ОЦЕНКА СООТНОШЕНИЯ СТОРОН (B/Y) В ПРОЕКТИРОВАНИИ ЛУЧШЕЙ СТОИМОСТИДЛЯ ТРАПЕЗОИДНОГО ПРОФИЛЯ КАНАЛА

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Информация о статье Научная статья

Аннотация *С давних пор возникает вопрос о том, должен ли канал быть рассчитан на максимальную гидравлическую эффективность или наименьшую стоимость. Дизайн сечения канала для оптимальной стоимости в условиях равномерного течения включает в себя минимизацию общей стоимости на единицу длины канала.В этом исследовании было изучено и проанализировано большое количество затрат на строительство канала, чтобы рассчитать стоимость канала как общую функции, связанную с приобретением земли, материалом и глубиной канала. Исследования, проведённые в работе, показывают, что разница между недорогими и эффективными профилями каналов тесно связана со стоимостью облицовки каналов и земли. Когда стоимость единицы облицовки каналов равна стоимости единицы земли, разница между двумя частями почти исчезает. Эти исследования были выполнены для недорогого канала.*

Ключевые слова: поток в открытом русле, наименьшая стоимость, поперечный профиль, соотношение сторон, гидравлическое проектирование

Содержание

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1. Introduction

Water is the immense part of living and its importance for living beings has not varied over the centuries. Whereas the request for this natural resource pursues to enhance quickly, and, at the same time, new sources of supply become tougher to discover[1, 2].Many different water supply ways are executed over the years but water has been always conveyed and diffused by using canals [3, 4].

A number of research studies have been undertaken toward optimal design of canal cross-sections [5].The lining of canal hinders soil erosion due to high velocity, which raises the cost of a canal system. A section of unlined canal system does not stand in trapezoidal shape during a long time. Nevertheless, the lined canal section is supplied with a tough surface coating around the perimeter of canals. Hence, the canal may be designed by using flow equations [6, 7]. It is vital to interrogate the issue of the most hydraulically optimum shape. Implies the geometry of the channels, which allows maximum flow for a specified area, surface roughness and bed slope .it means the best applicable hydraulic and economical execution in the construction cost cross section must be selected. Using the meaning of both, the most applicable channel cross-section can be obtained by minimizing the excavated channel cross-sectional area subject to a specified design discharge or maximizing the flow capacity subject to a specified channel excavated area[8].However, when the channel construction cost is more complicated than the earth volume excavation, the least-cost channel cross-section is different from the most efficient because different objective functions are used in the optimization process[9]. Since the lining will enhance additional cost to the project, the expense of a lining project should be legitimatized when the resultant annual advantage overpasses the annual cost, including interest on a capital investment. Accepting a lining project instead of continuing to use an existing unlined water supply system has several benefits, such as the decrease in the land occupied by the channel, saving in cost of earthworks and auxiliary works, and other affirmative effects [10].For a lining project, the savings from the previously mentioned advantages should be equal to or greater than the additional cost of the lining. Hence, optimal design of a lined channel is of immense importance.

All of these studies show that the most cost-effective channel cross-section can be related to channel width in relation to the depth of flow. The construction cost record now shows that the cost of building the channel is mainly comprised of land costs for the channel, coverage materials for the channel section and the depth of channel excavation [11, 12]. These three cost elements are directly related to channel width and depth of flow. This fact implies that both efficient and least-cost channel cross sections can be formulated and optimized by the channel width to depth ratio [13, 14].In this study, an attempt is made to calculate the aspect ratio, which is directly related to both channel construction cost and hydraulic efficiency.

2. Methodology

According to the published construction cost record, the total cost of construction of the channel consists of three elements: (1) the cost of drilling channels; (2) the cost of the surface coating of the cross-section; and (3) the cost of land acquisition [14, 15and 12].

Obviously, the total cost of channel construction varies with the geometry of the channel's cross-section. In this study, the cost function for channel construction is derived from [16], as:

$$\boldsymbol{C} = \boldsymbol{c_1}[\mathbf{y}(\mathbf{b}+\mathbf{zy})+\mathbf{f}(\mathbf{T}+\mathbf{zf})] + \mathbf{c_2}\left[\mathbf{2}\sqrt{\mathbf{y^2}+(\boldsymbol{zy})^2} + \mathbf{b} + \mathbf{2}\sqrt{\mathbf{f^2}+(\mathbf{zf})^2}\right] + \mathbf{c_3}[\mathbf{b}+\mathbf{2z}(\mathbf{y}+\mathbf{f})] \quad (1)$$

Where:

C –Cost of one unit length of channel construction; c_1–per unit area cost for channel excavation; c_2–per unit length cost for channel lining; c_3–per unit length cost for land acquisition;

