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CRITERIA FOR HYDRAULIC DESIGN OF SEDIMENT EJECTOR FOR IRRIGATION AND POWER CHANNELS

(*First Revision*)

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0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 17 March 1980, after the draft finalized by the Canals and Canal Linings Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Sediment ejector, also known as sediment extractor or silt ejector, is a contrivance to remove excessive sediment load after it has entered a canal. The extraction of sediment is effected by causing sediment concentration in the bottom layers and separating them in such a way that there is least disturbance in the sediment distribution of the approaching flow. This standard is intended to help in design of sediment ejectors. Sediment ejectors are usually provided in head reaches of canals which carry heavy silt, especially canals taking off from diversion weirs, anicut or barrages across rivers.

0.3 This standard was first issued in 1971. The present revision was taken up with a view to bring in further clarifications and modifications in the light of experience gained while applying the provisions of the earlier version of the code to practical situations.

0.4 The present revision includes the modified clauses on the data required for the design of sediment ejector, location, approach channel, main structure and outfall channel. A new clause on hydraulic model studies has also been included.

1. SCOPE

1.1 This standard deals with the criteria for hydraulic design of sediment ejector for irrigation and power channels.

2. DATA REQUIRED

2.1 The following data relating to the canal are needed for design of sediment ejector:

- a) Site plan;
- b) Cross section and other design data of the canal upstream and downstream of the proposed location;
- c) Canal discharge;
- d) Sediment data:
  - 1) Silt load both suspended and bed load daily, fortnightly or monthly, as available. For suspended silt, data should be available at different depths along atleast three equidistant verticals across the width, at the proposed site of the ejector. The bed load should be observed up to 0·2 *d*, where *d* is the depth of water (subject to a maximum of 0·5 m); and
  - 2) Permissible size of silt can safely be allowed downstream of the silt ejector. In case of power channels generally sediment size larger than 0·2 mm is intended to be ejected; and
- e) Data for existing reach of the outfall channel:
  - 1) Contour plan;
  - 2) Cross sections;
  - 3) Stage discharge curve and the hydrograph of the stream at the outfall; and
  - 4) Discharging capacity.

3. LOCATION

3.1 While deciding the location of the silt ejector, availability of suitable outfall channel has to be kept in view. The approach channel upstream of the ejector preferably be straight as otherwise it is likely to change the sediment concentration across the channel and disturb the uniform distribution of the flow in front of the ejector. In certain unavoidable cases where silt ejector has to be provided in the curved reach of the channel, it should be done after conducting model studies. The ejector should not be sited too near the head regulator as the residual turbulence may cause the sediment load to remain in suspension and prevent its ejection to the desired extent. At the same time it should not be far away from the head reach otherwise the sediment may settle down earlier and reduce the channel capacity upstream.

3.2 The working head available, that is, the difference in water level in the canal upstream of the ejector and the outfall channel at the exit of the ejector tunnel, shall be sufficient to extract the desired sediment. A working head of about 1 m is generally considered satisfactory for the purpose.

4. COMPONENTS

4.1 Generally, a silt ejector has the following components:

a) Approach channel;
b) Main structure which consists of:
  1) diaphragm,
  2) tunnels, and
  3) control structure; and
c) Outfall channel.

5. APPROACH CHANNEL

5.1 In order to increase the concentration of sediment in the bottom layers, the cross sections of the approach channel should be increased by depressing suitably the bed and/or increasing the width, to reduce the velocity of flow to the desired limit. At the start of approach channel suitable transition/splay of the order of 1 in 5 should be provided so as to obtain streamline flow. The setting velocity of the silt particles can be calculated by — Stoke's law which is given as under:

$$\text{Settling velocity, } V_S = \frac{1}{18}\left(\frac{P_S - P}{\mu}\right) g\, d^2$$

