-Group and C-Group experiments it was determined that the setup of B-Group Experiments provides better results than those of C-Group setup. Eventually, by considering the experimental results and observations obtained from A-B and C-Group experiments, it was decided to implement a final modification to the experimental setup to improve the system’s performance.

5.6. Results and Analysis of D-Group Experiments

In this part of the study, by considering the results of the previous experiments a final modification was implemented to the experimental setup. Bottom slope of the “Collection Channel-1” was kept as 6° in the flow direction while the lateral slope of the “Collection Channel-1” was reversed, again 6° lateral slope was applied starting from the bottom of the “Dividing Plate” towards the bottom of the upstream wall of the “Collection Channel-1”. The lateral bottom slope of the “Collection Channel-1” was kept constant along the channel in order to prevent sediment, which is directed towards the “Collection Channel-1” by means of the “Guide Plate”, from moving towards the “Dividing Plate” due to the secondary flows occurring within the “Collection Channel-1”.

The lateral slope of 6° prevents sediment from accumulating throughout the length of the “Dividing Plate” and therefore, the available sediment within the “Collection Channel-1” is forced to move along the channel towards the “Sliding Gate” and from there to the “Sediment Collection Channel” through the opening at the bottom of the “Sliding Gate”. After having the predefined modifications implemented on the slope of the “Collection Channel-1”, a series of experiments were conducted within the scope of D-Group Experiments. Measured and calculated results of the D-Group Experiments were presented in “Appendix E (Tables E.1-E.4).

By considering the results and impressions obtained from the previous experiments, the experiments with the parameters of α=10° and Z_1=5 cm were not repeated throughout D-Group Experiments because the “Guide Plate” angle of α=10° and the “Dividing Plate” height of Z_1=5 cm were far away from providing the expected results in the previous experiments.

Figures 5.31-5.34 show the variation of water capture efficiency with $(F_r)_e$ for specified clear bar spacings of the bottom rack, Z_1 and Z_2 parameters. From the assessment of these figures the following conclusions can be stated: The effect of α, Z_1 and Z_2 on the values of water capture efficiency is almost negligible for small values of $(F_r)_e$ tested in each setup of different e values. As the value of $(F_r)_e$ increases, small variations on the value of water capture efficiency are observed with varying values of α, Z_1 and Z_2. Although the data points of each setup tested follow very similar trends, the curves of each setup intersect each other at various values of $(F_r)_e$. However, it can be stated that the experimental setup of α= 40° yields the largest water capture efficiency values almost in each case tested.

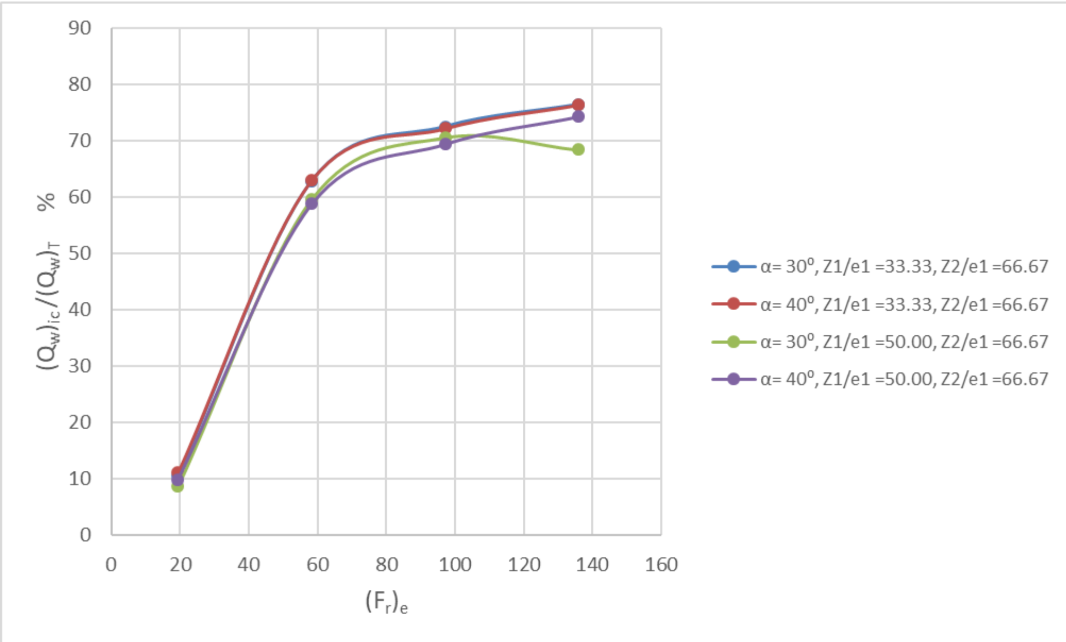

Figure 5.31. Variation of Water Capture Efficiency with $(F_r)_e$, α, Z_1/e_1 and Z_2/e_1 (e_1=3 mm, L=70 cm, Z_1= 10 -15 cm, Z_2=20-25 cm)

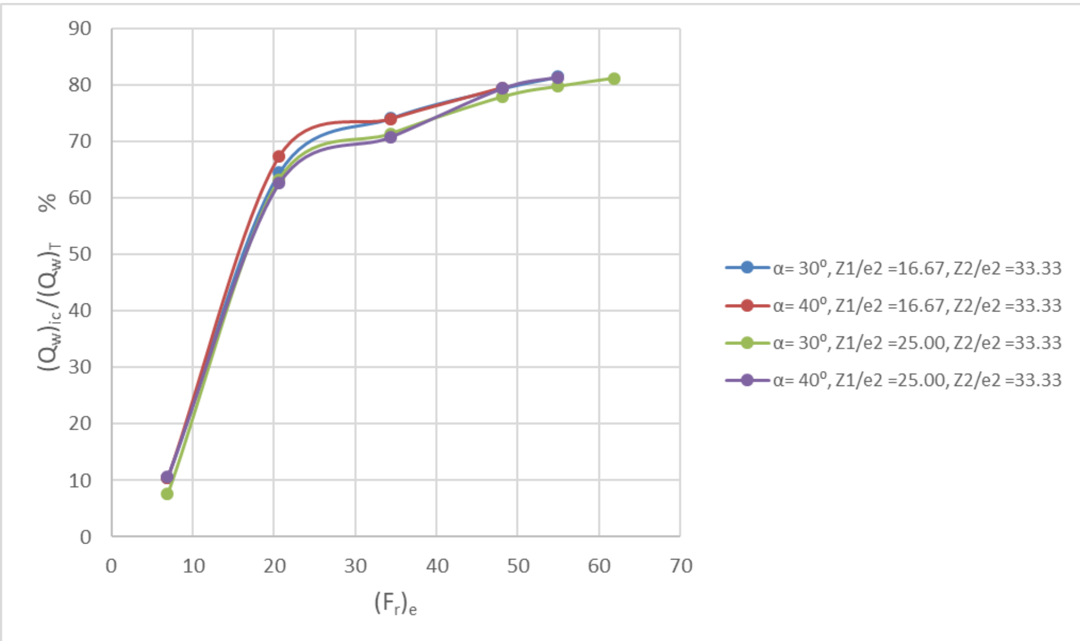

Figure 5.32. Variation of Water Capture Efficiency with $(F_r)_e$, α, Z_1/e_2 and Z_2/e_2 (e_2=6 mm, L=70 cm, Z_1= 10 -15 cm, Z_2=20-25 cm)

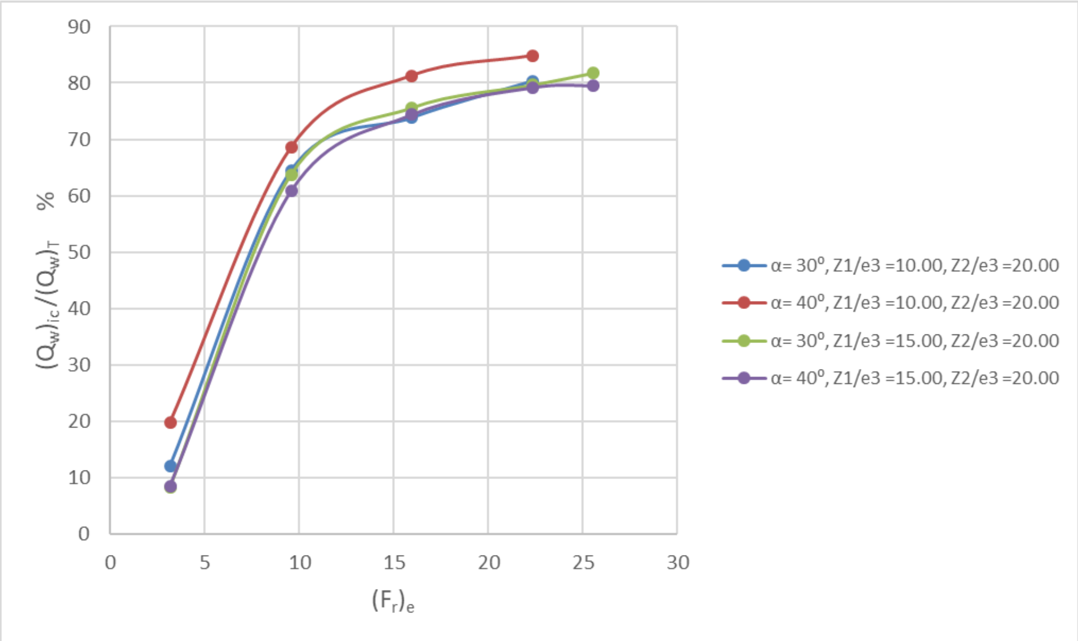

Figure 5.33. Variation of Water Capture Efficiency with $(F_r)_e$, α, Z_1/e_3 and Z_2/e_3 (e_3=10 mm, L=70 cm, Z_1= 10 -15 cm, Z_2=20-25 cm)

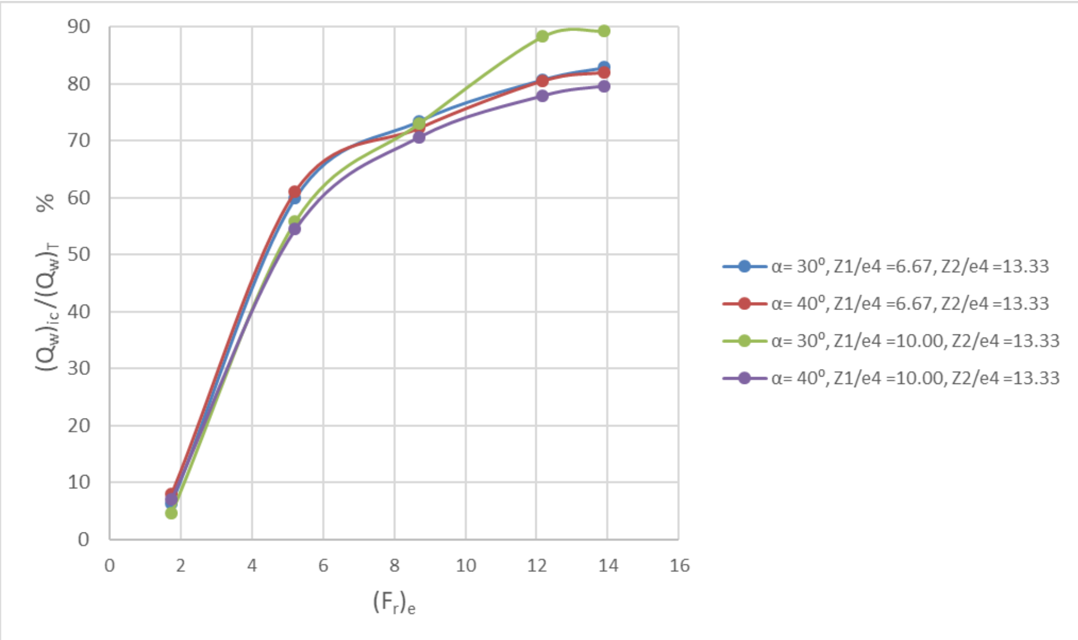

Figure 5.34. Variation of Water Capture Efficiency with $(F_r)_e$, α, Z_1/e_4 and Z_2/e_4 (e_4=15 mm, L=70 cm, Z_1= 15 cm, Z_2=20-25 cm)

By inspecting the results of D-Group Experiments presented in Tables E.1-E.4 of Appendix E, values of the parameters such as length of the "Guide Plate", height of the "Dividing Plate" and the angle between horizontal axis and the "Guide Plate" that convey the maximum amount of sediment to the "Sediment Collection Channel" for a specified clear bar spacing were tabulated in Table 5.3.

Table 5.3. *Values of the Parameters that Convey the Maximum Amount of Sediment to the "Sediment Collection Channel" in D-Group Experiments*

e (mm)	*3*	*6*	*10*	*15*
α (°)	40	40	40	40
Z_1 (cm)	15	15	15	15
Z_2 (cm)	20	20	20	20
$[(W_s)_{ic}]_R$ (%)	24.1	21.0	27.0	15.8
$(W_s)_{sc}$ (%)	75.0	68.0	63.0	63.0
$(W_s)_{cc}$ (%)	1.2	11.0	9.7	22.8

The assessment of Table 5.3 shows that α=40°, Z_1=15 cm and Z_2=20 cm are the ideal values of the parameters which will convey the maximum amount of sediment to the "Sediment Collection Channel" and minimum amount of sediment to the" Collection Channel-1" for specified clear bar spacings of e_1=3 mm, e_2= 6 mm, e_3=10 mm and e_4=15 mm.

Total sediment passes from the clear bar spacings are distributed between "Sediment Collection Channel" and "Intake Channel". Also, some portion of the sediment is accumulated within the "Collection Channels". Table 5.4 shows the optimum setup parameters resulting in maximum amount of sediment to be diverted from the main channel to the "Sediment Collection Channel".

Table 5.4. *Optimum Setup Parameters Result in Maximum Amount of Sediment to be Diverted from the Main Channel to the Sediment Collection Channel*

e (mm)	3	6	10	15
α (°)	40	40	40	40
Z_1 (cm)	15	15	15	15
Z_2 (cm)	20	20	20	20
$[(W_s)_{ic}]_R$ (%)	24.0	21.0	27.0	15.8
$[(W_s)_{sc}]_R + [(W_s)_{cc}]_R$ (%)	76.0	79.0	73.0	86.0

As it can be seen from Table 5.4, α=40°, Z_1=15 cm and Z_2=20 cm are the optimum values of the parameters which cause system to be operated under the maximum efficiency in terms of water capture efficiency and removal of sediment from the intake channel. For the given values of the parameters, at least 73 % of the sediment that passes from the clear bar spacings of e_1=3 mm, e_2=6 mm, e_3= 10 mm and e_4= 15 mm are conveyed to the downstream of the main channel and only 27 % of the remaining sediment can pass towards the settling basin at which considerable portion of that amount are settled and prevented from moving towards the turbines.

If Tyrolean weir without these modifications were used throughout the experiments, the whole amount of sediment that passes from the clear bar spacings would reach to the settling basin and cause settling basin to be filled with sediment in a short time.

5.7. Evaluation of the Results

The ideal values of the parameters α, Z_1 and Z_2 for a given system of providing the maximum water capture efficiency and maximum sediment diversion from the main channel should be generalized to use them in the design of such systems. For this reason, dimensionless forms of these parameters should be formed.

The aim of using the "Guide Plate" is to cover the upper part of the "Collection Channel-2" as well as conveying sediment to "Collection Channel-1". In addition, Z_1 is the height of the "Dividing Plate" which separates "Collection Channel-1" from

“Collection Channel-2”. Therefore, these two parameters; Z_1 and Z_2 are made dimensionless by dividing them by the width of the collection channels, B. As a result, the recommended dimensionless parameters are;

$$Z_1/_B = \frac{15}{45} = 0.33 \quad and \quad Z_2/_B = \frac{20}{45} = 0.44$$

Modified Tyrolean Weirs to be designed by using the dimensionless parameters obtained from the results of this study, which are $3/70 \leq e/L \leq 15/70$, $\alpha=40°$, $Z_1/B=0.33$, $Z_2/B=0.44$ and longitudinal slope and lateral slope of the “Collection Channel-1” towards the “Dividing Plate” should be larger than 6°, would be much more efficient in terms of water capture efficiency and sediment removal from the intake structure compared to traditional Tyrolean weirs.

CHAPTER 6

NUMERICAL ANALYSIS

6.1. Introduction

Computational fluid dynamics (CFD) is a computational method for solving fluid flow problems. Mathematical equations that represent fluid flow such as Navier-Stokes and continuity equations are solved for each computational cell within a given computational interval to represent fluid flow of the specified engineering problem. Before the development of the available computational power, fluid flow problems such as aircraft design are conducted by constructing laboratory model and application of wind-tunnel testing which is a time consuming and expensive process. But advances in the computational power lead engineers for computer aided design. However, computational aided design or solving problem numerically does not always end up with correct solutions. Therefore, numerical results should be validated with the experimental ones. Lots of software such as ANSYS Fluent, ANSYS CFX, FLOW-3D are developed for solving fluid flow problems. All package software use the same approach; discretization of the governing equations and solving those equations for specified problem. In this study, FLOW-3D is preferred for solving fluid flow through a water intake structure design.

FLOW-3D is a tool for computational fluid dynamics solutions. It is commonly used for simulating free surface flows. It includes different physical modules such as sediment scour model, heat transfer model, air entrainment model, shear stress model, cavitation model, compressible and incompressible flow model to simulate various physical phenomenon.

FLOW-3D uses state of the art "TruVOF" method. "Volume of Fluid Method (VOF)" is invented by Nichols and Hirt (1975) and further developed as "TruVOF" by Hirt and Nichols (1981) for solving free surface flows.

6.2. General Procedure

General procedure for constructing numerical model can be summarized as follows;

- Formation of geometry to be modelled on AutoCAD and converting the drawing to "stl" format,
- Formation of structured grids to cover entire computational domain.
- Defining related initial and boundary conditions to represent physical phenomenon.

It should be noted that forming strictly fine grid cause long simulation times and does not necessarily end up with correct solution while forming coarse grid can end up with the solution that is not related to real physical phenomenon. Therefore, grid generation is an important part of the CFD.

6.3. Implementation of the Numerical Model

Implementation of numerical model requires several steps;

- Grid Generations,
- Definition of initial and boundary conditions
- Physics, turbulence model and other solver options.

Each of these steps are investigated and explained in the following sub chapters.

6.3.1. Grid Generation

As mentioned before, most important part of constructing numerical model is the grid generation. Accurate results can be obtained only by creating appropriate grid size that is suitable for specified geometry. FLOW-3D allows construction of structured grid instead of unstructured grid. In addition, structured grid can be uniform or non-uniform which depends on engineering decision and geometry of computational domain.

Firstly, geometry file with an extension of “stl” was inserted into FLOW-3D and coordinate system was selected as cartesian coordinates. Moreover, there is an option for cylindrical coordinate system but for the system to be modelled, cartesian coordinates are more suitable than the cylindrical ones.

Secondly, mesh blocks were formed. FLOW-3D provides an option for constructing one or several mesh blocks. Again, constructing one mesh block or several mesh blocks that represents computational domain depends on geometry and engineering decisions.

FLOW-3D lecture notes provide guidelines for grid generation. According to lecture notes, it was suggested that cell aspect ratio should not exceed 2 for the cells in order to get proper solutions. In addition, it was suggested that size of one cell should not exceed 2 times the size of the other neighboring cells. These suggestions are depicted in Figure 6.1 and grid generation was performed by considering the guidelines provided by FLOW-3D lectures.

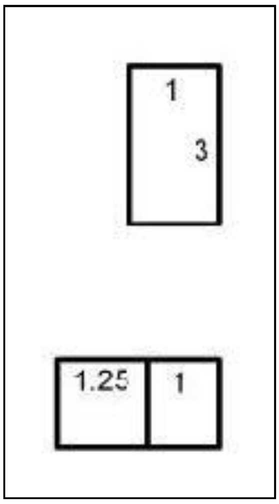

Figure 6.1. Cell Aspect Ratio and Size Ratio (FLOW-3D Lectures)

Three different grid systems were applied to the computational domain. These grids are explained in below sub-sections in detail.

6.3.1.1. Case-1 (Uniform Mesh)

At first, uniform structured grids were generated throughout the computational domain. In order to represent rack geometry, at least 2 or more grids should be placed between a clear bar spacings of 3 mm, 6 mm, 10 mm and 15 mm. Therefore, whole domain was covered with grids with a size of half of specified clear bar spacing. Moreover, after the simulation was started, estimated computational time was given as about 900 days which is unacceptable for a simulation of this size. Therefore, constructing of new mesh block became necessary.

6.3.1.2. Case-2

According to experiences gained by the first attempt, combination of non-uniform structured grids and uniform structured grids were generated throughout the computational domain given in Figure 6.2.

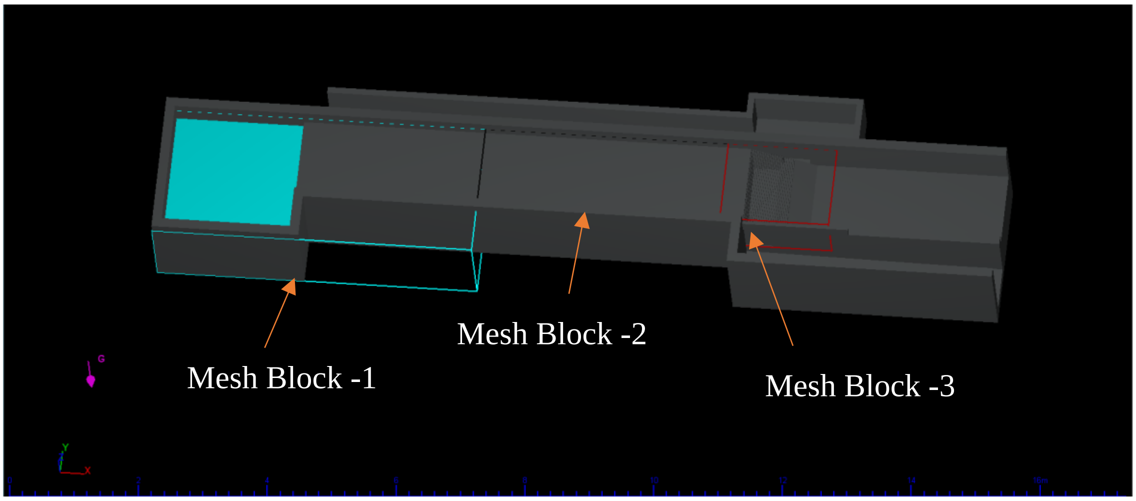

Figure 6.2. Mesh blocks and geometry to be modelled for Case-2

Channel length is about 13 m and its width is about 1.3 m. However, clear bar spacings of the system given in the Figure 6.2 is 3 mm, 6 mm, 10 mm and 15 mm. By considering the channel dimensions it can be stated that clear bar spacings are quite small compared to channel dimensions. Therefore, constructing uniform structured grid can cause enormous computational time. As a result, non-uniform structured grid that represents computational domain were generated. In order to obtain proper solutions, relatively fine grids are implemented to the areas where high velocity gradients or small areas that lead water flow exists and relatively coarse grids were implemented to the areas where geometry of the problem did not lead sudden changes. Mesh Block-1 covers the reservoir area where sudden changes did not take place. Therefore, Mesh Block-1 were generated by coarse uniform-structured grids. Mesh Block-2 were constructed by generating fine-uniform-structured grids because grids size of the one block should not exceed two times of the size of the other mesh block's grids. Mesh Block-3 covers the area where sudden changes did take place and small openings that lead discharge to pass. Therefore, Mesh Block-3 were constructed by generating fine non-uniform structured grids.

At first, only mesh block-1 part of the computational domain was run until the simulation has reached to steady state. Then, by applying grid overlay boundary condition steady state hydraulic data was used as an input for the second part of the simulation which covers the mesh blocks 2 and 3. Total simulation time takes nearly 8 days.

Two different grids (coarse and fine) were constructed and computational domain was solved. Results are presented and discussed in Chapter 7.

6.3.1.3. Case-3

In order to shorten the simulation time, different grids were generated by considering the experiences gained by Case-2. In this part only one mesh block was constructed by applying non-uniform structured grids. Computational time is about 1.5 day. Mesh blocks of Case-3 can be seen in Figure 6.3.

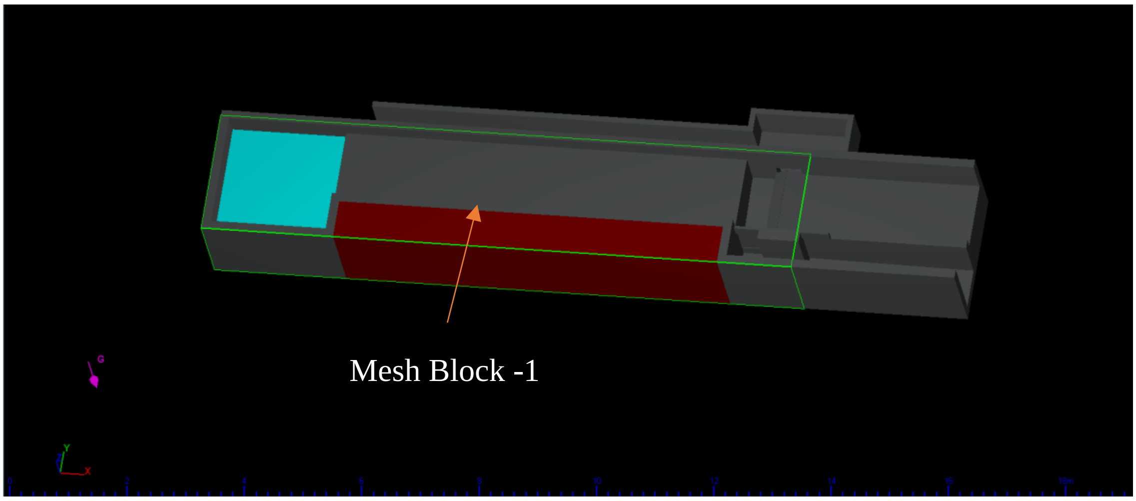

Figure 6.3. Mesh block and geometry to be modelled for Case-3

6.3.1.4. Case-4

After having the results obtained from the numerical simulation of Case-3 assessed, it was determined that simulation results were not compatible with the experimental ones. Therefore, final modifications were implemented to numerical model by improving mesh quality of Case-3. In order to improve mesh quality, mesh planes were defined throughout the computational domain. Due to the improved mesh quality, simulation time was lengthened in this case compared to Case-2. Computational domain and mesh block of Case-4 can be seen in Figure 6.4.

