IS 5186 (1994): Design of chute and side channel spillways - Criteria [WRD 9: Dams and Spillways]

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भारतीय मानक

ढलवाँ नाली और पार्श्व प्रणाल उत्प्लाव के डिजाइन का मसौदा – मापदंड

(पहला पुनरीक्षण)

Indian Standard

DESIGN OF CHUTE AND SIDE CHANNEL SPILLWAYS — CRITERIA

(First Revision)

UDC 627·83

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 1994 Price Group 5

AMENDMENT NO. 1 OCTOBER 2008
TO
IS 5186 : 1994 DESIGN OF CHUTE AND SIDE CHANNEL SPILLWAYS — CRITERIA

(First Revision)

(*Page* 1, *clause* **2**) — Substitute 'IS 11155 1994 Code of practice for construction of spillways and similar overflow structures (*first revision*)' *for* 'IS 11155 1984 Code of practice for construction of spillways and similar overflow structure'

(*Page* 9, *clause* **8.2.6**) — Substitute 'IS 11155 1994' *for* 'IS 11155 1984'

(WRD 9)

Reprography Unit, BIS, New Delhi, India

Spillways Including Energy Dissipators Sectional Committee, RVD 10

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Spillways Including Energy Dissipators Sectional Committee had been approved by the River Valley Division Council.

Spillway is an integral part of all river valley projects and is essentially required to pass down to the river or to some other natural drainage, surplus or flood water which cannot be safely retained upstream of the storage dam. Provision of a hydraulically efficient and structurally strong spillway is very important for the safety of the dam and the life and property along the river down below.

Generally the spillway can be provided directly over the dam in case of concrete or masonry dam. But for dams composed of earth or rock, or for dams over which it is impossible or undesirable, for special reasons, to pass water, some form of spillway adjacent to the dam is to be provided. These may be either closed conduit or open channel spillways. In open channel spillways water is conveyed from the reservoir to the river below the dam or to other natural drainage through an excavated and lined open channel with fairly steep slope and placed either along a dam abutment or through a saddle in the rim of the reservoir. These consist of a low crest and a paved channel on a steep slope on the natural or excavated earth or rock formation. Generally the control structure is placed normal or nearly normal to the centre line of the channel downstream. Such a spillway is termed chute spillway. In narrow canyons, or otherwise, where the site for the control structure is limited in width, the crest is placed almost parallel to the channel and the spillway is then called side channel spillway. A typical arrangement for chute and side channel spillway is shown in Fig. 1.

Chute and side channel spillways can be constructed on all types of foundation materials ranging from solid rock to soft clays. However, if the foundation material is incapable of passing the water without excessive erosion, it should always be protected by concrete paving. Due to possible use of large amounts of spillway excavation in the dam embankment, these spillways generally result in overall economy in earthfill dams. These structures are specially suited in situations where sound rocky foundations required for the conventional type of spillways (vertical drop type) are not available. Therefore, due to simplicity of their design and construction, adaptability to almost any foundation condition, these spillways are used with earthfill dams more often than any other type.

This standard was first published in 1969. This standard has been revised to update its contents based on the experience gained with the use of this standard. The principal modifications are in respect of design requirements of outlet channel, floor lining, drainage system and anchors.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, should be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DESIGN OF CHUTE AND SIDE CHANNEL SPILLWAYS — CRITERIA

(First Revision)

1 SCOPE

This standard covers the criteria for hydraulic and structural designs and other general requirements of chute and side channel spillways.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
4410 (Part 9) : 1982	Glossary of terms relating to river valley projects : Part 9 Spillways and syphons (*first revision*)
11155 : 1984	Code of practice for construction of spillways and similar overflow structure
11527 : 1985	Criteria for structural design of energy dissipators for spillways
11772 : 1986	Guidelines for design of drainage arrangements of energy dissipators and training walls of spillways

3 TERMINOLOGY

For the purpose of this standard the definitions given in IS 4410 (Part 9) : 1982 shall apply.

4 GEOLOGICAL INVESTIGATIONS

Geology of the site will be taken into consideration for designing the details of the structure.

