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Limiting Dimensions for Trapezoidal Channels and Control Notches (Design Aid)

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Abstract

Determining the channel dimensions leading to critical flow conditions for given values of specific energy or specific force plays an important role in channel transition design. A closed-form analytical solution for the problem can only be derived for triangular, rectangular and parabolic channels. This is not possible, however, for other practical geometries, such as trapezoidal channels. The dimensions of the trapezoidal control notch are determined by simultaneously satisfying the critical state of flow and specific energy equation. At present, graphical solutions are used for design discharges less than 2.83 m^3/s. In current study, direct solutions to compute the limiting dimensions of the trapezoidal channel and direct solutions to design of the trapezoidal control notch are derived. The proposed solutions are nearly exact and will be useful in the design and analysis of the trapezoidal channels and notches.

Keywords: *transition, control notch, specific energy, specific force, critical flow conditions, hydraulic design, closed-form solution*

1. Introduction

Trapezoidal open channels have many applications in hydrology and hydraulic engineering (Chow, 1959; Henderson, 1966; Das, 2007; Haltas and Kavvas, 2009). Designing and fabrication of the trapezoidal channels as well as its transitions are very common (Chow, 1959). For designing a channel transition, it is essential to avoid the condition that causes choke (Dey, 1994). The upstream flow condition in a trapezoidal channel is affected when the cross-section area downstream of the transition zone decreases a certain limit (Vatankhah, 2010a). When an open channel passes through a transition, the critical flow conditions govern the limits of changes in the geometric dimensions and alignment of the downstream channel (Das, 2011). A water structure designer should determine the smallest channel dimension (limiting channel dimensions) for which the flow can pass through the channel without any choking effects in its upstream.

Recently, a new and interesting methodology (iterative solution) has been proposed by Das (2011) for determining limiting channel dimensions of a trapezoidal channel. The developed methodology uses only one equation and works on extracting two equal roots of the specific energy and specific force expressions where the two equal roots yield the critical flow depth. Using the numerical examples, Das (2011) showed that his methodology has a potential for use by practical designers. However this methodology needs iteration techniques such as bi-section method for a trapezoidal channel. To determine the limiting dimensions of the trapezoidal channels, the critical flow conditions and either specific energy or specific force expression should be simultaneously satisfied.

A trapezoidal control section is used to control upstream water depths in a channel, and to maintain the normal water depth in the channel for any flow. It is usually applied at entrances of drop structures (known as notch falls) and chutes, thereby preventing increased shear force in the channel which otherwise could cause erosion. It is also applicable at inlets of inverted siphons to prevent water surface drawdown which may occur for flows less than design discharge (USBR, 1978). No simple and direct solution is available in the technical literature up until now for control notch design. At present, graphical solutions suggested by USBR (1978) are used for design discharges less than 2.83 m^3/s (100 ft^3/s) and for a given bottom width of 22.9 cm (9 in), 30.5 cm (12 in), 40.6 cm (16 in), 50.8 cm (20 in), 61 cm (24 in), 76.2 cm (30 in) and 91.4 cm (36 in). As noted these graphical solutions are limited to the small canal structures (discharges less than 2.83 m^3/s and a bottom width less than 1 m). Moreover using these seven graphical solutions (each solution belongs to a given bottom width and five side slope) for designing the control notch needs a trial and error procedure. The dimensions of the trapezoidal control notch can be determined by satisfaction of the critical flow conditions and specific energy equation.

In the current study, to avoid the inconvenience in available solutions, direct non-iterative solutions (also direct graphical solutions) are derived for (1) the limiting dimensions of a trapezoidal channel for given flow and either specific energy or

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