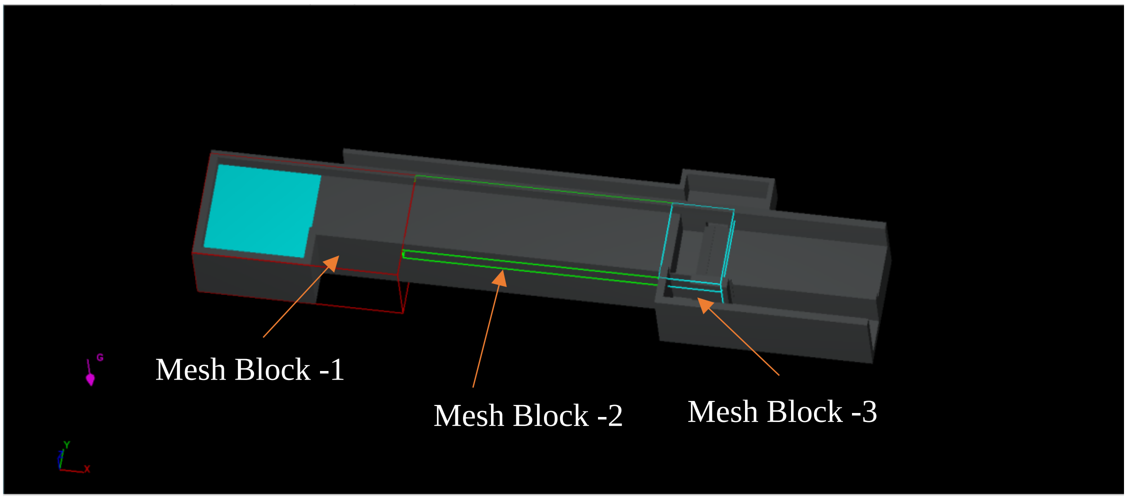

Figure 6.4. Mesh block and geometry to be modelled for Case-4

6.3.1.5. Case-5 (Sediment Application)

After having the numerical models with only water were completed, numerical simulations with sediment came into the scene. Due the limitations caused by the FLOW-3D, it is impossible to obtain reasonable results for the specific case. Because FLOW-3D suggests that sediment size should be one in tenth of mesh size. But in the case within the current study, maximum clear bar spacing is 15 mm and corresponding mesh size should be about 5-7 mm but maximum sediment diameter within the study is about 32 mm. Therefore, it was impossible to solve this scenario correctly.

6.3.2. Initial and Boundary Conditions

Determination of boundary conditions as well as initial conditions are another important part of the computational model implementation. In order to represent fluid flow correctly, appropriate boundary conditions should be selected. In addition, defining correct initial conditions can cause smaller computation time.

At first, initial condition was defined within the reservoir part of the computational domain by defining water body and coordinates of the water body were limited by the coordinates of the reservoir.

For the Case-2 where 3 mesh blocks were exist, proper boundary conditions were defined for each block. Boundary conditions for each mesh block was presented in Figure 6.5.

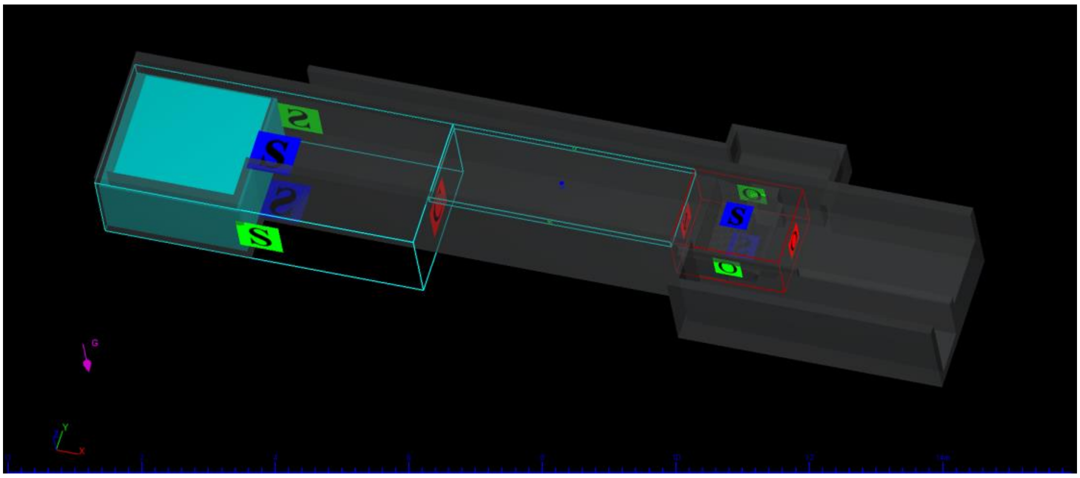

Figure 6.5. Boundary conditions for Case-2

For the Case-3 where only one mesh block was exist, boundary conditions were presented in Figure 6.6.

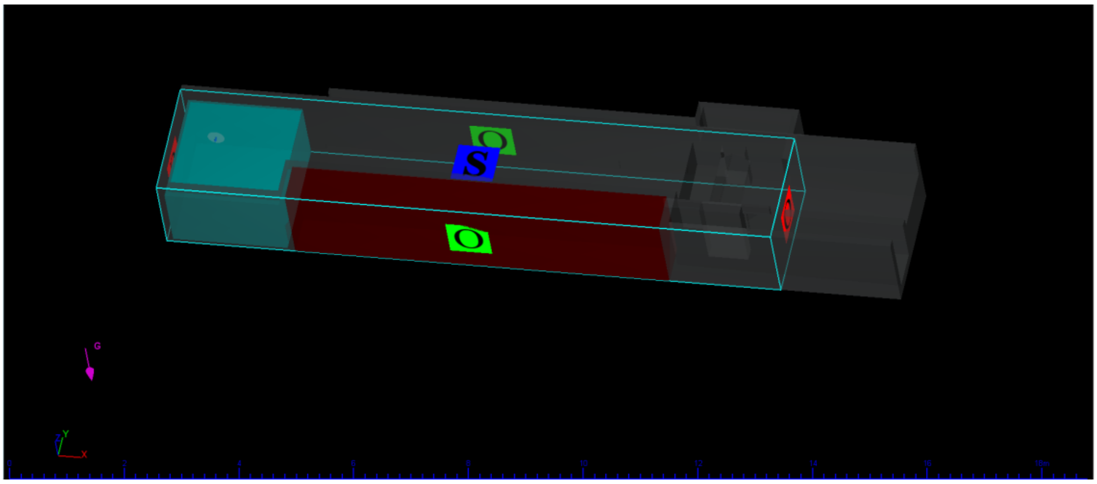

Figure 6.6. Boundary conditions for Case-3

Three mesh blocks were generated for Case-4 and boundary conditions of each block were presented in Figure 6.7.

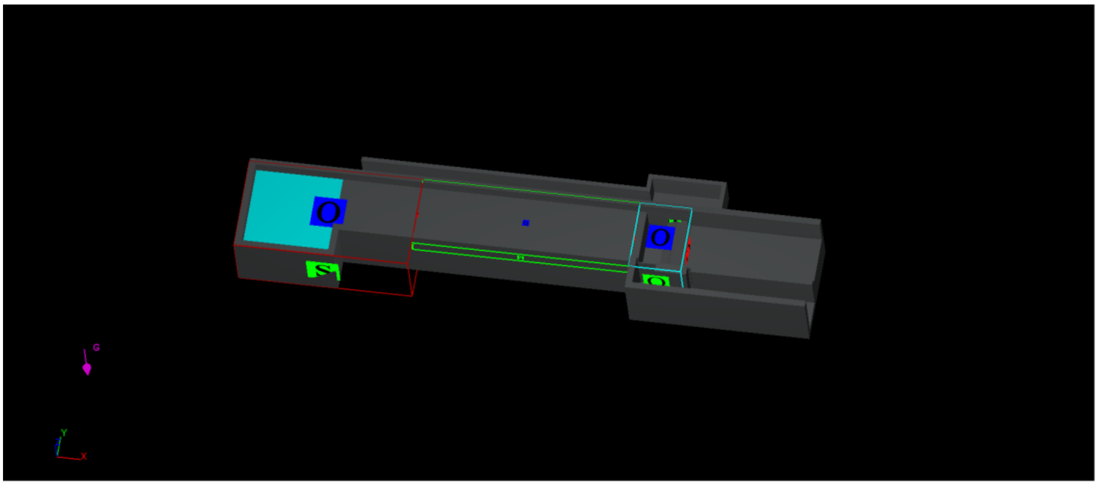

Figure 6.7. Boundary conditions for Case-4

6.3.3. Physics

In the physics part, there are options for defining gravity, turbulence model, heat transfer, mass source and sediment and etc.

For the model constructed for this study, mass source, turbulence model and gravity modules were activated.

In addition, mass source was defined in the lower part of the reservoir. Because, in the experiments, water is supplied by a pipe located at lower part of the reservoir. Therefore, in the numerical analyses part, same physical conditions with the experiments should be provided.

Gravity was defined in the – Z direction as a 9.81 m/sec^2.

There are seven turbulence models available in FLOW-3D. These are the Prandtl mixing length model, the one-equation, the k – ε, RNG models, the k-ω two equation model, large eddy simulation (LES) model and 2-D depth-averaged shallow water model. In the study, Renormalization group turbulence (RNG) model is selected.

RNG model solves the same equations with the k - ε model. However, constants of turbulence equations that are found empirically in the standard k – ε model are derived explicitly in the RNG model. Generally, the RNG model has wider applicability than the standard k - ε model. In particular, the RNG model is known to describe low intensity turbulence flows and flows having strong shear regions more accurately (FLOW-3D User Manuel). Turbulence models can be selected and activated in Physics tab, Viscosity and Turbulence option.

Fluid was selected as water at 20 º C as it was defined in the material properties. Viscosity, temperature and other physical properties of water were defined as default values provided by FLOW-3D.

CHAPTER 7

VALIDATION OF NUMERICAL MODEL

7.1. Introduction

Validation of numerical models were made by comparing results of the simulations with experimental ones. Due to numerous experimental cases, numerical models were constructed for selected cases only. Therefore, “Guide Plate” length of 20 cm and 25 cm as well as “Dividing Plate” height of 10 cm and 15 cm were selected for simulations. Because these values of the parameters provide best results in the experiments. Comparison of numerical and experimental results for different grids were presented in the below sub-chapter. Moreover, numerical simulations were conducted on a Dell Precision T7810 Work Station with 40 processor and 32 GB RAM.

7.2. Validation of Case-1 with Experiments

In this case, uniform structured grids were formed throughout the computational domain. Due to the having too narrow clear bars spacings compared to channel geometry, enormous computational time required by the software. Therefore, simulations have not been completed with useful results.

7.3. Validation of Case-2 with Experiments

In this case, non-uniform structured grids were formed throughout the computational domain in order to reduce high computation time. Solution of a model took about 8 days of computational time. In addition, results were presented in Table 7.1 given below.

Table 7.1. *Comparison of numerical results of Case-2 and experimental results*

	Numeric Model		*Experimental Model*		*Error (%)*	
Case	$(Q_w)_{ic}$ *(lt/s)*	$(Q_w)_{sc}$ *(lt/s)*	$(Q_w)_{ic}$ *(lt/s)*	$(Q_w)_{sc}$ *(lt/s)*	$(Q_w)_{ic}$ *(%)*	$(Q_w)_{sc}$ *(%)*
e 10 GPL 20 DPH 10 α30	26.72	2.58	25.91	2.89	3.1	10.7
e 15 GPL 20 DPH 15 α30	26.18	2.62	25.91	2.89	1.0	9.3

e represents clear bar spacing

GPL represents Guide Plate Length

DPH represents Dividing Plate Height

α represents Angle between Guide Plate and Horizontal

Both simulations resulted in a similar error ratio which was caused by the grid generated. Using finer mesh can end up with less error but higher simulation time. Therefore, results are acceptable. In addition, it should be noted that experimental results are reliable but contains insignificant errors due to the experimental procedure.

7.4. Validation of Case-3 with Experiments

In this case, non-uniform structured grids were formed throughout the computational domain. In order to reduce computational time further compared to Case-2 modifications were implemented to mesh blocks generated in Case-2. To do so, only one mesh block was generated and uniformity of the cells were arranged by considering the geometry. Results of the numerical model and comparison with the experimental ones are presented in Table 7.2

Table 7.2. *Comparison of numerical results of Case-3 with experimental results*

Case	*Numeric Model*		*Experimental Model*		*Error (%)*	
	$(Q_w)_{ic}$ (lt/s)	*$(Q_w)_{sc}$ (lt/s)*	*$(Q_w)_{ic}$ (lt/s)*	*$(Q_w)_{sc}$ (lt/s)*	*$(Q_w)_{ic}$ (%)*	*$(Q_w)_{sc}$ (%)*
e 15 GPL 20 DPH 10 α 30	18.10	9.60	25.91	2.89	30.1	232.2
e 15 GPL 20 DPH 10 α 30	41.89	11.16	49.56	3.74	15.5	198.4
e 15 GPL 20 DPH 10 α 30	59.14	11.77	70.18	4.12	15.7	185.7
e 15 GPL 20 DPH 15 α 30	22.83	2.62	25.91	12	11.9	78.2
e 15 GPL 20 DPH 15 α 30	41.25	10.55	49.56	3.74	16.8	182.1
e 15 GPL 20 DPH 15 α 30	63.73	12.50	70.18	4.12	9.2	203.4

e represents clear bar spacing

GPL represents Guide Plate Length

DPH represents Dividing Plate Height

α represents Angle between Guide Plate and Horizontal

Both simulations resulted in high error ratio which was caused by the grid generated. Using finer mesh can end up with less error but higher simulation time. Therefore, results are not acceptable. In addition, it should be noted that experimental results are reliable but contains insignificant errors due to the experimental procedure.

7.5. Validation of Case-4 with Experiments

In this case, non-uniform structured grids were formed throughout the computational domain. In order to reduce computational time further compared to Case-2 modifications were implemented to mesh blocks generated in Case-2. To do so, only one mesh block was generated and uniformity of the cells were arranged by considering the geometry. Results of the numerical model and comparison with the experimental ones are presented in Figure 7.1 and Figure 7.2.

As it can be seen from the figures, experimental and numerical data for a specified case are compatible. Non uniformity of computational grids and additional mesh planes increase accuracy of the simulation.

Table 7.3. *Comparison of numerical results of Case-4 with experimental results*

	Numeric Model		*Experimental Model*		*Error (%)*	
Case	$(Q_w)_{ic}$ *(lt/s)*	$(Q_w)_{sc}$ *(lt/s)*	$(Q_w)_{ic}$ *(lt/s)*	$(Q_w)_{sc}$ *(lt/s)*	$(Q_w)_{ic}$ *(%)*	$(Q_w)_{sc}$ *(%)*
e 10 GPL 20 DPH 10 α30	24.89	3.91	25.91	2.89	3.9	35.3
e 10 GPL 20 DPH 15 α30	69.47	4.83	70.18	4.12	1.0	17.2

e represents clear bar spacing

GPL represents Guide Plate Length

DPH represents Dividing Plate Height

α represents Angle between Guide Plate and Horizontal

7.5.1. Mesh Independency

In order to check the mesh independency, same mesh blocks of Case-4 were conserved but the mesh size were reduced to half of the Case-4 grids for each of the blocks and simulation was run again. Simulation time is about 10 days, nearly 2.5 times of the initial Case-4. Results were tabulated for a specific case in Table 7.4. As it can be determined from the Table 7.3, defining finer mesh was not affect simulation results significantly.

Table 7.4. *Comparison of numerical results of Case-4 with experimental results*

	Case-4		*Case-4 Modified*		*Difference (%)*	
Case	$(Q_w)_{ic}$ *(lt/s)*	$(Q_w)_{sc}$ *(lt/s)*	$(Q_w)_{ic}$ *(lt/s)*	$(Q_w)_{sc}$ *(lt/s)*	$(Q_w)_{ic}$ *(%)*	$(Q_w)_{sc}$ *(%)*
e 10 GPL 20 DPH 15 α30	24.89	3.91	25.2	3.6	1.2	7.9

CHAPTER 8

CONCLUSION

8.1. Conclusion

In this study, the bottom intake structure, so-called Tyrolean weir, which is widely used especially in heavy sediment carrying rivers, was redesigned to increase water capture efficiency as well as to decrease sediment amount diverted to the transmission line. In the experimental process, a laboratory flume was constructed by assessing the results of the previous studies by Yılmaz (2010), Şahiner (2012) and Melek (2017). Therefore, rack angle of θ was selected as 23º, bar length was selected as 70 cm. After selecting the initial design parameters, a large series of experiments were conducted and predefined important dimensionless parameters were determined. By considering the results of the A-B-C and D-Group experiments the following evaluations and recommendations can be made;

- "Dividing Plate" height of Z_1= 5 cm was not found to be sufficient. "Dividing Plate" is a plate that separates "Collection Channel-1" from "Collection Channel-2". Because of the formation of turbulence and lateral vortex within the collection channels, the "Dividing Plate" height should be set as high as possible. Therefore, discharge that conveys high amount of sediment within the "Collection Channel-1" can be stabilized and the amount of the sediment that pass from "Collection Channel-1" to "Collection Channel-2" over the "Dividing Plate" will decrease. For this reason, the experimental results show that the dimensionless "Dividing Plate" height of Z_1/B= 0.33 provides the best performance in terms of water capture efficiency and sediment removal.
- If the "Guide Plate" length of Z_2 is greater than 25 cm and the angle of α=40°, the space between the "Guide Plate" and "Dividing Plate" is narrowed and this

situation reduces the amount of discharge which will pass from “Collection Channel-1” to “Collection Channel-2”. Although “Guide Plate” angel of α= 30º provided better results with different Z_2 values compared to α= 40º, the ideal results were obtained with Z_2/B= 0.44 and α= 40º.

- The ratios of the accumulated sediment within the “Collection Channel-1” to the sediment that passes from the clear bar spacings vary between 1.2 % to 22.8 % according to the D-Group experiments. In order to reduce these ratio values, the bottom slope of 6° and the lateral slope of 6º of the “Collection Channel-1” should be increased. For example, the bottom slope and lateral slope of 10º increases the sediment particle’s velocity within the “Collection Channel-1” towards the “Sliding Gate”, so that sediment particles can be conveyed to the “Sediment Collection Channel” much faster so that less amount of sediment accumulation can be observed within the “Collection Channel-1”.
- Instead of increasing the “Dividing Plate” height, decreasing bottom elevation of the “Collection Channel-1” as well as widening the “Collection Channel-1” compared to the “Collection Channel-2” would decrease the turbulence intensity of the flow within the “Collection Channel-1” so that only fine sediment particles can pass to the “Collection Channel-2” over the “Guide Plate” while coarse sediment particles will move towards the bottom of the “Collection Channel-1”. Therefore, sediment amount that can reach to the intake channel can be minimized.

Optimum design parameters are presented in Table 8.1

Table 8.1. *Optimum values of parameters*

Parameter	Z_1/B	Z_2/B	e/L	α
Minimum Value			3/70	30°
Value	0.33	0.44		
Maximum Value			15/70	40°

In addition to the experimental study, newly designed bottom intake structure was solved numerically. The aim is to provide guidelines for implementing numerical model so that bottom intake design or the designed system in the study can be developed further by analyzing the system numerically instead of experimental study. Because, experimental study requires physical model construction which is time consuming and hard to do experiments that requires physical works. However, in this study, numerical results were validated by experimental ones so that further studies can be conducted only by implementing numerical models.

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APPENDICES

A. Results of the A-1 Group Experiments

Measured and calculated parameters with different e, α, Z_1, Z_2 values are tabulated below. (These experiments were conducted without sediment.)

Table A.1. *Measured and calculated parameters related to A1-Group Experiments (e_1= 3 mm)*

e_1=3 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.25	76.52	23.48	6.31	12.26	16.67	66.67
6.00	11.10	3.10	1.30	81.78	18.22	8.54	16.59	16.67	66.67
7.00	14.70	4.25	1.35	86.86	13.14	11.31	21.97	16.67	66.67
8.00	19.20	5.15	1.40	89.12	10.88	14.77	28.70	16.67	66.67
9.00	23.10	6.25	1.45	91.09	8.91	17.77	34.53	16.67	66.67
10.00	28.20	7.15	1.55	91.72	8.28	21.69	42.15	16.67	66.67
11.00	33.60	7.95	1.60	92.45	7.55	25.85	50.22	16.67	66.67
12.00	39.90	8.75	1.65	93.05	6.95	30.69	59.64	16.67	66.67
13.00	46.30	9.80	1.75	93.47	6.53	35.62	69.20	16.67	66.67
14.00	53.00	10.90	1.85	93.85	6.15	40.77	79.22	16.67	66.67
15.00	58.90	11.80	1.90	94.26	5.74	45.31	88.04	16.67	66.67
16.00	65.80	12.65	1.93	94.68	5.32	50.62	98.35	16.67	66.67
17.00	73.80	13.25	1.93	95.02	4.98	56.77	110.31	16.67	66.67

e_1=3 mm, T=4 mm, Z_1=5, Z_2=20, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.25	76.52	23.48	6.31	12.26	16.67	66.67
6.00	11.10	3.20	1.30	82.45	17.55	8.54	16.59	16.67	66.67
7.00	14.70	4.60	1.35	88.12	11.88	11.31	21.97	16.67	66.67
8.00	19.20	5.50	1.40	90.02	9.98	14.77	28.70	16.67	66.67
9.00	23.10	6.45	1.50	90.97	9.03	17.77	34.53	16.67	66.67
10.00	28.20	7.20	1.55	91.79	8.21	21.69	42.15	16.67	66.67
11.00	33.60	8.05	1.60	92.58	7.42	25.85	50.22	16.67	66.67
12.00	39.90	8.75	1.65	93.05	6.95	30.69	59.64	16.67	66.67
13.00	46.30	9.75	1.75	93.42	6.58	35.62	69.20	16.67	66.67
14.00	53.00	10.85	1.85	93.81	6.19	40.77	79.22	16.67	66.67
15.00	58.90	11.85	1.90	94.29	5.71	45.31	88.04	16.67	66.67
16.00	65.80	12.83	1.90	94.89	5.11	50.62	98.35	16.67	66.67
17.00	73.80	13.80	1.95	95.20	4.80	56.77	110.31	16.67	66.67

e_1=3 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.30	75.17	24.83	6.31	12.26	16.67	66.67
6.00	11.10	3.50	1.30	84.24	15.76	8.54	16.59	16.67	66.67
7.00	14.70	4.50	1.35	87.78	12.22	11.31	21.97	16.67	66.67
8.00	19.20	5.45	1.40	89.90	10.10	14.77	28.70	16.67	66.67
9.00	23.10	6.35	1.50	90.78	9.22	17.77	34.53	16.67	66.67
10.00	28.20	7.30	1.55	91.95	8.05	21.69	42.15	16.67	66.67
11.00	33.60	8.10	1.60	92.65	7.35	25.85	50.22	16.67	66.67
12.00	39.90	8.75	1.70	92.71	7.29	30.69	59.64	16.67	66.67
13.00	46.30	9.75	1.80	93.12	6.88	35.62	69.20	16.67	66.67
14.00	53.00	10.85	1.90	93.54	6.46	40.77	79.22	16.67	66.67
15.00	58.90	11.85	1.90	94.29	5.71	45.31	88.04	16.67	66.67
16.00	65.80	12.85	1.95	94.69	5.31	50.62	98.35	16.67	66.67
17.00	73.80	13.95	2.00	95.08	4.92	56.77	110.31	16.67	66.67

Table A.1 *Cont'd*

e_1=3 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.40	72.53	27.47	6.31	12.26	16.67	66.67
6.00	11.10	3.40	1.45	80.75	19.25	8.54	16.59	16.67	66.67
7.00	14.70	4.25	1.50	84.52	15.48	11.31	21.97	16.67	66.67
8.00	19.20	5.40	1.55	87.97	12.03	14.77	28.70	16.67	66.67
9.00	23.10	6.30	1.60	89.67	10.33	17.77	34.53	16.67	66.67
10.00	28.20	7.25	1.70	90.58	9.42	21.69	42.15	16.67	66.67
11.00	33.60	8.05	1.75	91.44	8.56	25.85	50.22	16.67	66.67
12.00	39.90	8.65	1.85	91.53	8.47	30.69	59.64	16.67	66.67
13.00	46.30	9.80	1.90	92.56	7.44	35.62	69.20	16.67	66.67
14.00	53.00	10.83	1.95	93.25	6.75	40.77	79.22	16.67	66.67
15.00	58.90	11.80	2.00	93.77	6.23	45.31	88.04	16.67	66.67
16.00	65.80	12.80	2.10	94.00	6.00	50.62	98.35	16.67	66.67
17.00	73.80	13.83	2.10	94.62	5.38	56.77	110.31	16.67	66.67
e_1=3 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.50	69.98	30.02	6.31	12.26	33.33	66.67
6.00	11.10	3.10	1.55	76.53	23.47	8.54	16.59	33.33	66.67
7.00	14.70	4.30	1.60	83.20	16.80	11.31	21.97	33.33	66.67
8.00	19.20	5.35	1.70	85.99	14.01	14.77	28.70	33.33	66.67
9.00	23.10	6.20	1.75	87.89	12.11	17.77	34.53	33.33	66.67
10.00	28.20	7.10	1.85	88.97	11.03	21.69	42.15	33.33	66.67
11.00	33.60	7.90	1.85	90.43	9.57	25.85	50.22	33.33	66.67
12.00	39.90	8.70	1.90	91.25	8.75	30.69	59.64	33.33	66.67
13.00	46.30	9.75	1.95	92.20	7.80	35.62	69.20	33.33	66.67
14.00	53.00	10.80	2.00	92.95	7.05	40.77	79.22	33.33	66.67
15.00	58.90	11.80	2.10	93.28	6.72	45.31	88.04	33.33	66.67
16.00	65.80	12.75	2.10	93.97	6.03	50.62	98.35	33.33	66.67
17.00	73.80	13.80	2.15	94.40	5.60	56.77	110.31	33.33	66.67
e_1=3 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.50	69.98	30.02	6.31	12.26	33.33	66.67
6.00	11.10	3.40	1.50	79.79	20.21	8.54	16.59	33.33	66.67
7.00	14.70	4.40	1.60	83.67	16.33	11.31	21.97	33.33	66.67
8.00	19.20	5.45	1.60	87.52	12.48	14.77	28.70	33.33	66.67
9.00	23.10	6.40	1.70	88.88	11.12	17.77	34.53	33.33	66.67
10.00	28.20	7.25	1.80	89.71	10.29	21.69	42.15	33.33	66.67
11.00	33.60	7.90	1.80	90.83	9.17	25.85	50.22	33.33	66.67
12.00	39.90	8.70	1.90	91.25	8.75	30.69	59.64	33.33	66.67
13.00	46.30	9.85	2.05	91.69	8.31	35.62	69.20	33.33	66.67
14.00	53.00	10.90	2.10	92.50	7.50	40.77	79.22	33.33	66.67
15.00	58.90	11.85	2.10	93.32	6.68	45.31	88.04	33.33	66.67
16.00	65.80	12.90	2.15	93.84	6.16	50.62	98.35	33.33	66.67
17.00	73.80	13.95	2.20	94.28	5.72	56.77	110.31	33.33	66.67

