PRESSURE DDISTRIBUTION ON THE UPSTREAM FACE OF TUNNEL GATE WITH DIFFERENT LIP SHAPES

Associated Prof.Dr.Thamer Mohammed Ahmed

Civil Engineering Department

Ishik University

Erbil/Iraq

e-mail: thamir.ahmed@ishik.edu.iq; website;www.ishikuniversity.net

Keywords: Upstream pressure distribution, Leaf gate, Tunnel-type high-head gate, Hydraulic model.

Abstract. *The lift gate which installed at specified position of the dam tunnel facing a great pressure according to the high water storage level in the reservoir of dam ,and this is the reason behind the need for choosing the suitable gate specifications withstand of such pressures .The one of important factors that affected the stability and bearing of gate is the pressure resulting from pressurized flow established along the tunnel which exerted on the upstream face of gate.The present research included the analyses of experimental measurements of pressure heads distribution indicated by fifteen peizometric holes located on upstream face of tunnel gate model as five holes on each of three vertical lines. The pressure heads have been obtained for many values of gate opening ratios and different shape of gate lips. These measurements were analyzed in details by using the surfer software program in addition of applying the equations based upon the principles of momentum. The relation among the of downpull forces and pressures on the gate upstream face were also studied* .The analysis include some graphs which have been provided to present the relationship among pressure heads and gate opening ,coefficients of downpull forces against pressures on the gate upstream face .The results revealed that pressure head are mostly concentrated at the upper portion of gate for most values of gate openings which indicate the need of make this part to be supported by steel beams or any other shapes and materials more than other parts of gate in order to satisfy the economical and safety requirements of gate design .

1 INTRODUCTION

High-head gates operate under heads larger than their height. The most widely used high-head gates for flow regulation or emergency closure of large conduits are leaf gates. Leaf gates can operate in a gate well located within a conduit transition and offer many advantages in construction and maintenance. From all types of high-head gates, leaf gates cause the greatest problems in connection with hydrodynamic forces. The pressure along the bottom surface of the gate is reduced during operation because of high efflux velocities. The accompanying downward hydrodynamic forces, the so-called downpull, are often greater than the dead weight of the gate.[9] . The design and operation of tunnel gate received much more attention from many researchers according to its importance in controlling and regulating the flow through outlet conduit of large hydraulic structures such as dams .The pressurized flow occurs through the dam tunnel produces pressures on the upstream face of gate as well as on its top and bottom since the flow passes over and beneath of the gate through the gate shaft.The downpull force which results from the difference between the upward force and downward force is affected the vertical movement of gate whereas the pressure produced on the upstream face of gate behave as hydrostatic pressure and need to study its effects on the gate with different openings in order to identify the region in gate as possible to be exposed to higher pressure. The evaluation of forces impacts the hydraulic gates has been studied by many researchers.

Cox et. al., [1960] [1],developed a dimensionless relationship for estimating the hydrodynamic forces depended on the effect of ventilation, geometry of gate bottom and clearance of gate shaft with its effect on the stability of gate. **Narasimhan and Bhargava, [1975],[4],** presented the factors that the magnitude and character of hydrodynamic force on a gate depended on it. The factors are Froud No., gate opening, the geometric parameters of the gate lip and the skin plate arrangements. The various forces acting on gate during opening and closing were discussed by **Sagar, [1977]**,[5],He determined the hoist capacity with some accuracy to avoid the risk of non-closure particularly in automatic systems. The downpull forces on gate are predicted as follow:-

$$F_d=F_t-F_b \quad (1)$$

$$F_t=\gamma.At.(H-v_o^2/2g) \quad (2)$$

$$F_b = \gamma.\ B.\ d.\ [Hz - (q^2/2g)\ /y\ (y + d \tan\theta)] \quad (3)$$

Where:

γ: specific weight of water.

F_t ,F_b : force on the top and bottom of gate respectively.

At: top area of gate exposed to water pressure = $Bd+B'd'$

d: thickness of the gate excluding the downstream skin plate and seal assembly.

B': width of skin plate and seal assembly.

d': thickness of downstream skin plate and seal assembly. $Hz= H - v_o^2/2g$.

v_o^2 : average velocity of the flow in the conduit upstream the gate.

q: discharge of water per unit width of the gate.

y: height of the gate opening.

θ : angle between horizontal and sloping bottom of the gate.

A method for prediction the gate shaft pressure was presented by **Sagar, [1978][6].** The principle of method based on the velocity head of the jet flowing through the upstream gap which is lost due to sudden expansion within the gate shaft as it moves toward downstream gap. Reinhard Prenner, et. al, [10],were investigated hoist forces on high head leaf gates in open and closed gate design. In addition to these investigations specific constructive measures were developed aimed at reducing hoist forces on these gate types.Helmut Drobir et. al .1,[9] investigated the downpull effects on high-head leaf gates by using a hydraulic model of tunnel-type. The model investigations were carried out for particular headwater and tailwater conditions, for different deep gate slots and for the most common top seal and skinplate arrangement which is with seal and skinplate on the downstream side. the resulting downward hydraulic forces of the hydraulic model test, the so-called downpull, are compared with results of calculation according to the method of Naudascher [2].

