HYDRAULIC CHARACTERISTICS OF TYROLEAN WEIRS HAVING STEEL RACKS AND CIRCULAR-PERFORATED ENTRY

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ABSTRACT

HYDRAULIC CHARACTERISTICS OF TYROLEAN WEIRS HAVING STEEL RACKS AND CIRCULAR-PERFORATED ENTRY

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Tyrolean type water-intake structures are commonly used on mountain rivers to supply water to hydropower stations. The amount of water to be diverted from the main channel is the major concern in these kind of structures and should not be less than the design discharge. In this study a physical model of a Tyrolean type water-intake structure was built at the laboratory and the diverted flow from the main channel through the intake structure having steel racks and perforated plates of different types were measured. The experiments were conducted in two stages. In the first stage the tests were carried out with only steel racks having three different bar openings and slopes, and in the second stage, perforated screens of three different circular openings and screen slopes were used. Applying dimensional analysis to the related parameters of the system the dimensionless terms were defined for the water capture efficiency and discharge coefficient of the system, and their variations with the relevant parameters were plotted. Using these diagrams one can determine the amount of water to be diverted by a Tyrolean weir of known geometry and main channel discharge.

Keywords: Tyrolean weirs, hydraulics, open channel flow, water capture efficiency, discharge coefficient, intake racks, perforated screens.

ÖZ

ÇUBUKLU VE DAİRESEL DELİKLİ IZGARASI OLAN TİROL TİPİ SAVAKLARIN HİDROLİK KARAKTERİSTİKLERİ

Şahiner, Halit

Yüksek Lisans, İnşaat Mühendisliği Bölümü

Tez Yöneticisi: Prof. Dr. Mustafa Göğüş

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Dağlık bölgelerdeki akarsular üzerine kurulan hidroelektrik santrellerde su alma yapıları için yaygın olarak tirol tipi regulatörler kullanılır. Hidrolik sisteme girecek olan su bu tip yapılarda büyük önem taşır ve sisteme girecek olan suyun tasarım debisinden küçük olmaması gerekmektedir. Bu çalışmada, Tirol tipi su alma yapısı laboratuvarda inşa edilmiştir ve ana kanaldan gelen su bu yapı üzerinde farklı özelliklerde, çubuklu ızgaralar ve dairesel açıklıklı levhalar kullanılarak ölçülmüştür. Deneyler iki aşamada yapılmıştır. İlk aşamada, sadece üç farklı eğime ve açıklığa sahip çubuklu ızgaralar, ve ikinci aşamada ise üç farklı eğim ve delik çapına sahip levhalar kullanılmıştır. Debi katsayısı ve sistemin ana kanaldan su alma kapasitesi için sistemin değişkenlerine boyut analizi uygulanarak boyutsuz terimler tanımlanmış ve ilgili grafikler çizilmiştir. Çizilen bu grafikler kullanılarak Tirol tipi savakla alınacak su miktarı, ana kanal debisi ve sistemin diğer boyutlarının verilmesi durumunda hesaplanabilir.

Anahtar kelimeler: Tirol tipi savaklar, hidrolik, açık kanal akımı, su alma verimliliği, debi katsayısı, su alma ızgaraları, dairesel delikli levhalar

To my parents

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First of all, I would like to express my sincere gratitude to Prof. Dr. Mustafa Göğüş, for his support, patience, encouragement and confidence on me from the very first day.

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a	:	Center distance between bars of the Tyrolean screen
A_{ro}	:	The net rack opening area per unit width of the rack
C_{d0}	:	Discharge coefficient for a horizontal screen
C_d	:	Discharge coefficient for an inclined Tyrolean screen
d	:	Circular diameter on Perforated plate
e	:	Clear distance between bars of the Tyrolean screen
$(F_r)_e$	:	Froude number based on bar spacing
$(F_r)_d$	:	Froude number based on perforated screen
g	:	Gravitational acceleration
h	:	Flow depth at just upstream of the Tyrolean screen
h_c , y_c	:	Critical flow depth at upstream of the Tyrolean screen
H_0	:	The energy head of the flow approaching the rack
H_c	:	Critical specific energy head of the flow over screen
L	:	Length of the Tyrolean screen
L_1	:	The distance of the point where the flow nappe crosses the axis of the Tyrolean weir
L_2	:	Total wetted rack length
$(q_w)_i$	:	Diverted unit discharge by the Tyrolean screen
$(q_w)_T$	:	Total unit discharge in the main channel
U_0	:	The average velocity of the flow approaching the rack
$(V_B)_n$	:	Velocity component of the flow perpendicular to the trash rack at the spacing between two rack bars
W	:	Width of the main channel
y_0	:	Normal flow depth in the main channel
$\propto$	:	Angle between the velocity vector V_B and the axis of the rack
θ	:	Angle of inclination of the screen
μ	:	Contraction coefficient
ρ_w	:	Density of water
c	:	Reduction factor
ω	:	Rack porosity
WCE	:	**W**ater **C**apture **E**fficiency

CHAPTER 1

INTRODUCTION

1.1 GENERAL

In the world, the most commonly used renewable energy source is hydropower. In the next 20 years, energy shortage will be a serious problem for Turkey according to the forecasts of the industrial improvement and increasing population. One of the most effective solutions of this problem is to increase the number of hydropower plants. In Turkey, all possible big dams are almost completed, however, when the total hydropower potential of the country is considered, it is seen that only a small percentage of it has been used. In the areas where the construction of the reservoirs are not possible, run-off river intakes are preferred.

One of the major problem of the run-off river power plants is the amount of the water to be diverted from the river for the power plant that should not be less than the design discharge, will be provided. Tyrolean weirs are known to be very suitable intake structures to divert required amount of water to the system with minimum amount of sediment carried by the flow. Figure 1.1 shows a typical Tyrolean weir with its important components.

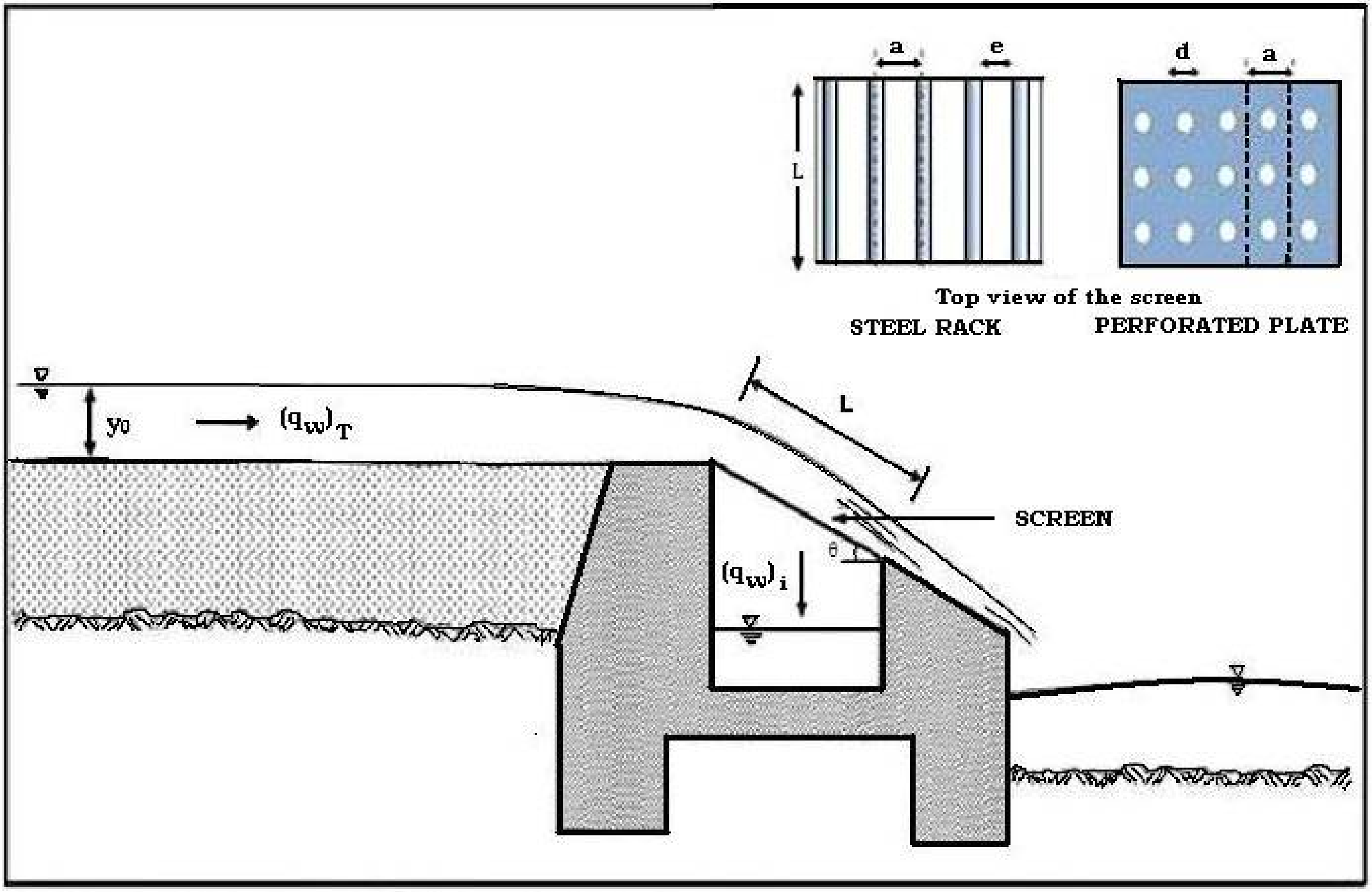

Figure 1.1 A typical Tyrolean weir and its screens

In Tyrolean weirs, water and some of the sediment carried by the river are diverted from the river through a screen into a collection channel that is commonly built by concrete on the river bed. From the collection channel water and sedimet flow by gravity into a sediment tank where all of the sediment in the flow is collected. The water intake screens are located over the collection channels at certain inclination in the direction of the tailwater to reduce the amount of sediment entry into the collection channel. The basic design variables for trash racks are the opening between the adjacent bars , e, for the circular-perforated screens are the diameter of the opening, d, and the center spacing “a” (Fig. 1.1). These values depend on the size of the material to be allowed to pass through the intake. Figure 1.2 shows some types of rack bars with different profiles. The rectangular racks are not recommended to be used for intake as they are easily and rapidly clogged by stones (Fig. 1.2a) The bulb-ended bars have better performance and are more rigid if required (Fig 1.2b). Finally the best shape is the round-head bars that prevent sediments from jamming and have better resistance against impact of stones because of higher moment of inertia (Fig. 1.2c).

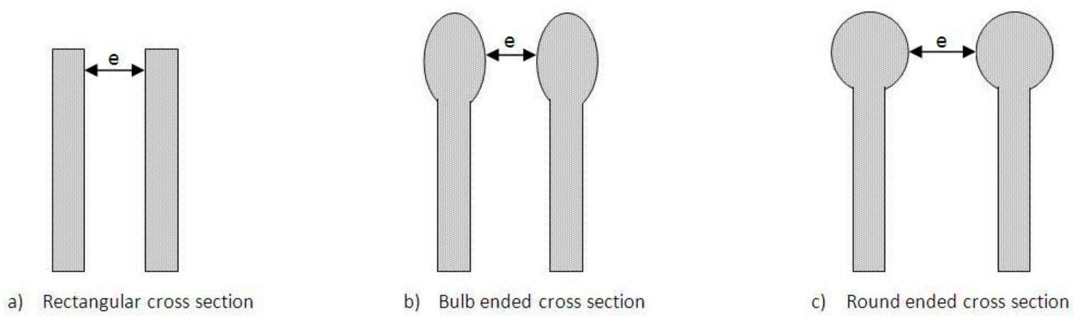

Figure 1.2 Types of rack bars with different profiles (after, Andaroodi M. 2005)

The purpose of this thesis was to investigate the relationship between the diverted flow and properties of the trash rack such as bar opening, e, bar length, L, and bar slope, θ, as well as the opening diameter of the circular-perforated screens, d. For this reason a series of experiments were performed in a hydraulic model of a Tyrolean weir with trash racks and circular-perforated screens of various properties.

In the next section the literature review conducted on the subject is given. The theoretical study is presented in Chapter II. The experimental setup and details of the experiments are explained in Chapter III. Analysis of the experimental data and discussion of the results are considered in Chapter IV. Conclusions and the further recommendations are given in Chapter V.

1.2 LITERATURE REVIEW

The following equation was derived by Frank for the trash rack length L in the direction of flow that is required to supply the unit discharge of $(q_w)_i$,

$$L = 2.561.\frac{(q_w)_i}{\lambda\sqrt{h}} \qquad (1.1)$$

where $\lambda = \psi.\mu\sqrt{2g\cos\theta}$; discharge coefficient,

$\psi = e/a$

e = clear distance between the trash rack bars,

a = distance between centers of the trash rack bars,

$\mu = 0.8052.\psi^{-0.16}.(a/h)^{0.13}$; contraction coefficient which is function of the shape of the trash rack and the flow depth over the trash rack and valid for trash rack bars having rectangular cross section,

g = gravitational acceleration,

h = flow depth at just upstream section of the trash rack taken as perpendicular to the trash rack, where $h = \chi . h_c$

$\chi =$ reduction factor and calculated from $2\cos\theta . \chi^3 - \chi^2 + 1 = 0$,

θ = angle of the trash rack inclination

$h_c = \sqrt[3]{{(q_w)_T}^2 / g}$; critical flow depth and $(q_w)_T$ is the discharge of the main channel (Huber, 2005)

The wetted rack length is calculated by Noseda's equation that is based on the assumption of the energy line, of the flow over the trash rack, is parallel to the trash rack,

$$L = 1.185 . \frac{H_c}{\mu_m \psi} \quad \text{...(1.2)}$$

where H_c is the specific energy head of the flow over the trash rack and $\mu_m = 1.22.\mu$ is suggested. This equation is only valid for horizontal racks. (Drobir et al. 1999).

A series of experiments were conducted on a Tyrolean weir model that was built to a scale of 1:10 in the hydraulic laboratory of the University of Technology, Vienna by Drobir in 1999. The wetted rack lengths were calculated for five different discharges [$(q_w)_T$ = 0.25, 0.50, 1.00, 1.50, 2.00 m^2/s] at four different rack inclination angles ranging from 0% to 30% and the width between the bars were 10.0 and 15.0 cm that circular cross section with 10.0 cm in diameter. Two different wetted rack lengths were measured during the experiments; the total wetted rack length, L_2, and the length , L_1, that was the distance of the point where the flow nappe crossed the axis of the Tyrolean weir (Figure 1.3).

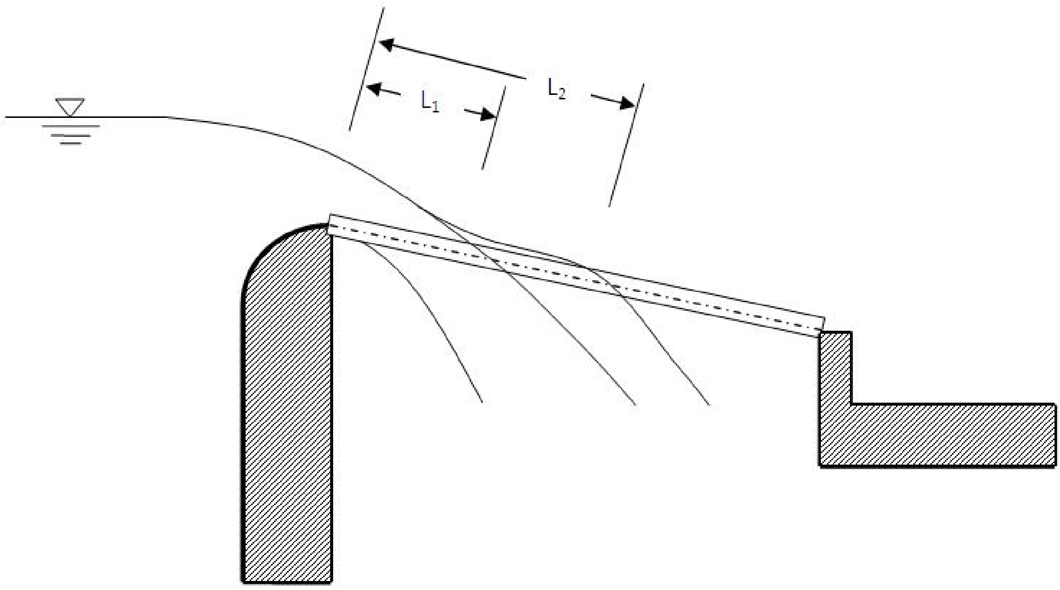

Figure 1.3 Definition sketch for wetted rack lengths L_1 and L_2 of a Tyrolean screen

Brunella, et al. (2003) conducted a series of experiments to show the effect of the rack porosity, the bottom slope and the the rack geometry on the performance of the bottom rack intake. They used a rectangular channel which was 0.5 m wide and 7.0 m long with circular bars of 12 and 6 mm in diameter each 0.60 m and 0.45 m long having a clear spacing of 6 and 3 mm and the bottom rack had the angles of 0, 7, 19, 28, 35, 39, 44 and 51°. In these experiments, the water surface profiles and velocity distributions were measured and it was stated that for large and small bottom slopes nearly the same free surface profiles were observed. An expression for relative intake rack was derived by Brunella et al. using their own data and some other data from the literature for obtained from the tests of circular racks and ovoid profiles practically 100% intake discharge $[(q_w)_i = (q_w)_T)]$

$$C_d \omega (L_2/H_c) = 0.83 \qquad (1.3)$$

where C_d is the discharge coefficient and was found varing between 0.87 and 1.10 as a function of ω, ω is the rack porosity corresponding to the ratio of the total net spacing between the rack bars to the main channel width, L_2 is the wetted rack length and H_c is the critic energy head. It was also stated that the value of C_d could attain values higher that one as a consequence of the Coando effect arising when the bar clearance is small enough (Hager and Minor, 2003).

Subramanya gave the following expression for C_d for subcritical approach flow and supercritical flow over the racks of rounded bars

$$C_d = 0.53 + 0.4 \log D/e - 0.61 \tan\theta \quad (1.4)$$

where D is the diameter of rack bars, e is the spacing of rack bars and θ is the inclination angle of the rack bars (Ahmed and Mittal, 2006)

The discharge characteristics of flat bars were experimentally investigated by Ghosh and Ahmad. As a result of their study it was stated that the specific energy over the racks was almost constant. C_d values for flat bars were also compared with C_d values calculated by Subramanya's relationship, i.e, Eq.(1.4). From this comparison it was concluded that two sets of C_d values are different and Subramanya's relationship overestimates the values of C_d (Ahmad and Mittal, 2006).

Ghosh and Ahmad proposed the following equation of C_d for flat bars

$$C_d = 0.1296(t/e) - 0.4284(\tan\theta)^2 + 0.1764 \quad (1.5)$$

where t is the thickness of the bars. The value of C_d for flat bars are predicted within ± %10 error by Equation 1.5. For the design of flat bars Equation 1.5 is proposed on the basis of limited data range. More experimental and field data are required to propose a better equation (Ahmad and Mittal, 2006).

Kamanbedast and Bejestan (2008) conducted experimental tests in a flume of 60 cm wide, 8 m long and 60 cm high to explore the effects of screen slope and area opening of the screen on the amount of diverted discharge.

Six models of bottom racks with three different percent of area opening equal to 30, 35 and 40 % using two different bars having diameters of 6 and 8 mm were tested. Each model was tested under four different slopes; 10, 20, 30 and 40% and five different flow discharges. For constant bar length which was not given it is stated that the ratio of the diverted discharge to the total incoming discharge is function of only the area spacing of the bars and the rack slope. From the results of the experimental data corresponding to only one discharge tested, 24.5 lt/s, one bar diameter, 8 mm, three rack slopes and four area spacing it was concluded that as the slope of the rack increases, the discharge ratio increases. The discharge ratio reaches to a maximum value of 0.8 when the rack area opening is 40% and the slope is 30 %. However as it was expected these values are smaller when the sediment is moving through the rack. The discharge ratio is about 10 % less when the sediment is presented because of clogging the opening area.

To investigate the hydraulic characteristics of Tyrolean weirs Yılmaz(2010) conducted a series of experiments at the Hydromechanics Laboratory in a model 7.0 m long and 1.98 m wide. The Tyrolean screens were made of metal bars of circular cross section that were 1 cm in diameter. The experiments were conducted with and without sediments and were repeated for three clear distances between bars; 3 mm, 6 mm and 10 mm, and three angles of rack inclination; 14.5°, 9.6° and 4.8°. Variations of the discharge coefficient C_d, the ratio of the diverted discharge to the total water discharge, $[(q_w)_i/(q_w)_T]$ and the dimensionless wetted rack length , L_2/e with relevant dimensionless parameters were plotted. From these figures for a given main channel discharge one can easily determine the amount of the diverted discharge for a Tyrolean screen of known rack length, rack inclination and bar opening within the limits of parameters tested in that study.

CHAPTER 2

THEORETICAL STUDY

2.1 INTRODUCTION

The theoretical studies related to the performance of the trash rack and the perforated screen of a Tyrolean weir were presented in this chapter. An expression for the discharge coefficient was derived in the first part and in the following section the relationships for the water capture efficiency and wetted rack length of the trash rack were presented.

2.2 DERIVATION OF THE DISCHARGE COEFFICIENT FOR TYROLEAN WEIRS

According to the definition sketch given in Figure 2.1 the energy equation can be written for a streamline passing from points A and B assuming that at point A the flow is critical, point B is located at the spacing between two adjacent rack bars and the energy loss is negligible.

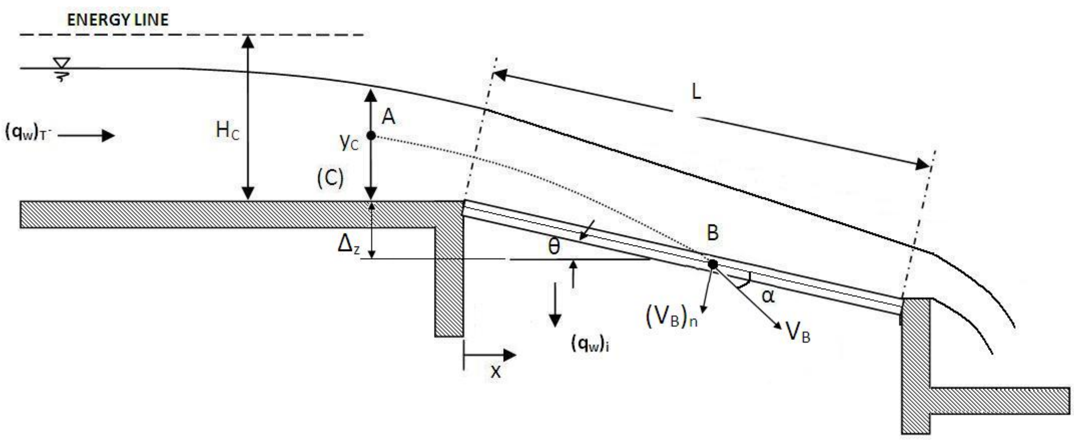

Figure 2.1 Definition sketch for a Tyrolean weir

$$H_c = \frac{V_B^{\,2}}{2g} - \Delta z \quad \text{.......(2.1)}$$

At point B , $(V_B)_n$ is the component of the velocity that is perpendicular to the trash rack and Eq. 2.1 can be written as

$$(V_B)_n = V_B.\sin\alpha = (\sqrt{2g(H_c + \Delta z)})\sin\alpha = \sin\alpha\sqrt{2gH_c(1+\frac{\Delta z}{H_c})} \quad \text{.......(2.2)}$$

Assuming that $\Delta z / H_c << 1$ especially for small values of θ the velocity $(V_B)_n$ can be written as

$$(V_B)_n \cong \sin\alpha\sqrt{2gH_c} \quad \text{.......(2.3)}$$

The unit diverted discharge by the bottom rack intake $(q_w)_i$, can be expressed as

$$(q_w)_i = A_{r0}(V_B)_n = A_{r0}\sin\alpha\sqrt{2gH_c} \quad \text{.......(2.4)}$$

where A_{ro} is the net rack opening area per unit width of the trash rack.

Equation 2.4 can also be written as

$$(q_w)_i = C_d A_{r0} \sqrt{2gH_c} \qquad (2.5)$$

where C_d is the discharge coefficient and it accounts for all of the assumptions made in the derivation of $(q_w)_i$ such as, hydrostatic pressure distribution, negligible energy loss, negligible effect of Δz on the velocity component $(V_B)_m$, …etc.

It should be emphasized that Eq. 2.5 is applicable if the flow of approach passes over the total length of the trash rack. This condition is satisfied if the total length of the trash rack to be used, L, is less than or equal to the length L_2 which is the essential length of the trash rack to divert all of the incoming discharge.

For a Tyrolean screen instead of a trash rack of steel bars if a perforated screen of circular openings having the net opening area as the trash rack for the unit width of the main channel is used, Eq.(2.5) can be used to determine the C_d value of the perforated screen.

2.3 WATER CAPTURE EFFICIENCY AND WETTED RACK LENGTH OF TYROLEAN WEIRS

For a Tyrolean weir of which the hydraulic and geometric parameters are described in Figure 2.1 the following equation for the diverted discharge $(q_w)_i$ through the bottom racks can be written as a function of the appropriate variables, assuming that the screen comprises the circular bars and surface tension, effects of viscosity and fluid compressibility are negligible.

$$(q_w)_i = f\left[(q_w)_T, e, a, L, \theta, g, \rho_w\right] \quad \text{..(2.6)}$$

where $(q_w)_T$ is the total water discharge of the flow approaching the rack per unit channel width, e is the clear distance between bars, a is the distance between centers of the two adjacent trash rack bars, L is the rack length, θ is the angle of inclination of the rack and g is the gravitational acceleration, ρ_w is the density of water. Selecting $(q_w)_T$, e and ρ_w as the repeating variables and applying the Buckingham's π theorem, the following relationship is obtained

$$\frac{(q_w)_i}{(q_w)_T} = f_1\left[\frac{(q_w)_T^2}{e^3 g}, \frac{L}{e}, \frac{a}{e}, \theta\right] \quad \text{..(2.7)}$$

where $[(q_w)_i/(q_w)_T]$ can be named as "water capture efficiency" of the Tyrolean weir and $(F_r)_e^2 = \frac{(q_w)_T^2}{e^3 g}$ square of the Froude number based on bar opening. Equation 2.7 can also be written as

$$\frac{(q_w)_i}{(q_w)_T} = f_1\left[(F_r)_e, \frac{L}{e}, \frac{a}{e}, \theta\right] \quad \text{..(2.8)}$$

In a similar way to that explained above, one can write the equations for the discharge coefficient C_d given in Equation 2.5 and the wetted rack length L_2 in terms of the relevant parameters as follows

$$C_d = f_3\left[(q_w)_T, e, a, L, \theta, g, \rho_w\right] \quad \text{..(2.9)}$$

and

$$L_2 = f_4\left[(q_w)_T, e, a, L, \theta, g, \rho_w\right] \quad \text{..(2.10)}$$

The application of the Buckingham's π theorem to the above equations yields

$$C_d = f_5\left[(F_r)_e, \frac{L}{e}, \frac{a}{e}, \theta\right] \qquad (2.11)$$

and

$$\frac{L_2}{e} = f_6\left[(F_r)_e, \frac{a}{e}, \theta\right] \qquad (2.12)$$

In the case of perforated screens are used instead of rack bars, the Equation (2.6) can be written as

$$(q_w)_i = f\left[(q_w)_T, d, a, L, \theta, g, \rho_w\right] \qquad (2.13)$$

where d is the diameter of the circular opening of the perforated screen and a is the distance centering the circular opening as shown in Figure 1.1. Equation 2.8 and 2.11 for $[(q_w)_i/(q_w)_T]$ and C_d, respectively, can be given as follows for perforated screens.

$$\frac{(q_w)_i}{(q_w)_T} = f\left[(Fr)_d, \frac{L}{d}, \frac{d}{a}, \theta\right] \qquad (2.14)$$

and

$$C_d = f\left[(Fr)_d, \frac{L}{d}, \frac{d}{a}, \theta\right] \qquad (2.15)$$

where. $(F_r)_d = \left[{(q_w)_T}^2 \big/ (d^3 g)\right]^{1/2}$

In Chapter 4, the variation of C_d, $\frac{(q_w)_i}{(q_w)_T}$ and $\frac{L_s}{s}$ with related dimensionless terms given in Equations 2.8, 2.11, 2.12, 2.14 and 2.15 will be presented.

CHAPTER 3

EXPERIMENTAL SETUP AND PROCEDURE

3.1 EXPERIMENTAL SETUP

In order to investigate the hydraulic characteristics of Tyrolean weirs of trash racks and perforated screens a physical model was constructed at the laboratory. The model includes a main and side channel, a water intake pipe, water intake screen and a reservoir at the head of the main channel (Figures 3.1-3.5). Water to the model is supplied from a large constant head reservoir by a pipe of 30 cm in diameter and is controlled with a mechanical valve. The amount of the discharge supplied to the system was evaluated with an ultrasonic flowmeter that was located on the water intake pipe. Water coming from the intake pipe is directed to a pond at the head of the main channel that is in 1.5 m height, 2.0 m length and width. Water from this pond was supplied to the main channel after having it passed through a filter layer formed by bricks to reduce the turbulence of the flow. To determine the water depth in the main channel, at location about 1 meter downstream from the inlet section of the main channels a manometer was placed on the side wall of the model. The main channels length, width and slope are 7.0 m , 1.98 m and 0.001, respectively.

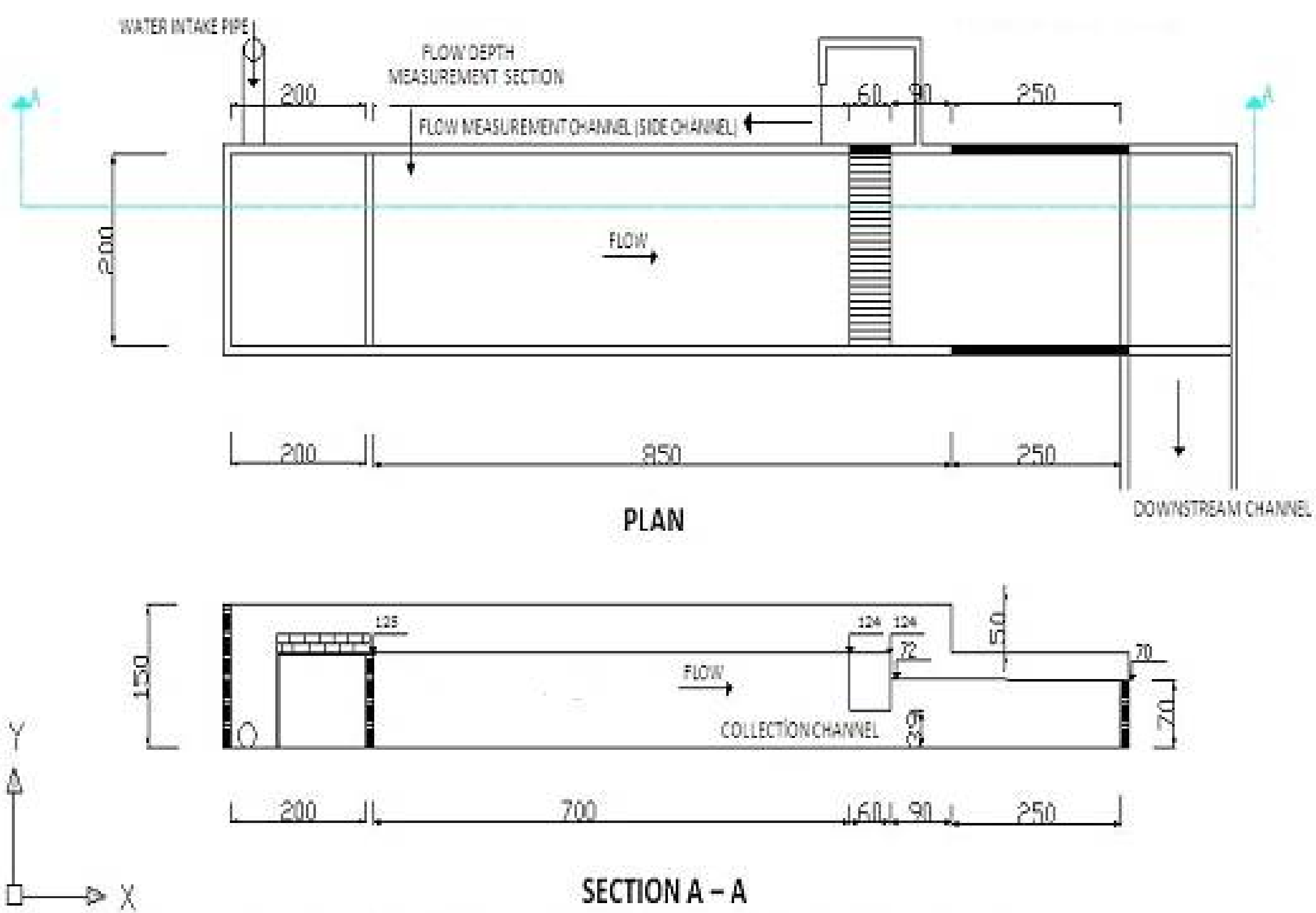

Figure 3.1 Plan and section views of the Tyrolean weir model constructed (the lengths are in cm)

Figure 3.2 General view of the Tyrolean weir model

Figure 3.3 Photograph of the main channel taken from downstream

Figure 3.4 Side view of the trash rack and the collection channel

Figure 3.5 Side channel with V-notch sharp-crested weir at downstream end

The Tyrolean screen was placed at the downstream end of the main channel. The elevation difference between upstream and downstream sections of the screen is 52 cm. The experiments were conducted with two different types of screens. One of the screens was made of circular metal bars 10 mm in diameter and other screen was made of perforated metal panel 2 mm thick. The experiments were duplicated for three different screen slopes (θ_1 = 37.0°, θ_2 = 32.8° and θ_3 = 27.8°) with metal bars having various clear distance between the bars (e_1 = 3 mm, e_2 = 6 mm and e_3 = 10 mm), and perforated metal panels having circular openings with three different diameters (d_1 = 3 mm, d_2 = 6 mm and d_3 = 10 mm). The circular openings were located on the screens in such a way that the net area of the openings of d_1 = 3 mm, d_2 = 6 mm and d_3 = 10 mm over the total area of the screens would be equal to the net opening area of the screens of racks of e_1 = 3 mm, e_2 = 6 mm and e_3 = 10 mm, respectively. Figures 3.6-3.8 show the photographs of the screens used in the experiments. At the bottom of the Tyrolean screen, there is a collection channel which is 0.60 m in width, 0.33 m in height, 1.98 m in length and 0.01 slope. Water and sediment coming into the intake structure are directed to the sediment trap reservoir by means of the collection channel. To keep the incoming sediment within this reservoir there is a 0.20 m high portable barrier at the downstream end of the reservoir. The water coming from the collection channel flows through the side channel which is 0.70 m in width and 6.5 m in length.

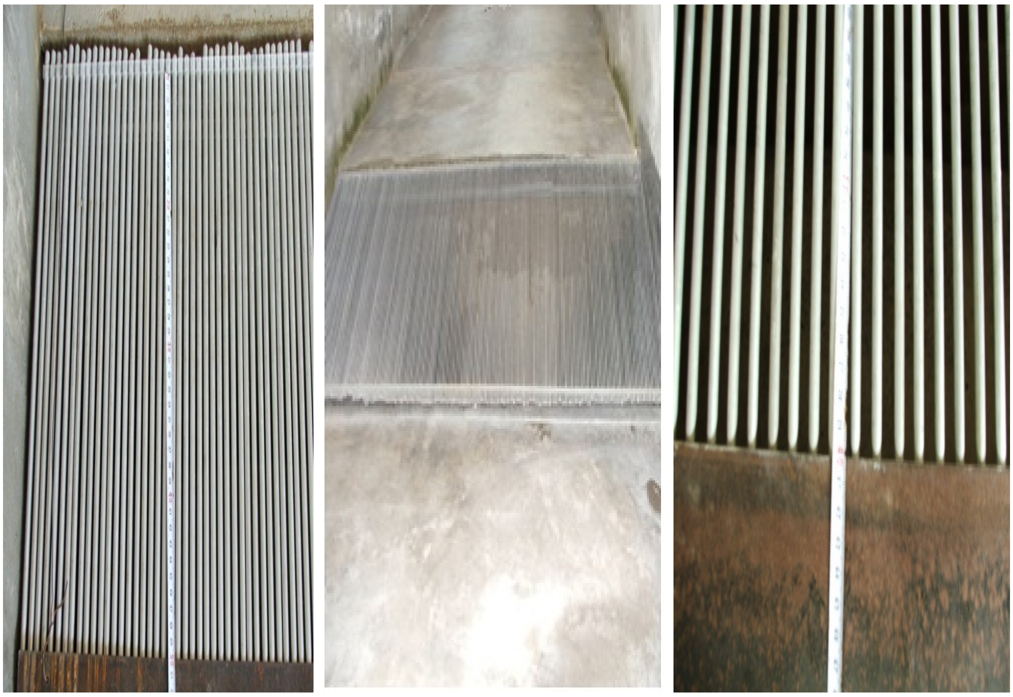

Figure 3.6 Tyrolean screens with e = 3 mm, 6 mm and 10 mm clear distances between bars, respectively

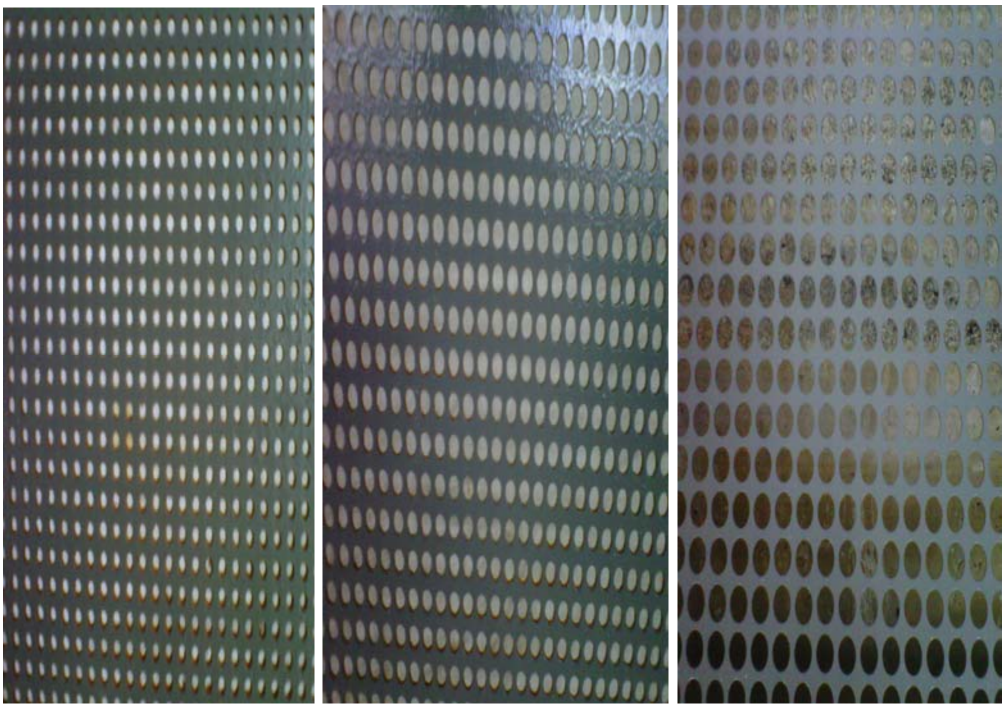

Figure 3.7 Tyrolean screens with d = 3 mm, 6 mm and 10 mm clear circular diameters on perforated plates, respectively

3.2 EXPERIMENTAL PROCEDURE

3.2.1 Discharge Measurements

A set of experiments was performed to find the discharge calibration curves of the main and side channel. Before placing the screen in its place, small amount of water was given to the system, and after waiting for about 6-10 minutes the flow depths at the upstream section of the main channel and at the downstream section of the side channel were recorded. Then the discharge was increased gradually with the valve at the end of the intake pipe. The water which was directly coming from the intake pipe, first collected in the collection channel then passed through the side channel. After having the flow stabilized in the side channel, the depth measurements were performed at about 1.50 m upstream from the V-notch weir located at the downstream end of the side channel. The discharge of the main channel was measured directly with the ultrasonic flow meter located on the intake pipe and then correlated with the measured upstream flow depth (Figure 3.8). The discharge of the side channel was taken from the records of the acoustic flow meter and then correlated with the head measurements recorded from the side channel (Figure 3.9).

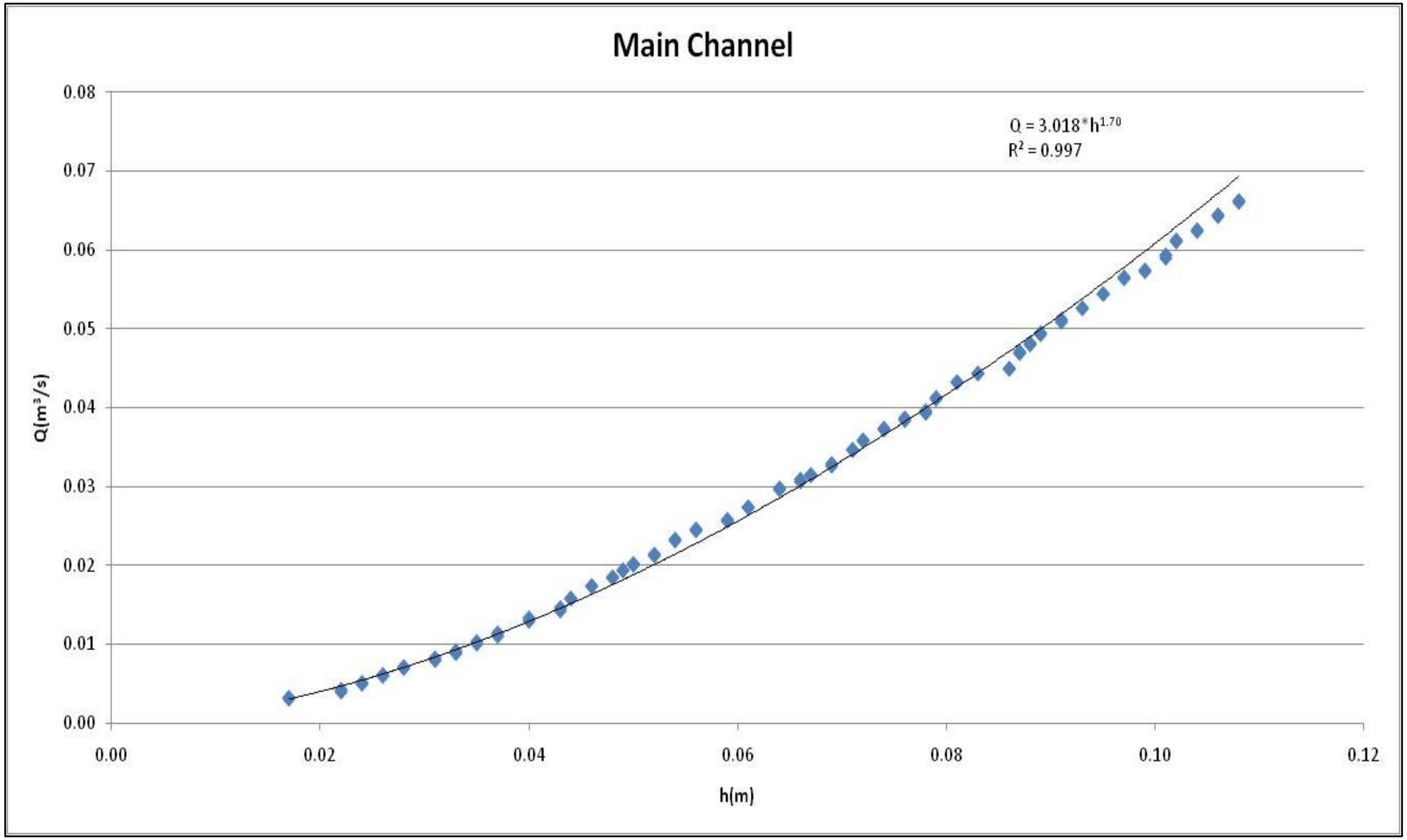

Figure 3.8 Discharge rating curve for the main channel

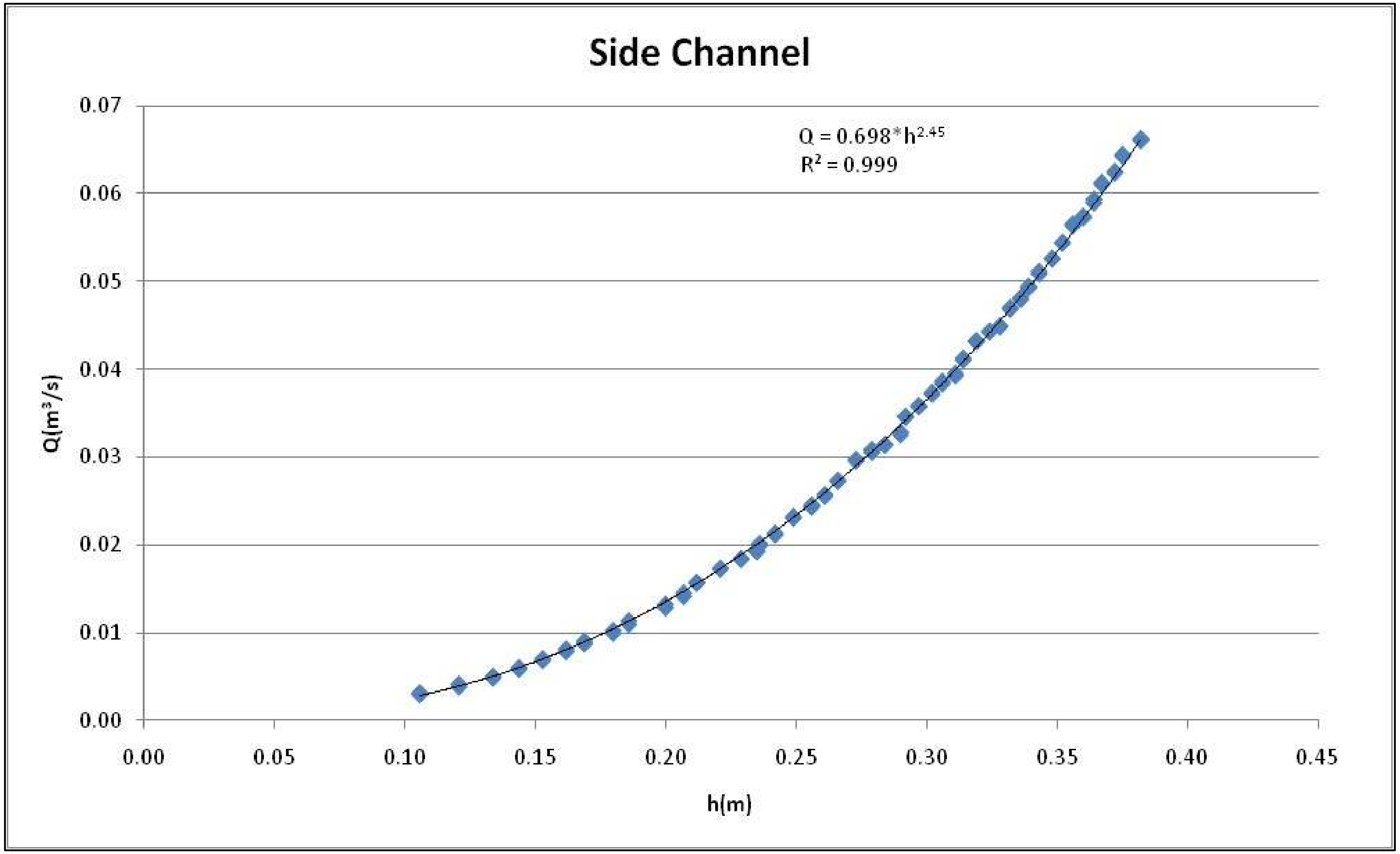

Figure 3.9 Discharge rating curve for the side channel

3.2.2 Measurements of the Wetted Rack Lengths

For measurements of the wetted rack lengths, the experiments were conducted by opening the discharge valve slowly until the depth of the flow at the upstream of the main channel was kepth at about 3.0 cm.When the water level was stabled, two lengths, L_1 and L_2, at 8 different bars were measured and their mean values were determined(Figure 1.3). At the point where the surface of the water nape crossed the axis of the rack bar the length L_1 was read. At the point where the discharge eventually came off the bar, the length L_2 was read (Drobir, et al. 1999). The maximum variation between these measured lengths along 8 bars found to be always less than 1.5 cm. These measured L_2 values were used in the analysis presented in Appendix A. Similar measurements were done for increased discharges in the main channel corresponding to the flow depths of 4 cm, 5 cm, ... up to 13 cm at the flow measurement section of the main channel. These measurements were done at each angle of rack inclination (θ_1 = 37.0°, θ_2 = 32.8° and θ_3 = 28.8°) for each clear distances between bars (e_1 = 3 mm, e_2 = 6 mm and e_3 = 10 mm). Similar measurements for perforated screens were not done.

