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Effect of Increasing The Inlets'sizes on The Discharge Efficiency of Rainwater Networks

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Abstract: *Proper drainage of the roadway is essential to highway safety. Drainage systems for roadways with gutters are designed to limit spread of water on the pavement. Excess water must be captured by curb and gutter inlets. To locate and size these inlets properly, designers need reliable information on their hydraulic performance. Hence, this study deals with the experimental investigation of the storm network drainage system efficiency by investigated of the effect of changing the size of inlets to the efficiency of the rainwater network. Three sizes of inlets will be used with radius (2.5cm, 3.75cm, and 5cm).in addition two types of inlets' widening (sudden and gradually widening) was studied with radius (3.75cm).As it turns out, with increasing radius of the inlets the efficiency of discharge increases at a rate 17%. In additional dimensional analysis equation is built to get the total efficiency of system. Finally, all the results were on a high resolution and the error rate was only 7 % where the results*

Keywords: *Hydraulics, inlet testing, water depth, drainage system, inlet efficiency, surface flow*

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I. Introduction

The storm-induced flood is the most severe and frequent natural flood disaster in the world. A rainstorm may generate a large rate of surface runoff in a short period of time in response to high-intensity rainfall. The resulting runoff cannot be drained quickly and leads to water accumulation and flooding in streets, roads and residential areas. Storm drain systems are typically designed to carry flow from a rainfall event away from areas where it is unwanted (such as parking lots and roadways).Flooding occurs when either a heavy storm that exceeds the design criteria of the structure or inadequate capacity. Thus storm water collection system (storm sewers) design is an important part of civil engineering. Storm water collection systems must be properly designed to provide necessary surface drainage and should meet other storm water management goals such as water quality, stream bank channel protection, habitat protection and groundwater recharge. **Izzard (1950)** [7], assumed that the flow across the inlet lip is critical (i.e., the inlet is behaving like a weir) and that the water depth decreases linearly along the inlet length. The discharge per length of the inlet was integrated for the entire inlet length to get the total flow into the inlet. **Motskow(1957) [10]**,proved that efficiency values experimentally increase as longitudinal slope approaches to horizontal slope. He also proved that this is valid only if grates bars are parallel to direction of flow. However, in real cases horizontal slopes may create clogging problems and debris accumulation so this will bring another problem in the design stage.**Hofstra and Klomp (1972) [6]**,found that the distortion in pavements was greater in loading enforcement surface and gradually reduced depending on the depth. In which, the wheel tracking is a permanent deformation and thus increasing the depth raises the resistance, in other hand, shear stresses are reduced. Asphalt with low shear strength, essential for resistance to repetitive loads of traffic, have intense display wheel tracking problem. The problem is more during the summer season, as increasing temperatures **Woo and Jones (1974)[14],**carried out experiments to make suggestions on both the hydraulic capacity and safety of the inlets for bicycle riders by trying inlets with different tilting angles. There are some Problems of flooded roads: (Natural life disorder, damage of roads, houses and underground lines, Water pollution, diseases of stagnant water, Increase of maintenance and construction cost and disruption of traffic movement).**Soares (1991)[13]**,studied the effects of altering a curb inlet's entrance and exit transitions with the hope of improving inlet efficiency. Their experiments tested a number of sharp and smooth entrance and exit transitions, yet none had any significant effects on inlet efficiency or reducing the oblique standing wave. slab supports can also cause standing waves, which indicates the HEC-22 recommendation to recess and round slab supports is likely credible. The standing waves at slab supports are likely similar to hydraulic effects at entrances and exits and might be similarly difficult to mitigate or alter to increase efficiency. **Bengtson,**

(2010) [5],using gradients to inlets near the curbs to collect water. If there is not well defined thawing or proper gradients that direct the flow through the inlets, the conventional system can be defined as ineffective. **Carvalho et al. (2011) [2],**using a 2D (Volume of Fluid / Fractional Area Volume Obstacle Representation) model. Rainfalls of different intensities were simulated via a network of pipes overhung 1m above the road surface with sprinklers at 2m staggered intervals.**PatilAbhijit(2011) [3],**talked about effects off bad drainage on roads, he explained that the effect of poor drainage condition on road is very adverse. It causes the failure of road in different ways. Proper drainage system provided to the road increases the life of roads. But the improper drainage system causes the failure of the road at its early edge.**Manuel Gómez(2013)[11],** studied the hydraulic efficiency of continuous transverse grates, despite the importance and the general use of this type of surface drainage structure. He used flume with dimension 1.5 m wide and 5.5 m long with a platform able to simulate road lanes with transverse slopes of up to 4% and a longitudinal slope up to 10% With the available system capacity, it is possible to test inlet grates and to study their hydraulic capacity for a large set of flows (0–200 L=s). Linear equations relating hydraulic efficiency, E, and Froude number, F, were presented. These results have been updated and improved by new data obtained from new experimental tests. These equations link the hydraulic efficiency to specific parameters related to the geometry of the grates and the flow rate per unit width upstream the grate. **Magdi, (2014) [8],**studied the impacts of poor drainage on road performance in Khartoum, a city in Sudan with two case studies; attempts were made to find out the reasons for road failure within the first five years as a result of poor drainage. In this quest, it was discovered that four basic reasons lead to early deterioration of road pavements in the study, these factors according to the research includes, poor drainage design and construction, poor maintenance structure, use of low-quality materials and no local standard of practice.**Muhammad, (2014) [9],**studied highway drainage system and started that highway is importance for removing water from the road surface, preventing ingress of water into the pavement, passing water across the road, either under or over and preventing scour and/ or washout of the pavement, shoulder, batter slopes, water courses and drainage structures. He identified types of drainage on the highway to include kerb and gullies, surface water channel, combined filter drain (French drain), over-the-edge drainage, drainage channel locks, combined kerb and drainage units, linear drainage channels, fin and narrow filter drain (sub-surface drainage) and edge drainage for porous asphalt.

