An Experimental Investigation of the Effect of Wing Walls on Dimensions of Scour Hole in the Downstream of Culverts

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1-Introduction

A culvert is one of the most important intersecting hydraulic structures, which is used primarily to convey water through embankments of roads, highways, railways or other types of flow obstructions. This structure plays an effective role in conveying flood and protecting the channels and related structures as well as embankments through conveying flood or any uncontrolled flow. Therefore, an accurate design and maintenance of culverts is necessary and plays an effective role in the life of the structure. Of the factors that threatens the stability of cculverts is the local scouring in their outlet. Moreover, scour hole is one of the common types of channel instability. Scour holes are caused by high outlet velocities and concentrated flows. Therefore, it is necessary to simulate this kind of scouring in different conditions so that it can provide suitable solutions for its control. An exact theoretical analysis of calvert flow is extremely complex. To facilitate the computation, culverts flow has been classified into six types based on the location of the control section and the relative heights of the headwater and tailwater elevations. These six types of flow are illustrated in fig.1. Many researchers have studied the parameters affecting scouring in the downstream of culverts. Wingwalls are used in the inlet and outlet of the culvert as conductive wings. These structures are employed to enhance the flow efficiency, to encourage the flow in the inlet and outlet of the calvert, reduce the head loss, help stabilize the structure, protect the adjacent embankment and also integrate the culvert connection to the energy dissipater structure or the natural channel structure in downstream. The schematic of wingwalls and headwall are shown in fig.2. Wingwalls flared with respect to the culvert axis are commonly used and are more efficient than parallel wingwalls. Therefore, due to the complexity of the hydraulic in the culverts and the possibility of creating different hydraulic conditions, and consequently, the effect of wingwalls flare angles on the flow pattern and scour mechanism in the culverts outlet, the simultaneous effect of these two parameters on the scouring demands investigation. Also, to minimize costs made by performing and constructing protective apron and stilling basin downstream of these structures in order to control scouring, the maximum depth and length of scouring as well as the sedimentation pattern in these areas have to be estimated. So far, no research has been conducted to investigate these parameters. In this research by using hydraulic types 1 and 4, the effect of flare angles of outlet wingwalls in circular and rectangular box culverts has been investigated so as to reduce the scouring parameters, as will be discussed in the following.

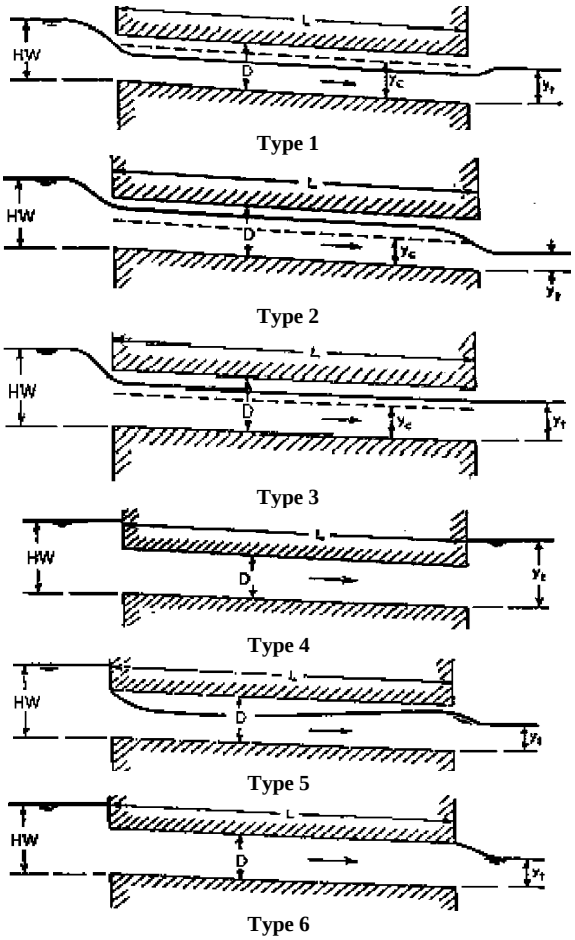

Fig.1. Classification of calvert flow

Fig.2. schematic of wingwalls and headwall

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2- Model Specifications

The present research was conducted by two different facilities (circular calvert and rectangular box calvert). The calvert models used in this study were made of plexiglass, and wingwalls and headwall were made of Galvanized sheet. The geometric parameters of the studied models are mentioned in Table 1.

