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DETERMINATION OF DISCHARGE COEFFICIENT IN TYROL WEIR USING SCREEN FROM OF CIRCLE WITH DIAMETER AND DISTANCE HOLE VARIATION

Nanang Saiful Rizal
Department of Civil Engineering, University of Muhammadiyah Jember,
Jl. Karimata 49 Jember, Jember 68121, Indonesia

Mohammad Bisri
Department Of Water Resources Engineering, Brawijaya University,
Jl. Veteran, Kota Malang, 65145, Indonesia

Pitojo Tri Juwono
Department of Water Resources Engineering, Brawijaya University,
Jl. Veteran, Kota Malang, 65145, Indonesia

Very Dermawan
Department of Water Resources Engineering, Brawijaya University,
Jl. Veteran, Kota Malang, 65145, Indonesia

ABSTRACT

Tyrol weir with a circular sieve hole is very effective in preventing sediment entry and has a channel collection capacity between 30% up to 40%. However, in the determination of the discharge coefficient (Cd) is still the use of equations not from the results of research on the hole sieve circle. The purpose of this study is to find the value of the coefficient of discharge (Cd) on the hole in the form of a circle by considering the factor of diameter and the distance between holes. The method is to test the physical model in a laboratory that connects several factors using three variations of slope and 10 variations of flow discharge. The discharge coefficient (Cd) increases with the higher slope of the filter (θ) and the larger the ratio of the hole area to the filter area (a / d). At the sub-critical flow conditions the value of the debit discharge coefficient (Cd) is between 0.12 - 0.24, whereas in the super critical flow the value of the debit coefficient (Cd) is between 0.18 - 0.32.

Key words: tyrol weir, screen distance, screen diameter, discharge coefficient.

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1. INTRODUCTION

Tyrol weirs are widely used for irrigation water harvesting in rivers derived from the mountains [2]. On the river it usually has a steep slope, transporting sediment materials from small to large diameter and requires buildings with low elevation. The screen planning of the tyrol weir is based on the need for loading and the speed required to prevent the entry of sediments into the collecting ducts. In the irrigation planning standard, the length of the screen is determined by the amount of discharge, the slope of the screen, the distance between the bars, the diameter of the bars, and the water level upstream of the tile weir. In determining the screen length it is necessary to consider the total width factor of the weir and the large runoff energy. Factors affecting tyrol weir planning have been re-examined by modeling in the Laboratory including the screen's slope factors [2]. The discharge entering the screen increases in the tilted sieve. Similarly, research on the effect of the distance between the screen and the screen bar width on the discharge characteristics flowing on the tyrol weir, the discharge coefficient decreases as the screen distance increases and the slope of the screen is lower [5]. Froude and specific energy numbers do not affect the value of the coefficient of discharge, it is the wet length of the screen which affects the discharge coefficient so that when the sinking flow of the collecting channel is completely full of water without air the discharge coefficient (Cd) decreases decrease [Kumar et al. 2010]. In the test of the screen with a circular cross section under submerged conditions there are water levels L_1 and L_2 and about 23% of water entering the tyre weir intake [2].

A peak perfomance hydraulic condition occurs when the screen slope is 30%, the screen opening is 40% then the loss loss ratio is only 10% [4]. The most important thing in tyrol weir planning is sedimentation factor because some tyrol weir, water catching performance decrease due to sedimentation factor. Selection of screen holes also affect the blockage factor. Tyrol bolt with a plate with a hole in the form of a circle, was very optimal in terms of the capacity of 30% up to 40% and effective to overcome the blockage in the screen [1].

Figure 1 Screen condition of tyrol weir which is sediment

Tyrol weir with a screen of a circular hole with various 3 hole diameter variations (D_1 = 3 mm, D_2 = 6 mm and D_3 = 10 mm) as well as some variation of slope of the screen gives maximum water catchment [9] the value of the discharge coefficient (Cd) based on the distance (a) and the hole diameter (d) has not been done. The development of incoming flow behavior at tye weir intake with various hole forms can be done by numerical method with good result [14] and Cd value is still recommended using previous research result whereas the previous Cd value is not from the research of circular sieve hole.