R. Veerappan and J. Le (2016) [12], studied the effect of different type of grates on the hydraulic efficiencies in terms of flow interception by using a network of overhanging pipes. the results indicated that the existing grate inlet designs can intercept up to 96% of the surface run-off and G2000 grate inlets intercepted more flows than G2012 grate inlets.

The aim of this study is to improve the efficiency of rain water networks by increasing the area of inlets with different number of inlets.

II. Dimensilal Analysis

Dimensional analysis based on **Buckingham (1914) [1],** theory is used to develop a functional relationship between the efficiency of discharge of inlets and the other physics quantities involved in the phenomenon. By applying the Buckingham theory, Equation (1) can be written in dimensionless form as:

$$£=f(Q, L_o, W_o, H_I, A_I) \tag{1}$$

In which:

H_I: water depth at inlets upstream
W: the channel width,
$I_1, I_2, I_3, I_4, I_5\ I_6$: refers to the inlet's position
a_I: area of inlet
A_I: relative inlet area (a_I/a_P)
H_I: relative inlet height = h_I/h_U,
W_o: relative inletwidth = W_I/W,
q_i: intercepted discharge
h_u : water depth at flume upstream,
W_I: the water spread beside every inlet
L: the length of the flume,
a_P: area of pipe
Q: the total inlet discharge
L_o: relative inlet length = L_I/L,
£: efficiency of discharge = q_i/Q.

III. Experimental Work

The experimental work was carried out in the" hydraulics and water engineering laboratory, **Faculty of Engineering, Zagazig University**. The Flume that made from a self-colored, glass reinforced plastic mounding is used during the experimental tests. The dimension of this flume is 0.63 m width, 0.1m depth and 6m length. The longitudinal slope, cross-section slopes were 0.3%, 2% respectively, sh. The total discharge is measured using a pre-calibrated orifice meter. The point gauge was used for measuring the water depths formed in the mobile bed. There were six holes at the bottom of the flume through a distance 0.54 m which far away the edge of flume by 2 cm. The holes are connected by a pipe with diameter 5 cm through which disposal drain surface water to a large tank with dimension (1.20m, 0.60m, and 0.60m), figure (1).In addition, four types of inlets were used with different sizes ($\frac{2}{2}$ inch, $\frac{3}{2}$ inch, and $\frac{4}{2}$inch) and widening (sudden, gradually) asshown in figure (2)produce different relative inlet area (100%, 225%, 400%).The number of 240 runs was done; each run took time 30 minutes to adjust the total inlet discharge. Water surface level along the flume in two directions and the amount of water which drained from inletsare measured.