Table A.1 *Cont'd*

y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
e_1=3 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 30°									
5.00	8.20	2.20	1.50	68.01	31.99	6.31	12.26	33.33	66.67
6.00	11.10	3.00	1.50	76.73	23.27	8.54	16.59	33.33	66.67
7.00	14.70	4.50	1.50	85.58	14.42	11.31	21.97	33.33	66.67
8.00	19.20	5.45	1.55	88.12	11.88	14.77	28.70	33.33	66.67
9.00	23.10	6.25	1.60	89.56	10.44	17.77	34.53	33.33	66.67
10.00	28.20	7.15	1.75	89.96	10.04	21.69	42.15	33.33	66.67
11.00	33.60	7.83	1.75	91.11	8.89	25.85	50.22	33.33	66.67
12.00	39.90	8.70	1.85	91.60	8.40	30.69	59.64	33.33	66.67
13.00	46.30	9.70	1.95	92.14	7.86	35.62	69.20	33.33	66.67
14.00	53.00	10.83	2.00	92.98	7.02	40.77	79.22	33.33	66.67
15.00	58.90	11.80	2.05	93.52	6.48	45.31	88.04	33.33	66.67
16.00	65.80	12.80	2.15	93.78	6.22	50.62	98.35	33.33	66.67
17.00	73.80	13.90	2.15	94.46	5.54	56.77	110.31	33.33	66.67
e_1=3 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.20	1.55	66.72	33.28	6.31	12.26	33.33	66.67
6.00	11.10	3.35	1.55	78.47	21.53	8.54	16.59	33.33	66.67
7.00	14.70	4.40	1.55	84.42	15.58	11.31	21.97	33.33	66.67
8.00	19.20	5.40	1.55	87.97	12.03	14.77	28.70	33.33	66.67
9.00	23.10	6.25	1.70	88.53	11.47	17.77	34.53	33.33	66.67
10.00	28.20	7.10	1.70	90.31	9.69	21.69	42.15	33.33	66.67
11.00	33.60	7.80	1.80	90.67	9.33	25.85	50.22	33.33	66.67
12.00	39.90	8.70	1.85	91.60	8.40	30.69	59.64	33.33	66.67
13.00	46.30	9.70	1.95	92.14	7.86	35.62	69.20	33.33	66.67
14.00	53.00	10.75	2.00	92.91	7.09	40.77	79.22	33.33	66.67
15.00	58.90	11.75	2.00	93.73	6.27	45.31	88.04	33.33	66.67
16.00	65.80	12.75	2.05	94.19	5.81	50.62	98.35	33.33	66.67
17.00	73.80	13.85	2.15	94.43	5.57	56.77	110.31	33.33	66.67
e_1=3 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20					6.31	12.26	50.00	66.67
6.00	11.10					8.54	16.59	50.00	66.67
7.00	14.70	4.20	1.80	79.61	20.39	11.31	21.97	50.00	66.67
8.00	19.20	5.25	1.80	84.41	15.59	14.77	28.70	50.00	66.67
9.00	23.10	6.10	1.90	86.03	13.97	17.77	34.53	50.00	66.67
10.00	28.20	7.10	1.95	88.07	11.93	21.69	42.15	50.00	66.67
11.00	33.60	7.90	2.00	89.23	10.77	25.85	50.22	50.00	66.67
12.00	39.90	8.60	2.05	90.02	9.98	30.69	59.64	50.00	66.67
13.00	46.30	9.65	2.05	91.46	8.54	35.62	69.20	50.00	66.67
14.00	53.00	10.70	2.10	92.30	7.70	40.77	79.22	50.00	66.67
15.00	58.90	11.75	2.10	93.24	6.76	45.31	88.04	50.00	66.67
16.00	65.80	12.65	2.13	93.79	6.21	50.62	98.35	50.00	66.67
17.00	73.80	13.25	2.15	94.07	5.93	56.77	110.31	50.00	66.67

Table A.1 *Cont'd*

y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
e_1=3 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 20°									
5.00	8.20					6.31	12.26	50.00	66.67
6.00	11.10					8.54	16.59	50.00	66.67
7.00	14.70	4.25	1.80	79.89	20.11	11.31	21.97	50.00	66.67
8.00	19.20	5.25	1.85	83.78	16.22	14.77	28.70	50.00	66.67
9.00	23.10	6.20	1.90	86.32	13.68	17.77	34.53	50.00	66.67
10.00	28.20	7.10	1.95	88.07	11.93	21.69	42.15	50.00	66.67
11.00	33.60	7.85	2.00	89.14	10.86	25.85	50.22	50.00	66.67
12.00	39.90	8.55	2.05	89.94	10.06	30.69	59.64	50.00	66.67
13.00	46.30	9.65	2.10	91.14	8.86	35.62	69.20	50.00	66.67
14.00	53.00	10.70	2.15	92.02	7.98	40.77	79.22	50.00	66.67
15.00	58.90	11.75	2.15	92.99	7.01	45.31	88.04	50.00	66.67
16.00	65.80	12.80	2.20	93.55	6.45	50.62	98.35	50.00	66.67
17.00	73.80	13.70	2.20	94.14	5.86	56.77	110.31	50.00	66.67
e_1=3 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	**$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)**	**$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	**Z_1/e_1**	**Z_2/e_1**
5.00	8.20					6.31	12.26	50.00	66.67
6.00	11.10					8.54	16.59	50.00	66.67
7.00	14.70	4.25	1.80	79.89	20.11	11.31	21.97	50.00	66.67
8.00	19.20	5.25	1.90	83.16	16.84	14.77	28.70	50.00	66.67
9.00	23.10	6.20	1.95	85.79	14.21	17.77	34.53	50.00	66.67
10.00	28.20	7.10	2.00	87.61	12.39	21.69	42.15	50.00	66.67
11.00	33.60	7.80	2.05	88.64	11.36	25.85	50.22	50.00	66.67
12.00	39.90	8.75	2.10	89.89	10.11	30.69	59.64	50.00	66.67
13.00	46.30	9.65	2.15	90.82	9.18	35.62	69.20	50.00	66.67
14.00	53.00	10.75	2.18	91.93	8.07	40.77	79.22	50.00	66.67
15.00	58.90	11.75	2.20	92.74	7.26	45.31	88.04	50.00	66.67
16.00	65.80	12.80	2.25	93.32	6.68	50.62	98.35	50.00	66.67
17.00	73.80	13.80	2.25	93.99	6.01	56.77	110.31	50.00	66.67
e_1=3 mm, T=4 mm, Z_1=5 cm, Z_2=25 cm, α= 40°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	**$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)**	**$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	**Z_1/e_1**	**Z_2/e_1**
5.00	8.20	2.35	1.40	72.53	27.47	6.31	12.26	16.67	83.33
6.00	11.10	3.40	1.45	80.75	19.25	8.54	16.59	16.67	83.33
7.00	14.70	4.40	1.50	85.17	14.83	11.31	21.97	16.67	83.33
8.00	19.20	5.40	1.55	87.97	12.03	14.77	28.70	16.67	83.33
9.00	23.10	6.30	1.60	89.67	10.33	17.77	34.53	16.67	83.33
10.00	28.20	7.20	1.70	90.49	9.51	21.69	42.15	16.67	83.33
11.00	33.60	7.90	1.80	90.83	9.17	25.85	50.22	16.67	83.33
12.00	39.90	8.65	1.90	91.18	8.82	30.69	59.64	16.67	83.33
13.00	46.30	9.75	1.95	92.20	7.80	35.62	69.20	16.67	83.33
14.00	53.00	10.80	2.00	92.95	7.05	40.77	79.22	16.67	83.33
15.00	58.90	11.80	2.10	93.28	6.72	45.31	88.04	16.67	83.33
16.00	65.80	12.80	2.10	94.00	6.00	50.62	98.35	16.67	83.33
17.00	73.80	13.80	2.15	94.40	5.60	56.77	110.31	16.67	83.33

Table A.1 *Cont'd*

e_1=3 mm, T=4 mm, Z_1=10 cm, Z_2=25 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.40	72.53	27.47	6.31	12.26	33.33	83.33
6.00	11.10	3.40	1.45	80.75	19.25	8.54	16.59	33.33	83.33
7.00	14.70	4.40	1.50	85.17	14.83	11.31	21.97	33.33	83.33
8.00	19.20	5.40	1.55	87.97	12.03	14.77	28.70	33.33	83.33
9.00	23.10	6.30	1.60	89.67	10.33	17.77	34.53	33.33	83.33
10.00	28.20	7.20	1.70	90.49	9.51	21.69	42.15	33.33	83.33
11.00	33.60	7.90	1.80	90.83	9.17	25.85	50.22	33.33	83.33
12.00	39.90	8.65	1.90	91.18	8.82	30.69	59.64	33.33	83.33
13.00	46.30	9.75	1.95	92.20	7.80	35.62	69.20	33.33	83.33
14.00	53.00	10.80	2.00	92.95	7.05	40.77	79.22	33.33	83.33
15.00	58.90	11.80	2.10	93.28	6.72	45.31	88.04	33.33	83.33
16.00	65.80	12.80	2.10	94.00	6.00	50.62	98.35	33.33	83.33
17.00	73.80	13.80	2.15	94.40	5.60	56.77	110.31	33.33	83.33

Table A.2. *Measured and calculated parameters related to A1-Group Experiments (e_2= 6 mm)*

e_2=6 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_2	Z_2/e_2
5.00	8.20	2.35	1.40	72.53	27.47	6.31	4.23	8.33	33.33
6.00	11.10	3.45	1.45	81.08	18.92	8.54	5.81	8.33	33.33
7.00	14.70	4.50	1.50	85.58	14.42	11.31	7.87	8.33	33.33
8.00	19.20	5.45	1.55	88.12	11.88	14.77	9.88	8.33	33.33
9.00	23.10	6.30	1.60	89.67	10.33	17.77	12.37	8.33	33.33
10.00	28.20	7.20	1.70	90.49	9.51	21.69	15.17	8.33	33.33
11.00	33.60	7.90	1.80	90.83	9.17	25.85	18.07	8.33	33.33
12.00	39.90	8.65	1.85	91.53	8.47	30.69	20.77	8.33	33.33
13.00	46.30	9.75	1.90	92.51	7.49	35.62	24.10	8.33	33.33
14.00	53.00	10.85	1.95	93.27	6.73	40.77	27.90	8.33	33.33
15.00	58.90	11.80	1.95	94.01	5.99	45.31	31.07	8.33	33.33
16.00	65.80	12.80	2.00	94.44	5.56	50.62	34.98	8.33	33.33
17.00	73.80	13.65	2.00	94.92	5.08	56.77	38.84	8.33	33.33

e_2=6 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_2	Z_2/e_2
5.00	8.20	2.30	1.40	71.92	28.08	6.31	4.23	8.33	33.33
6.00	11.10	3.10	1.45	78.60	21.40	8.54	5.81	8.33	33.33
7.00	14.70	4.30	1.55	83.97	16.03	11.31	7.87	8.33	33.33
8.00	19.20	5.40	1.60	87.37	12.63	14.77	9.88	8.33	33.33
9.00	23.10	6.25	1.65	89.05	10.95	17.77	12.37	8.33	33.33
10.00	28.20	7.20	1.70	90.49	9.51	21.69	15.17	8.33	33.33
11.00	33.60	7.95	1.75	91.30	8.70	25.85	18.07	8.33	33.33
12.00	39.90	8.70	1.85	91.60	8.40	30.69	20.77	8.33	33.33
13.00	46.30	9.85	1.90	92.61	7.39	35.62	24.10	8.33	33.33
14.00	53.00	10.85	1.95	93.27	6.73	40.77	27.90	8.33	33.33
15.00	58.90	11.80	1.95	94.01	5.99	45.31	31.07	8.33	33.33
16.00	65.80	12.83	2.00	94.46	5.54	50.62	34.98	8.33	33.33
17.00	73.80	13.85	2.00	95.03	4.97	56.77	38.84	8.33	33.33

e_2=6 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.40	1.40	73.12	26.88	6.31	4.23	8.33	33.33
6.00	11.10	3.15	1.45	78.98	21.02	8.54	5.81	8.33	33.33
7.00	14.70	4.55	1.50	85.78	14.22	11.31	7.87	8.33	33.33
8.00	19.20	5.45	1.60	87.52	12.48	14.77	9.88	8.33	33.33
9.00	23.10	6.30	1.70	88.65	11.35	17.77	12.37	8.33	33.33
10.00	28.20	7.25	1.75	90.15	9.85	21.69	15.17	8.33	33.33
11.00	33.60	7.85	1.85	90.35	9.65	25.85	18.07	8.33	33.33
12.00	39.90	8.70	1.90	91.25	8.75	30.69	20.77	8.33	33.33
13.00	46.30	9.75	1.95	92.20	7.80	35.62	24.10	8.33	33.33
14.00	53.00	10.85	2.00	93.00	7.00	40.77	27.90	8.33	33.33
15.00	58.90	11.80	2.00	93.77	6.23	45.31	31.07	8.33	33.33
16.00	65.80	12.80	2.05	94.22	5.78	50.62	34.98	8.33	33.33
17.00	73.80	13.80	2.05	94.80	5.20	56.77	38.84	8.33	33.33

Table A.2 *Cont'd*

e_2=6 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.40	72.53	27.47	6.31	4.23	8.33	33.33
6.00	11.10	3.20	1.45	79.36	20.64	8.54	5.81	8.33	33.33
7.00	14.70	4.40	1.55	84.42	15.58	11.31	7.87	8.33	33.33
8.00	19.20	5.45	1.60	87.52	12.48	14.77	9.88	8.33	33.33
9.00	23.10	6.30	1.70	88.65	11.35	17.77	12.37	8.33	33.33
10.00	28.20	7.30	1.75	90.24	9.76	21.69	15.17	8.33	33.33
11.00	33.60	7.90	1.85	90.43	9.57	25.85	18.07	8.33	33.33
12.00	39.90	8.65	1.85	91.53	8.47	30.69	20.77	8.33	33.33
13.00	46.30	9.80	1.90	92.56	7.44	35.62	24.10	8.33	33.33
14.00	53.00	10.85	1.95	93.27	6.73	40.77	27.90	8.33	33.33
15.00	58.90	11.85	1.98	93.93	6.07	45.31	31.07	8.33	33.33
16.00	65.80	12.90	2.05	94.28	5.72	50.62	34.98	8.33	33.33
17.00	73.80	13.85	2.10	94.63	5.37	56.77	38.84	8.33	33.33
e_2=6 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.20	1.55	66.72	33.28	6.31	4.23	16.67	33.33
6.00	11.10	3.00	1.60	74.63	25.37	8.54	5.81	16.67	33.33
7.00	14.70	4.35	1.60	83.44	16.56	11.31	7.87	16.67	33.33
8.00	19.20	5.35	1.70	85.99	14.01	14.77	9.88	16.67	33.33
9.00	23.10	6.20	1.75	87.89	12.11	17.77	12.37	16.67	33.33
10.00	28.20	7.15	1.85	89.07	10.93	21.69	15.17	16.67	33.33
11.00	33.60	7.90	1.90	90.03	9.97	25.85	18.07	16.67	33.33
12.00	39.90	8.70	1.95	90.89	9.11	30.69	20.77	16.67	33.33
13.00	46.30	9.70	1.95	92.14	7.86	35.62	24.10	16.67	33.33
14.00	53.00	10.90	2.00	93.04	6.96	40.77	27.90	16.67	33.33
15.00	58.90	11.95	2.00	93.88	6.12	45.31	31.07	16.67	33.33
16.00	65.80	12.90	2.05	94.28	5.72	50.62	34.98	16.67	33.33
17.00	73.80	13.70	2.05	94.75	5.25	56.77	38.84	16.67	33.33
e_2=6 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.15	1.55	66.01	33.99	6.31	4.23	16.67	33.33
6.00	11.10	2.95	1.60	74.17	25.83	8.54	5.81	16.67	33.33
7.00	14.70	4.35	1.60	83.44	16.56	11.31	7.87	16.67	33.33
8.00	19.20	5.35	1.65	86.61	13.39	14.77	9.88	16.67	33.33
9.00	23.10	6.28	1.75	88.08	11.92	17.77	12.37	16.67	33.33
10.00	28.20	7.15	1.80	89.52	10.48	21.69	15.17	16.67	33.33
11.00	33.60	7.90	1.90	90.03	9.97	25.85	18.07	16.67	33.33
12.00	39.90	8.65	1.95	90.82	9.18	30.69	20.77	16.67	33.33
13.00	46.30	9.70	1.95	92.14	7.86	35.62	24.10	16.67	33.33
14.00	53.00	10.80	1.95	93.23	6.77	40.77	27.90	16.67	33.33
15.00	58.90	11.80	2.00	93.77	6.23	45.31	31.07	16.67	33.33
16.00	65.80	12.75	2.05	94.19	5.81	50.62	34.98	16.67	33.33
17.00	73.80	13.83	2.08	94.72	5.28	56.77	38.84	16.67	33.33

Table A.2 *Cont'd*

e_2=6 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ **(%)**	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ **(%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	Z_1/e_1	Z_2/e_1
5.00	8.20	2.20	1.60	65.47	34.53	6.31	4.23	16.67	33.33
6.00	11.10	3.00	1.60	74.63	25.37	8.54	5.81	16.67	33.33
7.00	14.70	4.20	1.65	81.93	18.07	11.31	7.87	16.67	33.33
8.00	19.20	5.35	1.70	85.99	14.01	14.77	9.88	16.67	33.33
9.00	23.10	6.18	1.75	87.83	12.17	17.77	12.37	16.67	33.33
10.00	28.20	7.20	1.85	89.17	10.83	21.69	15.17	16.67	33.33
11.00	33.60	7.95	1.90	90.12	9.88	25.85	18.07	16.67	33.33
12.00	39.90	8.60	1.95	90.75	9.25	30.69	20.77	16.67	33.33
13.00	46.30	9.70	1.95	92.14	7.86	35.62	24.10	16.67	33.33
14.00	53.00	10.80	1.95	93.23	6.77	40.77	27.90	16.67	33.33
15.00	58.90	11.80	2.00	93.77	6.23	45.31	31.07	16.67	33.33
16.00	65.80	12.83	2.05	94.24	5.76	50.62	34.98	16.67	33.33
17.00	73.80	13.85	2.10	94.63	5.37	56.77	38.84	16.67	33.33

e_2=6 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ **(%)**	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ **(%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	Z_1/e_1	Z_2/e_1
5.00	8.20	2.15	1.60	64.74	35.26	6.31	4.23	16.67	33.33
6.00	11.10	2.95	1.60	74.17	25.83	8.54	5.81	16.67	33.33
7.00	14.70	4.20	1.65	81.93	18.07	11.31	7.87	16.67	33.33
8.00	19.20	5.35	1.70	85.99	14.01	14.77	9.88	16.67	33.33
9.00	23.10	6.25	1.75	88.02	11.98	17.77	12.37	16.67	33.33
10.00	28.20	7.15	1.85	89.07	10.93	21.69	15.17	16.67	33.33
11.00	33.60	7.85	1.90	89.95	10.05	25.85	18.07	16.67	33.33
12.00	39.90	8.65	1.95	90.82	9.18	30.69	20.77	16.67	33.33
13.00	46.30	9.70	2.00	91.83	8.17	35.62	24.10	16.67	33.33
14.00	53.00	10.85	2.00	93.00	7.00	40.77	27.90	16.67	33.33
15.00	58.90	11.85	2.05	93.56	6.44	45.31	31.07	16.67	33.33
16.00	65.80	12.85	2.10	94.03	5.97	50.62	34.98	16.67	33.33
17.00	73.80	13.85	2.10	94.63	5.37	56.77	38.84	16.67	33.33

e_2=6 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ **(%)**	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ **(%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	Z_1/e_1	Z_2/e_1
5.00	8.20	2.15	1.85	58.84	41.16	6.31	4.23	25.00	33.33
6.00	11.10	3.25	1.90	71.06	28.94	8.54	5.81	25.00	33.33
7.00	14.70	4.25	1.90	78.37	21.63	11.31	7.87	25.00	33.33
8.00	19.20	5.35	1.95	82.93	17.07	14.77	9.88	25.00	33.33
9.00	23.10	6.30	1.95	86.08	13.92	17.77	12.37	25.00	33.33
10.00	28.20	7.25	2.00	87.94	12.06	21.69	15.17	25.00	33.33
11.00	33.60	7.85	2.05	88.73	11.27	25.85	18.07	25.00	33.33
12.00	39.90	8.60	2.05	90.02	9.98	30.69	20.77	25.00	33.33
13.00	46.30	9.70	2.10	91.20	8.80	35.62	24.10	25.00	33.33
14.00	53.00	10.80	2.15	92.12	7.88	40.77	27.90	25.00	33.33
15.00	58.90	11.80	2.15	93.03	6.97	45.31	31.07	25.00	33.33
16.00	65.80	12.85	2.15	93.81	6.19	50.62	34.98	25.00	33.33
17.00	73.80	13.75	2.15	94.37	5.63	56.77	38.84	25.00	33.33

Table A.2 *Cont'd*

e_2=6 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ **(%)**	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ **(%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	Z_1/e_1	Z_2/e_1
5.00	8.20	2.00	1.85	56.39	43.61	6.31	4.23	25.00	33.33
6.00	11.10	2.90	1.85	68.57	31.43	8.54	5.81	25.00	33.33
7.00	14.70	4.30	1.90	78.66	21.34	11.31	7.87	25.00	33.33
8.00	19.20	5.25	1.93	82.85	17.15	14.77	9.88	25.00	33.33
9.00	23.10	6.20	1.93	86.06	13.94	17.77	12.37	25.00	33.33
10.00	28.20	7.10	2.00	87.61	12.39	21.69	15.17	25.00	33.33
11.00	33.60	7.80	2.05	88.64	11.36	25.85	18.07	25.00	33.33
12.00	39.90	8.53	2.10	89.53	10.47	30.69	20.77	25.00	33.33
13.00	46.30	9.60	2.10	91.07	8.93	35.62	24.10	25.00	33.33
14.00	53.00	10.70	2.13	92.16	7.84	40.77	27.90	25.00	33.33
15.00	58.90	11.75	2.15	92.99	7.01	45.31	31.07	25.00	33.33
16.00	65.80	12.80	2.18	93.66	6.34	50.62	34.98	25.00	33.33
17.00	73.80	13.80	2.20	94.20	5.80	56.77	38.84	25.00	33.33
e_2=6 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ **(%)**	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ **(%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	Z_1/e_1	Z_2/e_1
5.00	8.20	2.05	1.80	58.37	41.63	6.31	4.23	25.00	33.33
6.00	11.10	2.90	1.85	68.57	31.43	8.54	5.81	25.00	33.33
7.00	14.70	4.00	1.85	77.63	22.37	11.31	7.87	25.00	33.33
8.00	19.20	5.30	1.90	83.35	16.65	14.77	9.88	25.00	33.33
9.00	23.10	6.20	1.93	86.06	13.94	17.77	12.37	25.00	33.33
10.00	28.20	7.13	1.98	87.89	12.11	21.69	15.17	25.00	33.33
11.00	33.60	7.80	2.00	89.05	10.95	25.85	18.07	25.00	33.33
12.00	39.90	8.60	2.05	90.02	9.98	30.69	20.77	25.00	33.33
13.00	46.30	9.60	2.10	91.07	8.93	35.62	24.10	25.00	33.33
14.00	53.00	10.80	2.15	92.12	7.88	40.77	27.90	25.00	33.33
15.00	58.90	11.83	2.15	93.05	6.95	45.31	31.07	25.00	33.33
16.00	65.80	12.83	2.20	93.57	6.43	50.62	34.98	25.00	33.33
17.00	73.80	13.88	2.20	94.24	5.76	56.77	38.84	25.00	33.33
e_2=6 mm, T=4 mm, Z_1=5 cm, Z_2=25 cm, α= 40°									
y_0 (cm)	**$(Q_w)_T$ (lt/s)**	**y_i (cm)**	**y_{sc} (cm)**	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ **(%)**	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ **(%)**	**$(q_w)_T$ (lt/(s.m))**	**$(F_r)_e$**	Z_1/e_1	Z_2/e_1
5.00	8.20	2.35	1.40	72.53	27.47	6.31	4.23	8.33	41.67
6.00	11.10	3.20	1.45	79.36	20.64	8.54	5.81	8.33	41.67
7.00	14.70	4.55	1.55	85.05	14.95	11.31	7.87	8.33	41.67
8.00	19.20	5.45	1.60	87.52	12.48	14.77	9.88	8.33	41.67
9.00	23.10	6.30	1.65	89.16	10.84	17.77	12.37	8.33	41.67
10.00	28.20	7.15	1.75	89.96	10.04	21.69	15.17	8.33	41.67
11.00	33.60	7.90	1.85	90.43	9.57	25.85	18.07	8.33	41.67
12.00	39.90	8.65	1.95	90.82	9.18	30.69	20.77	8.33	41.67
13.00	46.30	9.75	2.00	91.89	8.11	35.62	24.10	8.33	41.67
14.00	53.00	10.80	2.05	92.68	7.32	40.77	27.90	8.33	41.67
15.00	58.90	11.75	2.10	93.24	6.76	45.31	31.07	8.33	41.67
16.00	65.80	12.85	2.15	93.81	6.19	50.62	34.98	8.33	41.67
17.00	73.80	13.85	2.20	94.23	5.77	56.77	38.84	8.33	41.67