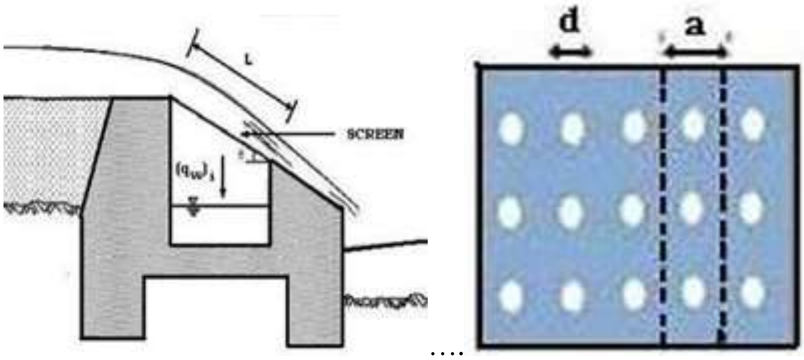


Figure 2 schematic flows on tyrol weir with a perforated hollow screen

Even for the simplicity of field practice has been developed a computer application for tile weir design with various forms of sieve and tilt [8] including determination of Cd value but computer application made only present value of Cd based on hole diameter only (d) while distance between holes (e) no research has been done. Although there are many developed methods of tyrol weir design, the key lies in the parameters used such as the value of the discharge coefficient [3]. In practice, it turns out the value of the discharge coefficient (Cd) in the tyrol weir design with the perforated screen still follows the standard on the longitudinal sieve [1]. While the shape of the hole and the distance between different holes so that the current discharge coefficient (Cd) will not be suitable for planning, so if used for the application, the results of the planning will experience errors or inaccurate.

2. STUDY LABORATORY

In the researching the discharge coefficient on a tyrol weir with a hollow plate-shaped screen [9] is done by making a model in a laboratory. In the model in the laboratory consists of main channel, side spillway, piping channel, screen and reservoir at the top. Water is supplied from a reservoir with a 30 cm diameter pipe whose flow is controlled by a faucet. The mai11n channel is 7.0 m wide and 1.98 m wide and its channel slope is 0.001. The physical model test layout is presented in Figure 3.

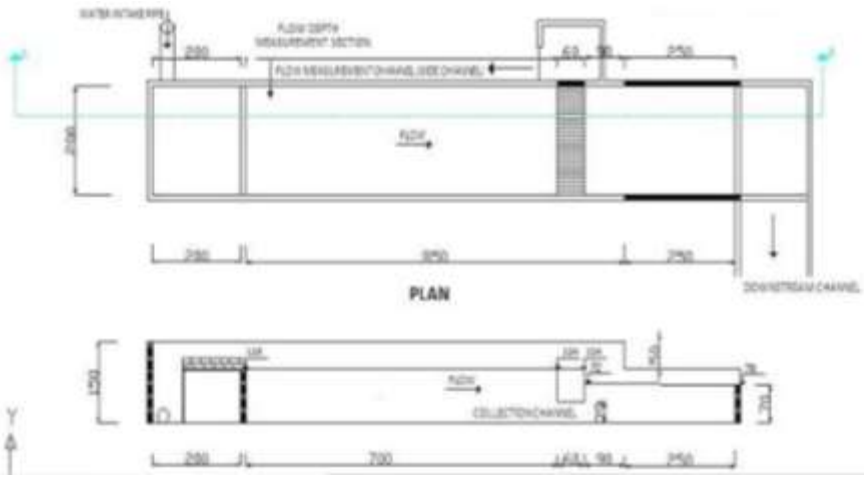


Figure 3 Layout of physical model test of tyrol weir in laboratory with a circular perforated plate screen

The screen is placed downstream of the main channel in the form of a hollow plate with a thickness of 2 mm. While the diameter of the hole made 3 variations (D_1 = 3 mm, D_2 = 6 mm and D_3 = 10 mm). Screen length of 0.20 meters with 3 variations of screen (θ_1 = 37.0 °, θ_2 = 32.8 ° and θ_3 = 27.8 °). The flow from the screen is then fed into the collector channel 0.6 m wide, 0.33 m altitude and 1.98 m long and the collector duct slope is 0.01. The water that flows in the collector channel then goes to the side spill with a width of 0.7 m and a length of 6.5 m. In carrying out the physical model test in the laboratory was performed with 10 variations of discharge for each channel (θ_1 = 37.0 °, θ_2 = 32.8 ° and θ_3 = 127.8 °). So that obtained 30 result of observation test of physical model in laboratory. So if it is done for 3 variations of the screen (D_1 = 3 mm, D_2 = 6 mm and D_3 = 10 mm), then 90 field observations are obtained.