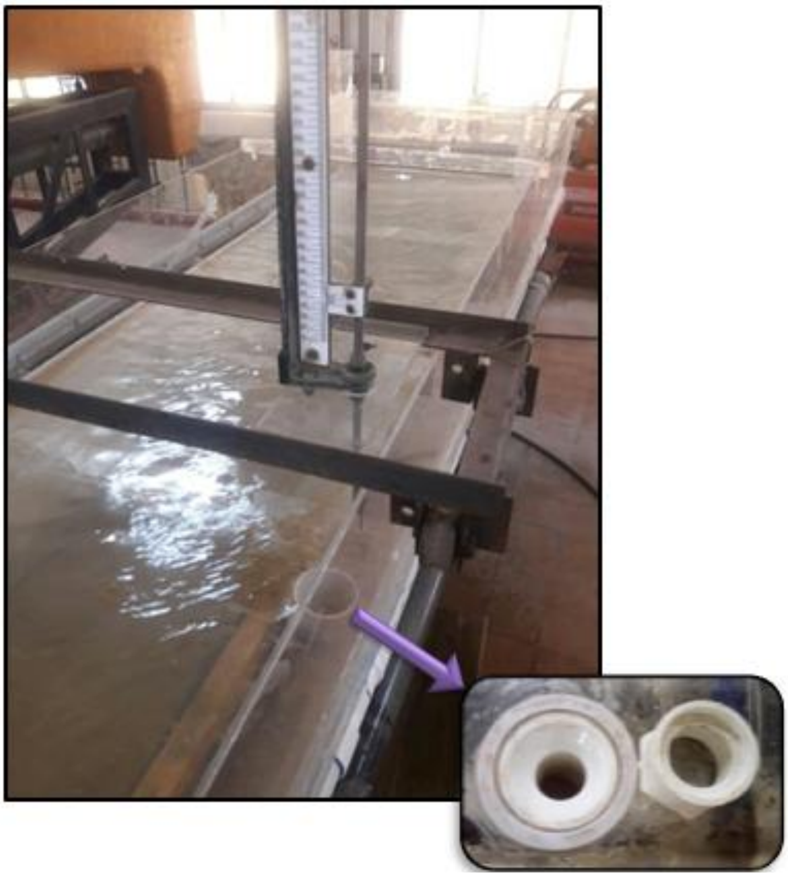

Fig.(1) The flume of experimental tests

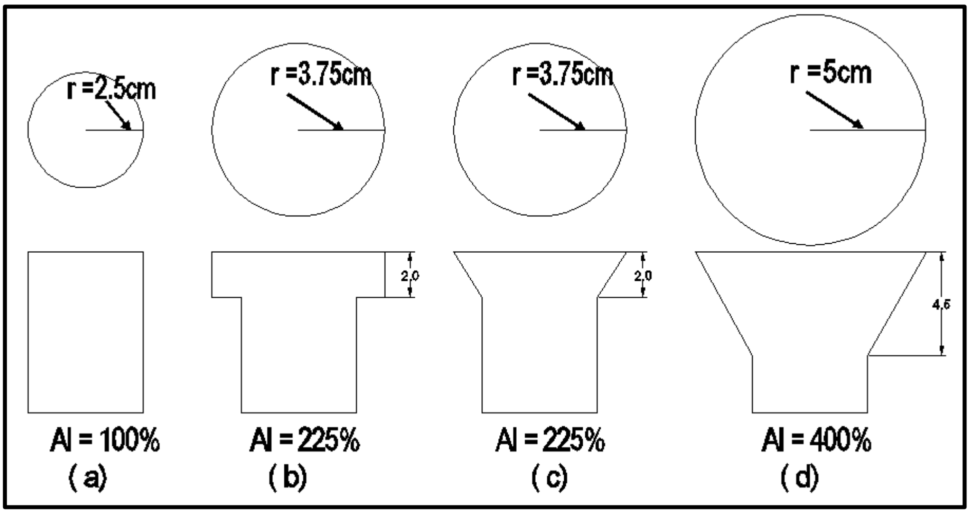

Fig.(2) The different sizes of inlets

IV. Analysis And Discussion

The experimental work was studied the effect of changing area of inletson storm water drainage system efficiency. During this study the effect of increasing inlet opening area on drainage system efficiency, the relative water depth and the relative water width were investigatedwith passing discharge from (1 L/sec to 6 L/sec) and various number of inlets (one inlet, 2 inlets, 3inlets, 4 inlets, and 6inlets) along the flume length.

4.1 Effect of changing relative area of inlets on the efficiency of discharge:

The effect of increasing relative area of inlets through the following values (100%, 225%, and 400%) on the drainage efficiency was studied with different passing discharge (1 L/sec to 6 L/sec). Also through experimental work, different number of inlets (1, 2, 3, 4, and 6) along the flume length are used, (e.g. 1 inlet, there is only one inlet along the flume length).

Figuresfrom (3) to (7) show the relationship between the passing discharge (Q) and the efficiency of dischargefor different relative area of inlets by using different number of inlets (1 inlet, 2inlets, 3inlets, 4inlets, and 6 inlets) respectively. The result indicated that the efficiency was decreasedby about (30% to 40%) as passing discharge increases when the number of inletsand side slope are constant. In addition, the increasing of the side slope from 1.5% to 2% and 4%, the efficiency increased by (2.1%) and (9.3%) respectively, this means that increased side slope by 100% the drainage efficiency increased by (7.2%).The result indicated that the efficiency was decrease as the passing discharge increases for using different number of inlets with different relative area of inlets.In addition, The efficiency of discharge increased with increasing area of opening inlets within (19.9%, 22.3%, 16.8%,14.2%, and 8.4%) for different number of inlets(1,2,3,4, and 6) thus allowing for better water harvesting from the catchment area.Moreover, by comparing the use of the same inlet's area 225% and the same number of inlets with the difference in the way of widening (gradually and sudden widening), it was found that the efficiency of the gradually widening better than the sudden widening by (0.9%) when used small passing discharge, but by using of large passing discharge the efficiency of the sudden widening better than the gradually widening by (1.9%).