5 SPILLWAY LAYOUT

5.1 The outflow characteristics of a spillway depend on the particular device selected to control the discharge. After having selected a spillway control with certain dimensions and crest level, the maximum spillway discharge and the maximum reservoir water level may be determined by flood routing for adopted designed flood. Other components of the spillway may then be proportioned to conform to the required capacity, topography and foundation conditions of the site.

5.2 Site conditions generally influence the location, type, and components of a spillway. The steepness of the terrain traversed by the control and discharge channel, the class and amount of excavation and the possibility for its use as embankment material, the chances of scour of the bounding surfaces and the need for lining, the permeability and bearing capacity of the foundation, and the stability of the excavated slopes should necessarily be considered in the selection of layout.

6 HYDRAULIC DESIGN

6.1 Chute or side channel spillways in general consist of the following components:

a) An approach channel,

b) Control structure,

c) Side channel trough,

d) Discharge channel,

e) Energy dissipator and/or terminal structure, and

f) Outlet channel.

6.2 Approach Channel

6.2.1 Where the spillway is located through an abutment, saddle or ridge, an approach channel is required to draw water from the reservoir and convey it to the control structure.

6.2.2 Approach velocities should be limited and channel curvatures and transitions should be made gradual, in order to minimize head loss through the channel and to obtain uniformity of flow over the spillway crest. Head loss in the approach channel has the effect of reducing the spillway discharge. High velocity may also necessitate lining of the channel depending upon the rock. Even distribution of flow should be ensured over the spillway crest as far as possible.

6.2.3 The approach velocity and depth below crest level have important influence on the discharge over an overflow crest. Preferably the depth below the crest may be about half of the head over the crest for good co-efficient of discharge.

6.3 Control Structure

6.3.1 The control structure in chute spillways is generally placed normal or nearly normal to the axis of the discharge channel in the head reach and in side channel spillways the control structure is placed along the side or approximately parallel to the upper portion of the spillway discharge channel. Control structure is to limit or prevent outflows below fixed reservoir levels and to regulate releases when the reservoir rises above that level.

6.3.2 Control structure in plan may be straight, semicircular, or U shaped. The crest may be gated or ungated. The overflow section may be ogee shaped, or broad crested.

6.3.3 The crest profile should be designed to suit the conditions of gate operation. At partial gate openings free flow profiles are likely to develop negative pressures. In low crests which are usually with these types of spillways the negative pressures may be avoided without any appreciable extra cost by adopting a jet flow profile for a small gate opening for the part of the crest downstream of the gate sill. The co-efficient of discharge in this case is reduced and can best be worked out on a hydraulic model.

6.4 Side Channel Trough

6.4.1 In side channel spillway the control structure is generally placed along the side of or approximately parallel to the upper portion of the spillway discharge channel. Flow over the crest falls into a trough, turns approximately at a right angle and then continues into the main discharge channel. The flow into the trough may enter only on one side in the case of a steep hillside location, or on both sides and over the end of the trough if it is located on a knoll or gently sloping abutment.

6.4.2 Reduction in discharge over the crest due to submergence, if it occurs, should be taken into consideration. The submergence may be due to some flow conditions along the reach of the trough under consideration or a control section or a construction in the channel downstream of the trough.

6.4.3 The crest structure should be designed as in **6.3.3**.

6.4.4 *Cross-Section of Trough*

The cross-sectional shape of the side channel trough is influenced by the overflow crest on one side and by bank conditions on the opposite side. A trapezoidal cross-section with minimum width to depth ratio is recommended for the side channel trough. However, the minimum width should be commensurate with both practical and structural aspects. If the width to depth ratio is large, the depth of flow in the channel will be shallow, resulting in poor diffusion of increasing flow with the channel flow. Moreover, with greater bed width the excavation will increase.

6.4.4.1 Because of turbulences and vibrations inherent in side channel flow the trough should be set well into the original formation for safety. The side slopes should be trimmed to the steepest angle at which the material will safely stand and lined with concrete anchored directly to the rock.

6.4.5 *Slope*

For the subcritical stage in the trough the incoming flow will not develop high transverse velocities because of the low drop before it meets the channel flow thus effecting a good diffusion with the water bulk in the trough. Since both the incoming velocities and the channel velocities will be relatively slow, a fairly complete intermingling of the flows will take place, thereby producing a comparatively smooth flow in the side channel. Where the channel flow is supercritical the channel velocities will be high and the intermixing of the high-energy transverse flow with the channel stream will be rough and turbulent. The transverse flows will tend to sweep the channel flow to the far side of the channel, producing violent wave action with attendant vibrations. Therefore, for good hydraulic performance the side channel trough should have mild slope or a steep slope with a control section at the downstream end of side channel trough so that the flow is subcritical in the trough. The slope depends on site conditions and should be so chosen as to reduce the excavation to a minimum.