Figure 4 Flow condition in Field and Laboratory

Field measurements include upstream water levels, flow discharge in the main channel as well as the flow of streams entering the screen. While calculated and analyzed include the width of the screen hole (Aro), the inlet velocity (Vo), the Froude Number (Fr), the critical water level (Yc), the ratio of the discharge to the screen with the discharge flowing in the main channel (Qwi / Qwt), the ratio between the distance between the holes and the hole diameter (d/a). The measured and analyzed parameter values are presented in the flow schematic in Figure 5. While calculated and analyzed include the width of the screen hole (Aro), the inlet velocity (Vo), the Froude Number (Fr), the critical water level (Yc), the ratio of the discharge to the screen with the discharge flowing in the main channel (Qwi / Qwt), the ratio between the distance between the holes and the hole diameter (d/a). The measured and analyzed parameter values are presented in the flow schematic in Figure 5.

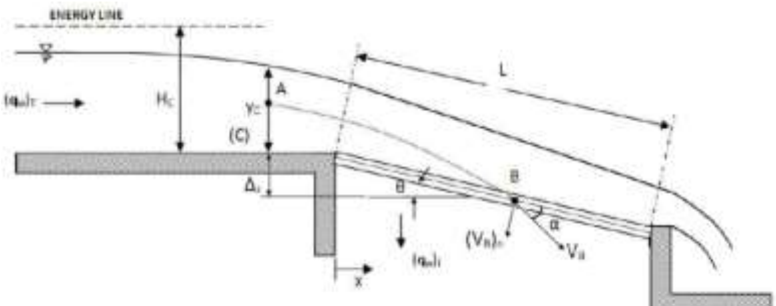


Figure 5 Schematic of water flow entering the tyrol weir

While the ratio between the distance between the holes and the hole diameter (d/a) with the discharge coefficient (Cd) to see the effect of distance change (d) and the diameter of the hole (a) to 1the discharge coefficient (Cd) in the plate screen due to flow changes from sub critical to critical and super critical.

Table 1 Limit Of Data In This Study

No	Paramater	Unit	Value limits
1	S	-	0.001
2	Θ	-	37.0^o, 32.8^o, 27.8^o
3	A	Mm	3 – 10
4	E	Mm	20 – 50
5	T	Mm	2
6	L	Mm	0.2
7	Qo	l/s.m	41.4
8	Qs	l/s.m	27.11
9	Yo	M	13.00

3. METHODS AND MATERIALS

Experimental results for the discharge coefficient as in the form of the following formula [13]. The discharge coefficient is described by Equation (1).

$$Cd = 0,66.\left(\frac{s}{m}\right)^{-0,16}\left(\frac{m}{h}\right)^{0,13} \tag{1}$$

With s is the distance of the screen rod, m is the distance between the center of the screen, h is the flow depth above the screen and equal to ycos θ where θ = the angle of the screen. In the subcritical flow above the sieve it is proposed the discharge coefficient equation as in the following formula [7]. The discharge coefficient is described by Equation (2).

$$Cd = K_1[1,3 - 0,2F] \tag{2}$$

With K_1 depending on the area of the screen opening (ε) and the ratio s / L, with s = screen distance, L = screen length and F = froude number. Based on experimental studies classify currents on horizontal and sloping shelves of circular bars [11] and [12] such as AA_1, AA_3, BB_1, and BB_2. For type AA_1 which occurs on a sloping rack with subcritical flow on approaching the channel and supercritical flow above the screen, the following relationship is developed. The discharge coefficient is described by Equation (3).

$$Cd = 0,53 + 0,4Log\left(\frac{D}{s}\right) - 0,61S \tag{3}$$

With D is the diameter of the bar, s is the distance between the bars and S = the slope of the screen. Research by developing several variables to obtain the equation for the discharge coefficient [10]. The discharge coefficient is described by Equation (4).

$$Cd = 0.223.\varepsilon^{-0,79}.F^{-0.295}\left(\frac{s}{L}\right)^{0,054} \tag{4}$$

With Cd, ε, F, s y1, L is the discharge coefficient, shelf porosity, froude number, water depth and screen length. For the peak perfomance hydraulic performance of the sieve, they found that the slope of the screen should be more than 20%.