An explanation of what happened was found with small passing dischargethe storm water capacity was controlled by transport capacityso the gradually widening was better to transport water molecules. In other hand, with using big passing dischargethe storm water capacity was controlled by storage capacity rather than water transport capacity {Guo (2000)} [4]

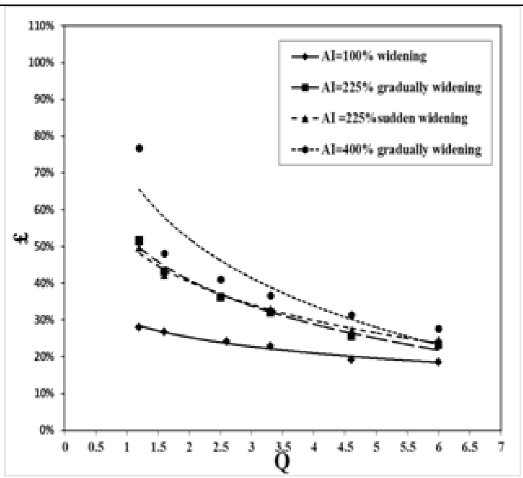

Fig.(3) relationship between £and Q for using 1 inlet with different inlets area

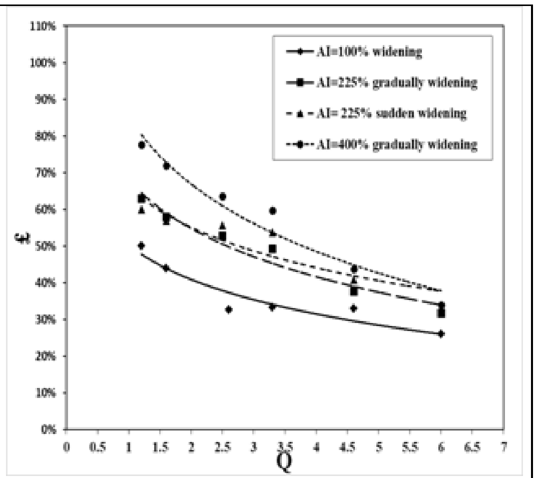

Fig.(4) relationship between £and Q for using 2 inlets with different inlets area

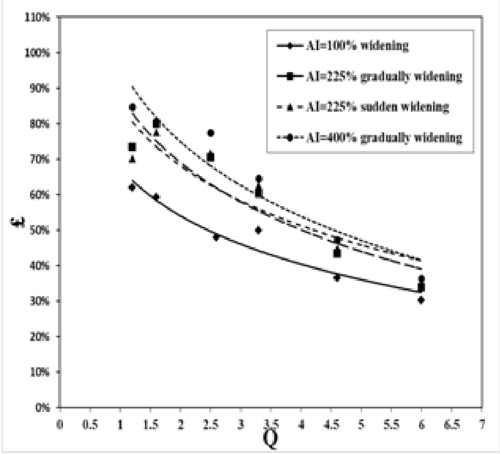

Fig.(5) relationship between £and Q for using 3 inlets with different inlets area

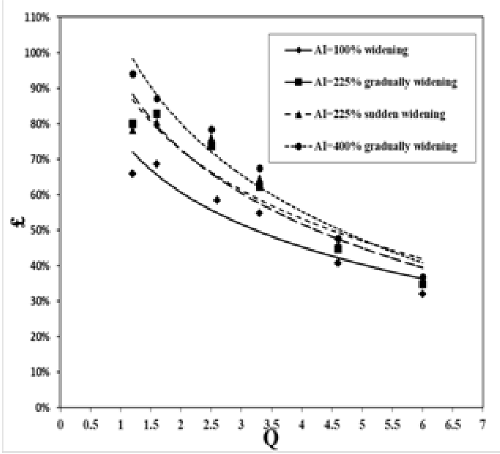

Fig.(6) relationship between £and Q for using 4 inlets with different inlets area

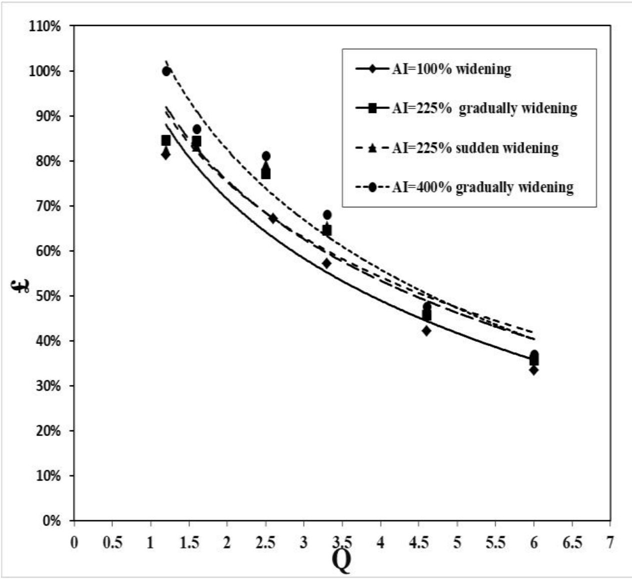

Fig.(7) relationship between £and Q for using 6 inlets with different inlets area

Figure (8)present the average efficiency of the different relative areas of inlets used with the difference in the number of inlets. In addition, the best relative inlet's area was (400%) with difference value 17% from the inlet's area (100%) as the volume of the inlet changed from 88.3cm^3 to 206cm^3. Moreover, the average efficiency for using A_I=225% with (gradually, suddenly widening) were about (10%, 11%)respectively in which, the volume of inlets changed from 88.3cm^3 to (111.5cm^3, 137.4cm^3). Thus the average efficiency of discharge of four different sizes of inlets (100%, 225% gradually widening, 225% sudden widening, and 400%, gradually widening) were (44%, 54%, 55%, and 61%) respectively.

