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Surveying Cavitation Index on Siphon Spillway

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ABSTRACT

Siphon spillways are used when a discharge capacity is required in dam design without the use of operating gated spillways. Cavitation is an expected phenomenon in each hydraulic structure when the pressure goes below the critical value. In the present study, by using a physical model occurrence of cavitation along the siphon spillway was experimentally investigated. To do so by considering all scale effects, the effect of three bucket angles, four heads (difference between upstream and downstream elevation) and more than ten discharges were checked on cavitation index in more than fourteen points along the siphon spillway. To make results more practical and also make easy the engineering judgment, the siphon spillway was divided into three different zones and possibility of cavitation on each one was calculated. All experiments were conducted in free state at tail water and rectangular cross section. Results showed that without using the aerator, occurrence of cavitation is probable in the first two zones. Finally it was concluded that by a bucket angel equal to 60 degrees, best performance in view of cavitation index for a rectangular siphon spillway was expected.

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INTRODUCTION

Siphons as a spillway usually employ in dams to control floods. Siphon spillways are easy to construct and may be constructed after dam construction with variable cross sections and could be a practical choice. Its ability to pass flow efficiently and safely has enabled hydraulic engineers to use it in a wide range. Several researches have been carried out on its design and operation (GovindaRao 1956; Ackers and Thomas, 1975; Head, 1975; Ervine and Elsawy, 1975; Perkins and Charlton, 1975; Ervine and Oliver, 1980; Xian and Huan, 1989; Prettyjohns and Markland, 1989; Bollrich, 1994; Vischer and Hager, 1997; Dornak and Horlacher, 1999; Babaeyan and Koopaei, 2002; Knoblauch *et al*., 2002; Khatsoriya, 2004; Holder and Schimpff, 2004; Walton *et al*., 2004 and 2005; Aigner and Horlacher, 2007; De Gennaro and Wright, 2007; Togawa and Pitt, 2009; Luckea and Beechama, 2010; Takamatsu *et al*., 2010; Jorabloo *et al*., 2011; Jafarinia *et al*., 2011). Although, many valuable works were carried out by the previous researchers, a comprehensive study on siphon spillway on view of cavitation phenomenon is not performed. In the present research, a physical hydraulic model study has been conducted to investigate the probability of cavitation phenomenon along the siphon spillways in different hydraulic conditions

Methodology:

2.1Experimental setup:

A physical model of a single siphon spillway was constructed between two channels representing the reservoir and downstream conditions. Water level control is provided in each channel. The physical model arrangement is shown in Figure 1. A rectangular flume 1m wide, 0.8 m and 1.6 m high was constructed (Figure 2). The flume was supported by two upstream and downstream channels to make water relax. In the experimental procedure, three different bucket angles were investigated: 30, 45 and 60 degrees. Water discharges were change from 0.009 m^3/s to 0.060 m^3/s. 14 different discharges between these two discharges were selected. The dimensions of rectangular section were (7.5cm × 30cm). The siphon was made from Perspex on both sides to allow observation and measurement (Figure 3). Moreover one side of the flume was constructed from Perspex to make possible the flow pattern observations. Froude similarity was considered as the base of modelling to minimize the scale effects on the model. The length of flume was so designed that the entry water

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had no disturbance and be uniform. The width of flume also was considered so that the side wall effects be minimize. The height of flume as well as two previous dimensions regulated with maximum tail water which was used in this research by considering a suitable free board. Constructed model included: the entrance reservoir, upstream channel for damping the flow energy and generating a uniform flow to siphon spillway, siphon spillway, the regulated gate at tail water. To arrange the tail water elevation one regulator gate was used. A rectangular spillway was used to measure downstream discharge in the model. The water in the model was circulated by an electro pump. The designed siphon spillway in the present work was made from Perspex and installed at the middle of the channel.