6.4.6 *Control Section*

The control section is a section downstream of side channel trough where the depth of flow changes from subcritical to supercritical. Control section may be provided by constricting the channel sides or elevating the channel bottom. The best location of a control section is usually at point where bed slope has to be steepened to keep the channel on the ground. Special conditions may require another location. For example, the section may be placed immediately downstream of the discharge trough.

6.4.7 *Water Surface Profile*

The water surface profile on the side channel trough may be determined using the following equation which is based on the law of conservation of linear momentum, assuming that the only forces producing motion in the channel result from the fall in the water surface in the direction of the axis and that the entire energy of flow over the crest is dissipated through its intermingling with the channel flow and is therefore of no assistance in moving the water along the channel Axial velocity is produced only after the incoming water particles join the channel stream

$$\Delta y = \frac{Q_1}{g}\left[\frac{(V_1+V_2)}{(Q_1+Q_2)}\right]\left[(V_2-V_1)+\frac{V_2}{Q_1}(Q_2-Q_1)\right]$$

where

- Δy = drop in water surface in a small reach between Section 1 and Section 2 in m,
- Q_1 = discharge at Section 1, in m^3/s,
- g = acceleration due to gravity in m/s^2,
- V_1 = velocity at Section 1, in m/s,
- V_2 = velocity at Section 2, in m/s, and
- Q_2 = discharge at Section 2 in m^3/s

Q_1 and Q_2 may be calculated for a particular reach knowing the discharge per unit length of the crest

6.4.8 *Design Procedure*

The following steps are recommended for the design of a side channel trough

a) Design the side channel crest controlled or uncontrolled, as required The length of the crest should be determined by the total discharge to be passed and the surcharge allowed,

b) Choose a suitable cross section, bottom profile and location and the datum of the control section,

c) Calculate the critical depth of flow at the control,

d) If the control section is not at the downstream end of trough, calculate the hydraulic properties of the downstream end of the trough using Bernoulli's theorem and by trial and error method,

e) Determine the water surface profile in the trough using the equation given in **6.4.7**,

f) Fit the channel profile to the crest datum by relating the water surface profile to the reservoir level such that the submergence of the overflow is consistent with the condition assumed for evaluating the discharge over the crest, and

g) Various designs should be made by assuming different bottom widths, different channel slopes and varying control sections The most economical design thus achieved by comparing several alternatives should be adopted.

6.5 Discharge Channel

6.5.1 Flow released through the control structure is conveyed to the terminal structure or stream bed below dam in an open channel excavated along the ground surface. The profile of the channel may be variably flat or steep, the cross-section may be variably rectangular or trapezoidal It may be wide or narrow, long or short

6.5.2 Discharge channel dimensions are governed primarily by hydraulic requirements, but the selection of the profile, cross sectional shape, etc, is influenced by the geological and topographical characteristics of the site In plan the channel may be straight or curved, with sides parallel, convergent, divergent or combination of these Where the discharge channel is curved, suitable super elevation may be adopted Discharge channel should always be cut through or lined with material which is resistance to the scouring action of the accelerating velocities, and which is structurally adequate to withstand the forces from backfill, uplift, water loads, etc

6.5.3 *Profile*

6.5.3.1 The profile of discharge channel should usually be selected to conform to topographic and geological site conditions and should be provided with uniform slope in reaches joined by vertical curves Sharp convex or concave curves should be avoided to prevent unsatisfactory flow in the channel

6.5.3.2 Convex curve should be sufficiently flat to maintain positive pressures and should, therefore, be flatter than the free flow trajectory at the specific energy at which the flow enters the curve The curvature should approximate the curve given by the equation

$$-y = x \tan\theta + \frac{x^2}{4k(d+h)\cos^2\theta}$$

where

- x, y = co-ordinate axes,
- θ = slope angle of the floor upstream of the curve,
- k = factor of safety to ensure positive pressure on the floor and should be equal to or greater than 1 5,
- d = depth of flow at the beginning of transition, and
- h = velocity head at the beginning of transition

6.5.3.3 Concave curve should have a sufficiently long radius of curvature to minimize the dynamic force on the floor due to centrifugal force and should not be less than $2 \times \frac{WdV^2}{pg}$, where W is unit weight of water, g is acceleration due to gravity, d is depth of flow, V is velocity and p is permissible intensity of dynamic pressure. In no case the radius should be less than 10 d except at the toe of the crest where it may be 5 d.