where

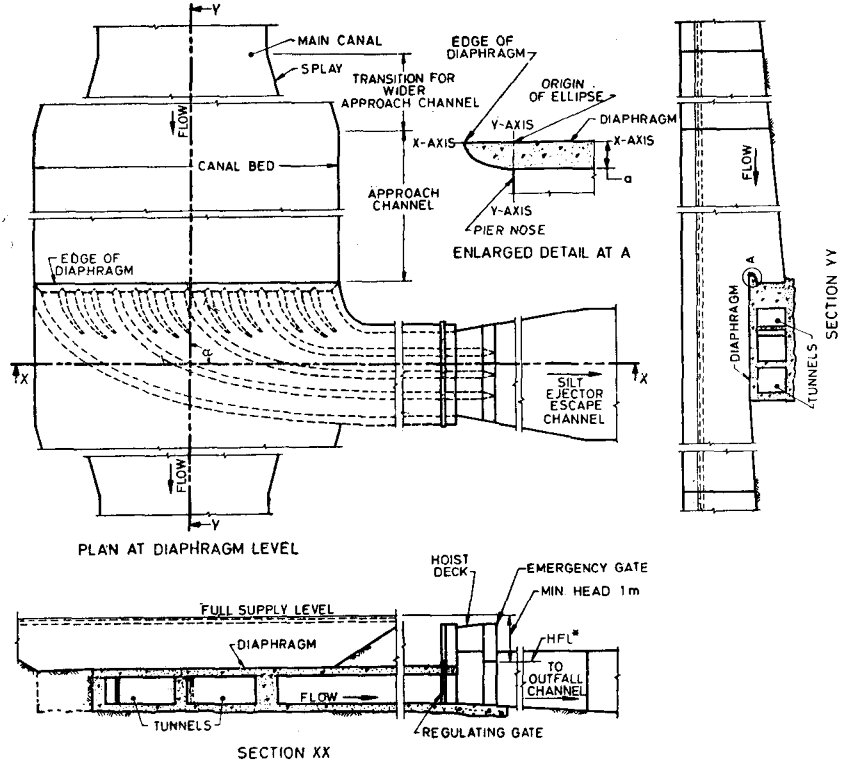
V_S = Settling velocity in cm/s,
P_S = Density of the particle in g/cm^3,
P = Density of the fluid in g/cm^3,
g = Acceleration due to gravity in cm/s^2,
μ = Absolute viscosity of the medium in poise, and
d = Diameter of the particle in cm.

The layout of the approach channel may be decided with the above guidelines. The reduced velocity should be maintained for a sufficient length to achieve the desired sediment concentration in the bottom layers.

6. MAIN STRUCTURE

6.1 Diaphragm (*see* **Fig. 1**) — The diaphragm shall be so designed that it causes least disturbance in the sediment concentration attained in the bottom layers of flow upstream of the ejector tunnels. In fixing the diaphragm level due consideration should be given to the following factors:

- a) Desired sediment size to be trapped and extracted,
- b) Bed level and size of tunnels,
- c) Thickness of diaphragm, and
- d) Bed level of canals downstream of the silt ejector.



Note 1 — Energy dissipation arrangement d/s of channel and in the escape channel not shown.

Note 2 — Radii of vanes to be such that requirement of clauses **6.2** to **6.2.3** are fulfilled.

*HFL/water level in exit channel.

Fig. 1 Typical Design for Sediment Ejector

The location of diaphragm can be determined by drawing the integrated discharge depth curve by using Vanoni's logarithmic velocity distribution,

$$v = V + \frac{1}{k}\sqrt{g y_0 s}\left(1 + 2{\cdot}3 \log_{10} y/y_0 \right)$$

where

v = Velocity of flow at a height y from channel bottom,
V = Mean velocity of flow,
k = Von Karman constant (assumed usually as 0·4),
s = Slope of the channel,
y = Height from channel bottom,
y_0 = Total depth of flow, and
g = Acceleration due to gravity.

(However these parameters should be confirmed by suitable model test experiments).

6.1.1 It is desirable to place the diaphragm at the downstream bed level of the canal. However, if the diaphragm has to be placed higher from other considerations, the condition of all particularly for low supplies should be checked and, if necessary, proper energy dissipation arrangements provided.

6.1.2 The diaphragm should be properly tied to the supports as otherwise the diaphragm is likely to be dislodged.

6.1.3 The diaphragm shall be extended beyond the pier noses and the underneath of the diaphragm shall be given a streamlined bell mouth (elliptical) shape conforming to the following equation:

$$\frac{x^2}{4\,a^2} + \frac{y^2}{a^2} = 1$$

where

a = the thickness of the diaphragm (*see* Fig. 1).

6.2 Tunnels — The ejector should normally span the entire width of the canal and shall be divided into a number of compartments of tunnels by vanes gradually converging so as to accelerate the escaping flow for delivering it to the outfall channel on one side of the canal. These main compartments shall be subdivided into smaller compartments or sub-tunnels by vanes of radii varying from 3 to 4 times the width of sub-tunnels to avoid cross flow in the transition section. The upstream noses of vanes shall have cut water shapes. Downstream end of vanes shall be fish tailed.