Y –depth of flow; f –freeboard height; z –preselected side slope expressed in a rise to run ratio as z (H):1(V); T –top width; and b –width of channel bottom [16]. (Fig.1 illustrates a typical symmetric trapezoidal channel cross section)

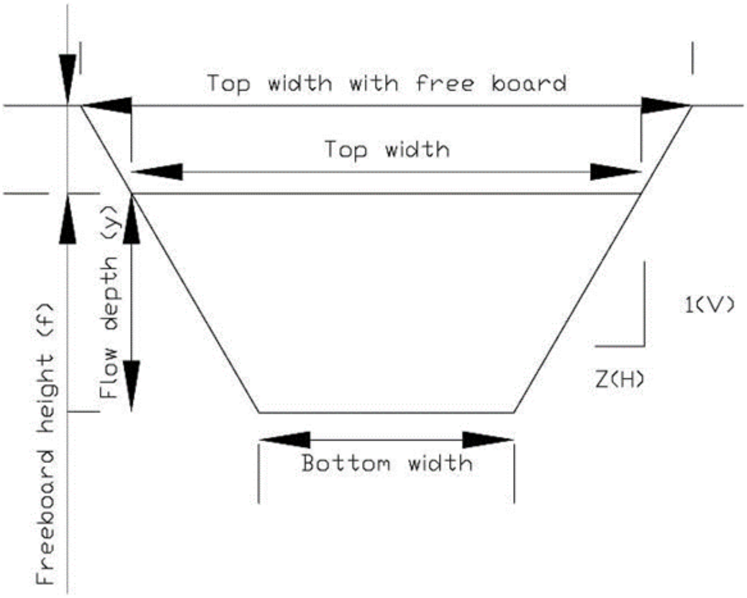

Fig.1. a typical symmetric trapezoidal channel cross section

The following steps summarize the recommended method for determining the proportion of a channel section [17]:

• (Step 1) Estimate Manning's coefficient (n) and determine longitudinal slope (S), Table 1 is the summary of the recommended design criterion used in this study.

Table 1.Recommended design criteria for channel cross-sectional optimization by Blackler and Guo[16].

Various type of channel lining				
Design constraints	Grass lining on erosive soils	Grass lining on cohesive soils	Riprap lining	Concrete lining
Maximum flow velocity	1.5m/s	2.1m/s	3.7m/s	N.A
Maximum manning's n	0.035	0.035	0.04	0.014
Maximum depth	1.5m	5m	NA	NA
Maximum channel longitudinal slope	0.60%	0.60%	1%	NA
Maximum side slope	4H:1V	4H:1V	2.5H:1V	1.5H:1V
Minimum free board	0.3m	0.3m	0.6m	0.6m

Note: NA=not applicable

• (Step 2) Compute the section factor:

$$AR^{2/3} = \frac{nQ}{\sqrt{S}} \qquad (2)$$

Where:

A is the cross-sectional area (m[2]), *R* is the hydraulic radius (m), *Q* is the discharge (m[3]/s), *S* is the bed slope, and *n* is the Manning's roughness coefficient (s/m[1/3]). Solve Eq. 2 for a given depth. In this step, width and side slope for trapezoidal sections may be assumed based on the type of the soil and topography, in order to find water depth.

• (Step 3) Check minimum and maximum permissible velocities

• (Step 4) Estimate free board value

Eq. 1 can be rearranged to be Eq. 2 and Eq. 3 as derived by Trout [18]

$$AR^{2/3} = \frac{A^{5/3}}{P^{2/3}} = \frac{(bd+zd^2)^{5/3}}{\left[b+2d\sqrt{1+z^2}\right]^{2/3}} = \frac{nQ}{\sqrt{S}} \qquad (3)$$

$$d = \frac{\left[\left(\frac{b}{d}\right)+2\sqrt{1+z^2}\right]^{\frac{1}{4}}}{\left[\left(\frac{b}{d}\right)+z\right]^{\frac{5}{8}}} \left(\frac{nQ}{\sqrt{S}}\right)^{\frac{3}{8}} \qquad (4)$$

Where:

d is the water depth (m), b is the bed width of the channel (m) and z is the lateral slope. In order to solve equation 4, the aspect ratio (b / d) must be assumed [18].

The results from studies [4, 19], are shown that relationship between width and depth is widespread depending on the design style. If the channel cross-section is used with hydraulic efficiency, z = 1 / √3, b = 2d / √3, b / d = 1.1547. If another value of z is used, the ratio can be as follows [19]:

$$\frac{b}{d} = 2(\sqrt{1+z^2} - z) \qquad (5)$$

In which the aspect ratio depends totally on side slope *z* [9].

