CONTRACTION AND DISCHARGE COEFFICIENT OF FREE FLOW PAST A SLUICE GATE

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Sluice gates are widely used for controlling discharge and water depth in irrigation channels, large sewers, and in hydraulic structures. Due to the practical importance of the sluice gate as a control and metering device, the prediction of flow characteristics under gates has been one of the classical problems of hydraulics.

Most features of the sluice gate flow seem to be predicted accurately by existing mathematical models based on potential flow theory, but there remain persistent discrepancies between the theoretical and experimental value of the contraction coefficient. Due to the existence of boundary layer growth (Henderson, 1966; Rajaratnam and Subramanya, 1967) and energy loss upstream of the gate (Montes, 1997), experimental values of the contraction coefficient always exceed the theoretical values by 5~10%. However, the experimental values of the discharge coefficient, which depends on a separate measurement of the discharge rather than depth, agree better with theoretical values.

All previous studies schematize the flow to some degree. The viscous real fluid and turbulent flow are assumed to be represented sufficiently well by an irrotational inviscid flow. In addition, some early researchers simplified the problem further by assuming that the free surface upstream of the gate could be represented by a horizontal plane; and by further assuming that gravitational effects could be neglected. An extensive review of the existing theoretical research on this field was summarized by Montes (1997). In this study, by performing a numerical analysis that does not employ the assumptions adopted in existing potential flow theory, the contraction coefficient (which could not be accurately obtained in existing studies) and discharge coefficient could be thoroughly analyzed.

This study shows that for a free flow past a sluice gate numerical tools using the Reynolds averaging Navier-Stokes equations are sufficiently advanced to calculate the contraction and discharge coefficient. The trend of the existing inviscid theoretical contraction coefficient is quite different from the existing experimental ones. The contraction coefficient for the present study gradually decreases in the range of $a/E_1 < 0.4$ and increases in the range of $a/E_1 > 0.4$ with increasing a/E_1, exhibiting a tendency similar to existing experiment data (see Fig. 1). This is because energy loss by friction and water surface oscillation increases as the approach velocity head at the upstream of the gate increases when a/E_1 is higher than 0.4 (see Fig. 2). The discharge coefficients from the present analysis also correspond closely with the existing experimental data.

In this study, by performing a numerical analysis that does not use the assumptions adopted in existing potential flow theory, the contraction coefficient (which existing studies could not obtain correctly) and discharge coefficient could be thoroughly analyzed. This study shows that existing numerical models using RANS can be a useful tool in the design and research of hydraulic structures.

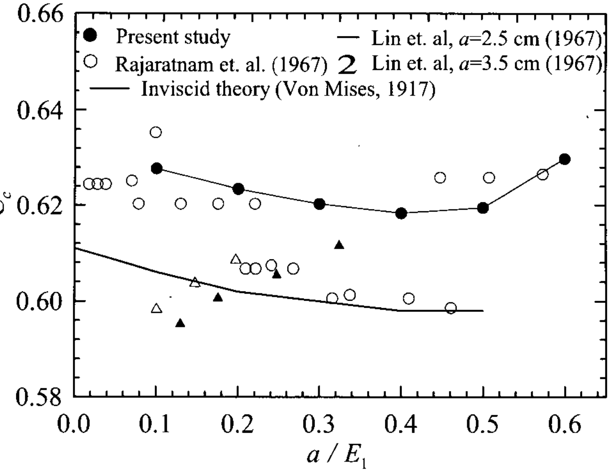

Fig. 1 Comparison of contraction coefficient from present analysis with experimental data

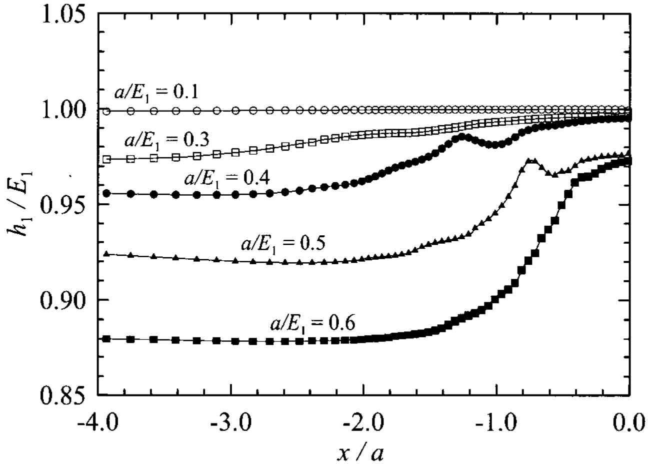

Fig. 2 Water surface profiles upstream from the gate

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