International Journal of Natural and Engineering Sciences 7 (3): 27-32, 2013
ISSN: 1307-1149, E-ISSN: 2146-0086, www.nobel.gen.tr

Optimizing Irrigation and Drainage Canals Coat (IDCC) (Case study: Rasht City in Iran)

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Received: September 25, 2013
Accepted: November 17, 2013

Abstract

Selecting cross sectional variables like canal subsidiary slope, floor width, flow depth, and canal section radius are different based on the purposes of designers. For different goals, various values and relations among sectional variables are possible. One of these goals is minimizing total costs of canal section for the passage of ensured Debbi from a definite area. In addition to low cost, optimal cross section variables should be determined in a way that enables meeting hydraulic constraints. In concrete trapezoid canals, there are problems like passing Debbi, canal subsidiary slope, and canal coat diameter. They need accurate calculations to optimize the design for passing proper Debbi based on land slope. This study uses an optimal technique of concrete coat diameter in trapezoid canals to maximize favorable Debbi with the most economical costs by a cost function and technical and executive constraints of irrigation and drainage coat dimensions.

Keywords: Canal coat diameter, canal slope, Debbi, Optimal, Trapezoid canals.

INTRODUCTION

The main obstacles on the way of executing irrigation and drainage canals are financial costs and considerable time duration for them which are needed in establishing them and completing their subsidiary nets. These high financial needs and timeliness of canal establishment have yielded many problems in irrigation transfer systems among which are delays in establishing subsidiary canals of irrigation, problems of capital inaction, and damaging the useful life of main net and other existing utilities. Subsidiary canals are designed and executed in the forms of concrete, ready-made, half-pipe, rectangular, trapezoid, instant concreting, and etc. Being made of concrete creates many problems in building irrigation transfer systems. Thus, using low cost canals that meet technical requirements can enormously help irrigation system development. This study evaluates optimization techniques of concrete coat diameter in trapezoid canals to transfer the maximum water amount with the least cost; it also selects the target cost function, optimizing different technical and executive constraints of irrigation and drainage canals.

Tools and materials

This paper gathered necessary data and the features of coating irrigation and drainage net canals in Gilan Province. Then, it represents a total cost proxy of canal coat. Examining different options for canal coating, section design was suggested for optimal coat and minimum costs (Monem,2002). Selecting target function including executive costs of canal coat and exerting proper hydraulic and structural constraints, optimal coat diameter in canals resulted. Finally, based on technical and economic evaluations, the best diameter for coating canals based on weather and local conditions of Gilan Province was suggested; this can be of main applications for irrigation system engineers and designers (Bahramloo. 2007). One of the most important reasons of selecting under-study canals can be topography and slope status of the lands in the project. Selecting areas with positive, zero, and negative slopes, the need to examine most of the existing canals in irrigation and drainage systems in Gilan province will be removed. This trend will proceed in the whole net of the province. The status of land slope in the whole area can be a replication of 3 selected canals. This positive slope for Gallehrood Canal has caused a shoot design with the height of 1.5m to overcome high land differences for keeping irrigation standard balance line. Zero land slopes in down and upper areas of Rasht canals have been examined. A significant point of investigating main canal of Fomanat Town from D3 construction unit is related to negative land slope in the area of building this canal which is essential for directing necessary irrigation of pumping operation.

Optimizing coated canal design

Based on Manning Equation, we have Equation (1),

$$Q = \frac{1}{n} A R^{2/3} S_0^{1/2}$$

N: roughness coefficient A: area R: hydraulic radius S: canal slope For trapezoid canals, we have:
Equation (2),

$$y = \frac{\left[(\frac{b}{y}) + 2\sqrt{1+z^2} \right]^{1/4}}{\left[(\frac{b}{y}) + z \right]^{5/8}} . (\frac{nQ}{\sqrt{S_0}})^{3/8}$$

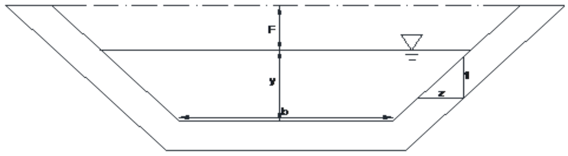

Fig1. Canal cost optimization

For the result of (2), i.e., $(\frac{b}{y})$ ratio, canal cost optimization based on coating is used:

Canal total cost $c = c_b$ (floor cost) $+c_s$ (wall cost)

$$c_b = Bb + k$$

$$c_s = 2\Gamma(y+F)\sqrt{1+Z^2}$$

Where,
B. floor concreting price per unit for definite floor diameter
Γ. Wall concreting price per unit for definite wall diameter
K. The material price of canal corners per length unit
Then, we have:
Cost function,

$$C = bB + k + 2\Gamma(y+F)\sqrt{Z^2+1}$$

Based on our variable b or y, the above function should be minimized:

$$\frac{\partial c}{\partial y} = \circ \quad \text{or} \quad \frac{\partial c}{\partial b} = \circ$$

Replacing Manning Equation in it, the following formulation results:

$$\frac{b}{y} = \frac{2K_1}{-K_2 + \left[K_2^2 + 20(\frac{B}{\Gamma})K_1\right]^{1/2}}$$

Where,

$$K_1 = 20(Z^2+1) - \left[1 + 4(\frac{B}{\Gamma})\right]4Z\sqrt{1+Z^2}$$

$$K_2 = (1-\frac{B}{\Gamma})6\sqrt{Z^2+1} - 10Z(\frac{B}{\Gamma})$$

Solving 2 above equations yields the values for b and y.
Optimizing coat design of main canal in down area of Rasht includes 3 different area ranges in which Q value (Debbi) and canal slope (i), floor width (b), canal height (h), and irrigation height (y) are regarded as the primary data resulting from executive plans of optimal coat design measures. In this study, first range was considered as the sample range for showing calculation trend and all other calculations for optimal coat design in other ranges are replicated similarly. In the optimal coat design, two variables include canal wall slope (z) and coat diameter (t). Z changes rangeis

$$\frac{b}{y} = \frac{2(33)}{1.6 + \left[(-1.6)^2 + 20(0.48)\times 33\right]^{1/2}} = 3.4$$

$$Z = 0.2,, 0.5, 0.7, 1, 1.5, 2, 2.5$$

The results are shown in the figures that come below. As seen in the calculations and figures, the slope of 1.5 (z=1.5) was proved to be the optimal slope for all canals. In the following section, optimal coat design operations in downside area of Rasht in first range will be shown as the sample.

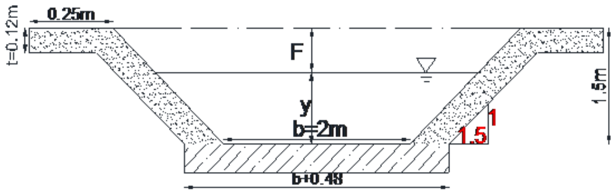

Fig2. Optimal coat design operations in downside area of Rasht in first range

$$Q = 3.5$$
$$i = 0.17$$
$$b = 2.00$$
$$H = 1.50$$
$$y = 1.25$$
$$F = H - y = 1.5 - 1.25 = 0.25$$

For the canal with diameter
$t = 0.12$ and $z = 1.5$

$$B = 2.48^m \times 0.12^m \times 1^m \times 65000\frac{T}{m^3} = 19344(T)$$

$$\Gamma = 2\times\left[\frac{1}{2}(2.7+2.5)\times 0.12\times 1\times 65000\right] = 40560$$

$$K = 2\times\left[0.12\times 0.25\times 1\times 65000\right] = 3900$$

$$Z = 1.5$$

$$Z^2 + 1 = 3.25$$

$$\sqrt{Z^2+1} = 1.8$$

$$\frac{B}{\Gamma} = 0.48$$

$$K_1 = 20(Z^2+1) - \left[1+4(\frac{B}{\Gamma})\right]4Z\sqrt{Z^2+1}$$

$$= 20(3.25) - \left[1+4(0.48)\right]4\times 1.5\times 1.8 = 33 = K_1$$

$$K_2 = (1-\frac{B}{\Gamma})6\sqrt{Z^2+1} - 10z(\frac{B}{\Gamma})$$

$$= (1-0.48)\times 6\times 1.8 - 10\times 1.5(0.48) = 5.6 - 7.2 = -1.6 = K_2$$

$$\frac{b}{y} = \frac{2K_1}{-K_2 + \left[K_2^2 + 20(\frac{B}{\Gamma})K_1\right]^{1/2}}$$