6.5.4 *Slope*

6.5.4.1 Discharge generally passes through the critical stage in the spillway control structure or at the control section downstream of side channel trough, and enters the discharge channel as supercritical or shooting flow. To avoid a hydraulic jump below the control, the flow should necessarily remain at the supercritical stage throughout the length of the channel. The flow in the channel may be uniform, accelerated or decelerated depending on the slopes and dimensions of the channel. Where different slopes are encountered during the length of the channel, it is desirable that the steeper slopes are adopted at the tail of the channel so that likely scour due to high velocities is as far away as possible from the control structure.

6.5.4.2 The head losses which occur in the channel are friction, turbulence, impact and transition losses, since in most channels changes are made gradually, ordinarily all losses except those due to friction should be neglected. The velocities along the channel should, therefore, be worked out by applying Bernoulli's theorem in sections:

$$\triangle Z + d_1 + h_1 = d_2 + h_2 + h_f$$

where

$\triangle Z$ = drop of head from Sections 1 to 2 in m;

d_1, d_2 = depth of flow at Sections 1 and 2 in m;

h_1, h_2 = velocity head at Sections 1 and 2 in m/s; and

h_f = total loss of head in the reach $\triangle L$ in m;

= $sL\triangle$, where s is average friction slope

= $\frac{1}{2}(s_1 + s_2)\triangle L$

where

s_1, s_2 = friction slopes at sections 1 and 2.

Friction slope s may be expressed by Mannings formula:

$$V = \frac{1}{n} r^{2/3} s^{1/2}$$

or

$$s = \left(\frac{Vn}{r^2/_3} \right)^2$$

where

V = velocity of flow in m/s;

n = coefficient of roughness; and

r = hydraulic mean depth in m.

6.5.4.3 The coefficient of roughness, n, will depend on the nature of the channel surface. The friction loss should be maximized for working out the depth of flow for free board, and minimized for working out net energy at the stilling basin for the design of the basin. For concrete lining the value of n may be taken as 0 018 for free board to account for air entrainment and swelling, and 0 008 for the design of stilling basin.

6.5.5 *Convergence and Divergence*

From economic considerations the channel section may be narrower or wider than either the crest or the terminal structure thus requiring converging or diverging transitions to fit the various components together. Side wall convergence in discharge channel should be made gradual to 'avoid cross, waves ride ups' on the walls and uneven distribution of flow across the channel. Similarly the rate of divergence of the side walls should be gradual to ensure the flow to spread uniformly over the entire width of the channel and to avoid undesirable flow conditions at the terminal structure and separation of flow at the side walls.

The side transition for convergence or divergence should be provided at an angle given by the following equation.

$$\tan \alpha = \frac{1}{3F}$$

where

α = angle of convergence or divergence; and

F = Froude number given by $\frac{V}{\sqrt{gd}}$

where

V = average of the velocities at the beginning and end of transition;

g = acceleration due to gravity; and

d = average of the depths of flow at the beginning and end of transition;

6.5.6 *Curves*

The centre line of the spillway should be kept straight as far as possible. However, on places where it has to be curved owing to unavoidable circumstances particular attention should be paid to the degree of superelevation to be provided at the outside of the bend. The superelevation should be determined by hydraulic model studies. Sloped sides of spillway channel should be avoided on the outside of sharp bends because they cause a higher superelevation of water surface than that by vertical walls.

6.5.7 *Free Board*

6.5.7.1 The free board provided for discharge channel where flow is supercritical should be not less than that given by the following formula:

$$\text{Free board (in m)} = 0.61 + 0.037\,8 v d^{1/3}$$

where

v = maximum velocity of flow in m/s, and

d = depth of flow in m.