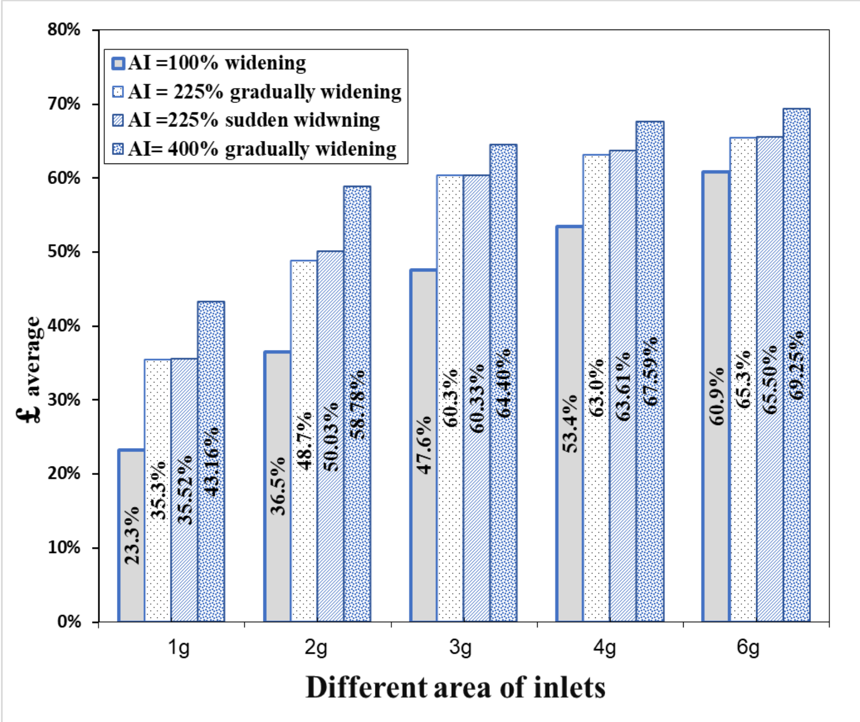

Fig.(8) Average efficiency for using different number of inlets with different relative inlet's area

4.2 Effect of changing area f inlets on the relative inlet height:

The water depth along the flume was measured at upstreameach inlet to investigate the effect of increasing the relative inlet area on water surface profile and redistribution of water along the flume. Figuresfrom(9) and (12) show the relationship between relative inlet water height, and relative inletdistance with different relative area of inlet for using different number of inlets (3, 6), in which as increasing relative inlet's area the relative inlet water heightwas decreased by (14.7%, 31.6%) for using (3, 6) number of inlets at passing discharge = 1.2L/sec. Also, decreasing in relative inlet water heightwas (6.7%, 7.34%) at passing discharge= 6L/sec.

Moreover, it can be obtained that with using 225% relative inlet's area at small passing dischargethe relative inlet water heightfor gradually widening area was lower than sudden widening area due to the efficiency of gradually widening area in drain the water, And vice versa with big passing discharge in which the relative inlet water heightfor gradually widening area was higher than sudden widening area.

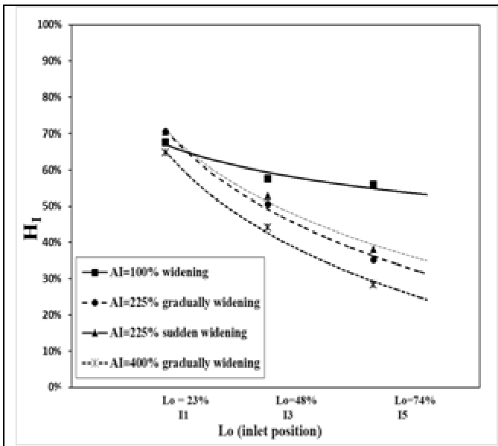

Fig. (9) relationship between relative inlet height and relative inlet distance for using 3 inlets at Q= 1.2L/sec with different area of inlet

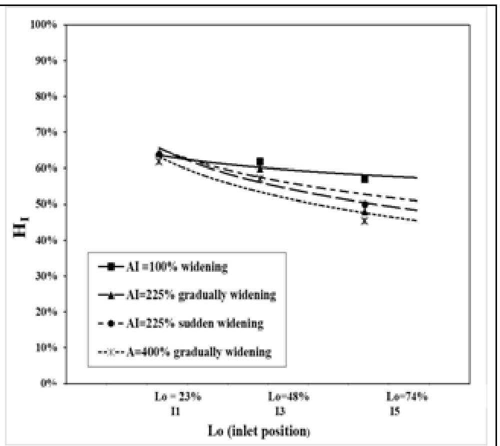

Fig. (10) relationship between relative inlet height and relative inlet distance for using 3 inlets at Q= 6.0L/sec with different area of inlet

