

25.1 CANAL LINING**25.2 TERMINOLOGY**

Black Cotton Soil - They are a type of expansive soil and form a major soil group in India. The colour of black cotton soil vary from black yellowish to grey. They are characterised by high shrinkage and swelling properties.

Beaching - A protective covering of properly packed or build in materials on the earthen surface slopes of irrigation canals, drainage channels, river banks etc. to protect them from the action of water.

Cohesive Non-swelling soil (CNS) - They are soils possessing the property of cohesion of varying degree and having non-expanding type clay minerals such as illite and kaolinite and their combination with low plasticity with liquid limit not exceeding 50.

Compaction - The densification of a soil by means of Mechanical manipulation.

Consolidation - The gradual reduction in volume of a soil resulting from an increase in compressive stress.

Construction Joint - A joint occurring in a structure composed of homogeneous material such as earth or concrete along a plane or surface formed by cessation of placing of material for a time, such as overnight or for several days.

Expansion Joint - A joint provided in exposed members between fixed point to permit vertical movements where different settlement is anticipated.

Expansive Soil - They are inorganic or organic clays of high plasticity with high compressibility and liquid limit more than 50 and are characterised by shrinkage and swelling properties.

Face - The surface of the slab, which will come in direct contact with either the subgrade or water in the canal.

Lip Cutting - Cutting of extra width provided at the inner face of the bank under compaction to allow for any lapses in compaction due to the inability of compacting rollers to cover the edge of the bank.

Made up ground - Excavated soil or rock deposited for the purpose of filling a depression or raising a site above the natural level of the ground.

Pressure, Relief Valve - A valve provided in a canal lining which opens in to the canal to relieve excess hydrostatic pressure behind the lining. The pressure relief valves shall be such that it will operate by a differential pressure less than that which will be damaging to the lining with safety factor of 2. This should be operative generally with a differential head of 100 mm and above. Pressure relief valves are generally of such material, which will be abrasive resistant and will not be effected due to its presence in the water.

Pipes/drain - Pipes are provided with filter all round so that sub soil water can flow in the pipe; without changing the soil strata beneath the lining. Pipes are kept open so as to facilitate the entry of water.

Sides - All the surfaces other than the faces of the slab.

Slip-Form - A steel plate provided at the leading edge of the slip-form machine extending across the bottom and up the slopes of the canals to form the finished surface of the lining.

Subgrade - The specially prepared surface on which lining shall be laid.

Toe Wall - A shallow wall constructed below the bed or floor level to provide footing for the sloped pitching or the face of an embankment.

25.3 PREPARATION OF SUBGRADE

25.3.1 Expansive Soils

The detailed position in this regard is given in IS 9451: 1985.

25.3.1.1 General

25.3.1.1.1 Expansive soils in side slopes and bed of canal in cutting or embankment when in contact with water swell, exerting a swelling pressure, which may range from 50 to 300 KN/m² or more. This characteristic of swelling and the swelling pressures of black cotton soil is attributed to the pressure of montmorillonite or combination of montmorillonite and illite clay minerals. A wide range of properties of expansive soils are found in India (see IS 1498: 1992 for identification and properties).

The swelling pressure and free swell index tests should be done in accordance with IS 2720 (Part 40): 1992 and IS 2720 (Part 41): 1992. Expansive soil met within the locality has to be analysed for swelling pressure before deciding the type of treatment. For testing the expansive soil for determination of swelling pressure the expansive soil specimen should be remolded at zero moisture content to the density obtainable at any time in the year in the field at a depth beyond 1.0 m (in expansive soil). The swelling pressure should be determined under no volume change condition when moisture content is increased from zero to fill saturation level.

25.3.1.2 *Identification of expansive soil:*

25.3.1.2.1 Following indications are generally observed in the case of expansive soil:

- (a). During summer wide deep and map type cracking is normally observed in expansive soils.
- (b). Walking over such soil is rendered difficult during heavy rains.
- (c). Thorny bushes, thorny trees (Babul) and cactus constitute the normal vegetation in such soil in India.
- (d). Buildings constructed using conventional methods exhibit heaving of floors, cracking of walls and jamming of doors during rainy season. Retaining structures get tilted and roads get rutted bed heaving and side slips and sloughing are noticed in canal.

25.3.1.2.2 The expansive soils can be identified by following visual properties.

Colour	-	Black, Grey, Yellow and Yellowish Grey
Land slope	-	Normally 0 to 2
Drainage	-	Generally poor

25.3.1.2.3 Physical properties of expansive soils

The grain size and index properties of such deposit expressed in percentage are in the following range.