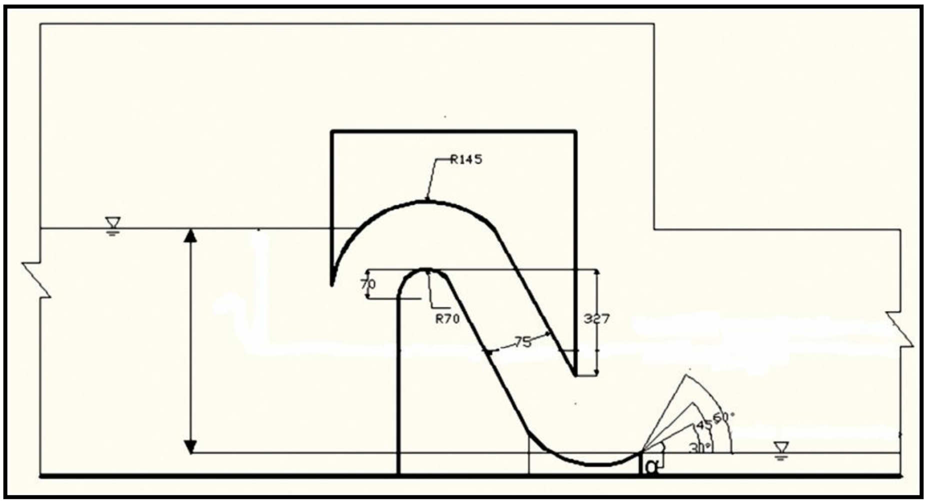

Fig. 1: Schematic of the longitudinal profile of the physical model

Fig. 2: Constructed experimental flume

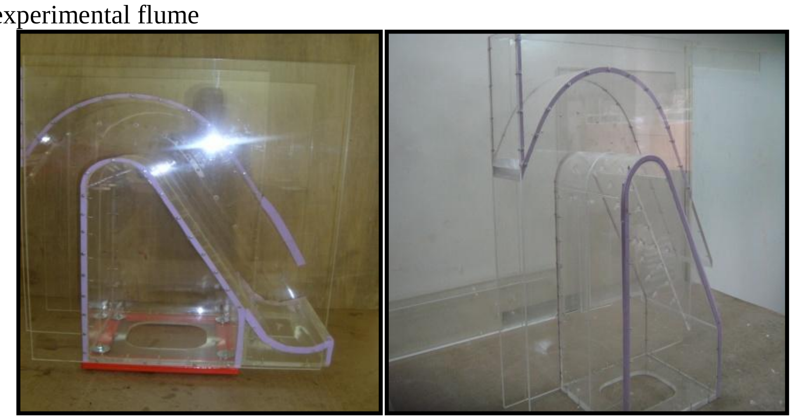

Fig. 3: Constructed siphon from Perspex material

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RESULTS AND DISCUSSION

Cavitation is a phenomenon which may cause damage and cavity in hydraulic structures at high velocities. By increasing velocity and existing small roughness at flow walls, pressure decreases. Decreasing local pressure may cause vapor pressure and creation of bubbles. Produced bubbles, distribute in the flow and transport farther, a place with high pressure. In this time, they will explode and produce noise and huge impact stresses into the walls. Due to the impact of exploded bubbles, walls may face serious damage that is known as "Cavitation phenomenon". In some cases the bubbles explode at the site of creation because of unstable flow regimes and leads to destruction just in place.

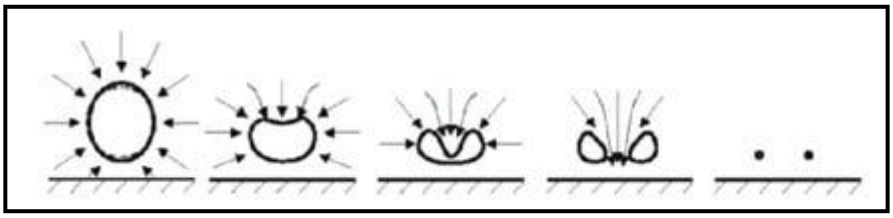

Fig. 4: Schematic view of cavitation process.

