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Experimental studies of determining the discharge coefficient of hydro gates

Alisher Fatxulloyev*, *Aziza* Gafarova and *Jasurbek* Hamroqulov

Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

Abstract. Article devoted to the determination of water discharge, which water consumption is determined using hydrogates, which are widely used for the management and distribution of water resources in internal irrigation networks. Research analysis provided in a laboratory settings, and the main focus given for determining the discharge coefficient. Research in this area will make possible to determine water discharge at the level of existing requirements. Experimental researches have been devoted to the development of existing research in this area, and only in the first stage gotten possibilities to determine the discharge coefficient on the state of free flow under the gate. Experimental researches conducted under different conditions have found that change in the flow coefficient depending on the dimensionless hydraulic parameters. The achieved results can be used mainly to determine water consumption at the level of current requirements, along with the management and distribution of water resources in the internal irrigation network.

1 Introduction

Today, a number of water metering facilities are used to determine water consumption in irrigation networks. Alternatively, many flat gates are used for the purpose of water distribution in irrigation networks. Although many studies have been provided to measure water consumption at these facilities, their use for standard water metering purposes has not been established. Many researchers have confirmed that a complex hydraulic process is observed in the flow of water under the gates, and the determination of water consumption using existing models leads to an average error of 20-30 percent. In this case, water metering devices (culverts, fixed streams, etc.) are installed in the lower reaches of water distribution facilities in hydro-ameliorative networks. To improve this process, one of the most pressing issues today is the possibility of determining the water consumption at the level of current demand in the flat gates installed in the reclamation networks.

2 Methods

A number of empirical expressions for determining the compression coefficient ε have been proposed in different researches and they are directly related to the flow coefficient,

*Corresponding author: a.fatxulloyev@tiiame.uz

velocity coefficient, and compression (vertical) coefficients and are generally recommended to be taken in the velocity coefficient (φ=0,85÷0,95). The expression proposed by Altshul A [1], Kiselev P [1], Zhukovsky N [20], including the use of empirical coefficients in this direction, leads to large errors in determining the water flow through flat gates.

$$\varepsilon = 0.57 + \frac{0.043}{1.1-n}; \quad n = \frac{a}{H} \tag{1}$$

To solve this problem, we consider studies on the dependence of the flow coefficient on the change in magnitude $\frac{a}{H}$ without a unit of measurement, based on $\mu = \varphi \cdot \varepsilon$.

Experimental studies on the study of water flow under flat gates were conducted in the Hydrology Laboratory of TIIAME. A Chipoletti water gate (ChWG-30) was used to determine water consumption. The studies were conducted on a flat gate with dimensions b=0.35 m, h=0.4 m and threshold height d=0.003 m in a straight rectangular tray L=15.0 m. The studies were carried out at different water discharge in the range of gate elevation height a=0.015-0.045.

The aim of the research was to determine the discharge coefficient of the gate opening height a, the position of the gate in the upper beam and the connection position of the beams in the buried position. The calculation scheme is in accordance with Figure 1 and as a hydraulic model of the process we accept the following equation:

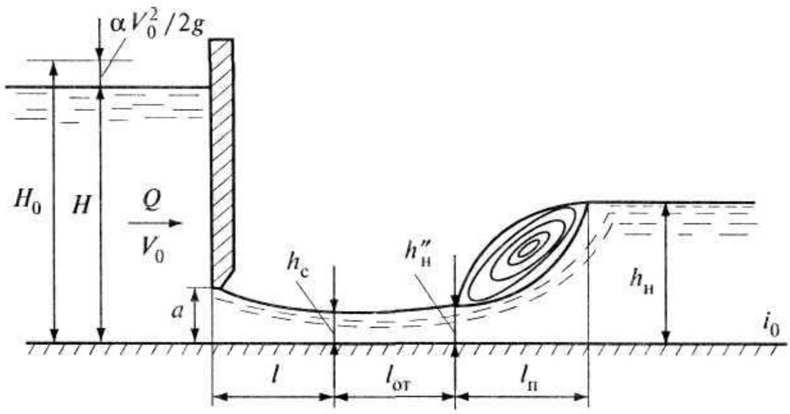

Fig. 1. Design scheme

there: H_0 is full pressure in the upper pond (m);
$\mu = \varphi \cdot \varepsilon$ is discharge coefficient;
a, b are the dimensions of the gate.
The research is devoted to the determination of the discharge coefficient $\mu = \varphi \cdot \varepsilon$ under laboratory conditions.

In the study of the discharge of water from under a flat gate, we examine the main parameter, i.e., the consumption coefficient. Determining the flow coefficient depends on the complex hydraulic processes and the flow coefficient depends on several hydraulic quantities [2, 4, 6, 8].

So,

$$\mu = f\left(\frac{a}{H}; Re; Fr\right) \tag{3}$$

Or

$$\mu = f(\frac{\mathrm{a}}{\mathrm{H}}; \frac{\upsilon 4\mathrm{R}}{\nu}; \frac{v}{\sqrt{2g}}) \quad (4)$$

there: $\frac{\upsilon 4\mathrm{R}}{\nu}$=Re is Reynolds number, y$\frac{v}{\sqrt{2g}} = Fr$ is Froud number.