Table A.2 *Cont'd*

e_2=6 mm, T=4 mm, Z_1=10 cm, Z_2=25 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_1	Z_2/e_1
5.00	8.20	2.25	1.60	66.18	33.82	6.31	4.23	8.33	41.67
6.00	11.10	3.00	1.60	74.63	25.37	8.54	5.81	8.33	41.67
7.00	14.70	4.40	1.70	82.17	17.83	11.31	7.87	8.33	41.67
8.00	19.20	5.40	1.75	85.55	14.45	14.77	9.88	8.33	41.67
9.00	23.10	6.25	1.80	87.50	12.50	17.77	12.37	8.33	41.67
10.00	28.20	7.15	1.85	89.07	10.93	21.69	15.17	8.33	41.67
11.00	33.60	7.85	1.90	89.95	10.05	25.85	18.07	8.33	41.67
12.00	39.90	8.58	1.95	90.71	9.29	30.69	20.77	8.33	41.67
13.00	46.30	9.65	2.00	91.77	8.23	35.62	24.10	8.33	41.67
14.00	53.00	10.70	2.00	92.86	7.14	40.77	27.90	8.33	41.67
15.00	58.90	11.80	2.05	93.52	6.48	45.31	31.07	8.33	41.67
16.00	65.80	12.80	2.10	94.00	6.00	50.62	34.98	8.33	41.67
17.00	73.80	13.58	2.10	94.48	5.52	56.77	38.84	8.33	41.67

Table A.3. *Measured and calculated parameters related to A1-Group Experiments (e_3= 10 mm)*

e_3=10 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.10	1.60	63.99	36.01	6.31	1.99	5.00	20.00
6.00	11.10	3.30	1.65	76.17	23.83	8.54	2.70	5.00	20.00
7.00	14.70	4.30	1.75	80.91	19.09	11.31	3.66	5.00	20.00
8.00	19.20	5.30	1.85	83.97	16.03	14.77	4.67	5.00	20.00
9.00	23.10	6.15	1.95	85.65	14.35	17.77	5.65	5.00	20.00
10.00	28.20	7.10	2.00	87.61	12.39	21.69	7.07	5.00	20.00
11.00	33.60	7.90	2.10	88.42	11.58	25.85	8.37	5.00	20.00
12.00	39.90	8.60	2.10	89.65	10.35	30.69	9.75	5.00	20.00
13.00	46.30	9.65	2.15	90.82	9.18	35.62	11.22	5.00	20.00
14.00	53.00	10.70	2.15	92.02	7.98	40.77	12.80	5.00	20.00
15.00	58.90	11.75	2.20	92.74	7.26	45.31	14.42	5.00	20.00
16.00	65.80	12.80	2.20	93.55	6.45	50.62	16.16	5.00	20.00
17.00	73.80	13.60	2.25	93.87	6.13	56.77	18.05	5.00	20.00
e_3=10 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{i}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.10	1.60	63.99	36.01	6.31	1.99	5.00	20.00
6.00	11.10	3.30	1.70	75.22	24.78	8.54	2.70	5.00	20.00
7.00	14.70	4.20	1.75	80.38	19.62	11.31	3.66	5.00	20.00
8.00	19.20	5.30	1.80	84.59	15.41	14.77	4.67	5.00	20.00
9.00	23.10	6.15	1.90	86.18	13.82	17.77	5.65	5.00	20.00
10.00	28.20	7.10	1.98	87.84	12.16	21.69	7.07	5.00	20.00
11.00	33.60	7.80	2.05	88.64	11.36	25.85	8.37	5.00	20.00
12.00	39.90	8.63	2.10	89.69	10.31	30.69	9.75	5.00	20.00
13.00	46.30	9.70	2.15	90.88	9.12	35.62	11.22	5.00	20.00
14.00	53.00	10.75	2.15	92.07	7.93	40.77	12.80	5.00	20.00
15.00	58.90	11.75	2.20	92.74	7.26	45.31	14.42	5.00	20.00
16.00	65.80	12.80	2.25	93.32	6.68	50.62	16.16	5.00	20.00
17.00	73.80	13.73	2.28	93.84	6.16	56.77	18.05	5.00	20.00
e_3=10 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{i}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.10	1.60	63.99	36.01	6.31	1.99	5.00	20.00
6.00	11.10	2.95	1.68	72.61	27.39	8.54	2.70	5.00	20.00
7.00	14.70	4.30	1.75	80.91	19.09	11.31	3.66	5.00	20.00
8.00	19.20	5.33	1.85	84.06	15.94	14.77	4.67	5.00	20.00
9.00	23.10	6.25	1.93	86.20	13.80	17.77	5.65	5.00	20.00
10.00	28.20	7.10	2.00	87.61	12.39	21.69	7.07	5.00	20.00
11.00	33.60	7.80	2.08	88.43	11.57	25.85	8.37	5.00	20.00
12.00	39.90	8.55	2.15	89.20	10.80	30.69	9.75	5.00	20.00
13.00	46.30	9.63	2.18	90.62	9.38	35.62	11.22	5.00	20.00
14.00	53.00	10.83	2.20	91.87	8.13	40.77	12.80	5.00	20.00
15.00	58.90	11.78	2.23	92.63	7.37	45.31	14.42	5.00	20.00
16.00	65.80	12.85	2.28	93.25	6.75	50.62	16.16	5.00	20.00
17.00	73.80	13.85	2.30	93.81	6.19	56.77	18.05	5.00	20.00

Table A.3 *Cont'd*

e$_3$=10 mm, T=4 mm, Z$_1$=5 cm, Z$_2$=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.30	1.60	66.86	33.14	6.31	1.99	5.00	20.00
6.00	11.10	3.40	1.65	76.94	23.06	8.54	2.70	5.00	20.00
7.00	14.70	4.43	1.75	81.55	18.45	11.31	3.66	5.00	20.00
8.00	19.20	5.35	1.85	84.16	15.84	14.77	4.67	5.00	20.00
9.00	23.10	6.25	1.93	86.20	13.80	17.77	5.65	5.00	20.00
10.00	28.20	7.25	2.00	87.94	12.06	21.69	7.07	5.00	20.00
11.00	33.60	7.85	2.10	88.33	11.67	25.85	8.37	5.00	20.00
12.00	39.90	8.50	2.15	89.12	10.88	30.69	9.75	5.00	20.00
13.00	46.30	9.80	2.15	91.01	8.99	35.62	11.22	5.00	20.00
14.00	53.00	10.90	2.15	92.22	7.78	40.77	12.80	5.00	20.00
15.00	58.90	11.85	2.20	92.82	7.18	45.31	14.42	5.00	20.00
16.00	65.80	12.90	2.23	93.51	6.49	50.62	16.16	5.00	20.00
17.00	73.80	13.90	2.28	93.95	6.05	56.77	18.05	5.00	20.00
e$_3$=10 mm, T=4 mm, Z$_1$=10 cm, Z$_2$=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	1.90	1.85	54.64	45.36	6.31	1.99	10.00	20.00
6.00	11.10	2.85	1.90	67.04	32.96	8.54	2.70	10.00	20.00
7.00	14.70	4.20	1.90	78.08	21.92	11.31	3.66	10.00	20.00
8.00	19.20	5.15	1.95	82.13	17.87	14.77	4.67	10.00	20.00
9.00	23.10	6.10	2.00	84.96	15.04	17.77	5.65	10.00	20.00
10.00	28.20	7.05	2.10	86.58	13.42	21.69	7.07	10.00	20.00
11.00	33.60	7.75	2.20	87.30	12.70	25.85	8.37	10.00	20.00
12.00	39.90	8.45	2.20	88.66	11.34	30.69	9.75	10.00	20.00
13.00	46.30	9.60	2.25	90.10	9.90	35.62	11.22	10.00	20.00
14.00	53.00	10.75	2.25	91.51	8.49	40.77	12.80	10.00	20.00
15.00	58.90	11.65	2.28	92.27	7.73	45.31	14.42	10.00	20.00
16.00	65.80	12.75	2.33	92.94	7.06	50.62	16.16	10.00	20.00
17.00	73.80	13.53	2.35	93.39	6.61	56.77	18.05	10.00	20.00
e$_3$=10 mm, T=4 mm, Z$_1$=10 cm, Z$_2$=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.25	1.85	60.37	39.63	6.31	1.99	10.00	20.00
6.00	11.10	3.20	1.90	70.60	29.40	8.54	2.70	10.00	20.00
7.00	14.70	4.25	1.95	77.62	22.38	11.31	3.66	10.00	20.00
8.00	19.20	5.23	2.00	81.81	18.19	14.77	4.67	10.00	20.00
9.00	23.10	6.10	2.05	84.43	15.57	17.77	5.65	10.00	20.00
10.00	28.20	7.05	2.10	86.58	13.42	21.69	7.07	10.00	20.00
11.00	33.60	7.75	2.18	87.51	12.49	25.85	8.37	10.00	20.00
12.00	39.90	8.48	2.23	88.51	11.49	30.69	9.75	10.00	20.00
13.00	46.30	9.58	2.25	90.07	9.93	35.62	11.22	10.00	20.00
14.00	53.00	10.70	2.25	91.45	8.55	40.77	12.80	10.00	20.00
15.00	58.90	11.65	2.30	92.14	7.86	45.31	14.42	10.00	20.00
16.00	65.80	12.70	2.33	92.90	7.10	50.62	16.16	10.00	20.00
17.00	73.80	13.65	2.40	93.26	6.74	56.77	18.05	10.00	20.00

Table A.3 *Cont'd*

e_3=10 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.10	1.85	58.04	41.96	6.31	1.99	10.00	20.00
6.00	11.10	3.15	1.90	70.12	29.88	8.54	2.70	10.00	20.00
7.00	14.70	4.20	1.90	78.08	21.92	11.31	3.66	10.00	20.00
8.00	19.20	5.30	1.95	82.74	17.26	14.77	4.67	10.00	20.00
9.00	23.10	6.15	2.00	85.12	14.88	17.77	5.65	10.00	20.00
10.00	28.20	7.10	2.10	86.70	13.30	21.69	7.07	10.00	20.00
11.00	33.60	7.75	2.20	87.30	12.70	25.85	8.37	10.00	20.00
12.00	39.90	8.48	2.25	88.32	11.68	30.69	9.75	10.00	20.00
13.00	46.30	9.60	2.25	90.10	9.90	35.62	11.22	10.00	20.00
14.00	53.00	10.70	2.25	91.45	8.55	40.77	12.80	10.00	20.00
15.00	58.90	11.70	2.30	92.18	7.82	45.31	14.42	10.00	20.00
16.00	65.80	12.75	2.35	92.83	7.17	50.62	16.16	10.00	20.00
17.00	73.80	13.83	2.40	93.38	6.62	56.77	18.05	10.00	20.00

e_3=10 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	1.95	1.80	56.68	43.32	6.31	1.99	10.00	20.00
6.00	11.10	2.75	1.85	66.91	33.09	8.54	2.70	10.00	20.00
7.00	14.70	4.10	1.90	77.47	22.53	11.31	3.66	10.00	20.00
8.00	19.20	5.23	1.95	82.44	17.56	14.77	4.67	10.00	20.00
9.00	23.10	6.10	2.00	84.96	15.04	17.77	5.65	10.00	20.00
10.00	28.20	7.03	2.10	86.52	13.48	21.69	7.07	10.00	20.00
11.00	33.60	7.83	2.20	87.46	12.54	25.85	8.37	10.00	20.00
12.00	39.90	8.60	2.23	88.73	11.27	30.69	9.75	10.00	20.00
13.00	46.30	9.65	2.25	90.17	9.83	35.62	11.22	10.00	20.00
14.00	53.00	10.70	2.25	91.45	8.55	40.77	12.80	10.00	20.00
15.00	58.90	11.75	2.25	92.48	7.52	45.31	14.42	10.00	20.00
16.00	65.80	12.80	2.30	93.10	6.90	50.62	16.16	10.00	20.00
17.00	73.80	13.90	2.35	93.64	6.36	56.77	18.05	10.00	20.00

e_3=10 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	1.85	2.13	47.94	52.06	6.31	1.99	15.00	20.00
6.00	11.10	3.05	2.15	64.57	35.43	8.54	2.70	15.00	20.00
7.00	14.70	4.10	2.15	73.66	26.34	11.31	3.66	15.00	20.00
8.00	19.20	5.00	2.20	78.26	21.74	14.77	4.67	15.00	20.00
9.00	23.10	6.05	2.20	82.65	17.35	17.77	5.65	15.00	20.00
10.00	28.20	6.88	2.25	84.73	15.27	21.69	7.07	15.00	20.00
11.00	33.60	7.65	2.30	86.24	13.76	25.85	8.37	15.00	20.00
12.00	39.90	8.35	2.35	87.33	12.67	30.69	9.75	15.00	20.00
13.00	46.30	9.48	2.40	88.93	11.07	35.62	11.22	15.00	20.00
14.00	53.00	10.63	2.43	90.36	9.64	40.77	12.80	15.00	20.00
15.00	58.90	11.65	2.45	91.36	8.64	45.31	14.42	15.00	20.00
16.00	65.80	12.70	2.48	92.20	7.80	50.62	16.16	15.00	20.00
17.00	73.80	13.45	2.50	92.69	7.31	56.77	18.05	15.00	20.00

Table A.3 *Cont'd*

e_3=10 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	1.95	2.13	49.74	50.26	6.31	1.99	15.00	20.00
6.00	11.10	2.70	2.15	60.50	39.50	8.54	2.70	15.00	20.00
7.00	14.70	3.95	2.18	72.21	27.79	11.31	3.66	15.00	20.00
8.00	19.20	5.05	2.20	78.50	21.50	14.77	4.67	15.00	20.00
9.00	23.10	6.05	2.20	82.65	17.35	17.77	5.65	15.00	20.00
10.00	28.20	7.00	2.25	85.07	14.93	21.69	7.07	15.00	20.00
11.00	33.60	7.65	2.30	86.24	13.76	25.85	8.37	15.00	20.00
12.00	39.90	8.50	2.33	87.81	12.19	30.69	9.75	15.00	20.00
13.00	46.30	9.50	2.35	89.30	10.70	35.62	11.22	15.00	20.00
14.00	53.00	10.55	2.38	90.56	9.44	40.77	12.80	15.00	20.00
15.00	58.90	11.60	2.40	91.57	8.43	45.31	14.42	15.00	20.00
16.00	65.80	12.75	2.45	92.36	7.64	50.62	16.16	15.00	20.00
17.00	73.80	13.63	2.50	92.82	7.18	56.77	18.05	15.00	20.00
e_3=10 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	1.85	2.15	47.45	52.55	6.31	1.99	15.00	20.00
6.00	11.10	2.70	2.15	60.50	39.50	8.54	2.70	15.00	20.00
7.00	14.70	4.05	2.15	73.31	26.69	11.31	3.66	15.00	20.00
8.00	19.20	5.15	2.18	79.30	20.70	14.77	4.67	15.00	20.00
9.00	23.10	6.10	2.20	82.83	17.17	17.77	5.65	15.00	20.00
10.00	28.20	7.00	2.25	85.07	14.93	21.69	7.07	15.00	20.00
11.00	33.60	7.70	2.33	86.15	13.85	25.85	8.37	15.00	20.00
12.00	39.90	8.45	2.35	87.52	12.48	30.69	9.75	15.00	20.00
13.00	46.30	9.45	2.40	88.89	11.11	35.62	11.22	15.00	20.00
14.00	53.00	10.55	2.45	90.12	9.88	40.77	12.80	15.00	20.00
15.00	58.90	11.60	2.45	91.31	8.69	45.31	14.42	15.00	20.00
16.00	65.80	12.65	2.50	92.04	7.96	50.62	16.16	15.00	20.00
17.00	73.80	13.58	2.60	92.34	7.66	56.77	18.05	15.00	20.00
e_3=10 mm, T=4 mm, Z_1=5 cm, Z_2=25 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	2.10	1.60	63.99	36.01	6.31	1.99	5.00	25.00
6.00	11.10	3.30	1.65	76.17	23.83	8.54	2.70	5.00	25.00
7.00	14.70	4.35	1.75	81.17	18.83	11.31	3.66	5.00	25.00
8.00	19.20	5.30	1.80	84.59	15.41	14.77	4.67	5.00	25.00
9.00	23.10	6.15	1.90	86.18	13.82	17.77	5.65	5.00	25.00
10.00	28.20	7.15	2.00	87.72	12.28	21.69	7.07	5.00	25.00
11.00	33.60	7.80	2.10	88.23	11.77	25.85	8.37	5.00	25.00
12.00	39.90	8.60	2.15	89.29	10.71	30.69	9.75	5.00	25.00
13.00	46.30	9.68	2.15	90.85	9.15	35.62	11.22	5.00	25.00
14.00	53.00	10.65	2.20	91.69	8.31	40.77	12.80	5.00	25.00
15.00	58.90	11.68	2.30	92.16	7.84	45.31	14.42	5.00	25.00
16.00	65.80	12.70	2.35	92.79	7.21	50.62	16.16	5.00	25.00
17.00	73.80	13.70	2.45	93.08	6.92	56.77	18.05	5.00	25.00

Table A.3 *Cont'd*

e_3=10 mm, T=4 mm, Z_1=10 cm, Z_2=25 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_3	Z_2/e_3
5.00	8.20	1.95	1.85	55.53	44.47	6.31	1.99	10.00	25.00
6.00	11.10	3.05	1.90	69.15	30.85	8.54	2.70	10.00	25.00
7.00	14.70	4.18	1.93	77.54	22.46	11.31	3.66	10.00	25.00
8.00	19.20	5.20	1.95	82.33	17.67	14.77	4.67	10.00	25.00
9.00	23.10	6.10	2.00	84.96	15.04	17.77	5.65	10.00	25.00
10.00	28.20	7.05	2.10	86.58	13.42	21.69	7.07	10.00	25.00
11.00	33.60	7.80	2.20	87.41	12.59	25.85	8.37	10.00	25.00
12.00	39.90	8.48	2.25	88.32	11.68	30.69	9.75	10.00	25.00
13.00	46.30	9.60	2.25	90.10	9.90	35.62	11.22	10.00	25.00
14.00	53.00	10.60	2.30	91.05	8.95	40.77	12.80	10.00	25.00
15.00	58.90	11.75	2.33	92.10	7.90	45.31	14.42	10.00	25.00
16.00	65.80	12.45	2.35	92.59	7.41	50.62	16.16	10.00	25.00
17.00	73.80	12.95	2.35	92.98	7.02	56.77	18.05	10.00	25.00

Table A.4. *Measured and calculated parameters related to A-1 Group Experiments (e_4= 15 mm)*

e_4=15 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.55	2.35	38.06	61.94	6.31	1.04	3.33	13.33
6.00	11.10	2.40	2.40	51.98	48.02	8.54	1.43	3.33	13.33
7.00	14.70	3.70	2.53	64.93	35.07	11.31	1.95	3.33	13.33
8.00	19.20	4.80	2.65	71.46	28.54	14.77	2.51	3.33	13.33
9.00	23.10	5.70	2.80	74.69	25.31	17.77	3.06	3.33	13.33
10.00	28.20	6.73	2.70	79.97	20.03	21.69	3.76	3.33	13.33
11.00	33.60	7.63	2.85	81.52	18.48	25.85	4.51	3.33	13.33
12.00	39.90	8.30	2.95	82.56	17.44	30.69	5.21	3.33	13.33
13.00	46.30	9.33	2.89	85.33	14.67	35.62	6.14	3.33	13.33
14.00	53.00	10.35	2.95	86.80	13.20	40.77	6.92	3.33	13.33
15.00	58.90	11.53	3.00	88.25	11.75	45.31	7.87	3.33	13.33
16.00	65.80	12.60	3.05	89.32	10.68	50.62	8.81	3.33	13.33
17.00	73.80	13.40	3.10	89.93	10.07	56.77	9.69	3.33	13.33
e_4=15 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.60	2.20	41.67	58.33	6.31	1.04	3.33	13.33
6.00	11.10	2.85	2.25	60.55	39.45	8.54	1.43	3.33	13.33
7.00	14.70	3.80	2.35	68.39	31.61	11.31	1.95	3.33	13.33
8.00	19.20	4.90	2.45	74.55	25.45	14.77	2.51	3.33	13.33
9.00	23.10	5.83	2.60	77.44	22.56	17.77	3.06	3.33	13.33
10.00	28.20	6.70	2.70	79.88	20.12	21.69	3.76	3.33	13.33
11.00	33.60	7.60	2.85	81.44	18.56	25.85	4.51	3.33	13.33
12.00	39.90	8.35	2.95	82.69	17.31	30.69	5.21	3.33	13.33
13.00	46.30	9.35	2.95	84.97	15.03	35.62	6.14	3.33	13.33
14.00	53.00	10.45	3.00	86.65	13.35	40.77	6.92	3.33	13.33
15.00	58.90	11.45	3.03	88.01	11.99	45.31	7.87	3.33	13.33
16.00	65.80	12.55	3.10	89.01	10.99	50.62	8.81	3.33	13.33
17.00	73.80	13.50	3.20	89.57	10.43	56.77	9.69	3.33	13.33
e_4=15 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.60	2.20	41.67	58.33	6.31	1.04	3.33	13.33
6.00	11.10	2.70	2.25	58.69	41.31	8.54	1.43	3.33	13.33
7.00	14.70	3.73	2.35	67.76	32.24	11.31	1.95	3.33	13.33
8.00	19.20	4.75	2.50	73.04	26.96	14.77	2.51	3.33	13.33
9.00	23.10	5.70	2.63	76.60	23.40	17.77	3.06	3.33	13.33
10.00	28.20	6.70	2.70	79.88	20.12	21.69	3.76	3.33	13.33
11.00	33.60	7.50	2.88	80.93	19.07	25.85	4.51	3.33	13.33
12.00	39.90	8.05	3.05	81.10	18.90	30.69	5.21	3.33	13.33
13.00	46.30	9.10	3.05	83.73	16.27	35.62	6.14	3.33	13.33
14.00	53.00	10.28	3.05	86.05	13.95	40.77	6.92	3.33	13.33
15.00	58.90	11.30	3.10	87.38	12.62	45.31	7.87	3.33	13.33
16.00	65.80	12.25	3.13	88.52	11.48	50.62	8.81	3.33	13.33
17.00	73.80	13.20	3.25	89.01	10.99	56.77	9.69	3.33	13.33

Table A.4 *Cont'd*

e_4=15 mm, T=4 mm, Z_1=5 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.60	2.20	41.67	58.33	6.31	1.04	3.33	13.33
6.00	11.10	2.85	2.25	60.55	39.45	8.54	1.43	3.33	13.33
7.00	14.70	3.85	2.35	68.80	31.20	11.31	1.95	3.33	13.33
8.00	19.20	4.90	2.45	74.55	25.45	14.77	2.51	3.33	13.33
9.00	23.10	5.80	2.63	77.05	22.95	17.77	3.06	3.33	13.33
10.00	28.20	6.70	2.70	79.88	20.12	21.69	3.76	3.33	13.33
11.00	33.60	7.58	2.88	81.16	18.84	25.85	4.51	3.33	13.33
12.00	39.90	8.35	3.00	82.30	17.70	30.69	5.21	3.33	13.33
13.00	46.30	9.28	3.00	84.46	15.54	35.62	6.14	3.33	13.33
14.00	53.00	10.35	3.00	86.49	13.51	40.77	6.92	3.33	13.33
15.00	58.90	11.40	3.00	88.08	11.92	45.31	7.87	3.33	13.33
16.00	65.80	12.50	3.10	88.95	11.05	50.62	8.81	3.33	13.33
17.00	73.80	13.65	3.18	89.84	10.16	56.77	9.69	3.33	13.33

e_4=15 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.30	2.50	30.61	69.39	6.31	1.04	6.67	13.33
6.00	11.10	2.25	2.55	47.25	52.75	8.54	1.43	6.67	13.33
7.00	14.70	13.20	2.60	92.04	7.96	11.31	1.95	6.67	13.33
8.00	19.20	4.43	2.65	68.97	31.03	14.77	2.51	6.67	13.33
9.00	23.10	5.70	2.75	75.23	24.77	17.77	3.06	6.67	13.33
10.00	28.20	6.60	2.83	78.32	21.68	21.69	3.76	6.67	13.33
11.00	33.60	7.50	3.05	79.44	20.56	25.85	4.51	6.67	13.33
12.00	39.90	8.25	3.10	81.26	18.74	30.69	5.21	6.67	13.33
13.00	46.30	9.15	3.10	83.49	16.51	35.62	6.14	6.67	13.33
14.00	53.00	10.33	3.15	85.51	14.49	40.77	6.92	6.67	13.33
15.00	58.90	11.48	3.15	87.36	12.64	45.31	7.87	6.67	13.33
16.00	65.80	12.48	3.18	88.54	11.46	50.62	8.81	6.67	13.33
17.00	73.80	13.35	3.23	89.30	10.70	56.77	9.69	6.67	13.33

e_4=15 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.33	2.55	30.45	69.55	6.31	1.04	6.67	13.33
6.00	11.10	2.30	2.58	47.63	52.37	8.54	1.43	6.67	13.33
7.00	14.70	3.25	2.60	59.42	40.58	11.31	1.95	6.67	13.33
8.00	19.20	4.30	2.65	68.07	31.93	14.77	2.51	6.67	13.33
9.00	23.10	5.73	2.75	75.35	24.65	17.77	3.06	6.67	13.33
10.00	28.20	6.60	2.85	78.08	21.92	21.69	3.76	6.67	13.33
11.00	33.60	7.45	3.05	79.28	20.72	25.85	4.51	6.67	13.33
12.00	39.90	8.20	3.10	81.12	18.88	30.69	5.21	6.67	13.33
13.00	46.30	9.08	3.13	83.15	16.85	35.62	6.14	6.67	13.33
14.00	53.00	10.33	3.15	85.51	14.49	40.77	6.92	6.67	13.33
15.00	58.90	11.43	3.18	87.14	12.86	45.31	7.87	6.67	13.33
16.00	65.80	12.40	3.23	88.20	11.80	50.62	8.81	6.67	13.33
17.00	73.80	13.38	3.30	88.97	11.03	56.77	9.69	6.67	13.33