6.2.1 The tunnel dimensions at the entry and exit shall be so fixed as to ensure velocities that would carry the size of sediment to be removed. The section of the sub-tunnel at the entry shall be so chosen that the velocity of flow at the intake is slightly higher than the velocity of bottom filaments of water upstream of the ejector. The section of sub-tunnels up to their exit, where these end into the main tunnels, shall be reduced gradually in such a way that there is an overall increase of 10 to 15 percent in velocity of emerging flow.

6.2.2 At the exit of sub-tunnels the section of the main tunnel shall be designed such that the flow velocities of the combined discharge are not less than the velocities emerging out from the sub-tunnels. The section at the exit of the main tunnels shall be so designed as to attain a velocity of 2·5 to 6 m/s depending on the grade of sediment to be ejected, but in all cases, the exit velocity shall be less than the critical velocity.

6.2.3 The depth of the main tunnels should be kept about 1·8 m to 2·2 m to facilitate inspection and repair work. Their width shall be so adjusted as to have equal losses in each tunnel. The tunnels shall be designed to run full bore to secure maximum efficiency.

NOTE — As the length of tunnels will be different, head loss in various tunnels would be different and, therefore, the shorter tunnels will tend to take a higher discharge than the longer ones, head available for both being the same. This will result in higher velocity of entry in shorter tunnels (nearer to escape channel) than in others and would lead to disturbance at entry. To counteract this possibility, either the shorter tunnels shall be made to serve a larger width of the canal as compared to longer tunnels or tunnel cross sections shall be altered each serving an equal width.

6.3 Control Structure — The discharge from the sediment ejector is controlled by set of emergency and regulating gates. The quantum of discharge to be run through sediment ejector and frequency of its operation would vary in different parts of the year depending on the sediment load carried in the canal and this is achieved by operating regulating gate as required. It would be desirable to operate the gates fully open or fully closed.

7. OUTFALL CHANNEL

7.1 The outflow from the ejector is led to a natural drainage through an outfall channel. The outfall channel should be designed to have a self-cleaning velocity so that the ejected material is transported witout deposition. Adequate drop between the full supply level of the outfall channel at its tail end and the normal high flood level of the natural stream is desirable for efficient functioning of the channel.

Of the several formulae available, the following equation by Neil can be adopted for working out approximate flushing velocity:

$$\frac{P}{\Delta \Upsilon} \frac{V_c^2}{d_g} = 2{\cdot}5 \left(\frac{d_g}{y_0} \right)^{-0{\cdot}20}$$

where

V_c = Competent mean velocity for first displacement of bed material,
P = Mass density of the fluid,
d_g = Effective diameter of bed grains,
y_0 = Depth of flow, and
$\triangle \Upsilon$ = Specific weight of the bed material in the fluid.

The velocity adopted should be well in excess of that worked out above. The adequacy of the section of the escape channel, especially when the available bed slope is not steep, should be tested for its carrying capacity. A triangular distribution of sediment concentration can be assumed at the mouth of the ejector to work out the quantity of sediment entering the ejector. The section of the escape channel should be so designed as to have adequate capacity to transport the total quantity of sediment entering it.

8. ESCAPE DISCHARGE

8.1 The escape discharge will be governed by the following considerations:

a) Discharge required to remove the desired sediment size and load, and

b) Minimum discharge required for flushing individual tunnels.

Generally an escape discharge equal to 10 to 20 percent of the full supply discharge of the canal downstream of the ejector will be adequate for this purpose.

9. LOSSES IN TUNNELS

9.1 These shall comprise friction losses and those due to bends and transitions in contractions or expansions and shall be evaluated as given in **9.1.1** to **9.1.4**.

9.1.1 *Friction Losses* — These shall be computed by the Manning's formula:

$$h_f = \frac{V^2 L n^2}{R^{4/3}}$$

where

h_f = Head loss in m,
V = Average velocity in m/s,
L = Length of tunnel in m,
n = Rugosity coefficient of the tunnel surface (*see* **9.1.1.1**), and
R = Hydraulic mean radius in m.

9.1.1.1 Values of rugosity coefficient (n) for various surfaces shall be taken in accordance with IS : 4745-1968*.

9.1.2 *Loss Due to Bend* — It shall be calculated by the following equation:

$$h_b = F \frac{V^2}{2g} \frac{\theta}{180}$$

where

h_b = Head loss due to bend in m,
$F = 0{\cdot}124 + 3{\cdot}104 \left(\frac{S}{2R} \right)^{\frac{1}{2}}$,
S = Width of tunnel in m,
R = Radius of the bend along centre line of tunnel in m,
g = Acceleration due to gravity in m/s^2, and
θ = Angle of deviation in degrees.