In an experimental channel with a width of 0.5 m and a length of 7 m with expanded parameters such as slope slope, screen form and shelf exposure ratio found that the discharge coefficient of a circular sieve with an opening area of 35% may be greater than one [1]. For the opening area of 0.664 the value of Cd is found to be equal to 0.87. They also found that for the purposes of screen length design calculated from the following equation (5).

$$Cd.\varepsilon.\left(\frac{L}{E}\right) = 1 \tag{5}$$

With Cd is the discharge coefficient, ε is the shelf porosity, L is the rack length and E is approaching a certain energy stream. To study the characteristics above the screen, we have also developed the following equations [3]. The discharge coefficient is described by Equation (6).

$$Cd = 0{,}1296\left(\frac{t}{s}\right) - 0{,}4284(S)^2 + 0{,}1764 \qquad (6)$$

With t = the thickness of the screen rod and s is the distance between the screens.

4. RESULT AND DISCUSSION

4.1. Flow Condition in Tyrol Weir

Determination of the debit coefficient is required for the purpose of discharge planning into the filter. For the purposes of determining the coefficient of discharge on the sieve with the hole in the form of a circle it is necessary to first review the change of the discharge coefficient due to the change of the flow behavior of the sub critical to be super critical for various slope of the filter and various variations of the filter hole diameter.

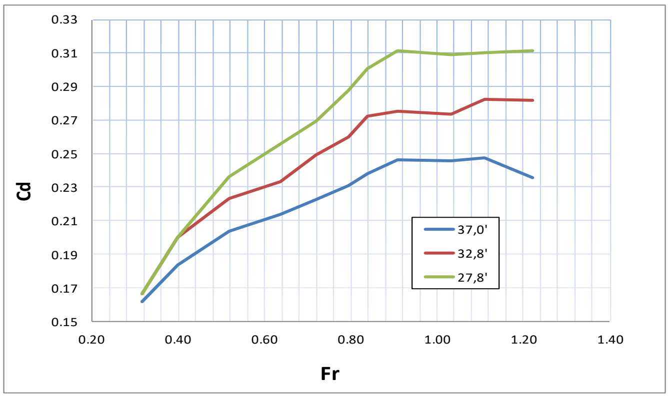


Figure 6 Relationship of Froude number (Fr) and the discharge coefficient (Cd) on Aro_1

Figure 6 shows a graph of the relationship between the froude number (Fr) and the coefficient for the filter openings Aro1 = 0.047 m^2/m. As shown in Figure 6, the value of the debit coefficient (Cd) ranges from 0.16 to 0.31. The higher the slope of the filter then the coefficient of debit increases. In the Froude (Fr) <1 number, the debit coefficient (Cd) rises significantly. However, when the Froude (Fr) = 1 number, the discharge coefficient (Cd) tends to remain, except in the sieve with a slope angle of 27.8^o the debit coefficient (Cd) tends to decrease.

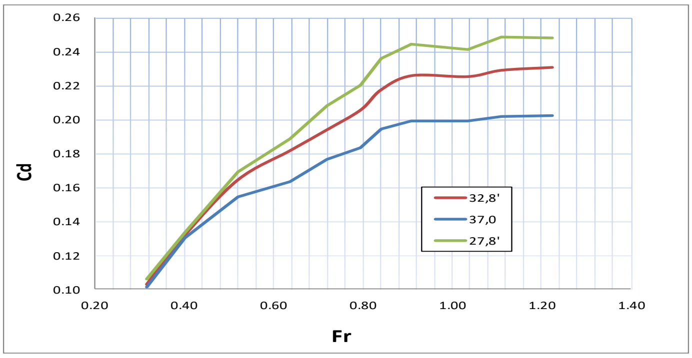


Figure 7 Relationship of the numbers Froude (Fr) and the discharge coefficient (Cd) on Aro_2

Figure 7 shows that the value of the discharge coefficient (Cd) for Aro2 = 0.076 m^2/m aperture ratio ranges from 0.10 to 0.25. The value of Cd is smaller than the value of Cd at the ratio of Aro1 openings. Different in the Aro2 opening ratio is when the value of Fr> 1, the value of Cd tends to be stable at a slope angle of 27.8^o, which means equal to the slope of 32.8^o and 37 ^{o}.