Table A.4 *Cont'd*

e_4=15 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.23	2.55	28.36	71.64	6.31	1.04	6.67	13.33
6.00	11.10	2.30	2.60	47.24	52.76	8.54	1.43	6.67	13.33
7.00	14.70	3.25	2.65	58.68	41.32	11.31	1.95	6.67	13.33
8.00	19.20	4.78	2.70	70.68	29.32	14.77	2.51	6.67	13.33
9.00	23.10	5.65	2.75	74.99	25.01	17.77	3.06	6.67	13.33
10.00	28.20	6.70	2.90	77.98	22.02	21.69	3.76	6.67	13.33
11.00	33.60	7.48	3.08	79.14	20.86	25.85	4.51	6.67	13.33
12.00	39.90	8.30	3.15	81.01	18.99	30.69	5.21	6.67	13.33
13.00	46.30	9.15	3.15	83.14	16.86	35.62	6.14	6.67	13.33
14.00	53.00	10.30	3.20	85.16	14.84	40.77	6.92	6.67	13.33
15.00	58.90	11.45	3.20	87.04	12.96	45.31	7.87	6.67	13.33
16.00	65.80	12.53	3.25	88.22	11.78	50.62	8.81	6.67	13.33
17.00	73.80	13.55	3.35	88.93	11.07	56.77	9.69	6.67	13.33
e_4=15 mm, T=4 mm, Z_1=10 cm, Z_2=20 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.25	2.50	29.55	70.45	6.31	1.04	6.67	13.33
6.00	11.10	2.25	2.55	47.25	52.75	8.54	1.43	6.67	13.33
7.00	14.70	3.35	2.60	60.47	39.53	11.31	1.95	6.67	13.33
8.00	19.20	4.70	2.65	70.83	29.17	14.77	2.51	6.67	13.33
9.00	23.10	5.80	2.75	75.71	24.29	17.77	3.06	6.67	13.33
10.00	28.20	6.65	2.85	78.27	21.73	21.69	3.76	6.67	13.33
11.00	33.60	7.40	3.05	79.11	20.89	25.85	4.51	6.67	13.33
12.00	39.90	8.30	3.10	81.40	18.60	30.69	5.21	6.67	13.33
13.00	46.30	9.20	3.15	83.25	16.75	35.62	6.14	6.67	13.33
14.00	53.00	10.40	3.15	85.65	14.35	40.77	6.92	6.67	13.33
15.00	58.90	11.45	3.15	87.32	12.68	45.31	7.87	6.67	13.33
16.00	65.80	12.53	3.18	88.60	11.40	50.62	8.81	6.67	13.33
17.00	73.80	13.58	3.25	89.42	10.58	56.77	9.69	6.67	13.33
e_4=15 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 10°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.10	2.80	22.93	77.07	6.31	1.04	10.00	13.33
6.00	11.10	2.05	2.90	39.03	60.97	8.54	1.43	10.00	13.33
7.00	14.70	3.05	2.95	52.19	47.81	11.31	1.95	10.00	13.33
8.00	19.20	4.35	2.98	64.31	35.69	14.77	2.51	10.00	13.33
9.00	23.10	5.63	3.00	72.16	27.84	17.77	3.06	10.00	13.33
10.00	28.20	6.60	3.05	76.17	23.83	21.69	3.76	10.00	13.33
11.00	33.60	7.35	3.25	77.22	22.78	25.85	4.51	10.00	13.33
12.00	39.90	8.20	3.30	79.56	20.44	30.69	5.21	10.00	13.33
13.00	46.30	9.10	3.33	81.79	18.21	35.62	6.14	10.00	13.33
14.00	53.00	10.25	3.35	84.12	15.88	40.77	6.92	10.00	13.33
15.00	58.90	11.30	3.40	85.68	14.32	45.31	7.87	10.00	13.33
16.00	65.80	12.40	3.40	87.30	12.70	50.62	8.81	10.00	13.33
17.00	73.80	13.30	3.43	88.30	11.70	56.77	9.69	10.00	13.33

Table A.4 *Cont'd*

y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
e_4=15 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 20°									
5.00	8.20	1.05	2.75	22.44	77.56	6.31	1.04	10.00	13.33
6.00	11.10	2.05	2.85	39.69	60.31	8.54	1.43	10.00	13.33
7.00	14.70	3.00	2.90	52.28	47.72	11.31	1.95	10.00	13.33
8.00	19.20	4.50	2.93	66.04	33.96	14.77	2.51	10.00	13.33
9.00	23.10	5.60	2.95	72.57	27.43	17.77	3.06	10.00	13.33
10.00	28.20	6.58	3.00	76.55	23.45	21.69	3.76	10.00	13.33
11.00	33.60	7.35	3.20	77.65	22.35	25.85	4.51	10.00	13.33
12.00	39.90	8.20	3.25	79.95	20.05	30.69	5.21	10.00	13.33
13.00	46.30	9.10	3.30	81.96	18.04	35.62	6.14	10.00	13.33
14.00	53.00	10.25	3.35	84.12	15.88	40.77	6.92	10.00	13.33
15.00	58.90	11.30	3.35	85.97	14.03	45.31	7.87	10.00	13.33
16.00	65.80	12.40	3.40	87.30	12.70	50.62	8.81	10.00	13.33
17.00	73.80	13.35	3.45	88.24	11.76	56.77	9.69	10.00	13.33
e_4=15 mm, T=4 mm, Z_1=15 cm, Z_2=20 cm, α= 30°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.05	2.75	22.44	77.56	6.31	1.04	10.00	13.33
6.00	11.10	2.05	2.85	39.69	60.31	8.54	1.43	10.00	13.33
7.00	14.70	13.08	2.88	90.66	9.34	11.31	1.95	10.00	13.33
8.00	19.20	4.38	2.90	65.42	34.58	14.77	2.51	10.00	13.33
9.00	23.10	5.58	2.95	72.43	27.57	17.77	3.06	10.00	13.33
10.00	28.20	6.55	3.00	76.45	23.55	21.69	3.76	10.00	13.33
11.00	33.60	7.40	3.20	77.83	22.17	25.85	4.51	10.00	13.33
12.00	39.90	8.23	3.30	79.64	20.36	30.69	5.21	10.00	13.33
13.00	46.30	9.05	3.30	81.84	18.16	35.62	6.14	10.00	13.33
14.00	53.00	10.28	3.35	84.17	15.83	40.77	6.92	10.00	13.33
15.00	58.90	11.35	3.38	85.91	14.09	45.31	7.87	10.00	13.33
16.00	65.80	12.40	3.40	87.30	12.70	50.62	8.81	10.00	13.33
17.00	73.80	13.40	3.45	88.29	11.71	56.77	9.69	10.00	13.33
e_4=15 mm, T=4 mm, Z_1=5 cm, Z_2=25 cm, α= 40°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.60	2.20	41.67	58.33	6.31	1.04	3.33	16.67
6.00	11.10	2.60	2.25	57.39	42.61	8.54	1.43	3.33	16.67
7.00	14.70	3.80	2.35	68.39	31.61	11.31	1.95	3.33	16.67
8.00	19.20	4.80	2.45	73.98	26.02	14.77	2.51	3.33	16.67
9.00	23.10	5.78	2.60	77.21	22.79	17.77	3.06	3.33	16.67
10.00	28.20	6.70	2.70	79.88	20.12	21.69	3.76	3.33	16.67
11.00	33.60	7.60	2.85	81.44	18.56	25.85	4.51	3.33	16.67
12.00	39.90	8.35	3.00	82.30	17.70	30.69	5.21	3.33	16.67
13.00	46.30	9.35	3.03	84.45	15.55	35.62	6.14	3.33	16.67
14.00	53.00	10.40	3.10	85.95	14.05	40.77	6.92	3.33	16.67
15.00	58.90	11.40	3.25	86.69	13.31	45.31	7.87	3.33	16.67
16.00	65.80	12.45	3.35	87.62	12.38	50.62	8.81	3.33	16.67
17.00	73.80	13.45	3.40	88.59	11.41	56.77	9.69	3.33	16.67

Table A.4 *Cont'd*

e_4=15 mm, T=4 mm, Z_1=10 cm, Z_2=25 cm, α= 20°									
y_0 (cm)	$(Q_w)_T$ (lt/s)	y_i (cm)	y_{sc} (cm)	$\frac{(Q_w)_{ic}}{(Q_w)_T}$ (%)	$\frac{(Q_w)_{sc}}{(Q_w)_T}$ (%)	$(q_w)_T$ (lt/(s.m))	$(F_r)_e$	Z_1/e_4	Z_2/e_4
5.00	8.20	1.40	2.55	31.99	68.01	6.31	1.04	6.67	16.67
6.00	11.10	2.35	2.60	47.99	52.01	8.54	1.43	6.67	16.67
7.00	14.70	3.70	2.65	63.14	36.86	11.31	1.95	6.67	16.67
8.00	19.20	4.80	2.70	70.84	29.16	14.77	2.51	6.67	16.67
9.00	23.10	5.73	2.80	74.81	25.19	17.77	3.06	6.67	16.67
10.00	28.20	6.65	2.90	77.79	22.21	21.69	3.76	6.67	16.67
11.00	33.60	7.43	3.10	78.76	21.24	25.85	4.51	6.67	16.67
12.00	39.90	8.20	3.15	80.73	19.27	30.69	5.21	6.67	16.67
13.00	46.30	9.15	3.20	82.79	17.21	35.62	6.14	6.67	16.67
14.00	53.00	10.20	3.30	84.34	15.66	40.77	6.92	6.67	16.67
15.00	58.90	11.30	3.25	86.53	13.47	45.31	7.87	6.67	16.67
16.00	65.80	11.95	3.25	87.48	12.52	50.62	8.81	6.67	16.67
17.00	73.80	12.20	3.25	87.81	12.19	56.77	9.69	6.67	16.67

B. Results of the A-2 Group Experiments

Measured and calculated parameters with different e, α, Z_1, Z_2 values are tabulated in the following tables (These experiments were conducted with sediment). The meaning of the symbols used in relation to the weights of solids in these tables are summarized below:

$(\mathrm{W_s})_\mathrm{T}$ = Total weight of the sediment mixture placed upstream of the main channel at the beginning of the experiments (kgf)

$(\mathrm{W_s})_0$ = Weight of the sediment passed over the rack and remained at the downstream of the main channel (kgf)

$(\mathrm{W_s})_\mathrm{rack}$ = Weight of the sediment that passes through the rack inside the "Intake Structure" $(\mathrm{W_s})_T - (\mathrm{W_s})_0$

$(\mathrm{W_s})_\mathrm{ic}$ = Weight of the sediment retained in the "Intake Channel" (kgf)

$(\mathrm{W_s})_\mathrm{sc}$ = Weight of the sediment retained in the "Sediment Discharge Channel" (kgf)

$(\mathrm{W_s})_\mathrm{cc}$ = Weight of the sediment retained in the "Collection Channel-1" (kgf)

$[(\mathrm{W_s})_\mathrm{ic}]_R = {(W_s)_{ic}}/{(W_s)_{rack}}$

$[(\mathrm{W_s})_\mathrm{sc}]_R = {(W_s)_{sc}}/{(W_s)_{rack}}$

$[(\mathrm{W_s})_\mathrm{cc}]_R = {(W_s)_{cc}}/{(W_s)_{rack}}$

Table B.1. *Measured and calculated parameters related to A2-Group Experiments (e_1= 3 mm)*

	e_1=3 mm, T= 2 cm, Z_1= 5 cm, Z_2= 20 cm																			
	α: 10° Z_1: 5 cm, Z_2: 20 cm					α: 20° Z_1: 5 cm, Z_2: 20 cm					α: 30° Z_1: 5 cm, Z_2: 20 cm					α: 40° Z_1: 5 cm, Z_2: 20 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 47 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 73.33 % $[(W_s)_{sc}]_R$ = 24.58 % $[(W_s)_{cc}]_R$ = 2.08 %					$[(W_s)_i]_R$ = % 69.24 % $[(W_s)_{sc}]_R$ = % 30.02 % $[(W_s)_{cc}]_R$ = % 0.74 %					$[(W_s)_i]_R$ = % 72.58 % $[(W_s)_{sc}]_R$ = % 26.08 % $[(W_s)_{cc}]_R$ = % 1.33 %					$[(W_s)_i]_R$ = % 60.23 % $[(W_s)_{sc}]_R$ = % 34.97 % $[(W_s)_{cc}]_R$ = % 4.80 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ ve Ort. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ ve Ort. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	28.23	37.21	71.77	62.79	10.00	30.37	35.07	69.63	64.93	10.00	44.73	45.91	55.27	54.09	10.00	27.28	35.12	72.72	64.79
	10.00	37.21		62.79		10.00	35.94		64.06		10.00	46.48		53.52		10.00	34.63		65.37	
	10.00	37.21		62.79		10.00	34.63		65.37		10.00	45.63		54.37		10.00	35.50		64.50	
	10.00	37.21		62.79		10.00	34.63		65.37		10.00	45.63		54.37		10.00	35.50		64.50	
58.29	30.00	76.12	75.75	23.88	24.25	30.00	75.65	74.24	24.35	24.77	30.00	74.72	74.04	25.28	25.96	30.00	76.31	75.98	23.69	24.02
	30.00	76.31		23.69		30.00	75.85		24.15		30.00	74.72		25.28		30.00	76.31		23.69	
	30.00	75.29		24.71		30.00	74.72		25.28		30.00	73.36		26.64		30.00	75.65		24.35	
	30.00	75.29		24.71		30.00	74.72		25.28		30.00	73.36		26.64		30.00	75.65		24.35	
97.15	50.00	80.96	80.39	19.04	19.61	50.00	81.64	81.12	18.36	18.88	50.00	79.34	79.34	20.66	20.66	50.00	80.96	80.52	19.04	19.48
	50.00	80.37		19.63		50.00	81.16		18.84		50.00	79.34		20.66		50.00	80.71		19.29	
	50.00	80.11		19.89		50.00	80.91		19.09		50.00	79.34		20.66		50.00	80.33		19.67	
	50.00	80.11		19.89		50.00	80.78		19.22		50.00	79.34		20.66		50.00	80.07		19.93	
136.01	70.00	82.85	82.85	17.15	17.15	70.00	83.14	83.14	16.86	16.86	70.00	81.58	81.58	18.42	18.42	70.00	83.04	83.04	16.96	16.96
	70.00					70.00					70.00					70.00				
	70.00					70.00					70.00					70.00				

Table B.1 *Continued*

e_1=3 mm, T= 2 cm, Z_1= 5 cm, Z_2= 25 cm

	α: 10° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 47 kgf				
	$[(W_s)_i]_R$ = 72.15 % $[(W_s)_{sc}]_R$ = 26.99 % $[(W_s)_{cc}]_R$ = 0.87 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	38.71	34.51	61.29	65.49
	10.00	34.98		65.02	
	10.00	34.98		65.02	
	10.00	33.58		66.42	
58.29	30.00	77.51	77.28	22.49	22.73
	30.00	77.51		22.49	
	30.00	77.04		22.96	
	30.00	77.04		22.96	
97.15	50.00	83.14	82.62	16.86	17.39
	50.00	82.44		17.56	
	50.00	82.44		17.56	
	50.00	82.44		17.56	
136.01	70.00	83.79	83.79	16.21	16.21
	70.00				
	70.00				

	α: 20° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 71.04 % $[(W_s)_{sc}]_R$ = 28.45 % $[(W_s)_{cc}]_R$ = 0.51 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	28.23	32.55	71.77	67.45
	10.00	31.95		68.05	
	10.00	32.85		67.15	
	10.00	32.85		67.15	
58.29	30.00	74.72	74.83	25.28	25.18
	30.00	74.93		25.07	
	30.00	74.93		25.07	
	30.00	74.72		25.28	
97.15	50.00	81.40	80.66	18.60	19.34
	50.00	80.46		19.54	
	50.00	80.46		19.54	
	50.00	80.33		19.67	
136.01	70.00	82.46	82.36	17.54	17.64
	70.00	82.26		17.74	
	70.00				

	α: 30° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 75.40 % $[(W_s)_{sc}]_R$ = 24.51 % $[(W_s)_{cc}]_R$ = 0.09 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	35.47	31.71	64.53	68.29
	10.00	33.58		66.42	
	10.00	30.77		69.23	
	10.00	30.77		69.23	
58.29	30.00	76.44	75.32	23.56	24.69
	30.00	75.54		24.46	
	30.00	74.64		25.36	
	30.00	74.64		25.36	
97.15	50.00	80.71	80.20	19.29	19.80
	50.00	80.03		19.97	
	50.00	80.03		19.97	
	50.00	80.03		19.97	
136.01	70.00	82.75	82.75	17.25	17.25
	70.00	82.75		17.25	
	70.00				

	α: 40° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 66.60 % $[(W_s)_{sc}]_R$ = 30.80 % $[(W_s)_{cc}]_R$ = 2.60 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	26.88	33.92	73.12	66.08
	10.00	34.79		65.21	
	10.00	33.48		66.52	
	10.00	33.48		66.52	
58.29	30.00	82.77	75.27	17.23	24.74
	30.00	72.91		27.09	
	30.00	72.69		27.31	
	30.00	72.69		27.31	
97.15	50.00	79.26	78.85	20.74	21.16
	50.00	79.00		21.00	
	50.00	78.73		21.27	
	50.00	78.39		21.61	
136.01	70.00	81.18	81.18	18.82	18.82
	70.00				
	70.00				

Table B.1 *Continued*

	e₁=3 mm, T= 2 cm, Z₁= 10 cm, Z₂= 20 cm																			
	α: 10° Z_1: 10 cm, Z_2: 20 cm					α: 20° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 47 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 47.05 % $[(W_s)_{sc}]_R$ = 52.34 % $[(W_s)_{cc}]_R$ = 0.61 %					$[(W_s)_i]_R$ = 49.82 % $[(W_s)_{sc}]_R$ = 49.36 % $[(W_s)_{cc}]_R$ = 0.83 %					$[(W_s)_i]_R$ = 45.32 % $[(W_s)_{sc}]_R$ = 47.02 % $[(W_s)_{cc}]_R$ = 7.67 %					$[(W_s)_i]_R$ = 36.94 % $[(W_s)_{sc}]_R$ = 52.89 % $[(W_s)_{cc}]_R$ = 10.17 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	19.88	21.62	80.12	78.38	10.00	14.48	16.89	85.52	83.11	10.00	19.79	22.47	80.21	77.53	10.00	12.79	13.05	87.21	86.95
	10.00	21.62		78.38		10.00	17.12		82.88		10.00	22.47		77.53		10.00	12.79		87.21	
	10.00	21.62		78.38		10.00	16.77		83.23		10.00	22.47		77.53		10.00	12.79		87.21	
	10.00	21.62		78.38		10.00	16.77		83.23		10.00	22.47		77.53		10.00	13.58		86.42	
58.29	30.00	69.22	69.22	30.78	30.78	30.00	69.64	69.23	30.36	30.77	30.00	71.10	70.86	28.90	29.14	30.00	71.78	69.07	28.22	30.93
	30.00	69.22		30.78		30.00	69.18		30.82		30.00	70.86		29.14		30.00	68.17		31.83	
	30.00	69.22		30.78		30.00	69.18		30.82		30.00	70.86		29.14		30.00	68.17		31.83	
	30.00	69.22		30.78		30.00	68.92		31.08		30.00	70.62		29.38		30.00	68.17		31.83	
97.15	50.00	77.39	77.04	22.61	22.96	50.00	76.54	76.76	23.46	23.24	50.00	78.67	78.43	21.33	21.58	50.00	75.75	75.23	24.25	24.77
	50.00	77.39		22.61		50.00	76.84		23.16		50.00	78.39		21.61		50.00	75.06		24.94	
	50.00	76.69		23.31		50.00	76.98		23.02		50.00	78.39		21.61		50.00	75.06		24.94	
	50.00	76.69		23.31		50.00	76.69		23.31		50.00	78.25		21.75		50.00	75.06		24.94	
136.01	70.00	79.86	79.45	20.14	20.55	70.00	80.68	80.68	19.32	19.32	70.00	81.49	81.49	18.51	18.51	70.00	79.79	79.86	20.21	20.14
	70.00	79.24		20.76		70.00					70.00					70.00	79.90		20.10	
	70.00	79.24		20.76		70.00					70.00					70.00	70.90		20.10	

Table B.1 *Continued*

	e_1=3 mm, T= 2 cm, Z_1= 10 cm, Z_2= 25 cm																			
	α: 10° Z_1: 10 cm, Z_2: 25 cm					α: 20° Z_1: 10 cm, Z_2: 25 cm					α: 30° Z_1: 10 cm, Z_2: 25 cm					α: 40° Z_1: 10 cm, Z_2: 25 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 46 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 47 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 60.21 % $[(W_s)_{sc}]_R$ = 39.79 % $[(W_s)_{cc}]_R$ = 0.00 %					$[(W_s)_i]_R$ = 58.30 % $[(W_s)_{sc}]_R$ = 40.88 % $[(W_s)_{cc}]_R$ = 0.82 %					$[(W_s)_i]_R$ = 66.03 % $[(W_s)_{sc}]_R$ = 33.33 % $[(W_s)_{cc}]_R$ = 0.64 %					$[(W_s)_i]_R$ = 40.85 % $[(W_s)_{sc}]_R$ = 51.80 % $[(W_s)_{cc}]_R$ = 7.35 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	16.94	19.20	83.06	80.80	10.00	14.95	16.61	85.05	83.39	10.00	17.76	19.36	82.24	80.64	10.00	17.45	19.70	82.55	80.30
	10.00	18.90		81.10		10.00	16.61		83.39		10.00	19.36		80.64		10.00	19.13		80.87	
	10.00	18.90		81.10		10.00	16.61		83.39		10.00	19.36		80.64		10.00	19.98		80.02	
	10.00	19.79		80.21		10.00	16.61		83.39		10.00	19.36		80.64		10.00	19.98		80.02	
58.29	30.00	72.46	72.46	27.54	27.54	30.00	68.31	68.31	31.69	31.69	30.00	69.30	69.13	30.70	30.87	30.00	67.41	67.41	32.59	32.59
	30.00	72.46		27.54		30.00	68.31		31.69		30.00	68.86		31.14		30.00	67.41		32.59	
	30.00	72.46		27.54		30.00	68.31		31.69		30.00	69.30		30.70		30.00	67.41		32.59	
	30.00	72.46		27.54		30.00	68.31		31.69		30.00	69.06		30.94		30.00	67.41		32.59	
97.15	50.00	79.50	78.88	20.50	21.12	50.00	77.56	77.56	22.44	22.44	50.00	77.42	76.93	22.58	23.07	50.00	75.29	75.13	24.71	24.87
	50.00	79.10		20.90		50.00	77.56		22.44		50.00	77.13		22.87		50.00	75.13		24.87	
	50.00	78.60		21.40		50.00	77.56		22.44		50.00	76.44		23.56		50.00	75.13		24.87	
	50.00	78.32		21.68		50.00	77.56		22.44		50.00	76.73		23.27		50.00	74.97		25.03	
136.01	70.00	79.98	79.98	20.02		70.00	81.35	81.35	18.65	18.65	70.00	80.30	80.30	19.70	19.70	70.00	79.10	79.10	20.90	20.90
	70.00					70.00					70.00					70.00				
	70.00					70.00					70.00					70.00				

Table B.1 *Continued*

	e_1=3 mm, T= 2 cm, Z_1= 15 cm, Z_2= 20 cm														
	α: 10° Z_1: 15 cm, Z_2: 20 cm					α: 20° Z_1: 15 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 50 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 43.86 % $[(W_s)_{sc}]_R$ = 32.92 % $[(W_s)_{cc}]_R$ = 23.22 %					$[(W_s)_i]_R$ = 36.00 % $[(W_s)_{sc}]_R$ = 40.73 % $[(W_s)_{cc}]_R$ = 23.27 %					$[(W_s)_i]_R$ = 30.28 % $[(W_s)_{sc}]_R$ = 35.00 % $[(W_s)_{cc}]_R$ = 34.72 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	13.88	17.86	86.12	82.14	10.00	14.95	17.17	85.05	82.83	10.00	16.94	23.21	83.06	76.79
	10.00	17.29		82.71		10.00	17.45		82.55		10.00	22.48		77.52	
	10.00	18.15		81.85		10.00	17.45		82.55		10.00	22.91		77.09	
	10.00	18.15		81.85		10.00	16.61		83.39		10.00	24.24		75.76	
58.29	30.00	71.56	71.73	28.44	28.27	30.00	70.25	70.19	29.75	29.81	30.00	72.68	71.79	27.32	28.21
	30.00	72.01		27.99		30.00	70.25		29.75		30.00	72.01		27.99	
	30.00	71.79		28.21		30.00	70.25		29.75		30.00	71.35		28.65	
	30.00	71.56		28.44		30.00	70.02		29.98		30.00	71.12		28.88	
97.15	50.00	78.94	78.60	21.06	21.40	50.00	78.04	77.80	21.96	22.21	50.00	79.08	78.69	20.92	21.31
	50.00	78.53		21.47		50.00	77.76		22.24		50.00	79.08		20.92	
	50.00	78.39		21.61		50.00	77.62		22.38		50.00	77.67		22.33	
	50.00	78.53		21.47		50.00	77.76		22.24		50.00	78.94		21.06	
136.01	70.00	81.95	81.95	18.05	18.05	70.00	82.07	82.07	17.93	17.93	70.00	82.65	82.65	17.35	17.35
	70.00	81.95		18.05		70.00					70.00				
	70.00					70.00					70.00				

Table B.1 *Continued*

	e_1=3 mm, T= 2 cm, Z_1= 15 cm, Z_2= 25 cm														
	α: 10° Z_1: 15 cm, Z_2: 25 cm					α: 20° Z_1: 15 cm, Z_2: 25 cm					α: 30° Z_1: 15 cm, Z_2: 25 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 50 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 39.41 % $[(W_s)_{sc}]_R$ = 51.29 % $[(W_s)_{cc}]_R$ = 9.29 %					$[(W_s)_i]_R$ = 40.93 % $[(W_s)_{sc}]_R$ = 46.26 % $[(W_s)_{cc}]_R$ = 12.80 %					$[(W_s)_i]_R$ = 43.54 % $[(W_s)_{sc}]_R$ = 40.38 % $[(W_s)_{cc}]_R$ = 16.08 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43		9.02	12.33	90.98	87.67	10.00	10.95	11.73	89.05	88.27	10.00	9.06	11.77	90.94	88.23
	10.00	11.84		88.16		10.00	11.73		88.27		10.00	11.26		88.74	
	10.00	12.57		87.43		10.00	11.73		88.27		10.00	12.02		87.98	
	10.00	12.57		87.43		10.00	11.73		88.27		10.00	12.02		87.98	
58.29	30.00	67.92	68.12	32.08	31.88	30.00	70.19	69.97	29.81	30.03	30.00	69.38	68.94	30.62	31.06
	30.00	68.47		31.53		30.00	70.19		29.81		30.00	68.95		31.05	
	30.00	68.04		31.96		30.00	70.19		29.81		30.00	68.95		31.05	
	30.00	68.04		31.96		30.00	69.30		30.70		30.00	68.47		31.53	
97.15	50.00	76.24	75.86	23.76	24.14	50.00	78.39	78.39	21.61	21.61	50.00	76.64	75.79	23.36	24.21
	50.00	76.24		23.76		50.00	78.39		21.61		50.00	75.79		24.21	
	50.00	75.48		24.52		50.00	78.39		21.61		50.00	75.29		24.71	
	50.00	75.48		24.52		50.00	78.39		21.61		50.00	75.44		24.56	
136.01	70.00	78.76		21.24		70.00	80.38		19.62		70.00	79.50		20.50	
	70.00					70.00					70.00				
	70.00					70.00					70.00				