This phenomenon is defined by following index:

$$\sigma = \frac{P - P_v}{\rho v^2/2} \tag{1}$$

where σ is the cavitation index, P is the absolute pressure, Pv is the absolute vapor pressure, ρ is the density and V is the velocity of fluid. It is suggested by some researchers that the cavitation index should not be exceed from 0.2-0.25 (Falvey 1990; Peterka 1953). In the present research by using a rectangular siphon spillway and different hydraulic condition, occurrence of cavitation phenomenon was investigated. Three different zones were selected to make more easy understanding and engineering judgment (Figure 5). Figures 6, 7 and 8 present calculated cavitation index in different heads (Δh). It should be noted that cavitation index in these figures are averaged values of all piezometers placed in each zone. As could be seen in Figures 6, 7 and 8 occurrence cavitation in third zone is expected strongly and in second zone the condition is critical in case of no aeration in system.

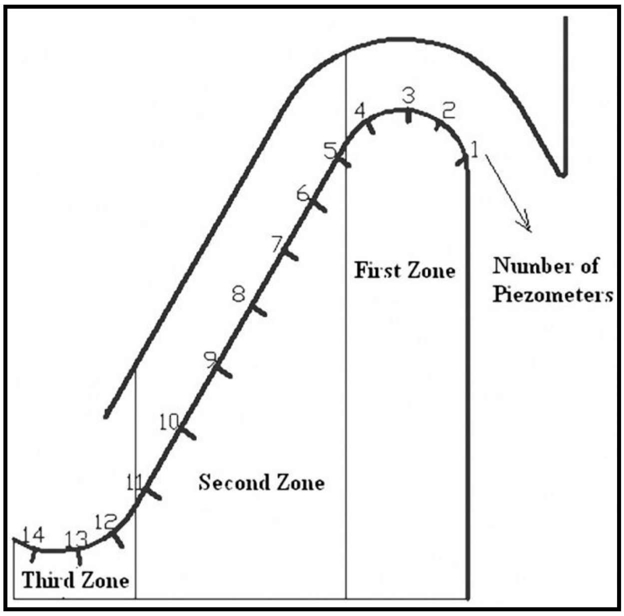

Fig. 5: Three different zones in siphon spillway

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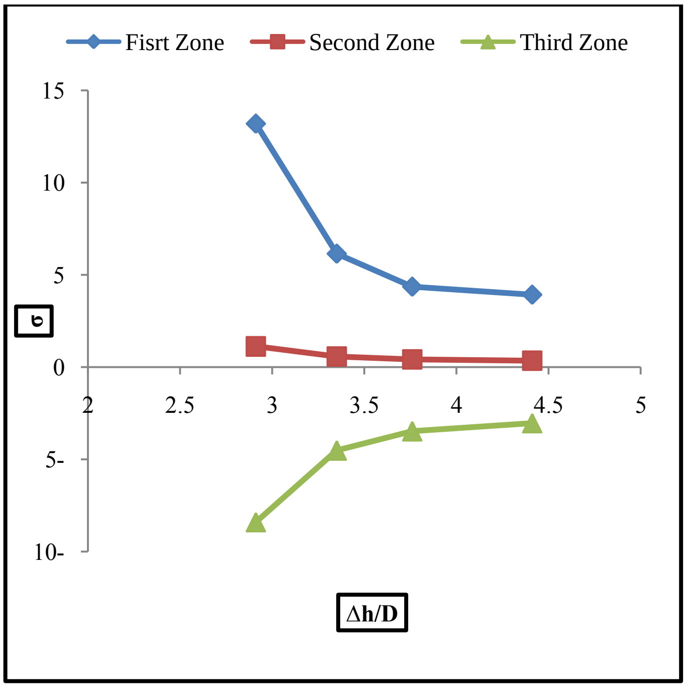