2 MODEL

The studies were made with an physical model shown in the fig.(1) [7],the rate of flow was found by using the integrated area method of the values of velocity measured in two locations upstream the gate shaft .The test section consisted of perplex conduit 20 cm wide , 30 cm high .The 5 cm thick gate leaf was made of heavy –gage sheet metal ,and was installed in the vertical steel frame to control the sliding movement of gate .Three columns of five piezometers were placed on upstream face of gate and connected to manometer board so the pressure distribution could be determined .The upstream pressure head was measured by piezometer located at a distance 20 cm from the position of gate shaft whereas downstream pressure head was measured by piezometer placed at a distance 10 cm downstream the gate shaft. The measurements of upstream and downstream piezometric head, top and bottom piezometric head d and pizometric heads along the upstream face of gate were repeated for different gate openings and gate lip shapes.

3 METHOD

The experimental works include the measurements of upstream and downstream heads (H_u & H_d) ,jet velocity head beneath the gate lip ($V_j^2/2g$) ,top and bottom heads (H_t &H_i) and the heads through all taps installed on the upstream gate face (H_f).The determination of downpull force is based upon the following equation [2], where $y_s = H_d$

$$F_d = (K_t - K_b).B.d.\rho.V_j^{\ 2}/2 \tag{4}$$

$$K_t = (H_t - Y_s)/(V_j^{\ 2}/2g) \tag{5}$$

$$K_b = (1/B.d)\iint[(H_i - Y_s)/(V_j^{\ 2}/2g)]dB.dX \tag{6}$$

The of upstream pressure coefficient (Kf) can be found by the following formula [3]:

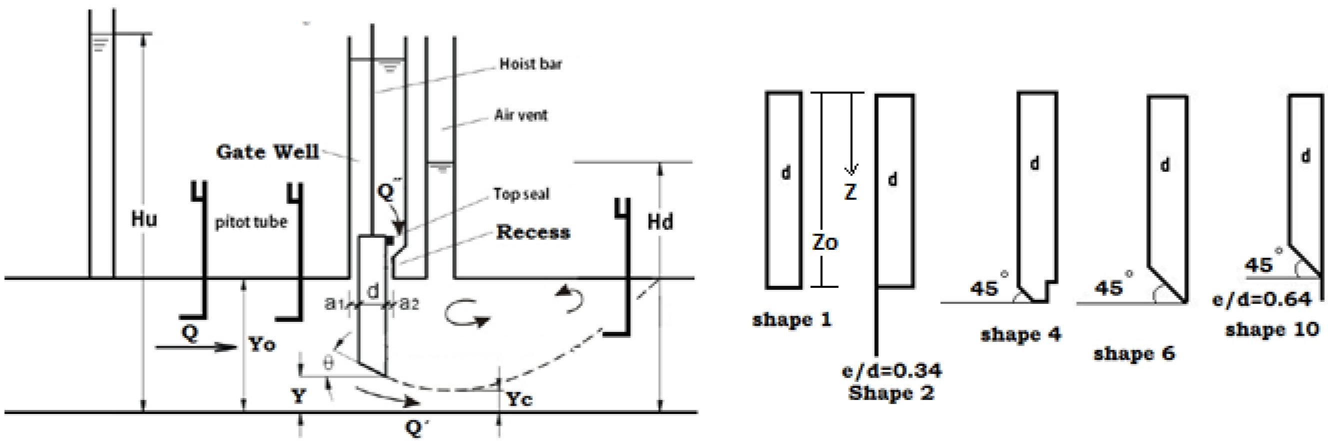

Figure 1.Scheme of hydraulic model.

$$K_f = (H_f - H_d)/(V_j^2/2g) \tag{7}$$

Finally ,the upstream forces on the tunnel gate can also be found by the following formula which based upon the principles of momentum equation in open channel [8] :

$$F_{gate} = \frac{1}{2}\gamma w(y_o^2 - y_1^2) + 2\,\rho\, g\, w\, y_o y_1\,\frac{y_1 - y_o}{y_o + y_1} = \frac{\gamma\,\omega\,(y_o - y_1)^3}{2(y_o + y_1)} \tag{8}$$

By rearrange the above equation in terms of parameters of pressurized flow in tunnel , (assume $y_o \approx$ Hu and $y_1 \approx$ Hd) the force can expressed by the following :

$$F_{gate} = \frac{1}{2}\gamma w\left(H_u^2 - H_d^2\right) + 2\,\rho\, g\, w\,.Hu.Hd\,\frac{Hu - Hd}{Hu + Hd} = \frac{\gamma\, w\,(Hu - Hd)^3}{2(Hu + Hd)} \tag{9}$$

4 RESULTS AND DISCUSSION

The experiments were achieved on four shapes of gate lips by the run of hydraulic model included all measurements required for evaluating the upstream pressure coefficient (Kf) and the downpull force coefficient (Kd) ,especially the top , bottom and upstream face piezometric head distributions which were necessary for determination the top , bottom and upstream face pressure coefficients (Kt , Kb and Kf) . Fig.(1) shows the different types of gate shapes used in the current research . Figures (2 to 7) show the variation of (Kf) coefficient verses vertical distance along the upstream face of the gate for various gate shapes and openings. It can be seen from these figures that the distributions of (Kf) have uniform trend for gate openings (10%,20%,30%,40%) and the values of (Kf) indicates an increase, whereas the high values of gate openings lead to decrease the of values of (Kf) and fluctuation in distribution .Figures (8 and 9) represent the variation of (Kf) for lip shape (10) ,the figures indicates that the distributions of (Kf) values are non-uniform for low values of gate openings and more uniform for high values of gate openings ,and this may be because of the lip extension in trailing edge of gate .Figure (10) represent relation between the (Kf) and gate openings of different shapes of gate lips which indicate that the values of (Kf) are independent of gate lip shapes especially for gate openings less than 80%.Figure (11) indicates that the forces exerted by water and obtained by equation (9) affected by gate lip shapes up to the 40% gate opening. Figures (12 to 15) represent the three dimensions of pressure head distribution of gate shape (1) and denoted the pressure will be high throughout the upper part of gate for low values of gate openings and become less and more uniform for high values of gate openings. Figure(16) indicates the comparisons between the (Kd ,Kf) against the different values of gate openings (Y/Yo) and it can be seen that when Kf increase Kd will decrease.