3.2.3 Measurements of the Water Capture Efficiencies

The purpose of the experiments was to understand the water capture efficiencies, $[(Q_W)_1/(Q_W)_T]$, of the given Tyrolean screen lengths L. The surface area of the screens to be tested were covered at desired lengths with a thin steel plate from downstream to upstream to obtain the desired partial openings. For the Tyrolean screen with 3 mm clear distance between bars, the first opening was 5 cm. After placing the screen and the steel plate, the valve was opened to give the system a discharge corresponding to 3 cm flow depth in the main channel. Using the manometer readings in the main channel and side channel the total discharge and the discharge of the side channel respectively were calculated by means of the rating curves derived earlier. The manometer readings were recorded for each 1 cm increment in the flow depth at the main channel until 13 cm flow depth was reached. After completing the experiment of the initial screen opening, the screen opening was increased to 10 cm. The experiments were repeated with 5 cm increments in the screen opening until the the total discharge corresponds to 13 cm flow depth in the main channel was diverted by the Tyrolean screen. The experimental procedure was similar for each screen having different angle of inclinations (θ_1 = 37.0°, θ_2 = 32.8° and θ_3 = 28.8°) clear distance between bars (e_1 = 3 mm, e_2 = 6 mm and e_3 = 10 mm) and perforated screens (d_1 = 3 mm, d_2 = 6 mm and d_3 = 10 mm). All of the measured quantities were presented in Appendix A and B.

3.2.4 Uncertainty Analysis

The manometers placed at the channels to measure the flow depths are in mm precision. By considering the minimum and maximum total discharges measured in the side channel and main channel as; 1.98 x 2.85 = 5.64 lt/s and 1.98 x 33.58 = 66.49 lt/s for the side channel and 1.98 x 5.14 = 10.18 lt/s and 1.98 x 41.40 = 81.97 lt/s for the main channel, one can state that the maximum possible errors made in the measurement of these discharges due to 1 mm misreading of the flow depths are 1.72% and 0.6% for the side channel and 4.71% and 1.41 % for the main channel for minimum and maximum measured discharges, respectively.

CHAPTER 4

ANALYSIS OF THE EXPERIMENTAL DATA AND DISCUSSION OF THE RESULTS

4.1 INTRODUCTION

The analysis of the data of discharge coefficient, water capture efficiency and wetted rack length obtained from the experiments performed in this study were presented in this chapter.

4.2 STUDIES RELATED TO TYROLEAN SCREENS OF STEEL RACKS

In this section the results of the experimental studies conducted on the Tyrolean screens of steel bars are presented.

4.2.1 Relationship Between the Discharge Coefficient C_d and the Related Dimensionless Parameters for Screens of Steel Racks

The relationship between C_d and the relevant dimensionless parameters are given by Equation 2.11. Figures 4.1-4.9 show the variation of C_d with $(F_r)_e$ and L/e for each screen type tested. Except the first two curves connecting the data of the two small L/e values laying on top of the figures, almost in each figure it is seen that the general trend of the data points for a given

L/e is the same; as $(F_r)_e$ increases C_d values gradually increase and attain maximum values at the largest $(Fr)_e$. Only the first two curves show slightly different trends. C_d values of these curves first rapidly increase and attain maximum C_d values and then either decrease with increasing $(Fr)_e$ or follow a horizontal trend. Regardless of the screen type and slope tested, the maximum C_d values are obtained almost all the time at these small L/e values. It can be seen from the figures that as L/e decreases, C_d values increase for a given $(F_r)_e$. It can be concluded from the comparison of the related figures that if the angle of inclination of a selected screen increases while keeping $(F_r)_e$ and L/e values constant, C_d value slightly decreases at small values of L/e while almost remains the same at larger values of L/e. If the bar spacing of a screen of given θ increases, C_d values decrease for constant values of $(F_r)_e$ and L/e. Finally it can be concluded that the screens having the smallest L/e gives the largest C_d values almost for the range of $(Fr)_e$ tested regardless of the rack inclination and spacing between the rack bars.

The similar results were obtained by Yılmaz (2010) for the variation of C_d with related dimensionless parameters, for the screen of having the slopes of θ = 14.5°, 9.6° and 4.8°, and the rack openings of e = 3 mm, e = 6 mm and 10 mm.

For a screen of known slope θ, rack opening e, and rack length L and given main channel discharge $(q_w)_T$ one can easily compute the diverted discharge $(q_w)_i$ from the main channel after determining the value of C_d from one of the relevant figures and then substituting its value in Equation 2.5.

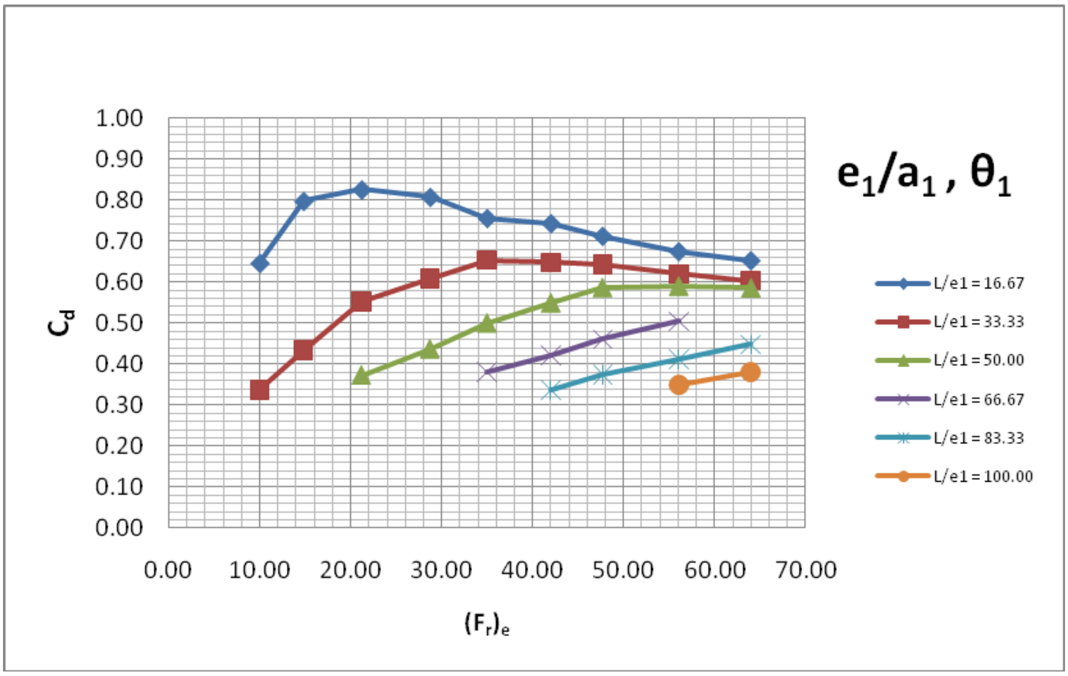

Figure 4.1 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_1/a_1 = 0.23 and θ_1 = 37.0°

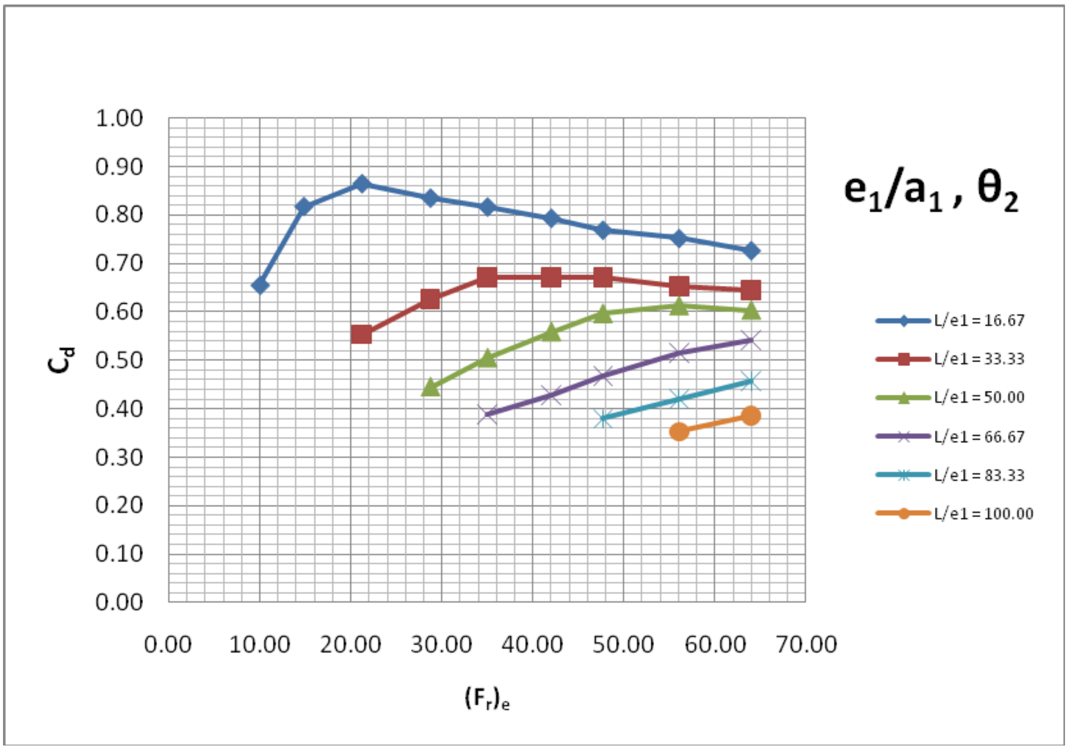

Figure 4.2 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_1/a_1 = 0.23 and θ_2 = 32.8°

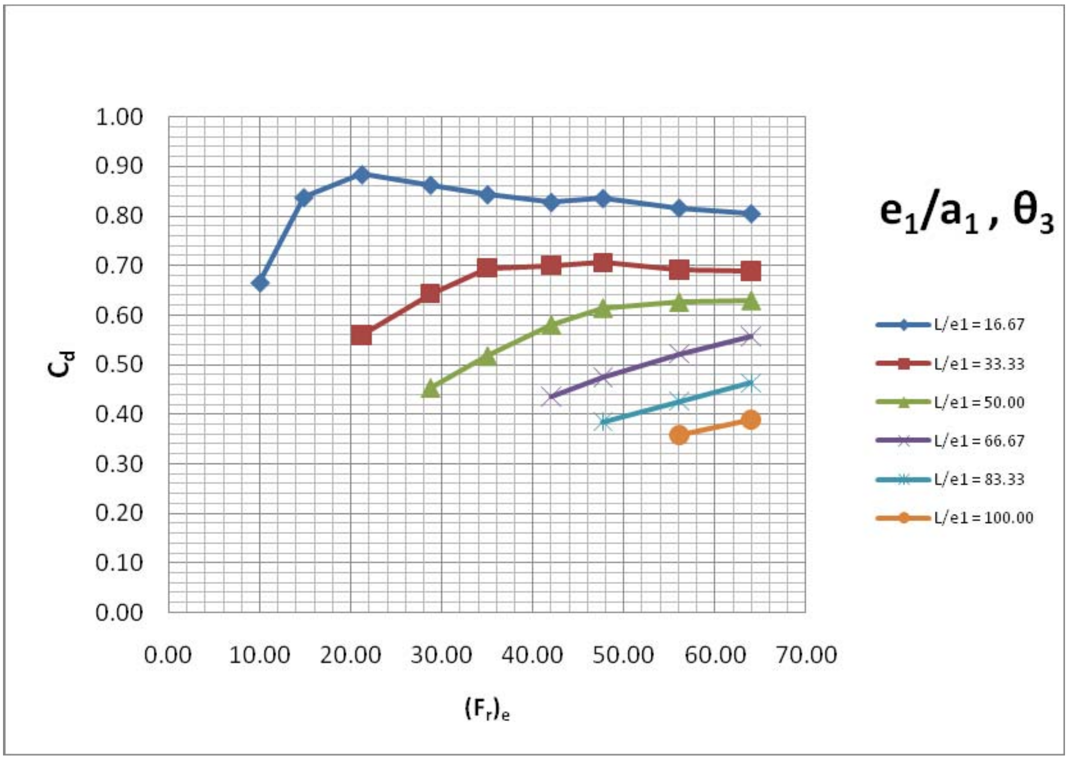

Figure 4.3 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_1/a_1 = 0.23 and θ_3 = 27.8°

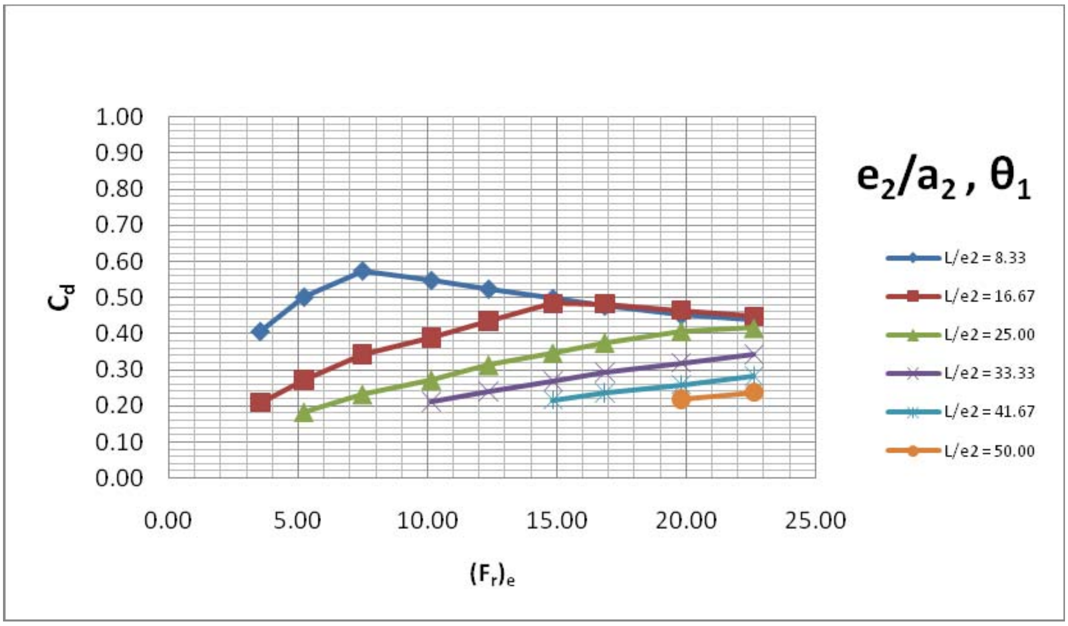

Figure 4.4 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_2/a_2 = 0.375 and θ_1 = 37.0°

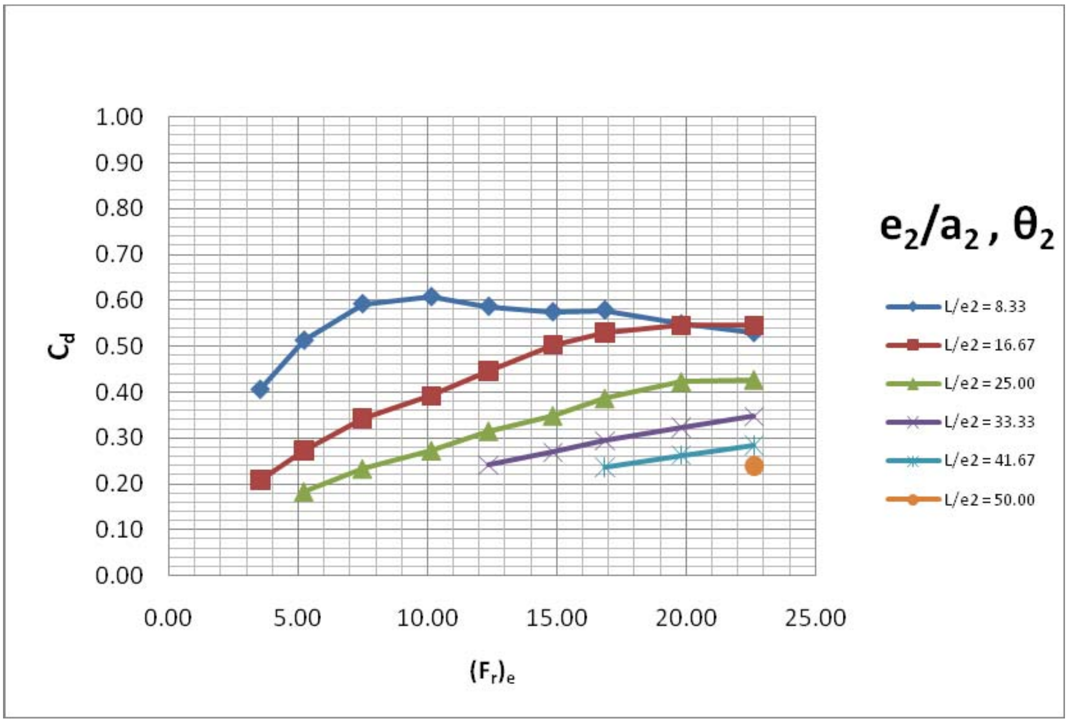

Figure 4.5 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_2/a_2 = 0.375 and θ_2 = 32.8°

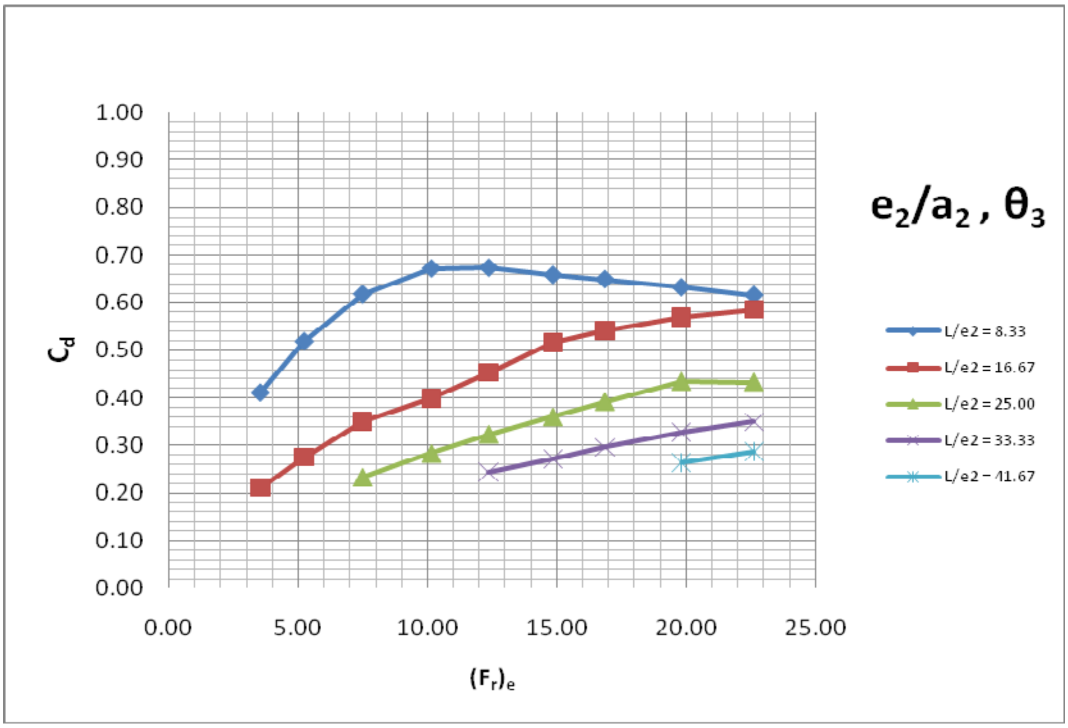

Figure 4.6 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_2/a_2 = 0.375 and θ_3 = 27.8°

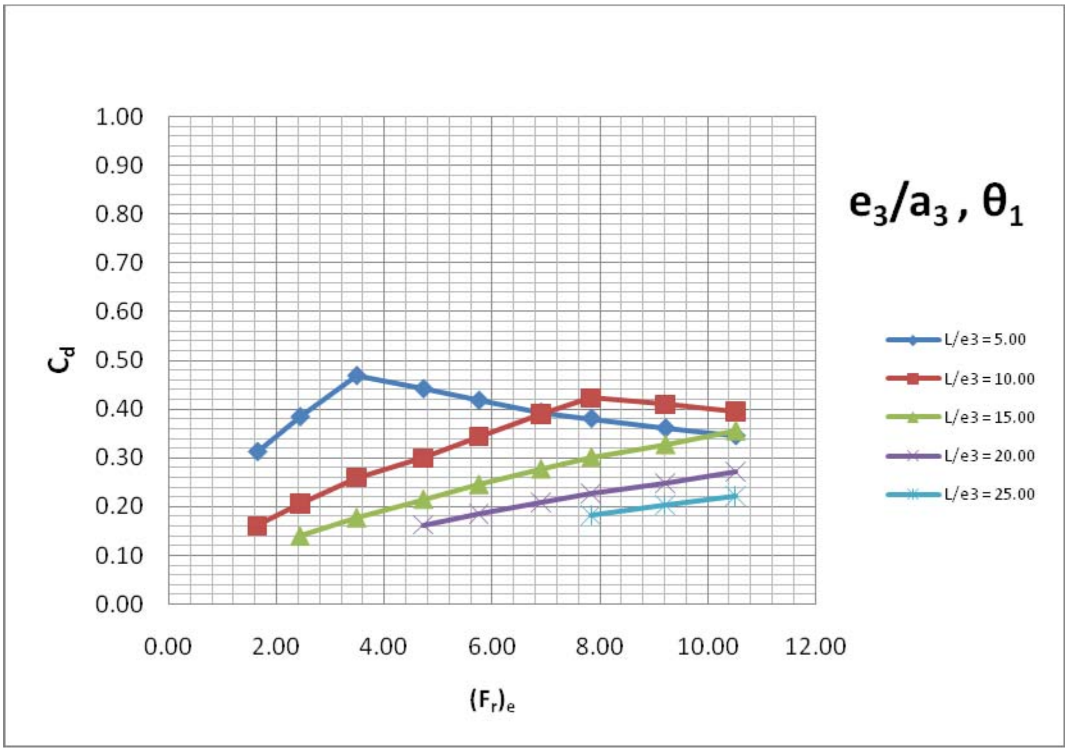

Figure 4.7 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_3/a_3 = 0.5 and θ_1 = 37.0°

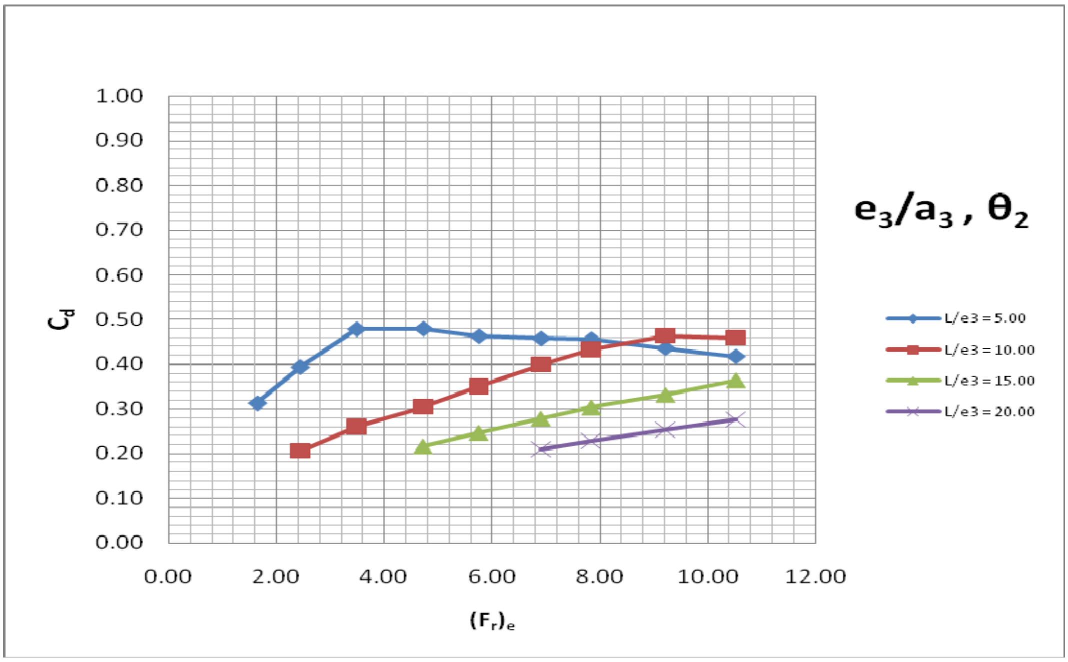

Figure 4.8 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_3/a_3 = 0.5 and θ_2 = 32.8°

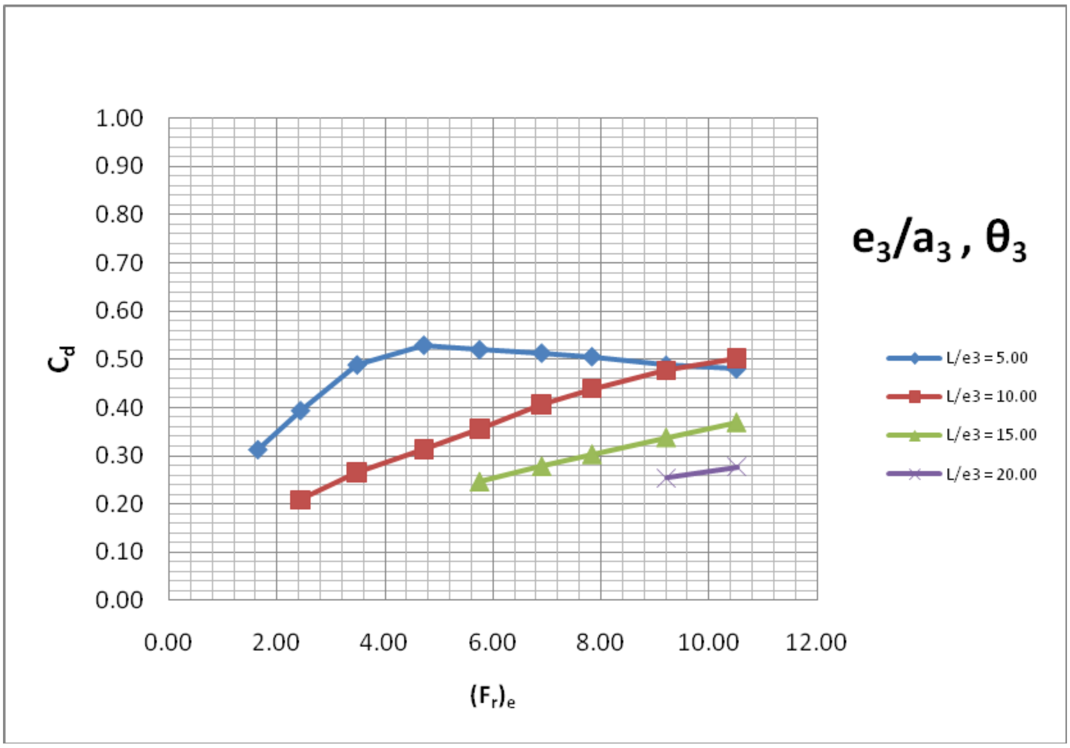

Figure 4.9 Variation of C_d with $(F_r)_e$ for the Tyrolean screen of e_3/a_3 = 0.5 and θ_3 = 27.8°

4.2.2 Relationship Between the Water Capture Efficiency (WCE) and the Related Dimensionless Parameters for Steel Racks

A relationship for the water capture efficiency of a Tyrolean screen is expressed with Equation 2.8 and the data of the related parameters for each experimental setup tested were plotted and presented in Figures 4.10-4.18. All of these figures show that the WCE depends on L/e and $(F_r)_e$ for a setup of known e/a and θ. For a screen of given slope and L/e the WCE value decreases with increasing $(F_r)_e$. As the value of L/e decreases, the dependency of the WCE on $(Fr)_e$ decreases and becomes almost negligible and approaches to the value of 1.0 for L/e values greater than about 83. As for the effect of rack inclination on the WCE it can be stated that with increasing θ, WCE decreases for a screen of given L/e and $(Fr)_e$.

When the bar spacing of the screen is increased while keeping the screen inclination and bar length constant, from e_1 to e_2 or from e_2 to e_3, the figures reveal that $(Fr)_e$ values are strongly affected and reduced for a given main channel discharge, and this change in the value of e results in higher

WCE values. The similar results were obtained by Yılmaz (2010) for the variation of WCE with the related dimensionless parameters for the screens having the slopes of θ = 14.5°, 9.6° and 4.8° and the rack openings of e =3 mm, 6 mm and 10 mm. Referring to Fig. 4.10-4.18 the WCE values of a screen of known properties; e/a, θ, (Fr)e and L/e, can be determined as long as these stated parameters are within the values tested in this study.

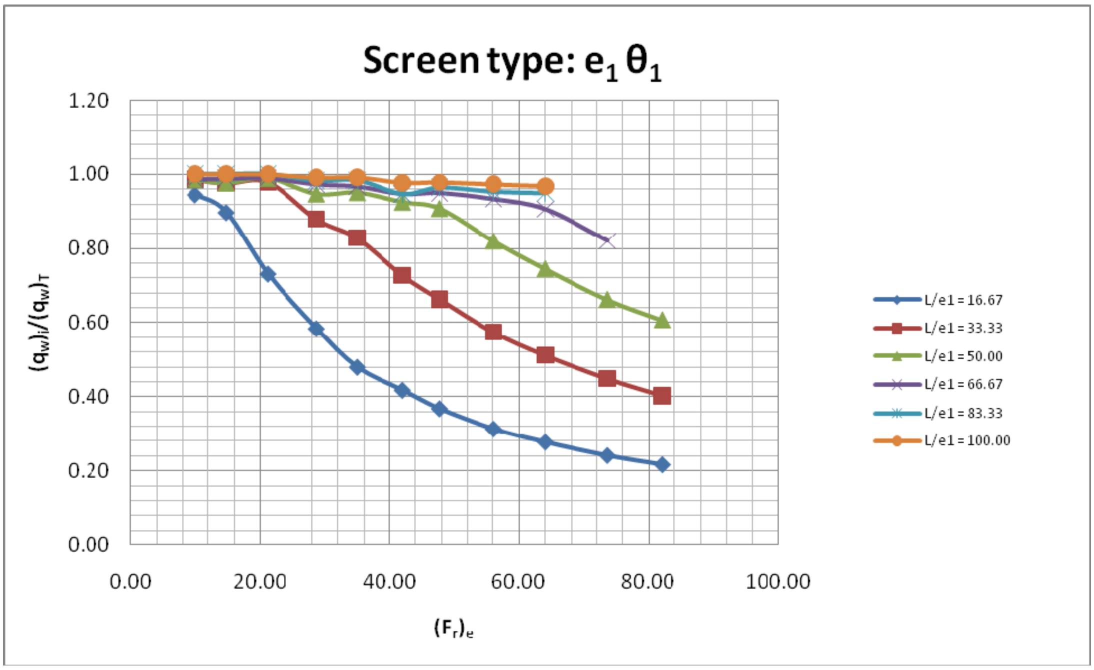

Figure 4.10 Water capture efficiencies for Tyrolean screen of e_1/a_1 = 0.23 and θ_1 = 37.0°

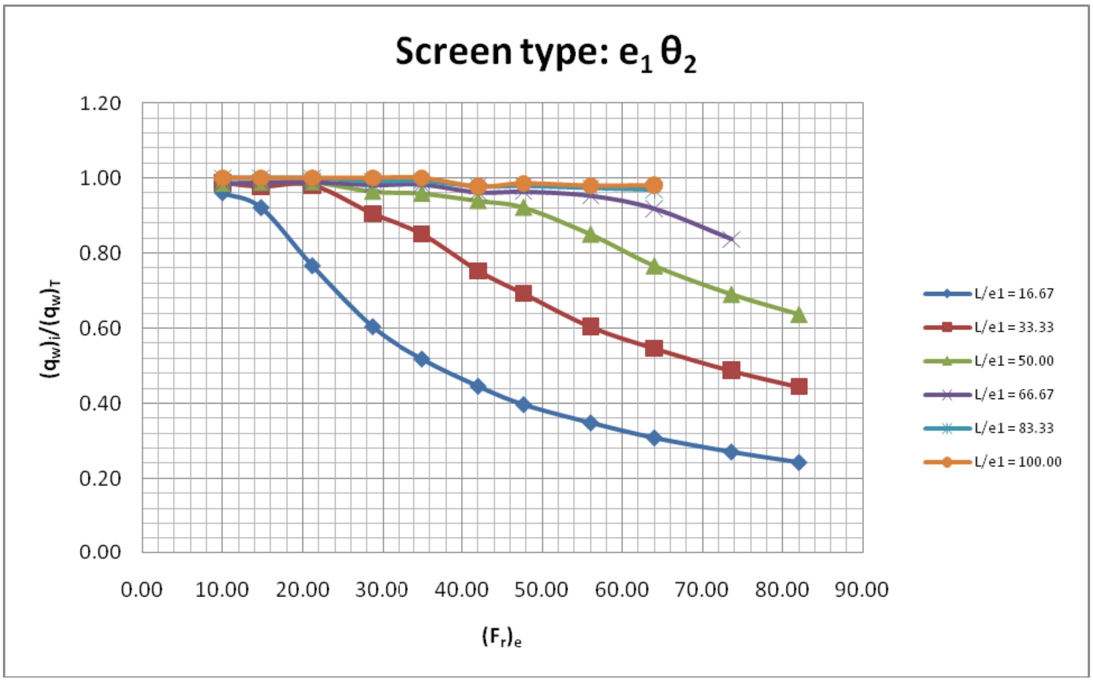

Figure 4.11 Water capture efficiencies for Tyrolean screen of e_1/a_1 = 0.23 and θ_2 = 32.8°

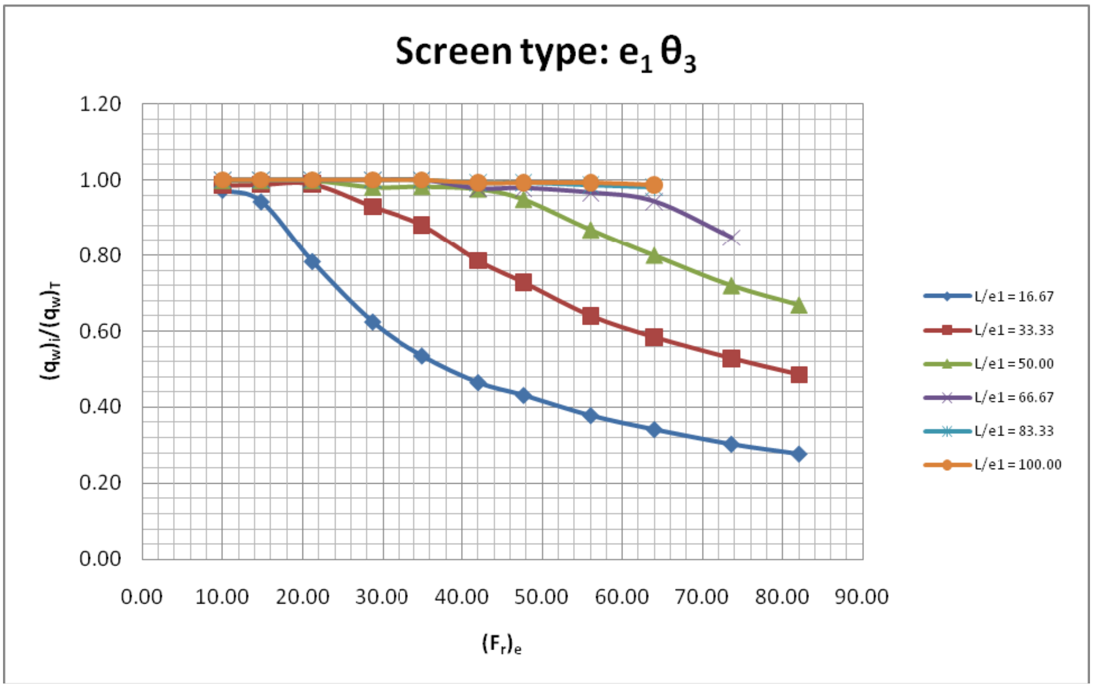

Figure 4.12 Water capture efficiencies for Tyrolean screen of e_1/a_1 = 0.23 and θ_3 = 27.8°

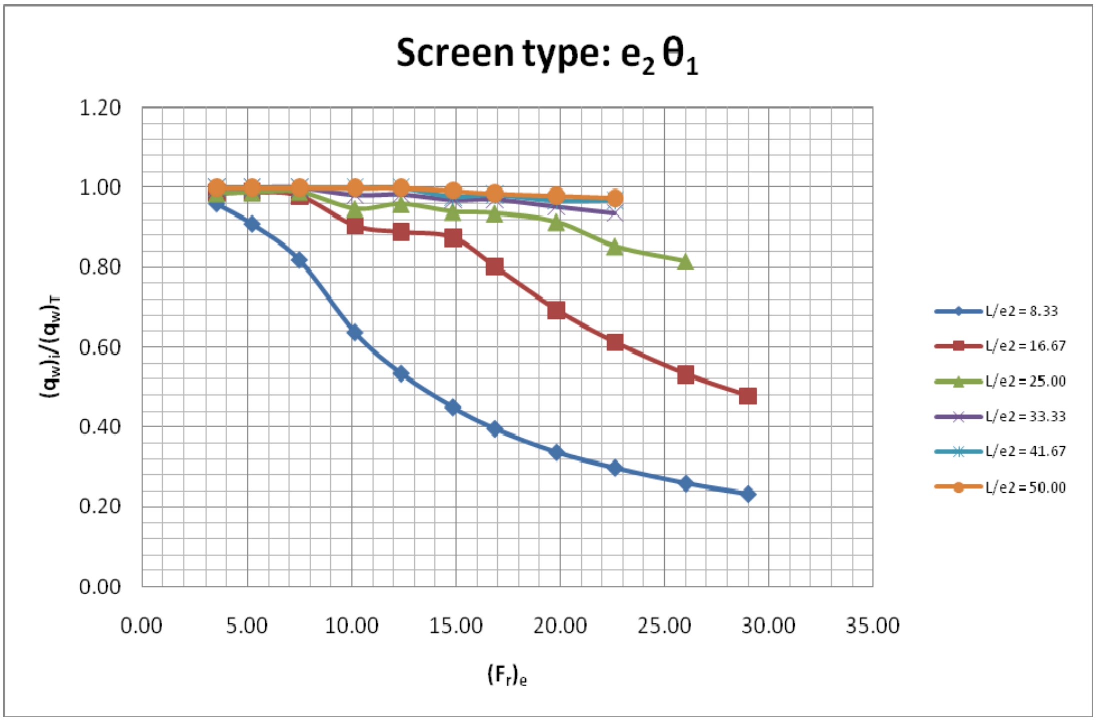

Figure 4.13 Water capture efficiencies for Tyrolean screen of e_2/a_2 = 0.375 and θ_1 = 37.0°

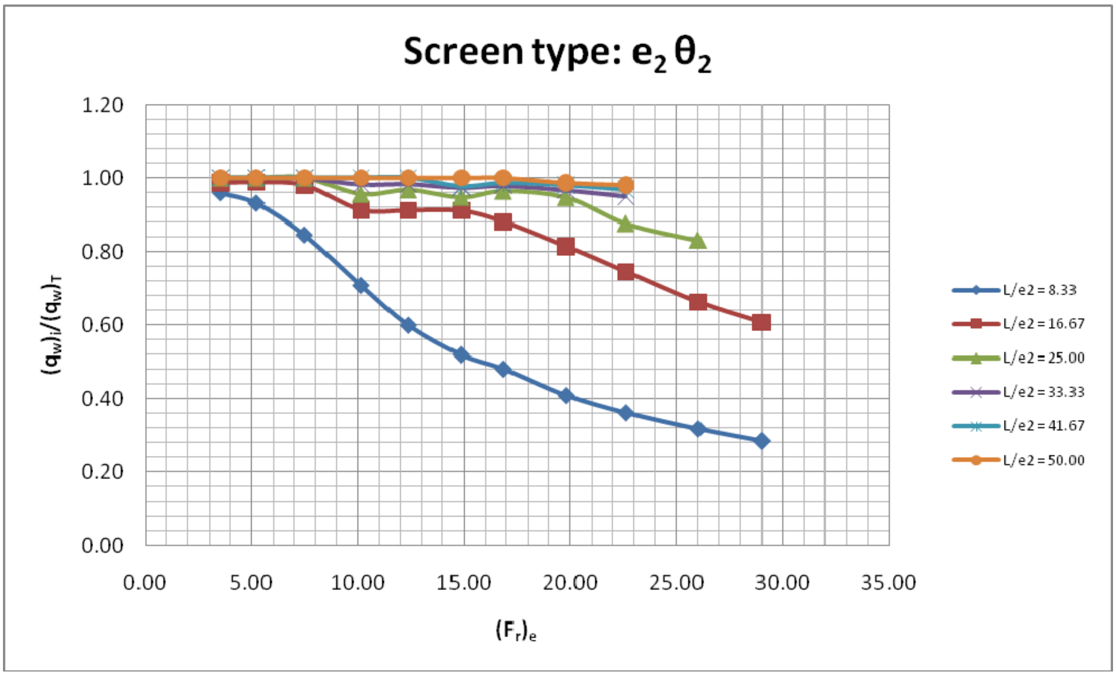

Figure 4.14 Water capture efficiencies for Tyrolean screen of e_2/a_2 = 0.375 and θ_2 = 32.8°