6.5.7.2 Where side walls of stilling basin are not desired to be overtopped by waves, surges, splash or spray, the free board for the side walls in the basin, in the absence of any model tests, should be given by the following formula:

$$\text{Free board (in m)} = 0.1\,(v_1 + d_2)$$

where

v_1 = incoming velocity to the basin in m/s, and

d_2 = conjugate tailwater depth in m.

6.6 Terminal Structure or Energy Dissipator

6.6.1 In order to avoid excessive scour on the downstream of discharge channel, the excessive energy of water should be dissipated before the discharge is returned to the downstream river channel.

6.7 Outlet Channel

6.7.1 Outlet channel conveys spillway flow from the terminal structure to the river channel below the dam. It should be of sufficient size to pass the anticipated flow without forming a control which will affect the tailwater levels for energy dissipators.

6.7.2 The dimension of channel and requirement of protective measures by lining or rip rap should depend upon the nature of channel bed and the velocity achieved after the energy dissipator. The scouring of channel affects the tailwater levels.

6.7.3 The tailwater level in the outlet channel may be affected by the scour of channel bed as above, and by retrogression in the river bed due to relatively clear water from the reservoir. In case the outlet channel is only a pilot channel in errodible material, the erroded material may form islands or bars in the channel downstream and raise the tailwater levels. These likely changes in the tailwater level should be taken care of in design of energy dissipators.

6.7.4 Where two or more types of energy dissipators have been used for the service or auxiliary spillway, adequate care should be taken to assess through model studies and taking into consideration the effect of the eroded material and its deposition further downstream in the overall planning and functioning of energy dissipators and other appurtenant structures such as tail race channels of the power houses so that the eroded material or its deposition does not interfere with energy dissipators or the appurtenant structures.

7 HYDRAULIC MODEL TESTS

7.1 Where necessary the design should be checked by conducting tests on geometrically similar or distorted models.

7.2 With proper care in hydraulic studies where the shape of the crest and other features are such that precedent is available, hydraulic model tests may not be necessary. However, for unusual conditions and wherever there is a bend in channel, appropriate model tests should be made.

8 STRUCTURAL REQUIREMENTS

8.1 Side Walls

Where retaining walls for sides of entrance channel, discharge channel and stilling basin are used, they should be designed to withstand all possible combinations of various loadings, for example, backfill, earth or rock pressure, water pressure, live load surcharge, uplift pressures and forces due to horizontal or vertical seismic acceleration.

8.2 Floor Lining

Where velocity of flow and type of bed rock warrant protection of bed rock against erosion, the bed rock should be lined with some protective material which generally takes the form of concrete lining. The lining may be required in entrance channel, discharge trough or channel and stilling basin.

8.2.1 *Thickness of Lining*

During spillway flows the floor lining is subjected to hydrostatic forces due to the weight of the water in the channel, to boundary drag forces due to frictional resistance along the surface to dynamic forces due to flow impingement, to uplift forces due to reduction of pressure along the boundary surface, or to uplift pressure caused by leakage through joints or cracks When there is no spill, the lining is subject to the action of expansion and contraction due to temperature variations, alternate freezing and thawing, weathering and chemical deterioration, to the effects of settlement and buckling, or to uplift pressures due to under seepage or high ground water condition Since it is not possible to evaluate the various forces which might occur and also not to make the lining heavy enough to resist them the thickness of the lining is established on a more or less empirical basis, and under drains anchors, cut offs, etc, are provided to stabilize the lining

8.2.1.1 The thickness of lining of approach channel will depend upon the velocities, depth of flow and poor rock/soil conditions The thickness of the order of 15 cm to 30 cm have been found satisfactory for normal circumstances

8.2.1.2 In the discharge channel, where the velocity of water is usually very high, the design of the floor slab should depend on the foundation (for example unyielding rock, relatively yielding rock or earth), velocity and intensity of flow, uplift head and other similar factors including the location of spillway with respect to dam Probable hydrostatic uplift forces under adverse condition may be considered partially relieved by the drainage system The forces should be estimated conservatively for particular foundation and drainage system To provide a relatively water tight functional lining which may withstand reasonable weathering and abrasion and will hold up against normal experienced forces, a minimum thickness of 20 cm is recommended for small spillways, where the lining is placed directly on rock When the lining is placed on foundations other than rock and subjected to forces other than normal experienced forces, a detailed design should be carried out and slab thickness arrived at accordingly