Table B.2. *Measured and calculated parameters related to A2-Group Experiments (e_2= 6 mm)*

	e_2=6 mm, T= 2 cm, Z_1= 5 cm, Z_2= 20,25 cm																			
	α: 10° Z_1: 5 cm, Z_2: 20 cm					α: 40° Z_1: 5 cm, Z_2: 20 cm					α: 30° Z_1: 5 cm, Z_2: 25 cm					α: 40° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= kgf				
	$[(W_s)_i]_R$ = 64.40 % $[(W_s)_{sc}]_R$ = 29.62 % $[(W_s)_{cc}]_R$ = 5.98 %					$[(W_s)_i]_R$ = 63.24 % $[(W_s)_{sc}]_{R\,c}$= 30.44 % $[(W_s)_{cc}]_R$ = 6.32 %					$[(W_s)_i]_R$ = 31.7 % $[(W_s)_{sc}]_R$ = 39.6 % $[(W_s)_{cc}]_R$ = %					$[(W_s)_i]_R$ = 26.2 % $[(W_s)_{sc}]_R$ = 40.3 % $[(W_s)_{cc}]_R$ = %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
6.87	5.00	36.82	37.82	63.18	62.18	10.00	26.61	36.82	73.39	63.18	10.00	33.20	36.36	66.80	63.64	10.00	30.66	37.29	69.34	62.71
	10.00	37.70		62.30		10.00	36.82		63.18		10.00	36.36		63.64		10.00	38.22		61.78	
	10.00	37.88		62.12		10.00	36.82		63.18		10.00	36.36		63.64		10.00	36.82		63.18	
	10.00	37.88		62.12		10.00	36.82		63.18		10.00	36.36		63.64		10.00	36.82		63.18	
20.61	30.00	75.48	75.26	24.52	24.74	30.00	74.23	74.23	25.77	25.77	30.00	74.64	74.33	25.36	25.67	30.00	74.30	73.83	25.70	26.17
	30.00	75.48		24.52		30.00	74.23		25.77		30.00	74.64		25.36		30.00	74.93		25.07	
	30.00	75.04		24.96		30.00	74.23		25.77		30.00	74.23		25.77		30.00	73.16		26.84	
	30.00	75.04		24.96		30.00	74.23		25.77		30.00	73.81		26.19		30.00	72.93		27.07	
34.35	50.00	80.86	80.61	19.14	19.39	50.00	80.35	80.02	19.65	19.98	50.00	81.08	80.57	18.92	19.43	50.00	79.47	79.03	20.53	20.98
	50.00	80.53		19.47		50.00	80.35		19.65		50.00	80.40		19.60		50.00	78.79		21.21	
	50.00	80.53		19.47		50.00	79.69		20.31		50.00	80.40		19.60		50.00	78.92		21.08	
	50.00	80.53		19.47		50.00	79.69		20.31		50.00	80.40		19.60		50.00	78.92		21.08	
48.09	70.00	84.64	84.03	15.36	15.97	70.00	84.46	84.09	15.54	15.91	70.00	84.43	84.15	15.57	15.85	70.00	83.98	84.12	16.02	15.88
	70.00	84.14		15.86		70.00	83.94		16.06		70.00	84.06		15.94		70.00	84.14		15.86	
	70.00	83.71		16.29		70.00	83.94		16.06		70.00	84.06		15.94		70.00	84.14		15.86	
	70.00	83.63		16.37		70.00	84.02		15.98		70.00	84.06		15.94		70.00	84.22		15.78	
54.96	80.00	84.20	84.20	15.80	15.80	80.00	85.20	85.20	14.80	14.80	80.00	85.30	85.46	14.70	14.54	80.00				
	80.00					80.00					80.00	85.44		14.56		80.00				
	80.00					80.00					80.00	85.44		14.56		80.00				
	80.00					80.00					80.00	85.65		14.35		80.00				
61.83	90.00					90.00					90.00	86.04	86.04	13.96	13.96	90.00				

Table B.2 *Continued*

	e_2=6 mm, T= 2 cm, Z_1= 10 cm, Z_2= 20 cm																			
	α: 10° Z_1: 10 cm, Z_2: 20 cm					α: 20° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf				
	$[(W_s)_i]_R$ = 56.64 % $[(W_s)_{sc}]_R$ = 36.19 % $[(W_s)_{cc}]_R$ = 7.18 %					$[(W_s)_i]_R$ = 52.76 % $[(W_s)_{sc}]_{R\,c}$= 38.15 % $[(W_s)_{cc}]_R$ = 9.09 %					$[(W_s)_i]_R$ = 54.27 % $[(W_s)_{sc}]_R$ = 31.68 % $[(W_s)_{cc}]_R$ = 14.05 %					$[(W_s)_i]_R$ = 51.49 $[(W_s)_{sc}]_R$ = 32.70 $[(W_s)_{cc}]_R$ = 15.82				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
	10.00	15.13		84.87		10.00	36.82		63.18		10.00	21.42		78.58		10.00	22.48		77.52	
6.87	10.00	22.45	22.45	77.55	77.55	10.00	37.70	37.82	62.30	62.18	10.00	22.44	22.12	77.56	77.88	10.00	23.77	23.77	76.23	76.23
	10.00	22.45		77.55		10.00	37.88		62.12		10.00	21.96		78.04		10.00	23.77		76.23	
	10.00	22.45		77.55		10.00	37.88		62.12		10.00	21.96		78.04		10.00	23.77		76.23	
	30.00	74.17		25.83		30.00	75.48		24.52		30.00	73.14		26.86		30.00	71.12		28.88	
20.61	30.00	74.17	73.63	25.83	26.37	30.00	75.48	75.26	24.52	24.74	30.00	73.14	73.14	26.86	26.86	30.00	70.68	70.79	29.32	29.21
	30.00	73.09		26.91		30.00	75.04		24.96		30.00	73.14		26.86		30.00	70.68		29.32	
	30.00	73.09		26.91		30.00	75.04		24.96		30.00	73.14		26.86		30.00	70.68		29.32	
	50.00	79.47		20.53		50.00	80.86		19.14		50.00	80.07		19.93		50.00	77.92		22.08	
34.35	50.00	79.47	79.33	20.53	20.67	50.00	80.53	80.61	19.47	19.39	50.00	80.19	80.16	19.81	19.84	50.00	78.19	77.95	21.81	22.05
	50.00	79.26		20.74		50.00	80.53		19.47		50.00	80.19		19.81		50.00	77.85		22.15	
	50.00	79.13		20.87		50.00	80.53		19.47		50.00	80.19		19.81		50.00	77.85		22.15	
	70.00	83.29		16.71		70.00	84.64		15.36		70.00	84.46		15.54		70.00	83.18		16.82	
48.09	70.00	83.29	83.25	16.71	16.76	70.00	84.14	84.03	15.86	15.97	70.00	84.20	84.27	15.80	15.74	70.00	83.00	83.05	17.00	16.96
	70.00	83.20		16.80		70.00	83.71		16.29		70.00	84.20		15.80		70.00	83.00		17.00	
	70.00	83.20		16.80		70.00	83.63		16.37		70.00	84.20		15.80		70.00	83.00		17.00	
	80.00	84.30		15.70		80.00					80.00					80.00				
54.96	80.00	84.46		15.54		80.00					80.00					80.00				
	80.00	84.46		15.54		80.00					80.00					80.00				
	80.00					80.00					80.00					80.00				

Table B.2 *Continued*

	e₂																			
	e_2=6 mm, T= 2 cm, Z_1= 10 cm, Z_2= 25 cm																			
	α: 10° Z_1: 10 cm, Z_2: 25 cm					α: 20° Z_1: 10 cm, Z_2: 25 cm					α: 30° Z_1: 10 cm, Z_2: 25 cm					α: 40° Z_1: 10 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 61.92 % $[(W_s)_{sc}]_R$ = 31.98 % $[(W_s)_{cc}]_R$ = 6.10 %					$[(W_s)_i]_R$ = 66.91 % $[(W_s)_{sc}]_R$ = 30.83 % $[(W_s)_{cc}]_R$ = 2.26 %					$[(W_s)_i]_R$ = 55.60 % $[(W_s)_{sc}]_R$ = 36.95 % $[(W_s)_{cc}]_R$ = 7.45 %					$[(W_s)_i]_R$ = 47.50 $[(W_s)_{sc}]_R$ = 38.79 $[(W_s)_{cc}]_R$ = 13.71				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
6.87	10.00	22.45	23.06	77.55	76.94	10.00	23.36	25.39	76.64	74.61	10.00	22.45	23.98	77.55	76.02	10.00	20.20	22.01	79.80	77.99
	10.00	22.45		77.55		10.00	25.12		74.88		10.00	23.37		76.63		10.00	22.01		77.99	
	10.00	23.37		76.63		10.00	26.00		74.00		10.00	24.28		75.72		10.00	22.01		77.99	
	10.00	23.37		76.63		10.00	25.06		74.94		10.00	24.28		75.72		10.00	22.01		77.99	
20.61	30.00	72.71	72.53	27.29	27.47	30.00	70.62	70.39	29.38	29.61	30.00	72.01	72.24	27.99	27.77	30.00	73.28	73.07	26.72	26.94
	30.00	72.47		27.53		30.00	70.62		29.38		30.00	72.91		27.09		30.00	73.28		26.72	
	30.00	72.47		27.53		30.00	70.62		29.38		30.00	72.01		27.99		30.00	72.85		27.15	
	30.00	72.47		27.53		30.00	69.71		30.29		30.00	72.01		27.99		30.00	72.85		27.15	
34.35	50.00	80.53	80.46	19.47	19.54	50.00	78.92	78.92	21.08	21.08	50.00	79.34	79.54	20.66	20.47	50.00	79.04	78.88	20.96	21.13
	50.00	80.44		19.56		50.00	78.92		21.08		50.00	79.60		20.40		50.00	79.04		20.96	
	50.00	80.44		19.56		50.00	78.92		21.08		50.00	79.60		20.40		50.00	78.71		21.29	
	50.00	80.44		19.56		50.00	78.92		21.08		50.00	79.60		20.40		50.00	78.71		21.29	
48.09	70.00	82.56	82.41	17.44	17.59	70.00	82.92	83.06	17.08	16.95	70.00	84.38	84.76	15.62	15.24	70.00	83.88	83.82	16.12	16.18
	70.00	82.36		17.64		70.00	83.10		16.90		70.00	84.46		15.54		70.00	83.78		16.22	
	70.00	82.36		17.64		70.00	83.10		16.90		70.00	84.77		15.23		70.00	83.94		16.06	
	70.00	82.36		17.64		70.00	83.10		16.90		70.00	85.43		14.57		70.00	83.69		16.31	
54.96	80.00	82.93	82.93	17.07	17.07	80.00	85.25	85.25	14.75	14.75	80.00					80.00	84.68	84.68	15.32	15.32
	80.00					80.00	85.25		14.75		80.00					80.00				
	80.00					80.00					80.00					80.00				

Table B.2 *Continued*

	e_2=6 mm, T= 2 cm, Z_1= 15 cm, Z_2= 20 cm																			
	α: 10° Z_1: 15 cm, Z_2: 20 cm					α: 20° Z_1: 15 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 55 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 50 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 56 kgf				
	$[(W_s)_i]_R$ = 39.45 % $[(W_s)_{sc}]_R$ = 38.55 % $[(W_s)_{cc}]_R$ = 22.00 %					$[(W_s)_i]_R$ = 31.39 % $[(W_s)_{sc}]_R$ = 41.61 % $[(W_s)_{cc}]_R$ = 27.00 %					$[(W_s)_i]_R$ = 30.59 % $[(W_s)_{sc}]_R$ = 40.35 % $[(W_s)_{cc}]_R$ = 29.07 %					$[(W_s)_i]_R$ = 30.01 % $[(W_s)_{sc}]_R$ = 35.18 % $[(W_s)_{cc}]_R$ = 34.81 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
6.87	10.00	9.12	12.23	90.88	87.77	10.00	12.79	15.98	87.21	84.02	10.00	9.77	11.26	90.23	88.74	10.00	8.85	10.21	91.15	89.79
	10.00	12.23		87.77		10.00	15.98		84.02		10.00	11.26		88.74		10.00	10.21		89.79	
	10.00	12.23		87.77		10.00	15.98		84.02		10.00	11.26		88.74		10.00	10.21		89.79	
	10.00	12.23		87.77		10.00	15.98		84.02		10.00	11.26		88.74		10.00	10.21		89.79	
20.61	30.00	71.53	70.26	28.47	29.74	30.00	69.22	68.54	30.78	31.46	30.00	68.76	68.55	31.24	31.45	30.00	65.66	65.02	34.34	34.99
	30.00	71.07		28.93		30.00	68.31		31.69		30.00	68.56		31.44		30.00	64.80		35.20	
	30.00	69.22		30.78		30.00	68.31		31.69		30.00	68.56		31.44		30.00	64.80		35.20	
	30.00	69.22		30.78		30.00	68.31		31.69		30.00	68.31		31.69		30.00	64.80		35.20	
34.35	50.00	79.31	79.31	20.69	20.69	50.00	78.12	77.68	21.88	22.32	50.00	78.12	77.57	21.88	22.43	50.00	75.88	75.88	24.12	24.12
	50.00	79.31		20.69		50.00	77.44		22.56		50.00	77.84		22.16		50.00	75.88		24.12	
	50.00	79.31		20.69		50.00	77.58		22.42		50.00	77.16		22.84		50.00	75.88		24.12	
	50.00	79.31		20.69		50.00	77.58		22.42		50.00	77.16		22.84		50.00	75.88		24.12	
48.09	70.00	83.67	83.39	16.33	16.61	70.00	81.48	81.62	18.52	18.38	70.00	82.02	82.29	17.98	17.71	70.00	80.01	80.33	19.99	19.68
	70.00	83.67		16.33		70.00	81.67		18.33		70.00	82.38		17.62		70.00	80.61		19.39	
	70.00	83.11		16.89		70.00	81.67		18.33		70.00	82.38		17.62		70.00	80.34		19.66	
	70.00	83.11		16.89		70.00	81.67		18.33		70.00	82.38		17.62		70.00	80.34		19.66	
54.96	80.00	83.11	83.11	16.89	16.89	80.00					80.00					80.00	81.73	81.73	18.27	18.27
	80.00					80.00					80.00					80.00				
	80.00					80.00					80.00					80.00				

Table B.2 *Continued*

$(F_r)_e$	α: 10° Z$_1$: 15 cm, Z$_2$: 25 cm					α: 20° Z$_1$: 15 cm, Z$_2$: 25 cm					α: 30° Z$_1$: 15 cm, Z$_2$: 25 cm					α: 40° Z$_1$: 15 cm, Z$_2$: 25 cm				
	e_2=6 mm, T= 2 cm, Z_1= 15 cm, Z_2= 25 cm																			
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 56 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= kgf				
	$[(W_s)_i]_R$ = 51.75 % $[(W_s)_{sc}]_R$ = 34.43 % $[(W_s)_{cc}]_R$ = 13.83 %					$[(W_s)_i]_R$ = 54.09 % $[(W_s)_{sc}]_R$ = 32.85 % $[(W_s)_{cc}]_R$ = 13.07 %					$[(W_s)_i]_R$ = 31.74 % $[(W_s)_{sc}]_R$ = 39.64 % $[(W_s)_{cc}]_R$ = 28.62 %					$[(W_s)_i]_R$ = 26.22 % $[(W_s)_{sc}]_R$ = 40.28 % $[(W_s)_{cc}]_R$ = 33.51 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
6.87	10.00	10.95		89.05		10.00	9.12		90.88		10.00	11.26		88.74		10.00	10.09		89.91	
	10.00	13.32	13.32	86.68	86.68	10.00	12.23	11.90	87.77	88.10	10.00	14.37	14.37	85.63	85.63	10.00	12.30	12.30	87.70	87.70
	10.00	13.32		86.68		10.00	11.73		88.27		10.00	14.37		85.63		10.00	12.30		87.70	
	10.00	13.32		86.68		10.00	11.73		88.27		10.00	14.37		85.63		10.00	12.30		87.70	
20.61	30.00	68.71		31.29		30.00	70.14		29.86		30.00	68.06		31.94		30.00	68.31		31.69	
	30.00	68.97	68.84	31.03	31.16	30.00	69.71	69.57	30.29	30.43	30.00	69.06	68.50	30.94	31.50	30.00	67.92	67.80	32.08	32.20
	30.00	68.97		31.03		30.00	69.22		30.78		30.00	68.56		31.44		30.00	67.92		32.08	
	30.00	68.71		31.29		30.00	69.22		30.78		30.00	68.31		31.69		30.00	67.05		32.95	
34.35	50.00	78.25		21.75		50.00	79.73		20.27		50.00	77.78	77.42	22.22		50.00	75.67		24.33	
	50.00	78.11	78.11	21.89	21.89	50.00	79.34	79.16	20.66	20.84	50.00	77.30		22.70	22.58	50.00	75.67	75.67	24.33	24.33
	50.00	78.11		21.89		50.00	78.79		21.21		50.00	77.30		22.70		50.00	75.67		24.33	
	50.00	77.97		22.03		50.00	78.79		21.21		50.00	77.30		22.70		50.00	75.67		24.33	
48.09	70.00	81.35		18.65		70.00	83.98		16.02		70.00	82.83		17.17		70.00	80.70		19.30	19.30
	70.00	81.56	81.43	18.44	18.57	70.00	83.45	83.41	16.55	16.60	70.00	82.83	82.74	17.17	17.26	70.00	80.70	80.70	19.30	
	70.00	81.46		18.54		70.00	83.36		16.64		70.00	82.65		17.35		70.00	80.70		19.30	
	70.00	81.35		18.65		70.00	82.83		17.17		70.00	82.65		17.35		70.00	80.70		19.30	
54.96	80.00	81.80		18.20		80.00	83.83		16.17		80.00	83.00		17.00		80.00	82.22		17.78	
	80.00	81.52		18.48	18.41	80.00		83.83		16.17	80.00		83.00		17.00	80.00	81.69	81.56	18.31	18.44
	80.00	81.52	81.59	18.48		80.00					80.00					80.00	81.17		18.83	
	80.00	81.52		18.48		80.00					80.00					80.00	81.17		18.83	

Table B.3. *Measured and calculated parameters related to A2-Group Experiments (e_3= 10 mm)*

	e_3=10 mm, T= 2 cm, Z_1= 5 cm, Z_2= 20,25 cm									
	α: 40° Z_1: 5 cm, Z_2: 20 cm					α: 40° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 51 kgf				
	$[(W_s)_i]_R$ = 56.44 % $[(W_s)_{sc}]_R$ = 31.23 % $[(W_s)_{cc}]_R$ = 12.32 %					$[(W_s)_i]_R$ = 61.56 % $[(W_s)_{sc}]_R$ = 23.26 % $[(W_s)_{cc}]_R$ = 15.18 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
3.19	10.00	35.71	37.05	64.29	62.95	10.00	29.41	33.20	70.59	66.80
	10.00	37.51		62.49		10.00	33.20		66.80	
	10.00	36.82		63.18		10.00	33.20		66.80	
	10.00	36.82		63.18		10.00	33.20		66.80	
9.58	30.00	74.72	74.15	25.28	25.85	30.00	74.72	74.04	25.28	25.96
	30.00	74.27		25.73		30.00	73.81		26.19	
	30.00	73.81		26.19		30.00	73.81		26.19	
	30.00	73.81		26.19		30.00	73.81		26.19	
15.96	50.00	80.86	80.99	19.14	19.01	50.00	80.77	80.95	19.23	19.05
	50.00	81.57		18.43		50.00	81.01		18.99	
	50.00	80.77		19.23		50.00	81.01		18.99	
	50.00	80.77		19.23		50.00	81.01		18.99	
22.35	70.00	84.08	83.68	15.92	16.33	70.00	85.19	85.53	14.81	14.47
	70.00	83.54		16.46		70.00	85.64		14.36	
	70.00	83.54		16.46		70.00	85.64		14.36	
	70.00	83.54		16.46		70.00	85.64		14.36	
25.54	80.00	85.16	85.18	14.84	14.82	80.00	87.12	86.98	12.88	13.02
	80.00	85.16		14.84		80.00	86.91		13.09	
	80.00	85.20		14.80		80.00	86.91		13.09	
	80.00	85.20		14.80		80.00				
28.73	90.00	85.06	85.06	14.94	14.94	90.00				

Table B.3 *Continued*

	e_3=10 mm, T= 2 cm, Z_1= 10 cm, Z_2= 20,25 cm																			
	α: 20° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 51kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf				
	$[(W_s)_i]_R$ = 40.79 % $[(W_s)_{sc}]_R$ = 36.76 % $[(W_s)_{cc}]_R$ = 22.45 %					$[(W_s)_i]_R$ = 33.55 % $[(W_s)_{sc}]_R$ = 45.04 % $[(W_s)_{cc}]_R$ = 21.41 %					$[(W_s)_i]_R$ = 36.34 $[(W_s)_{sc}]_R$ = 29.06 $[(W_s)_{cc}]_R$ = 34.60					$[(W_s)_i]_R$ = 58.78 $[(W_s)_{sc}]_R$ = 16.92 $[(W_s)_{cc}]_R$ = 24.30				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
	10.00	21.58		78.42		10.00	19.79		80.21		10.00	17.29		82.71		10.00	22.45		77.55	
3.19	10.00	24.24	24.24	75.76	75.76	10.00	21.58	21.88	78.42	78.12	10.00	19.02	20.17	80.98	79.83	10.00	24.28	25.49	75.72	74.51
	10.00	24.24		75.76		10.00	21.58		78.42		10.00	20.75		79.25		10.00	26.10		73.90	
	10.00	24.24		75.76		10.00	22.47		77.53		10.00	20.75		79.25		10.00	26.10		73.90	
	30.00	71.78		28.22		30.00	70.62		29.38		30.00	70.62		29.38		30.00	73.81		26.19	
9.58	30.00	72.24	72.07	27.76	27.93	30.00	69.71	69.94	30.29	30.06	30.00	70.64	70.53	29.36	29.47	30.00	73.81	73.36	26.19	26.64
	30.00	72.24		27.76		30.00	69.71		30.29		30.00	70.19		29.81		30.00	72.91		27.09	
	30.00	72.01		27.99		30.00	69.71		30.29		30.00	70.66		29.34		30.00	72.91		27.09	
	50.00	79.73		20.27		50.00	79.19		20.81		50.00	80.77		19.23		50.00	80.65		19.35	
15.96	50.00	79.73	79.67	20.27	20.34	50.00	79.19	78.92	20.81	21.08	50.00	81.01	80.95	18.99	19.05	50.00	80.65	80.25	19.35	19.75
	50.00	79.60		20.40		50.00	78.92		21.08		50.00	81.01		18.99		50.00	79.85		20.15	
	50.00	79.60		20.40		50.00	78.39		21.61		50.00	81.01		18.99		50.00	79.85		20.15	
	70.00	82.92		17.08		70.00	82.74		17.26		70.00	85.19		14.81		70.00	85.04		14.96	
22.35	70.00	83.19	83.25	16.81	16.75	70.00	83.45	83.05	16.55	16.95	70.00	86.23	86.64	13.77	13.36	70.00	85.04	85.02	14.96	14.98
	70.00	83.45		16.55		70.00	83.27		16.73		70.00	87.44		12.56		70.00	85.19		14.81	
	70.00	83.45		16.55		70.00	82.74		17.26		70.00	87.69		12.31		70.00	84.82		15.18	
	80.00	85.02		14.98		80.00	84.68		15.32		80.00					80.00	86.27		13.73	
25.54	80.00	85.16	85.14	14.84	14.86	80.00	84.89	84.86	15.11	15.14	80.00					80.00	85.79	85.91	14.21	14.09
	80.00	85.16		14.84		80.00	84.89		15.11		80.00					80.00	85.79		14.21	
	80.00	85.23		14.77		80.00	84.97		15.03		80.00					80.00	85.79		14.21	
28.73	90.00	86.43	86.43	13.57	13.57	90.00	85.91	85.91	14.09	14.09	90.00					90.00				

Table B.3 *Continued*

$(F_r)_e$	e_3=10 mm, T= 2 cm, Z_1= 15 cm, Z_2= 20,25 cm																			
	α: 20° Z_1: 15 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 20.39 % $[(W_s)_{sc}]_R$ = 57.73 % $[(W_s)_{cc}]_R$ = 21.89 %					$[(W_s)_i]_R$ = 29.25 % $[(W_s)_{sc}]_R$ = 34.21 % $[(W_s)_{cc}]_R$ = 36.54 %					$[(W_s)_i]_R$ = 27.32 % $[(W_s)_{sc}]_R$ = 37.60 % $[(W_s)_{cc}]_R$ = 35.08 %					$[(W_s)_i]_R$ = 27.29 % $[(W_s)_{sc}]_R$ = 34.52 % $[(W_s)_{cc}]_R$ = 38.20 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
3.19	10.00	9.98	13.05	90.02	86.95	10.00	9.02	10.40	90.98	89.60	10.00	13.05	15.17	86.95	84.83	10.00	9.02	12.82	90.98	87.18
	10.00	13.05		86.95		10.00	10.40		89.60		10.00	15.17		84.83		10.00	12.57		87.43	
	10.00	13.05		86.95		10.00	10.40		89.60		10.00	15.17		84.83		10.00	12.57		87.43	
	10.00	13.05		86.95		10.00	10.40		89.60		10.00	15.17		84.83		10.00	13.32		86.68	
9.58	30.00	68.25	67.68	31.75	32.32	30.00	64.91	65.66	35.09	34.34	30.00	65.81	66.18	34.19	33.83	30.00	66.89	65.83	33.11	34.17
	30.00	67.80		32.20		30.00	65.73		34.27		30.00	66.89		33.11		30.00	65.66		34.34	
	30.00	67.34		32.66		30.00	66.00		34.00		30.00	66.00		34.00		30.00	65.66		34.34	
	30.00	67.34		32.66		30.00	66.00		34.00		30.00	66.00		34.00		30.00	65.12		34.88	
15.96	50.00	77.70	76.64	22.30	23.36	50.00	75.63	74.99	24.37	25.01	50.00	76.54	75.58	23.46	24.42	50.00	74.33	73.11	25.67	26.89
	50.00	77.02		22.98		50.00	75.00		25.00		50.00	75.67		24.33		50.00	73.38		26.62	
	50.00	76.68		23.32		50.00	74.66		25.34		50.00	75.37		24.63		50.00	72.70		27.30	
	50.00	75.16		24.84		50.00	74.66		25.34		50.00	74.75		25.25		50.00	72.03		27.97	
22.35	70.00	81.26	81.04	18.74	18.96	70.00	79.38	79.55	20.62	20.45	70.00	80.85	81.21	19.15	18.79	70.00	79.47	79.63	20.53	20.37
	70.00	81.10		18.90		70.00	79.49		20.51		70.00	81.33		18.67		70.00	80.07		19.93	
	70.00	81.10		18.90		70.00	79.80		20.20		70.00	81.33		18.67		70.00	80.07		19.93	
	70.00	80.70		19.30		70.00	79.53		20.47		70.00	81.33		18.67		70.00	78.92		21.08	
25.54	80.00	83.39	83.43	16.61	16.56	80.00	80.73	81.51	19.27	18.49	80.00					80.00	79.94	79.94	20.06	20.06
	80.00	83.55		16.45		80.00	81.82		18.18		80.00					80.00	79.94		20.06	
	80.00	83.39		16.61		80.00	81.99		18.01		80.00					80.00				
	80.00	83.39				80.00					80.00					80.00				