9.1.3 *Contraction Losses* — It shall be obtained by the following formula:

$$h_e = 0{\cdot}1 \left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g} \right)$$

where

h_e = Head loss due to contraction in m,
V_2 = Average velocity at the exit of transition in m/s,
V_1 = Average velocity at the entrance of transition in m/s, and
g = Acceleration due to gravity in m/s^2.

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*Code of practice for design of cross section of lined canals.

9.1.4 *Expansion Losses* — These shall be computed by the following equation:

$$h_e = k\left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right)$$

where

h_e = Head loss due to expansion in m,
k = Coefficient which may be taken as 0·2 for gradual transitions,
V_2 = Average velocity in smaller section in m/s,
V_1 = Average velocity in expanded section in m/s, and
g = Acceleration due to gravity in m/s².

10. EFFICIENCY OF EJECTOR

10.1 The efficiency (E) of the ejector shall be calculated for the bed load primarily. It will also be indicated for suspended load. The samples of the sediment will be collected sufficiently away from the transitions of the silt ejector.

$$E = \frac{I_u - I_d}{I_u} \times 100 \text{ percent}$$

where

I_u = Silt intensity in canal upstream of the ejector, and
I_d = Silt intensity in canal downstream of the ejector.

11. FLUSHING

11.1 During the period when sediment ejector is not required to function, it is desirable to operate the regulation gates occasionally for short periods to flush the tunnels consistent with the economy in water requirements for irrigation and power generation. Otherwise, the tunnels are likely to get choked and may require manual clearance which may be possible only during closure of the canal.

11.2 At times during the normal operation of the sediment ejector, the approach channel and/or tunnels or both may require flushing. This may be done by running the tunnels in rotation to achieve higher velocities.

12. TYPICAL DESIGN

12.1 A typical sketch of sediment ejector is shown in Fig. 1.

13. HYDRAULIC MODEL STUDIES

13.1 There are many unknown factors in the design of silt ejector, such as the capacity of the silting basin in the approach channel, layout of the sub-tunnels and main tunnels, flushing velocity for the particular characteristics of the sediment to be ejected, and flow pattern of the bottom layers of the discharge, etc. As such it is essential that the layout based on the theoretical design be checked by model studies to ascertain the efficiency of the silt ejector.

INDIAN STANDARDS
ON
CANAL AND CANAL LININGS

IS:

3860-1966	Precast cement concrete slabs for canal linings
3872-1966	Code of practice for lining of canals with burnt clay tiles
3873-1978	Code of practice for laying *in-situ* cement concrete lining on canals (*first revision*)
4515-1967	Code of practice for boulder lining for canals
4558-1968	Code of practice for under-drainage of lined canals
4701-1968	Code of practice for earthwork on canals
4745-1968	Code of practice for design of cross section of lined canals
4839 (Part I)-1979	Code of practice for maintenance of canals: Part I Unlined canals (*first revision*)
4839 (Part II)-1979	Code of practice for maintenance of canals: Part II Lined canals (*first revision*)
4839 (Part III)-1979	Code of practice for maintenance of canals: Part III Canal structures, drains, outlets, jungle clearance plantation and regulation (*first revision*)
4969-1968	Method of test for determining flexural strength of precast cement concrete slabs for canal lining
5226-1969	Code of practice for sealing joints in concrete lining on canals
5331-1969	Guide for selection of type of lining for canals
5690-1969	Guide for laying combination lining for existing unlined canals
5968-1968	Guide for planning and layout of canal system for irrigation
6522-1972	Criteria for design of silt vanes for sediment control in offtaking canals
6936-1973	Criteria for location, selection and hydraulic design of canal escapes
7112-1973	Criteria for design of cross section for unlined canals in alluvial soil
7113-1973	Code of practice for soil-cement lining for canals
7114-1973	Criteria for hydraulic design of cross regulators for canals
7495-1974	Criteria for hydraulic design of silt selective head regulator for sediment control in off taking canals
7871-1975	Criteria for hydraulic design of groyne walls (curved wing) for sediment distribution at offtake points in a canal
7873-1975	Code of practice for lime concrete lining for canals
7880-1975	Criteria for hydraulic design of skimming platform for sediment control in offtaking canal
7986-1976	Code of practice for canal outlets
8835-1978	Guidelines for planning and design of surface drains
9097-1979	Guide for laying lining of canals with hot bitumen or bituminous felts

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