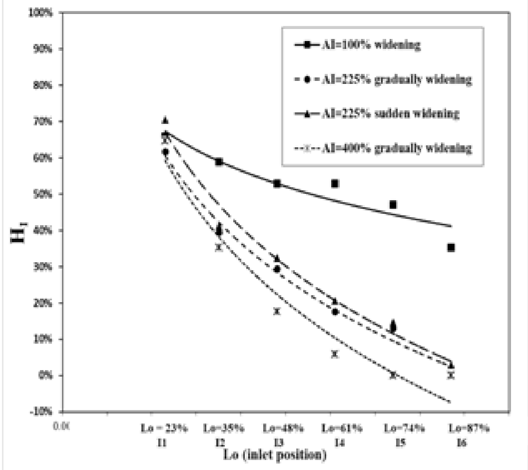

Fig. (11) relationship between relative inlet height and relative inlet distancefor using 6 inlets at Q= 1.2L/sec with different area of inlet

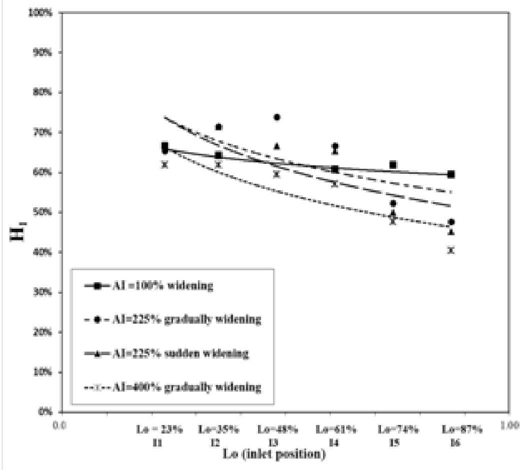

Fig. (12) relationship between relative inlet height and relative inlet distancefor using 6 inlets at Q= 6.0L/sec with different area of inlet

4.3 Effect of changing area of inlets on the relative width:

The water spread was observed on the flume with increasing relative area of inlets; the water had been recedingin the cross-section direction, indicating the efficiency of the inlets in the disposal of excess water. Figures from(13) to (16) show the relationship between relative water width and relative inlets distance for using different area of inlets at passing discharge(1.2L/sec), which present as the area of inlet increased the relative water width decrease by (18%, 19%, 24%, 34%), as a result of increased water harvesting efficiency due to increased gap capacity,in which shown in the figure (17).

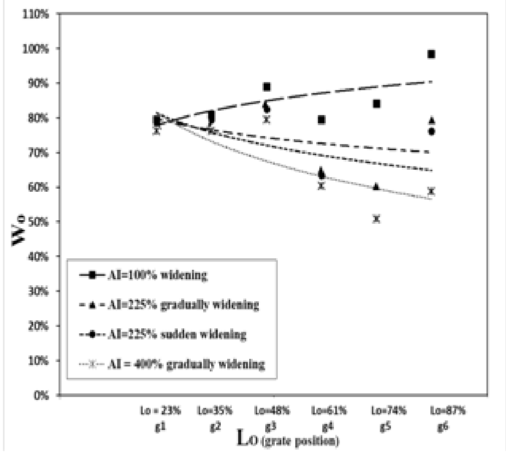

Fig. (13) relationship between RW and RID for using 1 inlet at Q= 1.2L/sec with different area of inlet

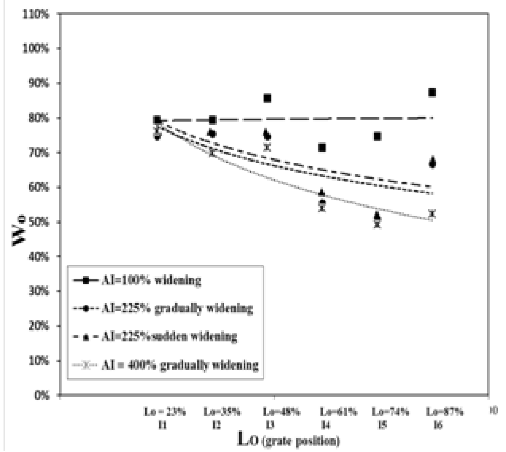

Fig. (14) relationship between RW and RID for using 2 inlets at Q= 1.2L/sec with different area of inlet

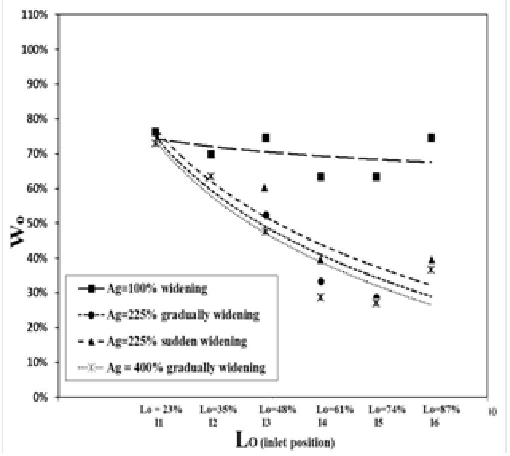

Fig. (15) relationship between RW and RID for using 3 inlets at Q= 1.2L/sec with different area of inlet