As mentioned above, the complex hydraulic processes involved in the connection of beams in hydraulic structures, the state of connection of beams (free flow, buried state) is also of great importance [13, 16, 17, 18, 19].

Given this situation, these experiments are initially carried out on the basis of the conditions of the free-flowing state. Experimental studies are devoted to the study of the interrelationship of the function $\mu = f(\frac{\mathrm{a}}{\mathrm{H}})$, taking into account the state of flow under flat gates.

The state of water flow under the gates is considered to depend on the total pressure $H_0 = H + \frac{\alpha v^2}{2g}$, υ-flow rate, f-liquid density, ν-μ-liquid viscosity and other parameters in the upper pond [3, 5, 7, 9, 11].

The correlation between these parameters [10, 12, 14, 15] can be expressed as follows:
That is

$$Q = f(\frac{\mathrm{a}}{\mathrm{H}}; \frac{v}{\sqrt{gH}}; \frac{\upsilon \Upsilon \mathrm{R}}{\nu}; \mu)$$

Or

$$Q = f(\frac{\mathrm{a}}{\mathrm{H}}; Fr; Re; \mu)$$

Consumption coefficient in the same case

$$\mu = f(\frac{\mathrm{a}}{\mathrm{H}}; Re; Fr)$$

if, $\sqrt{Fr} = \frac{v}{\sqrt{gH}} = \frac{Q}{B \cdot a \cdot \sqrt{gH}}$; or $Fr = 2\mu^2 \left(\frac{a}{H}\right)^2$; If we assume that, then

$$\mu^2 = \frac{Fr \cdot H^2}{2a^2}$$

Or

$$\mu = \sqrt{\frac{Fr \cdot H^2}{2a^2}} = \frac{\mathrm{H}}{\mathrm{a}} \sqrt{\frac{Fr}{2}}$$

3 Result and discussion

Although the flow coefficient is determined experimentally, its value varies significantly under the influence of various conditions and hydraulic processes. Therefore, it will be necessary to develop separate connections for these hydraulic processes under natural conditions for various hydraulic processes, i.e., for non-buried and buried cases. Based on the experiments, it was determined that the flow coefficient is obtained in the form of dimensionless magnitude of the flow mode (Re), energy state (Fr) and other hydraulic elements ($\frac{a}{H}$). The experimental results are presented in Figures 2, 3, 4, 5, 6.