Gradation:

GRAIN SIZE	PERCENTAGE
Clay (less than 2 micron)	50 to 70
Silt (0.06 mm to 0.002 mm).	20 to 35
Sand (2 mm to 0.06 mm)	30 to 50
Gravel (greater than 2 mm)	Less than 10%
Index properties:	
Liquid limit	60 to 100
Plastic limit	30 to 50
Plasticity index	30 to 40
Shrinkage limit:	8 to 12

25.3.1.3 Cohesive Non-swelling Soils (CNS) for Treatment

- 25.3.1.3.1** (a) They are soils possessing the property of cohesion of varying degree and non-expanding type clay minerals such as illite and kaolinite and their combination with low plasticity with liquid limit not exceeding 50 percent. Some of the soils which may be considered as cohesive non-swelling soils are all adequately compacted clayey soils, silty clays, sandy clays, gravelly sandy clays, etc., exhibiting cohesive- properties and containing predominantly non-expanding type clay minerals.
- (b). CNS material should be non-swelling with a maximum swelling pressure of 10 KN/m^2 when tested in accordance with IS 2720 (Part 41): 1992 at optimum moisture content and minimum cohesion (unconfined compression strength on saturated compacted soil, remoulded at OMC and compacted to standard proctor density) should be 10 KN/m^2 when tested according to IS 2720 (Part 10): 1991.
- (c). If given CNS material is not available, designed mix to produce blended CNS may be used. The artificial CNS should satisfy all the requirements of CNS. If stabilized material is to be used, special mix design needs to be evolved.

25.3.1.3.2 Identification of CNS Material.

The CNS material can be identified by using

- (a) Visual properties-

Colour - Red, Reddish, Yellow, Brown, White, whitish, Grey, Whitish yellow, Green and Greenish grey.

Land slope - Normal land slopes are between 2 and 10, though on flatter slopes they are many times encountered within 3m below the overlaying expansive soil