Fig. 6: Cavitation index in different Δh/D for bucket 30 degrees for free flow

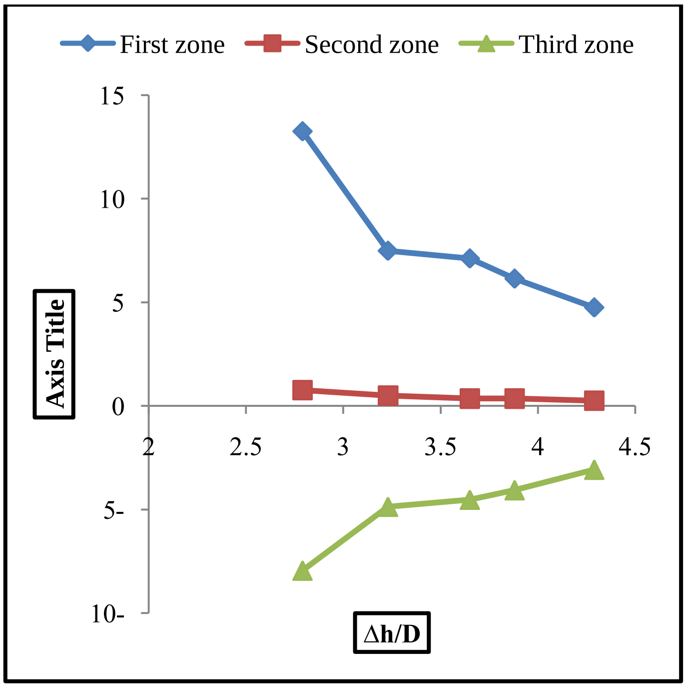

Fig. 7: Cavitation index in different Δh/D for bucket 45 degrees for free flow

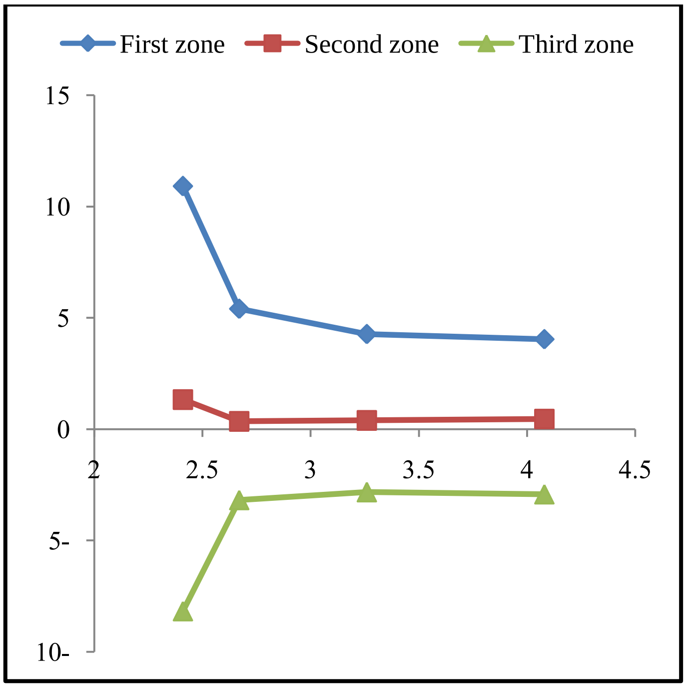

Fig. 8: Cavitation index in different Δh/D for bucket 60 degrees

Conclusion

In this physical model work, occurrence of cavitation along the siphon spillway was experimentally investigated. Three bucket angles, four heads and more than ten discharges were checked on cavitation index along the siphon spillway. Three different zones in siphon spillway were distinguished and possibility of cavitation on each one was estimated. All experiments were conducted in free state at tail water and rectangular cross section. Results showed that without using the aerator, occurrence of cavitation is probable in the third zone and second zone is in the critical condition. Finally it was concluded that by a bucket angel equal to 60 degrees, best performance in view of cavitation index for a rectangular siphon spillway is expected.

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