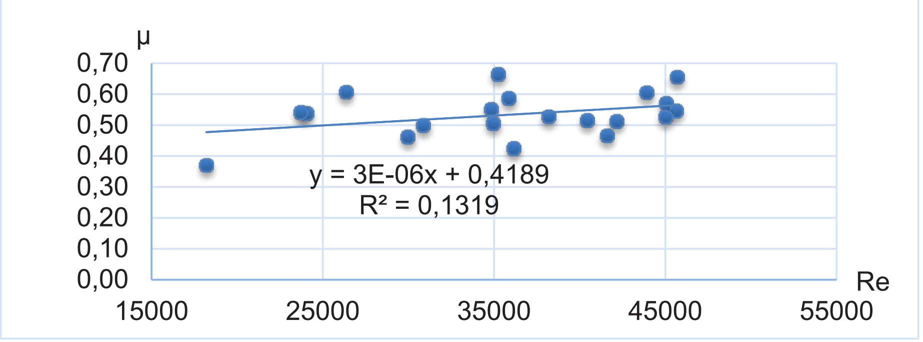

Fig. 2. Dependence *μ=f(Re)*

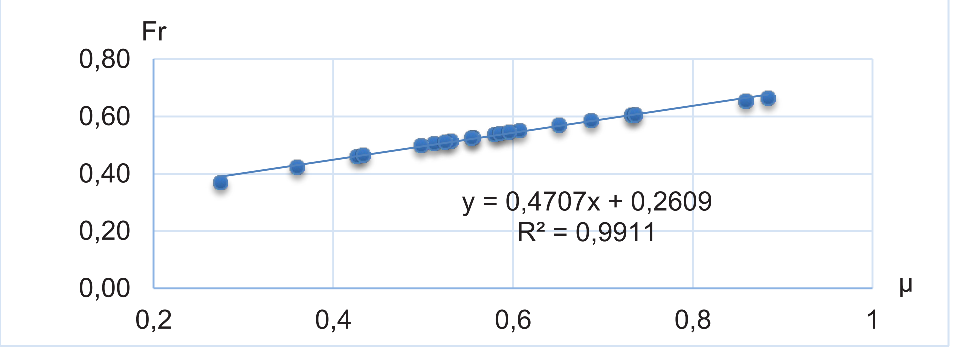

Fig. 3 Dependence *μ=f(Fr)*

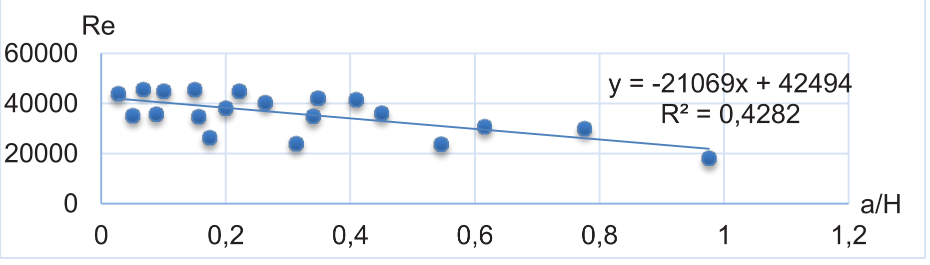

Fig. 4. Dependence *Re=f(a/H)*

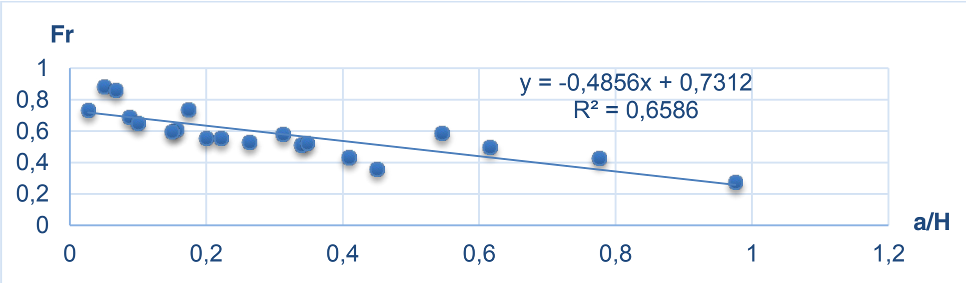

Fig. 5. Dependence *Fr=f(a/H)*

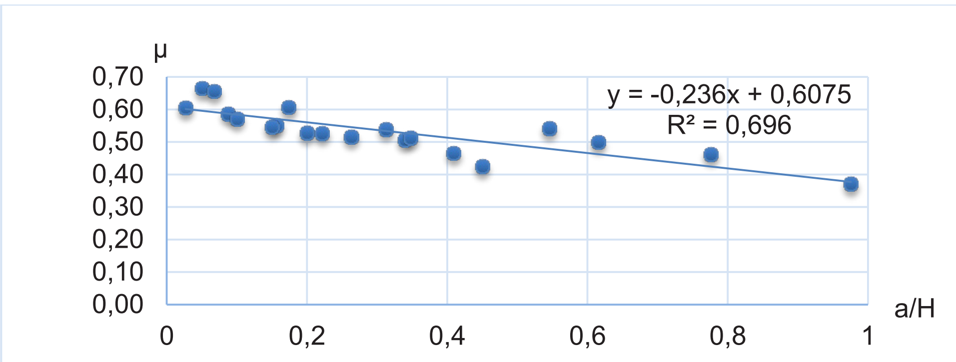

Fig. 6. Dependence *μ=f(a/H)*

The results of the experiment show that the state of the water flowing out from under the gate does not depend on the mode of movement. Experiments have shown that the correlation with the consumption coefficient μ=*f*(Re) is very low when Re=18000-46000 is R^2=0.13. The energy state of the current in the range Fr=0.27-0.85 indicates that there is a linear relationship between μ=*f*(Re) and R^2=0.99.

Also, the main purpose of the study was to determine the coefficient of flow in the case of free flow of current through flat gates under experimental conditions, and to determine the dependence of the flow coefficient on dimensionless quantities, $Re=f(\frac{a}{H})$, $Fr=f(\frac{a}{H})$ and $\mu=f(\frac{a}{H})$ connections were studied. The results of the experiment show that the relationship between the mode of action and $\frac{a}{H}$ is very low, and the degree of dependence is R^2=0.42. According to the above conclusions, the correlation between the consumption coefficient and the dimensionless magnitude $\frac{a}{H}$ adopted by the energy state of the current is at the level of demand. Hence, the fact that the binding rate of $Fr=f(\frac{a}{H})$ is R^2=0.65 and the binding rate of $\mu=f(\frac{a}{H})$ is R^2=0.7 represents the reliability of the experimental results.

4 Conclusion

According to the result one can conclude that, it is possible to determine the water discharge at the level of existing requirements with the help of gates, which are currently used for water distribution in the internal networks of the farm. Also, on the basis of experiments, it was possible to determine the flow coefficient (μ) for flat gates in relation to dimensionless hydraulic elements, and $\mu = f(\frac{\mathbf{a}}{\mathbf{H}})$ (Fig. 6) was created at the level of introduction into production. These results were developed for the free-flowing (buried) state of water under the gates in the first stage, and the continuation of experiments on the dimmed (buried) states in the next stage will serve to increase the effectiveness of research in this area.

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