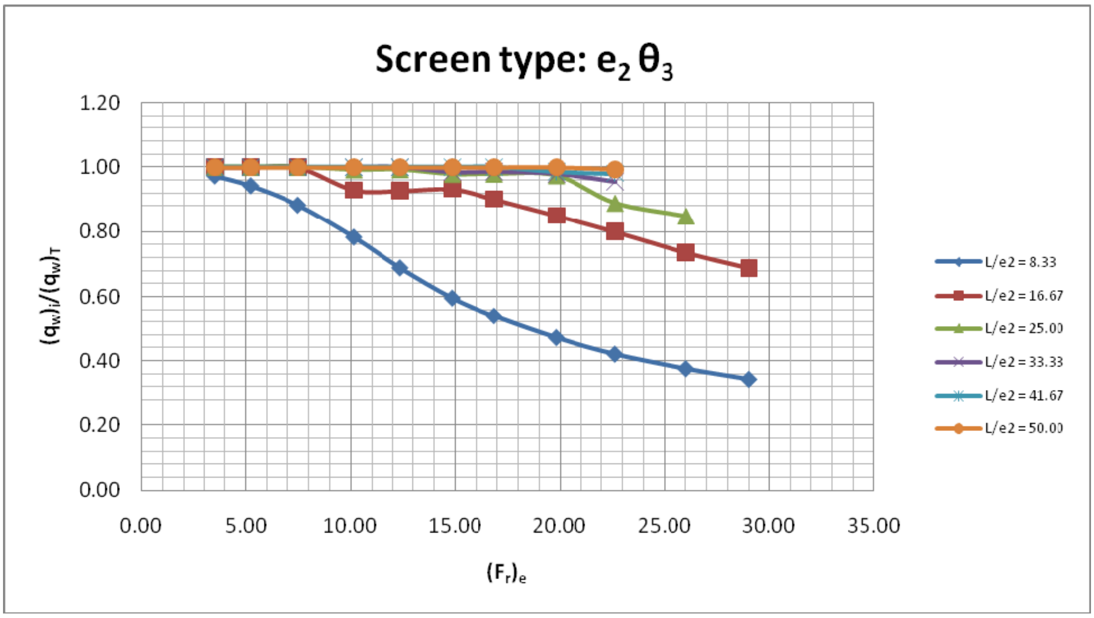

Figure 4.15 Water capture efficiencies for Tyrolean screen of e_2/a_2 = 0.375 and θ_3 = 27.8°

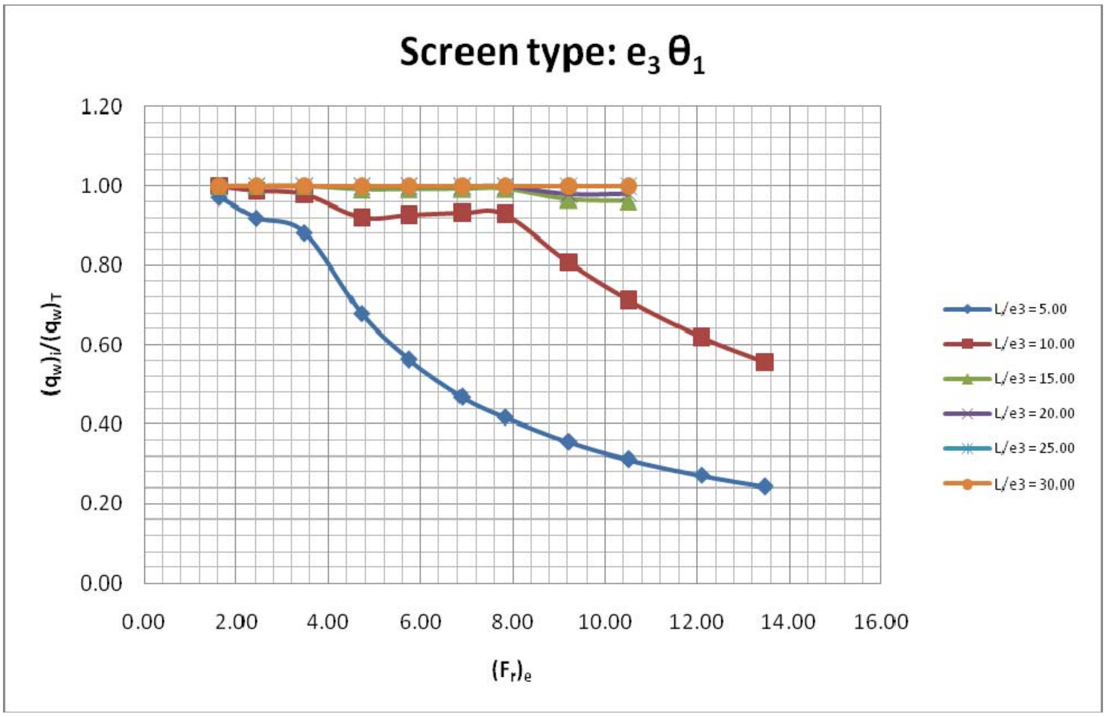

Figure 4.16 Water capture efficiencies for Tyrolean screen of e_3/a_3 = 0.5 and θ_1 = 37.0°

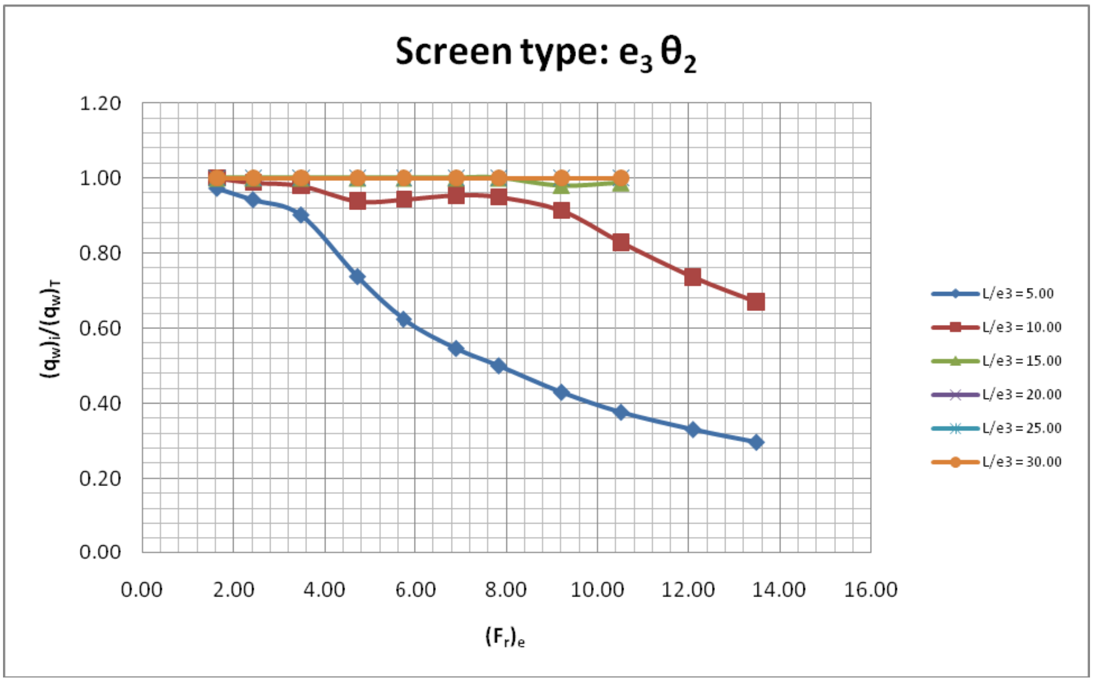

Figure 4.17 Water capture efficiencies for Tyrolean screen of $e_3/a_3 = 0.5$ and $\theta_2 = 32.8°$

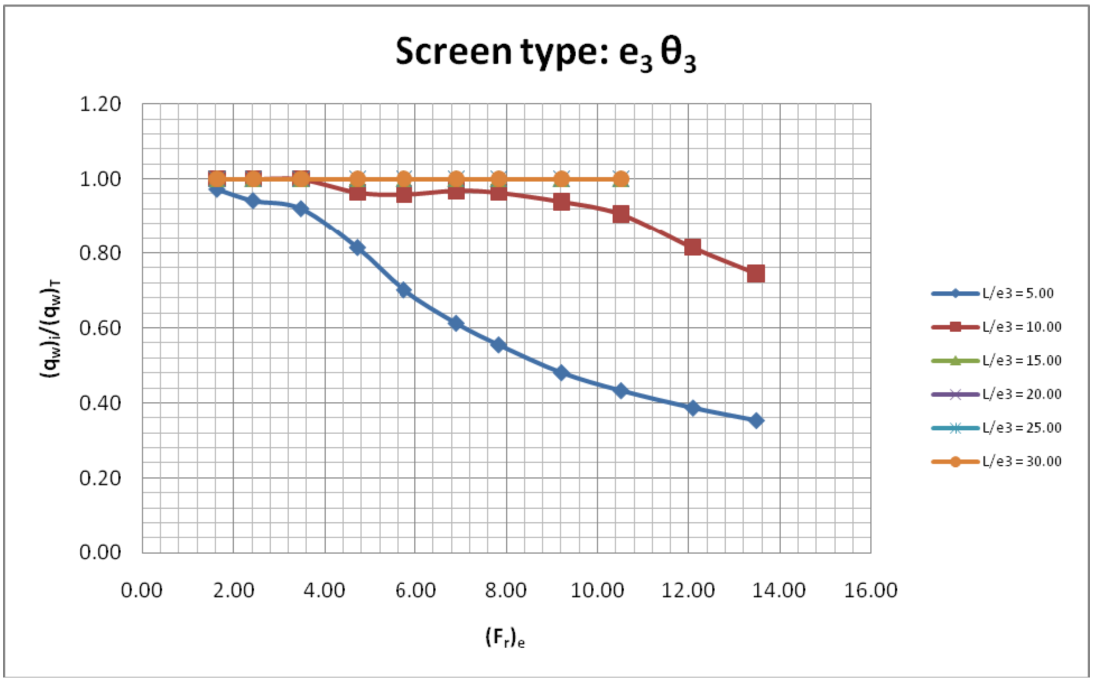

Figure 4.18 Water capture efficiencies for Tyrolean screen of $e_3/a_3 = 0.5$ and $\theta_3 = 27.8°$

4.2.3 Variation of the Dimensionless Wetted Rack Length, L_2/e, with $(F_r)_e$ and θ

The minimum rack length required to divert the desired flow discharge from the main channel is defined as the wetted rack length, L_2, of a Tyrolean weir. The measured data of L_2 for the screens tested in this study were presented in Figures 4.19 – 4.21 in the form of L_2/e as a function of $(F_r)_e$ and θ as stated in Equation(2.12). The general trend of the data given in these figures shows that L_2/e almost linearly increases with increasing $(F_r)_e$ for a given value of θ. For a given value of $(F_r)_e$, L_2/e increases with increasing θ. The values of L_2 for a screen of known e and θ can be determined from the related figure for the main channel discharge to be given.

The similar results were obtained by Yılmaz (2010) for the variation of L_2/e with the related dimensionless parameters for the screens having the slopes of θ = 14.5°, 9.6° and 4.8° and the rack openings of e =3 mm, 6 mm and 10 mm.

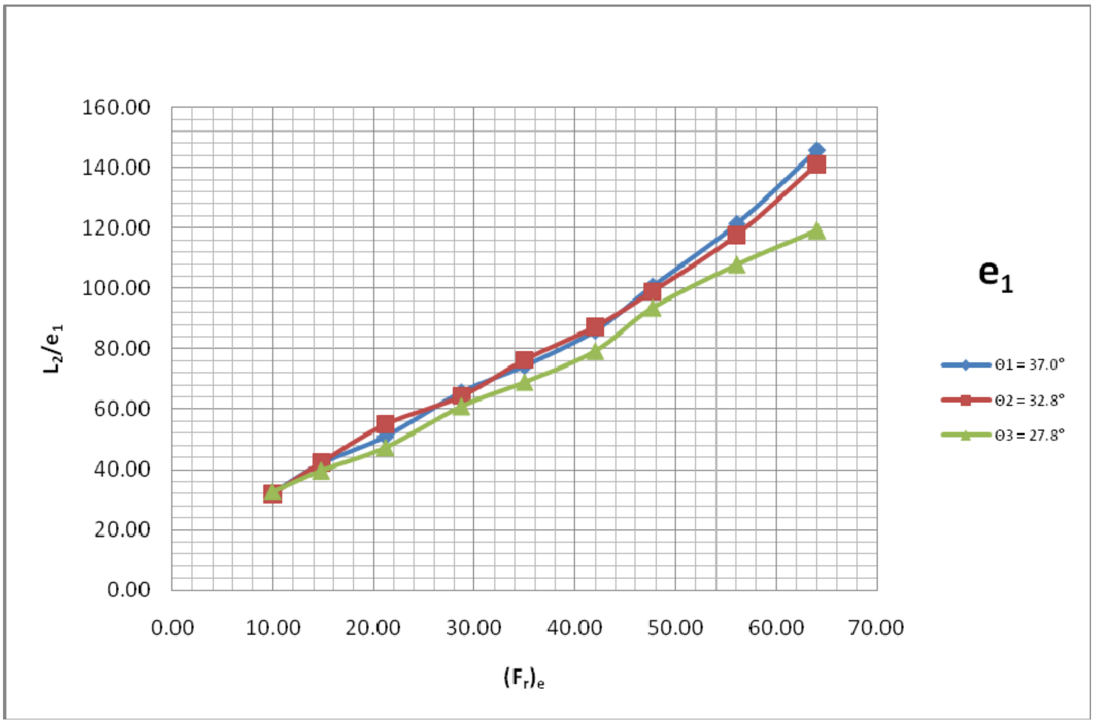

Figure 4.19 Variation of L_2/e_1 with $(F_r)_e$ and θ for screens of e_1/a_1 = 0.23

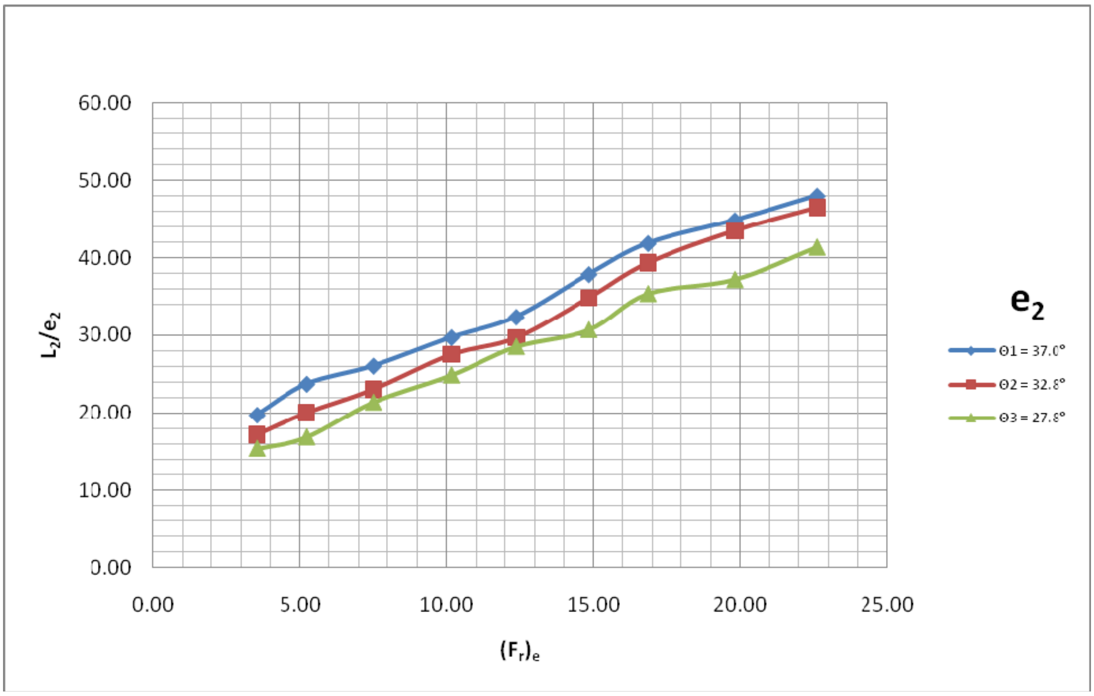

Figure 4.20 Variation of L_2/e_2 with $(F_r)_e$ and θ for screens of e_2/a_2 = 0.375

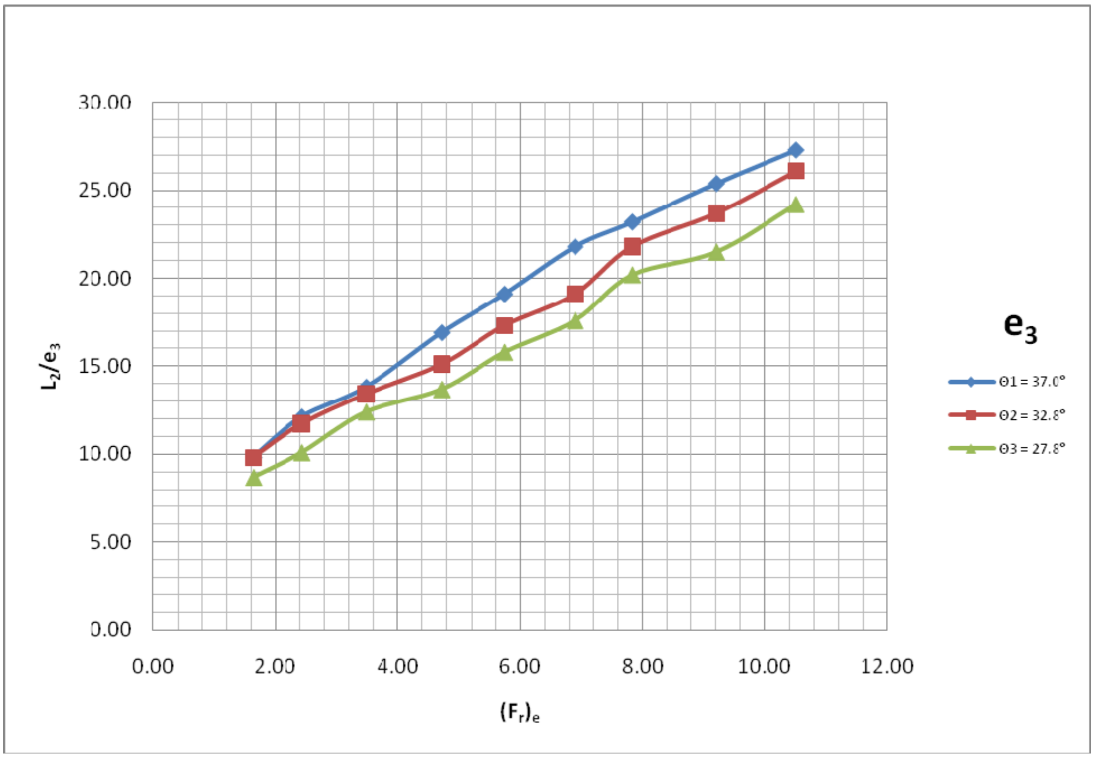

Figure 4.21 Variation of L_2/e_3 with $(F_r)_e$ and θ for screens of e_3/a_3 = 0.5

4.2.4 Variation of Water Capture Efficiency with Screen Angle

The water capture efficiency WCE data of the present study and those of Yılmaz(2010) (θ = 14.5°, 9.6° and 4.8°) were plotted as a function of screen slope θ for the same L/e values and presented in Figures 4.22-4.38. The figures of small L/e values corresponding to the screens of various rack openings(Figures : 4.22, 4.23, 4.27, 4.28, 4.33 and 4.34) clearly show that for a given main channel discharge, $(q_w)_T$, or corresponding constant $(Fr)_e$ the value of WCE first decreases with increasing θ up to value of about 15° and then increases with increasing value of θ up to the value of about 27° and finally decreases again with increasing θ. As the $(Fr)_e$ or the main channel discharge increases, the above mentioned trend of the data does not change while the value of WCE decreases for a given θ. For a constant $(Fr)_e$ the WCE attains almost the same maximum values at two different screen slopes of about θ = 5° and θ = 27° in the figures of small L/e. As the value of L/e increases for a screen of given e, WCE values become almost independent of θ and get values quite close to unity.

If it is asked to select the optimum screen angle which will provide the maximum WCE among the θ values tested among the two θ values stated above, θ = 27° should be selected to reduce the risk of clogging of the bar openings due to the presence of sediment in the flow in practical applications.

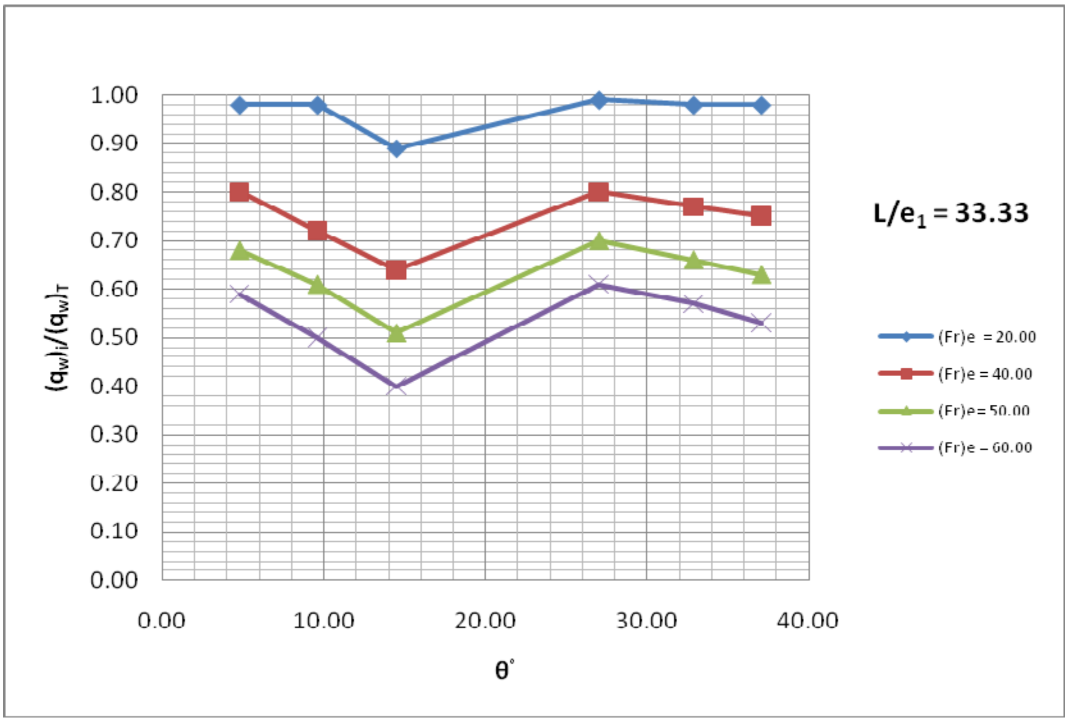

Figure 4.22 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_1 = 33.33 and e_1/a_1 = 0.23

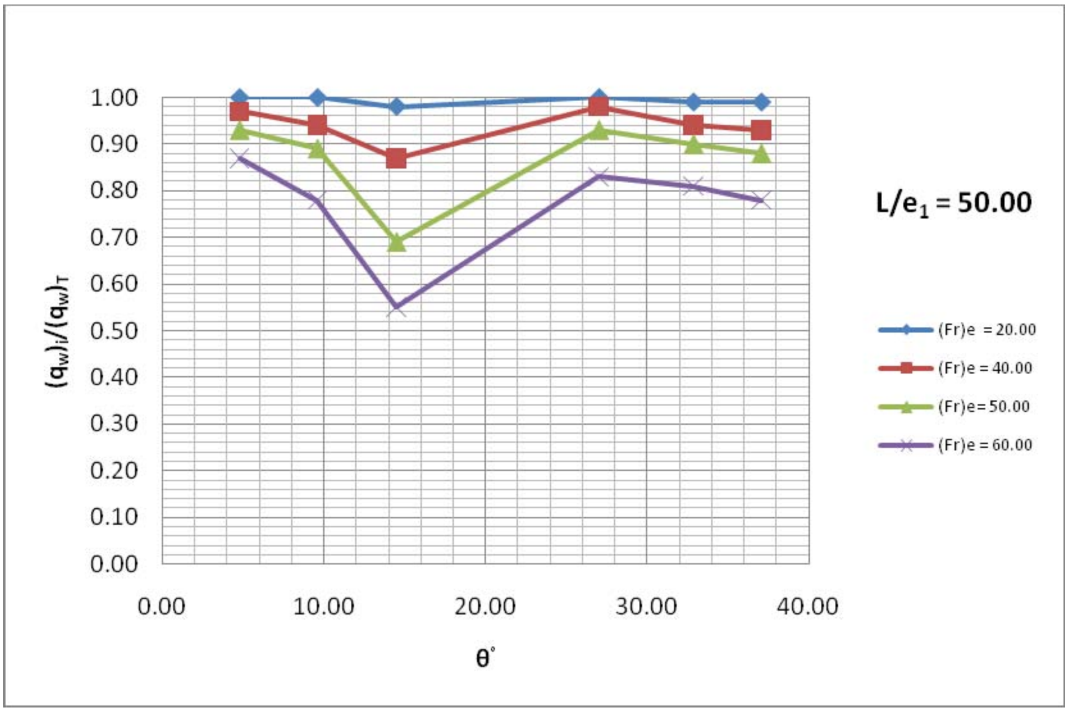

Figure 4.23 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_1 = 50.00 and e_1/a_1 = 0.23

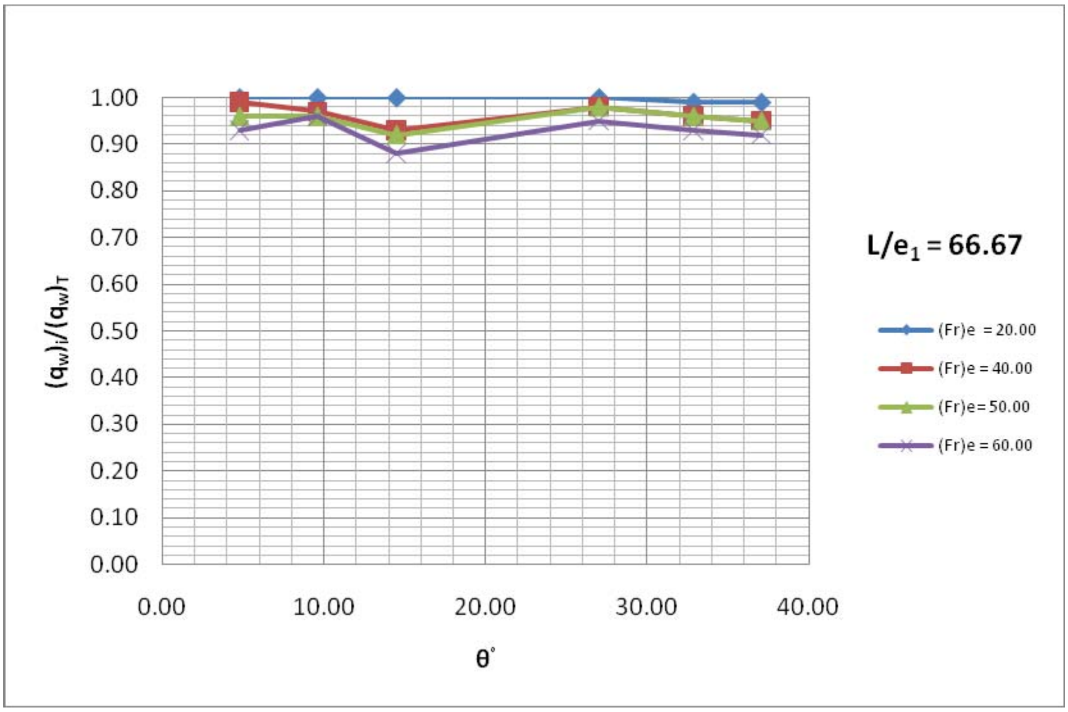

Figure 4.24 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_1 = 66.67 and e_1/a_1 = 0.23

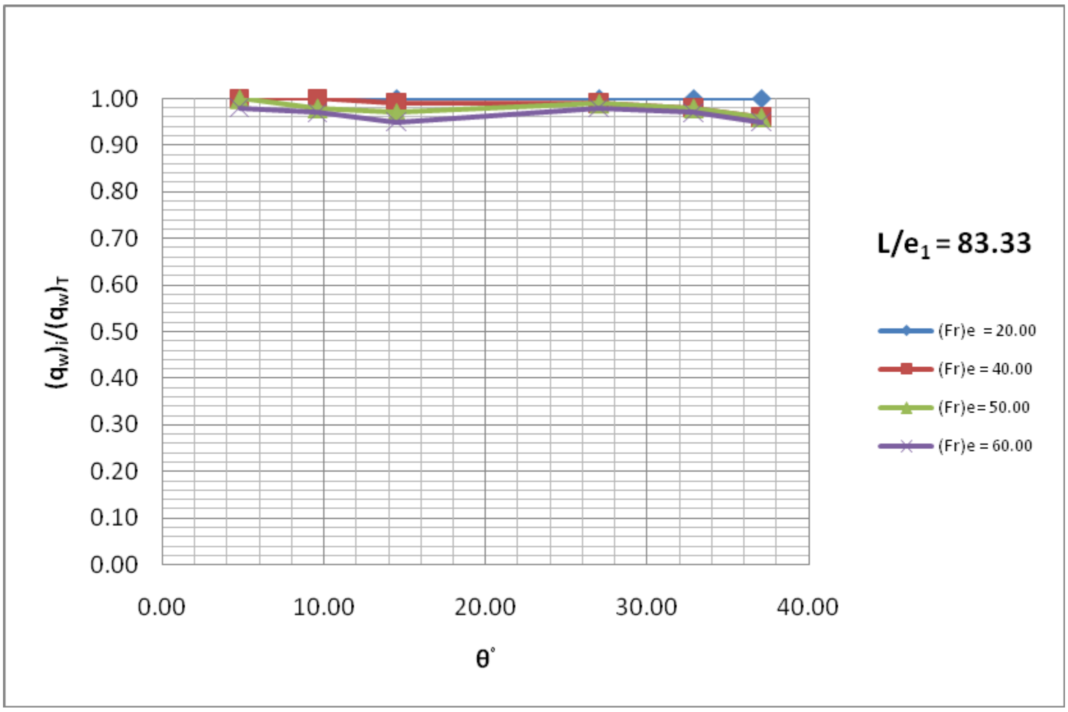

Figure 4.25 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_1 = 83.33 and e_1/a_1 = 0.23

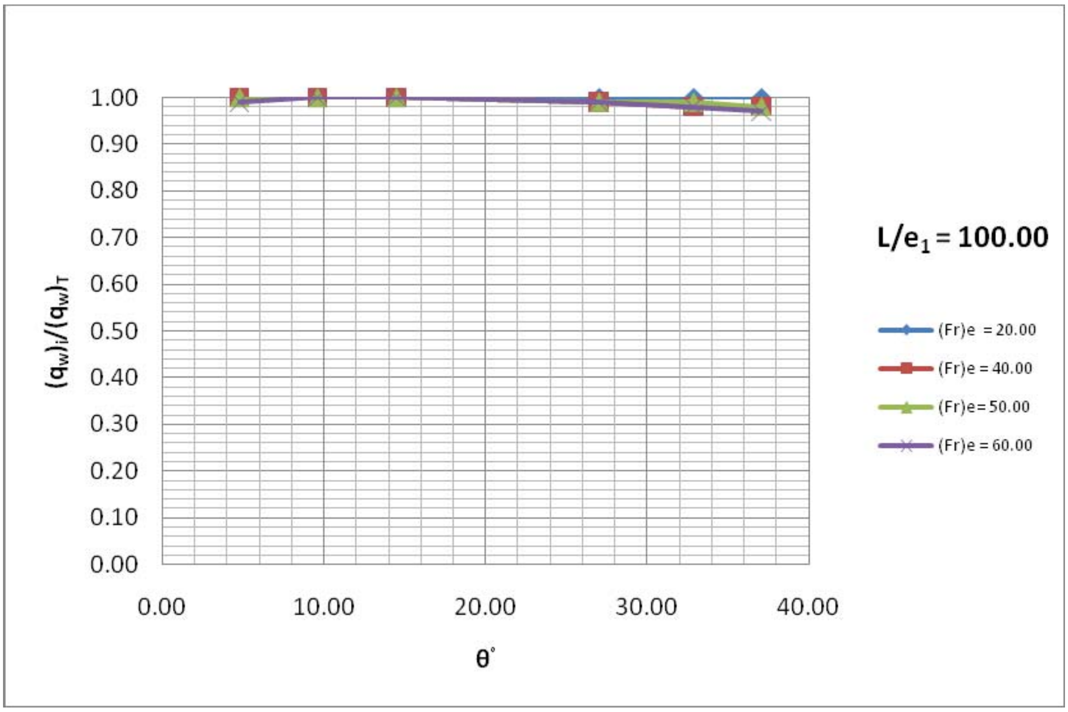

Figure 4.26 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_1 = 100.00 and e_1/a_1 = 0.23

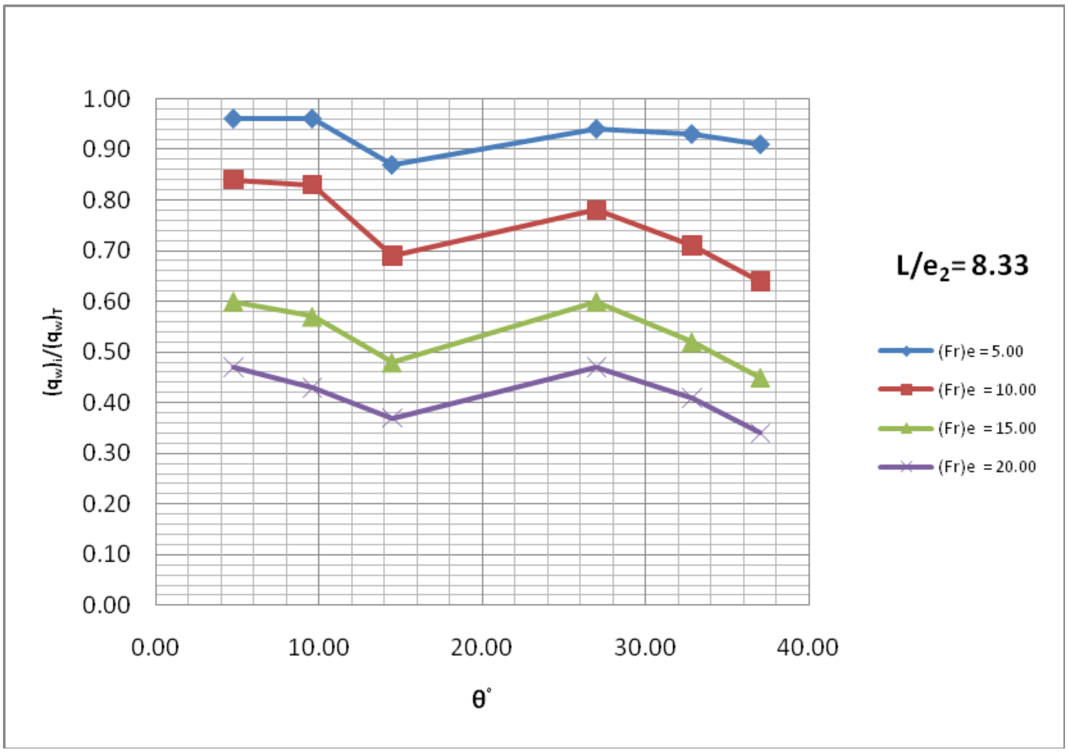

Figure 4.27 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_2 = 8.33 and e_2/a_2 = 0.375

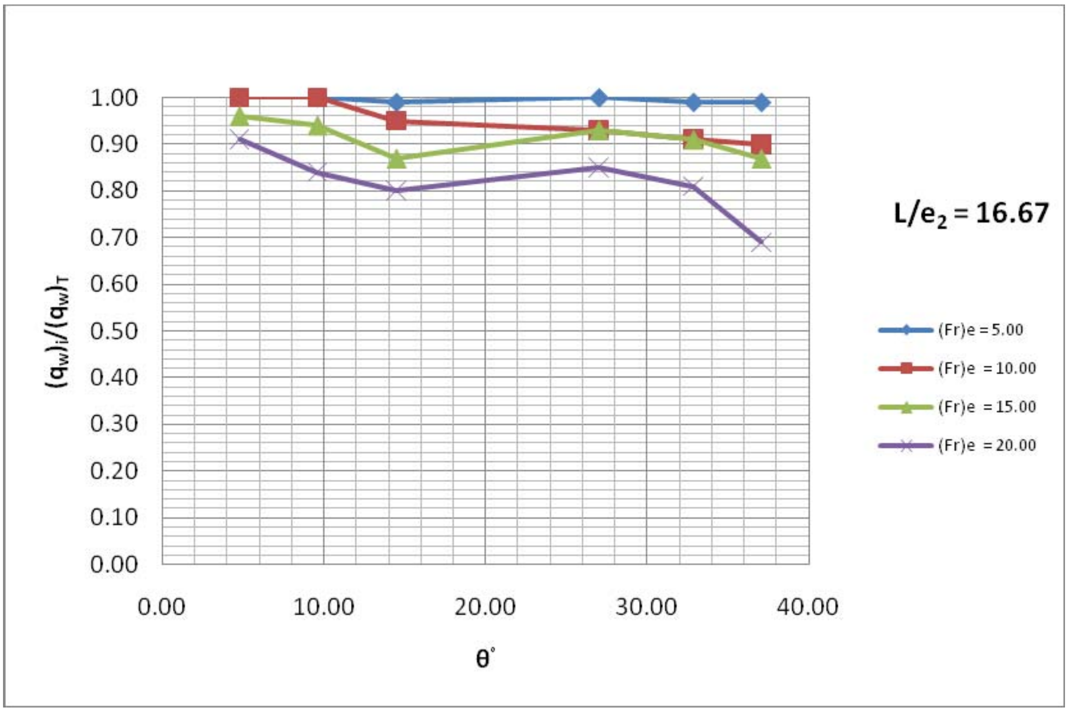

Figure 4.28 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_2 = 16.67 and e_2/a_2 = 0.375

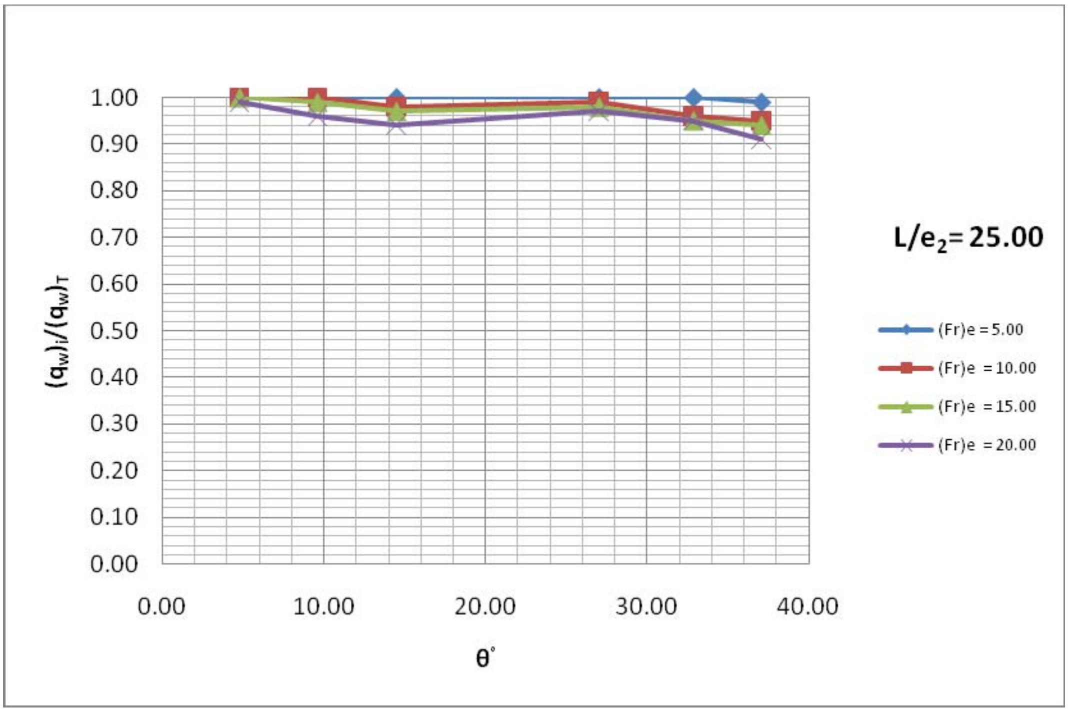

Figure 4.29 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_2 = 25.00 and e_2/a_2 = 0.375

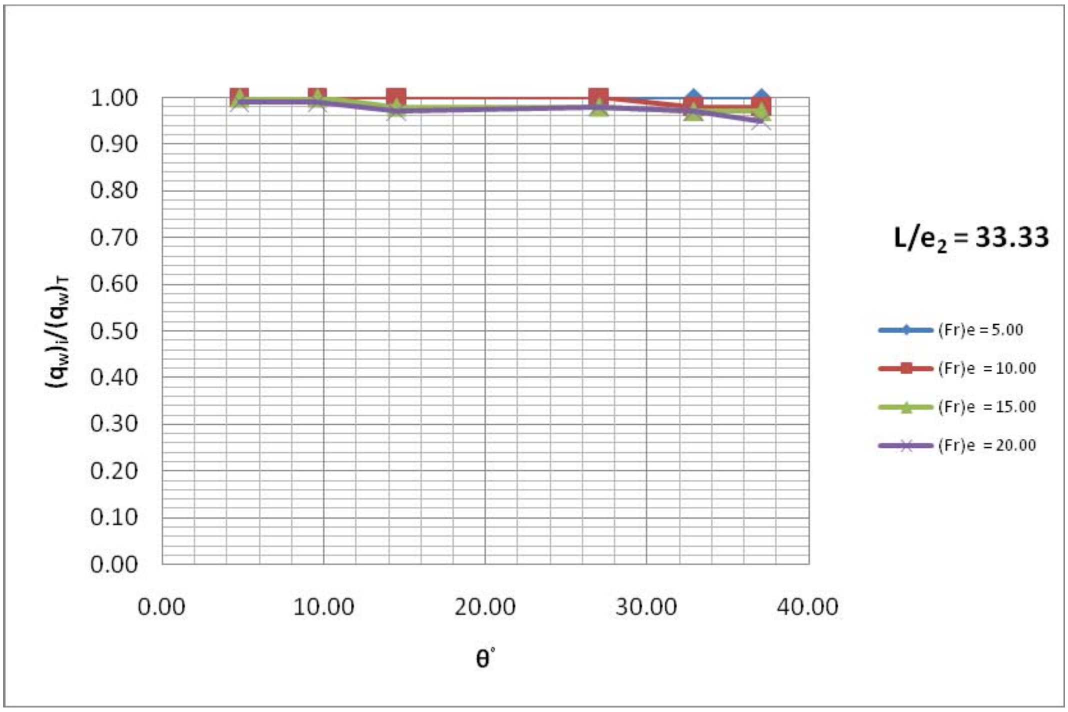

Figure 4.30 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_2 = 33.33 and e_2/a_2 = 0.375

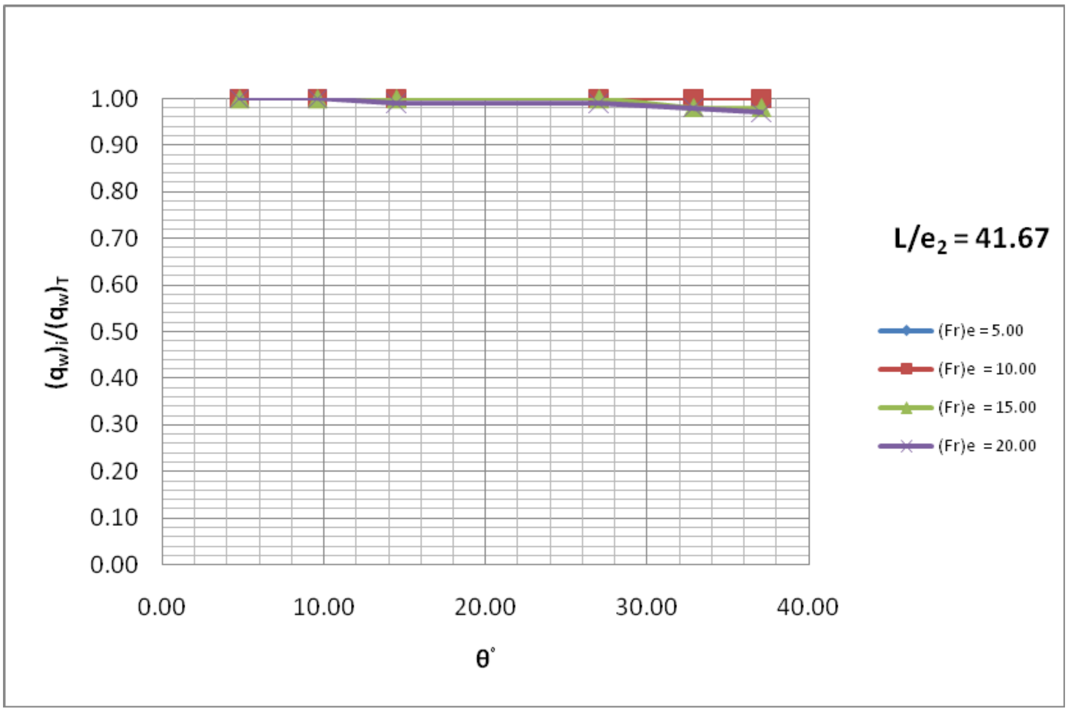

Figure 4.31 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_2 = 41.67 and e_2/a_2 = 0.375