$$\frac{b}{y} = 3.4$$

$$y=\frac{\left[(\frac{b}{y})+2\sqrt{1+z^2}\right]^{1/4}}{\left[(\frac{b}{y})+z\right]^{5/8}}.(\frac{nQ}{\sqrt{S_0}})^{3/8}$$

$$y=\frac{\left[3.4+2(1.8)\right]}{\left[3.4+1.5\right]^{5/8}}.(\frac{0.014\times3.5}{\sqrt{0.17}})^{3/8}=0.27$$

$$\frac{b}{y}=3.4\Rightarrow b=0.27\times3.4=0.92$$

From experience formulation,

$$F=0.3+0.25y=0.3+0.25(0.27)=0.37$$

$$c=bB+k+2\Gamma(y+F)\sqrt{Z^2+1}=0.92(19344)+3900+2(40560)(0.27+0.37)(1.8)=115147$$

$$\boxed{C=115147}$$

Optimal coat design

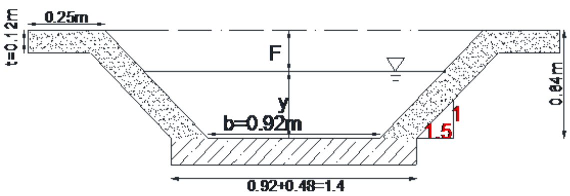

Fig.3.optimal coat design for calculating C_{opt} :

$$Q=3.5$$
$$i=0.17$$
$$b=0.92$$
$$H=0.37+0.27=0.64$$
$$y=0.27$$
$$B=1.4\times0.12\times1\times65000=10920$$
$$\Gamma=(1.6+0.93)\times0.12\times1\times65000=16302$$
$$K=2\left[0.12\times0.25\times1\times65000\right]=3900$$

α=arc tan1/1.5=34
W=1.5/sin34=2.7
w=1-0.12/sin34=2.5

$$W=\frac{0.65}{\sin34}=1.16$$

$$K_1=20(Z^2+1)-\left[1+4(\frac{B}{\Gamma})\right]4z\sqrt{z^2+1}$$

$$w=\frac{0.52}{\sin34}=0.93$$

$$K_1=20(3.25)-\left[1+4(0.67)\right]4(1.8)(1.S)=2S.26$$

$$Z=1.5$$

$$Z^2+1=3.25$$

$$K_2=(1-0.67)6(1.8)-10(1.5)(0.67)=-6.5$$

$$\sqrt{Z^2+1}=1.8$$

$$\frac{b}{y}=\frac{2(38.5)}{6.5+\left[42.25+20(0.67)(38.5)\right]^{1/2}}=1.9$$

$$\frac{B}{\Gamma}=\frac{10920}{16302}=0.67$$

$$y=\frac{\left[2.55+2(1.8)\right]^{1/4}}{\left[2.55+1.5\right]^{5/6}}\times0.45=0.32$$

$$b=0.32\times1.9=0.608$$

$$F=0.3+0.25(0.32)=0.38$$

$$C_{opt}=0.74\times10920+3900+2(16302)(0.29+0.37)(1.8)=51159$$

$$c_{opt/c}=0.4$$

For $Z=0.2,0.5,0.7,1,2,2.5$, with error and trial we get canal section features from the following formulations:

$$y=\frac{\left[(\frac{b}{y})+2\sqrt{1+z^2}\right]^{1/4}}{\left[(\frac{b}{y})+z\right]^{5/8}}.(\frac{nQ}{\sqrt{S_0}})^{3/8}$$

Where,

$$n=0.014$$
$$Q=3.5$$
$$S_0=0.17$$
$$Z=0.2$$
$$b=2$$

For example, in z=0.2, the above formulation is true for y=0.19. From F= 0.3+0.25 y, free height and H can be calculated. Calculations for this section is like the aforementioned ones. All results for related Zs are reflected in the figures.