5 CONCLUSION

The comparisons between the gate lip shapes considered in present research indicate the following :

1- The variation of the gate opening (Y/Yo) more than 40% has a significant effect on the values and distribution of pressure coefficient (Kf) for a given gate shapes.

2- The upper part of gates will need to resist the high pressure exerted by fluid especially for Y/Yo< 40% . coefficients have a main effect on the downpull which is influenced by the flow beneath the gate and the gate lip geometry.

3-For the same gate lip shape ,the gradual increase in Kf will lead to decrease in Kd for different values of (Y/Yo).

4- The comparison between the results of gate lip geometries indicate that shape (4) reduce the effects of fluctuations in the values of pressure head coefficient (Kf) along the upstream face of gate which may lead to make the gate more stable.

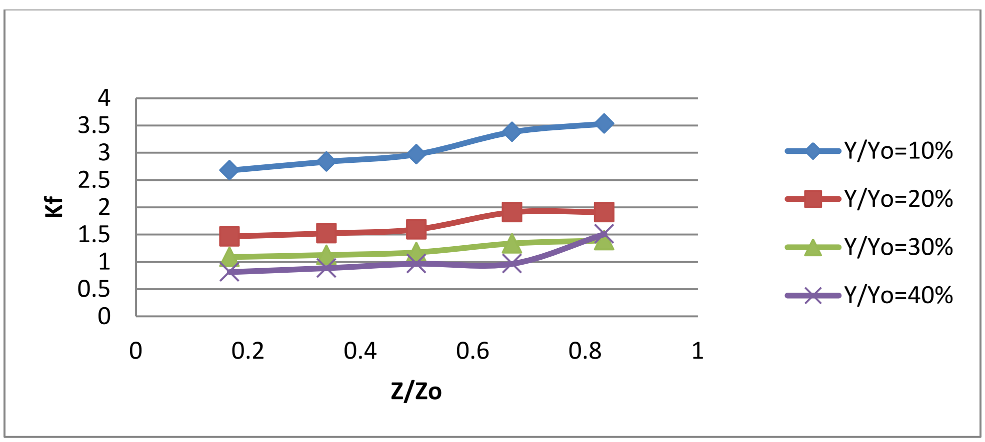

Figure 2 .Variation of Kf along the vertical gate face. (shape 2).

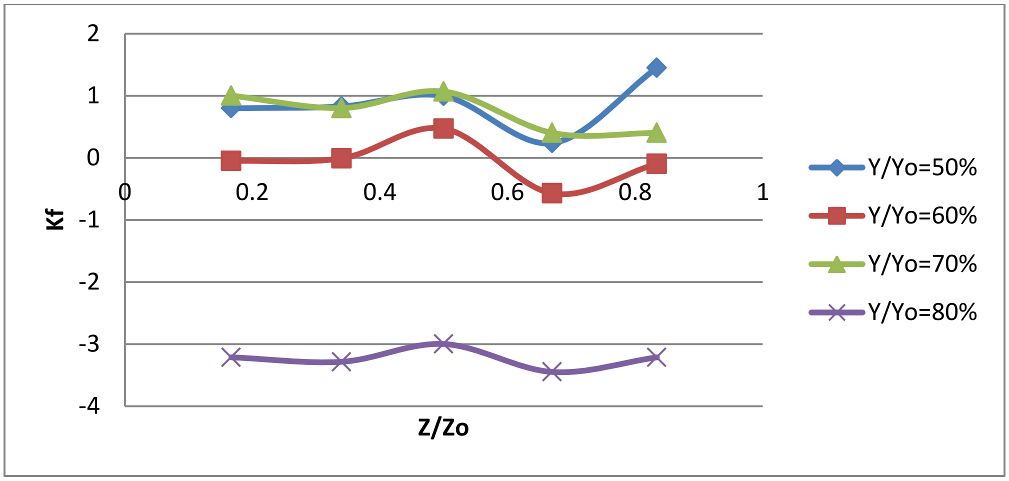

Figure 3.Variation of Kf along vertical gate face .(shape 2).