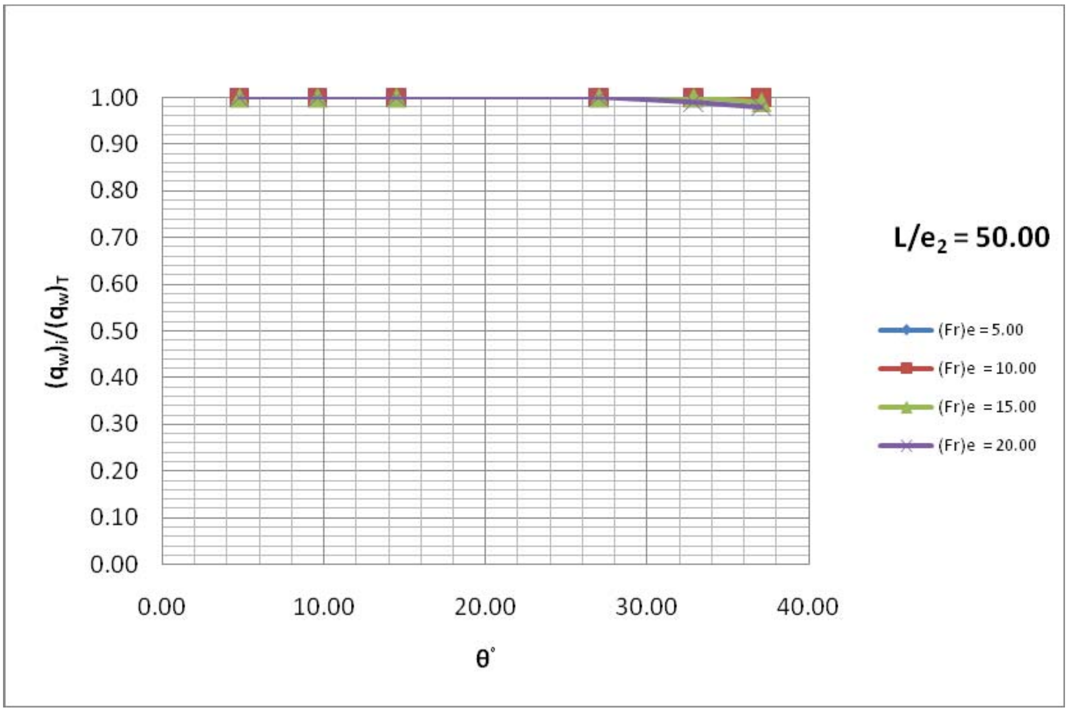

Figure 4.32 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_2 = 50.00 and e_2/a_2 = 0.375

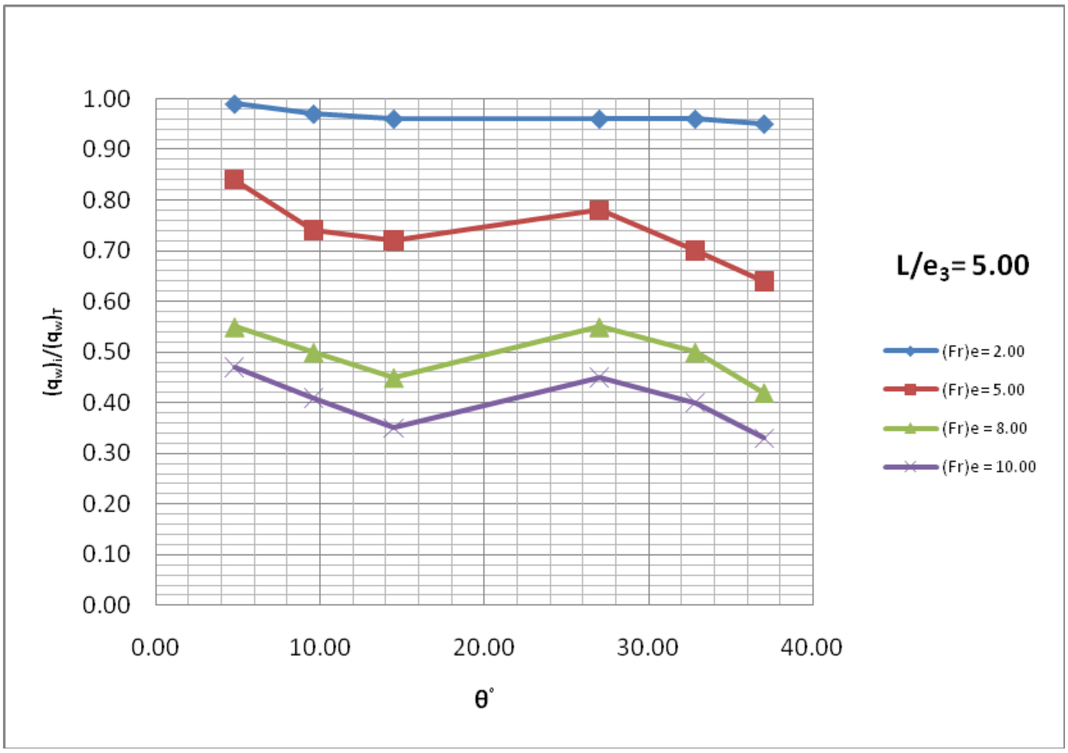

Figure 4.33 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_3 = 5.00 and e_3/a_3 = 0.5

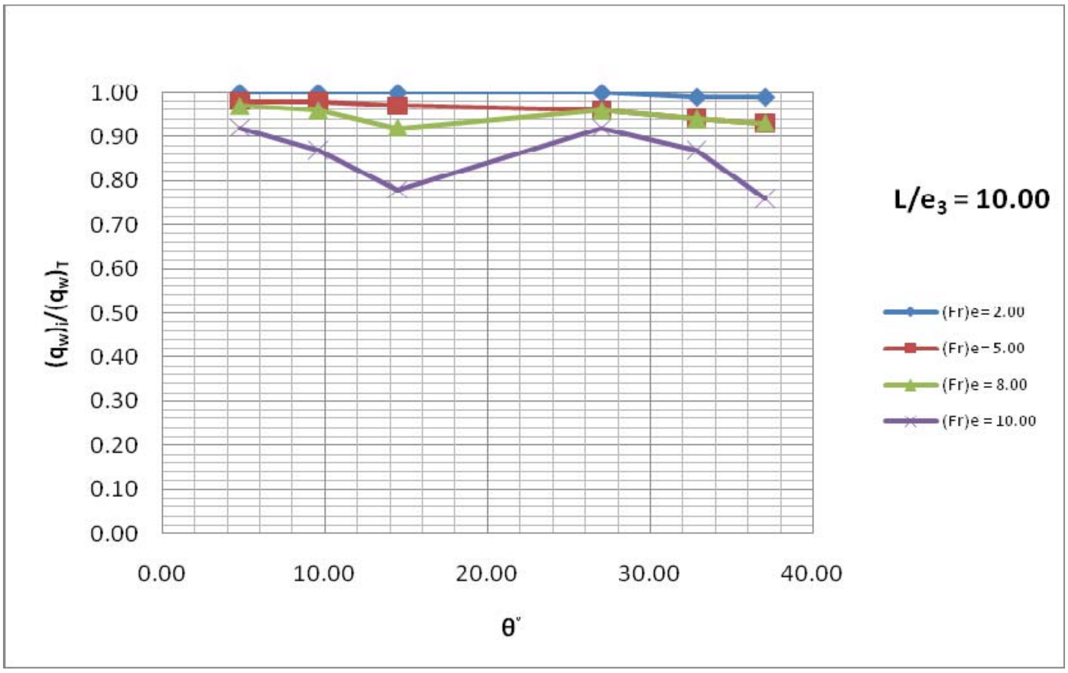

Figure 4.34 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_3 = 10.00 and e_3/a_3 = 0.5

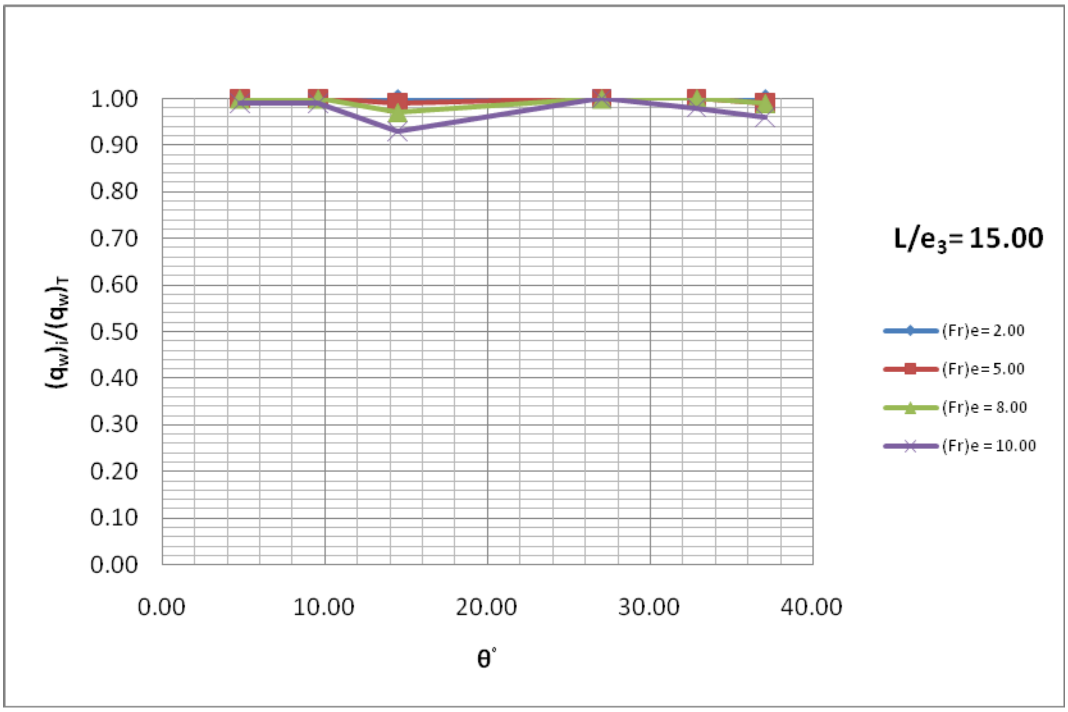

Figure 4.35 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_3 = 15.00 and e_3/a_3 = 0.5

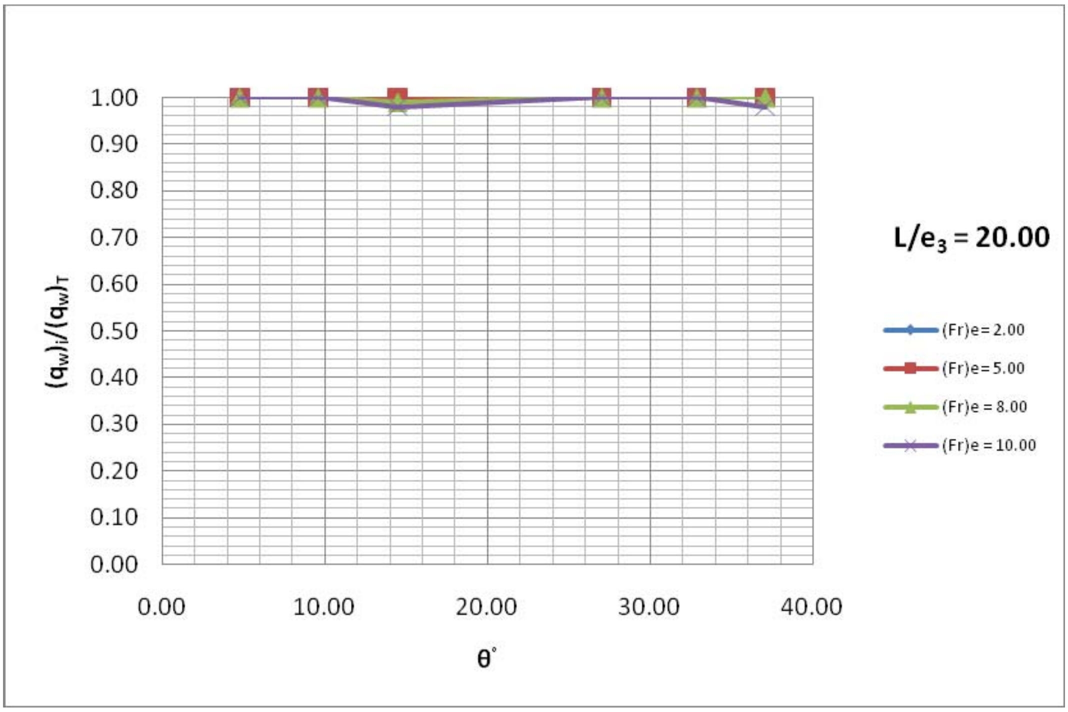

Figure 4.36 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_3 = 20.00 and e_3/a_3 = 0.5

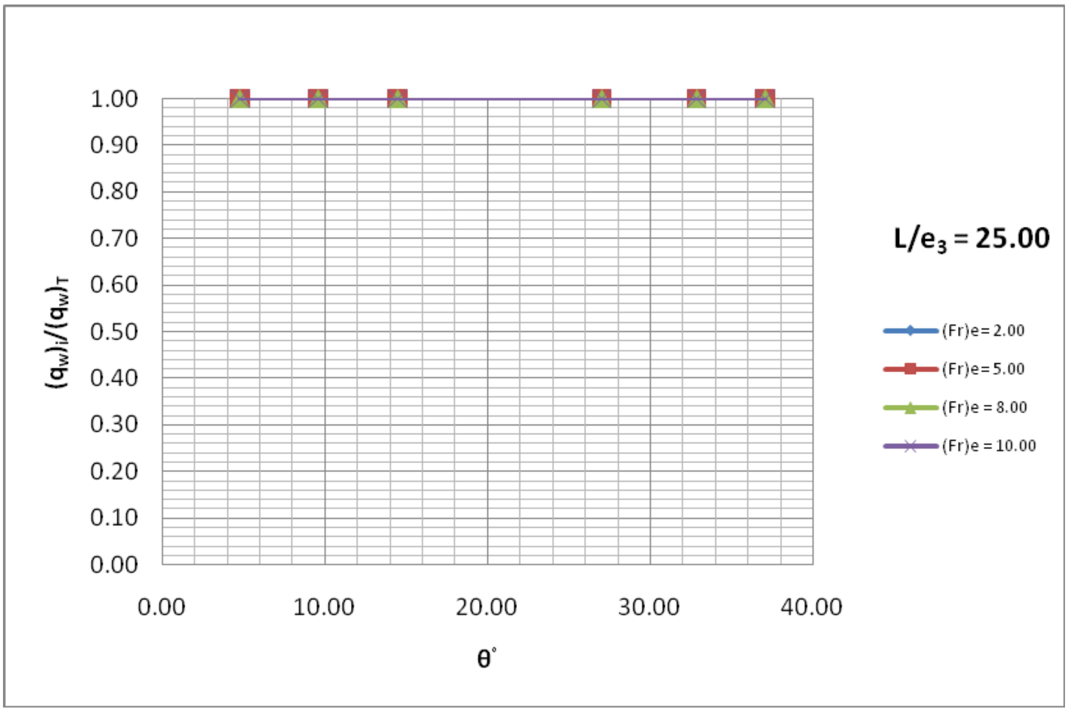

Figure 4.37 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_3 = 25.00 and e_3/a_3 = 0.5

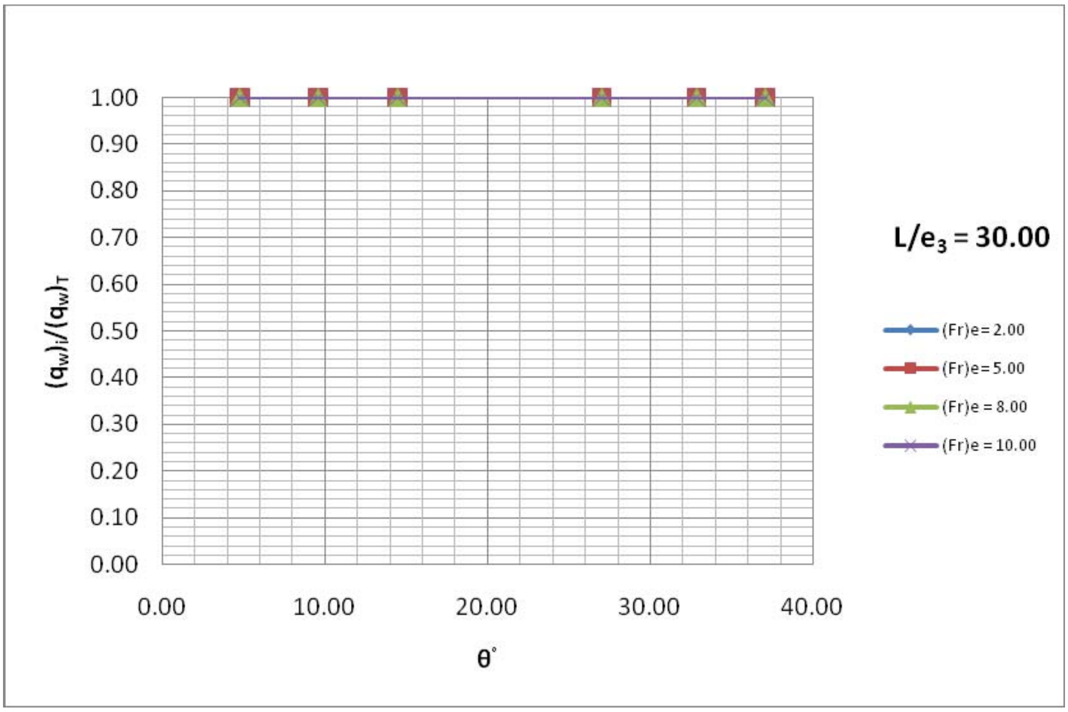

Figure 4.38 Variation of water capture efficiencies with θ and $(F_r)_e$ for screens of L/e_3 = 30.00 and e_3/a_3 = 0.5

4.3 STUDIES RELATED TO CIRCULAR –PERFORATED SCREENS

In this section the results of the experimental studies conducted on circular-perforated screens are presented.

4.3.1 Relationship Between the Discharge Coefficient C_d and the Related Dimensionless Parameters for Circular-Perforated Screens

The relationship between C_d and other related dimensionless parameters are given by Equation 2.15. When the variation of C_d with $(F_r)_d$ and L/d is plotted one by one for each test conducted (Figs 4.39 – 4.47) it is seen that almost in each figure the data points of a given L/d follow the same trend; as $(F_r)_d$ increases, C_d values first slightly increase and then at larger values of $(F_r)_d$ become almost constant. From the presented figures it can be stated that for a screen of known inclination angle and opening diameter as L/d decreases, C_d value increases for a given $(F_r)_d$. At the smallest L/d values of all of the perforated screens tested regardless of the screen slope and opening diameter the maximum C_d values are observed. C_d values of large L/d ratios are almost constant for the whole range of $(Fr)_d$ and numerically approaches to each other. If the angle of inclination of a selected screen increases while keeping $(F_r)_d$ and L/d values constant, C_d value slightly decreases at small values of L/d while almost remains the same at larger values of L/d. If the opening diameter increases, C_d values decrease for given values of $(F_r)_d$ and L/d.

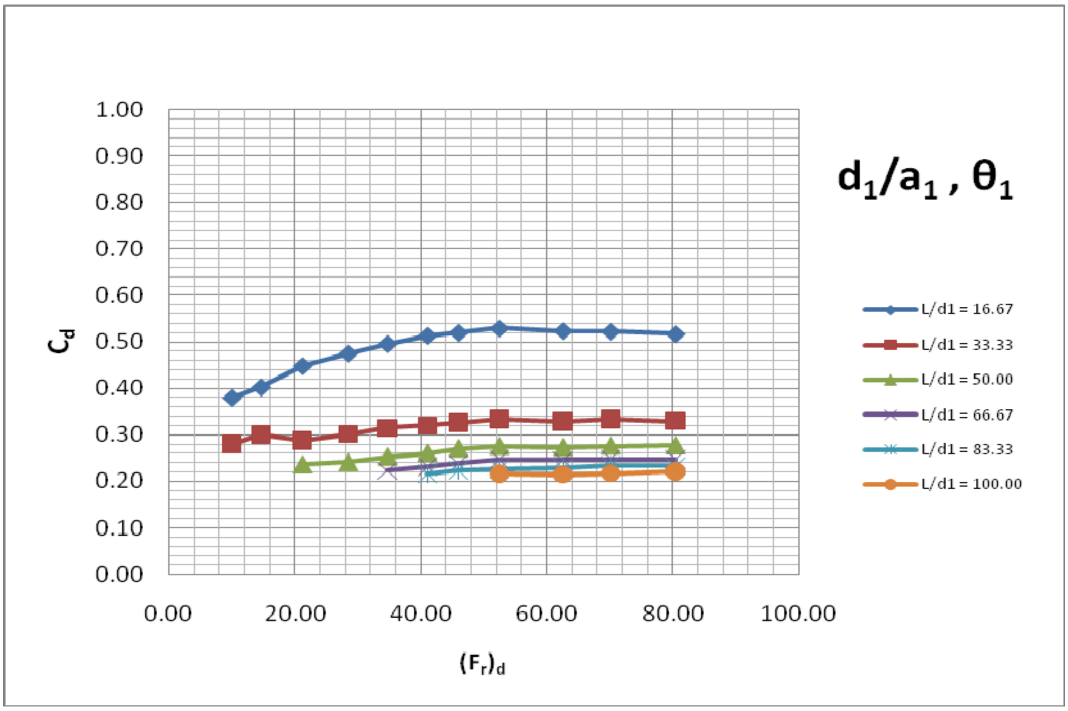

Figure 4.39 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_1/a_1 = 0.60 and θ_1 = 37.0°

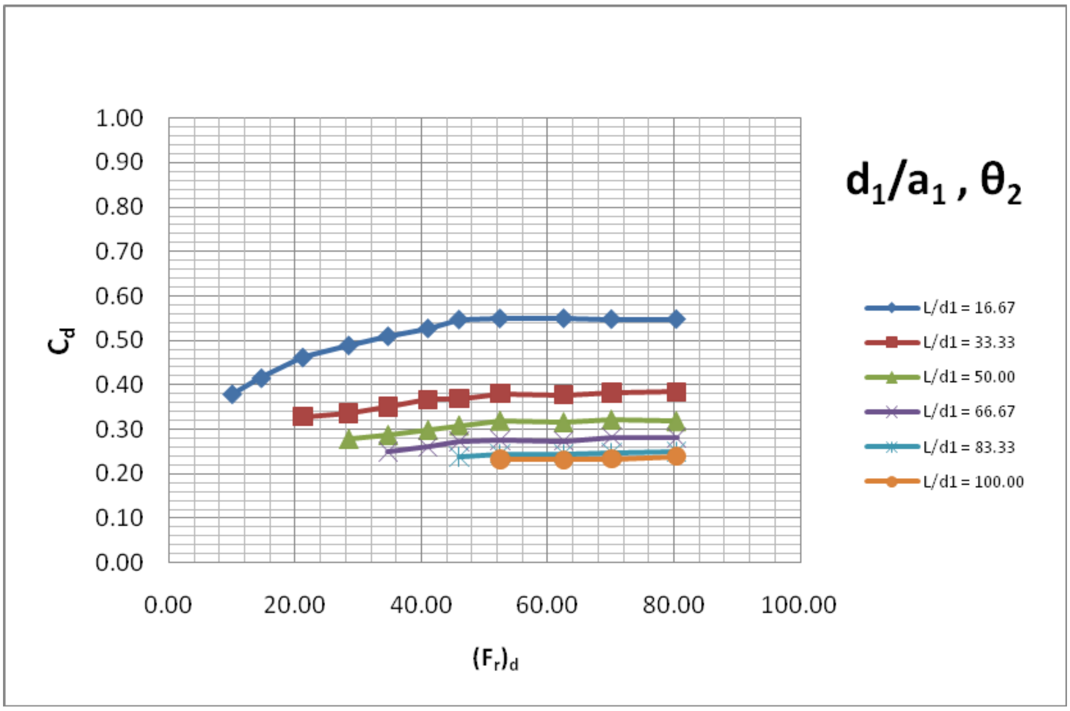

Figure 4.40 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_1/a_1 = 0.60 and θ_2 = 32.8°

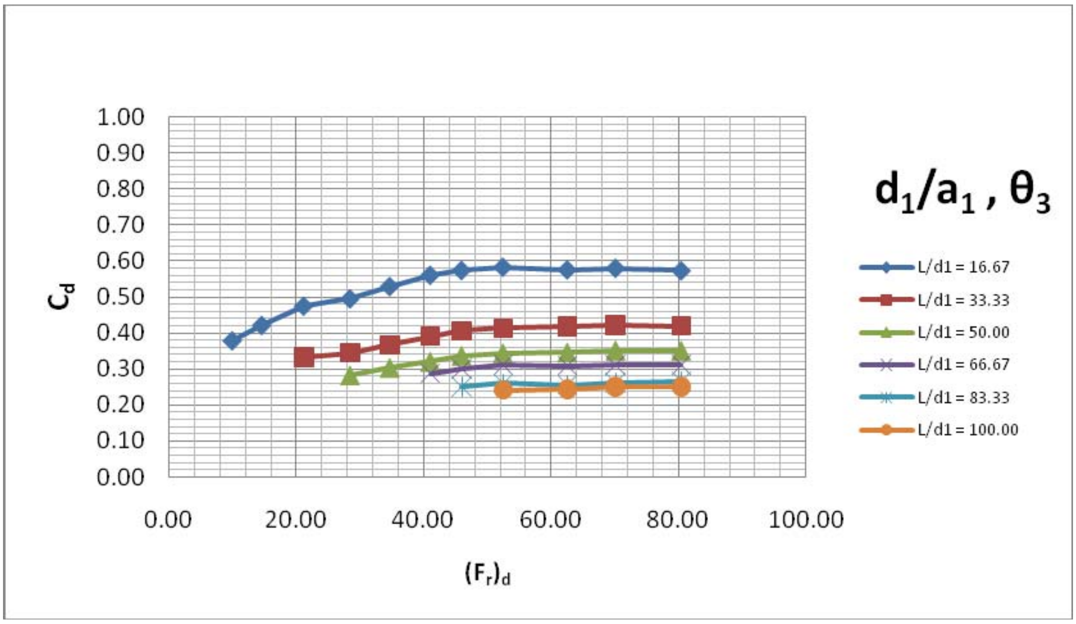

Figure 4.41 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_1/a_1 = 0.60 and θ_3 = 27.8°

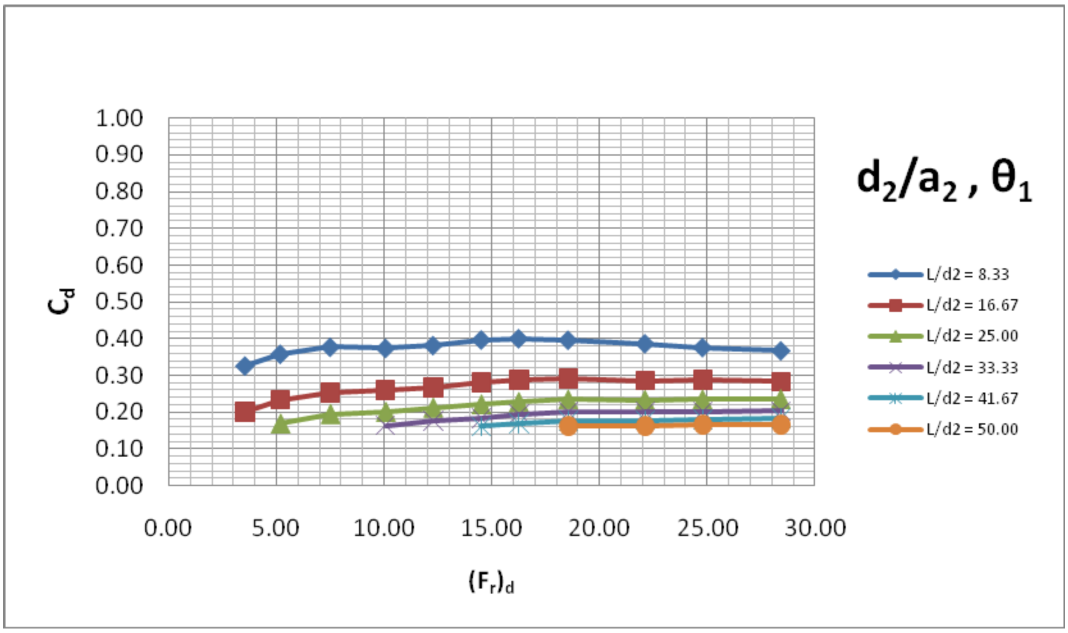

Figure 4.42 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_2/a_2 = 0.86 and θ_1 = 37.0°

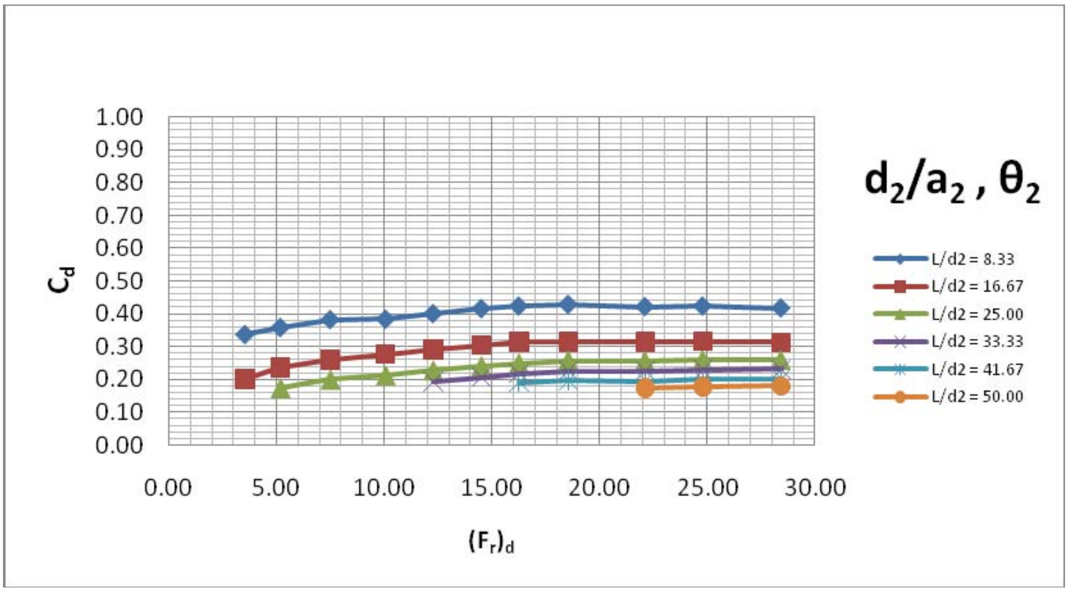

Figure 4.43 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_2/a_2 = 0.86 and θ_2 = 32.8°

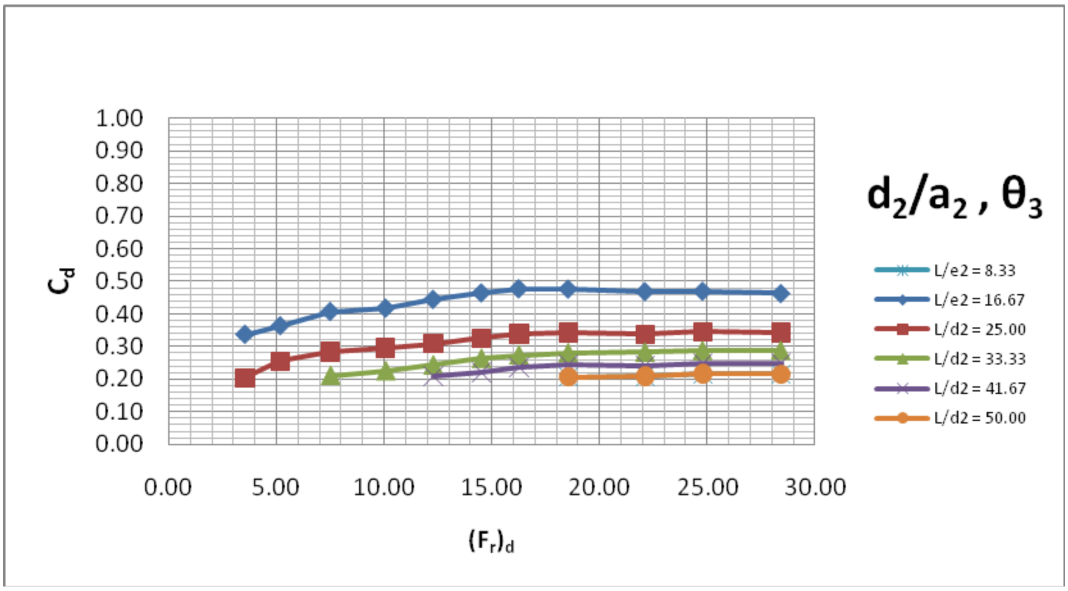

Figure 4.44 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_2/a_2 = 0.86 and θ_3 = 27.8°

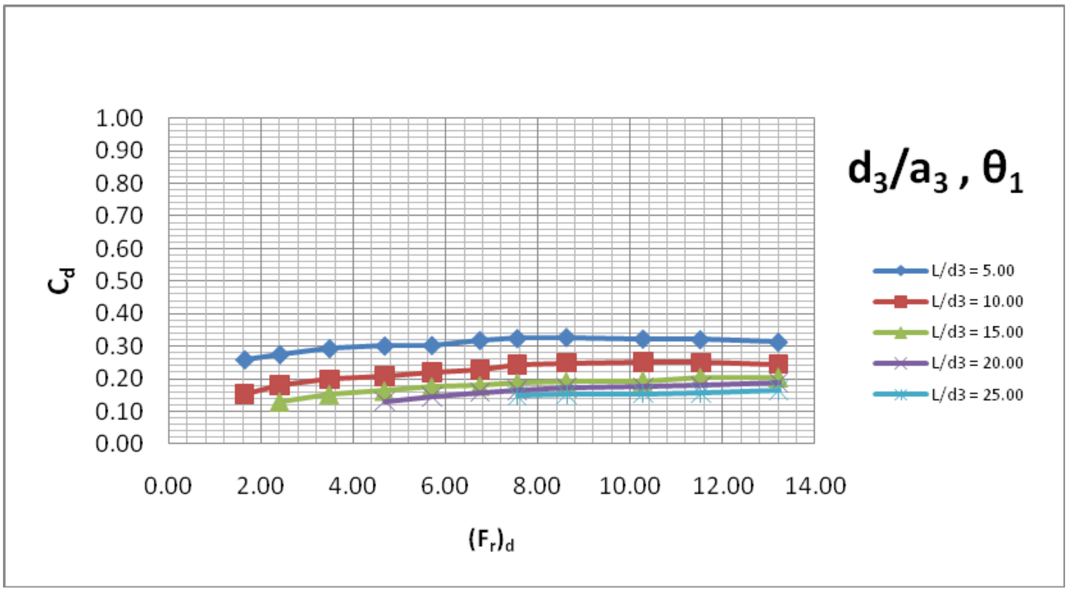

Figure 4.45 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_3/a_3 = 0.83 and θ_1 = 37.0°

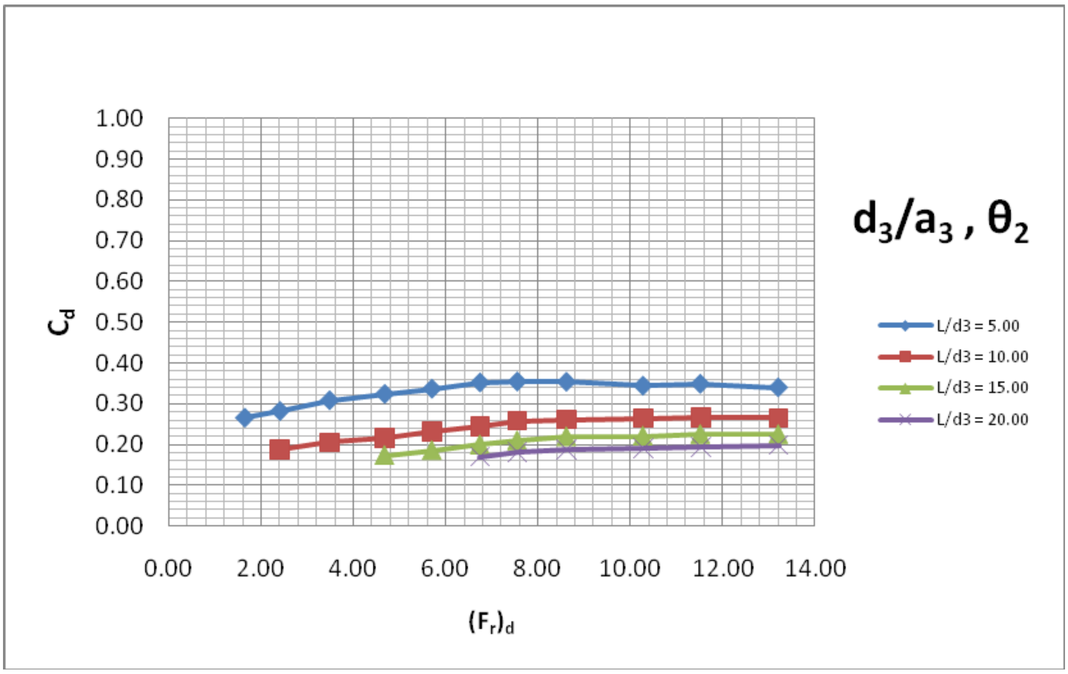

Figure 4.46 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_3/a_3 = 0.83 and θ_2 = 32.8°

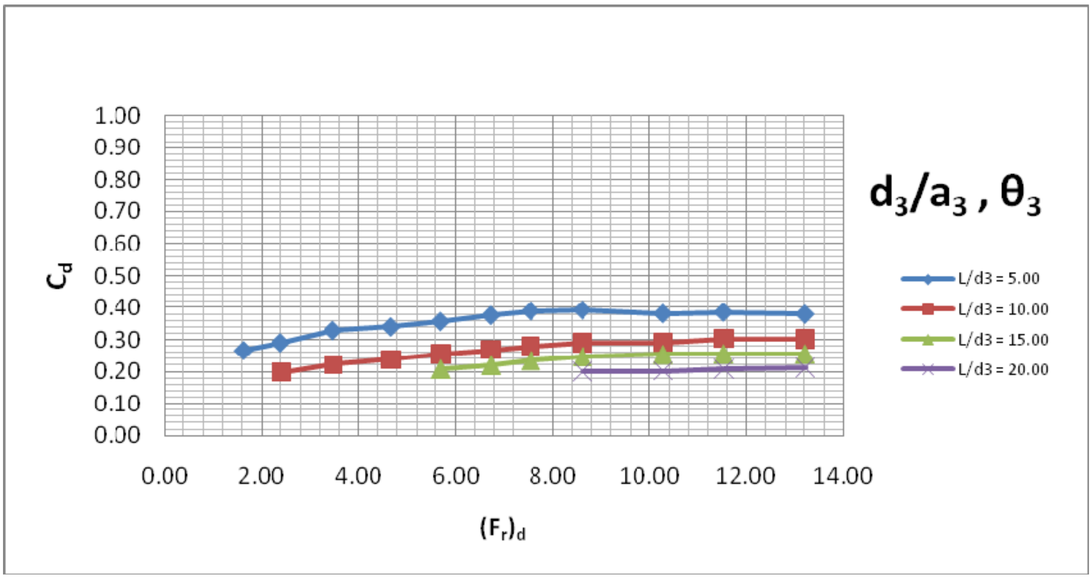

Figure 4.47 Variation of C_d with $(F_r)_d$ for the Tyrolean screen of d_3/a_3 = 0.83 and θ_3 = 27.8°

4.3.2 Relationship Between the Water Capture Efficiency (WCE) and the Related Dimensionless Parameters for Circular-Perforated Screens

Referring to Equation 2.14 which expresses a relationship for the water capture efficiency of a Tyrolean screen, Figures 4.48 – 4.56 were plotted for each experimental setup tested. From the figures it can be stated that WCE depends on L/d and $(F_r)_d$ for a screen of known d/a and θ, and decreases with increasing $(F_r)_d$ and attains its minimum values at largest $(Fr)_d$ tested. The data of the largest L/d give the maximum WCE values for the whole range of $(Fr)_d$ tested compared to the WCE values of the other L/d curves.

When the inclination angle of the perforated screen is increased while keeping the opening diameter and screen length constant, it is seen that WCE values decrease. If the opening diameter of the perforated screen is increased while keeping the screen angle and length constant, as it is expected WCE values increase.