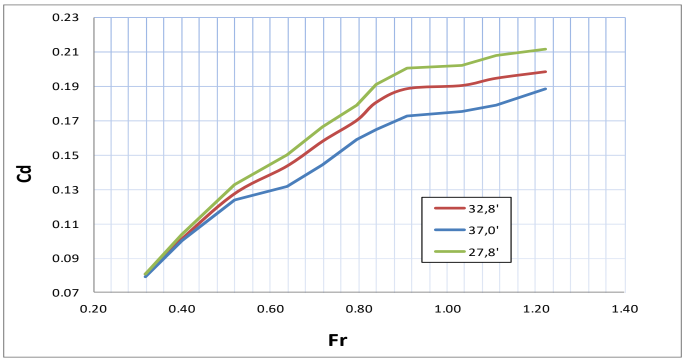


Figure 8 Relationship of Froude numbers (Fr) and the discharge coefficient (Cd) on Aro_3

As shown in Fig. 8, we present the relationship of Froude number (Fr) with the debit coefficient (Cd) at Aro_3 = 0.10 m^2/m. The value of the debit coefficient (Cd) on Aro_3 ranges from 0.08 to 0.21. At the time Fr = 1, the discharge coefficient (Cd) tends to be stable. However, in the condition Fr <1 also occurs in Fr >1, the debit coefficient (Cd) increases as the froude number (Fr) increases. However, the change in the increase of the discharge coefficient under Fr> 1 is lower than that of Fr <1. This indicates that the slope of the filter (S) and the extension of the filter opening (Aro) is the variable that influences the determination of the discharge coefficient (Cd) on the Tyrol weir.

4.2. Water Capture Efficiencies (WCE)

At each opening ratio (Aro) will certainly result in a different water catch (WCE), this may be affected by the filter slope and flow conditions. Not always the coefficient of discharge (Cd) increases then the catchment of water (WCE) is increasing in every stream flow. So we need to examine how the relationship between the number froude (Fr) with the amount of water catchment (WCE).

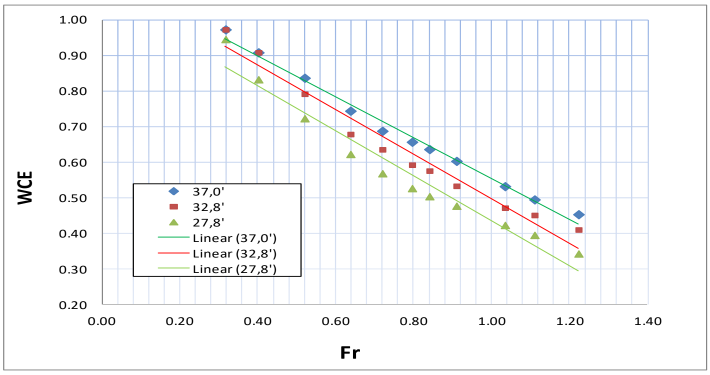


Figure 9 Relationship of Froude numbers (Fr) and water catchment (WCE) on Aro1

In figure 9, it is seen that water catch (WCE) decreases when Froude number increases and vice versa. This occurs in all types of filter slopes. The WCE degradation process follows the linear line trend with the lowest correlation coefficient on the 27.8° sieve with R^2 = 0.96, whereas the highest correlation coefficient on the 37° filter with R^2 = 0.99.

