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New Open Channel with Elliptic Sides and Horizontal Bottom

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Abstract

This paper presents a new general open channel section with elliptic sides and horizontal bottom. The proposed section produces special channel forms, such as a circular section with a horizontal bottom, a circular section, and a rectangular section. Exact and approximate formulas for the area and perimeter of the channel are derived. These formulas are then used to develop an optimization model for determining the optimal section design that minimizes the total construction cost for excavation and composite linings. In addition, the most hydraulically efficient elliptic section was derived. The constraints of the optimization model include channel discharge and physical requirements, such as flow depth, top width, and side slope with fixed or depth-dependent freeboard. The cost performance of the proposed section was compared with another general open channel section (power-law) and the trapezoidal section using different design scenarios. The results show that the new section is substantially more economical and more flexible than the existing power-law section, and is generally superior to the trapezoidal section.

Keywords: *channel, elliptic sides, power-law, optimization model, construction cost*

1. Introduction

Many types of open channel cross sections have been proposed in the literature. The main focus in the design has been to minimize construction cost or maximize hydraulic efficiency (Chow, 1959). Methods are available for the design of different sections, including trapezoidal sections (Guo and Hughes, 1984; Froehlich, 1994; Jain *et al*., 2004; Bhattacharjya and Satish, 2007), parabolic sections (Loganathan, 1991; Das *et al*., 2001; Merkley, 2005; Chahar, 2005; Aksoy and Altan-Sakarya, 2006), parabolic sections with horizontal bottoms (Das, 2007), and a parabolic-bottomed triangular sections (Babaeyan-Koopaei *et al*., 2000). Other recent improvements to open channel design include a section with two-segment parabolic sides and a horizontal bottom (Easa, 2009), a section with two-segment linear sides (Vatankhah, 2010; Easa, 2010), and a section with piecewise multiple linear sides (Easa, 2011).

A general open channel that can produce several special sections is the power-law channel (Strelkoff and Clemmens, 2000; Anwar and de Vries, 2003; Anwar and Clarke, 2005; Hussein, 2008). The special forms of the power-law section are parabolic, rectangular, and triangular sections. Therefore, the power-law section provides more flexibility in design. However, the computation of the perimeter of the general power-law channels requires the numerical evaluation of elliptic integrals using approximate series expansion.

This paper presents a new general elliptic section, similar to the general power-law section that can produce several special sections. The special forms are a section with circular sides and a horizontal bottom, a circular section, and a rectangular section. The general and special sections of the power-law and elliptic

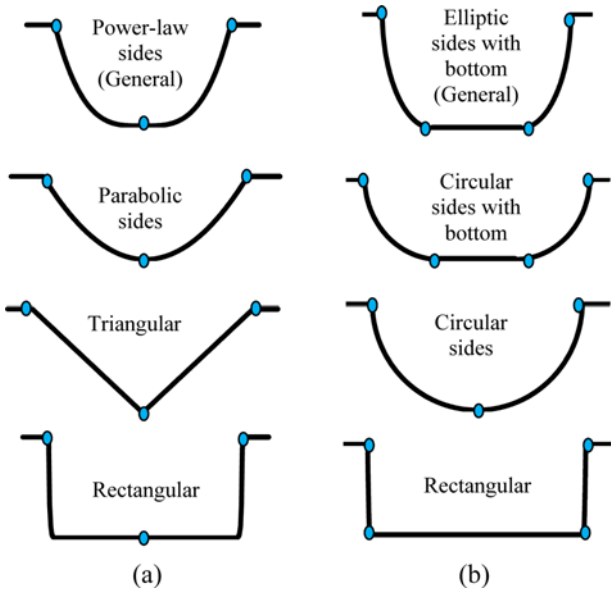

Fig. 1. Comparison of the Special Cases of The Proposed and Power-Law Sections: (a) Power-Law Section, (b) Elliptic Section

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