Fig.5. Canal chart for down area of Rasht (range 2)
Q=3.5 I=0.4 b=2 H=1.3 Y=1.05

Fig. 6.Canal chart for down area of Rasht (range 3)
Q=3.5 I=0.05 b=2 H=1.8 Y=1.5

Fig.7.Canal chart for upper area of Rasht (range 3)
Q=7.5 I=0.6 b=2.5 H=1.5 Y=1.25
Fig. 8. Canal chart for upper area of Rasht (range 2)
Q=7.5 I=0.54 b=3 H=1.5 Y=1.25

Fig.9. Main canal of D_3 construction unit (range 1)
Q=6 I=0.27 b=3 H=1.5 Y=1.25

Fig. 10. Main canal of D_3 construction unit (range 2)
Q=6 I=0.51 b=2 H=1.5 Y=1.25

Fig.11. Main canal of D_3 construction unit (range 3)
Q=4.8 I=0.32 b=2 H=1.5 Y=1.26

Fig. 12.Main canal of D_3 construction unit (range 4)
Q=4.8 I=0.32 b=2 H=1.5 Y=1.26

Fig. 13.Gallerood main canal of G1construction unit (range 1)
Q=16.5 I=0.5 b=3 H=2.1 Y=1.8

Fig. 14. Gallerood main canal of G1construction unit (range 2)
Q=16.5 I=4 b=3 H=2.1 Y=1.05

Coated canals design optimization based on t changes

Fig.15. Canal coat design optimization for down area of Rasht (range 1)

$$Q = 3.5$$
$$i = 0.17$$
$$b = 2.00$$
$$H = 1.50$$
$$y = 1.25$$
$$F = H - y = 1.5 - 1.25 = 0.25$$

T =canal coat diameter
Copt/c=optimal cost/ cost

For $t = 0.08$

$$B = 2.48 \times t \times 1 \times 65000 = 12896$$

$$W = \frac{1.S}{\sin 34} = 2.7 \qquad z = 1.5 \qquad z^2 + 1 = 3.25$$

$$\Gamma = (27 + 2.5) \times t \times 1 \times 65000 = 27040$$

$$w = \frac{1.s - t}{\sin 34} = 2.5 \qquad \sqrt{Z^2 + 1} = 1.8 \qquad \frac{B}{\Gamma} = 0.48$$

$$k = 2(0.25 \times t \times 1 \times 65000) = 2600$$

$$K_1 = 20(Z^2 + 1) - \left[1 + 4(\frac{B}{\Gamma})\right] 4Z\sqrt{z^2 + 1}$$
$$= 20(3.25) - [1 + 4(0.48)]4 \times 1.5 \times 1.8 = 33$$

$$K_2 = (1 - \frac{B}{\Gamma})6\sqrt{Z^2 + 1} - 10Z(\frac{B}{\Gamma})$$
$$= (1 - 0.48) \times 6 \times 1.8 - 10 \times 1.5(0.48) = -1.6$$

$$\frac{b}{y} = \frac{2K_1}{-K_2 + \left[K_2^2 + 20(\frac{B}{\Gamma})K_1\right]^{1/2}}$$

$$\frac{b}{y} = \frac{2(33)}{1.6 + \left[(-1.6)^2 + 20(0.48) \times 33\right]^{1/2}} = 3.4$$

$$\frac{b}{y} = 3.4$$

$$y = \frac{\left[(\frac{b}{y}) + 2\sqrt{1 + z^2}\right]^{1/4}}{\left[(\frac{b}{y}) + z\right]^{5/8}} . (\frac{nQ}{\sqrt{S_0}})^{3/8}$$

$$Y = \frac{[3.4 + 2(1.8)]^{1/4}}{[3.4 + 1.5]^{5/8}} . \left(\frac{0.014 \times 3.5}{\sqrt{0.17}}\right)^{3/8} = 0.27$$

$$\Rightarrow b = 0.27 \times 3.4 = 0.92$$
$$F = 0.3 + 0.25y = 0.3 + 0.25(0.27) = 0.37$$
$$C = bB + K + 2\Gamma$$
$$(y + F)\sqrt{Z^2 + 1} = 0.92(12896) + 2600 + 2(27040)(0.27 + 0.37)(1.8) = 76912$$