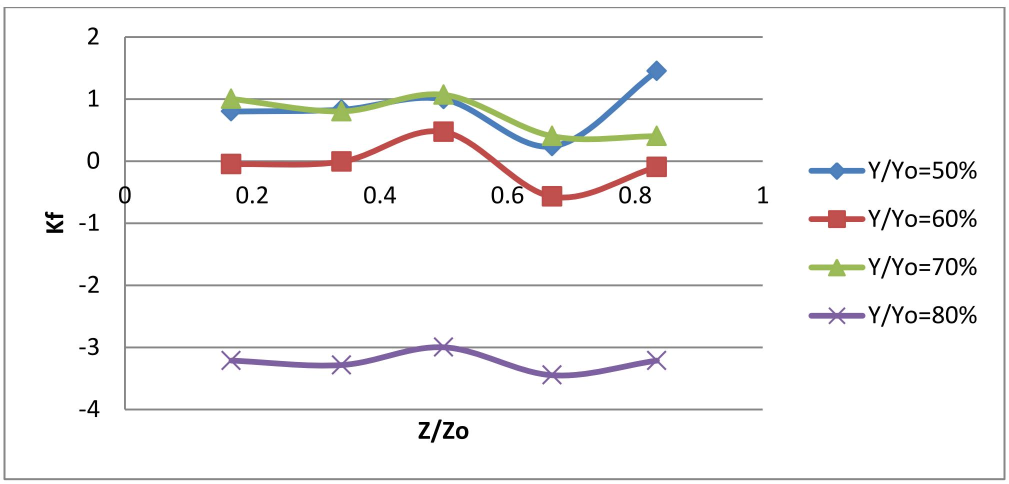

Figure3.Variation of Kf along vertical gate face .(shape 2).

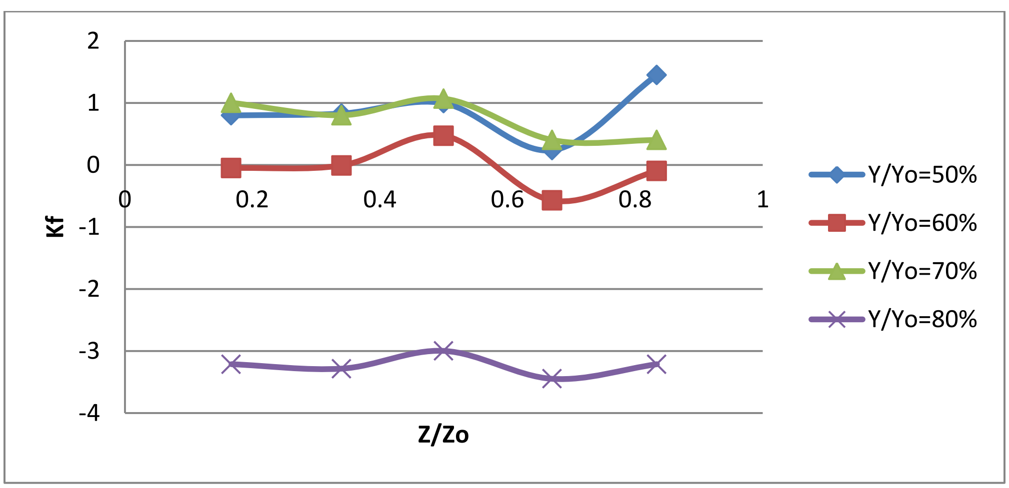

Figure 3 .Variation of Kf along vertical gate face .(shape 2).

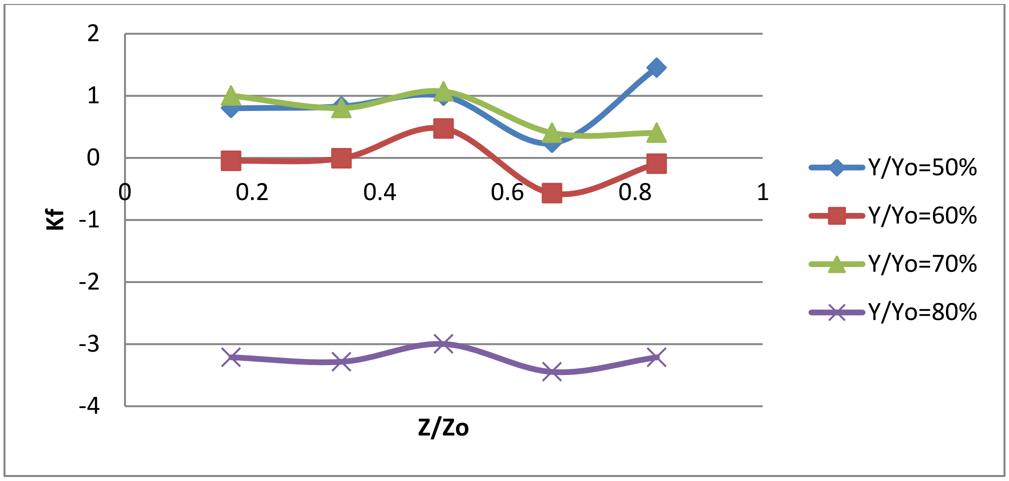

Figure 3.Variation of Kf along vertical gate face .(shape 2).

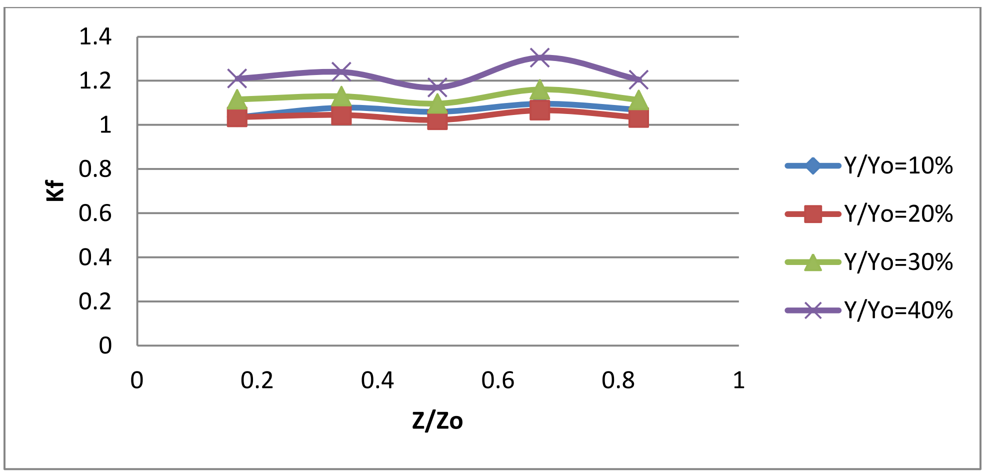

Figure 4 .Variation of Kf along the vertical gate face .(shape 4).