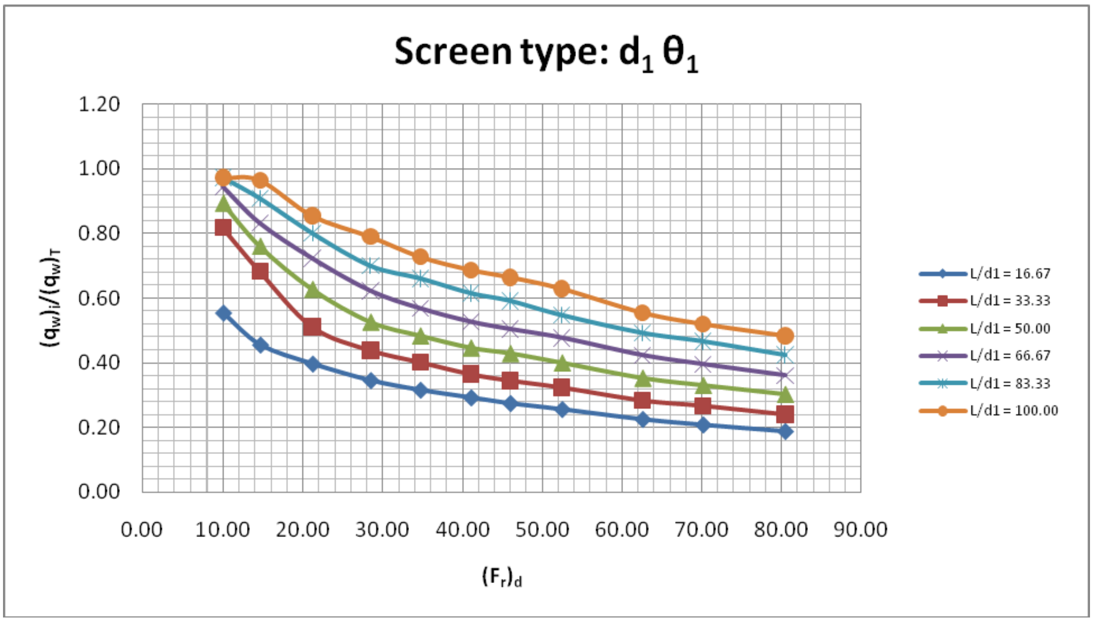

Figure 4.48 Water capture efficiencies for Tyrolean screen of d_1/a_1 = 0.60 and θ_1 = 37.0°

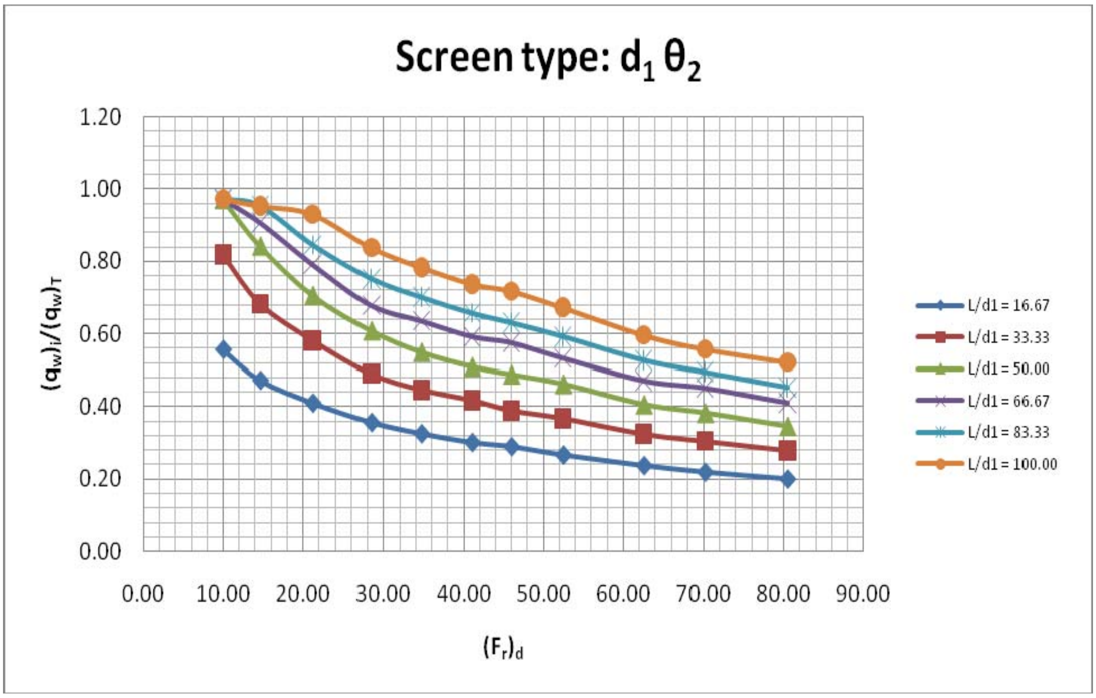

Figure 4.49 Water capture efficiencies for Tyrolean screen of d_1/a_1 = 0.60 and θ_2 = 32.8°

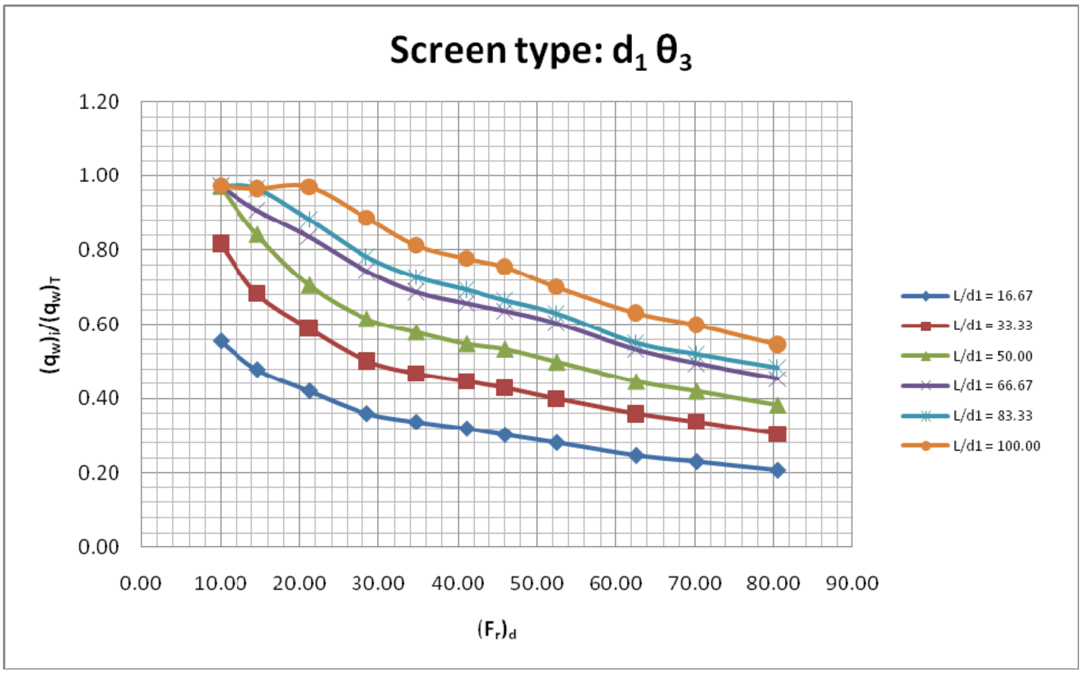

Figure 4.50 Water capture efficiencies for Tyrolean screen of d_1/a_1 = 0.60 and θ_3 = 27.8°

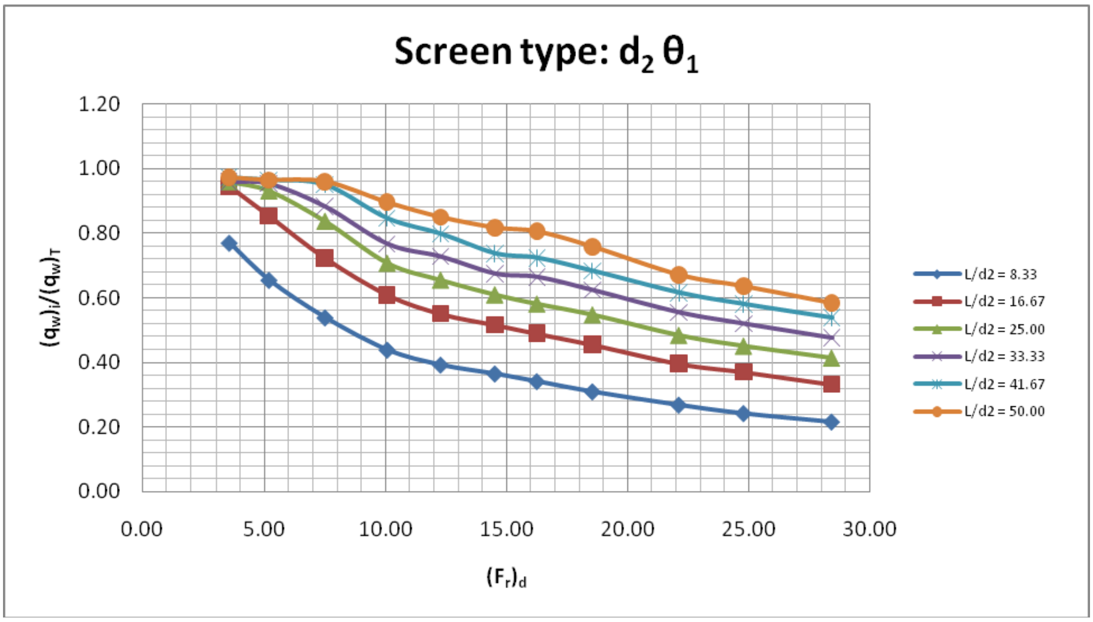

Figure 4.51 Water capture efficiencies for Tyrolean screen of d_2/a_2 = 0.857 and θ_1 = 37.0°

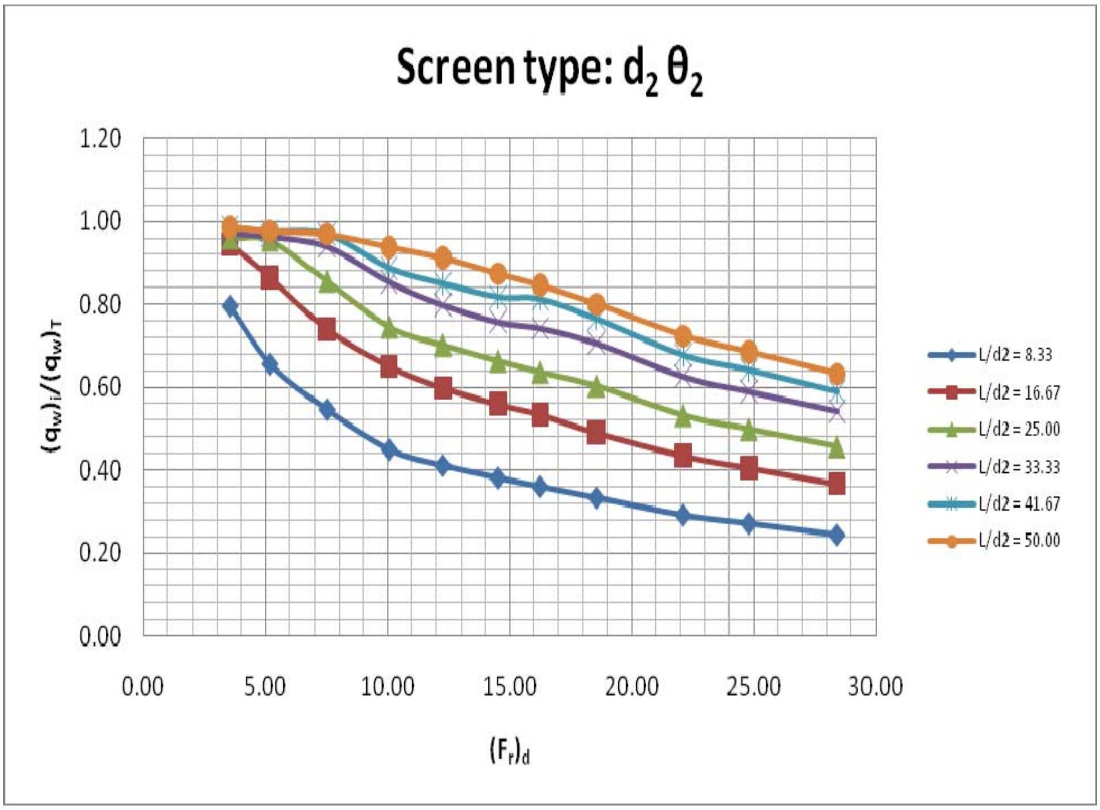

Figure 4.52 Water capture efficiencies for Tyrolean screen of d_2/a_2 = 0.857 and θ_2 = 32.8°

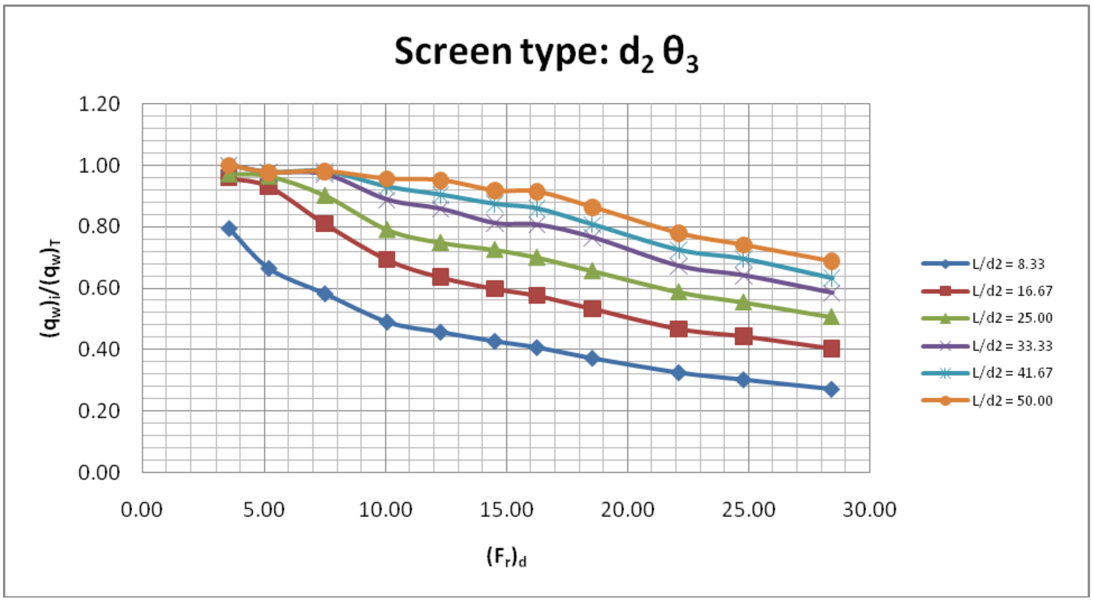

Figure 4.53 Water capture efficiencies for Tyrolean screen of d_2/a_2 = 0.857 and θ_3 = 27.8°

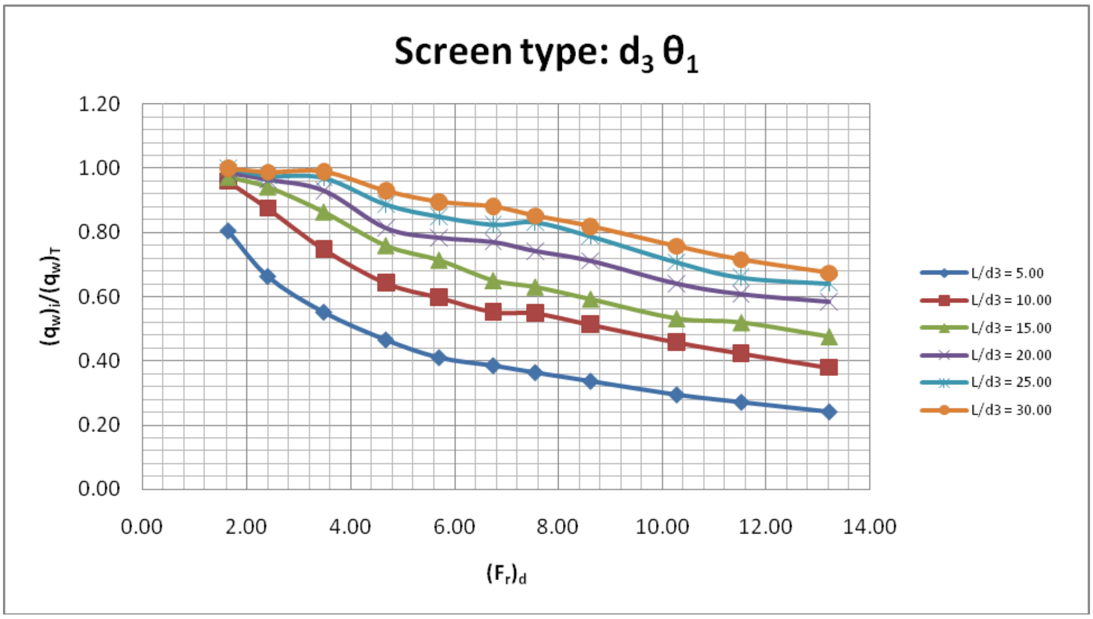

Figure 4.54 Water capture efficiencies for Tyrolean screen of d_3/a_3 = 0.833 and θ_1 = 37.0°

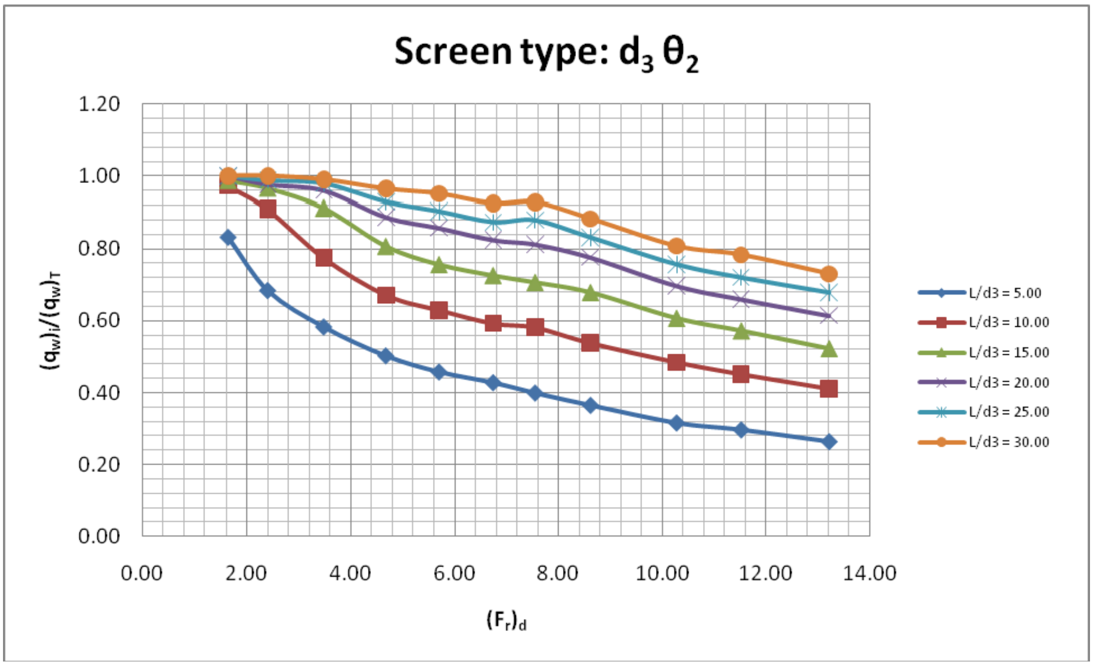

Figure 4.55 Water capture efficiencies for Tyrolean screen of d_3/a_3 = 0.833 and θ_2 = 32.8°

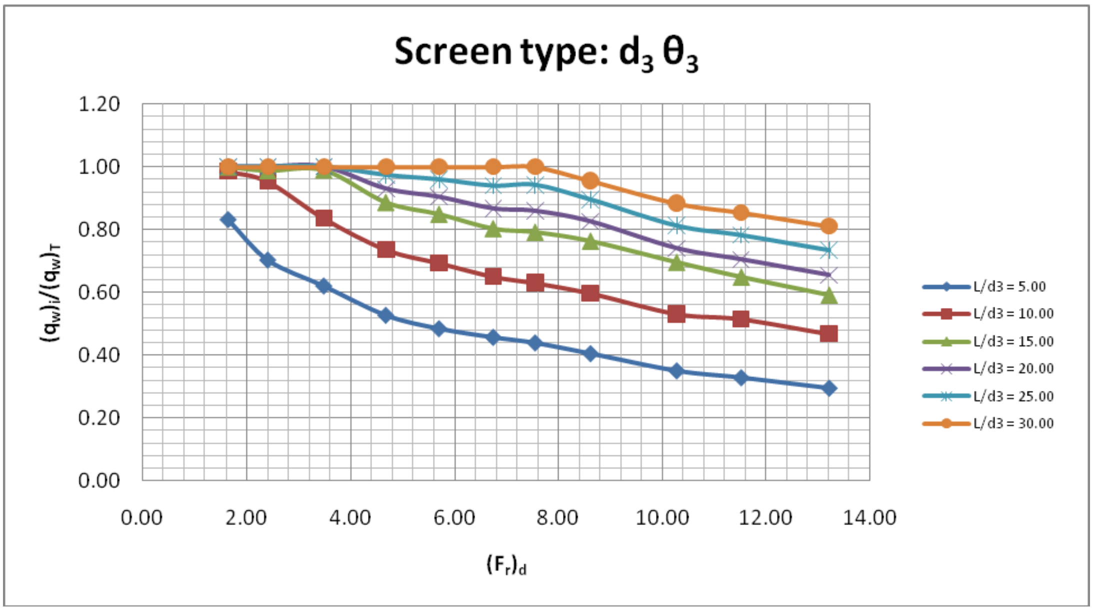

Figure 4.56 Water capture efficiencies for Tyrolean screen of d_3/a_3 = 0.833 and θ_3 = 27.8°

4.4 COMPARISON OF TYROLEAN WEIRS HAVING STEEL RACKS AND CIRCULAR-PERFORATED SCREENS

To compare the water capture efficiencies of Tyrolean weirs having steel racks and circular-perforated screens with the same net opening areas per unit width under the same hydraulic conditions, some of the figures which have already been presented in this study are given in this section and then a comparison between them is made. For this reason Figures 4.52 and 4.14, 4.48 and 4.10, and 4.56 and 4.18 are presented again as Figures 4.57 and 4.58, 4.59 and 4.60, and 4.61 and 4.62, respectively.

If these figures are carefully examined it is seen that , for the screens of the same slope, θ, but different type of openings; one having e and the other one d, WCE values of the screens having steel racks are much larger than those of the screens having circular openings for all of the L/d and L/e values tested. To show some numerical values Table 4.1 was prepared and the range of the WCE values of the screens for the same (Fr)d and (Fr)e were tabulated. From this table it can be pointed out that the screens having steel racks always have larger WCE values than the perforated screens especially at small main channel discharges. As the discharge of the main channel increases the difference observed between the WCE values of both screens gets smaller.

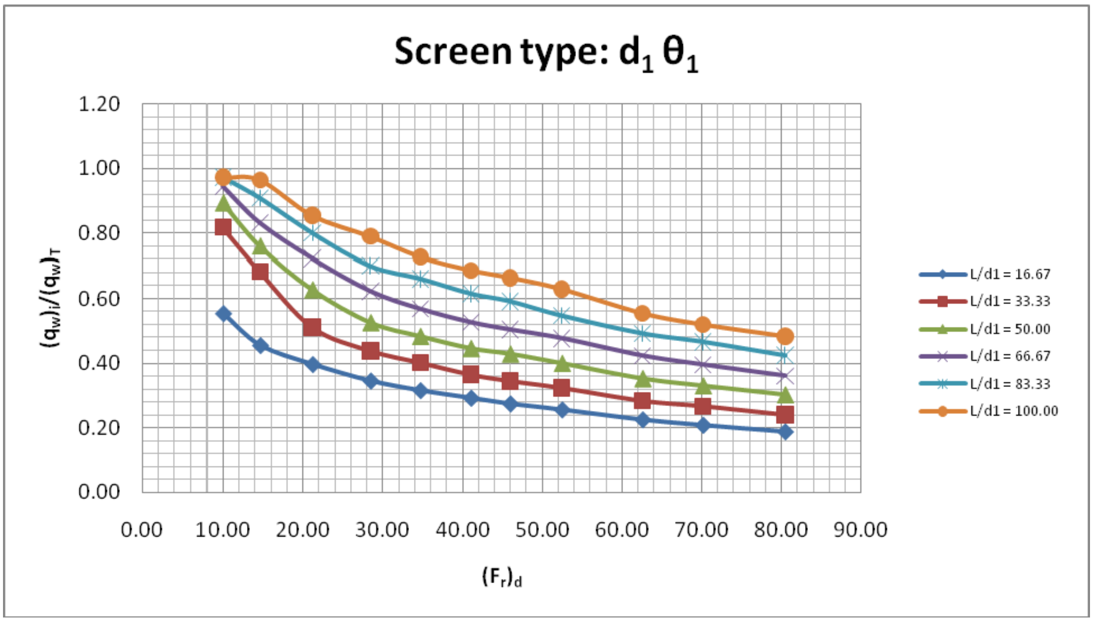

Figure 4.57 Water capture efficiencies for Tyrolean screen of d_1/a_1 = 0.60 and θ_1 = 37.0°

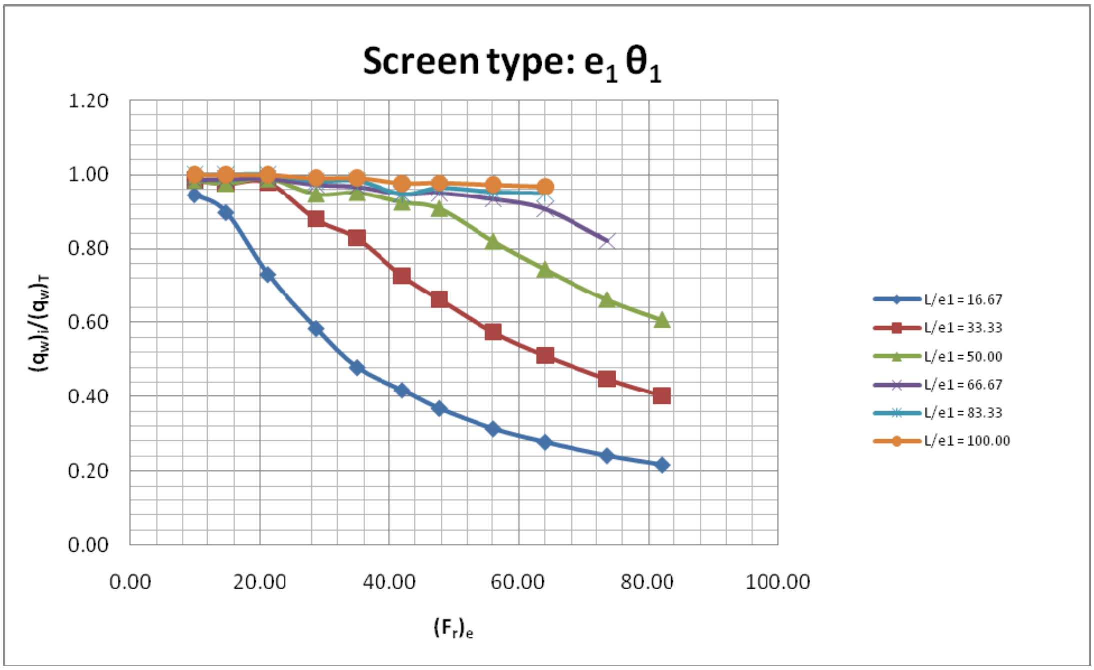

Figure 4.58 Water capture efficiencies for Tyrolean screen of e_1/a_1 = 0.23 and θ_1 = 37.0°

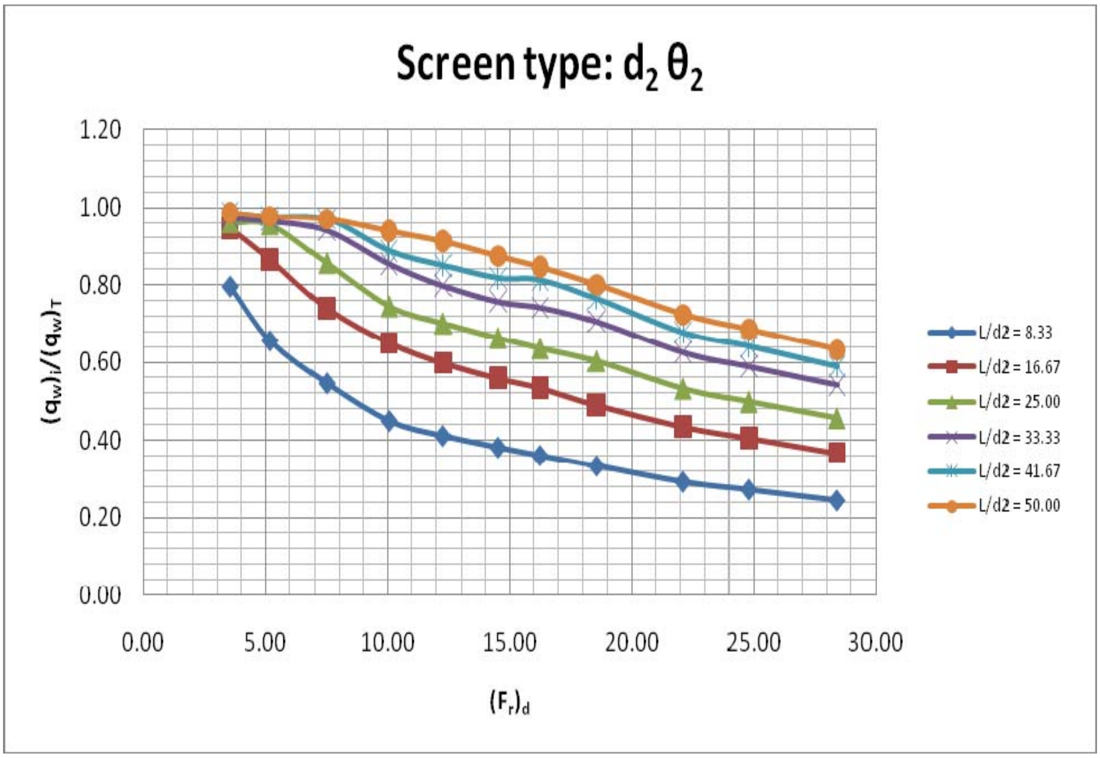

Figure 4.59 Water capture efficiencies for Tyrolean screen of d_2/a_2 = 0.86 and θ_2 = 32.8°

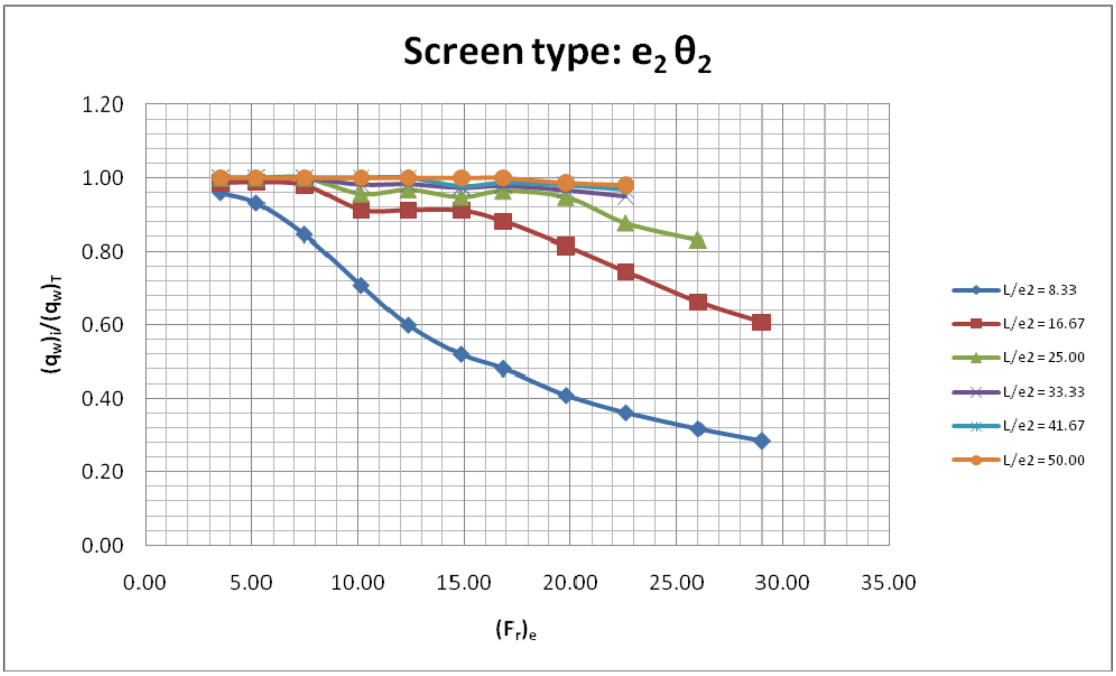

Figure 4.60 Water capture efficiencies for Tyrolean screen of e_2/a_2 = 0.375 and θ_2 = 32.8°

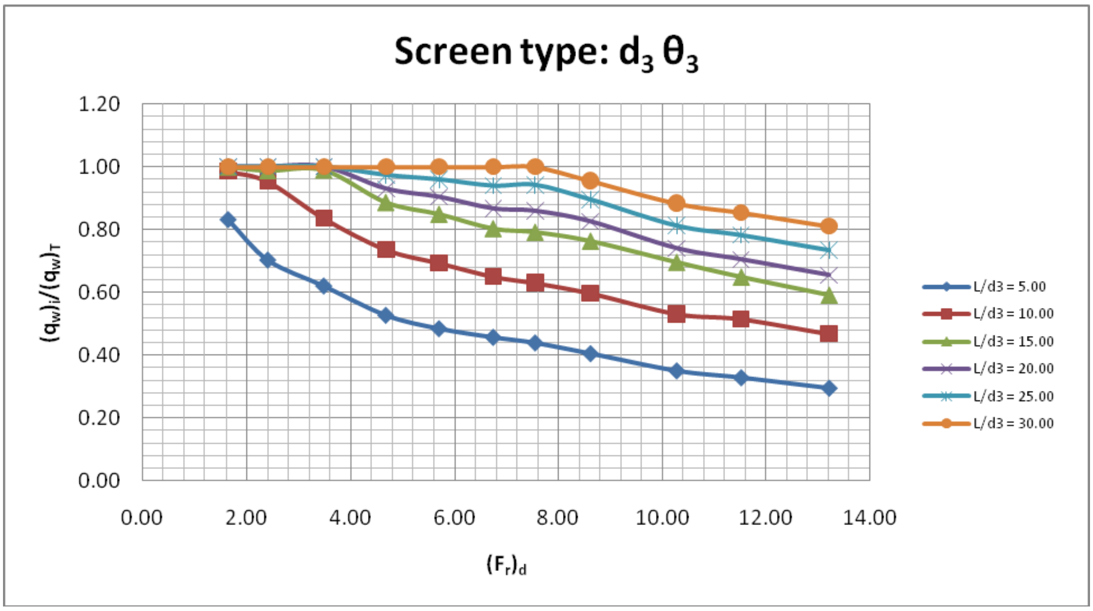

Figure 4.61 Water capture efficiencies for Tyrolean screen of d_3/a_3 = 0.83 and θ_3 = 27.8°

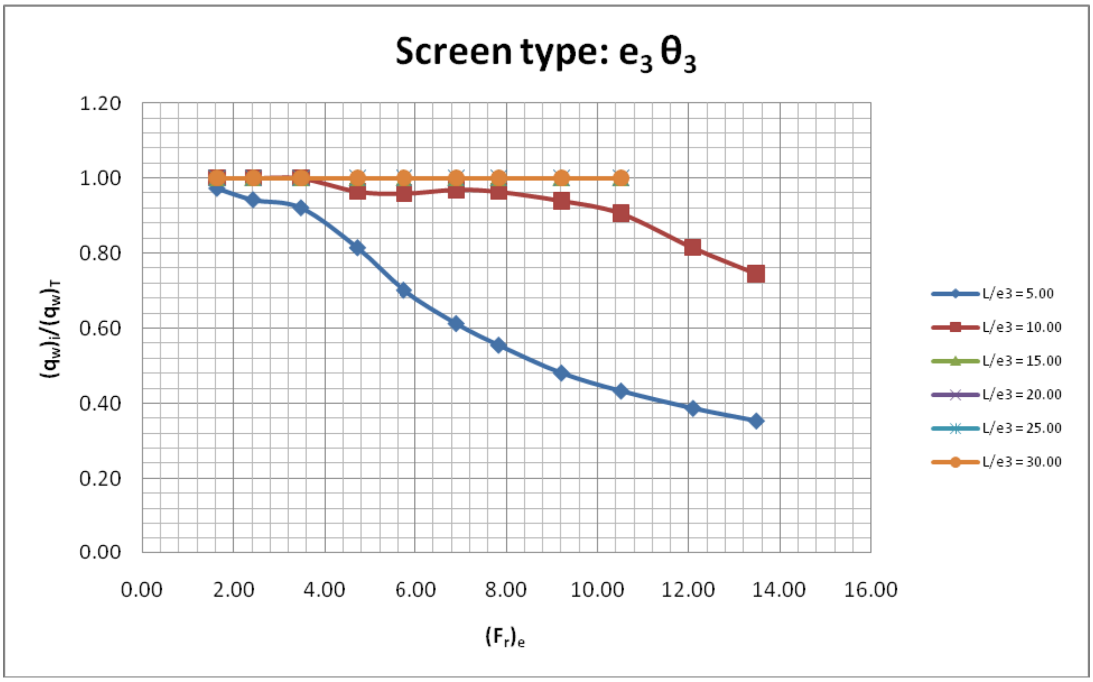

Figure 4.62 Water capture efficiencies for Tyrolean screen of e_3/a_3 = 0.5 and θ_3 = 27.8°

Table 4.1 Comparison of WCE values for screens having steel racks and circular openings

Screent Type	$(\mathbf{Fr})_{d,e}$	**Range of WCE**
$d_1\theta_1$	30	0.35-0.80
$e_1\theta_1$	30	0.56-1.00
$d_1\theta_1$	55	0.25-0.60
$e_1\theta_1$	55	0.32-1.00
$d_2\theta_2$	10	0.44-0.94
$e_2\theta_2$	10	0.72-1.00
$d_2\theta_2$	22	0.30-0.76
$e_2\theta_2$	22	0.37-0.98
$d_3\theta_3$	4	0.58-1.00
$e_3\theta_3$	4	0.88-1.00
$d_3\theta_3$	10	0.37-0.95
$e_3\theta_3$	10	0.45-1.00

4.5 NUMERICAL EXAMPLES FOR THE APPLICATION OF THE RELATIONSHIPS PRESENTED IN THIS STUDY

In order to show how the presented diagrams are used in the design of a Tyrolean weir the the following numerical examples are given.

4.5.1 Determination of C_d and $(q_w)_i$ for a Tyrolean Weir

1) **Given parameters** : $\theta = 37.0°$, $e_1 = 2.0$ cm ($e/a = 0.23$)

$L = 100$ cm ($L / e = 50.00$) , and $(q_w)_T = 0.5$ m^2/s

Determine : $(q_w)_i$ and L_2[required rack length for $(q_w)_i = (q_w)_T$] using the related figures

1**) Solution**

(a) : $Fr_e = (q_w)_T / (e^3g)^{1/2} = 0.5 / ((0.02)^3*9.81)^{1/2} = 56.4$

From Fig. 4.1 for $Fr_e = 56.4$ and $L/e = 50$ $\longrightarrow$

$C_d = 0.59$

$e = 2$ cm , $e/a = 0.23$ $\longrightarrow$ $a = 8.7$ cm

$A_{r0} = 0.23$ m^2

For $(q_w)_T = 0.5$ m^2/s $\longrightarrow$ $y_c = ((q_w)_T^2/g)^{1/3}$

$y_c = 0.294$ m

$H_c = 3/2\ y_c = 0.441$ m

$(q_w)_i = C_dA_{r0}\ (2gH_c)^{1/2} = 0.59 \times 0.23 \times (2\times 9.81 \times 0.441)^{1/2}$

$(q_w)_i = 0.399$ m^2/s

(b) : $Fr_e = (q_w)_T / (e^3g)^{1/2} = 0.5 / ((0.02)^3*9.81)^{1/2} = 56.4$

From Fig. 4.10 for $Fr_e = 56.4$ and $L/e = 50$ $\longrightarrow$

$(q_w)_i / (q_w)_T = 0,78$ $\longrightarrow$ $(q_w)_i = 0,40$ m^2/s

(c) : From Figure 4.19 for $(Fr)_e = 56.4$ and $\theta = 37.0°$

$L_2/e = 124$ $\longrightarrow$ $L_2 = 0,02 \times 124 = 2.48$ m

2) **Given parameters** : $\theta = 37.0°$, $(q_w)_T = 0.50\ m^2/s$, $(q_w)_i = 0.40\ m^2/s$

$(q_w)_i / (q_w)_T = 0.80$

Determine : e and L required.

Solution : Select L/e = 50 and e/a = 0.23

From Fig. 4.10 $\longrightarrow$ for $(q_w)_i / (q_w)_T = 0.80$

$\longrightarrow (Fr)_e = 58$

$58 = (q_w)_T / (e^3 g)^{1/2} \longrightarrow e^3 = (0,50)^2 / 58^2 x 9,81$

$\longrightarrow e = 0.020$ m

L/e = 50 $\longrightarrow$ L = 1.00 m

e/a = 0.23 $\longrightarrow$ a = 0.087

If L/e = 33.33 is selected;

From Fig. 4.10 $\longrightarrow$ for $(q_w)_i / (q_w)_T = 0.80$

$\longrightarrow (Fr)_e = 37$

$e^3 = (0.50)^2 / (37)^2 x 9,81 \longrightarrow e = 0,0265$ m

L/e = 33.33 $\longrightarrow$ L = 0.883 m

CHAPTER 5

CONCLUSIONS AND FURTHER RECOMMENDATIONS

In this experimental study, the effect of the rack inclination angle, the rack bar spacing and the rack length of a Tyrolean weir on the amount of diverted flow from the main channel were investigated. Similar experiments were repeated with the same Tyrolean weir having perforated screens of three different circular diameters instead of racks. An expression for the discharge coefficient of a Tyrolean weir was derived and its variation with the related dimensionless parameters were presented. Water capture efficiencies of each setup tested were determined and compared with each other.

From the analysis of the experimental results the following conclusions can be drawn:

1) For diverted flow discharge from the main channel per unit width an equation was derived in terms of the discharge coefficient of the Tyrolean weir, net bar opening area per unit width and the critical energy head of the flow in the main channel (Equation 2.5). If the flow discharge of the main channel and screen properties are known, by selecting the proper discharge coefficient from the related diagrams, one can determine the diverted flow discharge.
2) Water capture efficiency and wetted rack length of Tyrolean weirs were presented as a function of dimensionless parameters $(F_r)_e$ or $(Fr)_d$, L/e or L/d, e/a or d/a and θ using the dimensional analysis.
3) The discharge coefficient C_d, in general, increases with increasing $(F_r)_e$ or $(Fr)_d$ for a screen of given e or d, θ and variable length L. When

the weir has very short lengths that is small L/e or L/d values, C_d value first increases rapidly as $(F_r)_e$ or $(Fr)_d$ increase, and then gradually decreases or continues horizontally as a function of the bar inclination angle of θ.

4) If the angle of inclination of a selected screen increases while keeping $(F_r)_e$ or $(Fr)_d$ and L/e or L/d constant, C_d values slightly decrease.

5) If the bar spacing, e, or the diameter of the circular opening, d, of a screen of constant θ increases while keeping $(F_r)_e$ or $(Fr)_d$ and L/e or L/d constant, C_d values decrease.

6) The water capture efficiency, WCE, of a Tyrolean screen strongly depends on L/e or L/d and $(F_r)_e$ or $(Fr)_d$ for a screen of known e/a or e/d and θ. For a given L/e or L/d the value of WCE decreases with increasing $(F_r)_e$ or $(Fr)_{d.}$

7) With increasing θ, WCE decreases for a screen of given bar spacing, L/e or L/d and $(F_r)_e$ or $(Fr)_d$.

8) When the bar spacing or diameter of the circular opening of the screen increased while keeping the screen inclination and bar length constant, for a given main channel discharge WCE values increase.

9) The dimensionless wetted rack lengths, L_2/e, are functions of $(F_r)_e$ and θ. For a given $(F_r)_e$, L_2/e values increase with increasing θ.

10) Based on the tests conducted on Tyrolean weirs having steel racks of various inclination angles between 5° and 27° it can be stated that those weirs of θ = 5° and θ = 27° give the maximum WCE values. For practical purposes to reduce the risk of clogging of the bar spacings due to the presence of sediment in the flow, the screen slope of 27° can be suggested to use in practice.

11) WCE values of Tyrolean weirs having steel racks are always larger than those of having circular-perforated screens and the difference between these values get smaller as the main channel discharge increases.

Recommendations for future studies are as follows;

Experiments similar to those conducted in this study should be repeated using rack bars of different diameters and shapes with different bar inclination angles. After that general charts to be used in practical applications can be formed.