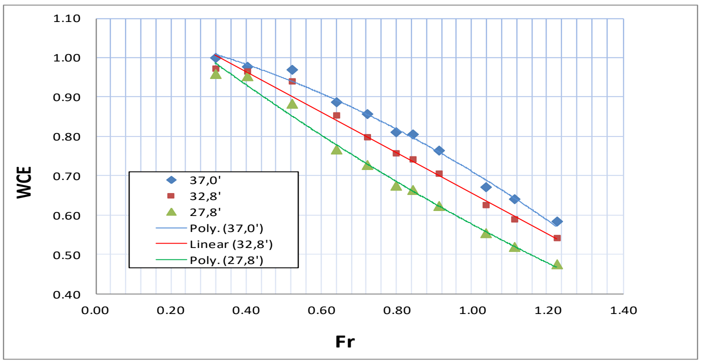


Figure 10 Relationship of Froude numbers (Fr) and water catchment (WCE) on Aro2

A somewhat different condition occurs in Fig. 10. The decrease in WCE value due to the increase of Froude (Fr) value in the form of straight line occurs only in the filter 32.8° while for the sieve 27,8° and 37° has done approach with line line but R^2 value is low so done approach with polynomial line R^2 result better. When the froude number (Fr) is about 0.3 then in all types of filter slope, the value of WCE is almost the same. Significant variations of WCE values occur during critical flow (Fr = 1) and when Fr > 1 WCE values on all filters are almost equal.

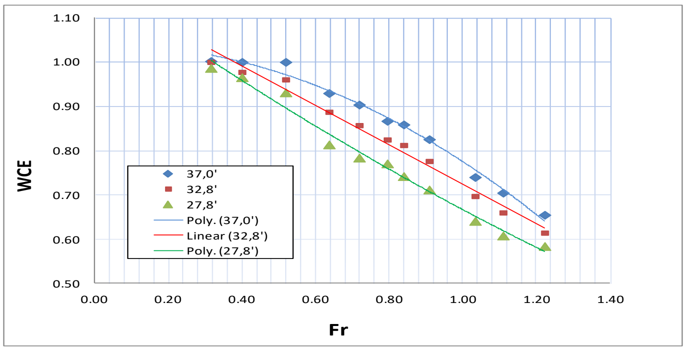


Figure 11 Relationship of the Froude number (Fr) and water catchment (WCE) on Aro3

A more different condition occurs in Fig. 11. The decrease of WCE value due to the increase of Froude number of straight line still occurs in the filter with the slope of 32.8o while for the sieve 27,8 o and 37 o is done approach with polynomial line. At the ratio of Aro3 openings and froude number (Fr) about 0.3 then on all types of slope WCE value is almost the same. Significant variation occurs during critical stream (Fr = 1) and then the value of WCE approaches when Fr > 1. These values when compared with the Aro^2 con- period, then Aro3 is closer. So from this description it can be assured that the more rendan the value of Fr and the greater Aro, then the value of WCE on all the slope of the filter is closer to the same number. The same thing happens when the value of Fr and Aro increases then the WCE value approaches the same number.

Based on the relationship between the value of the froude number (Fr) and the debit coefficient (Cd) at various Aro values there is an increase in the Cd value and then the Cd value stagnant (Figs. 6, 7 and 8). Based on the relationship between WCE and froude (Fr) values at various Aro values, the WCE values decrease due to the increase of the froude (Fr) (Fig. 9,10 and 11). So from the two relationships mentioned above, there is unity trend between variables that need to be studied. In determining the value of Aro1, Aro2 and ARo3 there are 2 determinant variable that is the diameter of the hole (d) and the distance between centers of hole point (a). So it is necessary to make a relationship analysis between the ratio value of distance and the diameter of the hole (d / a) on all types of slope and all flow constants, especially when Fr <1 and Fr> 1.

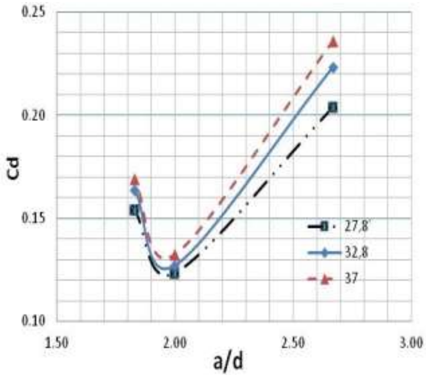
4.3. Equation Discharge Coefficient in Tyrol Weir

To find the distance between holes (a) at each hole diameter, then calculated based on Aro data that has been made by Halit (2012). The calculations are performed on every 3 variations in diameter (d1 = 3 mm, d2 = 6 mm and d3 = 10 mm). The results of the calculations are presented in Table 2. The relationship between the distance between the diameter of the hole and the diameter of the hole is presented in figure 8. In the graph shows that the greater the value of a / e then the value of coefficient of discharge (Cd) is also greater. The increase of the discharge coefficient (Cd) occurs in a linear line with the greater the distance between the holes (a) and the small diameter of the hole (e). In the table it is also seen that the slope of the straight line gets sharper when the sub-critical flow conditions, then more gentle on critical and super critical conditions.