Drainage - Generally good

Fig 1 ACTIVITY CHART

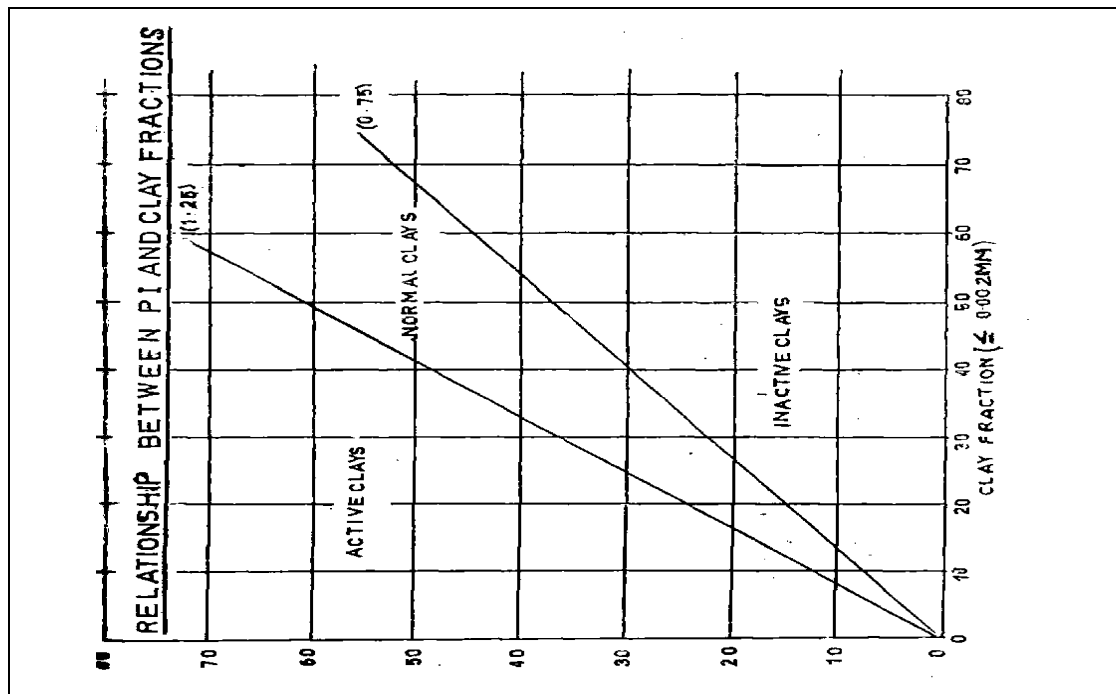
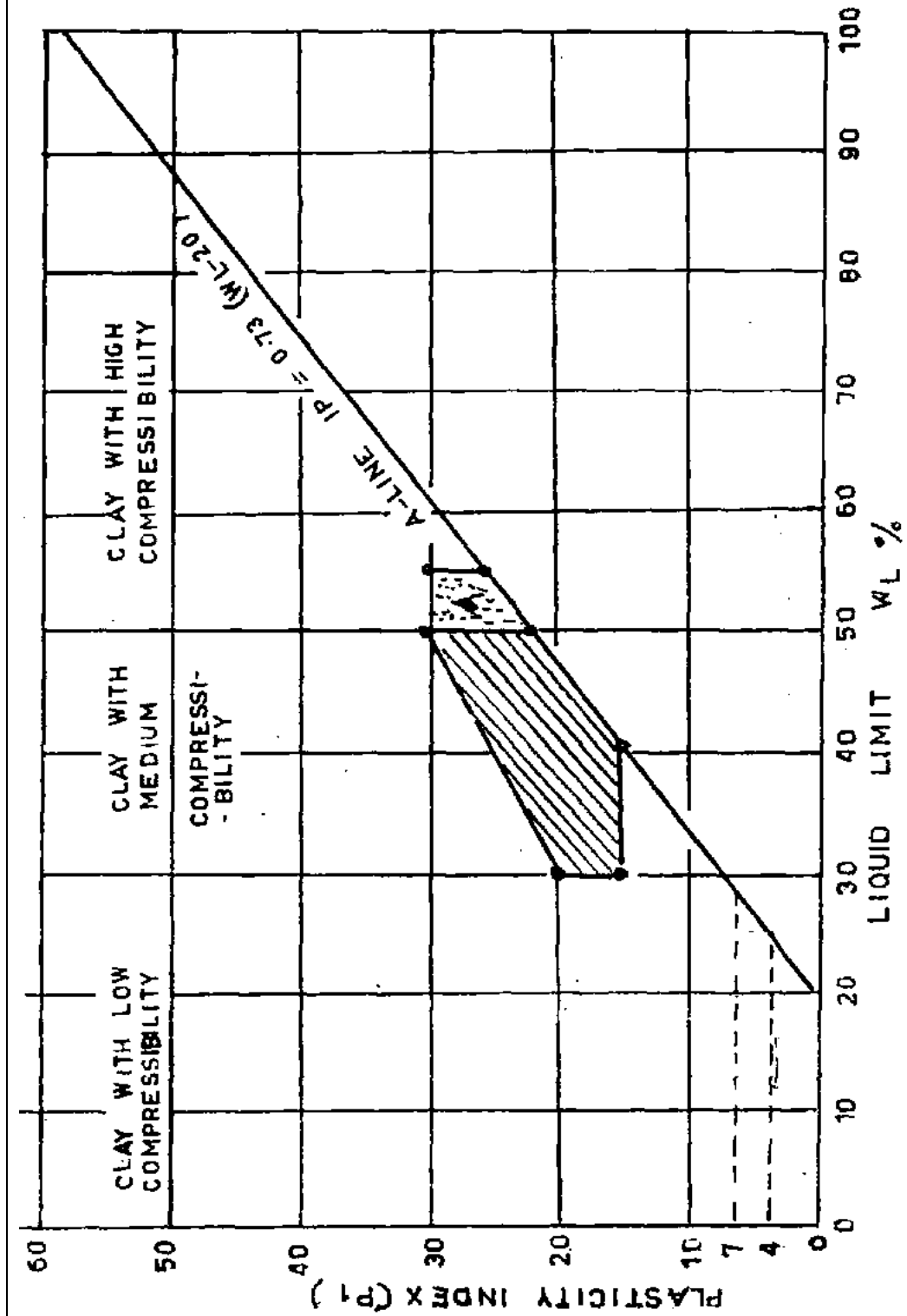


Fig 2 PLASTICITY CHART



(b) Identification using Activity Chart -

This chart (Fig.1) classifies the soil into active" Normal and Inactive soils based on plasticity Index and clay fraction present in the soil.

It is desirable to first check sample on this chart to see that the soil does not fall into active zone. The soil sample identified on this chart as suitable, i.e. not falling into active zone shall only be checked on A-line chart (Plasticity Chart) in accordance with the procedure laid down in para -C below.

(c) Use of A line chart (fig.2) is made for general identification of the CNS material. In this method the data required is only liquid limit (LL) and Plasticity Index (PI). The CNS soil has to resist internal erosion due to seepage and form suitable base for lining the soil with LL less than 30% and PI less than 15% is not considered suitable. The Zone covered between LL 30 to 50% and PI 15 to 30% is shown hatched. Soils falling in this zone can be considered suitable to be used as CNS material.