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APPENDIX A

MEASURED AND CALCULATED PARAMETERS FOR THE EXPERIMENTS CONDUCTED WITH THE TRASH RACKS OF DIFFERENT e AND θ

Table A .1 Measured and calculated parameters for the experiments conducted with the trash rack of e_1 and θ_1

Bar Spacing: $e_1 = 3$ mm   Angle of rack inclination: $\theta_1 = 37.0^{\circ}$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	4.86	5	9.7	0.012	17.1	0.32	1.39	2.09	0.647	32.33	16.67	0.95	9.98
4	7.61	6.83	5	12.6	0.012	19.0	0.30	1.81	2.71	0.798	42.00	16.67	0.90	14.79
5	10.90	7.97	5	15.3	0.012	21.8	0.31	2.30	3.45	0.826	51.00	16.67	0.73	21.18
6	14.78	8.63	5	19.7	0.012	24.6	0.32	2.81	4.22	0.808	65.67	16.67	0.58	28.72
7	18.01	8.63	5	22.3	0.012	25.7	0.31	3.21	4.81	0.756	74.33	16.67	0.48	34.99
8	21.62	9.02	5	25.8	0.012	27.0	0.31	3.63	5.44	0.744	86.00	16.67	0.42	42.00
9	24.54	9.02	5	30.2	0.012	27.3	0.29	3.94	5.92	0.713	100.67	16.67	0.37	47.68
10	28.85	9.02	5	36.4	0.012	28.8	0.29	4.39	6.59	0.676	121.33	16.67	0.31	56.06
11	32.94	9.12	5	43.7	0.012	29.9	0.29	4.80	7.20	0.654	145.67	16.67	0.28	63.99
3	5.14	5.07	10	9.7	0.023	17.1	0.32	1.39	2.09	0.337	32.33	33.33	0.99	9.98
4	7.61	7.44	10	12.6	0.023	19.0	0.30	1.81	2.71	0.434	42.00	33.33	0.98	14.79
5	10.90	10.68	10	15.3	0.023	21.8	0.31	2.30	3.45	0.553	51.00	33.33	0.98	21.18
6	14.78	13.00	10	19.7	0.023	24.6	0.32	2.81	4.22	0.608	65.67	33.33	0.88	28.72
7	18.01	14.91	10	22.3	0.023	25.7	0.31	3.21	4.81	0.653	74.33	33.33	0.83	34.99
8	21.62	15.72	10	25.8	0.023	27.0	0.31	3.63	5.44	0.648	86.00	33.33	0.73	42.00
9	24.54	16.28	10	30.2	0.023	27.3	0.29	3.94	5.92	0.643	100.67	33.33	0.66	47.68
10	28.85	16.56	10	36.4	0.023	28.8	0.29	4.39	6.59	0.620	121.33	33.33	0.57	56.06
11	32.94	16.84	10	43.7	0.023	29.9	0.29	4.80	7.20	0.603	145.67	33.33	0.51	63.99

Table A .1 Continued

Bar Spacing: $e_1 = 3$ mm Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_c = (3/2\ y_c)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	5.07	15	9.7	0.035	17.1	0.32	1.39	2.09	-	32.33	50.00	0.99	9.98
4	7.61	7.44	15	12.6	0.035	19.0	0.30	1.81	2.71	-	42.00	50.00	0.98	14.79
5	10.90	10.79	15	15.3	0.035	21.8	0.31	2.30	3.45	0.373	51.00	50.00	0.99	21.18
6	14.78	14.00	15	19.7	0.035	24.6	0.32	2.81	4.22	0.437	65.67	50.00	0.95	28.72
7	18.01	17.13	15	22.3	0.035	25.7	0.31	3.21	4.81	0.500	74.33	50.00	0.95	34.99
8	21.62	20.00	15	25.8	0.035	27.0	0.31	3.63	5.44	0.550	86.00	50.00	0.93	42.00
9	24.54	22.29	15	30.2	0.035	27.3	0.29	3.94	5.92	0.587	100.67	50.00	0.91	47.68
10	28.85	23.66	15	36.4	0.035	28.8	0.29	4.39	6.59	0.591	121.33	50.00	0.82	56.06
11	32.94	24.54	15	43.7	0.035	29.9	0.29	4.80	7.20	0.586	145.67	50.00	0.75	63.99
3	5.14	5.07	20	9.7	0.047	17.1	0.32	1.39	2.09	-	32.33	66.67	0.99	9.98
4	7.61	7.52	20	12.6	0.047	19.0	0.30	1.81	2.71	-	42.00	66.67	0.99	14.79
5	10.90	10.79	20	15.3	0.047	21.8	0.31	2.30	3.45	-	51.00	66.67	0.99	21.18
6	14.78	14.39	20	19.7	0.047	24.6	0.32	2.81	4.22	-	65.67	66.67	0.97	28.72
7	18.01	17.42	20	22.3	0.047	25.7	0.31	3.21	4.81	0.382	74.33	66.67	0.97	34.99
8	21.62	20.48	20	25.8	0.047	27.0	0.31	3.63	5.44	0.422	86.00	66.67	0.95	42.00
9	24.54	23.31	20	30.2	0.047	27.3	0.29	3.94	5.92	0.461	100.67	66.67	0.95	47.68
10	28.85	26.93	20	36.4	0.047	28.8	0.29	4.39	6.59	0.504	121.33	66.67	0.93	56.06
11	32.94	29.84	20	43.7	0.047	29.9	0.29	4.80	7.20	0.535	145.67	66.67	0.91	63.99

Table A .1 Continued

Bar Spacing: $e_1 = 3$ mm Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	5.14	25	9.7	0.059	17.1	0.32	1.39	2.09	-	32.33	83.33	1.00	9.98
4	7.61	7.61	25	12.6	0.059	19.0	0.30	1.81	2.71	-	42.00	83.33	1.00	14.79
5	10.90	10.90	25	15.3	0.059	21.8	0.31	2.30	3.45	-	51.00	83.33	1.00	21.18
6	14.78	14.52	25	19.7	0.059	24.6	0.32	2.81	4.22	-	65.67	83.33	0.98	28.72
7	18.01	17.71	25	22.3	0.059	25.7	0.31	3.21	4.81	-	74.33	83.33	0.98	34.99
8	21.62	20.48	25	25.8	0.059	27.0	0.31	3.63	5.44	0.338	86.00	83.33	0.95	42.00
9	24.54	23.66	25	30.2	0.059	27.3	0.29	3.94	5.92	0.374	100.67	83.33	0.96	47.68
10	28.85	27.49	25	36.4	0.059	28.8	0.29	4.39	6.59	0.412	121.33	83.33	0.95	56.06
11	32.94	31.26	25	43.7	0.059	29.9	0.29	4.80	7.20	0.448	145.67	83.33	0.95	63.99
3	5.14	5.14	30	9.7	0.070	17.1	0.32	1.39	2.09	-	32.33	100.00	1.00	9.98
4	7.61	7.61	30	12.6	0.070	19.0	0.30	1.81	2.71	-	42.00	100.00	1.00	14.79
5	10.90	10.90	30	15.3	0.070	21.8	0.31	2.30	3.45	-	51.00	100.00	1.00	21.18
6	14.78	14.65	30	19.7	0.070	24.6	0.32	2.81	4.22	-	65.67	100.00	0.99	28.72
7	18.01	17.86	30	22.3	0.070	25.7	0.31	3.21	4.81	-	74.33	100.00	0.99	34.99
8	21.62	21.12	30	25.8	0.070	27.0	0.31	3.63	5.44	-	86.00	100.00	0.98	42.00
9	24.54	24.01	30	30.2	0.070	27.3	0.29	3.94	5.92	-	100.67	100.00	0.98	47.68
10	28.85	28.07	30	36.4	0.070	28.8	0.29	4.39	6.59	0.350	121.33	100.00	0.97	56.06
11	32.94	31.88	30	43.7	0.070	29.9	0.29	4.80	7.20	0.381	145.67	100.00	0.97	63.99

Table A .2 Measured and calculated parameters for the experiments conducted with the trash rack of e_1 and θ_2

Bar Spacing: $e_1 = 3$ mm Angle of rack inclination: $\theta_2 = 32.8^{\circ}$														
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	4.93	5	9.6	0.012	17.1	0.32	1.39	2.09	0.656	32.00	16.67	0.96	9.98
4	7.61	7.00	5	12.7	0.012	19.0	0.30	1.81	2.71	0.818	42.33	16.67	0.92	14.79
5	10.90	8.35	5	16.5	0.012	21.8	0.31	2.30	3.45	0.865	55.00	16.67	0.77	21.18
6	14.78	8.92	5	19.3	0.012	24.6	0.32	2.81	4.22	0.835	64.33	16.67	0.60	28.72
7	18.01	9.32	5	22.9	0.012	25.7	0.31	3.21	4.81	0.817	76.33	16.67	0.52	34.99
8	21.62	9.63	5	26.2	0.012	27.0	0.31	3.63	5.44	0.794	87.33	16.67	0.45	42.00
9	24.54	9.73	5	29.7	0.012	27.3	0.29	3.94	5.92	0.769	99.00	16.67	0.40	47.68
10	28.85	10.04	5	35.3	0.012	28.8	0.29	4.39	6.59	0.752	117.67	16.67	0.35	56.06
11	32.94	10.15	5	42.3	0.012	29.9	0.29	4.80	7.20	0.727	141.00	16.67	0.31	63.99
3	5.14	5.07	10	9.6	0.023	17.1	0.32	1.39	2.09	-	32.00	33.33	0.99	9.98
4	7.61	7.44	10	12.7	0.023	19.0	0.30	1.81	2.71	-	42.33	33.33	0.98	14.79
5	10.90	10.68	10	16.5	0.023	21.8	0.31	2.30	3.45	0.553	55.00	33.33	0.98	21.18
6	14.78	13.37	10	19.3	0.023	24.6	0.32	2.81	4.22	0.626	64.33	33.33	0.90	28.72
7	18.01	15.31	10	22.9	0.023	25.7	0.31	3.21	4.81	0.671	76.33	33.33	0.85	34.99
8	21.62	16.28	10	26.2	0.023	27.0	0.31	3.63	5.44	0.671	87.33	33.33	0.75	42.00
9	24.54	16.98	10	29.7	0.023	27.3	0.29	3.94	5.92	0.671	99.00	33.33	0.69	47.68
10	28.85	17.42	10	35.3	0.023	28.8	0.29	4.39	6.59	0.652	117.67	33.33	0.60	56.06
11	32.94	18.01	10	42.3	0.023	29.9	0.29	4.80	7.20	0.645	141.00	33.33	0.55	63.99

Table A .2 Continued

Bar Spacing: $e_1 = 3$ mm						Angle of rack inclination: $\theta_2 = 32.8°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_c)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	5.07	15	9.6	0.035	17.1	0.32	1.39	2.09	-	32.00	50.00	0.99	9.98
4	7.61	7.52	15	12.7	0.035	19.0	0.30	1.81	2.71	-	42.33	50.00	0.99	14.79
5	10.90	10.79	15	16.5	0.035	21.8	0.31	2.30	3.45	-	55.00	50.00	0.99	21.18
6	14.78	14.26	15	19.3	0.035	24.6	0.32	2.81	4.22	0.445	64.33	50.00	0.96	28.72
7	18.01	17.27	15	22.9	0.035	25.7	0.31	3.21	4.81	0.505	76.33	50.00	0.96	34.99
8	21.62	20.32	15	26.2	0.035	27.0	0.31	3.63	5.44	0.558	87.33	50.00	0.94	42.00
9	24.54	22.62	15	29.7	0.035	27.3	0.29	3.94	5.92	0.596	99.00	50.00	0.92	47.68
10	28.85	24.54	15	35.3	0.035	28.8	0.29	4.39	6.59	0.613	117.67	50.00	0.85	56.06
11	32.94	25.26	15	42.3	0.035	29.9	0.29	4.80	7.20	0.603	141.00	50.00	0.77	63.99
3	5.14	5.07	20	9.6	0.047	17.1	0.32	1.39	2.09	-	32.00	66.67	0.99	9.98
4	7.61	7.52	20	12.7	0.047	19.0	0.30	1.81	2.71	-	42.33	66.67	0.99	14.79
5	10.90	10.79	20	16.5	0.047	21.8	0.31	2.30	3.45	-	55.00	66.67	0.99	21.18
6	14.78	14.52	20	19.3	0.047	24.6	0.32	2.81	4.22	-	64.33	66.67	0.98	28.72
7	18.01	17.71	20	22.9	0.047	25.7	0.31	3.21	4.81	0.388	76.33	66.67	0.98	34.99
8	21.62	20.80	20	26.2	0.047	27.0	0.31	3.63	5.44	0.429	87.33	66.67	0.96	42.00
9	24.54	23.66	20	29.7	0.047	27.3	0.29	3.94	5.92	0.467	99.00	66.67	0.96	47.68
10	28.85	27.49	20	35.3	0.047	28.8	0.29	4.39	6.59	0.515	117.67	66.67	0.95	56.06
11	32.94	30.24	20	42.3	0.047	29.9	0.29	4.80	7.20	0.542	141.00	66.67	0.92	63.99

Table A .2 Continued

Bar Spacing: $e_1 = 3$ mm Angle of rack inclination: $\theta_2 = 32.8°$														
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_c = (3/2\ y_c)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	5.14	25	9.6	0.059	17.1	0.32	1.39	2.09	-	32.00	83.33	1.00	9.98
4	7.61	7.61	25	12.7	0.059	19.0	0.30	1.81	2.71	-	42.33	83.33	1.00	14.79
5	10.90	10.90	25	16.5	0.059	21.8	0.31	2.30	3.45	-	55.00	83.33	1.00	21.18
6	14.78	14.65	25	19.3	0.059	24.6	0.32	2.81	4.22	-	64.33	83.33	0.99	28.72
7	18.01	17.86	25	22.9	0.059	25.7	0.31	3.21	4.81	-	76.33	83.33	0.99	34.99
8	21.62	21.12	25	26.2	0.059	27.0	0.31	3.63	5.44	-	87.33	83.33	0.98	42.00
9	24.54	24.01	25	29.7	0.059	27.3	0.29	3.94	5.92	0.380	99.00	83.33	0.98	47.68
10	28.85	28.07	25	35.3	0.059	28.8	0.29	4.39	6.59	0.420	117.67	83.33	0.97	56.06
11	32.94	31.88	25	42.3	0.059	29.9	0.29	4.80	7.20	0.457	141.00	83.33	0.97	63.99
3	5.14	5.14	30	9.6	0.070	17.1	0.32	1.39	2.09	-	32.00	100.00	1.00	9.98
4	7.61	7.61	30	12.7	0.070	19.0	0.30	1.81	2.71	-	42.33	100.00	1.00	14.79
5	10.90	10.90	30	16.5	0.070	21.8	0.31	2.30	3.45	-	55.00	100.00	1.00	21.18
6	14.78	14.78	30	19.3	0.070	24.6	0.32	2.81	4.22	-	64.33	100.00	1.00	28.72
7	18.01	18.01	30	22.9	0.070	25.7	0.31	3.21	4.81	-	76.33	100.00	1.00	34.99
8	21.62	21.12	30	26.2	0.070	27.0	0.31	3.63	5.44	-	87.33	100.00	0.98	42.00
9	24.54	24.19	30	29.7	0.070	27.3	0.29	3.94	5.92	-	99.00	100.00	0.99	47.68
10	28.85	28.26	30	35.3	0.070	28.8	0.29	4.39	6.59	0.353	117.67	100.00	0.98	56.06
11	32.94	32.30	30	42.3	0.070	29.9	0.29	4.80	7.20	0.386	141.00	100.00	0.98	63.99

Table A .3 Measured and calculated parameters for the experiments conducted with the trash rack of e_1 and θ_3

Bar Spacing: e_1 = 3 mm Angle of rack inclination: θ_3 = 27.8°

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	5.00	5	9.8	0.012	17.1	0.32	1.39	2.09	0.665	32.67	16.67	0.97	9.98
4	7.61	7.17	5	11.9	0.012	19.0	0.30	1.81	2.71	0.838	39.67	16.67	0.94	14.79
5	10.90	8.54	5	14.2	0.012	21.8	0.31	2.30	3.45	0.884	47.33	16.67	0.78	21.18
6	14.78	9.22	5	18.3	0.012	24.6	0.32	2.81	4.22	0.863	61.00	16.67	0.62	28.72
7	18.01	9.63	5	20.7	0.012	25.7	0.31	3.21	4.81	0.843	69.00	16.67	0.53	34.99
8	21.62	10.04	5	23.8	0.012	27.0	0.31	3.63	5.44	0.828	79.33	16.67	0.46	42.00
9	24.54	10.57	5	28.1	0.012	27.3	0.29	3.94	5.92	0.836	93.67	16.67	0.43	47.68
10	28.85	10.90	5	32.4	0.012	28.8	0.29	4.39	6.59	0.816	108.00	16.67	0.38	56.06
11	32.94	11.24	5	35.8	0.012	29.9	0.29	4.80	7.20	0.805	119.33	16.67	0.34	63.99
3	5.14	5.07	10	9.8	0.023	17.1	0.32	1.39	2.09	-	32.67	33.33	0.99	9.98
4	7.61	7.52	10	11.9	0.023	19.0	0.30	1.81	2.71	-	39.67	33.33	0.99	14.79
5	10.90	10.79	10	14.2	0.023	21.8	0.31	2.30	3.45	0.559	47.33	33.33	0.99	21.18
6	14.78	13.75	10	18.3	0.023	24.6	0.32	2.81	4.22	0.643	61.00	33.33	0.93	28.72
7	18.01	15.86	10	20.7	0.023	25.7	0.31	3.21	4.81	0.695	69.00	33.33	0.88	34.99
8	21.62	16.98	10	23.8	0.023	27.0	0.31	3.63	5.44	0.700	79.33	33.33	0.79	42.00
9	24.54	17.86	10	28.1	0.023	27.3	0.29	3.94	5.92	0.706	93.67	33.33	0.73	47.68
10	28.85	18.46	10	32.4	0.023	28.8	0.29	4.39	6.59	0.691	108.00	33.33	0.64	56.06
11	32.94	19.22	10	35.8	0.023	29.9	0.29	4.80	7.20	0.689	119.33	33.33	0.58	63.99

Table A .3 Continued

Bar Spacing: $e_1 = 3$ mm   Angle of rack inclination: $\theta_3 = 27.8°$

Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(e_1{}^3 g))^{0.5}$
3	5.14	5.14	15	9.8	0.035	17.1	0.32	1.39	2.09	-	32.67	50.00	1.00	9.98
4	7.61	7.61	15	11.9	0.035	19.0	0.30	1.81	2.71	-	39.67	50.00	1.00	14.79
5	10.90	10.90	15	14.2	0.035	21.8	0.31	2.30	3.45	-	47.33	50.00	1.00	21.18
6	14.78	14.52	15	18.3	0.035	24.6	0.32	2.81	4.22	0.453	61.00	50.00	0.98	28.72
7	18.01	17.71	15	20.7	0.035	25.7	0.31	3.21	4.81	0.517	69.00	50.00	0.98	34.99
8	21.62	21.12	15	23.8	0.035	27.0	0.31	3.63	5.44	0.581	79.33	50.00	0.98	42.00
9	24.54	23.31	15	28.1	0.035	27.3	0.29	3.94	5.92	0.614	93.67	50.00	0.95	47.68
10	28.85	25.08	15	32.4	0.035	28.8	0.29	4.39	6.59	0.626	108.00	50.00	0.87	56.06
11	32.94	26.36	15	35.8	0.035	29.9	0.29	4.80	7.20	0.630	119.33	50.00	0.80	63.99
3	5.14	5.14	20	9.8	0.047	17.1	0.32	1.39	2.09	-	32.67	66.67	1.00	9.98
4	7.61	7.61	20	11.9	0.047	19.0	0.30	1.81	2.71	-	39.67	66.67	1.00	14.79
5	10.90	10.90	20	14.2	0.047	21.8	0.31	2.30	3.45	-	47.33	66.67	1.00	21.18
6	14.78	14.78	20	18.3	0.047	24.6	0.32	2.81	4.22	-	61.00	66.67	1.00	28.72
7	18.01	18.01	20	20.7	0.047	25.7	0.31	3.21	4.81	-	69.00	66.67	1.00	34.99
8	21.62	21.12	20	23.8	0.047	27.0	0.31	3.63	5.44	0.435	79.33	66.67	0.98	42.00
9	24.54	24.01	20	28.1	0.047	27.3	0.29	3.94	5.92	0.474	93.67	66.67	0.98	47.68
10	28.85	27.88	20	32.4	0.047	28.8	0.29	4.39	6.59	0.522	108.00	66.67	0.97	56.06
11	32.94	31.06	20	35.8	0.047	29.9	0.29	4.80	7.20	0.556	119.33	66.67	0.94	63.99

Table A .3 Continued

Bar Spacing: $e_1 = 3$ mm Angle of rack inclination: $\theta_3 = 27.8^{\circ}$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_1	L/e_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_1^3 g))^{0.5}$
3	5.14	5.14	25	9.8	0.059	17.1	0.32	1.39	2.09	-	32.67	83.33	1.00	9.98
4	7.61	7.61	25	11.9	0.059	19.0	0.30	1.81	2.71	-	39.67	83.33	1.00	14.79
5	10.90	10.90	25	14.2	0.059	21.8	0.31	2.30	3.45	-	47.33	83.33	1.00	21.18
6	14.78	14.78	25	18.3	0.059	24.6	0.32	2.81	4.22	-	61.00	83.33	1.00	28.72
7	18.01	18.01	25	20.7	0.059	25.7	0.31	3.21	4.81	-	69.00	83.33	1.00	34.99
8	21.62	21.45	25	23.8	0.059	27.0	0.31	3.63	5.44	-	79.33	83.33	0.99	42.00
9	24.54	24.36	25	28.1	0.059	27.3	0.29	3.94	5.92	0.385	93.67	83.33	0.99	47.68
10	28.85	28.46	25	32.4	0.059	28.8	0.29	4.39	6.59	0.426	108.00	83.33	0.99	56.06
11	32.94	32.30	25	35.8	0.059	29.9	0.29	4.80	7.20	0.463	119.33	83.33	0.98	63.99
3	5.14	5.14	30	9.8	0.070	17.1	0.32	1.39	2.09	-	32.67	100.00	1.00	9.98
4	7.61	7.61	30	11.9	0.070	19.0	0.30	1.81	2.71	-	39.67	100.00	1.00	14.79
5	10.90	10.90	30	14.2	0.070	21.8	0.31	2.30	3.45	-	47.33	100.00	1.00	21.18
6	14.78	14.78	30	18.3	0.070	24.6	0.32	2.81	4.22	-	61.00	100.00	1.00	28.72
7	18.01	18.01	30	20.7	0.070	25.7	0.31	3.21	4.81	-	69.00	100.00	1.00	34.99
8	21.62	21.45	30	23.8	0.070	27.0	0.31	3.63	5.44	-	79.33	100.00	0.99	42.00
9	24.54	24.36	30	28.1	0.070	27.3	0.29	3.94	5.92	-	93.67	100.00	0.99	47.68
10	28.85	28.65	30	32.4	0.070	28.8	0.29	4.39	6.59	0.358	108.00	100.00	0.99	56.06
11	32.94	32.51	30	35.8	0.070	29.9	0.29	4.80	7.20	0.388	119.33	100.00	0.99	63.99

Table A .4 Measured and calculated parameters for the experiments conducted with the trash rack of e_2 and θ_1

Bar Spacing: $e_2 = 6$ mm   Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	4.93	5	11.8	0.019	17.1	0.32	1.39	2.09	0.407	19.67	8.33	0.96	3.53
4	7.61	6.92	5	14.2	0.019	19.0	0.30	1.81	2.71	0.501	23.67	8.33	0.91	5.23
5	10.90	8.92	5	15.6	0.019	21.8	0.31	2.30	3.45	0.573	26.00	8.33	0.82	7.49
6	14.78	9.42	5	17.8	0.019	24.6	0.32	2.81	4.22	0.547	29.67	8.33	0.64	10.15
7	18.01	9.63	5	19.4	0.019	25.7	0.31	3.21	4.81	0.523	32.33	8.33	0.53	12.37
8	21.62	9.73	5	22.7	0.019	27.0	0.31	3.63	5.44	0.497	37.83	8.33	0.45	14.85
9	24.54	9.73	5	25.1	0.019	27.3	0.29	3.94	5.92	0.477	41.83	8.33	0.40	16.86
10	28.85	9.73	5	26.9	0.019	28.8	0.29	4.39	6.59	0.452	44.83	8.33	0.34	19.82
11	32.94	9.83	5	28.8	0.019	29.9	0.29	4.80	7.20	0.437	48.00	8.33	0.30	22.63
3	5.14	5.07	10	11.8	0.038	17.1	0.32	1.39	2.09	0.209	19.67	16.67	0.99	3.53
4	7.61	7.52	10	14.2	0.038	19.0	0.30	1.81	2.71	0.272	23.67	16.67	0.99	5.23
5	10.90	10.68	10	15.6	0.038	21.8	0.31	2.30	3.45	0.343	26.00	16.67	0.98	7.49
6	14.78	13.37	10	17.8	0.038	24.6	0.32	2.81	4.22	0.388	29.67	16.67	0.90	10.15
7	18.01	16.00	10	19.4	0.038	25.7	0.31	3.21	4.81	0.435	32.33	16.67	0.89	12.37
8	21.62	18.91	10	22.7	0.038	27.0	0.31	3.63	5.44	0.483	37.83	16.67	0.87	14.85
9	24.54	19.69	10	25.1	0.038	27.3	0.29	3.94	5.92	0.482	41.83	16.67	0.80	16.86
10	28.85	20.00	10	26.9	0.038	28.8	0.29	4.39	6.59	0.464	44.83	16.67	0.69	19.82
11	32.94	20.16	10	28.8	0.038	29.9	0.29	4.80	7.20	0.448	48.00	16.67	0.61	22.63

Table A .4 Continued

Bar Spacing: $e_2 = 6$ mm						Angle of rack inclination: $\theta_1 = 37.0°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	5.07	15	11.8	0.057	17.1	0.32	1.39	2.09	-	19.67	25.00	0.99	3.53
4	7.61	7.52	15	14.2	0.057	19.0	0.30	1.81	2.71	0.182	23.67	25.00	0.99	5.23
5	10.90	10.79	15	15.6	0.057	21.8	0.31	2.30	3.45	0.231	26.00	25.00	0.99	7.49
6	14.78	14.00	15	17.8	0.057	24.6	0.32	2.81	4.22	0.271	29.67	25.00	0.95	10.15
7	18.01	17.27	15	19.4	0.057	25.7	0.31	3.21	4.81	0.313	32.33	25.00	0.96	12.37
8	21.62	20.32	15	22.7	0.057	27.0	0.31	3.63	5.44	0.346	37.83	25.00	0.94	14.85
9	24.54	22.97	15	25.1	0.057	27.3	0.29	3.94	5.92	0.375	41.83	25.00	0.94	16.86
10	28.85	26.36	15	26.9	0.057	28.8	0.29	4.39	6.59	0.408	44.83	25.00	0.91	19.82
11	32.94	28.07	15	28.8	0.057	29.9	0.29	4.80	7.20	0.416	48.00	25.00	0.85	22.63
3	5.14	5.14	20	11.8	0.076	17.1	0.32	1.39	2.09	-	19.67	33.33	1.00	3.53
4	7.61	7.61	20	14.2	0.076	19.0	0.30	1.81	2.71	-	23.67	33.33	1.00	5.23
5	10.90	10.90	20	15.6	0.076	21.8	0.31	2.30	3.45	-	26.00	33.33	1.00	7.49
6	14.78	14.52	20	17.8	0.076	24.6	0.32	2.81	4.22	0.211	29.67	33.33	0.98	10.15
7	18.01	17.71	20	19.4	0.076	25.7	0.31	3.21	4.81	0.241	32.33	33.33	0.98	12.37
8	21.62	20.96	20	22.7	0.076	27.0	0.31	3.63	5.44	0.268	37.83	33.33	0.97	14.85
9	24.54	23.83	20	25.1	0.076	27.3	0.29	3.94	5.92	0.292	41.83	33.33	0.97	16.86
10	28.85	27.49	20	26.9	0.076	28.8	0.29	4.39	6.59	0.319	44.83	33.33	0.95	19.82
11	32.94	30.85	20	28.8	0.076	29.9	0.29	4.80	7.20	0.343	48.00	33.33	0.94	22.63

Table A .4 Continued

Bar Spacing: $e_2 = 6$ mm						Angle of rack inclination: $\theta_1 = 37.0°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	5.14	25	11.8	0.095	17.1	0.32	1.39	2.09	-	19.67	41.67	1.00	3.53
4	7.61	7.61	25	14.2	0.095	19.0	0.30	1.81	2.71	-	23.67	41.67	1.00	5.23
5	10.90	10.90	25	15.6	0.095	21.8	0.31	2.30	3.45	-	26.00	41.67	1.00	7.49
6	14.78	14.78	25	17.8	0.095	24.6	0.32	2.81	4.22	-	29.67	41.67	1.00	10.15
7	18.01	18.01	25	19.4	0.095	25.7	0.31	3.21	4.81	-	32.33	41.67	1.00	12.37
8	21.62	21.12	25	22.7	0.095	27.0	0.31	3.63	5.44	0.216	37.83	41.67	0.98	14.85
9	24.54	24.10	25	25.1	0.095	27.3	0.29	3.94	5.92	0.236	41.83	41.67	0.98	16.86
10	28.85	27.88	25	26.9	0.095	28.8	0.29	4.39	6.59	0.259	44.83	41.67	0.97	19.82
11	32.94	31.88	25	28.8	0.095	29.9	0.29	4.80	7.20	0.283	48.00	41.67	0.97	22.63
3	5.14	5.14	30	11.8	0.114	17.1	0.32	1.39	2.09	-	19.67	50.00	1.00	3.53
4	7.61	7.61	30	14.2	0.114	19.0	0.30	1.81	2.71	-	23.67	50.00	1.00	5.23
5	10.90	10.90	30	15.6	0.114	21.8	0.31	2.30	3.45	-	26.00	50.00	1.00	7.49
6	14.78	14.78	30	17.8	0.114	24.6	0.32	2.81	4.22	-	29.67	50.00	1.00	10.15
7	18.01	18.01	30	19.4	0.114	25.7	0.31	3.21	4.81	-	32.33	50.00	1.00	12.37
8	21.62	21.45	30	22.7	0.114	27.0	0.31	3.63	5.44	-	37.83	50.00	0.99	14.85
9	24.54	24.19	30	25.1	0.114	27.3	0.29	3.94	5.92	-	41.83	50.00	0.99	16.86
10	28.85	28.26	30	26.9	0.114	28.8	0.29	4.39	6.59	0.219	44.83	50.00	0.98	19.82
11	32.94	32.09	30	28.8	0.114	29.9	0.29	4.80	7.20	0.238	48.00	50.00	0.97	22.63

Table A .5 Measured and calculated parameters for the experiments conducted with the trash rack of e_2 and θ_2

Bar Spacing: $e_2 = 6$ mm Angle of rack inclination: $\theta_2 = 32.8°$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	4.93	5	10.3	0.019	17.1	0.32	1.39	2.09	0.407	17.17	8.33	0.96	3.53
4	7.61	7.09	5	12.0	0.019	19.0	0.30	1.81	2.71	0.513	20.00	8.33	0.93	5.23
5	10.90	9.22	5	13.8	0.019	21.8	0.31	2.30	3.45	0.592	23.00	8.33	0.85	7.49
6	14.78	10.47	5	16.5	0.019	24.6	0.32	2.81	4.22	0.607	27.50	8.33	0.71	10.15
7	18.01	10.79	5	17.8	0.019	25.7	0.31	3.21	4.81	0.586	29.67	8.33	0.60	12.37
8	21.62	11.24	5	20.9	0.019	27.0	0.31	3.63	5.44	0.574	34.83	8.33	0.52	14.85
9	24.54	11.81	5	23.6	0.019	27.3	0.29	3.94	5.92	0.579	39.33	8.33	0.48	16.86
10	28.85	11.81	5	26.1	0.019	28.8	0.29	4.39	6.59	0.548	43.50	8.33	0.41	19.82
11	32.94	11.92	5	27.9	0.019	29.9	0.29	4.80	7.20	0.530	46.50	8.33	0.36	22.63
3	5.14	5.07	10	10.3	0.038	17.1	0.32	1.39	2.09	0.209	17.17	16.67	0.99	3.53
4	7.61	7.52	10	12.0	0.038	19.0	0.30	1.81	2.71	0.272	20.00	16.67	0.99	5.23
5	10.90	10.68	10	13.8	0.038	21.8	0.31	2.30	3.45	0.343	23.00	16.67	0.98	7.49
6	14.78	13.49	10	16.5	0.038	24.6	0.32	2.81	4.22	0.391	27.50	16.67	0.91	10.15
7	18.01	16.42	10	17.8	0.038	25.7	0.31	3.21	4.81	0.446	29.67	16.67	0.91	12.37
8	21.62	19.69	10	20.9	0.038	27.0	0.31	3.63	5.44	0.503	34.83	16.67	0.91	14.85
9	24.54	21.62	10	23.6	0.038	27.3	0.29	3.94	5.92	0.530	39.33	16.67	0.88	16.86
10	28.85	23.48	10	26.1	0.038	28.8	0.29	4.39	6.59	0.545	43.50	16.67	0.81	19.82
11	32.94	24.54	10	27.9	0.038	29.9	0.29	4.80	7.20	0.545	46.50	16.67	0.75	22.63

Table A .5 Continued

Bar Spacing: $e_2 = 6$ mm   Angle of rack inclination: $\theta_2 = 32.8°$

Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	5.14	15	10.3	0.057	17.1	0.32	1.39	2.09	-	17.17	25.00	1.00	3.53
4	7.61	7.61	15	12.0	0.057	19.0	0.30	1.81	2.71	0.184	20.00	25.00	1.00	5.23
5	10.90	10.90	15	13.8	0.057	21.8	0.31	2.30	3.45	0.233	23.00	25.00	1.00	7.49
6	14.78	14.13	15	16.5	0.057	24.6	0.32	2.81	4.22	0.273	27.50	25.00	0.96	10.15
7	18.01	17.42	15	17.8	0.057	25.7	0.31	3.21	4.81	0.315	29.67	25.00	0.97	12.37
8	21.62	20.48	15	20.9	0.057	27.0	0.31	3.63	5.44	0.349	34.83	25.00	0.95	14.85
9	24.54	23.66	15	23.6	0.057	27.3	0.29	3.94	5.92	0.386	39.33	25.00	0.96	16.86
10	28.85	27.30	15	26.1	0.057	28.8	0.29	4.39	6.59	0.423	43.50	25.00	0.95	19.82
11	32.94	28.85	15	27.9	0.057	29.9	0.29	4.80	7.20	0.427	46.50	25.00	0.88	22.63
3	5.14	5.14	20	10.3	0.076	17.1	0.32	1.39	2.09	-	17.17	33.33	1.00	3.53
4	7.61	7.61	20	12.0	0.076	19.0	0.30	1.81	2.71	-	20.00	33.33	1.00	5.23
5	10.90	10.90	20	13.8	0.076	21.8	0.31	2.30	3.45	-	23.00	33.33	1.00	7.49
6	14.78	14.52	20	16.5	0.076	24.6	0.32	2.81	4.22	-	27.50	33.33	0.98	10.15
7	18.01	17.71	20	17.8	0.076	25.7	0.31	3.21	4.81	0.241	29.67	33.33	0.98	12.37
8	21.62	21.04	20	20.9	0.076	27.0	0.31	3.63	5.44	0.269	34.83	33.33	0.97	14.85
9	24.54	24.01	20	23.6	0.076	27.3	0.29	3.94	5.92	0.294	39.33	33.33	0.98	16.86
10	28.85	27.88	20	26.1	0.076	28.8	0.29	4.39	6.59	0.324	43.50	33.33	0.97	19.82
11	32.94	31.26	20	27.9	0.076	29.9	0.29	4.80	7.20	0.347	46.50	33.33	0.95	22.63

Table A .5 Continued

Bar Spacing: $e_2 = 6$ mm	Angle of rack inclination: $\theta_2 = 32.8^{\circ}$														
Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2{}^3 g))^{0.5}$
3	5.14	5.14	25	10.3	0.095	17.1	0.32	1.39	2.09	-	17.17	41.67	1.00	3.53
4	7.61	7.61	25	12.0	0.095	19.0	0.30	1.81	2.71	-	20.00	41.67	1.00	5.23
5	10.90	10.90	25	13.8	0.095	21.8	0.31	2.30	3.45	-	23.00	41.67	1.00	7.49
6	14.78	14.78	25	16.5	0.095	24.6	0.32	2.81	4.22	-	27.50	41.67	1.00	10.15
7	18.01	18.01	25	17.8	0.095	25.7	0.31	3.21	4.81	-	29.67	41.67	1.00	12.37
8	21.62	21.12	25	20.9	0.095	27.0	0.31	3.63	5.44	-	34.83	41.67	0.98	14.85
9	24.54	24.19	25	23.6	0.095	27.3	0.29	3.94	5.92	0.237	39.33	41.67	0.99	16.86
10	28.85	28.26	25	26.1	0.095	28.8	0.29	4.39	6.59	0.262	43.50	41.67	0.98	19.82
11	32.94	31.88	25	27.9	0.095	29.9	0.29	4.80	7.20	0.283	46.50	41.67	0.97	22.63
3	5.14	5.14	30	10.3	0.114	17.1	0.32	1.39	2.09	-	17.17	50.00	1.00	3.53
4	7.61	7.61	30	12.0	0.114	19.0	0.30	1.81	2.71	-	20.00	50.00	1.00	5.23
5	10.90	10.90	30	13.8	0.114	21.8	0.31	2.30	3.45	-	23.00	50.00	1.00	7.49
6	14.78	14.78	30	16.5	0.114	24.6	0.32	2.81	4.22	-	27.50	50.00	1.00	10.15
7	18.01	18.01	30	17.8	0.114	25.7	0.31	3.21	4.81	-	29.67	50.00	1.00	12.37
8	21.62	21.62	30	20.9	0.114	27.0	0.31	3.63	5.44	-	34.83	50.00	1.00	14.85
9	24.54	24.54	30	23.6	0.114	27.3	0.29	3.94	5.92	-	39.33	50.00	1.00	16.86
10	28.85	28.46	30	26.1	0.114	28.8	0.29	4.39	6.59	-	43.50	50.00	0.99	19.82
11	32.94	32.30	30	27.9	0.114	29.9	0.29	4.80	7.20	0.239	46.50	50.00	0.98	22.63

Table A .6 Measured and calculated parameters for the experiments conducted with the trash rack of e_2 and θ_3

Bar Spacing: $e_2 = 6$ mm						Angle of rack inclination: $\theta_3 = 27.8^\circ$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	5.00	5	9.2	0.019	17.1	0.32	1.39	2.09	0.412	15.33	8.33	0.97	3.53
4	7.61	7.17	5	10.1	0.019	19.0	0.30	1.81	2.71	0.519	16.83	8.33	0.94	5.23
5	10.90	9.63	5	12.8	0.019	21.8	0.31	2.30	3.45	0.618	21.33	8.33	0.88	7.49
6	14.78	11.58	5	14.9	0.019	24.6	0.32	2.81	4.22	0.672	24.83	8.33	0.78	10.15
7	18.01	12.39	5	17.1	0.019	25.7	0.31	3.21	4.81	0.673	28.50	8.33	0.69	12.37
8	21.62	12.88	5	18.4	0.019	27.0	0.31	3.63	5.44	0.658	30.67	8.33	0.60	14.85
9	24.54	13.24	5	21.2	0.019	27.3	0.29	3.94	5.92	0.649	35.33	8.33	0.54	16.86
10	28.85	13.62	5	22.3	0.019	28.8	0.29	4.39	6.59	0.632	37.17	8.33	0.47	19.82
11	32.94	13.87	5	24.8	0.019	29.9	0.29	4.80	7.20	0.616	41.33	8.33	0.42	22.63
3	5.14	5.14	10	9.2	0.038	17.1	0.32	1.39	2.09	0.212	15.33	16.67	1.00	3.53
4	7.61	7.61	10	10.1	0.038	19.0	0.30	1.81	2.71	0.276	16.83	16.67	1.00	5.23
5	10.90	10.90	10	12.8	0.038	21.8	0.31	2.30	3.45	0.350	21.33	16.67	1.00	7.49
6	14.78	13.75	10	14.9	0.038	24.6	0.32	2.81	4.22	0.399	24.83	16.67	0.93	10.15
7	18.01	16.70	10	17.1	0.038	25.7	0.31	3.21	4.81	0.454	28.50	16.67	0.93	12.37
8	21.62	20.16	10	18.4	0.038	27.0	0.31	3.63	5.44	0.515	30.67	16.67	0.93	14.85
9	24.54	22.12	10	21.2	0.038	27.3	0.29	3.94	5.92	0.542	35.33	16.67	0.90	16.86
10	28.85	24.54	10	22.3	0.038	28.8	0.29	4.39	6.59	0.570	37.17	16.67	0.85	19.82
11	32.94	26.36	10	24.8	0.038	29.9	0.29	4.80	7.20	0.586	41.33	16.67	0.80	22.63

Table A .6 Continued

Bar Spacing: $e_2 = 6$ mm						Angle of rack inclination: $\theta_3 = 27.8°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	5.14	15	9.2	0.057	17.1	0.32	1.39	2.09	-	15.33	25.00	1.00	3.53
4	7.61	7.61	15	10.1	0.057	19.0	0.30	1.81	2.71	-	16.83	25.00	1.00	5.23
5	10.90	10.90	15	12.8	0.057	21.8	0.31	2.30	3.45	0.233	21.33	25.00	1.00	7.49
6	14.78	14.65	15	14.9	0.057	24.6	0.32	2.81	4.22	0.283	24.83	25.00	0.99	10.15
7	18.01	17.86	15	17.1	0.057	25.7	0.31	3.21	4.81	0.323	28.50	25.00	0.99	12.37
8	21.62	21.12	15	18.4	0.057	27.0	0.31	3.63	5.44	0.360	30.67	25.00	0.98	14.85
9	24.54	24.01	15	21.2	0.057	27.3	0.29	3.94	5.92	0.392	35.33	25.00	0.98	16.86
10	28.85	28.07	15	22.3	0.057	28.8	0.29	4.39	6.59	0.434	37.17	25.00	0.97	19.82
11	32.94	29.24	15	24.8	0.057	29.9	0.29	4.80	7.20	0.433	41.33	25.00	0.89	22.63
3	5.14	5.14	20	9.2	0.076	17.1	0.32	1.39	2.09	-	15.33	33.33	1.00	3.53
4	7.61	7.61	20	10.1	0.076	19.0	0.30	1.81	2.71	-	16.83	33.33	1.00	5.23
5	10.90	10.90	20	12.8	0.076	21.8	0.31	2.30	3.45	-	21.33	33.33	1.00	7.49
6	14.78	14.78	20	14.9	0.076	24.6	0.32	2.81	4.22	-	24.83	33.33	1.00	10.15
7	18.01	18.01	20	17.1	0.076	25.7	0.31	3.21	4.81	0.245	28.50	33.33	1.00	12.37
8	21.62	21.29	20	18.4	0.076	27.0	0.31	3.63	5.44	0.272	30.67	33.33	0.98	14.85
9	24.54	24.19	20	21.2	0.076	27.3	0.29	3.94	5.92	0.296	35.33	33.33	0.99	16.86
10	28.85	28.26	20	22.3	0.076	28.8	0.29	4.39	6.59	0.328	37.17	33.33	0.98	19.82
11	32.94	31.47	20	24.8	0.076	29.9	0.29	4.80	7.20	0.349	41.33	33.33	0.96	22.63

Table A .6 Continued

Bar Spacing: $e_2 = 6$ mm	Angle of rack inclination: $\theta_3 = 27.8^{\circ}$														
Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_2	L/e_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_2^3 g))^{0.5}$
3	5.14	5.14	25	9.2	0.095	17.1	0.32	1.39	2.09	-	15.33	41.67	1.00	3.53
4	7.61	7.61	25	10.1	0.095	19.0	0.30	1.81	2.71	-	16.83	41.67	1.00	5.23
5	10.90	10.90	25	12.8	0.095	21.8	0.31	2.30	3.45	-	21.33	41.67	1.00	7.49
6	14.78	14.78	25	14.9	0.095	24.6	0.32	2.81	4.22	-	24.83	41.67	1.00	10.15
7	18.01	18.01	25	17.1	0.095	25.7	0.31	3.21	4.81	-	28.50	41.67	1.00	12.37
8	21.62	21.62	25	18.4	0.095	27.0	0.31	3.63	5.44	-	30.67	41.67	1.00	14.85
9	24.54	24.54	25	21.2	0.095	27.3	0.29	3.94	5.92	-	35.33	41.67	1.00	16.86
10	28.85	28.46	25	22.3	0.095	28.8	0.29	4.39	6.59	0.264	37.17	41.67	0.99	19.82
11	32.94	32.30	25	24.8	0.095	29.9	0.29	4.80	7.20	0.287	41.33	41.67	0.98	22.63
3	5.14	5.14	30	9.2	0.114	17.1	0.32	1.39	2.09	-	15.33	50.00	1.00	3.53
4	7.61	7.61	30	10.1	0.114	19.0	0.30	1.81	2.71	-	16.83	50.00	1.00	5.23
5	10.90	10.90	30	12.8	0.114	21.8	0.31	2.30	3.45	-	21.33	50.00	1.00	7.49
6	14.78	14.78	30	14.9	0.114	24.6	0.32	2.81	4.22	-	24.83	50.00	1.00	10.15
7	18.01	18.01	30	17.1	0.114	25.7	0.31	3.21	4.81	-	28.50	50.00	1.00	12.37
8	21.62	21.62	30	18.4	0.114	27.0	0.31	3.63	5.44	-	30.67	50.00	1.00	14.85
9	24.54	24.54	30	21.2	0.114	27.3	0.29	3.94	5.92	-	35.33	50.00	1.00	16.86
10	28.85	28.85	30	22.3	0.114	28.8	0.29	4.39	6.59	-	37.17	50.00	1.00	19.82
11	32.94	32.72	30	24.8	0.114	29.9	0.29	4.80	7.20	-	41.33	50.00	0.99	22.63

Table A .7 Measured and calculated parameters for the experiments conducted with the trash rack of e_3 and θ_1

Bar Spacing: e_3 = 10 mm Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_c)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.00	5	9.8	0.025	17.1	0.32	1.39	2.09	0.312	9.80	5.00	0.97	1.64
4	7.61	7.00	5	12.1	0.025	19.0	0.30	1.81	2.71	0.384	12.10	5.00	0.92	2.43
5	10.90	9.63	5	13.8	0.025	21.8	0.31	2.30	3.45	0.468	13.80	5.00	0.88	3.48
6	14.78	10.04	5	16.9	0.025	24.6	0.32	2.81	4.22	0.441	16.90	5.00	0.68	4.72
7	18.01	10.15	5	19.1	0.025	25.7	0.31	3.21	4.81	0.418	19.10	5.00	0.56	5.75
8	21.62	10.15	5	21.8	0.025	27.0	0.31	3.63	5.44	0.393	21.80	5.00	0.47	6.90
9	24.54	10.25	5	23.2	0.025	27.3	0.29	3.94	5.92	0.381	23.20	5.00	0.42	7.84
10	28.85	10.25	5	25.4	0.025	28.8	0.29	4.39	6.59	0.361	25.40	5.00	0.36	9.21
11	32.94	10.25	5	27.3	0.025	29.9	0.29	4.80	7.20	0.345	27.30	5.00	0.31	10.52
3	5.14	5.14	10	9.8	0.050	17.1	0.32	1.39	2.09	0.161	9.80	10.00	1.00	1.64
4	7.61	7.52	10	12.1	0.050	19.0	0.30	1.81	2.71	0.206	12.10	10.00	0.99	2.43
5	10.90	10.68	10	13.8	0.050	21.8	0.31	2.30	3.45	0.260	13.80	10.00	0.98	3.48
6	14.78	13.62	10	16.9	0.050	24.6	0.32	2.81	4.22	0.299	16.90	10.00	0.92	4.72
7	18.01	16.70	10	19.1	0.050	25.7	0.31	3.21	4.81	0.344	19.10	10.00	0.93	5.75
8	21.62	20.16	10	21.8	0.050	27.0	0.31	3.63	5.44	0.390	21.80	10.00	0.93	6.90
9	24.54	22.79	10	23.2	0.050	27.3	0.29	3.94	5.92	0.423	23.20	10.00	0.93	7.84
10	28.85	23.31	10	25.4	0.050	28.8	0.29	4.39	6.59	0.410	25.40	10.00	0.81	9.21
11	32.94	23.48	10	27.3	0.050	29.9	0.29	4.80	7.20	0.395	27.30	10.00	0.71	10.52

Table A .7 Continued

Bar Spacing: $e_3 = 10$ mm   Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.14	15	9.8	0.075	17.1	0.32	1.39	2.09	-	9.80	15.00	1.00	1.64
4	7.61	7.61	15	12.1	0.075	19.0	0.30	1.81	2.71	0.139	12.10	15.00	1.00	2.43
5	10.90	10.90	15	13.8	0.075	21.8	0.31	2.30	3.45	0.177	13.80	15.00	1.00	3.48
6	14.78	14.65	15	16.9	0.075	24.6	0.32	2.81	4.22	0.215	16.90	15.00	0.99	4.72
7	18.01	17.86	15	19.1	0.075	25.7	0.31	3.21	4.81	0.245	19.10	15.00	0.99	5.75
8	21.62	21.45	15	21.8	0.075	27.0	0.31	3.63	5.44	0.277	21.80	15.00	0.99	6.90
9	24.54	24.36	15	23.2	0.075	27.3	0.29	3.94	5.92	0.301	23.20	15.00	0.99	7.84
10	28.85	27.88	15	25.4	0.075	28.8	0.29	4.39	6.59	0.327	25.40	15.00	0.97	9.21
11	32.94	31.68	15	27.3	0.075	29.9	0.29	4.80	7.20	0.355	27.30	15.00	0.96	10.52
3	5.14	5.14	20	9.8	0.100	17.1	0.32	1.39	2.09	-	9.80	20.00	1.00	1.64
4	7.61	7.61	20	12.1	0.100	19.0	0.30	1.81	2.71	-	12.10	20.00	1.00	2.43
5	10.90	10.90	20	13.8	0.100	21.8	0.31	2.30	3.45	-	13.80	20.00	1.00	3.48
6	14.78	14.78	20	16.9	0.100	24.6	0.32	2.81	4.22	0.162	16.90	20.00	1.00	4.72
7	18.01	18.01	20	19.1	0.100	25.7	0.31	3.21	4.81	0.185	19.10	20.00	1.00	5.75
8	21.62	21.62	20	21.8	0.100	27.0	0.31	3.63	5.44	0.209	21.80	20.00	1.00	6.90
9	24.54	24.54	20	23.2	0.100	27.3	0.29	3.94	5.92	0.228	23.20	20.00	1.00	7.84
10	28.85	28.26	20	25.4	0.100	28.8	0.29	4.39	6.59	0.249	25.40	20.00	0.98	9.21
11	32.94	32.30	20	27.3	0.100	29.9	0.29	4.80	7.20	0.272	27.30	20.00	0.98	10.52