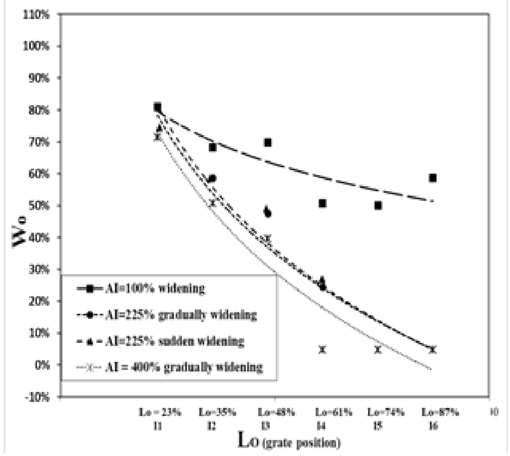

Fig. (16) relationship between RW and RID for using 6 inlets at Q= 1.2L/sec with different area of inlet

Fig.(17) Water receding in the transverse direction

V. Prediction Of Efficiency

A statistical tool was used, by use data analysis for measure data. Eq. (2) was developed to correlate the water discharge efficiency (£) relative total discharge, area of inlet, and number of inlets.

$$\pounds = -0.0827Q - 0.056n + 0.055A_I + 0.499 \quad (2)$$

The correlation coefficient and the stander error of estimate for Eq. (1) are 94%, 0.07. Figure(18) show the relationship between the predicted values of £ using Eq. (2) versus the measured ones while figure (19) shows the distribution of the residuals around the line of zero error. Both figures indicates that Eq.(2)

represented the measured data very well and hence could be used safely to predict the relative efficiency for different no of inlets at total discharge ranging from 1 to 6L/sec.

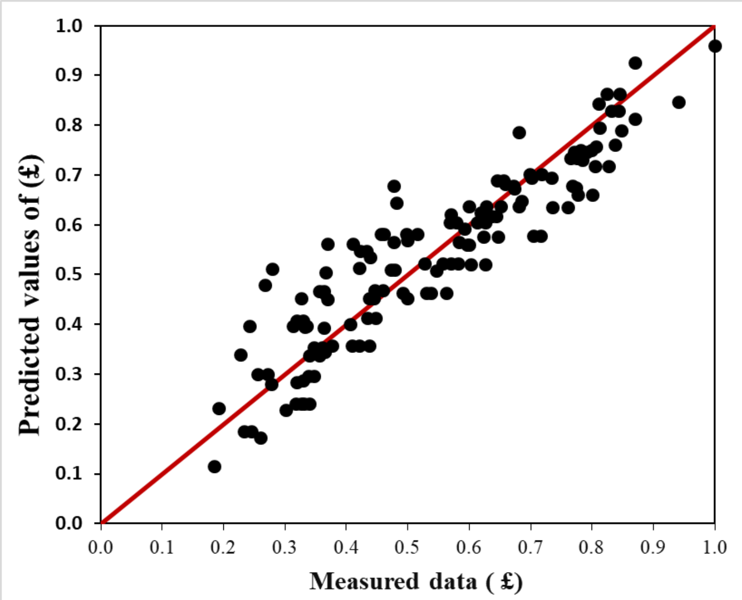

Fig. (18) Measured £ versus Predicted ones from Eq.(2)

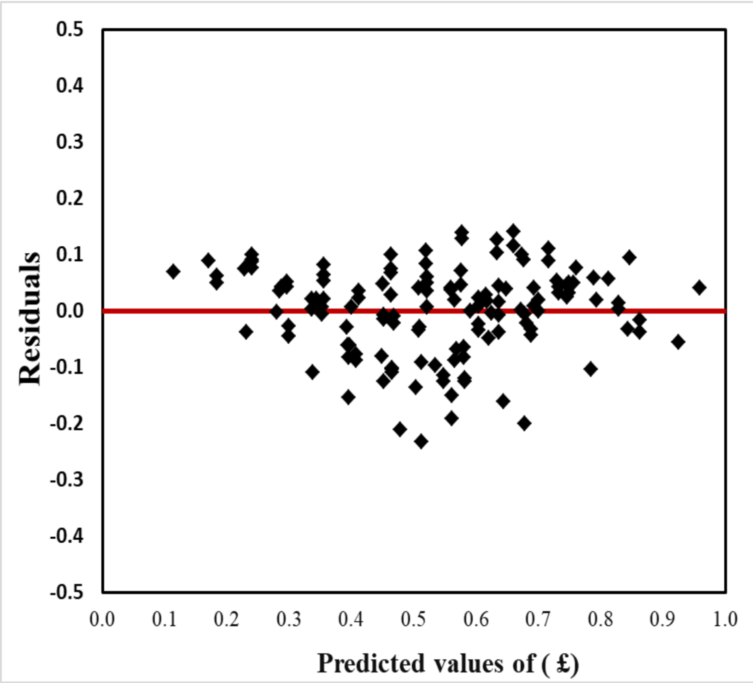

Fig. (19) Measured £ versus Predicted ones from Eq. (2)