However, it is desirable to have a few representative samples tested for swelling pressure as a cross check. In case of samples failing in Zone 'A' of the chart, it would be necessary to ascertain swelling pressure and cohesion of such sample before accepting the same as CNS material.

CNS soil normally should not exhibit swelling pressure, but in exceptional cases swelling pressure less than 0.1 kg/cm² is acceptable, Minimum cohesion should be 0.1 kg/ cm² (10 KN/m²).

25.3.1.3.3 Physical Properties Of CNS Soils

Most murums of laterite, laterite type and siliceous sandy clay exhibit CNS characteristics, however some murums may be of swelling type. Unlike swelling soils, they do not exhibit cracking during summer, nor heaving and stickiness during rainy season. Structures constructed on such soil do not exhibit heave though they may sometimes settle. The CNS are generally red, reddish yellow, brown, yellow, white, whitish grey, whitish yellow, green and greenish grey in colour. Although, several soils containing non-expanding type clay mineral, exhibit CNS properties, the following range helps in locating such types :

	Percent
Clay (less than 2 microns)	15 to 20
Silt (0.06 mm-0.002 mm)	30 to 40
Sand (2 mm- 0.06 mm)	30 to 40
Gravel (Greater than 2 mm)	0 to 10
Liquid limit	Greater than 30, but less than 50
Plasticity index	Greater than 15 but less than 30

25.3.1.4 Criteria For Fixing The Thickness Of CNS Layer.

25.3.1.4.1 Thickness of CNS materials is related to swelling pressure and the resultant deformation. The permissible deformation is 2 cm.

25.3.1.4.2 Guidelines for choosing the thickness of CNS materials required for balancing the different swelling pressures is given in Table 1. Slopes should be in accordance with IS 10430: 1982.

Table 1. A THICKNESS OF CNS LAYER CARRYING CAPACITY LESS THAN 2 CUMECS

Discharge in cumecs	Thickness of CNS Swell Pressure 50-150 KN/m2	Layer in cm (Min) Swell Pressure More Than 150KN/m2
1.4-2	60	75
0.7-1.4	50	60
0.3-0.7	40	50
0.03-0.3	30	40

Table 1.B. A THICKNESS OF CNS LAYER, CARRYING CAPACITY OF 2 CUMECS AND MORE

Swelling Pressure of Soil KN/m2 cm (Min)	Thickness of CNS Materials
50 to 150	75
150 to 300	85
300 to 500	100

NOTE: However, optimum thickness of CNS material needs to be determined for different swelling pressures by actual experiments both in field and laboratory: if required.

25.3.1.5 Construction Procedure.

To counteract the swelling pressure and prevent deformation of the rigid lining materials, a CNS material of required thickness depending on the swelling pressure of expansive soil, is sandwiched between the soil and the rigid lining material. The thickness of CNS layer should be measured perpendicular to the surface of expansive soil.

25.3.1.5.1 Canal in Cutting

Long deep cuts in expansive soils should be avoided and where possible a detour should be considered.

In cutting special care will be necessary to compact the CNS materials against the excavated surface of the cuts. The material should be spread uniformly in their horizontal layers of specified thickness (15 cm thick). Care also is necessary in obtaining a good joint between the two materials, by thoroughly wetting the excavated surface, so as to avoid slips at the junction plane. The construction should be carried out in the following step's:

- a). While excavating provision should be made for accommodating required thickness of CNS layer on bed and sides. The subgrade on which CNS layer is to be laid should generally not be kept exposed for more than four days, prior to the placement of the CNS layer.
- b). Serrations should be provided in expansive soil to prevent contact slides between CNS materials and expansive soil.
- c). Proper moisture should be added to CNS materials.
- d). CNS materials should be compacted in layer by appropriate equipment to ensure proper density.
- e). CNS on side slopes should be trimmed to the required thickness. The thickness is measured perpendicular to the surface of expansive soil.
- f). Suitable canal lining over CNS material should be provided depending on the site and economic condition.
- g). To avoid slipping and rain cuts during the rainy season, it is advisable to provide CNS right up to the ground level.
- h). In deep cuts CNS material should be provided not only behind the lining of the canal but also above the canal prism, all along the excavated surface, so as to prevent large scale heaving above the canal level. The CNS material above the canal prism may be of lesser thickness say 15 to 20 cm. However, full design thickness behind the lining should be continued at least 100 cm above the top level of lining (illustratory arrangement shown in Fig.3)

