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Depending upon the up factors, the irrigation channels can be broadly classified into the following types:

1. Rigid boundary channels.
2. Non- alluvial channels.
3. Alluvial channels.

1. In the rigid boundary channel, the surface of the cannels is lined .The quantity of silt transported by such channels remains more or less the same as that has entered the channel at its head. In such channels, relatively high velocity of flow is usually permitted which does not allow the silt to get deposited.

2. The non-alluvial channels are excavated in non-alluvial soils such as loam, clay, etc .Generally, there is no silt problem in these channels and they are relatively stable.

3. The alluvial channels are excavated in alluvial soils, such as silt. The silt content may increase due to scouring of bed and side of the channel.

<u>Design of lined canals.</u>

A lined canal is a rigid boundary channel. A lined canal decreases the seepage loss and, thus, reduces the chances of water logging.

A lined canal provides safety against breaches and prevents weed growth, reducing the annual maintenance cost of the canal. However, the only factor against lining is it cost.

<u>Type of lining.</u>

1. Concrete lining.
2. Precast concrete lining.
3. Brick lining, etc.

However, the maximum permissible velocity is relatively high. Table (1.1) gives the values of the maximum permissible velocity usually adopted in practice.

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Table 1-1 maximum permissible velocity

No	TYPE of LINING	Max velocity(m/s)
1.	Boulder lining	1.5
2.	Brick tile lining	1.8
3.	Cement concrete lining	2.7

- Water logging when the pores of soil within the root zone of plant gets saturated and the normal growth of the plant is affect due to in sufficient air circulation .

Design By Trial And Error Solution.

The design of lined canal is usually done by Manning's formula. The value of Manning's coefficient (N) depends upon the type of lining. The higher values are for relatively rough surface and the lower, for smooth surface.

$$v = \frac{1}{n} R^{2/3} S^{1/2}$$

$Q = V * A$ $\qquad R = \frac{A}{P} \quad (m)$

Where:

Q= max. discharge for a given (A) where the p is min. (m^3/s)

A: cross-sectional area (m^2) of flow.

P: wetted parameter (m).

S: longitudinal slope (m/m).

R: hydraulic radius (m). n: Manning's roughness coefficient.

n: 0.015 for lined canals with concrete.

For trapezoidal section

$A = (b + Zy) * y$ $\qquad$ *p=b+2y**$\sqrt{1+z^2}$

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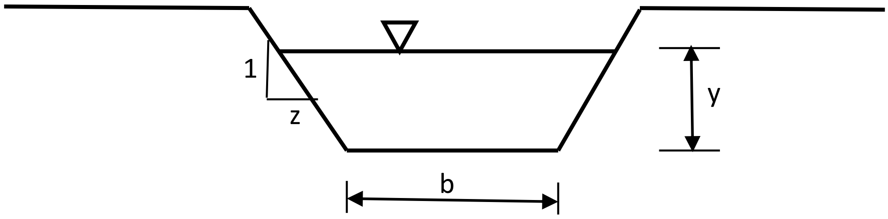

Cross-section of lined canals: for the most economical section, the hydraulic radius (R) should be a maximum. Theoretically, a semi- circular section is the best section for an open channel. However, it is not practicable to a depot this section. From the practical considerations, a channel of trapezoidal section or triangular section is usually selected. The corners of these sections are rounded to increase hydraulic radius

(a) ***Side slope***

The side slopes depend on the properties of the material thorough which the channel is to pass.

Table (1-2) show Sui table side Slopes for channels excavated through different types of material

NO	*Material*	*Side slope (H:V)*
1	*Rock*	*N early vertical*
2	*Muck and Peat* سماد حيواني و فحم	*0.25:1*
3	*Stiff clay or earth with concrete lining*	*0.5:1 to 1:1*
4	*Earth with stone lining*	*1:1*
5	Firm clay	*1.5 : 1*
6	*Loose, sandy soil*	*2: 1*

Side slope for the canals should be assume 1V = 1.5 H

Note: Side slope for small lined canal, which has depth less than (0.7m), is taken (1:1) (for water course)

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(b) Longitudinal Slope S

Assumption

- Uniform flow,
- longitudinal slope should be suitable to prevent the growth of grass and sedimentation of silt

$$\left.\begin{aligned} S_{\circ min} &= 0.00015\ Q^{-0.2} \\ S_{\circ max} &= 0.00025\ Q^{-0.2} \end{aligned}\right\} \qquad \text{تؤخذ متوسط الناتج}$$

Q = full supply discharge in(m^3/s)Plus (10%)for over flow

Note: For water course the longitudinal slope should be (10-60 cm/km)

The slope of an irrigation canal is generally less than the ground slope in the head reaches of the canal, hence, vertical falls have often to be constricted. Power houses maybe constructed at these falls to generate power and, thus, irrigation canal can be used for power generation also.