Coat optimal design for calculating C_{opt} :

$$Q = 3.5$$
$$i = 0.17$$
$$b = 0.92$$
$$H = 0.37 + 0.27 = 0.64$$

$$W = \frac{0.64}{0.56} = 1.1$$

$$y = 0.27$$
$$\forall : t = 0.08$$

$$w = \frac{0.64 - t}{0.56} = 0.9$$

$$B = t \times (0.92 + 0.48) \times 65000 = 7280$$

$$\Gamma = 2 \times t \times 65000 = 10400$$

$$K = 2(0.25 \times t \times 65000) = 2600$$

$$\frac{B}{\Gamma} = 0.7$$

$$K_1 = 20(Z^2 + 1) - \left[1 + 4(\frac{B}{\Gamma})\right] \times 4 \times Z \times \sqrt{Z^2 + 1}$$

$$K_1 = 20(3.25) - [1 + 4(0.7)] \times 4 \times 1.5 \times 1.8 = 24$$

$$K_2 = (1 - \frac{B}{\Gamma})6\sqrt{Z^2 + 1} - 10Z(\frac{B}{\Gamma})$$

$$= (1 - 0.7) \times 6 \times 1.8 - 10 \times 1.5 \times 0.7 = -7$$

$$\frac{b}{y} = \frac{2(24)}{7 + [49 + 20(0.7)24]^{1/2}}$$

$$y = \frac{[1.8 + 2(1.8)]^{1/4}}{[1.8 + 1.5]^{5/8}} \times 0.45 = 0.3$$

$$b = 1.8 \times 0.3 = 0.55$$

$$F = 0.3 + 0.25(0.3) = 0.375$$

$$C_{opt} = bB + K + 2\Gamma(y + F)\sqrt{1 + Z^2} = 0.55(7280) + 2600 + 2 \times (10400)$$
$$(0.3 + 0.375)(1.8) = 31876$$

$$C_{opt}/C = 0.4$$

All above calculations for diameters $t = 10,12,14,16cm$ is calculated and chart t is drawn based on $C_{opt/C}$.

Fig16. Canal figure of down area of Rasht (range 2)
Q=3.5 I=0.4 b=2 H=1.3 Y=1.05

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 17. Canal figure of down area of Rasht (range 3)
Q=3.5 I=0.05 b=2 H=1.8 Y=1.5

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 18. Canal figure of upper area of Rasht (range 3)
Q=7.5 I=0.6 b=2.5 H=1.5 Y=1.25

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 19.Canal figure of upper area of Rasht (range 2)
Q=7.5 I=0.54 b=3 H=1.5 Y=1.25

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 20. Main canal chart of D_3 construction (range 1)
Q=6 I=0.27 b=3 H=1.5 Y=1.25

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 21. Main canal of D_3construction(range 2)
Q=6 I=0.51 b=2 H=1.5 Y=1.25

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 22.Main canal of D_3construction(range 3)
Q=4.8 I=0.32 b=2 H=1.5 Y=1.26

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 23. Main canal of D_3 construction (range 4)
Q=4.8 I=0.32 b=2 H=1.5 Y=1.26

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 24.Gallehrood main canal of G_1 construction unit (range 1)
Q=16.5 I=0.5 b=3 H=2.1 Y=1.8

T =canal coat diameter
Copt/c=optimal cost/ cost
Fig. 25.Gallehrood main canal of G_1 construction unit (range 2)
Q=16.5 I=4 b=3 H=2.1 Y=1.05

T =canal coat diameter
Copt/c=optimal cost/ cost

Optimal slope of 1.5 and optimal diameter between 10-14 cm resulted for this study. Based on the findings, trapezoid canal design with subsidiary wall slope for the values smaller than 1 and bigger than 2 and coat diameter of 0.11 is optimal. Since these results are reasonable for Z and T, they are acceptable. All these optimization trends can be calculation criteria for any supposed section with different forms that can finally lead to minimizing section design costs.

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