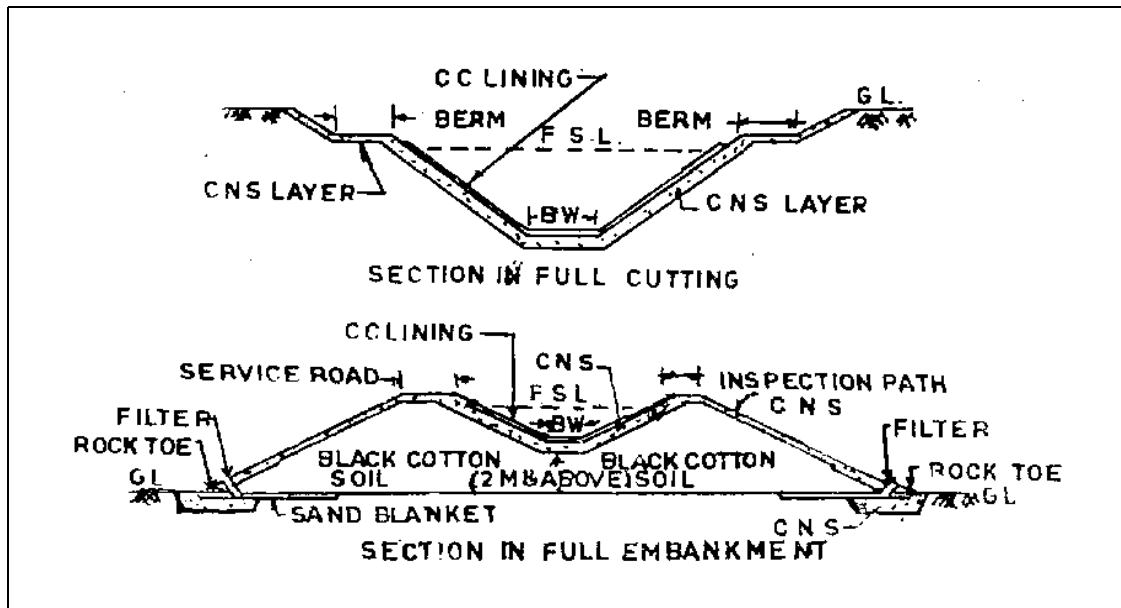


Fig. 3

i) The stability of the slopes, particularly in the case of cuts, is very adversely affected by rain water finding its way into the tension cracks and exerting hydrostatic force on the slipping mass of the soil. Covering the surface of the slopes by CNS materials and proper surface drainage will reduce the chances of rain water finding its way into the cracks.

k) It is necessary to stack the excavated soil away from the cuts to prevent it inducing slips by surcharge.

25.3.1.5.2 Canal in Embankment

The construction should be carried out, in the following steps:

- a) Proper moisture should be added to CNS material and expansive soil.
- b) Expansive soils CNS Material above ground level should be composed simultaneously in layers with appropriate equipments to ensure proper density,
- c) The CNS material in embankment should be laid and compacted in layers simultaneously with the body of the banks" so as to obtain good compaction and to avoid any slippage plane being developed between the two materials. The compaction of CNS materials should also be to the standard proctor density with optimum moisture content. It may be done either with sheep foot rollers or 8 to 10 ton ordinary rollers.
- d) Provision of surface drain and internal drainage filter should be made to minimize external/ internal erosion. A rock toe with inverted filter may be provided at either end of canal bank.
- e) Special care is required to be taken to provide internal drainage for the banks, having bed filling of 2 meters or more. A sand blanket is spread on the base of the bank and rockfills with regular inverted filters are also necessary at the outer toes.
- f) For both the cuts and banks, paved surface drains should be provided at the berms, to avoid erosion of the finished surface. As far as possible, water from these drains, should be drained away from the canal
- g) The drainage properties of the CNS material itself need to be given due consideration as water locked up in this saturated layer is likely to cause pore pressures on the lining during canal draw-down conditions.
- h) Murum (gravelly soil) material on outer slopes of canal embankment should be trimmed to the required thickness.
- i) To protect outer slopes from erosion, proper turfing should be used.

25.3.1.5.3 Similar procedure should be followed for canal in partial cutting and embankment.

25.3.1.5.4 Pride

25.3.15.4.1 The problem of effectively compacting the subgrade for side lining on slopes is .very important in case of black cotton expansive soil zone in cutting or embankments, where backfill of CNS material is required to Replaced for the sides and bed, in addition to design thickness. Twenty cm or so (Perpendicular to side slope) of extra pride may be provided and compacted in horizontal layers to the required density. This pride should be removed only just prior to the placement of lining, thus making a fresh and well compacted surface available for bedding.

25.3.1.5.4.2 For cutting in soft material where the CNS backfilling is not required the best method is to leave the cutting 20 cm or so undercut (Perpendicular to the canal slope) and remove this undercut only just prior to the placement of concrete lining. Similar procedure may be' adopted in case of cutting in hard strata.