Table B.4. *Measured and calculated parameters related to A2-Group Experiments (e_3= 15 mm)*

	e_4=15 mm, T= 2 cm, Z_1= 5 cm, Z_2= 20,25 cm									
	α: 40° Z_1: 5 cm, Z_2: 20 cm					α: 40° Z_1: 5 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 21 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 22 kgf				
	$[(W_s)_i]_R$ = 61.17 %, $[(W_s)_{sc}]_R$ = 16.35 % $[(W_s)_{cc}]_R$ = 22.30 %					$[(W_s)_i]_R$ = 73.44 %, $[(W_s)_{sc}]_R$ = 8.70 %, $[(W_s)_{cc}]_R$ = 17.85 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
1.74	10.00	22.45	26.40	77.55	73.90	10.00	20.54	30.47	79.46	69.53
	10.00	26.10		73.90		10.00	29.87		70.13	
	10.00	26.10		73.90		10.00	30.77		69.23	
	10.00	27.00		73.00		10.00	30.77		69.23	
5.21	30.00	69.39	70.67	30.61	29.33	30.00	71.07	71.66	28.93	28.34
	30.00	71.10		28.90		30.00	72.01		27.99	
	30.00	71.10		28.90		30.00	71.78		28.22	
	30.00	71.10		28.90		30.00	71.78		28.22	
8.69	50.00	80.89	80.49	19.11	19.51	50.00	87.17	90.42	12.83	9.58
	50.00	80.40		19.60		50.00	91.12		8.88	
	50.00	80.28		19.72		50.00	91.70		8.30	
	50.00	80.40		19.60		50.00	91.70		8.30	
12.17	70.00	83.81	85.86	16.19	14.14	70.00	94.32	94.42	5.68	5.58
	70.00	84.30		15.70		70.00	94.38		5.62	
	70.00	85.64		14.36		70.00	94.53		5.47	
	70.00	89.70		10.30		70.00	94.44		5.56	
13.90	80.00	95.01	95.61	4.99	4.39	80.00	94.31	94.31	5.69	5.69
	80.00	95.11		4.89		80.00	94.31		5.69	
	80.00	95.25		4.75		80.00	94.31		5.69	
	80.00	97.06		2.94		80.00	94.31		5.69	
15.64	90.00					90.00	94.85	94.85	5.15	5.15

Table B.4 *Continued*

	e_4=15 mm, T= 2 cm, Z_1= 10 cm, Z_2= 20,25 cm																			
	α: 20° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 25 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 19 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 21 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 17 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 20 kgf				
	$[(W_s)_i]_R$ = 44.45% $[(W_s)_{sc}]_R$ = 17.85 % $[(W_s)_{cc}]_R$ = 37.70 %					$[(W_s)_i]_R$ = 40.52 % $[(W_s)_{sc}]_R$ = 17.08 %, $[(W_s)_{cc}]_R$ = 42.40 %					$[(W_s)_i]_R$ = 47.82% $[(W_s)_{sc}]_R$ = 12.57 % $[(W_s)_{cc}]_R$ = 39.61 %					$[(W_s)_i]_R$ = 48.82 % $[(W_s)_{sc}]_R$ = 10.05 % $[(W_s)_{cc}]_R$ = 41.11 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
	10.00	13.62		86.38		10.00	10.64		89.36		10.00	18.00		82.00		10.00	11.73		88.27	
1.74	10.00	18.00	18.00	82.00	82.00	10.00	15.57	15.57	84.43	84.43	10.00	19.79	19.79	80.21	80.21	10.00	13.32	14.41	86.68	85.59
	10.00	18.00		82.00		10.00	15.57		84.43		10.00	19.79		80.21		10.00	14.95		85.05	
	10.00	18.00		82.00		10.00	15.57		84.43		10.00	19.79		80.21		10.00	14.95		85.05	
	30.00	71.31		28.69		30.00	72.91		27.09		30.00	67.24		32.76		30.00	69.64		30.36	
5.21	30.00	72.01	71.72	27.99	28.28	30.00	73.55	73.78	26.45	26.22	30.00	67.12	67.22	32.88	32.78	30.00	68.71	68.49	31.29	31.51
	30.00	71.78		28.22		30.00	74.44		25.56		30.00	67.39		32.61		30.00	67.80		32.20	
	30.00	71.78		28.22		30.00	74.23		25.77		30.00	67.12		32.88		30.00	67.80		32.20	
	50.00	80.25		19.75		50.00	85.37		14.63		50.00	78.92		21.08		50.00	80.10		19.90	
8.69	50.00	80.81	80.62	19.19	19.39	50.00	86.11	88.73	13.89	11.27	50.00	79.19	79.55	20.81	20.45	50.00	84.27	84.19	15.73	15.81
	50.00	80.70		19.30		50.00	90.52		9.48		50.00	79.85		20.15		50.00	85.56		14.44	
	50.00	80.70		19.30		50.00	92.91		7.09		50.00	80.23		19.77		50.00	86.84		13.16	
	70.00	90.45		9.55		70.00	94.69		5.31		70.00	89.37		10.63		70.00	92.32		7.68	
12.17	70.00	93.64	94.06	6.36	5.94	70.00	94.72	94.63	5.28	5.37	70.00	89.48	89.81	10.52	10.19	70.00	92.40	92.52	7.60	7.48
	70.00	95.68		4.32		70.00	94.78		5.22		70.00	89.92		10.08		70.00	92.64		7.36	
	70.00	96.46		3.54		70.00	94.32		5.68		70.00	90.46		9.54		70.00	92.72		7.28	
	80.00	96.90		3.10		80.00	94.23		5.77		80.00	93.26		6.74		80.00	93.61		6.39	
13.90	80.00	96.90	96.90	3.10	3.10	80.00	94.23	94.26	5.77	5.74	80.00	93.39	93.37	6.61	6.63	80.00	93.61	93.61	6.39	6.39
	80.00					80.00	94.23		5.77		80.00	93.42		6.58		80.00	93.61		6.39	
	80.00					80.00	94.34		5.66		80.00	93.42		6.58		80.00				
15.64	90.00					90.00	95.86	95.86	4.14	4.14	90.00	94.02	94.02	5.98	5.98	90.00				
	90.00						95.88													

Table B.4 *Continued*

	e_4=15 mm, T= 2 cm, Z_1= 15 cm, Z_2= 20,25 cm																			
	α: 20°					α: 30°					α: 40°					α: 40°				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 21 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 21 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 20 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 21 kgf				
	$[(W_s)_i]_R$ = 30.62 %, $[(W_s)_{sc}]_R$ = 14.62 %, $[(W_s)_{cc}]_R$ = 54.77 %					$[(W_s)_i]_R$ = 24.36 %, $[(W_s)_{sc}]_R$ = 22.12 %, $[(W_s)_{cc}]_R$ = 53.53 %					$[(W_s)_i]_R$ = 30.26 %, $[(W_s)_{sc}]_R$ = 13.79 %, $[(W_s)_{cc}]_R$ = 55.95 %					$[(W_s)_i]_R$ = 31.44, $[(W_s)_{sc}]_R$ = 14.17 % $[(W_s)_{cc}]_R$ = 54.39%				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
1.74	10.00	9.02	11.11	90.98	88.89	10.00	8.36	11.11	91.64	88.89	10.00	7.06	8.37	92.94	91.63	10.00	7.42	8.68	92.58	91.32
	10.00	11.11		88.89		10.00	11.11		88.89		10.00	8.37		91.63		10.00	8.68		91.32	
	10.00	11.11		88.89		10.00	11.11		88.89		10.00	8.37		91.63		10.00	8.68		91.32	
	10.00	11.11		88.89		10.00	11.11		88.89		10.00	8.37		91.63		10.00	8.68		91.32	
5.21	30.00	63.17	62.64	36.83	37.36	30.00	67.86	68.62	32.14	31.38	30.00	67.27	67.37	32.73	32.63	30.00	65.46	65.70	34.54	34.31
	30.00	64.91		35.09		30.00	69.10		30.90		30.00	66.89		33.11		30.00	66.00		34.00	
	30.00	64.63		35.37		30.00	69.10		30.90		30.00	67.41		32.59		30.00	65.66		34.34	
	30.00	57.86		42.14		30.00	68.42		31.58		30.00	67.92		32.08		30.00	65.66		34.34	
8.69	50.00	76.63	79.73	23.37	20.27	50.00	79.69	80.43	20.31	19.57	50.00	79.44	79.57	20.56	20.44	50.00	77.58	79.56	22.42	20.44
	50.00	77.44		22.56		50.00	79.57		20.43		50.00	79.44		20.56		50.00	79.44		20.56	
	50.00	81.08		18.92		50.00	80.35		19.65		50.00	79.69		20.31		50.00	79.31		20.69	
	50.00	83.76		16.24		50.00	82.12		17.88		50.00	79.69		20.31		50.00	81.90		18.10	
12.17	70.00	90.41	93.30	9.59	6.70	70.00	89.03	89.10	10.97	10.90	70.00	87.94	88.95	12.06	11.05	70.00	86.02	86.19	13.98	13.82
	70.00	91.64		8.36		70.00	89.09		10.91		70.00	89.11		10.89		70.00	86.24		13.76	
	70.00	95.00		5.00		70.00	89.09		10.91		70.00	89.11		10.89		70.00	86.24		13.76	
	70.00	96.15		3.85		70.00	89.20		10.80		70.00	89.65		10.35		70.00	86.24		13.76	
13.90	80.00	96.58	96.58	3.42	3.42	80.00	90.36	90.45	9.64	9.55	80.00	93.83	93.94	6.17	6.06	80.00	86.67	86.72	13.33	13.28
	80.00	96.58		3.42		80.00	90.40		9.60		80.00	93.83		6.17		80.00	86.80		13.20	
	80.00	96.58		3.42		80.00	90.50		9.50		80.00	93.83		6.17		80.00	86.74		13.26	
	80.00	96.58		3.42		80.00	90.54		9.46		80.00	94.28		5.72		80.00	86.67		13.33	
15.64	90.00	97.36	97.36	2.64	2.64	90.00					90.00	94.66				90.00	85.79	85.79	14.21	14.21

C. Results of the B-Group Experiments

Measured and calculated parameters with different e, α, Z_1, Z_2 values are tabulated in the following tables (These experiments were conducted with sediment). The meaning of the symbols used in relation to the weights of solids in these tables are summarized below:

$(W_s)_T$ = Total weight of the sediment mixture placed upstream of the main channel at the beginning of the experiments (kgf)

$(W_s)_0$ = Weight of the sediment passed over the rack and remained at the downstream of the main channel (kgf)

$(W_s)_{rack}$ = Weight of the sediment that passes through the rack inside the "Intake Structure" $(W_s)_T - (W_s)_0$

$(W_s)_{ic}$ = Weight of the sediment retained in the "Intake Channel" (kgf)

$(W_s)_{sc}$ = Weight of the sediment retained in the "Sediment Discharge Channel" (kgf)

$(W_s)_{cc}$ = Weight of the sediment retained in the "Collection Channel-1" (kgf)

$[(W_s)_{ic}]_R = {(W_s)_{ic}}/{(W_s)_{rack}}$

$[(W_s)_{sc}]_R = {(W_s)_{sc}}/{(W_s)_{rack}}$

$[(W_s)_{cc}]_R = {(W_s)_{cc}}/{(W_s)_{rack}}$

Table C.1. *Measured and calculated parameters related to B-Group Experiments (e_1= 3 mm)*

	e_1=3 mm, T= 2 cm, Z_1= 10,15 cm, Z_2= 20 cm																			
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 57,5 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 47 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 57.35 % $[(W_s)_{sc}]_R$ = 42.3 % $[(W_s)_{cc}]_R$ = 0.4 %					$[(W_s)_i]_R$ = 41.5 % $[(W_s)_{sc}]_R$ = 51.8 % $[(W_s)_{cc}]_R$ = 0.7 %					$[(W_s)_i]_R$ = 34.9 % $[(W_s)_{sc}]_R$ = 64.4 % $[(W_s)_{cc}]_R$ = 0.8 %					$[(W_s)_i]_R$ = 34.1 % $[(W_s)_{sc}]_R$ = 63. 8 % $[(W_s)_{cc}]_R$ = 2.1 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	21.50	25.45	78.50	74.55	10.00	28.97	28.84	71.03	71.16	10.00	12.52	14.95	87.48	85.05	10.00	15.13	19.69	84.87	80.31
	10.00	26.10		73.90		10.00	28.97		71.03		10.00	14.95		85.05		10.00	19.69		80.31	
	10.00	25.12		74.88		10.00	28.97		71.03		10.00	14.95		85.05		10.00	19.69		80.31	
	10.00	25.12		74.88		10.00	28.59		71.41		10.00	14.95		85.05		10.00	19.69		80.31	
58.29	30.00	73.34	72.23	26.66	27.77	30.00	72.45	71.24	27.55	28.77	30.00	68.56	68.05	31.44	31.95	30.00	67.80	66.92	32.20	33.09
	30.00	72.45		27.55		30.00	71.12		28.88		30.00	68.81		31.19		30.00	67.67		32.33	
	30.00	71.57		28.43		30.00	71.12		28.88		30.00	67.41		32.59		30.00	66.53		33.47	
	30.00	71.57		28.43		30.00	70.25		29.75		30.00	67.41		32.59		30.00	65.66		34.34	
97.15	50.00	78.53	77.13	21.47	22.87	50.00	78.04	76.45	21.96	23.56	50.00	76.68	75.60	23.32	24.40	50.00	75.44	74.43	24.56	25.57
	50.00	77.54		22.46		50.00	76.78		23.22		50.00	75.44		24.56		50.00	74.59		25.41	
	50.00	76.23		23.77		50.00	75.48		24.52		50.00	75.06		24.94		50.00	74.27		25.73	
	50.00	76.23		23.77		50.00	75.48		24.52		50.00	75.22		24.78		50.00	73.41		26.59	
136.01	70.00	81.59	81.59	18.41	18.41	70.00	80.60	80.60	19.40	19.40	70.00	79.79	79.79	20.21	20.21	70.00	78.02	78.14	21.98	21.86
	70.00					70.00					70.00					70.00	78.14		21.86	
	70.00					70.00					70.00					70.00	78.26		21.74	
	70.00					70.00					70.00					70.00				

Table C.2 *Measured and calculated parameters related to B-Group Experiments (e_2= 6 mm)*

	e_2=6 mm, T= 2 cm, Z_1= 10,15 cm, Z_2= 20 cm																			
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm,					α: 40° Z_1: 15 cm, Z_2: 20 cm,				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf				
	$[(W_s)_i]_R$ = 50.34 % $[(W_s)_{sc}]_R$ = 47 % $[(W_s)_{cc}]_R$ = 2.66 %					$[(W_s)_i]_R$ = 47.8 % $[(W_s)_{sc}]_R$ = 49.6 % $[(W_s)_{cc}]_R$ = 2.8 %					$[(W_s)_i]_R$ = 30.54 % $[(W_s)_{sc}]_R$ = 58.7 % $[(W_s)_{cc}]_R$ = 10.8 %					$[(W_s)_i]_R$ = 30.9 % $[(W_s)_{sc}]_R$ = 58.6 % $[(W_s)_{cc}]_R$ = 10.6 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
	10.00	16.23		83.77		10.00	22.44		77.56		10.00	13.05		86.95		10.00	13.32		86.68	
6.87	10.00	21.58	21.58	78.42	78.42	10.00	25.27	25.27	74.73	74.73	10.00	16.79	16.79	83.21	83.21	10.00	14.37	14.90	85.63	85.10
	10.00	21.58		78.42		10.00	25.27		74.73		10.00	16.79		83.21		10.00	15.17		84.83	
	10.00	21.58		78.42		10.00	25.27		74.73		10.00	16.79		83.21		10.00	15.17		84.83	
	30.00	73.38		26.62		30.00	74.38		25.62		30.00	68.56		31.44		30.00	67.27		32.73	
20.61	30.00	72.46	72.41	27.54	27.59	30.00	73.20	73.08	26.80	26.92	30.00	68.91	68.37	31.09	31.63	30.00	66.89	66.99	33.11	33.02
	30.00	72.46		27.54		30.00	72.48		27.52		30.00	68.47		31.53		30.00	66.89		33.11	
	30.00	71.33		28.67		30.00	72.25		27.75		30.00	67.55		32.45		30.00	66.89		33.11	
	50.00	79.98		20.02		50.00	80.71		19.29		50.00	77.02		22.98		50.00	77.30		22.70	
34.35	50.00	78.79	78.92	21.21	21.08	50.00	80.03	79.86	19.97	20.15	50.00	76.00	76.26	24.00	23.75	50.00	75.71	75.86	24.29	24.14
	50.00	78.92		21.08		50.00	79.34		20.66		50.00	76.00		24.00		50.00	75.37		24.63	
	50.00	77.98		22.02		50.00	79.34		20.66		50.00	76.00		24.00		50.00	75.06		24.94	
	70.00	83.98		16.02		70.00	84.67		15.33		70.00	82.47		17.53		70.00	81.84		18.16	18.12
48.09	70.00	83.98	83.94	16.02	16.07	70.00	84.67	84.47	15.33	15.53	70.00	82.47	82.38	17.53	17.62	70.00	81.84	81.89	18.16	
	70.00	83.89		16.11		70.00	84.40		15.60		70.00	82.20		17.80		70.00	81.56		18.44	
	70.00	83.89		16.11		70.00	84.14		15.86		70.00					70.00	82.30		17.70	
	80.00					70.00	84.14		15.86		80.00					80.00	83.30		16.70	
54.96	80.00					80.00		84.14		15.86	80.00					80.00				
	80.00					80.00					80.00					80.00				
	80.00					80.00					80.00					80.00				

Table C.3. *Measured and calculated parameters related to B-Group Experiments (e_3= 10 mm)*

	e₃																			
	e_3=10 mm, T= 2 cm, Z_1= 10,15 cm, Z_2= 20 cm																			
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 31.8 % $[(W_s)_{sc}]_R$ = 52.8 % $[(W_s)_{cc}]_R$ = 15.5 %					$[(W_s)_i]_R$ = 38.9 % $[(W_s)_{sc}]_R$ = 42.3 % $[(W_s)_{cc}]_R$ = 18.9 %					$[(W_s)_i]_R$ = 35.3 % $[(W_s)_{sc}]_R$ = 49.4 % $[(W_s)_{cc}]_R$ = 15.3 %					$[(W_s)_i]_R$ = 32.1 % $[(W_s)_{sc}]_R$ = 51.6 % $[(W_s)_{cc}]_R$ = 16.2 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ ve Ort. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
3.19	10.00	16.61	16.61	83.39	83.39	10.00	17.29	19.85	82.71	80.15	10.00	10.01	12.84	89.99	87.16	10.00	14.95	16.61	85.05	83.39
	10.00	16.61		83.39		10.00	19.02		80.98		10.00	12.84		87.16		10.00	16.61		83.39	
	10.00	16.61		83.39		10.00	19.02		80.98		10.00	12.84		87.16		10.00	16.61		83.39	
	10.00	16.61		83.39		10.00	21.50		78.50		10.00	12.84		87.16		10.00	16.61		83.39	
9.58	30.00	69.18	68.61	30.82	31.39	30.00	71.53	70.01	28.47	29.99	30.00	68.37	66.77	31.63	33.23	30.00	68.34	68.35	31.66	31.65
	30.00	69.22		30.78		30.00	71.08		28.92		30.00	66.89		33.11		30.00	68.66		31.34	
	30.00	68.25		31.75		30.00	68.71		31.29		30.00	65.91		34.09		30.00	68.20		31.80	
	30.00	67.80		32.20		30.00	68.71		31.29		30.00	65.91		34.09		30.00	68.20		31.80	
15.96	50.00	77.76	77.42	22.24	22.58	50.00	78.39	79.24	21.61	20.76	50.00	75.40	76.65	24.60	23.35	50.00	78.11	76.94	21.89	23.06
	50.00	77.42		22.58		50.00	79.44		20.56		50.00	82.08		17.92		50.00	77.13		22.87	
	50.00	77.42		22.58		50.00	79.44		20.56		50.00	74.41		25.59		50.00	76.44		23.56	
	50.00	77.08		22.92		50.00	79.69		20.31		50.00	74.72		25.28		50.00	76.09		23.91	
22.35	70.00	81.92	81.79	18.08	18.21	70.00	85.19	85.49	14.81	14.51	70.00	81.02	81.02	18.98	18.98	70.00	81.45	81.30	18.55	18.70
	70.00	81.94		18.06		70.00	85.35		14.65		70.00	81.02		18.98		70.00	81.75		18.25	
	70.00	81.56		18.44		70.00	85.50		14.50		70.00	81.02		18.98		70.00	80.90		19.10	
	70.00	81.75		18.25		70.00	85.93		14.07		70.00	81.02		18.98		70.00	81.10		18.90	
25.54	80.00	83.79	83.79	16.21	16.21	80.00	86.21	86.21	13.79	13.79	80.00	83.14	83.14	16.86	16.86	80.00	81.10	81.10	18.90	18.90
	80.00					80.00					80.00					80.00				
	80.00					80.00					80.00					80.00				
	80.00					80.00					80.00					80.00				

Table C.4. *Measured and calculated parameters related to B-Group Experiments (e_4= 15 mm)*

	e_4=15 mm, T= 3 cm, Z_1= 10 cm, Z_2= 20 cm																			
	α: 10° Z_1: 10 cm, Z_2: 20 cm					α: 20° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 55 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 50 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 56 kgf				
	$[(W_s)_i]_R$ = 38.2 % $[(W_s)_{sc}]_R$ = 32.8 % $[(W_s)_{cc}]_R$ = 29.1 %					$[(W_s)_i]_R$ = 32.0 % $[(W_s)_{sc}]_R$ = 45.0 % $[(W_s)_{cc}]_R$ = 23.0 %					$[(W_s)_i]_R$ = 50.0 % $[(W_s)_{sc}]_R$ = 20.8 % $[(W_s)_{cc}]_R$ = 29.6 %					$[(W_s)_i]_R$ = 33.8 % $[(W_s)_{sc}]_R$ = 37.6 % $[(W_s)_{cc}]_R$ = 28.6 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
1.74	10.00	13.83	16.36	86.17	83.64	10.00	32.95	17.47	67.05	82.53	10.00	11.26	15.17	88.74	84.83	10.00	13.57	15.11	86.43	84.89
	10.00	16.36		83.64		10.00	18.51		81.49		10.00	15.17		84.83		10.00	15.11		84.89	
	10.00	16.36		83.64		10.00	17.29		82.71		10.00	15.17		84.83		10.00	15.11		84.89	
	10.00	16.36		83.64		10.00	16.61		83.39		10.00	15.17		84.83		10.00	15.11		84.89	
5.21	30.00	64.91	63.51	35.09	36.50	30.00	66.73	64.97	33.27	35.03	30.00	68.97	68.00	31.03	32.00	30.00	65.12	63.98	34.88	36.02
	30.00	63.70		36.30		30.00	65.36		34.64		30.00	68.56		31.44		30.00	64.26		35.74	
	30.00	63.14		36.86		30.00	63.89		36.11		30.00	67.67		32.33		30.00	63.83		36.17	
	30.00	62.27		37.73		30.00	63.89		36.11		30.00	66.79		33.21		30.00	62.70		37.30	
8.69	50.00	75.59	76.77	24.41	23.23	50.00	76.34	75.40	23.66	24.60	50.00	77.16	77.06	22.84	22.95	50.00	76.25	76.57	23.75	23.43
	50.00	76.17		23.83		50.00	74.38		25.62		50.00	77.02		22.98		50.00	76.25		23.75	
	50.00	76.54		23.46		50.00	75.00		25.00		50.00	77.02		22.98		50.00	76.58		23.42	
	50.00	78.78		21.22		50.00	75.88		24.12		50.00	77.02		22.98		50.00	77.19		22.81	
12.17	70.00	87.29	89.09	12.71	10.91	70.00	84.46	85.81	15.54	14.19	70.00	87.82	88.55	12.18	11.46	70.00	86.16	87.65	13.84	12.35
	70.00	88.56		11.44		70.00	85.39		14.61		70.00	88.30		11.70		70.00	87.44		12.56	
	70.00	90.02		9.98		70.00	86.44		13.56		70.00	88.79		11.21		70.00	87.94		12.06	
	70.00	90.51		9.49		70.00	86.96		13.04		70.00	89.27		10.73		70.00	89.05		10.95	
13.90	80.00	92.26	92.29	7.74	7.80	80.00	89.60	90.04	10.40	9.97	80.00	90.41	90.44	9.59	9.56	80.00	92.18	92.18	7.82	7.82
	80.00	92.14		7.86		80.00	90.47		9.53		80.00	90.47		9.53		80.00				
	80.00					80.00					80.00					80.00				
	80.00					80.00					80.00					80.00				