8.2.1.3 *Stilling basin floor lining*

Stilling basin floor lining should be as given in IS 11527 1985 (*under revision*)

8.2.1.4 The reinforcement in slabs should be provided as follows

a) For slabs on rock, a minimum shrinkage/temperature reinforcement equal to 0 15 percent of the cross sectional area may be provided on the top face both ways for thickness up to 450 mm For thickness greater than 450 mm, only 450 mm may be considered In case of high strength deformed steel bars, this percentage may be reduced to 0 12 percent

b) For slabs on yielding foundations like earth/poor rock, depending upon the actual site conditions, the reinforcement should be designed suitably

8.2.2 *Waterstops and Joints*

The lining should be laid in panels approximately 10 m × 10 m so as to make the entrance channel lining a reasonably water tight upstream apron to reduce uplift on the control structures Where required, the joints in the lining should be provided with waterstops in all the joints The requirement of waterstops in the lining of discharge channel will depend upon the degree of water tightness required against the exterior water heads Where a layer of gravel has been provided under the lining the provision of waterstops may not be necessary, otherwise waterstops should be provided in the longitudinal joints, and in transverse joints at the concave curves Because of high velocity flow passing across the joint with an offset (*see* **8.2.2.2**) the possibility of water seeping water the transverse joints is very little The down stops should not be provided in transverse joints unless complete water tightness against exterior water heads is required because these transverse joints should otherwise serve as a relief against built up of high uplift pressure under the lining in case of any possible chocking of under drains Where the foundations are permeable, waterstops should be provided in the joints of stilling basin floor lining so as to avoid circulating flow under the lining due to differential head on the joints in the zone of hydraulic jump

8.2.2.1 The waterstops should also be provided in the joints of side walls where seepage of flow behind the walls is undesirable

8.2.2.2 The transverse joints should be provided with 13 mm offset, as shown in Fig 2 so as to avoid high velocity flow striking against the edge of the lower floor cause water to seep through the joint under a very high pressure and dislodge or uplift the lining To further ensure against this, the lifting of upstream edge of lower slab due to differential settlements or heaving should be checked by providing cut-off (*see* **8.2.3**), especially when the lining is founded on a layer of gravel or earth

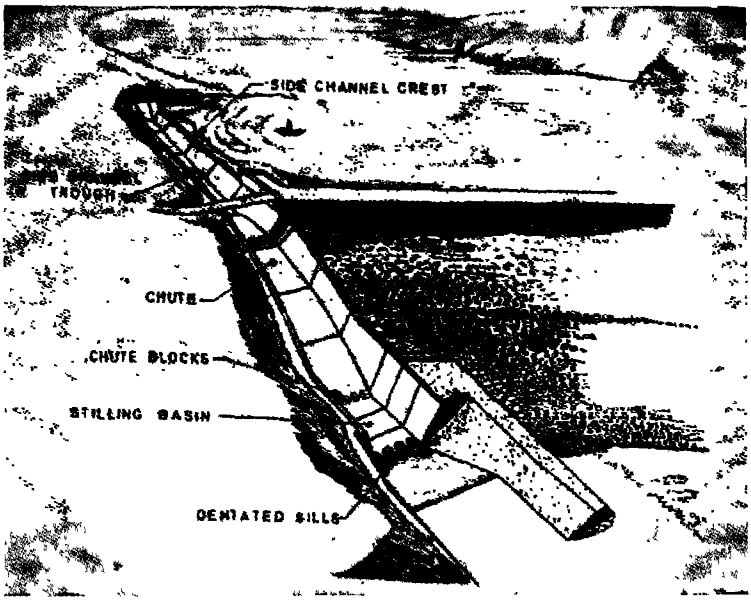
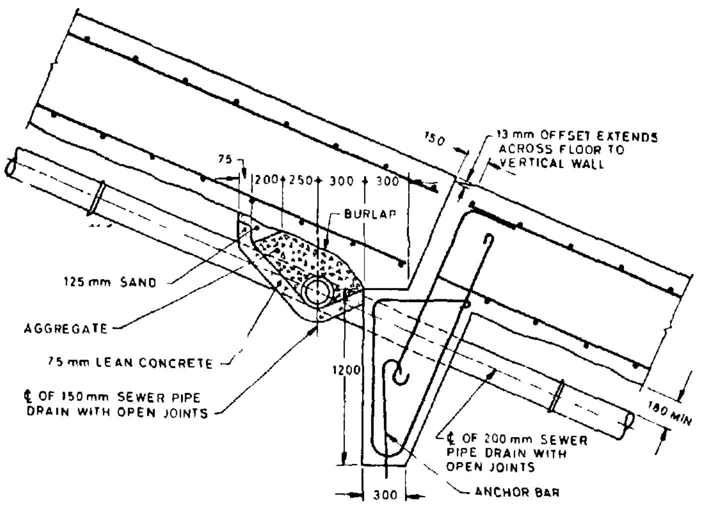


