Flow-Induced Vibration of Sluice Gates Due to Different Hydraulic Conditions

Abstract

Vertical sluice gates are one of the most common hydraulic structures that are used in dam engineering. Fluid-structure interaction is a frequent problem of design engineers and researchers. Present study focuses on the interaction between water flow and sluice gate operation namely flow induced vibration of sluice gates. Numerical investigation was performed to study the fluid-structure interaction using finite element method. Three dimensional behavior of the sluice gate with respect to the boundary conditions of gate and flow was considered. According to the results of former investigations, the gate upstream face should be beveled with an angle of ٤٥° to give the best operational condition *e.g.* to reduce the gate stream-wise vibrations. For stream-wise gate vibrations, the small gate's opening with one degree of freedom (f_{xo}/f_{yo} = ٠: ١-DOF in *x*-direction where *y*-deflection is blocked, where f_{xo} and f_{yo} are respectively) have been investigated previously. In general, in the concept of structural dynamics, the fluid-induced vibrations are characterized by a hydrodynamic dimensionless parameter namely "reduced velocity". This parameter relates to the ration of a typical flow frequency V/d (where V is the flow velocity and d is the gate's thickness) to the solid natural frequency n. According to former researches, the flow-induced vibrations of sluice gates establish in three distinct vibration domains characterized by a range of dimensionless reduced velocity number.

Numerical results indicate that stream-wise gate vibration reduces significantly if the upstream edge of the gate is beveled at an angle of ٤٥° compared to rectangular-lip gates. However, the maximum vibration occurs for the same rate of gate's opening to the gate thickness δ/b. The cross-flow vibrations have also been investigated for the condition of f_{xo}/f_{yo} = ∞: ١-DOF in *y*-direction and *x*-deflection blocked.). Numerical modeling was performed for different values of gate opening to the gate thickness ratios and reduced velocities ranging between from ٢ to ٣,٥. Results compare well with those of former investigations. Flow-induced vibrations of sluice gates with ٢-DOF was also studied considering the reduced velocities V_{rx} and V_{ry} for different values of f_{xo}/f_{yo}. For f_{xo}/f_{yo} = ٢,٨٩, close to the natural frequency f_y. of the vertical d.o.f, dominant vertical vibrations due to ILEV-excitation occur in range $٢<V_{ry}<٤$. Numerical results indicates that horizontal amplitudes in ٢-d.o.f become much larger than the amplitudes of the gate with only one horizontal d.o.f. Close to the natural frequency f_x. of the horizontal d.o.f, vibrations due to MIE-excitation occur in range $٣,٥<V_{rx}<٧$, $V_{ry}>١٠$. Horizontal response vibration in ٢-d.o.f is the same response with only one horizontal d.o.f.

Keywords: Flow-induced vibration, Gate vibration, , Numerical modeling, Sluice gates.