(c) Minimum permissible velocity

- Velocity with sedimentation basin at the head of the system

$V_{min} = 0.33\ Q^{0.2}$ (m/s)

$$Fr = \frac{V}{\sqrt{gy}} < 0.6$$

Fr = Froude number.

- Velocity without sedimentation basin at the head of the system

$V_{min} = 0.5\ Q^{0.2}$ (m/s)

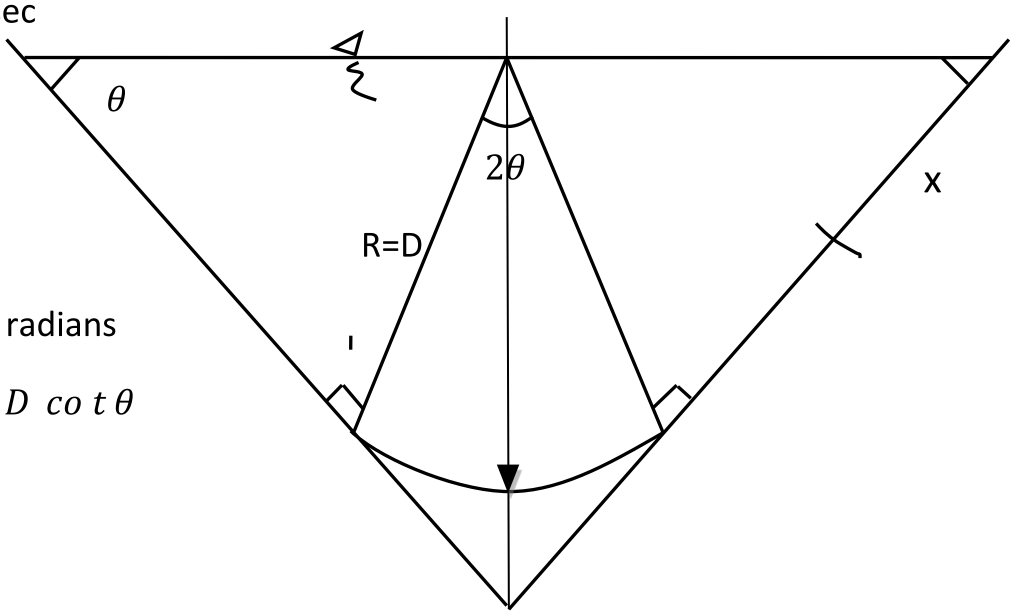
To avoid damage to the lining, the maximum velocity is restricted to (2m/sec). In general velocities of (0.7 -1 m/sec) will be adequate for prevent sedimentation as well as growth of vegetation if the sediment load is high.

(d) Bed-width and depth of water ratio (b/y)

$b/y = (1-2)$ for discharges Less than ($10m^3/s$)

<u>ملاحظات عامة</u>

Triangular section is usually adopted for channels of discharge less than 50 m^3/sec



θ in radians

$X = D\ cot\ \theta$

The radius of the bottom is equal to the depth of water (D). The angle in the center is ($2\ \theta$)

A= $(\pi D^2)\ (2\theta/2\pi) + 2(\frac{1}{2}D.Dcot\theta)$

A= $D^2(\theta + cot\theta)$

P= $2\pi D\ (2\theta/2\pi) + 2D\ cot\theta$

P= 2D $(\theta + cot\theta)$

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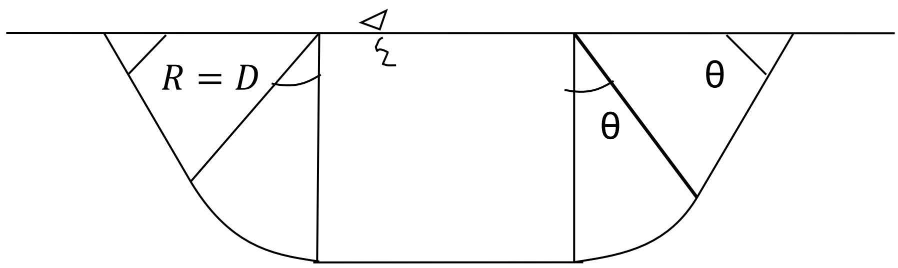

The trapezoidal section for the lined canals with discharge greater than 50 m^3/sec.