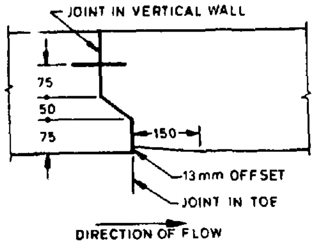
FIG. 1 TYPICAL SIDE CHANNEL AND CHUTE SPILLWAY ARRANGEMENT



All dimensions in millimetres

FIG. 2 TYPICAL DETAILS OF TRANSVERSE JOINTS

8.2.2.3 The offset in the downstream slab at the transverse joint, as shown in Fig. 2, should also be provided in the joints of side walls (Fig. 3).



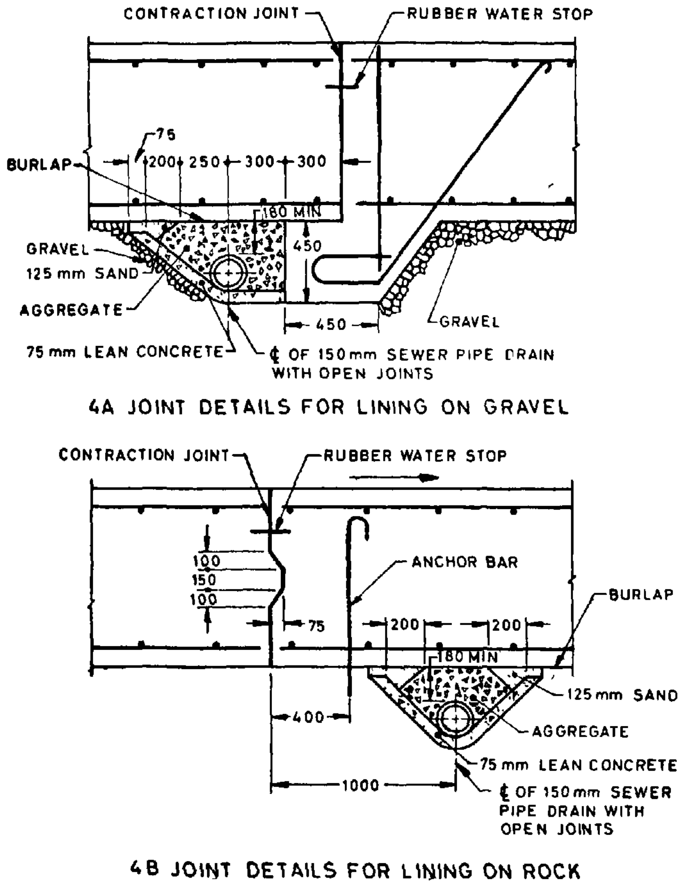
All dimensions in millimetres.

FIG. 3 DETAILS OF JOINTS IN SIDE WALLS

8.2.3 *Cut-offs*

Where the lining is placed on earth on a steep gradient or the lining is placed on a layer of gravel and not anchored to the foundation, a cut-off should be provided on the upstream end of each panel to check the creeping (Fig. 2). This cut-off should also check the lower slab lifting above the lower edge of the upper slab. These cut-offs should also form barriers against seepage of water in the gravel layer or among the contact of lining and foundations, and divert the seepage water to the transverse drains.

8.2.3.1 Similar small cut-offs should be provided in the longitudinal joints as well, where lining is founded on a layer of gravel as shown in Fig. 4A. Typical joint details for lining on rock are shown in Fig. 4B.