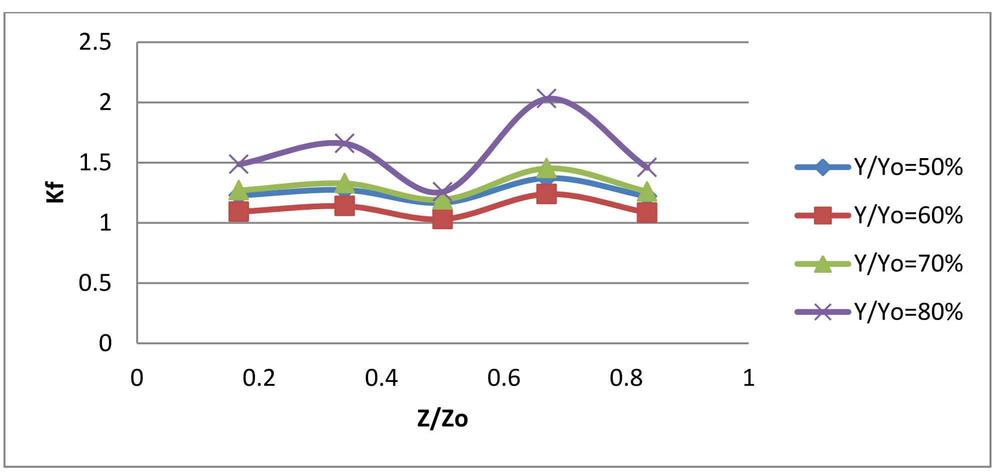

Figure 5 .Variation of Kf along vertical gate face .(shape 4).

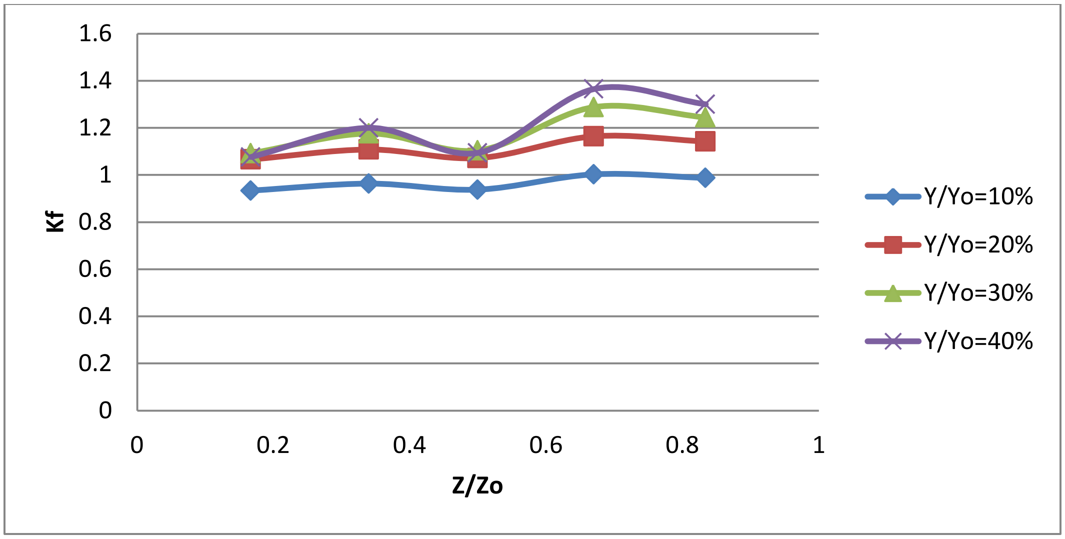

Figure 6 .Variation of Kf along the vertical gate face .(shape 6).

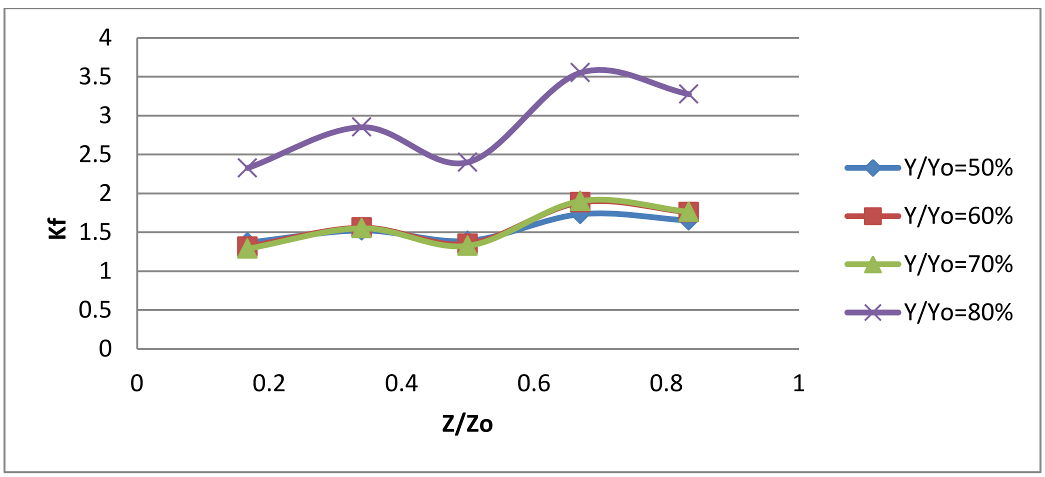

Figure 7.Variation of Kf along the vertical gate face .(shape 6).