Table 1. Parameters of calvert geometry

symbol model	Circular calvert	rectangular box calvert
h(cm)	-	15
b (r) (cm)	10	20
L (cm)	180	180
Q (l/s)	6	15

The culvert assembly was set at a slope of 0.005. The culvert models are placed in a flume with a length of 16 meters and a width of 70 cm and a longitudinal slope of 0.0027. The test section in the flume was 0.70 meters wide and 2 meters long and 0.20 meters deep and recess were filled with sand deposits (d_{50}= 0.78 mm and σ_g = 1.25). This paper concentrates on scour occurrence at calvert outlet and the effect of wingwalls flare angles in two hydraulic types 1 and 4 has been investigated. Thus, the outlet wingwalls flare angles which equal to 15, 30, 45, 60, 75 and 90 were investigated.

3- Observations and Discussion

The observations show that when the flow from the calvert encounters the bed at all wingwalls flare angles, scouring starts at a higher rate at the beginning of the experiments. As time passes, the dimensions of the scouring hole expand and the sediment is deposited in the downstream of the scouring hole. Then the increasing rate in scouring depth decreases. In this research, the maximum depth of scouring hole, the length of scour hole and the sedimentation height were investigated. Measuring the maximum depth and length of the scouring hole is necessary to estimate the protection length as well as the type of energy dissipater structure in the downstream of the calvert. In Figure 3, the variation in the scour depth in relation to the wingwalls flare angles is shown.

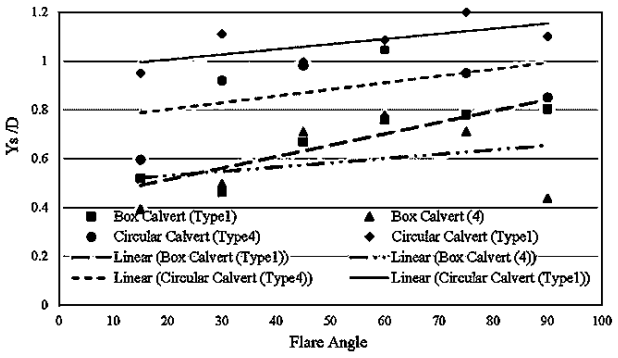

Fig 3. The variation in scour depth

In Figures 4 and 5, the variation in scour length and sedimentation height in relation to the wingwalls flare angles is shown.

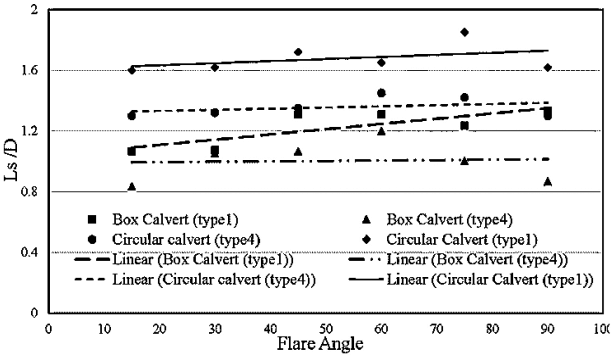

Fig 4. The variation in scour length

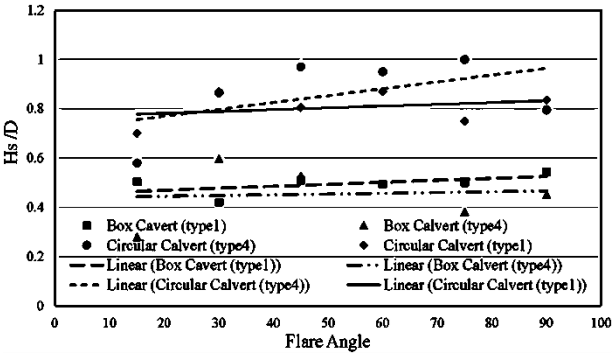

Fig 5. The variation in sedimentation height

4- Conclusions

The conclusions drawn from analysis are:

1- The dimensions of the scouring hole in the downstream of the circular culvert outnumbered the rectangular box section; consequently, in the circular section in hydraulic type 1, the scour depth increased by 35% when compared to the rectangular box culvert as in the type 4 hydraulic 95% was observed.

2- The depth and length of the scouring hole in hydraulic type 2 were higher than those of type 4 in both circular and rectangular culverts.

3- The height of sedimentation in the circular section was higher than that of the rectangular section, which was more frequent in type 4 than type 1.

4- The wingwalls with the 15 ° flare angle decrease the depth and length of the scouring hole and the sedimentation height in downstream where the rate of scour depth reduction in rectangular culvert with hydraulic type 3 was 35.3% higher than the control test. Also, the 30 ° flare angle showed the best performance in rectangular culvert with type 1 and reduced scour by 46%.