A=BD+$\pi D^2(2\theta/2\pi) + 2\left(\frac{1}{2}\right) D.D\ cot\theta$

A= BD+$D^2(\theta + cot\theta)$

P=B+2D$(\theta + cot\theta)$

In the side slope is 1:1 $(\theta = 45^0 = \pi/4)$

A= BD+1.785D^2

P=B+3.57D

Ex: Design the cross- section of a concrete lined canal (trapezoidal section) to carry a discharge of 1.2 m^3/sec (By Manning Eq.)

Q=$\frac{1}{n} R^{2/3} S^{1/2} A$ $\qquad n = 0.015$

Assume 1:Z 1:1.5

S_{min} = 0.00015 $Q^{-0.2}$

$S_{min} = 1.446 \times 10^{-4}$

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$S_{max} = 0.00025\ Q^{-0.2}$

$S_{max} = 2.41 \times 10^{-4}$

$S_{av.} = 1.928 * 10^{-4} \approx 2 * 10^{-4} = 0.0002$

Assume b=1m y=1m

$\therefore b/y = 1 \quad o.k \quad (1-2)$

$A = (b + zy)y \qquad = (1 + 1.5 \times 1) \times 1 = 2.5m^2$

$P = b + 2y\sqrt{1 + z^2} = 1 + 2 * 1\sqrt{1.5^2 + 1} = 4.68m$

$$R = \frac{A}{P} = 0.543\ m$$

$$\therefore Q = \frac{1}{0.015} * (0.543)^{\frac{2}{3}} (0.0002)^{\frac{1}{2}} * 2.5$$

$= 1.56 m^3/sec > 1.2 m^3/sec$

Assume b=1m y=0.9m b/y=1.111

$A = 2.115m^2$

$P = 4.242m$

: R=A/P =0.498m

V= 0.592 m/s check for velocity

$V_{min} = 0.5\ Q^{0.2}$

$V_{min} = 0.5\ (1.2)^{0.2}$

$= 0.5186$ m/sec

$\therefore V > V_{min} \qquad \text{o.k}$

$Q = V.A$

$= 0.592 \times 2.115$

= 1.252 m^3/sec $>$ 1.2 m^3/sec

Assume b=1m $y = 0.88m$ b/y=1.136

$A = 2.041m^2$

$P = 4.173m$

$R = 0.487m$

$V = 0.585 \quad > V_{min}$

Q= 1.194 m^3/sec $\approx$ $1.2\ m^3/sec$

Check Fr

$\text{Fr} = \frac{0.585}{\sqrt{9.81*0.88}} = 0.199 \ < 0.6$ o.k

Ex: Design a lined canal to carry discharge of 50 m^3. Assume bed slope as 1 in 8100, N as 0.015 and side slope as 45°

<u>Sol:</u> let us adopt a triangular section for $\theta = \pi/4$

A= 1.785 D^2

P= 3.570 D

Q=V.A $= \frac{1}{n}\ A.S^{1/2}R^{2/3}$

$$50 = \frac{1}{0.015}\ (1.785\ D^2)\ .\ (\frac{1}{8100})^{\frac{1}{2}}\ .\ (\frac{1.785D^2}{3.570\ D})^{\frac{2}{3}}$$

50 = 0.833 $D^{8/3}$ $\rightarrow$ D=4.64m

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Design by Section Factor Method by using the chart

1. Determine the value of (A $R^{2/3}$ / $B^{8/3}$).

2. Determine z.

3. Compute b/y.

Ex: Design the cross-section of a concrete lined canal for a discharge of 1.8m^3/sec, on slope of 20 cm/km by using section factor method.

Solution

Assume 1:Z 1:1.5 for lined canal

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

$$\frac{Qn}{\sqrt{s}} = A\, R^{2/3}$$

$$\frac{1.8 * 0.015}{\sqrt{0.0002}} = 1.91 \approx 2$$

2= A $R^{2/3}$

Assume b = 1m $\therefore (AR\text{^}(2/3))/b\text{^}(8/3) = 2$

Z=1.5 $\longrightarrow$ from fig $\frac{b}{y} = 1$

$\therefore y = 1m \quad check\ for \quad Fr \quad no$.