VI. Conclusions

The following conclusions, which are valid within the experimental delimitations, could be stated as follows:

1. As the passing discharge increased the efficiency of water discharge system decrease for all tests done
2. The efficiency of discharge increases as the number of inlets increase from 1 inlet to 6 inlets with using four sizes of inlets (100%, 225% gradually widening, 225% sudden widening, and 400%, gradually widening) within (32%, 30%. 29%, and 56%) respectively.
3. The average efficiency of discharge of four different sizes of inlets (100%, 225% gradually widening, 225% sudden widening, and 400%, gradually widening) were (44%, 54%, 55%, and 61%) respectively.
4. The amount of increasing of inlets efficiency with increasing area of opening inlets were (19.9%, 22.3%, 16.8%,14.2%, and 8.4%) for using different number of inlets(1,2,3,4, and 6) respectively.

5. by comparing the use of the same inlet's area 225% and the same number of inlets with the difference in the way of widening (gradually and sudden widening), the efficiency of the gradually widening better than the sudden widening by (0.9%) when used small passing discharge, but by using of large passing discharge the efficiency of the sudden widening better than the gradually widening by (1.9%).
6. As increasing relative inlet's area the relative inlet water height was decreased by (14.7%, 31.6%) for using (3, 6) number of inlets at passing discharge = 1.2L/sec. Also, decreasing in relative inlet water height was (6.7%, 7.34%) at passing discharge = 6L/sec.
7. Also, decreasing in relative inlet water height was (6.7%, 7.34%) at passing discharge = 6L/sec for using (3, 6) number of inlets.
8. Using different area of inlets at passing discharge(1.2L/sec), the relative water width decreased by (18%, 19%, 24%, 34%),
9. The best size of inlet was $\frac{4}{2}$ inch with difference value 17% from the inlet's area $\frac{2}{2}$ size as the volume of the inlet changed from 88.3cm^3 to 206cm^3 , in which using big passing discharge the storm water capacity was controlled by storage capacity rather than water transport capacity

Reference

[1]. Buckingham, E. (1914). "On physically similar systems; illustrations of the use of dimensional equations." Physical Review, 4(4), 345-376.

[2]. Carvalho, R.F., Leandro, J., David, L.M., Martins, R., and Melo, N., 2011. "Numerical Research of the Inflow Into Different Gullies Outlets". In: Computing and Control for the Water Industry. Exeter, UK

[3]. D.Y.PatilPrathisthan'sY.B.Patil Polytechnic, Akurdi, PatilJalindar (Civil and Environmental Research) www.iiste.org ISSN 2224-5790 (Print) ISSN 2225-0514 (Online) Vol 1, No.1, [2011] Effects of Bad Drainage on Roads PatilAbhijit (Corresponding author

[4]. Guo, J. C.Y. 2000. Street stormwater storage capacity. Water Environment Research 72: (5) 626-630

[5]. Harlan Bengtson, Excel Spreadsheets for Design of Storm Water Drains and Their Inlets,[2010]

[6]. Hofstra, A., and Klomp, A.J.G.,(1972). Permanent Deformation of Flexible Pavements Under

[7]. Simulated Road Traffic Conditions, Proceedings, Third International Conference on the Structural Design of Asphalt Pavements, Vol. I, London, 613621

[8]. Izzard, C. F. (1946). "Hydraulics of Runoff from Developed Surfaces," Proceedings, 26th Annual Meeting, Highway Research Board, pp. 129-150.

[9]. Magdi, M. E. Z. (2014). The Impacts of Poor Drainage on Road Performance in Khartoum. International Journal of Multidisciplinary and Scientific Emerging Research.

[10]. Muhammad, B. B. (2014). Highway drainage system. https://www.linkedin.com/pulse/ 20141125045254-112545392 -highway-drainage-system

[11]. Mostkow M.A., Sur le calcul des grilles de prised'eau (Theoretical study of bottom type water intake), La Houille blanche, Grenoble, 12th yr., no, pp. 570-580, September,[1957]

[12]. Manuel Gómez, and Jackson and, TellezArticle (Estimate the Hydraulic Efficiency of Nontested Continuous Transverse Grates), in Journal of Irrigation and Drainage Engineering • October [2013] DOI: 10.1061/(ASCE)IR.1943-4774.0000625

[13]. R. Veerappan& J. Le Catchment and Waterways Department, Public Utilities Board, Singapore Hydraulic efficiency of road drainage inlets for storm drainage system under clogging effect 2016This paper is part of the Proceedings of the 5 International Conference th on Flood Risk Management and Response (FRIAR 2016) www.witconferences.com

[14]. Soares, C. E. (1991). Analysis of the efficiency of an alternative South Carolina storm water drainage structure. Thesis. Clemson University.

[15]. Woo D.C., Jones S.J., Final Technical Report, Report No: FHWA-RD-74-77, Federal Highway Administration, Washington, 1974.

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