25.3.1.5.4.3 Use of Polyethylene Sheets Below Concrete Lining

The use of polyethylene sheet below concrete lining could be either for achieving better ultimate imperviousness of the lining as a whole or it may be used only for limited purpose as an assistance, during construction, for avoiding the cement slurry from concrete escaping in the subgrade below. Use of LDPE sheets 200 gauge (50 microns) is to achieve only the latter limited purpose. If overall imperviousness is proposed to be achieved, it would be necessary to use HDPE-HM sheet of sufficient thickness, strength, toughness and durability.

25.3.1.5.4.4 Under Drainage Arrangements and Joints in Lining.

The drainage properties of CNS material itself need to be given due consideration as water locked up in this saturated layer is likely to cause pore pressure on the lining during canal draw down conditions. To release the 'same if holes are provided for drainage in concrete lining, care will have to be taken to provide inverted filters at the back of the holes so as to avoid the CNS material being washed away by fluctuating water levels in the canal. Such drainage holes are, however; not advocated for general adoption.

25.3.1.5.4.5 It is recommended to provide regular drainage arrangements using porous concrete sleepers, 7.7 cm x20 cm with 50 mm perforated G.I. Pipes at 3 m centre to centre coming out through the sides of the lining. Two porous concrete sleepers on either side of the bed, below, the side may be provided. A50 to 75 mm thick sand mat below the bed and side cast in-situ lining (below the polyethylene sheet) should be provided. Where the sand mat is not economically feasible additional porous concrete sleepers may instead be provided at right angles to the longitudinal rails (along the cross section of the canal) at 3 m centre to centre. The porous concrete sleepers have to be encased in filter materials:

An illustratory arrangement is shown in Fig. 4

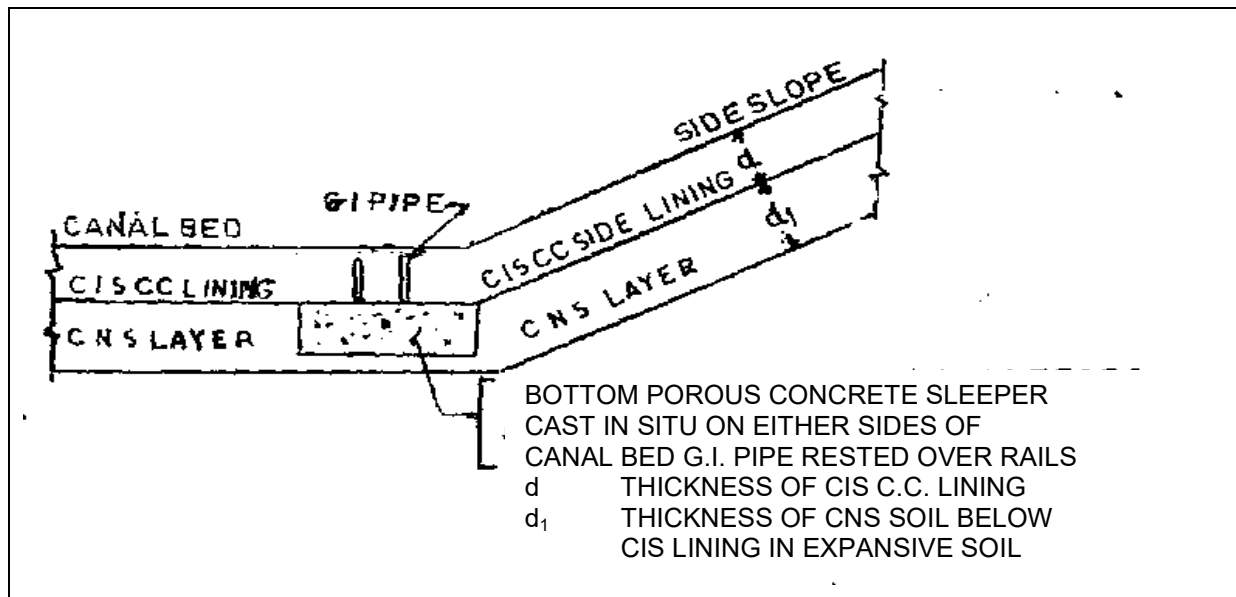


Fig.4- ILLUSTRATORY DETAIL OF BOTTOM RAILS

25.3.1.6 *Laying of CNS Soil.*

25.3.1.6.1 The CNS layers should be firmly bonded at the interface of CNS and expansive soil through provision of serration in expansive soil base and thorough compaction of interface layers.

25.3.1.6.2 Before placement of CNS material the surface of excavation of embankment to receive CNS shall be roughened & thoroughly wetted about 15 cm so as to ensure firm bond between the original surface & CNS layer.