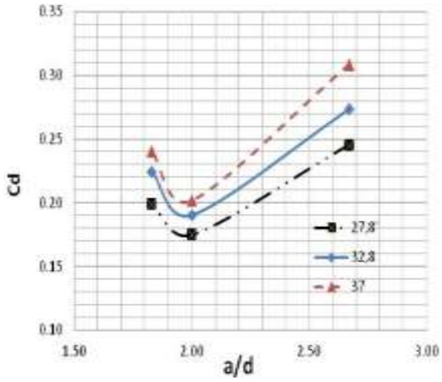
Table 2 Paramater of Data Hole Diameter

No	Paramater	Unit	Hole diameter (D) in mm		
			$D_1 = 3$	$D_2 = 6$	$D_3 = 10$
1	Aro	m^2/m	0.047	0.076	0.1
2	A total	m^2	2	2	2
3	Aro total	m^2	0.094	0.152	0.2
4	Aro per hole	m^2	0.00003	0.00011	0.00031
5	Number of holes	Unit	3326.256	1344.657	636.943
6	Number of hole columns (X)	Unit	180	120	86
7	Number of hole rows (Y)	Unit	18	11	8
8	Control Number of holes	Unit	3240	1320	688
9	Distance X	mm	8.066	10.579	20.023
10	Distance Y	mm	7.684	11.167	19.556
11	A	mm	8	11	20
12	a / d		2.67	1.83	2.00

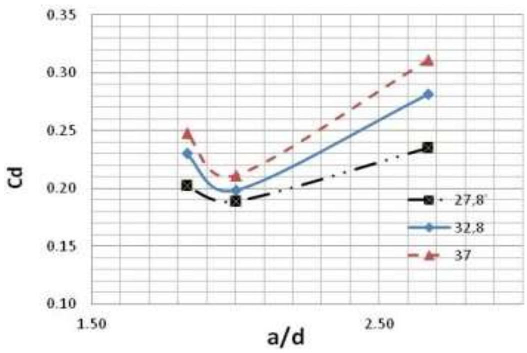
The bigger slope of the filter the greater the discharge coefficient, as well as the slope of the filter the debit coefficient is also getting smaller. In sub-critical flow conditions it is seen that at all slope of the filter the value of the discharge coefficient (Cd) lies between 0.12 - 0.24. Whereas in the critical flow the value of the discharge coefficient (Cd) lies between 0.17 - 0.30 as well as at super critical flow the value of the discharge coefficient (Cd) lies between 0.18 - 0.32.



a). Sub-critical flow (Fr < 1)



b). Critical flow (Fr < 1)



c). Super critical flow (Fr < 1)

Figure 12 The value of coefficient of discharge (Cd) and distance ratio between holes (a/d)

When the value of a/d < 2 cd value continues to rise up to 0.25, while when the value of a/d > 2 Cd value continues to rise up to 0.32. However, based on Figure 6, the variation of the slope of the screen also influences the magnitude of the discharge coefficient.

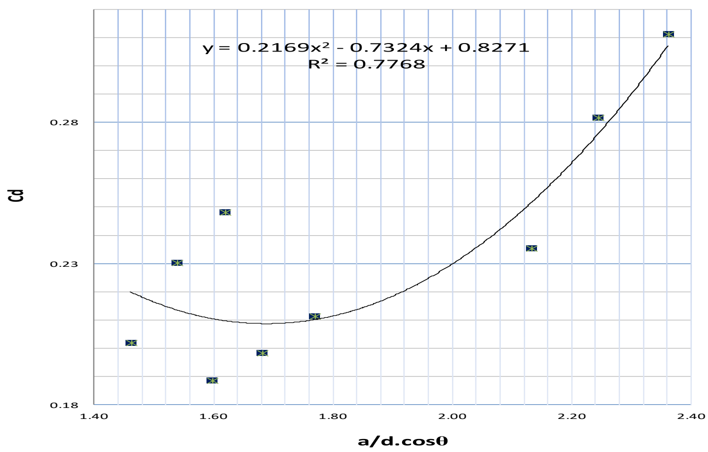


Figure 13 Relationship between coefficients discharge (Cd) with a/d Cos θ in Sub-critical flow (Fr < 1)

So there needs to be made a relationship between the value of a/d and the slope of the screen against the value of Cd generated, based on figure 6 also seen the greater the slope of the channel then the discharge coefficient is also greater. Thus the discharge coefficient is directly proportional to the slope of the channel, this is inconsistent with the formulas already obtained by Ghosh and Ahmad (2005). So to define the relationship between the screen slope, the a/d value and the discharge coefficient are shown in Fig. 13.