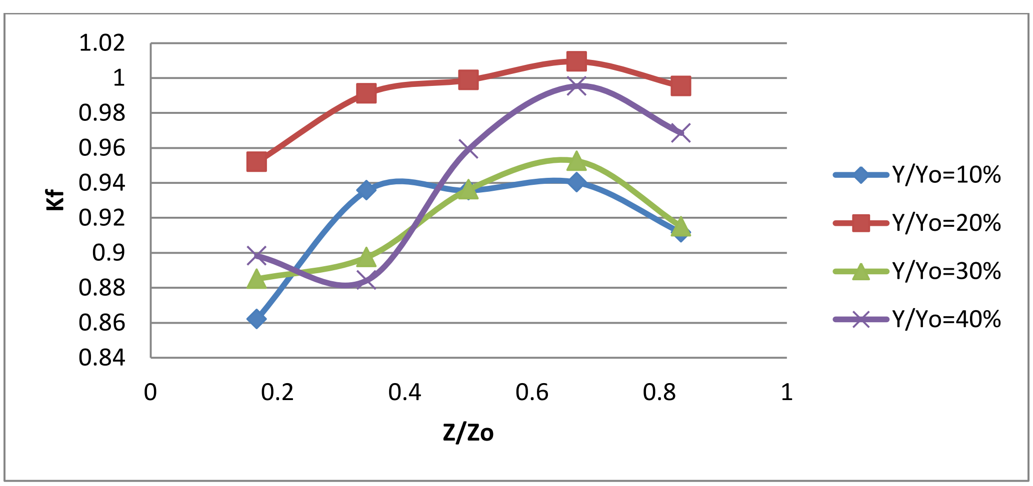

Figure 8.Variation of Kf along the vertical gate face .(shape 10).

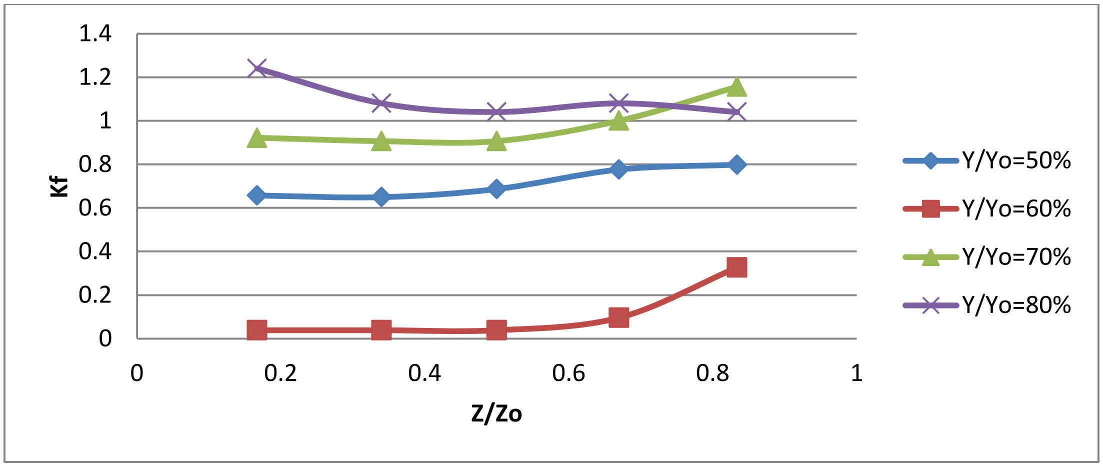

Figure 9 .Variation of Kf along the vertical gate face .(shape 10).

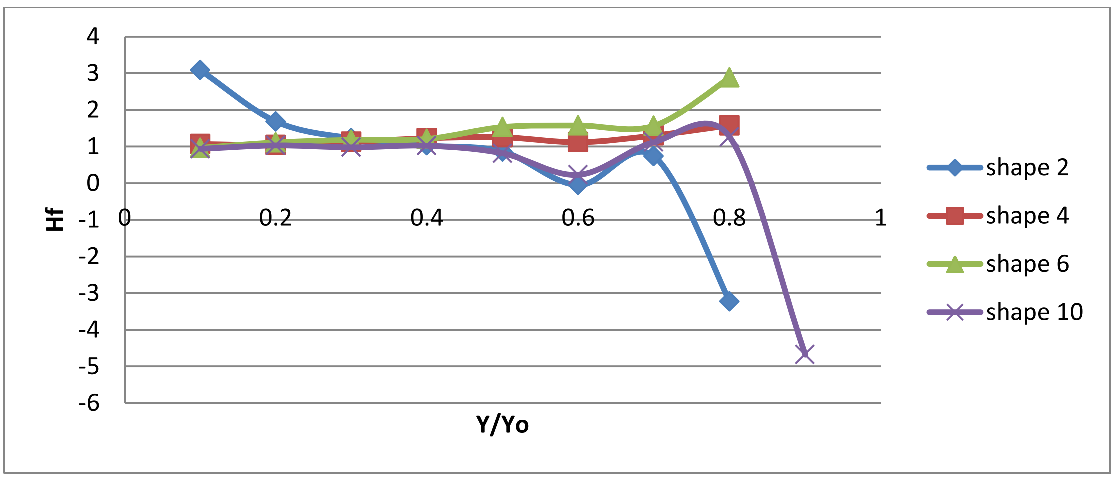

Figure.(10).Variation of Kf with different shapes and gate openings.