25.3.1.6.3 C.N.S. soil should be compacted in suitable layers so as to. Obtain the density not less than 90% of M.D.D. at its optimum moisture content or slightly on the drier side of optimum but not lower than 1 percent.

25.3.2 *Preparation Of Subgrade Consisting of Soil*

The subgrade should be prepared, dressed and rolled true to level and according to the required cross-section of the canal to form a firm compacted subgrade for the lining.

25.3.2.1 In other than predominantly sandy reaches where the dry bulk density of the natural soil is not less than 1.8 g/cm³ initial excavation should be done up to about 30 cm above the final section and the cutting to final shape should be done immediately before lining.

25.3.2.2 For checking the uniformity of side slopes, sample profiles at an interval of about 20 m. in straight reaches and 10m in curved, reaches should be made. Concrete templates of suitable size should be laid on the sample profiles. To begin with the top and bottom of the side templates should be fixed with reference to the established centre line of the canal and the corresponding design levels. For verifying the slope of the templates representing the sample profiles the diagonals of the cross-section of canal, between the two opposite side templates are checked. After laying the templates to the correct profile a cord should be stretched over the two templates (representing the same profiles) and run along the slope till the surface between the two profiles is properly leveled and dressed from top to bottom.

25.3.2.3 If at any point material of prepared sub grade has been excavated, beyond the neat lines required to receive lining, the excess excavation should be filled with graded filter material compatible with subgrade material and thoroughly compacted in accordance with 25.3.2.5 and 25.3.2.6.

25.3.2.3.1 When partial filling of an existing canal is necessary to adequately reduce the cross-sectional area to that required for lined canal, the fill should be placed and suitably compacted to avoid its settlement and rupture of the lining

25.3.2.4 To cover up any lapses in the compaction of the inner core of the banks near the edges and to allow sufficient width for a labourer to work conveniently a lip cutting width of not less than 50 cm horizontally should be provided.

25.3.2.5.1 Compaction of Subgrade Predominantly Sandy Reaches

25.3.2.5.1 Bed

The compaction of the bed should be done by over saturating the bed by flooding it with water before lining is laid.

25.3.2.5.2 Sides

The compaction of sides should be done by over cutting the subgrade by 15 cm and refilling it with lean mortar with adequate quantities of lime or cement or by vibro-compactors.

25.3.2.6 Compaction of Subgrade in Other than Predominantly Sandy Reaches. All compaction should be done at optimum moisture content in layers not more than 15 cm thick to obtain a dry bulk density of not less than 95 percent of the density at optimum moisture content obtained in accordance with IS 2720 (Part 7) 1992.

25.3.2.6.1 Where the dry bulk density of the natural soil is equal to or more than 1.8 g/cm³ the procedure described in 25.3.2.1 should be followed.

25.3.2.6.2 *Bed*

Where the dry bulk density of the natural soil is less than 1.8 g/cm³ and the subsoil water is near the Subgrade, the consolidation should be done by under cutting the bed by 7.5 cm and then ploughing up to 15 cm below the sub grade level, the loosened soil should then be recompacted with sheep foot rollers or other suitable devices. Where the subsoil water is low, requiring no dewatering and the dry bulk density of the natural soil is less than 1.8 g/cm³ the consolidation should be done by digging the canal up to subgrade level and after loosening the earth below subgrade up to 15 cm by disc harrows, or ploughing and compacting the same to a depth of 11 cm. After there, the second layer of 15 cm of earth should be laid over the compacted layer by taking earth from lip cutting and compacting this to a depth of 11 cm. The compacted layer of 7 cm above the subgrade level, should be removed and the subgrade brought to design before laying the lining

25.3.2.6.3 *Sides*

Consolidation on sides should be done, by manual labour or suitable compactors to a depth of 30 cm to obtain a minimum dry bulk density of not less than 90 percent of the density at optimum moisture content

25.3.3 *Anti - Salt Treatment*

Soil in all reaches should be tested for salt content before the lining is started. Where the salt content is over 1.00 percent or sodium sulphate is over 0.36 percent, the subgrade should first be covered with about 2mm thick layer of bitumen obtained by evenly spraying bitumen at a rate of about 2.35 kg/m². To get a good bond bitumen, bitumen and soil, crude oil at a rate of 60.5 lit/m² should be sprayed over it in advance of spraying bitumen. In case such a situation is encountered only in small packets the replacement of subgrade up to suitable depth by suitable earth from adjoining reaches should be considered, if economical. Before spraying crude oil, subgrade should be perfectly dry, clean and free from dirt, and crude oil should be allowed to penetrate the subgrade surface. Bitumen should be heated to a temperature of 175°C and applied to the subgrade by a suitable sprayer, immediately following the application of bitumen, dry sand should be uniformly spread. Lining should be started 6-12 hours after spraying.