Based on figure 14 it is seen that at the time of Cos a/d ranged from betwen 1,4 – 2,0 then Cd value tends to stable. However when the value of a/d Cos $\theta > 2$ tends to rise significantly. This shows that the value of a/d is most influential to the increase of Cd value. But the slope of the screen also affects but is not significant. So to obtain the picture of the relationship between the hole diameter factor, the distance between the screen sieve hole and the resulting discharge coefficient on made a polynomial equation that describes the relationship between the variables mentioned above.

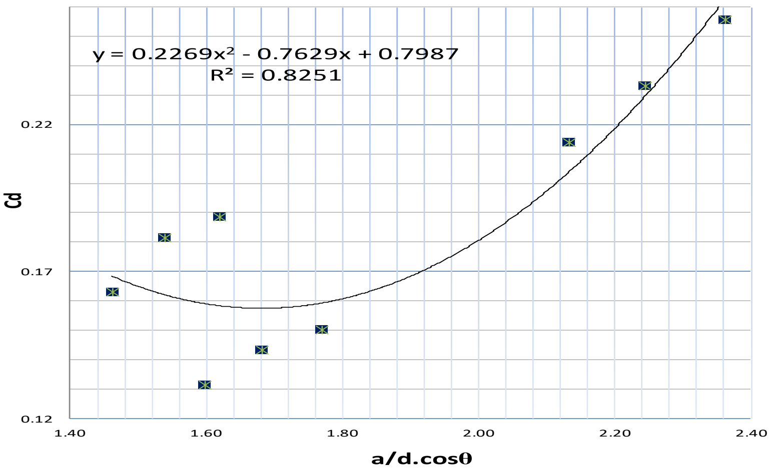


Figure 14 Relationship between coefficients discharge (Cd)with a/d Cos θ in Super critical flow (Fr > 1)

At the critical sub stream condition the Cd value decreases and then rises, in contrast to the super critical flow condition the Cd value tends to be flat and tilted significantly. In the sub-critical condition, the correlation coefficient is quite close to 0.78 with the obtained equation is $Y = 0.217.a/d^2.\cos^2\theta - 0.732.a/d.\cos\theta + 0.827$. While In the super-critical condition, the correlation coefficient is quite close to 0.83 with the obtained equation is $Y = 0.227.a/d^2.\cos^2\theta - 0.763.a/d.\cos\theta + 0.799$.

5. CONCLUSION

The discharge coefficient (Cd) increases with the higher slope of the screen (θ) and the larger the ratio of the hole area to the screen area (a/d). The water catchment (WCE) in the screen is optimal under sub-critical flow conditions (Fr <1) and decreases drastically due to changes in flow conditions from sub-critical to super ktiris. The increase of the discharge coefficient (Cd) occurs in a linear line with the increasing distance between the holes (a) and the small diameter of the hole (d), the slope of the straight line getting sharper during sub-critical flow conditions, then increasingly rampant in critical and super critical conditions.

In sub-critical flow conditions it is seen that at all slope of the screen the value of the discharge coefficient (Cd) lies between 0.12 - 0.24, whereas in the critical flow the value of the discharge coefficient (Cd) lies between 0.17 - 0.30 as well as at super critical flow the value of the discharge coefficient (Cd) lies between 0.18 - 0.32. The significant result in this research is finding the equation of debit coefficient value (Cd) at sub critical condition and super critical by inserting the ratio of distance between hole and hole diameter (a / d). In the sub-critical condition, the correlation coefficient is quite close to 0.78 with the obtained equation is $Y = 0.217.a/d^2.\cos^2\theta - 0.732.a/d.\cos\theta + 0.827$. While In the super-critical condition, the correlation coefficient is quite close to 0.83 with the obtained equation is $Y = 0.227.a/d^2.\cos^2\theta - 0.763.a/d.\cos\theta + 0.799$.

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