All dimensions in millimetres.

FIG. 4 DETAILS OF LONGITUDINAL JOINTS

8.2.3.2 Cut-offs should also be provided at the upstream end of the spillway to reduce seepage of flow along the lining, increase path of percolation, intercept permeable strata and reduce uplift under the spillway and adjacent structures. Cut-offs should also be provided at the downstream end of spillway to check erosion and undermining of the structures. The depth and thickness of such cut-offs would depend upon the nature of the foundations.

8.2.4 *Drainage System*

As mentioned in **8.2**, the stability of floor lining is increased by providing underdrains. These drains reduce the uplift on the lining. The drainage for floor lining, energy dissipators and training walls of spillways and the drainage for backfill should be according to the provisions given in IS 11772 : 1986.

8.2.4.1 Where the foundation is sufficiently impervious to prevent leakage from draining away or where it is subject to draw moisture to the underside of the lining by capillary action, a continuous gravel blanket should be provided under the lining, especially where the area is subject to frost action. This blanket should serve to insulate the foundations against frost penetration. The thickness of gravel layer would depend upon the climate of the area and susceptibility of the foundation to frost heaving.

8.2.4.2 The gravel blanket should be well graded to safeguard against movement of foundation material with the seepage flow.

8.2.4.3 The drains under the lining should consist of a network of pipe drains which should follow the joints in the lining. The drains should either be perforated or non-perforated clay or cement sewer pipes laid with open joints in gravel and bedded on a mortar or porous concrete pad to prevent the foundation material from being leached into the pipe.

8.2.4.4 Where the stratifications in foundation rock are almost parallel to channel bed, vertical drainage holes piercing through the layers of stratifications, backfilled with gravel should be provided to relieve uplift on the layers of foundation due to seepage or ground water. These holes should be connected to the pipe drains.

8.2.4.5 The drains under the discharge channel should have their outlets either in the discharge channel itself through the side walls, or into drainage gallery in case of wide and long spillway. The outlets should be connected to the pipe drains.

8.2.4.6 The drains under the lining below maximum tailwater level and stilling basin should have their outlets into the chute blocks of the basin. The drainage system of stilling basin floor should, however, be kept separate from that of the other floor lining.

8.2.4.7 Sewer pipe drains with open joints should also be provided at the toe of the heel of the side walls to collect seepage water from the backfill and relieve the side walls from water pressure. These pipes should have their outlets in the discharge channel through the side walls or independent outlets elsewhere.

8.2.5 *Anchors*

The floor of the chute should be anchored to the foundation by anchor bars to increase the effective weight of the slab against displacement due to uplift and other forces.

8.2.5.1 For chute spillways on rock foundation, it may be generally sufficient to provide nominal anchors, say 25 mm mild steel rounds 3 m long at the rate of 1.5 m centre to centre (staggered) in the rock with suitable drainage arrangement, in the absence of any analysis. Anchors below and around the energy dissipation arrangement should be designed according to IS 11527 : 1985.

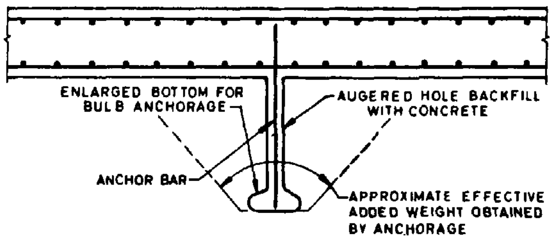
8.2.5.2 The diameter of hole into which the anchor bars should be placed and grouted should not be less than one and a half times the maximum transverse dimension of the bar.

8.2.5.3 Actual pull out tests should be carried out at the site to determine the depth and spacing of anchors, diameter of holes and type of anchors to be provided.

8.2.5.4 In soft rocks where bond bewteen rock and grout is very poor, or in earth, bulb anchors as shown in Fig. 5 should be used.

8.2.6 *Surface Finish*

Because of very high velocity of flow in chute or side channel spillways, the concrete surface finish against which water should flow, is of paramount importance. The abrupt or gradual irregularities for such formed or unformed surfaces should be reduced to the minimum and should conform to the details given in IS 11155 : 1984.



All dimensions in millimetres.

FIG. 5 DETAILS OF BULB ANCHORS

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