Table A .7 Continued

Bar Spacing: $e_3 = 10$ mm						Angle of rack inclination: $\theta_1 = 37.0°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.14	25	9.8	0.125	17.1	0.32	1.39	2.09	-	9.80	25.00	1.00	1.64
4	7.61	7.61	25	12.1	0.125	19.0	0.30	1.81	2.71	-	12.10	25.00	1.00	2.43
5	10.90	10.90	25	13.8	0.125	21.8	0.31	2.30	3.45	-	13.80	25.00	1.00	3.48
6	14.78	14.78	25	16.9	0.125	24.6	0.32	2.81	4.22	-	16.90	25.00	1.00	4.72
7	18.01	18.01	25	19.1	0.125	25.7	0.31	3.21	4.81	-	19.10	25.00	1.00	5.75
8	21.62	21.62	25	21.8	0.125	27.0	0.31	3.63	5.44	-	21.80	25.00	1.00	6.90
9	24.54	24.54	25	23.2	0.125	27.3	0.29	3.94	5.92	0.182	23.20	25.00	1.00	7.84
10	28.85	28.85	25	25.4	0.125	28.8	0.29	4.39	6.59	0.203	25.40	25.00	1.00	9.21
11	32.94	32.94	25	27.3	0.125	29.9	0.29	4.80	7.20	0.222	27.30	25.00	1.00	10.52
3	5.14	5.14	30	9.8	0.150	17.1	0.32	1.39	2.09	-	9.80	30.00	1.00	1.64
4	7.61	7.61	30	12.1	0.150	19.0	0.30	1.81	2.71	-	12.10	30.00	1.00	2.43
5	10.90	10.90	30	13.8	0.150	21.8	0.31	2.30	3.45	-	13.80	30.00	1.00	3.48
6	14.78	14.78	30	16.9	0.150	24.6	0.32	2.81	4.22	-	16.90	30.00	1.00	4.72
7	18.01	18.01	30	19.1	0.150	25.7	0.31	3.21	4.81	-	19.10	30.00	1.00	5.75
8	21.62	21.62	30	21.8	0.150	27.0	0.31	3.63	5.44	-	21.80	30.00	1.00	6.90
9	24.54	24.54	30	23.2	0.150	27.3	0.29	3.94	5.92	-	23.20	30.00	1.00	7.84
10	28.85	28.85	30	25.4	0.150	28.8	0.29	4.39	6.59	-	25.40	30.00	1.00	9.21
11	32.94	32.94	30	27.3	0.150	29.9	0.29	4.80	7.20	-	27.30	30.00	1.00	10.52

Table A .8 Measured and calculated parameters for the experiments conducted with the trash rack of e_3 and θ_2

Bar Spacing: $e_3 = 10$ mm Angle of rack inclination: $\theta_2 = 32.8°$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.00	5	9.8	0.025	17.1	0.32	1.39	2.09	0.312	9.80	5.00	0.97	1.64
4	7.61	7.17	5	11.7	0.025	19.0	0.30	1.81	2.71	0.393	11.70	5.00	0.94	2.43
5	10.90	9.83	5	13.4	0.025	21.8	0.31	2.30	3.45	0.478	13.40	5.00	0.90	3.48
6	14.78	10.90	5	15.1	0.025	24.6	0.32	2.81	4.22	0.479	15.10	5.00	0.74	4.72
7	18.01	11.24	5	17.3	0.025	25.7	0.31	3.21	4.81	0.462	17.30	5.00	0.62	5.75
8	21.62	11.81	5	19.1	0.025	27.0	0.31	3.63	5.44	0.457	19.10	5.00	0.55	6.90
9	24.54	12.28	5	21.8	0.025	27.3	0.29	3.94	5.92	0.456	21.80	5.00	0.50	7.84
10	28.85	12.39	5	23.7	0.025	28.8	0.29	4.39	6.59	0.436	23.70	5.00	0.43	9.21
11	32.94	12.39	5	26.1	0.025	29.9	0.29	4.80	7.20	0.417	26.10	5.00	0.38	10.52
3	5.14	5.14	10	9.8	0.050	17.1	0.32	1.39	2.09	-	9.80	10.00	1.00	1.64
4	7.61	7.52	10	11.7	0.050	19.0	0.30	1.81	2.71	0.206	11.70	10.00	0.99	2.43
5	10.90	10.68	10	13.4	0.050	21.8	0.31	2.30	3.45	0.260	13.40	10.00	0.98	3.48
6	14.78	13.87	10	15.1	0.050	24.6	0.32	2.81	4.22	0.305	15.10	10.00	0.94	4.72
7	18.01	16.98	10	17.3	0.050	25.7	0.31	3.21	4.81	0.350	17.30	10.00	0.94	5.75
8	21.62	20.64	10	19.1	0.050	27.0	0.31	3.63	5.44	0.400	19.10	10.00	0.95	6.90
9	24.54	23.31	10	21.8	0.050	27.3	0.29	3.94	5.92	0.433	21.80	10.00	0.95	7.84
10	28.85	26.36	10	23.7	0.050	28.8	0.29	4.39	6.59	0.464	23.70	10.00	0.91	9.21
11	32.94	27.30	10	26.1	0.050	29.9	0.29	4.80	7.20	0.459	26.10	10.00	0.83	10.52

Table A .8 Continued

Bar Spacing: $e_3 = 10$ mm						Angle of rack inclination: $\theta_2 = 32.8°$									
Measured Parameters						Calculated Parameters									
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.14	15	9.8	0.075	17.1	0.32	1.39	2.09	-	9.80	15.00	1.00	1.64
4	7.61	7.61	15	11.7	0.075	19.0	0.30	1.81	2.71	-	11.70	15.00	1.00	2.43
5	10.90	10.90	15	13.4	0.075	21.8	0.31	2.30	3.45	-	13.40	15.00	1.00	3.48
6	14.78	14.78	15	15.1	0.075	24.6	0.32	2.81	4.22	0.217	15.10	15.00	1.00	4.72
7	18.01	18.01	15	17.3	0.075	25.7	0.31	3.21	4.81	0.247	17.30	15.00	1.00	5.75
8	21.62	21.62	15	19.1	0.075	27.0	0.31	3.63	5.44	0.279	19.10	15.00	1.00	6.90
9	24.54	24.54	15	21.8	0.075	27.3	0.29	3.94	5.92	0.304	21.80	15.00	1.00	7.84
10	28.85	28.26	15	23.7	0.075	28.8	0.29	4.39	6.59	0.331	23.70	15.00	0.98	9.21
11	32.94	32.51	15	26.1	0.075	29.9	0.29	4.80	7.20	0.365	26.10	15.00	0.99	10.52
3	5.14	5.14	20	9.8	0.100	17.1	0.32	1.39	2.09	-	9.80	20.00	1.00	1.64
4	7.61	7.61	20	11.7	0.100	19.0	0.30	1.81	2.71	-	11.70	20.00	1.00	2.43
5	10.90	10.90	20	13.4	0.100	21.8	0.31	2.30	3.45	-	13.40	20.00	1.00	3.48
6	14.78	14.78	20	15.1	0.100	24.6	0.32	2.81	4.22	-	15.10	20.00	1.00	4.72
7	18.01	18.01	20	17.3	0.100	25.7	0.31	3.21	4.81	-	17.30	20.00	1.00	5.75
8	21.62	21.62	20	19.1	0.100	27.0	0.31	3.63	5.44	0.209	19.10	20.00	1.00	6.90
9	24.54	24.54	20	21.8	0.100	27.3	0.29	3.94	5.92	0.228	21.80	20.00	1.00	7.84
10	28.85	28.85	20	23.7	0.100	28.8	0.29	4.39	6.59	0.254	23.70	20.00	1.00	9.21
11	32.94	32.94	20	26.1	0.100	29.9	0.29	4.80	7.20	0.277	26.10	20.00	1.00	10.52

Table A .8 Continued

Bar Spacing: $e_3 = 10$ mm						Angle of rack inclination: $\theta_2 = 32.8°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.14	25	9.8	0.125	17.1	0.32	1.39	2.09	-	9.80	25.00	1.00	1.64
4	7.61	7.61	25	11.7	0.125	19.0	0.30	1.81	2.71	-	11.70	25.00	1.00	2.43
5	10.90	10.90	25	13.4	0.125	21.8	0.31	2.30	3.45	-	13.40	25.00	1.00	3.48
6	14.78	14.78	25	15.1	0.125	24.6	0.32	2.81	4.22	-	15.10	25.00	1.00	4.72
7	18.01	18.01	25	17.3	0.125	25.7	0.31	3.21	4.81	-	17.30	25.00	1.00	5.75
8	21.62	21.62	25	19.1	0.125	27.0	0.31	3.63	5.44	-	19.10	25.00	1.00	6.90
9	24.54	24.54	25	21.8	0.125	27.3	0.29	3.94	5.92	-	21.80	25.00	1.00	7.84
10	28.85	28.85	25	23.7	0.125	28.8	0.29	4.39	6.59	-	23.70	25.00	1.00	9.21
11	32.94	32.94	25	26.1	0.125	29.9	0.29	4.80	7.20	-	26.10	25.00	1.00	10.52
3	5.14	5.14	30	9.8	0.150	17.1	0.32	1.39	2.09	-	9.80	30.00	1.00	1.64
4	7.61	7.61	30	11.7	0.150	19.0	0.30	1.81	2.71	-	11.70	30.00	1.00	2.43
5	10.90	10.90	30	13.4	0.150	21.8	0.31	2.30	3.45	-	13.40	30.00	1.00	3.48
6	14.78	14.78	30	15.1	0.150	24.6	0.32	2.81	4.22	-	15.10	30.00	1.00	4.72
7	18.01	18.01	30	17.3	0.150	25.7	0.31	3.21	4.81	-	17.30	30.00	1.00	5.75
8	21.62	21.62	30	19.1	0.150	27.0	0.31	3.63	5.44	-	19.10	30.00	1.00	6.90
9	24.54	24.54	30	21.8	0.150	27.3	0.29	3.94	5.92	-	21.80	30.00	1.00	7.84
10	28.85	28.85	30	23.7	0.150	28.8	0.29	4.39	6.59	-	23.70	30.00	1.00	9.21
11	32.94	32.94	30	26.1	0.150	29.9	0.29	4.80	7.20	-	26.10	30.00	1.00	10.52

Table A .9 Measured and calculated parameters for the experiments conducted with the trash rack of e_3 and θ_3

Bar Spacing: $e_3 = 10$ mm   Angle of rack inclination: $\theta_3 = 27.8°$

Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.00	5	8.7	0.025	17.1	0.32	1.39	2.09	0.312	8.70	5.00	0.97	1.64
4	7.61	7.17	5	10.1	0.025	19.0	0.30	1.81	2.71	0.393	10.10	5.00	0.94	2.43
5	10.90	10.04	5	12.4	0.025	21.8	0.31	2.30	3.45	0.489	12.40	5.00	0.92	3.48
6	14.78	12.04	5	13.7	0.025	24.6	0.32	2.81	4.22	0.529	13.70	5.00	0.81	4.72
7	18.01	12.63	5	15.8	0.025	25.7	0.31	3.21	4.81	0.520	15.80	5.00	0.70	5.75
8	21.62	13.24	5	17.6	0.025	27.0	0.31	3.63	5.44	0.513	17.60	5.00	0.61	6.90
9	24.54	13.62	5	20.2	0.025	27.3	0.29	3.94	5.92	0.506	20.20	5.00	0.55	7.84
10	28.85	13.87	5	21.5	0.025	28.8	0.29	4.39	6.59	0.488	21.50	5.00	0.48	9.21
11	32.94	14.26	5	24.2	0.025	29.9	0.29	4.80	7.20	0.480	24.20	5.00	0.43	10.52
3	5.14	5.14	10	8.7	0.050	17.1	0.32	1.39	2.09	-	8.70	10.00	1.00	1.64
4	7.61	7.61	10	10.1	0.050	19.0	0.30	1.81	2.71	0.209	10.10	10.00	1.00	2.43
5	10.90	10.90	10	12.4	0.050	21.8	0.31	2.30	3.45	0.265	12.40	10.00	1.00	3.48
6	14.78	14.26	10	13.7	0.050	24.6	0.32	2.81	4.22	0.313	13.70	10.00	0.96	4.72
7	18.01	17.27	10	15.8	0.050	25.7	0.31	3.21	4.81	0.355	15.80	10.00	0.96	5.75
8	21.62	20.96	10	17.6	0.050	27.0	0.31	3.63	5.44	0.406	17.60	10.00	0.97	6.90
9	24.54	23.66	10	20.2	0.050	27.3	0.29	3.94	5.92	0.439	20.20	10.00	0.96	7.84
10	28.85	27.11	10	21.5	0.050	28.8	0.29	4.39	6.59	0.477	21.50	10.00	0.94	9.21
11	32.94	29.84	10	24.2	0.050	29.9	0.29	4.80	7.20	0.502	24.20	10.00	0.91	10.52

Table A .9 Continued

Bar Spacing: $e_3 = 10$ mm						Angle of rack inclination: $\theta_3 = 27.8°$								
Measured Parameters						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.14	15	8.7	0.075	17.1	0.32	1.39	2.09	-	8.70	15.00	1.00	1.64
4	7.61	7.61	15	10.1	0.075	19.0	0.30	1.81	2.71	-	10.10	15.00	1.00	2.43
5	10.90	10.90	15	12.4	0.075	21.8	0.31	2.30	3.45	-	12.40	15.00	1.00	3.48
6	14.78	14.78	15	13.7	0.075	24.6	0.32	2.81	4.22	-	13.70	15.00	1.00	4.72
7	18.01	18.01	15	15.8	0.075	25.7	0.31	3.21	4.81	0.247	15.80	15.00	1.00	5.75
8	21.62	21.62	15	17.6	0.075	27.0	0.31	3.63	5.44	0.279	17.60	15.00	1.00	6.90
9	24.54	24.54	15	20.2	0.075	27.3	0.29	3.94	5.92	0.304	20.20	15.00	1.00	7.84
10	28.85	28.85	15	21.5	0.075	28.8	0.29	4.39	6.59	0.338	21.50	15.00	1.00	9.21
11	32.94	32.94	15	24.2	0.075	29.9	0.29	4.80	7.20	0.369	24.20	15.00	1.00	10.52
3	5.14	5.14	20	8.7	0.100	17.1	0.32	1.39	2.09	-	8.70	20.00	1.00	1.64
4	7.61	7.61	20	10.1	0.100	19.0	0.30	1.81	2.71	-	10.10	20.00	1.00	2.43
5	10.90	10.90	20	12.4	0.100	21.8	0.31	2.30	3.45	-	12.40	20.00	1.00	3.48
6	14.78	14.78	20	13.7	0.100	24.6	0.32	2.81	4.22	-	13.70	20.00	1.00	4.72
7	18.01	18.01	20	15.8	0.100	25.7	0.31	3.21	4.81	-	15.80	20.00	1.00	5.75
8	21.62	21.62	20	17.6	0.100	27.0	0.31	3.63	5.44	-	17.60	20.00	1.00	6.90
9	24.54	24.54	20	20.2	0.100	27.3	0.29	3.94	5.92	-	20.20	20.00	1.00	7.84
10	28.85	28.85	20	21.5	0.100	28.8	0.29	4.39	6.59	0.254	21.50	20.00	1.00	9.21
11	32.94	32.94	20	24.2	0.100	29.9	0.29	4.80	7.20	0.277	24.20	20.00	1.00	10.52

Table A .9 Continued

Bar Spacing: $e_3 = 10$ mm						Angle of rack inclination: $\theta_3 = 27.8°$								
						Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	L_2 (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L_2/e_3	L/e_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(e_3^3 g))^{0.5}$
3	5.14	5.14	25	8.7	0.125	17.1	0.32	1.39	2.09	-	8.70	25.00	1.00	1.64
4	7.61	7.61	25	10.1	0.125	19.0	0.30	1.81	2.71	-	10.10	25.00	1.00	2.43
5	10.90	10.90	25	12.4	0.125	21.8	0.31	2.30	3.45	-	12.40	25.00	1.00	3.48
6	14.78	14.78	25	13.7	0.125	24.6	0.32	2.81	4.22	-	13.70	25.00	1.00	4.72
7	18.01	18.01	25	15.8	0.125	25.7	0.31	3.21	4.81	-	15.80	25.00	1.00	5.75
8	21.62	21.62	25	17.6	0.125	27.0	0.31	3.63	5.44	-	17.60	25.00	1.00	6.90
9	24.54	24.54	25	20.2	0.125	27.3	0.29	3.94	5.92	-	20.20	25.00	1.00	7.84
10	28.85	28.85	25	21.5	0.125	28.8	0.29	4.39	6.59	-	21.50	25.00	1.00	9.21
11	32.94	32.94	25	24.2	0.125	29.9	0.29	4.80	7.20	-	24.20	25.00	1.00	10.52
3	5.14	5.14	30	8.7	0.150	17.1	0.32	1.39	2.09	-	8.70	30.00	1.00	1.64
4	7.61	7.61	30	10.1	0.150	19.0	0.30	1.81	2.71	-	10.10	30.00	1.00	2.43
5	10.90	10.90	30	12.4	0.150	21.8	0.31	2.30	3.45	-	12.40	30.00	1.00	3.48
6	14.78	14.78	30	13.7	0.150	24.6	0.32	2.81	4.22	-	13.70	30.00	1.00	4.72
7	18.01	18.01	30	15.8	0.150	25.7	0.31	3.21	4.81	-	15.80	30.00	1.00	5.75
8	21.62	21.62	30	17.6	0.150	27.0	0.31	3.63	5.44	-	17.60	30.00	1.00	6.90
9	24.54	24.54	30	20.2	0.150	27.3	0.29	3.94	5.92	-	20.20	30.00	1.00	7.84
10	28.85	28.85	30	21.5	0.150	28.8	0.29	4.39	6.59	-	21.50	30.00	1.00	9.21
11	32.94	32.94	30	24.2	0.150	29.9	0.29	4.80	7.20	-	24.20	30.00	1.00	10.52

APPENDIX B

MEASURED AND CALCULATED PARAMETERS FOR THE EXPERIMENTS CONDUCTED WITH THE PERFORATED PLATES OF DIFFERENT d AND θ

Table B .1 Measured and calculated parameters for the experiments conducted with the trash rack of d_1 and θ_1

Diameter of circle : $d_1 = 3$ mm								Angle of rack inclination: $\theta_1 = 37.0^{\circ}$				
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	2.85	5	0.012	17.1	0.32	1.39	2.09	0.380	16.67	0.56	9.98
4	7.52	3.43	5	0.012	18.8	0.30	1.79	2.69	0.402	16.67	0.46	14.62
5	10.90	4.33	5	0.012	21.8	0.31	2.30	3.45	0.448	16.67	0.40	21.18
6	14.65	5.07	5	0.012	24.4	0.32	2.80	4.19	0.476	16.67	0.35	28.46
7	17.86	5.65	5	0.012	25.5	0.31	3.19	4.79	0.496	16.67	0.32	34.70
8	21.12	6.18	5	0.012	26.4	0.30	3.57	5.35	0.514	16.67	0.29	41.05
9	23.66	6.50	5	0.012	26.3	0.28	3.85	5.77	0.520	16.67	0.27	45.97
10	27.00	6.92	5	0.012	27.0	0.27	4.20	6.31	0.530	16.67	0.26	52.46
11	32.20	7.26	5	0.012	29.3	0.28	4.73	7.09	0.524	16.67	0.23	62.57
12	36.10	7.52	5	0.012	30.1	0.28	5.10	7.65	0.523	16.67	0.21	70.14
13	41.40	7.79	5	0.012	31.8	0.28	5.59	8.39	0.517	16.67	0.19	80.44
3	5.14	4.20	10	0.023	17.1	0.32	1.39	2.09	0.280	33.33	0.82	9.98
4	7.52	5.14	10	0.023	18.8	0.30	1.79	2.69	0.301	33.33	0.68	14.62
5	10.90	5.57	10	0.023	21.8	0.31	2.30	3.45	0.289	33.33	0.51	21.18
6	14.65	6.42	10	0.023	24.4	0.32	2.80	4.19	0.301	33.33	0.44	28.46
7	17.86	7.17	10	0.023	25.5	0.31	3.19	4.79	0.315	33.33	0.40	34.70
8	21.12	7.70	10	0.023	26.4	0.30	3.57	5.35	0.320	33.33	0.36	41.05
9	23.66	8.16	10	0.023	26.3	0.28	3.85	5.77	0.326	33.33	0.34	45.97
10	27.00	8.73	10	0.023	27.0	0.27	4.20	6.31	0.334	33.33	0.32	52.46
11	32.20	9.12	10	0.023	29.3	0.28	4.73	7.09	0.329	33.33	0.28	62.57
12	36.10	9.63	10	0.023	30.1	0.28	5.10	7.65	0.334	33.33	0.27	70.14
13	41.40	9.94	10	0.023	31.8	0.28	5.59	8.39	0.330	33.33	0.24	80.44

Table B .1 Continued

Diameter of circle : $d_1 = 3$ mm					Angle of rack inclination: $\theta_1 = 37.0°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_1{}^3 g))^{0.5}$
3	5.14	4.59	15	0.035	17.1	0.32	1.39	2.09	-	50.00	0.89	9.98
4	7.52	5.72	15	0.035	18.8	0.30	1.79	2.69	-	50.00	0.76	14.62
5	10.90	6.83	15	0.035	21.8	0.31	2.30	3.45	0.236	50.00	0.63	21.18
6	14.65	7.70	15	0.035	24.4	0.32	2.80	4.19	0.241	50.00	0.53	28.46
7	17.86	8.63	15	0.035	25.5	0.31	3.19	4.79	0.253	50.00	0.48	34.70
8	21.12	9.42	15	0.035	26.4	0.30	3.57	5.35	0.261	50.00	0.45	41.05
9	23.66	10.15	15	0.035	26.3	0.28	3.85	5.77	0.271	50.00	0.43	45.97
10	27.00	10.79	15	0.035	27.0	0.27	4.20	6.31	0.275	50.00	0.40	52.46
11	32.20	11.35	15	0.035	29.3	0.28	4.73	7.09	0.273	50.00	0.35	62.57
12	36.10	11.92	15	0.035	30.1	0.28	5.10	7.65	0.276	50.00	0.33	70.14
13	41.40	12.51	15	0.035	31.8	0.28	5.59	8.39	0.277	50.00	0.30	80.44
3	5.14	4.86	20	0.047	17.1	0.32	1.39	2.09	-	66.67	0.95	9.98
4	7.52	6.26	20	0.047	18.8	0.30	1.79	2.69	-	66.67	0.83	14.62
5	10.90	7.88	20	0.047	21.8	0.31	2.30	3.45	-	66.67	0.72	21.18
6	14.65	9.12	20	0.047	24.4	0.32	2.80	4.19	-	66.67	0.62	28.46
7	17.86	10.15	20	0.047	25.5	0.31	3.19	4.79	0.223	66.67	0.57	34.70
8	21.12	11.12	20	0.047	26.4	0.30	3.57	5.35	0.231	66.67	0.53	41.05
9	23.66	11.92	20	0.047	26.3	0.28	3.85	5.77	0.238	66.67	0.50	45.97
10	27.00	12.88	20	0.047	27.0	0.27	4.20	6.31	0.246	66.67	0.48	52.46
11	32.20	13.62	20	0.047	29.3	0.28	4.73	7.09	0.246	66.67	0.42	62.57
12	36.10	14.26	20	0.047	30.1	0.28	5.10	7.65	0.248	66.67	0.39	70.14
13	41.40	14.91	20	0.047	31.8	0.28	5.59	8.39	0.248	66.67	0.36	80.44

Table B .1 Continued

Diameter of circle : $d_1 = 3$ mm					Angle of rack inclination: $\theta_1 = 37.0^{\circ}$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	5.00	25	0.059	17.1	0.32	1.39	2.09	-	83.33	0.97	9.98
4	7.52	6.83	25	0.059	18.8	0.30	1.79	2.69	-	83.33	0.91	14.62
5	10.90	8.73	25	0.059	21.8	0.31	2.30	3.45	-	83.33	0.80	21.18
6	14.65	10.25	25	0.059	24.4	0.32	2.80	4.19	-	83.33	0.70	28.46
7	17.86	11.81	25	0.059	25.5	0.31	3.19	4.79	-	83.33	0.66	34.70
8	21.12	13.00	25	0.059	26.4	0.30	3.57	5.35	0.216	83.33	0.62	41.05
9	23.66	14.00	25	0.059	26.3	0.28	3.85	5.77	0.224	83.33	0.59	45.97
10	27.00	14.78	25	0.059	27.0	0.27	4.20	6.31	0.226	83.33	0.55	52.46
11	32.20	15.86	25	0.059	29.3	0.28	4.73	7.09	0.229	83.33	0.49	62.57
12	36.10	16.84	25	0.059	30.1	0.28	5.10	7.65	0.234	83.33	0.47	70.14
13	41.40	17.56	25	0.059	31.8	0.28	5.59	8.39	0.233	83.33	0.42	80.44
3	5.14	5.00	30	0.070	17.1	0.32	1.39	2.09	-	100.00	0.97	9.98
4	7.52	7.26	30	0.070	18.8	0.30	1.79	2.69	-	100.00	0.97	14.62
5	10.90	9.32	30	0.070	21.8	0.31	2.30	3.45	-	100.00	0.85	21.18
6	14.65	11.58	30	0.070	24.4	0.32	2.80	4.19	-	100.00	0.79	28.46
7	17.86	13.00	30	0.070	25.5	0.31	3.19	4.79	-	100.00	0.73	34.70
8	21.12	14.52	30	0.070	26.4	0.30	3.57	5.35	-	100.00	0.69	41.05
9	23.66	15.72	30	0.070	26.3	0.28	3.85	5.77	-	100.00	0.66	45.97
10	27.00	16.98	30	0.070	27.0	0.27	4.20	6.31	0.217	100.00	0.63	52.46
11	32.20	17.86	30	0.070	29.3	0.28	4.73	7.09	0.215	100.00	0.55	62.57
12	36.10	18.76	30	0.070	30.1	0.28	5.10	7.65	0.217	100.00	0.52	70.14
13	41.40	20.00	30	0.070	31.8	0.28	5.59	8.39	0.221	100.00	0.48	80.44

Table B.2 Measured and calculated parameters for the experiments conducted with the trash rack of d_1 and θ_2

Diameter of circle : d_1 = 3 mm					Angle of rack inclination: $\theta_2 = 32.8^o$							
Measured Parameters					**Calculated Parameters**							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	2.85	5	0.012	17.1	0.32	1.39	2.09	0.380	16.67	0.56	9.98
4	7.52	3.55	5	0.012	18.8	0.30	1.79	2.69	0.416	16.67	0.47	14.62
5	10.90	4.46	5	0.012	21.8	0.31	2.30	3.45	0.462	16.67	0.41	21.18
6	14.65	5.21	5	0.012	24.4	0.32	2.80	4.19	0.489	16.67	0.36	28.46
7	17.86	5.80	5	0.012	25.5	0.31	3.19	4.79	0.509	16.67	0.32	34.70
8	21.12	6.34	5	0.012	26.4	0.30	3.57	5.35	0.527	16.67	0.30	41.05
9	23.66	6.83	5	0.012	26.3	0.28	3.85	5.77	0.547	16.67	0.29	45.97
10	27.00	7.17	5	0.012	27.0	0.27	4.20	6.31	0.549	16.67	0.27	52.46
11	32.20	7.61	5	0.012	29.3	0.28	4.73	7.09	0.550	16.67	0.24	62.57
12	36.10	7.88	5	0.012	30.1	0.28	5.10	7.65	0.548	16.67	0.22	70.14
13	41.40	8.25	5	0.012	31.8	0.28	5.59	8.39	0.548	16.67	0.20	80.44
3	5.14	4.20	10	0.023	17.1	0.32	1.39	2.09	-	33.33	0.82	9.98
4	7.52	5.14	10	0.023	18.8	0.30	1.79	2.69	-	33.33	0.68	14.62
5	10.90	6.34	10	0.023	21.8	0.31	2.30	3.45	0.329	33.33	0.58	21.18
6	14.65	7.17	10	0.023	24.4	0.32	2.80	4.19	0.337	33.33	0.49	28.46
7	17.86	7.97	10	0.023	25.5	0.31	3.19	4.79	0.350	33.33	0.45	34.70
8	21.12	8.83	10	0.023	26.4	0.30	3.57	5.35	0.367	33.33	0.42	41.05
9	23.66	9.22	10	0.023	26.3	0.28	3.85	5.77	0.369	33.33	0.39	45.97
10	27.00	9.94	10	0.023	27.0	0.27	4.20	6.31	0.380	33.33	0.37	52.46
11	32.20	10.47	10	0.023	29.3	0.28	4.73	7.09	0.378	33.33	0.33	62.57
12	36.10	11.01	10	0.023	30.1	0.28	5.10	7.65	0.383	33.33	0.31	70.14
13	41.40	11.58	10	0.023	31.8	0.28	5.59	8.39	0.384	33.33	0.28	80.44

Table B .2 Continued

Diameter of circle : $d_1 = 3$ mm					Angle of rack inclination: $\theta_2 = 32.8^{\circ}$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	5.00	15	0.035	17.1	0.32	1.39	2.09	-	50.00	0.97	9.98
4	7.52	6.34	15	0.035	18.8	0.30	1.79	2.69	-	50.00	0.84	14.62
5	10.90	7.70	15	0.035	21.8	0.31	2.30	3.45	-	50.00	0.71	21.18
6	14.65	8.92	15	0.035	24.4	0.32	2.80	4.19	0.279	50.00	0.61	28.46
7	17.86	9.83	15	0.035	25.5	0.31	3.19	4.79	0.288	50.00	0.55	34.70
8	21.12	10.79	15	0.035	26.4	0.30	3.57	5.35	0.299	50.00	0.51	41.05
9	23.66	11.58	15	0.035	26.3	0.28	3.85	5.77	0.309	50.00	0.49	45.97
10	27.00	12.51	15	0.035	27.0	0.27	4.20	6.31	0.319	50.00	0.46	52.46
11	32.20	13.12	15	0.035	29.3	0.28	4.73	7.09	0.316	50.00	0.41	62.57
12	36.10	13.87	15	0.035	30.1	0.28	5.10	7.65	0.321	50.00	0.38	70.14
13	41.40	14.39	15	0.035	31.8	0.28	5.59	8.39	0.318	50.00	0.35	80.44
3	5.14	5.00	20	0.047	17.1	0.32	1.39	2.09	-	66.67	0.97	9.98
4	7.52	6.83	20	0.047	18.8	0.30	1.79	2.69	-	66.67	0.91	14.62
5	10.90	8.63	20	0.047	21.8	0.31	2.30	3.45	-	66.67	0.79	21.18
6	14.65	9.94	20	0.047	24.4	0.32	2.80	4.19	-	66.67	0.68	28.46
7	17.86	11.35	20	0.047	25.5	0.31	3.19	4.79	0.249	66.67	0.64	34.70
8	21.12	12.51	20	0.047	26.4	0.30	3.57	5.35	0.260	66.67	0.59	41.05
9	23.66	13.62	20	0.047	26.3	0.28	3.85	5.77	0.272	66.67	0.58	45.97
10	27.00	14.39	20	0.047	27.0	0.27	4.20	6.31	0.275	66.67	0.53	52.46
11	32.20	15.18	20	0.047	29.3	0.28	4.73	7.09	0.274	66.67	0.47	62.57
12	36.10	16.28	20	0.047	30.1	0.28	5.10	7.65	0.283	66.67	0.45	70.14
13	41.40	16.98	20	0.047	31.8	0.28	5.59	8.39	0.282	66.67	0.41	80.44

Table B .2 Continued

Diameter of circle : $d_1 = 3$ mm Angle of rack inclination: $\theta_2 = 32.8^{\circ}$													
Measured Parameters					Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	5.00	25	0.059	17.1	0.32	1.39	2.09	-	83.33	0.97	9.98
4	7.52	7.17	25	0.059	18.8	0.30	1.79	2.69	-	83.33	0.95	14.62
5	10.90	9.22	25	0.059	21.8	0.31	2.30	3.45	-	83.33	0.85	21.18
6	14.65	11.01	25	0.059	24.4	0.32	2.80	4.19	-	83.33	0.75	28.46
7	17.86	12.51	25	0.059	25.5	0.31	3.19	4.79	-	83.33	0.70	34.70
8	21.12	13.87	25	0.059	26.4	0.30	3.57	5.35	-	83.33	0.66	41.05
9	23.66	14.91	25	0.059	26.3	0.28	3.85	5.77	0.239	83.33	0.63	45.97
10	27.00	16.00	25	0.059	27.0	0.27	4.20	6.31	0.245	83.33	0.59	52.46
11	32.20	16.98	25	0.059	29.3	0.28	4.73	7.09	0.245	83.33	0.53	62.57
12	36.10	17.86	25	0.059	30.1	0.28	5.10	7.65	0.248	83.33	0.49	70.14
13	41.40	18.76	25	0.059	31.8	0.28	5.59	8.39	0.249	83.33	0.45	80.44
3	5.14	5.00	30	0.070	17.1	0.32	1.39	2.09	-	100.00	0.97	9.98
4	7.52	7.17	30	0.070	18.8	0.30	1.79	2.69	-	100.00	0.95	14.62
5	10.90	10.15	30	0.070	21.8	0.31	2.30	3.45	-	100.00	0.93	21.18
6	14.65	12.28	30	0.070	24.4	0.32	2.80	4.19	-	100.00	0.84	28.46
7	17.86	14.00	30	0.070	25.5	0.31	3.19	4.79	-	100.00	0.78	34.70
8	21.12	15.59	30	0.070	26.4	0.30	3.57	5.35	-	100.00	0.74	41.05
9	23.66	16.98	30	0.070	26.3	0.28	3.85	5.77	-	100.00	0.72	45.97
10	27.00	18.16	30	0.070	27.0	0.27	4.20	6.31	0.232	100.00	0.67	52.46
11	32.20	19.22	30	0.070	29.3	0.28	4.73	7.09	0.231	100.00	0.60	62.57
12	36.10	20.16	30	0.070	30.1	0.28	5.10	7.65	0.233	100.00	0.56	70.14
13	41.40	21.62	30	0.070	31.8	0.28	5.59	8.39	0.239	100.00	0.52	80.44

Table B .3 Measured and calculated parameters for the experiments conducted with the trash rack of d_1 and θ_3

Diameter of circle: d_1 = 3 mm					Angle of rack inclination: $\theta_3 = 27.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	2.85	5	0.012	17.1	0.32	1.39	2.09	0.380	16.67	0.56	9.98
4	7.52	3.60	5	0.012	18.8	0.30	1.79	2.69	0.422	16.67	0.48	14.62
5	10.90	4.59	5	0.012	21.8	0.31	2.30	3.45	0.475	16.67	0.42	21.18
6	14.65	5.28	5	0.012	24.4	0.32	2.80	4.19	0.496	16.67	0.36	28.46
7	17.86	6.03	5	0.012	25.5	0.31	3.19	4.79	0.530	16.67	0.34	34.70
8	21.12	6.75	5	0.012	26.4	0.30	3.57	5.35	0.561	16.67	0.32	41.05
9	23.66	7.17	5	0.012	26.3	0.28	3.85	5.77	0.574	16.67	0.30	45.97
10	27.00	7.61	5	0.012	27.0	0.27	4.20	6.31	0.583	16.67	0.28	52.46
11	32.20	7.97	5	0.012	29.3	0.28	4.73	7.09	0.576	16.67	0.25	62.57
12	36.10	8.35	5	0.012	30.1	0.28	5.10	7.65	0.580	16.67	0.23	70.14
13	41.40	8.63	5	0.012	31.8	0.28	5.59	8.39	0.573	16.67	0.21	80.44
3	5.14	4.20	10	0.023	17.1	0.32	1.39	2.09	-	33.33	0.82	9.98
4	7.52	5.14	10	0.023	18.8	0.30	1.79	2.69	-	33.33	0.68	14.62
5	10.90	6.42	10	0.023	21.8	0.31	2.30	3.45	0.333	33.33	0.59	21.18
6	14.65	7.35	10	0.023	24.4	0.32	2.80	4.19	0.345	33.33	0.50	28.46
7	17.86	8.35	10	0.023	25.5	0.31	3.19	4.79	0.367	33.33	0.47	34.70
8	21.12	9.42	10	0.023	26.4	0.30	3.57	5.35	0.391	33.33	0.45	41.05
9	23.66	10.15	10	0.023	26.3	0.28	3.85	5.77	0.406	33.33	0.43	45.97
10	27.00	10.79	10	0.023	27.0	0.27	4.20	6.31	0.413	33.33	0.40	52.46
11	32.20	11.58	10	0.023	29.3	0.28	4.73	7.09	0.418	33.33	0.36	62.57
12	36.10	12.16	10	0.023	30.1	0.28	5.10	7.65	0.422	33.33	0.34	70.14
13	41.40	12.63	10	0.023	31.8	0.28	5.59	8.39	0.419	33.33	0.31	80.44

Table B .3 Continued

Diameter of circle: $d_1 = 3$ mm					Angle of rack inclination: $\theta_3 = 27.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_1{}^3 g))^{0.5}$
3	5.14	5.00	15	0.035	17.1	0.32	1.39	2.09	-	50.00	0.97	9.98
4	7.52	6.34	15	0.035	18.8	0.30	1.79	2.69	-	50.00	0.84	14.62
5	10.90	7.70	15	0.035	21.8	0.31	2.30	3.45	-	50.00	0.71	21.18
6	14.65	9.02	15	0.035	24.4	0.32	2.80	4.19	0.282	50.00	0.62	28.46
7	17.86	10.36	15	0.035	25.5	0.31	3.19	4.79	0.303	50.00	0.58	34.70
8	21.12	11.58	15	0.035	26.4	0.30	3.57	5.35	0.321	50.00	0.55	41.05
9	23.66	12.63	15	0.035	26.3	0.28	3.85	5.77	0.337	50.00	0.53	45.97
10	27.00	13.49	15	0.035	27.0	0.27	4.20	6.31	0.344	50.00	0.50	52.46
11	32.20	14.39	15	0.035	29.3	0.28	4.73	7.09	0.346	50.00	0.45	62.57
12	36.10	15.18	15	0.035	30.1	0.28	5.10	7.65	0.352	50.00	0.42	70.14
13	41.40	15.86	15	0.035	31.8	0.28	5.59	8.39	0.351	50.00	0.38	80.44
3	5.14	5.00	20	0.047	17.1	0.32	1.39	2.09	-	66.67	0.97	9.98
4	7.52	6.83	20	0.047	18.8	0.30	1.79	2.69	-	66.67	0.91	14.62
5	10.90	9.12	20	0.047	21.8	0.31	2.30	3.45	-	66.67	0.84	21.18
6	14.65	10.90	20	0.047	24.4	0.32	2.80	4.19	-	66.67	0.74	28.46
7	17.86	12.28	20	0.047	25.5	0.31	3.19	4.79	-	66.67	0.69	34.70
8	21.12	13.87	20	0.047	26.4	0.30	3.57	5.35	0.288	66.67	0.66	41.05
9	23.66	15.05	20	0.047	26.3	0.28	3.85	5.77	0.301	66.67	0.64	45.97
10	27.00	16.28	20	0.047	27.0	0.27	4.20	6.31	0.312	66.67	0.60	52.46
11	32.20	17.13	20	0.047	29.3	0.28	4.73	7.09	0.309	66.67	0.53	62.57
12	36.10	17.86	20	0.047	30.1	0.28	5.10	7.65	0.310	66.67	0.49	70.14
13	41.40	18.76	20	0.047	31.8	0.28	5.59	8.39	0.311	66.67	0.45	80.44

Table B.3 Continued

Diameter of circle: $d_1 = 3$ mm					Angle of rack inclination: $\theta_3 = 27.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_1	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_1^3 g))^{0.5}$
3	5.14	5.00	25	0.059	17.1	0.32	1.39	2.09	-	83.33	0.97	9.98
4	7.52	7.26	25	0.059	18.8	0.30	1.79	2.69	-	83.33	0.97	14.62
5	10.90	9.63	25	0.059	21.8	0.31	2.30	3.45	-	83.33	0.88	21.18
6	14.65	11.46	25	0.059	24.4	0.32	2.80	4.19	-	83.33	0.78	28.46
7	17.86	13.00	25	0.059	25.5	0.31	3.19	4.79	-	83.33	0.73	34.70
8	21.12	14.65	25	0.059	26.4	0.30	3.57	5.35	-	83.33	0.69	41.05
9	23.66	15.72	25	0.059	26.3	0.28	3.85	5.77	0.252	83.33	0.66	45.97
10	27.00	16.98	25	0.059	27.0	0.27	4.20	6.31	0.260	83.33	0.63	52.46
11	32.20	17.71	25	0.059	29.3	0.28	4.73	7.09	0.256	83.33	0.55	62.57
12	36.10	18.76	25	0.059	30.1	0.28	5.10	7.65	0.261	83.33	0.52	70.14
13	41.40	20.00	25	0.059	31.8	0.28	5.59	8.39	0.266	83.33	0.48	80.44
3	5.14	5.00	30	0.070	17.1	0.32	1.39	2.09	-	100.00	0.97	9.98
4	7.52	7.26	30	0.070	18.8	0.30	1.79	2.69	-	100.00	0.97	14.62
5	10.90	10.57	30	0.070	21.8	0.31	2.30	3.45	-	100.00	0.97	21.18
6	14.65	13.00	30	0.070	24.4	0.32	2.80	4.19	-	100.00	0.89	28.46
7	17.86	14.52	30	0.070	25.5	0.31	3.19	4.79	-	100.00	0.81	34.70
8	21.12	16.42	30	0.070	26.4	0.30	3.57	5.35	-	100.00	0.78	41.05
9	23.66	17.86	30	0.070	26.3	0.28	3.85	5.77	-	100.00	0.75	45.97
10	27.00	18.91	30	0.070	27.0	0.27	4.20	6.31	0.241	100.00	0.70	52.46
11	32.20	20.32	30	0.070	29.3	0.28	4.73	7.09	0.244	100.00	0.63	62.57
12	36.10	21.62	30	0.070	30.1	0.28	5.10	7.65	0.250	100.00	0.60	70.14
13	41.40	22.62	30	0.070	31.8	0.28	5.59	8.39	0.250	100.00	0.55	80.44

Table B .4 Measured and calculated parameters for the experiments conducted with the trash rack of d_2 and θ_1

Diameter of circle : d_2 = 6 mm   Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_2^3 g))^{0.5}$
3	5.14	3.96	5	0.019	17.1	0.32	1.39	2.09	0.327	8.33	0.77	3.53
4	7.52	4.93	5	0.019	18.8	0.30	1.79	2.69	0.358	8.33	0.65	5.17
5	10.90	5.87	5	0.019	21.8	0.31	2.30	3.45	0.377	8.33	0.54	7.49
6	14.65	6.42	5	0.019	24.4	0.32	2.80	4.19	0.374	8.33	0.44	10.06
7	17.86	7.00	5	0.019	25.5	0.31	3.19	4.79	0.382	8.33	0.39	12.27
8	21.12	7.70	5	0.019	26.4	0.30	3.57	5.35	0.397	8.33	0.36	14.51
9	23.66	8.07	5	0.019	26.3	0.28	3.85	5.77	0.400	8.33	0.34	16.25
10	27.00	8.35	5	0.019	27.0	0.27	4.20	6.31	0.396	8.33	0.31	18.55
11	32.20	8.63	5	0.019	29.3	0.28	4.73	7.09	0.386	8.33	0.27	22.12
12	36.10	8.73	5	0.019	30.1	0.28	5.10	7.65	0.376	8.33	0.24	24.80
13	41.40	8.92	5	0.019	31.8	0.28	5.59	8.39	0.367	8.33	0.22	28.44
3	5.14	4.86	10	0.038	17.1	0.32	1.39	2.09	0.201	16.67	0.95	3.53
4	7.52	6.42	10	0.038	18.8	0.30	1.79	2.69	0.233	16.67	0.85	5.17
5	10.90	7.88	10	0.038	21.8	0.31	2.30	3.45	0.253	16.67	0.72	7.49
6	14.65	8.92	10	0.038	24.4	0.32	2.80	4.19	0.260	16.67	0.61	10.06
7	17.86	9.83	10	0.038	25.5	0.31	3.19	4.79	0.268	16.67	0.55	12.27
8	21.12	10.90	10	0.038	26.4	0.30	3.57	5.35	0.281	16.67	0.52	14.51
9	23.66	11.58	10	0.038	26.3	0.28	3.85	5.77	0.287	16.67	0.49	16.25
10	27.00	12.28	10	0.038	27.0	0.27	4.20	6.31	0.291	16.67	0.45	18.55
11	32.20	12.75	10	0.038	29.3	0.28	4.73	7.09	0.285	16.67	0.40	22.12
12	36.10	13.37	10	0.038	30.1	0.28	5.10	7.65	0.288	16.67	0.37	24.80
13	41.40	13.75	10	0.038	31.8	0.28	5.59	8.39	0.283	16.67	0.33	28.44