Table C.4 *Continued*

	e_4=15 mm, T= 3 cm, Z_1= 15cm, Z_2= 20 cm																			
	α: 10° Z_1: 15 cm, Z_2: 20 cm					α: 20° Z_1: 15 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 51 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 55 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 50 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 56 kgf				
	$[(W_s)_i]_R$ = 24.1 % $[(W_s)_{sc}]_R$ = 69.5 % $[(W_s)_{cc}]_R$ = 7.8 %					$[(W_s)_i]_R$ = 25.2 % $[(W_s)_{sc}]_R$ = 71.0 % $[(W_s)_{cc}]_R$ = 13.8 %					$[(W_s)_i]_R$ = 15.8 % $[(W_s)_{sc}]_R$ = 70.3 % $[(W_s)_{cc}]_R$ = 13.8 %					$[(W_s)_i]_R$ = 17.7 % $[(W_s)_{sc}]_R$ = 71.1 % $[(W_s)_{cc}]_R$ = 11.2 %				
$(F_r)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
	10.00	4.11		95.89		10.00	7.14		92.86		10.00	4.99		95.01		10.00	5.19		94.81	
1.74	10.00	4.99	5.09	95.01	94.91	10.00	7.14	7.14	92.86	92.86	10.00	5.48	5.83	94.52	94.17	10.00	6.25	6.25	93.75	93.75
	10.00	4.99		95.01		10.00	7.14		92.86		10.00	6.01		93.99		10.00	6.25		93.75	
	10.00	5.28		94.72		10.00	7.14		92.86		10.00	6.01		93.99		10.00	6.25		93.75	
	30.00	55.81		44.19		30.00	59.22		40.78		30.00	60.48		39.52		30.00	57.68		42.32	
5.21	30.00	55.66	55.69	44.34	44.31	30.00	57.48	57.71	42.52	42.30	30.00	59.38	59.14	40.62	40.86	30.00	56.82	56.62	43.18	43.39
	30.00	55.00		45.00		30.00	57.48		42.52		30.00	58.76		41.24		30.00	55.98		44.02	
	30.00	56.30		43.70		30.00	56.64		43.36		30.00	57.93		42.07		30.00	55.98		44.02	
	50.00	67.93		32.07		50.00	70.18		29.82		50.00	70.31		29.69		50.00	70.00		30.00	
8.69	50.00	65.82	66.14	34.18	33.86	50.00	68.97	69.79	31.03	30.21	50.00	68.59	68.74	31.41	31.27	50.00	69.33	68.55	30.67	31.45
	50.00	65.41		34.59		50.00	68.97		31.03		50.00	68.21		31.79		50.00	67.43		32.57	
	50.00	65.41		34.59		50.00	71.05		28.95		50.00	67.83		32.17		50.00	67.43		32.57	
	70.00	71.76		28.24		70.00	80.99		19.01		70.00	75.10		24.90		70.00	76.74		23.26	
12.17	70.00	73.18	73.29	26.82	26.71	70.00	82.56	82.94	17.44	17.06	70.00	75.29	75.23	24.71	24.77	70.00	77.09	76.75	22.91	23.25
	70.00	73.99		26.01		70.00	83.59		16.41		70.00	75.54		24.46		70.00	77.09		22.91	
	70.00	74.24		25.76		70.00	84.62		15.38		70.00	75.00		25.00		70.00	76.08		23.92	
	80.00	74.50		25.50		80.00	86.68		13.32		80.00	76.84		23.16		80.00	77.78		22.22	
13.90	80.00	74.24	74.37	25.76	25.63	80.00		86.68		13.32	80.00		76.84		23.16	80.00	77.89	77.86	22.11	22.14
	80.00					80.00					80.00					80.00	77.89		22.11	
	80.00					80.00					80.00					80.00	77.89		22.11	

D. Results of the C-Group Experiments

Measured and calculated parameters with different e, α, Z_1, Z_2 values are tabulated in the following tables (These experiments were conducted with sediment). The meaning of the symbols used in relation to the weights of solids in these tables are summarized below:

$(W_s)_T$ = Total weight of the sediment mixture placed upstream of the main channel at the beginning of the experiments (kgf)

$(W_s)_0$ = Weight of the sediment passed over the rack and remained at the downstream of the main channel (kgf)

$(W_s)_{rack}$ = Weight of the sediment that passes through the rack inside the "Intake Structure" $(W_s)_T - (W_s)_0$

$(W_s)_{ic}$ = Weight of the sediment retained in the "Intake Channel" (kgf)

$(W_s)_{sc}$ = Weight of the sediment retained in the "Sediment Discharge Channel" (kgf)

$(W_s)_{cc}$ = Weight of the sediment retained in the "Collection Channel-1" (kgf)

$[(W_s)_{ic}]_R = {(W_s)_{ic}}/{(W_s)_{rack}}$

$[(W_s)_{sc}]_R = {(W_s)_{sc}}/{(W_s)_{rack}}$

$[(W_s)_{cc}]_R = {(W_s)_{cc}}/{(W_s)_{rack}}$

Table D.1. *Measured and calculated parameters related to C-Group Experiments (e_1= 3 mm)*

	e_1=3 mm, T= 2 cm, Z_1=10 cm, Z_2= 20 cm									
	α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 47 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 49 kgf				
	$[(W_s)_i]_R$ = 41.17 % $[(W_s)_{sc}]_R$ = 50.33 % $[(W_s)_{cc}]_R$ = 0.70 %					$[(W_s)_i]_R$ = 63.00 % $[(W_s)_{sc}]_R$ = 33.30 % $[(W_s)_{cc}]_R$ = 0.70 %				
$(Fr)_e$	$(Q_w)_T$ (Lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (Lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%).		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%).	
19.43	10.00	30.11	40.23	69.89	59.77	10.00	66.01	51.50	33.99	48.50
	10.00	39.69		60.31		10.00	52.57		47.43	
	10.00	40.50		59.50		10.00	50.96		49.04	
	10.00	40.50		59.50		10.00	50.96		49.04	
58.29	30.00	75.73	75.08	24.27	24.92	30.00	78.08	77.86	21.92	22.15
	30.00	75.73		24.27		30.00	78.26		21.74	
	30.00	74.64		25.36		30.00	77.81		22.19	
	30.00	74.23		25.77		30.00	77.27		22.73	
97.15	50.00	80.03	79.77	19.97	20.23	50.00	82.67	82.06	17.33	17.95
	50.00	79.77		20.23		50.00	81.85		18.15	
	50.00	79.64		20.36		50.00	81.85		18.15	
	50.00	79.64		20.36		50.00	81.85		18.15	
136.01	70.00	82.46	82.46	17.54	17.54	70.00	84.75	84.60	15.25	15.40
	70.00					70.00	84.46		15.54	
	70.00					70.00				

E. Results of the D-Group Experiments

Measured and calculated parameters with different e, α, Z_1, Z_2 values are tabulated in the following tables (These experiments were conducted with sediment). The meaning of the symbols used in relation to the weights of solids in these tables are summarized below:

$(W_s)_T$ = Total weight of the sediment mixture placed upstream of the main channel at the beginning of the experiments (kgf)

$(W_s)_0$ = Weight of the sediment passed over the rack and remained at the downstream of the main channel (kgf)

$(W_s)_{rack}$ = Weight of the sediment that passes through the rack inside the "Intake Structure" $(W_s)_T - (W_s)_0$

$(W_s)_{ic}$ = Weight of the sediment retained in the "Intake Channel" (kgf)

$(W_s)_{sc}$ = Weight of the sediment retained in the "Sediment Discharge Channel" (kgf)

$(W_s)_{cc}$ = Weight of the sediment retained in the "Collection Channel-1" (kgf)

$[(W_s)_{ic}]_R = {(W_s)_{ic}}/{(W_s)_{rack}}$

$[(W_s)_{sc}]_R = {(W_s)_{sc}}/{(W_s)_{rack}}$

$[(W_s)_{cc}]_R = {(W_s)_{cc}}/{(W_s)_{rack}}$

Table E.1. *Measured and calculated parameters related to D-Group Experiments (e_1= 3 mm)*

	e_1=3 mm, T= 2 cm, Z_1= 10,15 cm, Z_2= 20 cm																			
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 100 kgf, $(W_s)_O$= 57.5 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$= 45.6 kgf					$(W_s)_T$= 100 kgf, $(W_s)_O$=47.9 kgf				
	$[(W_s)_i]_R$ = 30.89 % $[(W_s)_{sc}]_R$= 68.48 % $[(W_s)_{cc}]_R$= 0.43 %					$[(W_s)_i]_R$ = 32.14 % $[(W_s)_{sc}]_R$ = 67.60 % $[(W_s)_{cc}]_R$ = 0.26 %					$[(W_s)_i]_R$ = 28.65 % $[(W_s)_{sc}]_R$ = 70.75 % $[(W_s)_{cc}]_R$ = 0.60 %					$[(W_s)_i]_R$ = 23.99 % $[(W_s)_{sc}]_R$ = 74.81 % $[(W_s)_{cc}]_R$ = 1.21 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
19.43	10.00	8.20	10.64	91.80	89.36	10.00	10.40	11.11	89.60	88.89	10.00	6.37	8.69	93.63	91.31	10.00	7.71	9.94	92.29	90.06
	10.00	10.30		89.70		10.00	11.11		88.89		10.00	8.85		91.15		10.00	9.02		90.98	
	10.00	10.81		89.19		10.00	11.11		88.89		10.00	8.85		91.15		10.00	10.40		89.60	
	10.00	10.81		89.19		10.00	11.11		88.89		10.00	8.36		91.64		10.00	10.40		89.60	
58.29	30.00	63.29	62.81	36.71	37.19	30.00	63.40	62.91	36.60	37.09	30.00	59.61	59.60	40.39	40.40	30.00	58.13	58.76	41.87	41.24
	30.00	63.14		36.86		30.00	63.40		36.60		30.00	60.41		39.59		30.00	59.38		40.62	
	30.00	62.70		37.30		30.00	62.42		37.58		30.00	59.19		40.81		30.00	58.76		41.24	
	30.00	62.12		37.88		30.00	62.42		37.58		30.00	59.19		40.81		30.00	58.76		41.24	
97.15	50.00	72.70	72.45	27.30	27.55	50.00	72.36	72.11	27.64	27.89	50.00	70.99	70.54	29.01	29.47	50.00	70.31	69.38	29.69	30.62
	50.00	72.70		27.30		50.00	72.36		27.64		50.00	70.63		29.37		50.00	69.58		30.42	
	50.00	72.03		27.97		50.00	72.03		27.97		50.00	70.63		29.37		50.00	69.20		30.80	
	50.00	72.37		27.63		50.00	71.69		28.31		50.00	69.89		30.11		50.00	68.42		31.58	
136.01	70.00	76.37	76.37	23.63	23.63	70.00	76.29	76.29	23.71	23.71	70.00	68.36	68.36	31.64	31.64	70.00	74.24	74.24	25.76	25.76
	70.00					70.00					70.00					70.00				
	70.00					70.00					70.00					70.00				
	70.00					70.00					70.00					70.00				

Table E.2. *Measured and calculated parameters related to D-Group Experiments (e_2= 6 mm)*

	e_2=6 mm, T= 2 cm, Z_1= 10,15 cm, Z_2= 20 cm																			
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 53 kgf				
	$[(W_s)_i]_R$ = 32.24 % $[(W_s)_{sc}]_R$ = 66.43 % $[(W_s)_{cc}]_R$ = 1.31 %					$[(W_s)_i]_R$ = 29.99 % $[(W_s)_{sc}]_R$ = 68.75 % $[(W_s)_{cc}]_R$ = 1.26 %					$[(W_s)_i]_R$ = 28.34 % $[(W_s)_{sc}]_R$ = 60.63 % $[(W_s)_{cc}]_R$ = 11.04 %					$[(W_s)_i]_R$ = 21.05 % $[(W_s)_{sc}]_R$ = 67.85 % $[(W_s)_{cc}]_R$ = 11.10 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
6.87	10.00	7.71	10.40	92.29	89.60	10.00	6.50	10.40	93.50	89.60	10.00	5.29	7.56	94.71	92.44	10.00	7.87	10.61	92.13	89.39
	10.00	10.40		89.60		10.00	10.40		89.60		10.00	7.56		92.44		10.00	10.61		89.39	
	10.00	10.40		89.60		10.00	10.40		89.60		10.00	7.56		92.44		10.00	10.61		89.39	
	10.00	10.40		89.60		10.00	10.40		89.60		10.00	7.56		92.44		10.00	10.61		89.39	
20.61	30.00	64.02	64.44	35.98	35.56	30.00	67.26	67.31	32.74	32.69	30.00	64.26	63.26	35.74	36.74	30.00	63.14	62.56	36.86	37.45
	30.00	64.58		35.42		30.00	67.33		32.67		30.00	63.95		36.05		30.00	61.97		38.03	
	30.00	64.58		35.42		30.00	67.33		32.67		30.00	62.98		37.02		30.00	61.97		38.03	
	30.00	64.58		35.42		30.00	67.33		32.67		30.00	61.85		38.15		30.00	63.14		36.86	
34.35	50.00	75.30	74.09	24.70	25.91	50.00	74.29	73.98	25.71	26.02	50.00	72.03	71.34	27.97	28.66	50.00	72.36	70.72	27.64	29.28
	50.00	74.33		25.67		50.00	74.29		25.71		50.00	71.35		28.65		50.00	70.29		29.71	
	50.00	73.70		26.30		50.00	73.67		26.33		50.00	70.99		29.01		50.00	70.29		29.71	
	50.00	73.03		26.97		50.00	73.67		26.33		50.00	70.99		29.01		50.00	69.95		30.05	
48.09	70.00	79.77	79.34	20.23	20.66	70.00	79.48	79.48	20.52	20.52	70.00	77.67	77.84	22.33	22.16	70.00	79.08	79.33	20.92	20.67
	70.00	78.92		21.08		70.00	79.48		20.52		70.00	77.90		22.10		70.00	79.28		20.72	
	70.00	79.34		20.66		70.00	79.48		20.52		70.00	77.90		22.10		70.00	79.48		20.52	
	70.00	79.34		20.66		70.00	79.48		20.52		70.00	77.90		22.10		70.00	79.48		20.52	
54.96	80.00	81.42	81.42	18.58	18.58	80.00					80.00	79.95	79.71	20.05	20.30	80.00	81.35	81.35	18.65	18.65
	80.00					80.00					80.00	79.95		20.05		80.00				
	80.00					80.00					80.00	79.46		20.54		80.00				
	80.00					80.00					80.00	79.46		20.54		80.00				
61.83	90.00					90.00					90.00	81.14	81.14	18.86	18.86	90.00				

Table E.3. *Measured and calculated parameters related to D-Group Experiments (e_3= 10 mm)*

	e3=10 mm, T= 2 cm, Z_1= 10,15 cm, Z_2= 20 cm																			
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_i]_R$ = 24.01 % $[(W_s)_{sc}]_R$ = 65.55 % $[(W_s)_{cc}]_R$ = 10.44 %					$[(W_s)_i]_R$ = 28.33 % $[(W_s)_{sc}]_R$ = 58.99 % $[(W_s)_{cc}]_R$ = 12.67 %					$[(W_s)_i]_R$ = 21.04 % $[(W_s)_{sc}]_R$ = 62.97 % $[(W_s)_{cc}]_R$ = 15.99 %					$[(W_s)_i]_R$ = 27.25 % $[(W_s)_{sc}]_R$ = 63.03 % $[(W_s)_{cc}]_R$ = 9.72 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
3.19	10.00	10.81	12.15	89.19	87.85	10.00	16.97	19.89	83.03	80.11	10.00	6.50	8.36	93.50	91.64	10.00	6.50	8.53	93.50	91.47
	10.00	12.30		87.70		10.00	19.36		80.64		10.00	8.36		91.64		10.00	7.71		92.29	
	10.00	12.07		87.93		10.00	20.15		79.85		10.00	8.36		91.64		10.00	9.02		90.98	
	10.00	12.07		87.93		10.00	20.15		79.85		10.00	8.36		91.64		10.00	8.85		91.15	
9.58	30.00	65.14	64.45	34.86	35.55	30.00	68.16	68.58	31.84	31.42	30.00	62.56	63.73	37.44	36.27	30.00	61.66	60.78	38.34	39.23
	30.00	64.22		35.78		30.00	68.16		31.84		30.00	63.44		36.56		30.00	60.48		39.52	
	30.00	64.22		35.78		30.00	69.00		31.00		30.00	63.73		36.27		30.00	60.48		39.52	
	30.00	64.22		35.78		30.00	69.00		31.00		30.00	65.19		34.81		30.00	60.48		39.52	
15.96	50.00	74.72	73.82	25.28	26.18	50.00	80.65	81.29	19.35	18.71	50.00	75.67	75.61	24.33	24.39	50.00	74.59	74.37	25.41	25.64
	50.00	74.08		25.92		50.00	80.88		19.12		50.00	75.67		24.33		50.00	74.29		25.71	
	50.00	73.41		26.59		50.00	81.50		18.50		50.00	75.06		24.94		50.00	74.29		25.71	
	50.00	73.06		26.94		50.00	82.13		17.87		50.00	76.05		23.95		50.00	74.29		25.71	
22.35	70.00	81.21	80.32	18.79	19.68	70.00	84.11	84.83	15.89	15.17	70.00	79.04	79.63	20.96	20.37	70.00	79.22	79.18	20.78	20.82
	70.00	80.48		19.52		70.00	85.00		15.00		70.00	79.26		20.74		70.00	79.30		20.70	
	70.00	80.01		19.99		70.00	85.07		14.93		70.00	80.11		19.89		70.00	79.05		20.95	
	70.00	79.59		20.41		70.00	85.15		14.85		70.00	80.11		19.89		70.00	79.15		20.85	
25.54	80.00					80.00	87.11		12.89		80.00	81.65	81.74	18.35	18.26	80.00	79.58	79.58	20.42	20.42
	80.00					80.00	87.05		12.95		80.00	81.74		18.26		80.00				
	80.00					80.00					80.00	81.74		18.26		80.00				
	80.00					80.00					80.00	81.74		18.26		80.00				

Table E.4. *Measured and calculated parameters related to D-Group Experiments (e_4= 15 mm)*

	e_4=15 mm, T= 3 cm, Z_1= 10,15 cm, Z_2= 20 cm															
	α: 30° Z_1: 10 cm, Z_2: 20 cm					α: 40° Z_1: 10 cm, Z_2: 20 cm					α: 30° Z_1: 15 cm, Z_2: 20 cm					α: 40° Z_1: 15 cm, Z_2: 20 cm				
	$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 54 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 52 kgf					$(W_s)_T$= 120 kgf, $(W_s)_O$= 48 kgf				
	$[(W_s)_{ic}]_R$= 23.29 % $[(W_s)_{sc}]_R$ = 58.48 % $[(W_s)_{cc}]_R$ = 18.23 %					$[(W_s)_{ic}]_R$ = 21.55 % $[(W_s)_{sc}]_R$ = 57.36 % $[(W_s)_{cc}]_R$ = 21.09 %					$[(W_s)_{ic}]_R$ = 17.15 % $[(W_s)_{sc}]_R$ = 39.02 % $[(W_s)_{cc}]_R$ = 43.83 %					$[(W_s)_{ic}]_R$ = 15.78 % $[(W_s)_{sc}]_R$ = 62.46 % $[(W_s)_{cc}]_R$ = 21.75 %				
$(Fr)_e$	$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)		$(Q_w)_T$ (lt/s)	$\frac{(Q_W)_{ic}}{(Q_W)_T}$ and Ave. (%)		$\frac{(Q_W)_{sc}}{(Q_W)_T}$ and Ave. (%)	
1.74	10.00	5.40	6.33	94.60	93.67	10.00	8.03	8.03	91.97	91.97	10.00	4.64	4.64	95.36	95.36	10.00	7.09	7.09	92.91	92.91
	10.00	6.50		93.50		10.00	8.03		91.97		10.00	4.64		95.36		10.00	7.09		92.91	
	10.00	6.25		93.75		10.00	8.03		91.97		10.00	4.64		95.36		10.00	7.09		92.91	
	10.00	6.25		93.75		10.00	8.03		91.97		10.00	4.64		95.36		10.00	7.09		92.91	
5.21	30.00	58.34	60.00	41.66	40.00	30.00	59.54	61.09	40.46	38.92	30.00	54.25	55.87	45.75	44.13	30.00	53.90	54.43	46.10	45.58
	30.00	60.83		39.17		30.00	60.53		39.47		30.00	55.30		44.70		30.00	54.60		45.40	
	30.00	60.83		39.17		30.00	61.13		38.87		30.00	56.97		43.03		30.00	54.60		45.40	
	30.00	60.41		39.59		30.00	63.14		36.86		30.00	56.97		43.03		30.00	54.60		45.40	
8.69	50.00	73.35	73.44	26.65	26.57	50.00	71.53	72.16	28.47	27.84	50.00	70.53	73.03	29.47	26.97	50.00	70.60	70.57	29.40	29.43
	50.00	73.35		26.65		50.00	75.59		24.41		50.00	71.19		28.81		50.00	70.78		29.22	
	50.00	73.35		26.65		50.00	71.02		28.98		50.00	72.70		27.30		50.00	70.78		29.22	
	50.00	73.69		26.31		50.00	70.49		29.51		50.00	77.70		22.30		50.00	70.13		29.87	
12.17	70.00	80.48	80.73	19.52	19.27	70.00	81.26	80.45	18.74	19.55	70.00	88.19	88.30	11.81	11.70	70.00	79.27	77.84	20.73	22.16
	70.00	80.68		19.32		70.00	80.15		19.85		70.00	88.26		11.74		70.00	77.40		22.60	
	70.00	80.87		19.13		70.00	80.04		19.96		70.00	88.38		11.62		70.00	77.40		22.60	
	70.00	80.87		19.13		70.00	80.35		19.65		70.00	88.38		11.62		70.00	77.29		22.71	
13.90	80.00	82.89	82.89	17.11	17.11	80.00	82.40	81.97	17.60	18.03	80.00	89.30	89.33	10.70	10.68	80.00	79.60	79.60	20.40	20.40
	80.00					80.00	82.00		18.00		80.00	89.35		10.65		80.00				
	80.00					80.00	81.91		18.09		80.00					80.00				
	80.00					80.00	81.57		18.43		80.00					80.00				

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name	: Yılmaz, Kutay
Nationality	: Turkish (TC)
Date and Place of Birth	: 13 June 1988, Ankara
Phone	: +90 505 600 31 21
E-mail	: ktyylmz@gmail.com

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Civil Engineering	2014
BS	METU Environmental Engineering	2011
High School	İnönü High School, İzmir	2006

PUBLICATIONS

Journal Papers

1. Yavuz, C., Dincer, A. E.,Yilmaz, K., Dursun, S. (2015). Head Loss Estimation of Water Jets from Flip Bucket of CAKMAK-1 Diversion Weir and HEPP. J. Civil Eng. Architect. Res. Vol.2, No. 9, 2015; Published: September 25, 2015

2. Yavuz C., Yilmaz K. (2017) "Estimation of Energy Reduction for Ski Jump Jets", Eurasian Journal of Engineering Sciences and Technology

3. Yilmaz K., Yavuz C. (2017) "Numerical Investigation of Cavitation Problem on A Specified Geometry", International Journal of Engineering and Science. Vol.6, Issue 9 PP 45 – 49

Conference Papers

1. Koken, M., Gogus, M., Yilmaz, K. (2014). "Application of collars as scour countermeasure at various contraction ratios caused by two spill-through abutments.",

7th International Conference on Fluvial Hydraulics, Lausanne, Switzerland, September 2014.

2. Gogus, M., Altan-Sakarya, A. B., Aydin, I., Koken, M., Yavuz, C., Dincer, A. E., Yilmaz, K. (2014). “Experimental Investigation of Beyhan-I Dam and hydroelectric power plant water intake structure.”, 3rd. IAHR Europe Congress, Porto, April 2014.

3. Gogus,M, Aydin,I, Altan-Sakarya,A.B, Koken,M, Yavuz,C, Dincer,A.E, Yilmaz,K., Beyhan 1 Barajı ve Hidroelektrik Santrali Su Alma Yapısının Deneysel Araştırılması. "DSİ 2. Barajlar Kongresi, 13-15 Şubat 2014, İstanbul", (2014).

4. Yavuz, C., Dincer, A. E.,Yilmaz, K., Dursun, S. (2015). Head Loss Estimation of Water Jets from Flip Bucket of CAKMAK-1 Diversion Weir and HEPP. Dam World 2015

5. Yilmaz, K., Eren, O., Marim, G. (2016). “Hydropower Potential in Water Supply and Irrigation Network Projects.” International Symposium of Water and Wastewater Management (ISWWM), October, 2016, Malatya

6. Yavuz C., Yilmaz K. (2017) “Estimation of Energy Reduction for Ski Jump Jets”, International Conference on Civil and Environmental Engineering, May 2017, Cappadocia, Turkey.

7. Gogus, M., Yilmaz, K., Melek, B. A. (2017). “Determination of Optimum Rack Angle of Tyolean Type Intakes to Increase Water Capture Efficiency”, 37th IAHR World Congress, Kuala Lumpur, Malaysia.

8. Gogus, M., Melek, B. A., Yilmaz, K. (2017). “Effect of Rack Angle of Tyrolean Type Intakes on Sediment Capture Efficiency”, 37th IAHR World Congress, Kuala Lumpur, Malaysia.

9. Yavuz C., Gokmener S., Yilmaz, K. (2018). “Trajectory Length Determination for Bottom Outlet of Inoren Regulator and HEPP”, 13th International Congress on Advances in Civil Engineering, Çeşme, Turkey.

10. Gogus M., Melek A.B., Yilmaz K. (2018). Numerical Validation of Optimum Rack Angle of Tyrolean Intakes to Increase Water Capture Efficiency. 3. International Conference on Civil and Environmental Engineering Conference E-Book Vol.2, p.20, Izmir, Turkey.

PROJECTS

2012-2013 Research Project: Beyhan 1 Barajı ve Hidroelektrik Enerji Santrali Su Alma Yapıları Hidrolik Model Çalışmaları

2011-2014 TÜBİTAK Research Project (111M377): Nehirlerde Köprü Yan Ayakları Sebebiyle Oluşan Daralmanın Oyulma Ve Akım Karakteristiklerine Etkisi Ve Oyulmayı Azaltıcı Düzeneklerin Araştırılması.

2015-2017 TÜBİTAK Research Project (214M028): Tirol Tipi Su Alma Yapılarında İletim Hattına En Az Katı Madde Yönlendirecek Düzenlemelerin Araştırılması

AWARDS

1. Water-Loss Reduction of Keçiören N8.1 Region (Ankara) Water Distribution Network by Means of Pressure Drop at Night, 2014, UNDP.

2. Evaporation Shield, 2014, UNPD.

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2018-2019	DHI- Turkey - Sumodel Mühendislik	Project Manager/Hydraulic Eng.
2019-	MOSTLAB Laboratory Services Inc.	Project Manager

FOREIGN LANGUAGES

Advanced English