EXPERIMENTAL STUDY USING A PHYSICAL SCALE MODEL OF A MOBILE BARRAGE FOR WATER INTAKE AND SEDIMENT FLUSHING

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This work deals with the verification and optimization results of the intake hydraulic performance of Verde river as a whole using a hydraulic scale model. The project is located eastern of the Ecuadorian Andes – South America and the diversion flow is for the Hydroelectric San Francisco system to add the power to be generated.

The main hydraulic characteristic of the Verde river diversion works is the operation of the system with two ranges of flows. Those discharges occurring more often – 98% of the time - during the year for which the diversion flow of 9 m^3/s must be constant; and those with flows of less occurrence – 2% of the time - for which the flood control structures must operate to avoid the entrance of both water and solid material to the intake.

For reaching such a purposes the hydraulic system was initially designed by a diversion weir with three flapped - radial gates so that for river discharges de until 62 m^3/s with 98% of probability of occurrence during any given year, the spilling flaps operate with radial gates fully closed and for river discharges between 62 and 420 m^3/s the radial gate can automatically be opened up and the intake gate can closed down, to avoid entering of high sediment loads to the diversion system

To study this operation a fixed-bed and undistorted scale model was conceived, and for the model design, the Froude Similitude Law with a ratio 1:25 and the classical theories of hydraulic modeling were adopted. In addition, to simulate the sediment flushing effectiveness a graded sand layer was built on the river bed upstream of the mobile barrage. Therefore experimental studies were addressed to simulate the approaching flow pattern around the intake with and without suspension-load sediment transport and to know the flapped – radial gate efficiency to control the headwater level.

The tests with the closed radial gate and the spilling flaps under operation were carried out for the following river discharges: 5.9 m^3/s, 9 m^3/s, 14.2 m^3/s and 62 m^3/s. For these flow two alternative of constant diversion discharge - 9 and 11 m^3/s - to the water intake were analyzed. Thus, for river discharge until 20.8 m^3/s, the 9 m^3/s as diversion flow was reached lowering the three spilling flaps, but for greater river discharges, flow control gate operation was implemented to keep constant the water level. As a consequence when the right radial gate was partially open strong vertical vortices were formed. At the same time the intake gate was partially closed so as to keep constant the diversion flow, the reservoir water level was raised with possibility of overflow through the river banks. With regard to the 11 m^3/s as constant diversion flow, it was possible to obtain it with the spilling flaps operation for river discharges less than 29.6 m^3/s, and for greater flows, the operation of the control flow gates were necessary, with similar problems as already mentioned.

For river flow grater than 62 m^3/s, discharges of 120, 225 and 420 m^3/s were tested, with the intake gate fully closed and the mobile barrage radial gates fully open. It can be pointed out that for river discharges between 62 and 200 m^3/s, there not exist flow water into the entrance to the intake and a mild piers-backwater effect is formed. However for discharges between 200 and 420 m^3/s, a steep piers–backwater effect is observed but no river bank overtop is registered. On the other hand, strong vertical vortices and pier flow separation are observed as well, and in the mean time shock waves on the apron and strong scour downstream on the river bed are also formed.

After several tests under different design and operation conditions of radial gates and spilling flaps, the final optimized design for the hydraulic performance was obtained. This design is as follows: the left spilling flap was eliminated and changed for a spillweir with its crest level at 1530.60 masl. The central and right spilling flap pivot level were displaced to the elevation 1529.00 masl. On the other hand, in order to reduce piers-backwater effects and pier flow separation, the nose vertical piers were changed to a 15°-ship´s prow profile.

Around 14 experiments were carried out for flows ranging from 9 to 58.4 m^3/s by lowering 50, 75, 100% of the spilling flaps. In general, for all these tests the flaps–intake system performance was efficiently acceptable, with a water intake range from 7.6 to 11 m^3/s. However, to obtain diversion flows closer to 9 m^3/s, an additional operation program was necessary to implement it, being one of them to lower 30% both the central and right spilling flaps at the same time, for which the best hydraulic performance was obtained, and the other one was by lowering in 50% the central spilling flap only. The reservoir water level and the excess discharge ratio is evaluated for the spillweir operation only and when both spilling flaps are working as well. These ratios are shown in the full paper by figures under different sceneries of spilling flaps operations. Other scenarios for systems operation as the river discharges range between 5.9 m^3/s and 58 m^3/s and the diversion flows test results are also shown for the same operations program above described.

For river flows grater than 58 m^3/s with the two spilling flaps lowering up to 100%, a sensor for higher water level must be activated in order to switch on the system operation to fully open the radial gates. Under this circumstances a sediment flushing efficiency between 80 and 90% is obtained with time duration of 1-1.5 hours for prototype. With regard to the gravels trap, the flushing efficiency reached 98% for which it was necessary to change the longitudinal bottom slope from 3% to 5%.

As a conclusions of the present study using a physical scale model two important aspects must be pointed out. The first one is related to the spilling flaps and spillweir implementation and its operation for water level regulations of flows getting into the intake at an almost constant rate of 9 m^3/s, keeping the radial gates fully closed, for river discharges with 65% frequency of occurrence. The second one is that concerning with the automatic system operation by sensors for flow control and efficient sediment flushing.