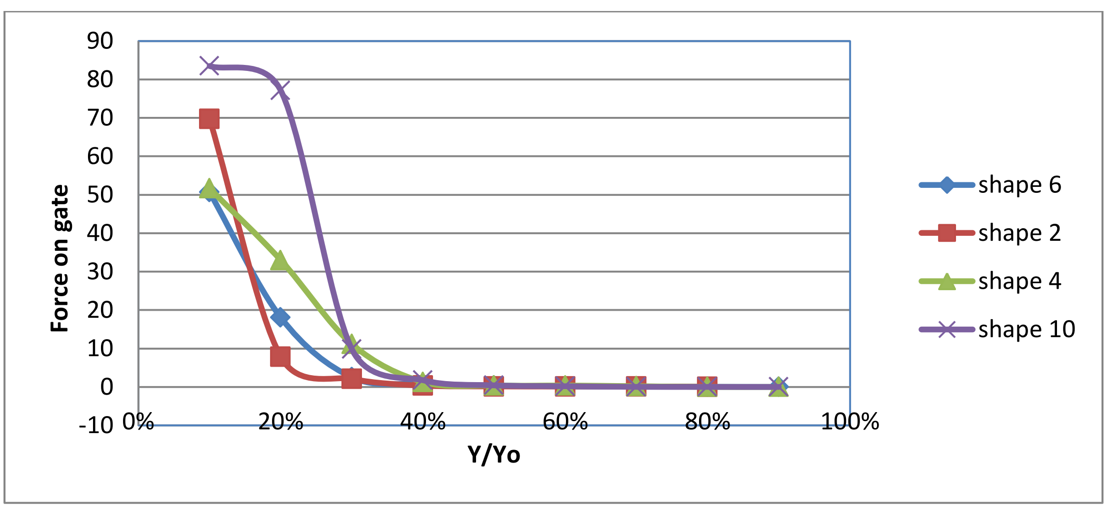

Figure.(11).Variation of force on upstream gate face by momentum equation with different gate opening.

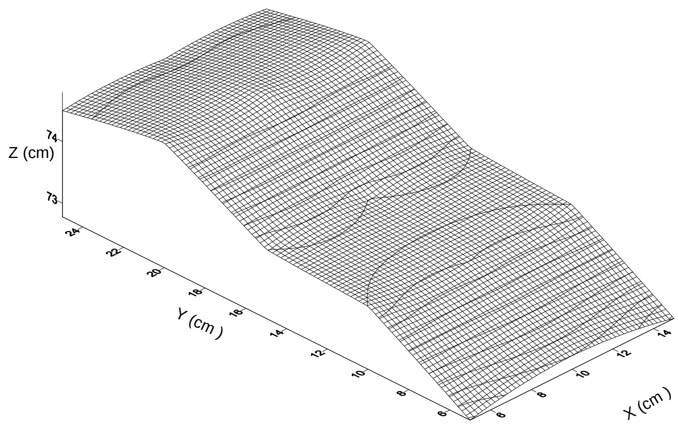

Fig.(12). Pressure head distribution on u/s gate face with Y/Yo=0.1 (lip gate No.1)

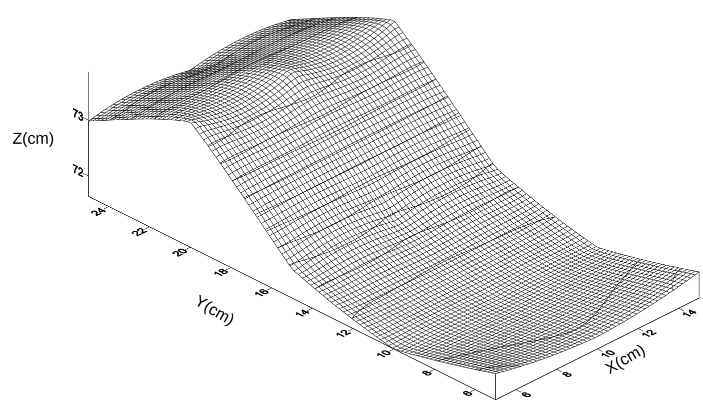

Fig.(13). Pressure head distribution on u/s gate face with Y/Y0=0.2 (lip gate No.1)