Table B .4 Continued

Diameter of circle : $d_2 = 6$ mm					Angle of rack inclination: $\theta_1 = 37.0^o$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_c)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_2^3 g))^{0.5}$
3	5.14	4.93	15	0.057	17.1	0.32	1.39	2.09	-	25.00	0.96	3.53
4	7.52	7.00	15	0.057	18.8	0.30	1.79	2.69	0.170	25.00	0.93	5.17
5	10.90	9.12	15	0.057	21.8	0.31	2.30	3.45	0.195	25.00	0.84	7.49
6	14.65	10.36	15	0.057	24.4	0.32	2.80	4.19	0.201	25.00	0.71	10.06
7	17.86	11.69	15	0.057	25.5	0.31	3.19	4.79	0.212	25.00	0.65	12.27
8	21.12	12.88	15	0.057	26.4	0.30	3.57	5.35	0.221	25.00	0.61	14.51
9	23.66	13.75	15	0.057	26.3	0.28	3.85	5.77	0.227	25.00	0.58	16.25
10	27.00	14.78	15	0.057	27.0	0.27	4.20	6.31	0.234	25.00	0.55	18.55
11	32.20	15.59	15	0.057	29.3	0.28	4.73	7.09	0.233	25.00	0.48	22.12
12	36.10	16.28	15	0.057	30.1	0.28	5.10	7.65	0.234	25.00	0.45	24.80
13	41.40	17.13	15	0.057	31.8	0.28	5.59	8.39	0.235	25.00	0.41	28.44
3	5.14	4.93	20	0.076	17.1	0.32	1.39	2.09	-	33.33	0.96	3.53
4	7.52	7.17	20	0.076	18.8	0.30	1.79	2.69	-	33.33	0.95	5.17
5	10.90	9.63	20	0.076	21.8	0.31	2.30	3.45	-	33.33	0.88	7.49
6	14.65	11.24	20	0.076	24.4	0.32	2.80	4.19	0.163	33.33	0.77	10.06
7	17.86	13.00	20	0.076	25.5	0.31	3.19	4.79	0.177	33.33	0.73	12.27
8	21.12	14.26	20	0.076	26.4	0.30	3.57	5.35	0.184	33.33	0.67	14.51
9	23.66	15.72	20	0.076	26.3	0.28	3.85	5.77	0.195	33.33	0.66	16.25
10	27.00	16.84	20	0.076	27.0	0.27	4.20	6.31	0.200	33.33	0.62	18.55
11	32.20	17.86	20	0.076	29.3	0.28	4.73	7.09	0.200	33.33	0.55	22.12
12	36.10	18.76	20	0.076	30.1	0.28	5.10	7.65	0.202	33.33	0.52	24.80
13	41.40	19.69	20	0.076	31.8	0.28	5.59	8.39	0.203	33.33	0.48	28.44

Table A .4 Continued

Bar Spacing: $d_2 = 6$ mm   Angle of rack inclination: $\theta_1 = 37.0°$

Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_2^3 g))^{0.5}$
3	5.14	5.00	25	0.095	17.1	0.32	1.39	2.09	-	41.67	0.97	3.53
4	7.52	7.26	25	0.095	18.8	0.30	1.79	2.69	-	41.67	0.97	5.17
5	10.90	10.36	25	0.095	21.8	0.31	2.30	3.45	-	41.67	0.95	7.49
6	14.65	12.39	25	0.095	24.4	0.32	2.80	4.19	-	41.67	0.85	10.06
7	17.86	14.26	25	0.095	25.5	0.31	3.19	4.79	-	41.67	0.80	12.27
8	21.12	15.59	25	0.095	26.4	0.30	3.57	5.35	0.161	41.67	0.74	14.51
9	23.66	17.13	25	0.095	26.3	0.28	3.85	5.77	0.170	41.67	0.72	16.25
10	27.00	18.46	25	0.095	27.0	0.27	4.20	6.31	0.175	41.67	0.68	18.55
11	32.20	19.84	25	0.095	29.3	0.28	4.73	7.09	0.178	41.67	0.62	22.12
12	36.10	20.96	25	0.095	30.1	0.28	5.10	7.65	0.181	41.67	0.58	24.80
13	41.40	22.29	25	0.095	31.8	0.28	5.59	8.39	0.183	41.67	0.54	28.44
3	5.14	5.00	30	0.114	17.1	0.32	1.39	2.09	-	50.00	0.97	3.53
4	7.52	7.26	30	0.114	18.8	0.30	1.79	2.69	-	50.00	0.97	5.17
5	10.90	10.47	30	0.114	21.8	0.31	2.30	3.45	-	50.00	0.96	7.49
6	14.65	13.12	30	0.114	24.4	0.32	2.80	4.19	-	50.00	0.90	10.06
7	17.86	15.18	30	0.114	25.5	0.31	3.19	4.79	-	50.00	0.85	12.27
8	21.12	17.27	30	0.114	26.4	0.30	3.57	5.35	-	50.00	0.82	14.51
9	23.66	19.06	30	0.114	26.3	0.28	3.85	5.77	-	50.00	0.81	16.25
10	27.00	20.48	30	0.114	27.0	0.27	4.20	6.31	0.162	50.00	0.76	18.55
11	32.20	21.62	30	0.114	29.3	0.28	4.73	7.09	0.161	50.00	0.67	22.12
12	36.10	22.97	30	0.114	30.1	0.28	5.10	7.65	0.165	50.00	0.64	24.80
13	41.40	24.19	30	0.114	31.8	0.28	5.59	8.39	0.166	50.00	0.58	28.44

Table B .5 Measured and calculated parameters for the experiments conducted with the trash rack of d_2 and θ_2

Diameter of circle: $d_2 = 6$ mm					Angle of rack inclination: $\theta_2 = 32.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_2{}^3 g))^{0.5}$
3	5.14	4.08	5	0.019	17.1	0.32	1.39	2.09	0.337	8.33	0.79	3.53
4	7.52	4.93	5	0.019	18.8	0.30	1.79	2.69	0.358	8.33	0.65	5.17
5	10.90	5.95	5	0.019	21.8	0.31	2.30	3.45	0.382	8.33	0.55	7.49
6	14.65	6.59	5	0.019	24.4	0.32	2.80	4.19	0.383	8.33	0.45	10.06
7	17.86	7.35	5	0.019	25.5	0.31	3.19	4.79	0.400	8.33	0.41	12.27
8	21.12	8.07	5	0.019	26.4	0.30	3.57	5.35	0.416	8.33	0.38	14.51
9	23.66	8.54	5	0.019	26.3	0.28	3.85	5.77	0.423	8.33	0.36	16.25
10	27.00	9.02	5	0.019	27.0	0.27	4.20	6.31	0.428	8.33	0.33	18.55
11	32.20	9.42	5	0.019	29.3	0.28	4.73	7.09	0.422	8.33	0.29	22.12
12	36.10	9.83	5	0.019	30.1	0.28	5.10	7.65	0.424	8.33	0.27	24.80
13	41.40	10.15	5	0.019	31.8	0.28	5.59	8.39	0.418	8.33	0.25	28.44
3	5.14	4.86	10	0.038	17.1	0.32	1.39	2.09	0.201	16.67	0.95	3.53
4	7.52	6.50	10	0.038	18.8	0.30	1.79	2.69	0.236	16.67	0.86	5.17
5	10.90	8.07	10	0.038	21.8	0.31	2.30	3.45	0.259	16.67	0.74	7.49
6	14.65	9.52	10	0.038	24.4	0.32	2.80	4.19	0.277	16.67	0.65	10.06
7	17.86	10.68	10	0.038	25.5	0.31	3.19	4.79	0.291	16.67	0.60	12.27
8	21.12	11.81	10	0.038	26.4	0.30	3.57	5.35	0.304	16.67	0.56	14.51
9	23.66	12.63	10	0.038	26.3	0.28	3.85	5.77	0.313	16.67	0.53	16.25
10	27.00	13.24	10	0.038	27.0	0.27	4.20	6.31	0.314	16.67	0.49	18.55
11	32.20	14.00	10	0.038	29.3	0.28	4.73	7.09	0.313	16.67	0.43	22.12
12	36.10	14.65	10	0.038	30.1	0.28	5.10	7.65	0.316	16.67	0.41	24.80
13	41.40	15.18	10	0.038	31.8	0.28	5.59	8.39	0.312	16.67	0.37	28.44

Table B .5 Continued

Diameter of circle: d_2 = 6 mm					Angle of rack inclination: $\theta_2 = 32.8^{\circ}$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_2{}^3 g))^{0.5}$
3	5.14	4.93	15	0.057	17.1	0.32	1.39	2.09	-	25.00	0.96	3.53
4	7.52	7.17	15	0.057	18.8	0.30	1.79	2.69	0.174	25.00	0.95	5.17
5	10.90	9.32	15	0.057	21.8	0.31	2.30	3.45	0.200	25.00	0.85	7.49
6	14.65	10.90	15	0.057	24.4	0.32	2.80	4.19	0.212	25.00	0.74	10.06
7	17.86	12.51	15	0.057	25.5	0.31	3.19	4.79	0.227	25.00	0.70	12.27
8	21.12	14.00	15	0.057	26.4	0.30	3.57	5.35	0.240	25.00	0.66	14.51
9	23.66	15.05	15	0.057	26.3	0.28	3.85	5.77	0.249	25.00	0.64	16.25
10	27.00	16.28	15	0.057	27.0	0.27	4.20	6.31	0.258	25.00	0.60	18.55
11	32.20	17.13	15	0.057	29.3	0.28	4.73	7.09	0.256	25.00	0.53	22.12
12	36.10	18.01	15	0.057	30.1	0.28	5.10	7.65	0.259	25.00	0.50	24.80
13	41.40	18.91	15	0.057	31.8	0.28	5.59	8.39	0.259	25.00	0.46	28.44
3	5.14	5.00	20	0.076	17.1	0.32	1.39	2.09	-	33.33	0.97	3.53
4	7.52	7.26	20	0.076	18.8	0.30	1.79	2.69	-	33.33	0.97	5.17
5	10.90	10.25	20	0.076	21.8	0.31	2.30	3.45	-	33.33	0.94	7.49
6	14.65	12.51	20	0.076	24.4	0.32	2.80	4.19	-	33.33	0.85	10.06
7	17.86	14.26	20	0.076	25.5	0.31	3.19	4.79	0.194	33.33	0.80	12.27
8	21.12	16.00	20	0.076	26.4	0.30	3.57	5.35	0.206	33.33	0.76	14.51
9	23.66	17.56	20	0.076	26.3	0.28	3.85	5.77	0.218	33.33	0.74	16.25
10	27.00	19.06	20	0.076	27.0	0.27	4.20	6.31	0.226	33.33	0.71	18.55
11	32.20	20.16	20	0.076	29.3	0.28	4.73	7.09	0.226	33.33	0.63	22.12
12	36.10	21.29	20	0.076	30.1	0.28	5.10	7.65	0.229	33.33	0.59	24.80
13	41.40	22.45	20	0.076	31.8	0.28	5.59	8.39	0.231	33.33	0.54	28.44

Table B .5 Continued

Diameter of circle: $d_2 = 6$ mm Angle of rack inclination: $\theta_2 = 32.8^o$												
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_2{}^3 g))^{0.5}$
3	5.14	5.07	25	0.095	17.1	0.32	1.39	2.09	-	41.67	0.99	3.53
4	7.52	7.35	25	0.095	18.8	0.30	1.79	2.69	-	41.67	0.98	5.17
5	10.90	10.57	25	0.095	21.8	0.31	2.30	3.45	-	41.67	0.97	7.49
6	14.65	13.00	25	0.095	24.4	0.32	2.80	4.19	-	41.67	0.89	10.06
7	17.86	15.18	25	0.095	25.5	0.31	3.19	4.79	-	41.67	0.85	12.27
8	21.12	17.27	25	0.095	26.4	0.30	3.57	5.35	-	41.67	0.82	14.51
9	23.66	19.22	25	0.095	26.3	0.28	3.85	5.77	0.191	41.67	0.81	16.25
10	27.00	20.64	25	0.095	27.0	0.27	4.20	6.31	0.196	41.67	0.76	18.55
11	32.20	21.78	25	0.095	29.3	0.28	4.73	7.09	0.195	41.67	0.68	22.12
12	36.10	23.14	25	0.095	30.1	0.28	5.10	7.65	0.199	41.67	0.64	24.80
13	41.40	24.36	25	0.095	31.8	0.28	5.59	8.39	0.201	41.67	0.59	28.44
3	5.14	5.07	30	0.114	17.1	0.32	1.39	2.09	-	50.00	0.99	3.53
4	7.52	7.35	30	0.114	18.8	0.30	1.79	2.69	-	50.00	0.98	5.17
5	10.90	10.57	30	0.114	21.8	0.31	2.30	3.45	-	50.00	0.97	7.49
6	14.65	13.75	30	0.114	24.4	0.32	2.80	4.19	-	50.00	0.94	10.06
7	17.86	16.28	30	0.114	25.5	0.31	3.19	4.79	-	50.00	0.91	12.27
8	21.12	18.46	30	0.114	26.4	0.30	3.57	5.35	-	50.00	0.87	14.51
9	23.66	20.00	30	0.114	26.3	0.28	3.85	5.77	-	50.00	0.85	16.25
10	27.00	21.62	30	0.114	27.0	0.27	4.20	6.31	-	50.00	0.80	18.55
11	32.20	23.31	30	0.114	29.3	0.28	4.73	7.09	0.174	50.00	0.72	22.12
12	36.10	24.72	30	0.114	30.1	0.28	5.10	7.65	0.178	50.00	0.68	24.80
13	41.40	26.18	30	0.114	31.8	0.28	5.59	8.39	0.180	50.00	0.63	28.44

Table B .6 Measured and calculated parameters for the experiments conducted with the trash rack of d_2 and θ_3

Diameter of circle : d_2 = 6 mm					Angle of rack inclination: $\theta_3 = 27.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_2^3 g))^{0.5}$
3	5.14	4.08	5	0.019	17.1	0.32	1.39	2.09	0.337	8.33	0.79	3.53
4	7.52	5.00	5	0.019	18.8	0.30	1.79	2.69	0.363	8.33	0.66	5.17
5	10.90	6.34	5	0.019	21.8	0.31	2.30	3.45	0.407	8.33	0.58	7.49
6	14.65	7.17	5	0.019	24.4	0.32	2.80	4.19	0.418	8.33	0.49	10.06
7	17.86	8.16	5	0.019	25.5	0.31	3.19	4.79	0.445	8.33	0.46	12.27
8	21.12	9.02	5	0.019	26.4	0.30	3.57	5.35	0.465	8.33	0.43	14.51
9	23.66	9.63	5	0.019	26.3	0.28	3.85	5.77	0.477	8.33	0.41	16.25
10	27.00	10.04	5	0.019	27.0	0.27	4.20	6.31	0.477	8.33	0.37	18.55
11	32.20	10.47	5	0.019	29.3	0.28	4.73	7.09	0.468	8.33	0.33	22.12
12	36.10	10.90	5	0.019	30.1	0.28	5.10	7.65	0.470	8.33	0.30	24.80
13	41.40	11.24	5	0.019	31.8	0.28	5.59	8.39	0.463	8.33	0.27	28.44
3	5.14	4.93	10	0.038	17.1	0.32	1.39	2.09	0.203	16.67	0.96	3.53
4	7.52	7.00	10	0.038	18.8	0.30	1.79	2.69	0.254	16.67	0.93	5.17
5	10.90	8.83	10	0.038	21.8	0.31	2.30	3.45	0.283	16.67	0.81	7.49
6	14.65	10.15	10	0.038	24.4	0.32	2.80	4.19	0.295	16.67	0.69	10.06
7	17.86	11.35	10	0.038	25.5	0.31	3.19	4.79	0.309	16.67	0.64	12.27
8	21.12	12.63	10	0.038	26.4	0.30	3.57	5.35	0.325	16.67	0.60	14.51
9	23.66	13.62	10	0.038	26.3	0.28	3.85	5.77	0.338	16.67	0.58	16.25
10	27.00	14.39	10	0.038	27.0	0.27	4.20	6.31	0.341	16.67	0.53	18.55
11	32.20	15.05	10	0.038	29.3	0.28	4.73	7.09	0.337	16.67	0.47	22.12
12	36.10	16.00	10	0.038	30.1	0.28	5.10	7.65	0.345	16.67	0.44	24.80
13	41.40	16.70	10	0.038	31.8	0.28	5.59	8.39	0.344	16.67	0.40	28.44

Table B .6 Continued

Diameter of circle : d_2 = 6 mm	Angle of rack inclination: θ_3 = 27.8°											
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_2{}^3 g))^{0.5}$
3	5.14	5.00	15	0.057	17.1	0.32	1.39	2.09	-	25.00	0.97	3.53
4	7.52	7.26	15	0.057	18.8	0.30	1.79	2.69	-	25.00	0.97	5.17
5	10.90	9.83	15	0.057	21.8	0.31	2.30	3.45	0.210	25.00	0.90	7.49
6	14.65	11.58	15	0.057	24.4	0.32	2.80	4.19	0.225	25.00	0.79	10.06
7	17.86	13.37	15	0.057	25.5	0.31	3.19	4.79	0.243	25.00	0.75	12.27
8	21.12	15.31	15	0.057	26.4	0.30	3.57	5.35	0.263	25.00	0.72	14.51
9	23.66	16.56	15	0.057	26.3	0.28	3.85	5.77	0.274	25.00	0.70	16.25
10	27.00	17.71	15	0.057	27.0	0.27	4.20	6.31	0.280	25.00	0.66	18.55
11	32.20	18.91	15	0.057	29.3	0.28	4.73	7.09	0.282	25.00	0.59	22.12
12	36.10	20.00	15	0.057	30.1	0.28	5.10	7.65	0.287	25.00	0.55	24.80
13	41.40	20.96	15	0.057	31.8	0.28	5.59	8.39	0.288	25.00	0.51	28.44
3	5.14	5.14	20	0.076	17.1	0.32	1.39	2.09	-	33.33	1.00	3.53
4	7.52	7.35	20	0.076	18.8	0.30	1.79	2.69	-	33.33	0.98	5.17
5	10.90	10.57	20	0.076	21.8	0.31	2.30	3.45	-	33.33	0.97	7.49
6	14.65	13.00	20	0.076	24.4	0.32	2.80	4.19	-	33.33	0.89	10.06
7	17.86	15.31	20	0.076	25.5	0.31	3.19	4.79	0.209	33.33	0.86	12.27
8	21.12	17.13	20	0.076	26.4	0.30	3.57	5.35	0.221	33.33	0.81	14.51
9	23.66	19.06	20	0.076	26.3	0.28	3.85	5.77	0.236	33.33	0.81	16.25
10	27.00	20.64	20	0.076	27.0	0.27	4.20	6.31	0.245	33.33	0.76	18.55
11	32.20	21.62	20	0.076	29.3	0.28	4.73	7.09	0.242	33.33	0.67	22.12
12	36.10	23.14	20	0.076	30.1	0.28	5.10	7.65	0.249	33.33	0.64	24.80
13	41.40	24.19	20	0.076	31.8	0.28	5.59	8.39	0.249	33.33	0.58	28.44

Table B .6 Continued

Diameter of circle : $d_2 = 6$ mm					Angle of rack inclination: $\theta_3 = 27.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_2	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_2{}^3 g))^{0.5}$
3	5.14	5.14	25	0.095	17.1	0.32	1.39	2.09	-	41.67	1.00	3.53
4	7.52	7.35	25	0.095	18.8	0.30	1.79	2.69	-	41.67	0.98	5.17
5	10.90	10.68	25	0.095	21.8	0.31	2.30	3.45	-	41.67	0.98	7.49
6	14.65	13.62	25	0.095	24.4	0.32	2.80	4.19	-	41.67	0.93	10.06
7	17.86	16.14	25	0.095	25.5	0.31	3.19	4.79	-	41.67	0.90	12.27
8	21.12	18.46	25	0.095	26.4	0.30	3.57	5.35	-	41.67	0.87	14.51
9	23.66	20.32	25	0.095	26.3	0.28	3.85	5.77	-	41.67	0.86	16.25
10	27.00	21.78	25	0.095	27.0	0.27	4.20	6.31	0.207	41.67	0.81	18.55
11	32.20	23.31	25	0.095	29.3	0.28	4.73	7.09	0.209	41.67	0.72	22.12
12	36.10	25.08	25	0.095	30.1	0.28	5.10	7.65	0.216	41.67	0.69	24.80
13	41.40	26.18	25	0.095	31.8	0.28	5.59	8.39	0.216	41.67	0.63	28.44
3	5.14	5.14	30	0.114	17.1	0.32	1.39	2.09	-	50.00	1.00	3.53
4	7.52	7.35	30	0.114	18.8	0.30	1.79	2.69	-	50.00	0.98	5.17
5	10.90	10.68	30	0.114	21.8	0.31	2.30	3.45	-	50.00	0.98	7.49
6	14.65	14.00	30	0.114	24.4	0.32	2.80	4.19	-	50.00	0.96	10.06
7	17.86	16.98	30	0.114	25.5	0.31	3.19	4.79	-	50.00	0.95	12.27
8	21.12	19.37	30	0.114	26.4	0.30	3.57	5.35	-	50.00	0.92	14.51
9	23.66	21.62	30	0.114	26.3	0.28	3.85	5.77	-	50.00	0.91	16.25
10	27.00	23.31	30	0.114	27.0	0.27	4.20	6.31	-	50.00	0.86	18.55
11	32.20	25.08	30	0.114	29.3	0.28	4.73	7.09	-	50.00	0.78	22.12
12	36.10	26.74	30	0.114	30.1	0.28	5.10	7.65	-	50.00	0.74	24.80
13	41.40	28.46	30	0.114	31.8	0.28	5.59	8.39	-	50.00	0.69	28.44

Table B .7 Measured and calculated parameters for the experiments conducted with the trash rack of d_3 and θ_1

Diameter of circle : d_3 = 10 mm **Angle of rack inclination: $\theta_1 = 37.0^\circ$**

Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\, y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_3{}^3 g))^{0.5}$
3	5.14	4.14	5	0.025	17.1	0.32	1.39	2.09	0.259	5.00	0.81	1.64
4	7.52	5.00	5	0.025	18.8	0.30	1.79	2.69	0.275	5.00	0.66	2.40
5	10.90	6.03	5	0.025	21.8	0.31	2.30	3.45	0.293	5.00	0.55	3.48
6	14.65	6.83	5	0.025	24.4	0.32	2.80	4.19	0.301	5.00	0.47	4.68
7	17.86	7.35	5	0.025	25.5	0.31	3.19	4.79	0.303	5.00	0.41	5.70
8	21.12	8.16	5	0.025	26.4	0.30	3.57	5.35	0.318	5.00	0.39	6.74
9	23.66	8.63	5	0.025	26.3	0.28	3.85	5.77	0.324	5.00	0.36	7.55
10	27.00	9.12	5	0.025	27.0	0.27	4.20	6.31	0.328	5.00	0.34	8.62
11	32.20	9.52	5	0.025	29.3	0.28	4.73	7.09	0.323	5.00	0.30	10.28
12	36.10	9.83	5	0.025	30.1	0.28	5.10	7.65	0.321	5.00	0.27	11.53
13	41.40	10.04	5	0.025	31.8	0.28	5.59	8.39	0.313	5.00	0.24	13.22
3	5.14	4.93	10	0.050	17.1	0.32	1.39	2.09	0.154	10.00	0.96	1.64
4	7.52	6.59	10	0.050	18.8	0.30	1.79	2.69	0.181	10.00	0.88	2.40
5	10.90	8.16	10	0.050	21.8	0.31	2.30	3.45	0.198	10.00	0.75	3.48
6	14.65	9.42	10	0.050	24.4	0.32	2.80	4.19	0.208	10.00	0.64	4.68
7	17.86	10.68	10	0.050	25.5	0.31	3.19	4.79	0.220	10.00	0.60	5.70
8	21.12	11.69	10	0.050	26.4	0.30	3.57	5.35	0.228	10.00	0.55	6.74
9	23.66	13.00	10	0.050	26.3	0.28	3.85	5.77	0.244	10.00	0.55	7.55
10	27.00	13.87	10	0.050	27.0	0.27	4.20	6.31	0.249	10.00	0.51	8.62
11	32.20	14.78	10	0.050	29.3	0.28	4.73	7.09	0.251	10.00	0.46	10.28
12	36.10	15.31	10	0.050	30.1	0.28	5.10	7.65	0.250	10.00	0.42	11.53
13	41.40	15.72	10	0.050	31.8	0.28	5.59	8.39	0.245	10.00	0.38	13.22

Table B .7 Continued

Diameter of circle : d_3 = 10 mm					Angle of rack inclination: θ_1 = 37.0°							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_3{}^3 g))^{0.5}$
3	5.14	5.00	15	0.075	17.1	0.32	1.39	2.09	-	15.00	0.97	1.64
4	7.52	7.09	15	0.075	18.8	0.30	1.79	2.69	0.130	15.00	0.94	2.40
5	10.90	9.42	15	0.075	21.8	0.31	2.30	3.45	0.153	15.00	0.86	3.48
6	14.65	11.12	15	0.075	24.4	0.32	2.80	4.19	0.164	15.00	0.76	4.68
7	17.86	12.75	15	0.075	25.5	0.31	3.19	4.79	0.175	15.00	0.71	5.70
8	21.12	13.75	15	0.075	26.4	0.30	3.57	5.35	0.179	15.00	0.65	6.74
9	23.66	14.91	15	0.075	26.3	0.28	3.85	5.77	0.187	15.00	0.63	7.55
10	27.00	16.00	15	0.075	27.0	0.27	4.20	6.31	0.192	15.00	0.59	8.62
11	32.20	17.13	15	0.075	29.3	0.28	4.73	7.09	0.194	15.00	0.53	10.28
12	36.10	18.76	15	0.075	30.1	0.28	5.10	7.65	0.204	15.00	0.52	11.53
13	41.40	19.69	15	0.075	31.8	0.28	5.59	8.39	0.205	15.00	0.48	13.22
3	5.14	5.07	20	0.100	17.1	0.32	1.39	2.09	-	20.00	0.99	1.64
4	7.52	7.26	20	0.100	18.8	0.30	1.79	2.69	-	20.00	0.97	2.40
5	10.90	10.15	20	0.100	21.8	0.31	2.30	3.45	-	20.00	0.93	3.48
6	14.65	11.92	20	0.100	24.4	0.32	2.80	4.19	0.131	20.00	0.81	4.68
7	17.86	14.00	20	0.100	25.5	0.31	3.19	4.79	0.144	20.00	0.78	5.70
8	21.12	16.28	20	0.100	26.4	0.30	3.57	5.35	0.159	20.00	0.77	6.74
9	23.66	17.56	20	0.100	26.3	0.28	3.85	5.77	0.165	20.00	0.74	7.55
10	27.00	19.22	20	0.100	27.0	0.27	4.20	6.31	0.173	20.00	0.71	8.62
11	32.20	20.64	20	0.100	29.3	0.28	4.73	7.09	0.175	20.00	0.64	10.28
12	36.10	21.95	20	0.100	30.1	0.28	5.10	7.65	0.179	20.00	0.61	11.53
13	41.40	24.19	20	0.100	31.8	0.28	5.59	8.39	0.189	20.00	0.58	13.22

Table B .7 Continued

Diameter of circle : $d_3 = 10$ mm	Angle of rack inclination: $\theta_1 = 37.0^o$												
Measured Parameters					Calculated Parameters								
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2{}_T/(d_3{}^3 g))^{0.5}$
3	5.14	5.14	25	0.125	17.1	0.32	1.39	2.09	-	25.00	1.00	1.64
4	7.52	7.35	25	0.125	18.8	0.30	1.79	2.69	-	25.00	0.98	2.40
5	10.90	10.57	25	0.125	21.8	0.31	2.30	3.45	-	25.00	0.97	3.48
6	14.65	13.00	25	0.125	24.4	0.32	2.80	4.19	-	25.00	0.89	4.68
7	17.86	15.18	25	0.125	25.5	0.31	3.19	4.79	-	25.00	0.85	5.70
8	21.12	17.42	25	0.125	26.4	0.30	3.57	5.35	-	25.00	0.82	6.74
9	23.66	19.69	25	0.125	26.3	0.28	3.85	5.77	0.148	25.00	0.83	7.55
10	27.00	21.29	25	0.125	27.0	0.27	4.20	6.31	0.153	25.00	0.79	8.62
11	32.20	22.79	25	0.125	29.3	0.28	4.73	7.09	0.155	25.00	0.71	10.28
12	36.10	23.83	25	0.125	30.1	0.28	5.10	7.65	0.156	25.00	0.66	11.53
13	41.40	26.55	25	0.125	31.8	0.28	5.59	8.39	0.166	25.00	0.64	13.22
3	5.14	5.14	30	0.150	17.1	0.32	1.39	2.09	-	30.00	1.00	1.64
4	7.52	7.44	30	0.150	18.8	0.30	1.79	2.69	-	30.00	0.99	2.40
5	10.90	10.79	30	0.150	21.8	0.31	2.30	3.45	-	30.00	0.99	3.48
6	14.65	13.62	30	0.150	24.4	0.32	2.80	4.19	-	30.00	0.93	4.68
7	17.86	16.00	30	0.150	25.5	0.31	3.19	4.79	-	30.00	0.90	5.70
8	21.12	18.61	30	0.150	26.4	0.30	3.57	5.35	-	30.00	0.88	6.74
9	23.66	20.16	30	0.150	26.3	0.28	3.85	5.77	-	30.00	0.85	7.55
10	27.00	22.12	30	0.150	27.0	0.27	4.20	6.31	-	30.00	0.82	8.62
11	32.20	24.36	30	0.150	29.3	0.28	4.73	7.09	-	30.00	0.76	10.28
12	36.10	25.81	30	0.150	30.1	0.28	5.10	7.65	-	30.00	0.71	11.53
13	41.40	27.88	30	0.150	31.8	0.28	5.59	8.39	-	30.00	0.67	13.22

Table B .8 Measured and calculated parameters for the experiments conducted with the trash rack of d_3 and θ_2

Diameter of circle: $d_3 = 10$ mm					Angle of rack inclination: $\theta_2 = 32.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_3^3 g))^{0.5}$
3	5.14	4.27	5	0.025	17.1	0.32	1.39	2.09	0.267	5.00	0.83	1.64
4	7.52	5.14	5	0.025	18.8	0.30	1.79	2.69	0.283	5.00	0.68	2.40
5	10.90	6.34	5	0.025	21.8	0.31	2.30	3.45	0.309	5.00	0.58	3.48
6	14.65	7.35	5	0.025	24.4	0.32	2.80	4.19	0.324	5.00	0.50	4.68
7	17.86	8.16	5	0.025	25.5	0.31	3.19	4.79	0.337	5.00	0.46	5.70
8	21.12	9.02	5	0.025	26.4	0.30	3.57	5.35	0.352	5.00	0.43	6.74
9	23.66	9.42	5	0.025	26.3	0.28	3.85	5.77	0.354	5.00	0.40	7.55
10	27.00	9.83	5	0.025	27.0	0.27	4.20	6.31	0.354	5.00	0.36	8.62
11	32.20	10.15	5	0.025	29.3	0.28	4.73	7.09	0.344	5.00	0.32	10.28
12	36.10	10.68	5	0.025	30.1	0.28	5.10	7.65	0.349	5.00	0.30	11.53
13	41.40	10.90	5	0.025	31.8	0.28	5.59	8.39	0.340	5.00	0.26	13.22
3	5.14	5.00	10	0.050	17.1	0.32	1.39	2.09	-	10.00	0.97	1.64
4	7.52	6.83	10	0.050	18.8	0.30	1.79	2.69	0.188	10.00	0.91	2.40
5	10.90	8.44	10	0.050	21.8	0.31	2.30	3.45	0.205	10.00	0.77	3.48
6	14.65	9.83	10	0.050	24.4	0.32	2.80	4.19	0.217	10.00	0.67	4.68
7	17.86	11.24	10	0.050	25.5	0.31	3.19	4.79	0.232	10.00	0.63	5.70
8	21.12	12.51	10	0.050	26.4	0.30	3.57	5.35	0.244	10.00	0.59	6.74
9	23.66	13.75	10	0.050	26.3	0.28	3.85	5.77	0.258	10.00	0.58	7.55
10	27.00	14.52	10	0.050	27.0	0.27	4.20	6.31	0.261	10.00	0.54	8.62
11	32.20	15.59	10	0.050	29.3	0.28	4.73	7.09	0.264	10.00	0.48	10.28
12	36.10	16.28	10	0.050	30.1	0.28	5.10	7.65	0.266	10.00	0.45	11.53
13	41.40	16.98	10	0.050	31.8	0.28	5.59	8.39	0.265	10.00	0.41	13.22

Table B.8 Continued

Diameter of circle: $d_3 = 10$ mm					Angle of rack inclination: $\theta_2 = 32.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_3^3 g))^{0.5}$
3	5.14	5.07	15	0.075	17.1	0.32	1.39	2.09	-	15.00	0.99	1.64
4	7.52	7.26	15	0.075	18.8	0.30	1.79	2.69	-	15.00	0.97	2.40
5	10.90	9.94	15	0.075	21.8	0.31	2.30	3.45	-	15.00	0.91	3.48
6	14.65	11.81	15	0.075	24.4	0.32	2.80	4.19	0.174	15.00	0.81	4.68
7	17.86	13.49	15	0.075	25.5	0.31	3.19	4.79	0.186	15.00	0.76	5.70
8	21.12	15.31	15	0.075	26.4	0.30	3.57	5.35	0.199	15.00	0.72	6.74
9	23.66	16.70	15	0.075	26.3	0.28	3.85	5.77	0.209	15.00	0.71	7.55
10	27.00	18.31	15	0.075	27.0	0.27	4.20	6.31	0.219	15.00	0.68	8.62
11	32.20	19.53	15	0.075	29.3	0.28	4.73	7.09	0.221	15.00	0.61	10.28
12	36.10	20.64	15	0.075	30.1	0.28	5.10	7.65	0.225	15.00	0.57	11.53
13	41.40	21.62	15	0.075	31.8	0.28	5.59	8.39	0.225	15.00	0.52	13.22
3	5.14	5.14	20	0.100	17.1	0.32	1.39	2.09	-	20.00	1.00	1.64
4	7.52	7.35	20	0.100	18.8	0.30	1.79	2.69	-	20.00	0.98	2.40
5	10.90	10.47	20	0.100	21.8	0.31	2.30	3.45	-	20.00	0.96	3.48
6	14.65	13.00	20	0.100	24.4	0.32	2.80	4.19	-	20.00	0.89	4.68
7	17.86	15.31	20	0.100	25.5	0.31	3.19	4.79	-	20.00	0.86	5.70
8	21.12	17.42	20	0.100	26.4	0.30	3.57	5.35	0.170	20.00	0.82	6.74
9	23.66	19.22	20	0.100	26.3	0.28	3.85	5.77	0.181	20.00	0.81	7.55
10	27.00	20.96	20	0.100	27.0	0.27	4.20	6.31	0.188	20.00	0.78	8.62
11	32.20	22.45	20	0.100	29.3	0.28	4.73	7.09	0.190	20.00	0.70	10.28
12	36.10	23.83	20	0.100	30.1	0.28	5.10	7.65	0.194	20.00	0.66	11.53
13	41.40	25.44	20	0.100	31.8	0.28	5.59	8.39	0.198	20.00	0.61	13.22

Table B .8 Continued

Diameter of circle: $d_3 = 10$ mm Angle of rack inclination: $\theta_2 = 32.8°$

Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_3^3 g))^{0.5}$
3	5.14	5.14	25	0.125	17.1	0.32	1.39	2.09	-	25.00	1.00	1.64
4	7.52	7.44	25	0.125	18.8	0.30	1.79	2.69	-	25.00	0.99	2.40
5	10.90	10.68	25	0.125	21.8	0.31	2.30	3.45	-	25.00	0.98	3.48
6	14.65	13.62	25	0.125	24.4	0.32	2.80	4.19	-	25.00	0.93	4.68
7	17.86	16.14	25	0.125	25.5	0.31	3.19	4.79	-	25.00	0.90	5.70
8	21.12	18.46	25	0.125	26.4	0.30	3.57	5.35	-	25.00	0.87	6.74
9	23.66	20.80	25	0.125	26.3	0.28	3.85	5.77	-	25.00	0.88	7.55
10	27.00	22.45	25	0.125	27.0	0.27	4.20	6.31	-	25.00	0.83	8.62
11	32.20	24.36	25	0.125	29.3	0.28	4.73	7.09	-	25.00	0.76	10.28
12	36.10	25.99	25	0.125	30.1	0.28	5.10	7.65	-	25.00	0.72	11.53
13	41.40	28.07	25	0.125	31.8	0.28	5.59	8.39	-	25.00	0.68	13.22
3	5.14	5.14	30	0.150	17.1	0.32	1.39	2.09	-	30.00	1.00	1.64
4	7.52	7.52	30	0.150	18.8	0.30	1.79	2.69	-	30.00	1.00	2.40
5	10.90	10.79	30	0.150	21.8	0.31	2.30	3.45	-	30.00	0.99	3.48
6	14.65	14.13	30	0.150	24.4	0.32	2.80	4.19	-	30.00	0.96	4.68
7	17.86	16.98	30	0.150	25.5	0.31	3.19	4.79	-	30.00	0.95	5.70
8	21.12	19.53	30	0.150	26.4	0.30	3.57	5.35	-	30.00	0.92	6.74
9	23.66	21.95	30	0.150	26.3	0.28	3.85	5.77	-	30.00	0.93	7.55
10	27.00	23.83	30	0.150	27.0	0.27	4.20	6.31	-	30.00	0.88	8.62
11	32.20	25.99	30	0.150	29.3	0.28	4.73	7.09	-	30.00	0.81	10.28
12	36.10	28.26	30	0.150	30.1	0.28	5.10	7.65	-	30.00	0.78	11.53
13	41.40	30.24	30	0.150	31.8	0.28	5.59	8.39	-	30.00	0.73	13.22

Table B .9 Measured and calculated parameters for the experiments conducted with the trash rack of d_3 and θ_3

Diameter of circle : d_3 = 10 mm					Angle of rack inclination: $\theta_3 = 27.8^o$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_3^3 g))^{0.5}$
3	5.14	4.27	5	0.025	17.1	0.32	1.39	2.09	0.267	5.00	0.83	1.64
4	7.52	5.28	5	0.025	18.8	0.30	1.79	2.69	0.291	5.00	0.70	2.40
5	10.90	6.75	5	0.025	21.8	0.31	2.30	3.45	0.328	5.00	0.62	3.48
6	14.65	7.70	5	0.025	24.4	0.32	2.80	4.19	0.340	5.00	0.53	4.68
7	17.86	8.63	5	0.025	25.5	0.31	3.19	4.79	0.356	5.00	0.48	5.70
8	21.12	9.63	5	0.025	26.4	0.30	3.57	5.35	0.376	5.00	0.46	6.74
9	23.66	10.36	5	0.025	26.3	0.28	3.85	5.77	0.389	5.00	0.44	7.55
10	27.00	10.90	5	0.025	27.0	0.27	4.20	6.31	0.392	5.00	0.40	8.62
11	32.20	11.24	5	0.025	29.3	0.28	4.73	7.09	0.381	5.00	0.35	10.28
12	36.10	11.81	5	0.025	30.1	0.28	5.10	7.65	0.385	5.00	0.33	11.53
13	41.40	12.16	5	0.025	31.8	0.28	5.59	8.39	0.379	5.00	0.29	13.22
3	5.14	5.07	10	0.050	17.1	0.32	1.39	2.09	-	10.00	0.99	1.64
4	7.52	7.17	10	0.050	18.8	0.30	1.79	2.69	0.197	10.00	0.95	2.40
5	10.90	9.12	10	0.050	21.8	0.31	2.30	3.45	0.222	10.00	0.84	3.48
6	14.65	10.79	10	0.050	24.4	0.32	2.80	4.19	0.238	10.00	0.74	4.68
7	17.86	12.39	10	0.050	25.5	0.31	3.19	4.79	0.256	10.00	0.69	5.70
8	21.12	13.75	10	0.050	26.4	0.30	3.57	5.35	0.268	10.00	0.65	6.74
9	23.66	14.91	10	0.050	26.3	0.28	3.85	5.77	0.280	10.00	0.63	7.55
10	27.00	16.14	10	0.050	27.0	0.27	4.20	6.31	0.290	10.00	0.60	8.62
11	32.20	17.13	10	0.050	29.3	0.28	4.73	7.09	0.290	10.00	0.53	10.28
12	36.10	18.61	10	0.050	30.1	0.28	5.10	7.65	0.304	10.00	0.52	11.53
13	41.40	19.37	10	0.050	31.8	0.28	5.59	8.39	0.302	10.00	0.47	13.22

Table B .9 Continued

Diameter of circle : d_3 = 10 mm Angle of rack inclination: $\theta_3 = 27.8°$

Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_C = (3/2\ y_C)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_3^3 g))^{0.5}$
3	5.14	5.14	15	0.075	17.1	0.32	1.39	2.09	-	15.00	1.00	1.64
4	7.52	7.44	15	0.075	18.8	0.30	1.79	2.69	-	15.00	0.99	2.40
5	10.90	10.79	15	0.075	21.8	0.31	2.30	3.45	-	15.00	0.99	3.48
6	14.65	13.00	15	0.075	24.4	0.32	2.80	4.19	-	15.00	0.89	4.68
7	17.86	15.18	15	0.075	25.5	0.31	3.19	4.79	0.209	15.00	0.85	5.70
8	21.12	16.98	15	0.075	26.4	0.30	3.57	5.35	0.221	15.00	0.80	6.74
9	23.66	18.76	15	0.075	26.3	0.28	3.85	5.77	0.235	15.00	0.79	7.55
10	27.00	20.64	15	0.075	27.0	0.27	4.20	6.31	0.247	15.00	0.76	8.62
11	32.20	22.45	15	0.075	29.3	0.28	4.73	7.09	0.254	15.00	0.70	10.28
12	36.10	23.48	15	0.075	30.1	0.28	5.10	7.65	0.256	15.00	0.65	11.53
13	41.40	24.54	15	0.075	31.8	0.28	5.59	8.39	0.255	15.00	0.59	13.22
3	5.14	5.14	20	0.100	17.1	0.32	1.39	2.09	-	20.00	1.00	1.64
4	7.52	7.52	20	0.100	18.8	0.30	1.79	2.69	-	20.00	1.00	2.40
5	10.90	10.90	20	0.100	21.8	0.31	2.30	3.45	-	20.00	1.00	3.48
6	14.65	13.62	20	0.100	24.4	0.32	2.80	4.19	-	20.00	0.93	4.68
7	17.86	16.14	20	0.100	25.5	0.31	3.19	4.79	-	20.00	0.90	5.70
8	21.12	18.31	20	0.100	26.4	0.30	3.57	5.35	-	20.00	0.87	6.74
9	23.66	20.32	20	0.100	26.3	0.28	3.85	5.77	-	20.00	0.86	7.55
10	27.00	22.29	20	0.100	27.0	0.27	4.20	6.31	0.200	20.00	0.83	8.62
11	32.20	23.83	20	0.100	29.3	0.28	4.73	7.09	0.202	20.00	0.74	10.28
12	36.10	25.44	20	0.100	30.1	0.28	5.10	7.65	0.208	20.00	0.70	11.53
13	41.40	27.11	20	0.100	31.8	0.28	5.59	8.39	0.211	20.00	0.65	13.22

Table B .9 Continued

Diameter of circle : $d_3 = 10$ mm					Angle of rack inclination: $\theta_3 = 27.8°$							
Measured Parameters					Calculated Parameters							
y_0 (cm)	$(q_w)_T$ (lt/(s.m))	$(q_w)_i$ (lt/(s.m))	L (cm)	A_{ro} (m^2/m)	V_0 (cm/s)	$(F_r)_0$	y_c (cm)	$H_c = (3/2\ y_c)$ (cm)	C_d (Eqn 2.5)	L/d_3	$(q_w)_i/(q_w)_T$	$(F_r)_e = ((q_w)^2_T/(d_3^3 g))^{0.5}$
3	5.14	5.14	25	0.125	17.1	0.32	1.39	2.09	-	25.00	1.00	1.64
4	7.52	7.52	25	0.125	18.8	0.30	1.79	2.69	-	25.00	1.00	2.40
5	10.90	10.90	25	0.125	21.8	0.31	2.30	3.45	-	25.00	1.00	3.48
6	14.65	14.26	25	0.125	24.4	0.32	2.80	4.19	-	25.00	0.97	4.68
7	17.86	17.13	25	0.125	25.5	0.31	3.19	4.79	-	25.00	0.96	5.70
8	21.12	19.84	25	0.125	26.4	0.30	3.57	5.35	-	25.00	0.94	6.74
9	23.66	22.29	25	0.125	26.3	0.28	3.85	5.77	-	25.00	0.94	7.55
10	27.00	24.19	25	0.125	27.0	0.27	4.20	6.31	-	25.00	0.90	8.62
11	32.20	26.18	25	0.125	29.3	0.28	4.73	7.09	-	25.00	0.81	10.28
12	36.10	28.26	25	0.125	30.1	0.28	5.10	7.65	-	25.00	0.78	11.53
13	41.40	30.45	25	0.125	31.8	0.28	5.59	8.39	-	25.00	0.74	13.22
3	5.14	5.14	30	0.150	17.1	0.32	1.39	2.09	-	30.00	1.00	1.64
4	7.52	7.52	30	0.150	18.8	0.30	1.79	2.69	-	30.00	1.00	2.40
5	10.90	10.90	30	0.150	21.8	0.31	2.30	3.45	-	30.00	1.00	3.48
6	14.65	14.65	30	0.150	24.4	0.32	2.80	4.19	-	30.00	1.00	4.68
7	17.86	17.86	30	0.150	25.5	0.31	3.19	4.79	-	30.00	1.00	5.70
8	21.12	21.12	30	0.150	26.4	0.30	3.57	5.35	-	30.00	1.00	6.74
9	23.66	23.66	30	0.150	26.3	0.28	3.85	5.77	-	30.00	1.00	7.55
10	27.00	25.81	30	0.150	27.0	0.27	4.20	6.31	-	30.00	0.96	8.62
11	32.20	28.46	30	0.150	29.3	0.28	4.73	7.09	-	30.00	0.88	10.28
12	36.10	30.85	30	0.150	30.1	0.28	5.10	7.65	-	30.00	0.85	11.53
13	41.40	33.58	30	0.150	31.8	0.28	5.59	8.39	-	30.00	0.81	13.22