A cross-sectional function similar to Eq. 5 was adopted by Blackler and Guo [16] and the following aspect ratio was introduced taking into consideration the cost factor:

$$\frac{b}{d} = 2(1-R)(\sqrt{1+z^2} - z) \qquad (6)$$

Where:

The R-cost factor determined by channel lining to land cost ratio. It is shown by Blackler and Guo[16].

If ($c_2/c_3 \leq 4$):

$$R = -0.189\ln\left(\frac{c_2}{c_3}\right) + 0.41 \qquad (7)$$

If ($4 < c_2/c_3 \leq 20$):

$$R = -0.058\ln\left(\frac{c_2}{c_3}\right) + 0.21 \qquad (8)$$

For values where c_2 /c_3 are greater than 20, the difference between the most efficient and least-cost channel cross-sections become negligible. Also, when *R*=0, the least cost is the same as the most efficient channel cross section [16, 20].

3. Result and discussion

A concrete channel is designed to carry a peak flow of 1.157 m3/son a slope of 0.05%.The objective is to minimize the construction cost by selecting a proper b/y ratio. For this case, a side slope of 1V:1.5H is adopted or z=1.5.

The Manning's roughness coefficient of 0.014 is recommended for hydraulic calculations [21, 22].

The unit costs at the project site are found to be 20$/m2 per linear length for earth excavation, 346.8$/m2 per linear length for concrete linings, and 80$/m2 per linear length for land acquisition. Asc2/c3=3.75 and is less than 4, Eq. (7) is applied to this case and R for the least-cost channel section is calculated as R=0.16.

The b/y ratio for the least-cost channel section is calculated using Eq.(6)to be 0.498, Applying Manning's equation to this case [23], the normal depth is found to be y=0.59 m. As a result, the channel width is b=0.294m for the least-cost channel section. The above-presented solutions can be verified by the cost comparison among a range of b/y ratios varying from 0.01 to 3.00. As plotted in Fig. 1, the b/y ratio is identified as the minimum total cost.

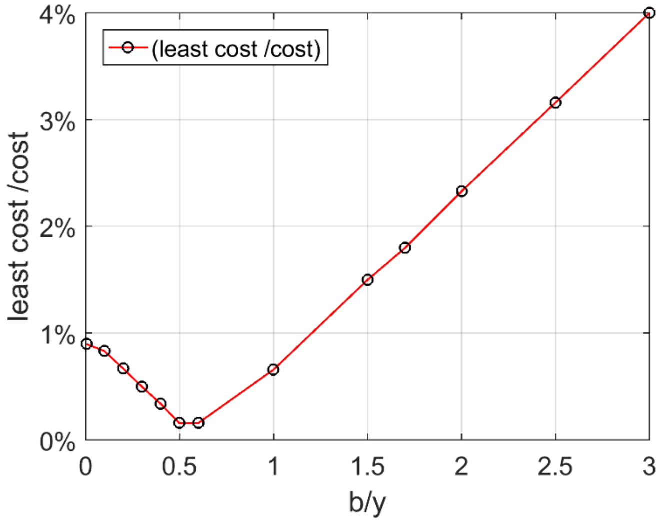

Fig.2. Cost comparison of minimal cost to total cost

4. Conclusion

As it is shown, in this study according to Eq.5 and Eq.6, the aspect ratio (b/y), was taken from optimal hydraulic cross-section (b/y= 0.6) and least-cost cross-section (b/y = 0.5) is not the same. Whereas the difference between those mentioned equations only in existence R,(cost factor),and this value depends on the cost of lining and excavation ,Also, when R=0, the least cost is the same as the most efficient channel cross-section so the aspect ratio can't be more optimal implies it is impossible to reduce the difference both cross-section. The application of Eq. 6 is used for an engineer who concerns with the cost of the construction channel project in design practice, and for those who would like to design with considering of the optimal hydraulic cross-section, it is recommended to use Eq.5.

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EVALUATION OF ASPECT RATIO (B/Y) IN DESIGN OF LEAST-COST TRAPEZOIDAL CHANNEL SECTION

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Article info review article

Abstract *From a long time ago, there is a question to decide if a channel should be designed to have the highest hydraulic efficiency or the least cost.Channel cross-section design with an optimal cost under uniform-flow conditions includes minimizing the total cost per unit length of the channel. In this study, a large amount of construction cost of the channel was investigated and analyzed to calculate the cost function of the channel as a total cost associated with the land acquisition, channel material coverage and ground drilling depth for the channel. Case studies carried out in this technical note show that the difference between low-cost and efficient sections is closely related to the cost of the channel lining relative to the cost of land. When the base cover disappears to the unit cost of the land, the difference between the two parts is almost decreasing. This transaction was performed in the normal equation to provide a straightforward solution to the low-cost channel.*

Keywords: open-channel flow, least-Cost, cross-section, aspect ratio, hydraulic design

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