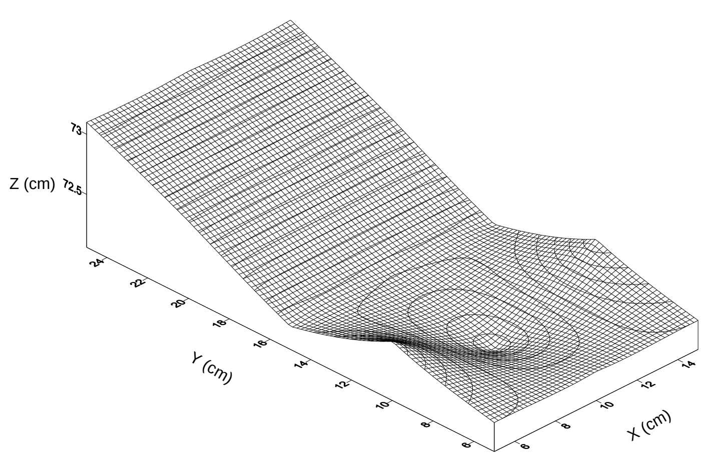

Figure 14.Three dimension of pressur head distribution on u/s gate face with Y/Yo=0.4 (lip gate No.1)

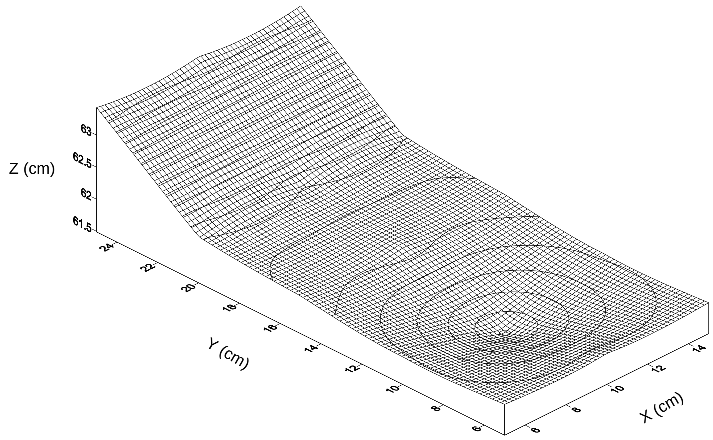

Figure 15 .Three dimension of pressure head distribution on u/s gate face with Y/Yo=0.7 (lip gate No.1)

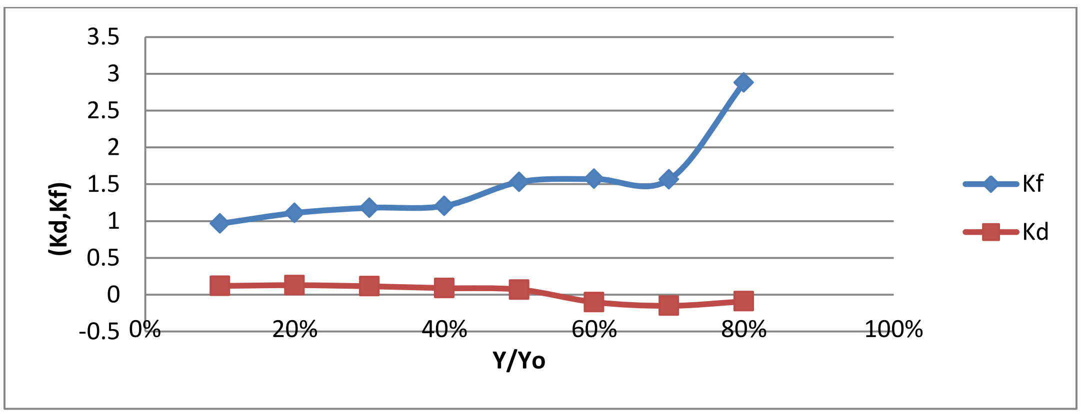

Figure.(16).variation of Kd and Kf with gate openings for shape (6).

6 REFERENCES

1-Cox Robert G.and Ellis B.Pickket and W.p.Simmons.. May (1960), "Hydraulic Downpull on High Head Gates ",*Asce Discussion HY5*,.

2-Naudascher ,E.,Helmut E.Kobus .and Ragam P.Rao, (1964),"Hydrodynamics Analysis For High Head Leaf Gates *", ASCE Vol.90,No.HY3.*

3-US Bureau of Reclamation," Hydraulic Downpull Force on large Gates ",*Research Report No.4 (1966).*

4- Narasimhan , S. and V. P., Bhargava .(March 1975),"Flow-Induced Forces on Protruding Walls ", ASCE Discussion , Hy. No. 3.

5-Sagar,B.T.A..(1977),"Downpull In High –Head Gates Installation", Water Power &Dam Construction.

6-Sagar,B.T.A. . March (1978),"Prediction of gate shaft pressure in tunnel Gates ", Water Power &Dam Construction.

7-Ahmed,Th.M. (1999), "Effects of Gate Lip Shapes On The Downpull Force In Tunnel Gates", *Thesis Presented To The Baghdad University In Partial Fulfillment Of The Requirements For degree Of Doctor Of Philosophy In Hydraulic Engineering* ,.

8-Stern F., Muste M., Beninati M-L., and Eichinger W.E. (1999). "Summary of Experimental Uncertainty Assessment Methodology with Example", *IIHR Report No. 406, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, IA.*

9- Drobir H., Volker K. and Johannes S.(2001), "Downpull on Tunnel-Type High –Head Leaf Gates", *IAHR/AIRH Hydraulic Report, Balkema, Rotterdam.*

10- Reinhard Prenner, Anne Joeppen, Helmut Drobir, Volker Kienberger, Stefan Winkler.(2006, July 31 to August 4, 2006, "Downpull Forces on Different High-Head Leaf Gate Types" *,Hydro Vision, Portland, Oregon, USA.*