$A = (1 + 1.5 \times 1) \times 1 = 2.5m^2$

$V_{min} = 0.5\, Q^{0.2} = 0.562\, m/s$ [Without sedimentation basin]

$$V = \frac{Q}{A} = \frac{1.8}{2.5} = 0.72\, m/\mathrm{s} > V_{min}$$

$$Fr = \frac{V}{\sqrt{gy}} = \frac{0.72}{\sqrt{1 * 9.81}} = 0.23 < 0.6 \qquad o.k$$

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Design of unlined canal

- Design by Manning Equation

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

(a) Side slope

Side slope in an un lined canal depend mainly on the nature of geological formations through which the canal is excavated. Side slopes in an un lined canal should be flatter than the angle of repose of saturated bank soil.

Initially, flatter slopes are provided for reasons of stability. Later, with the deposition of fine sediments, this side slope become steeper

and attain a value of (0.5 H: 1V) irrespective of the initial side slope provided. These steeper side slopes are stable and the design is usually based on these slopes. Table below show the side slopes for un lined canals in different types of soil.

Use (1.5 to 2 H): 1V   For Large canal

for water course use (1.5 H:1V)

Type of soil   H:V

Loose sand to average sandy soil	1.5:1 to2:1(in cutting) 2:1 to 3:1 (in filling)
sandy loam and black cotton soil	1:1 to 1.5:1 (in cutting) 2:1 (in filling)
Gravel	1:1 to 2:1
Murum or hard soil	0.75:1 to 1.5:1
Rock	0.25:1 to 0.5:1

(b) Bed width and water depth ratio (b/y)

$$\frac{b}{y} = (2-3) \, for \; discharege \; less \; than \; (10m^3/s)$$

*b=0.4m usually for watercourse.

y = 0.75 $Q^{0.33}$

Where

Q: Design discharge (m^3/s)

(c) Permissible velocities

V min = C_2 $y^{0.64}$

Where:

V min: minimum permissible velocity to prevent sediment depositions (m/s)

C_2: constant

Type of suspended material C_2

- Light loam and very fine sand	0.4
- Find sand (Dia.=0.4mm)	0.55
-Moderate Coarser sand	0.63
- Coarser Sand	0.67
- Very Coarser Sand	0.90

(d) Maximum permissible Velocity

The design of the canal should be to prevent scouring, there by, the design should be based on the concept of tractive force. Scour on a channel bed occurs, when the tractivc force on the bed exerted by the flow is adequate to cause the movement of the bed particles. If the tractive force acting on the bed or the resultant of the tractive force and the component of the gravitational force both acting on the side slopes is larger than the force resisting the movement of the particles erosion starts.

i- Empirical equation

V max = C_1 $y^{0.64}$

Type of bed material C_1

Fine , light sandy loam	0.55
Coarser , light sandy loam	0.60
sandy , loamy silt	0.66
coarser silt	0.71

ii- Tractive force method

tractive force $\tau_{\circ}$ is calculated and it should be less thanτ_c(the max. permissible tractive force, critical shear stress) depending on bed material, maximum shear stress on the bed.

In uniform flow the average tractive stress, $\tau_{\circ}$ is given as:

$$\tau_{\circ} = w\,.R\,.S \qquad KN/m^2$$

$where$:

w: density of water (ρg) (KN/m^3)

R: the hydraulic radius (m)

S: slope of water surface (m/m)

If $\tau_{\circ} < \tau_c$ the bed will not scour

τ_c *اما تعطى او من جداول خاصة*

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Serval investigators have given the expression for the critical tractive stress. Some of the commonly used expressions are given below:

1. **Shield's equation** According to shield, the critical stress (τ_c) is operational to gain diameter and the submerged unit weight of the sediment, and is given by

$$\tau_c = 0.06\, w\, (G-1)\, d$$

Where τ_c is the critical share stress (KN/m^2). w is the specific weight of water (KN/m^2). *G* is the specific gravity of the sediment and *d* is the gain diameter (m).

Taking $G = 2.65\ and\ w = 9.81\ \ KN/m^2.\ Eq.22.42\ becomes$

$$\tau_c = 0.98\, d$$

2. **White equation** According to white. $\tau_c = 0.801\, d$

Where *d* is the grain diameter (m). and τ_c in KN/m^2.

3. **Lane's equation** lane gave the following equation. $\tau_c = 0.78\, d$

All the above equation are for fully-developed turbulent flow.