25.3.4 *Reaches Consisting Of Rock*

25.3.4.1 The subgrade in rock shall be excavated to the required cross section. Over excavation in rock is generally unavoidable and should be minimized by using wedging and barring methods, for final dressing.

25.3.4.2 Over-excavation in hard strata having side slopes flatter than 1:1 beyond the profile line may be backfilled with gravel and aggregate, large aggregate forming the bulk of backfill with smaller aggregate filling the voids and a layer of pea gravel as binding material. The bed may then be compacted with road roller and sides with hammers to form a firm backing for the lining.

For over excavation in hard strata having side slope steeper than 1:1 beyond the profile, the backfilling may be suitably done with chip masonry or lean concrete. However, for bed the backfilling may be done with properly compacted murrum. Over excavation upto 5 cm may be back filled. If over excavation is up to 10cm, lean concrete may be used. Beyond 10 cm backfilling with chip masonry is preferable.

25.3.4.3 For slip-form paving, over excavation up to 10 to 15 cm may be required. Such over excavation may be backfilled with selected material and compacted at optimum moisture. The material selected, should be machine trimable and be gravel/stone-free earth.

25.3.4.4 Tar paper shall be used for placing concrete.

25.3.4.5 Tolerance in Excavation

Excavated profile provides the final base for the lining and the tolerance should be comparable to those required for paving.

Departure from established alignment:

$\pm 20\text{mm}$ on straight section

$\pm 50\text{ mm}$ on tangents, and

$\pm 100\text{ mm}$ on curves.

Departure from established grade:

$\pm 20\text{mm}$

25.4 UNDER DRAINAGE OF LINED CANALS

25.4.1 General- Where a lined canal crosses areas subject to seasonal high ground water or where the soil is sufficiently watertight to prevent the free draining of the seepage or leakage from the canal, suitable under drainage; shall be provided to protect the lining. Where the sub-grade is free draining but the area is subject to high ground water, excessive hydrostatic pressure sufficient to damage the lining may develop at its back when the canal is empty or the water level in the canal is relatively low and the ground water level is high. A similar situation may occur in areas where the canal is lined for reasons other than to prevent seepage and soil is sufficiently watertight to prevent free drainage of the leakage from the canal, the accumulation of water in the soil surrounding the canal may result in local high ground water table, which during a period of rapid draw down of water level in canal may produce damaging hydrostatic back pressure.

25.4.2 Methods Of Under Drainage.

25.4.2.1 The under drainage of canal lining for the following types of sub-grades may be accomplished by the methods specified in 25.4.2.2

- (a). **Free draining sandy soil-** Soil comprising of gravel and clear sand or clear sand. This may have a permeability greater than 10^{-4} cm/sec but less than 10^{-3} cm/sec.
- (b). **Poor draining-** Soil comprising of very fine sand admixture of sand, silt and clay or clay. Soil with permeability less than 10^{-4} cm/sec and greater than 10^{-6} cm/sec; and
- (c). **Practically impervious -** Soil comprising of homogeneous clays below zone of weathering. Soil with a permeability less than 10^{-6} cm/sec.

25.4.2.2 Selection of Drainage Arrangement:-

The drainage arrangements provided to reduce or eliminate hydrostatic pressure behind lining usually comprise of longitudinal drains, cross-drains, pressure release valves and continuous filters. These are provided singly or in combination depending upon classification of sub-grade and position of GWT. The type of drainage arrangement to be adopted depending upon discharge of canal classification of sub-grade and position of GWT is given; Annexure-1. Where extensive lining works are involved, the adequacy of various drainage arrangements could be determined on three dimensional Electrical Analogy Model at the discretion of Chief Engineer. Various components of drainage arrangements are described in following paras.

25.4.3 Pressure Release Valve (PRV) :-

Pressure release valve (PRV) is a valve provided in a canal lining which opens into the canal to relieve excess hydrostatic pressure behind the lining. The PRV shall be such that it will operate a differential pressure less than which will be damaging to the lining with factor of safety of two. This should be operative generally with a differential head of 100 mm and above. PRV should generally be of such material which will be abrasive resistant and which will not be affected due to its presence in the water. PRVs made of plastic, fibre glass, P. V. C etc. which are strong but have no resale value should be used. This would discourage pilferage which is common with metallic valves 50 mm, 75mm, 100mm and 150 mm diameter valves are generally used for release of pressure-behind lining. Typical pressure release valve and PRV housed in pocket filter is shown in (Fig.5)

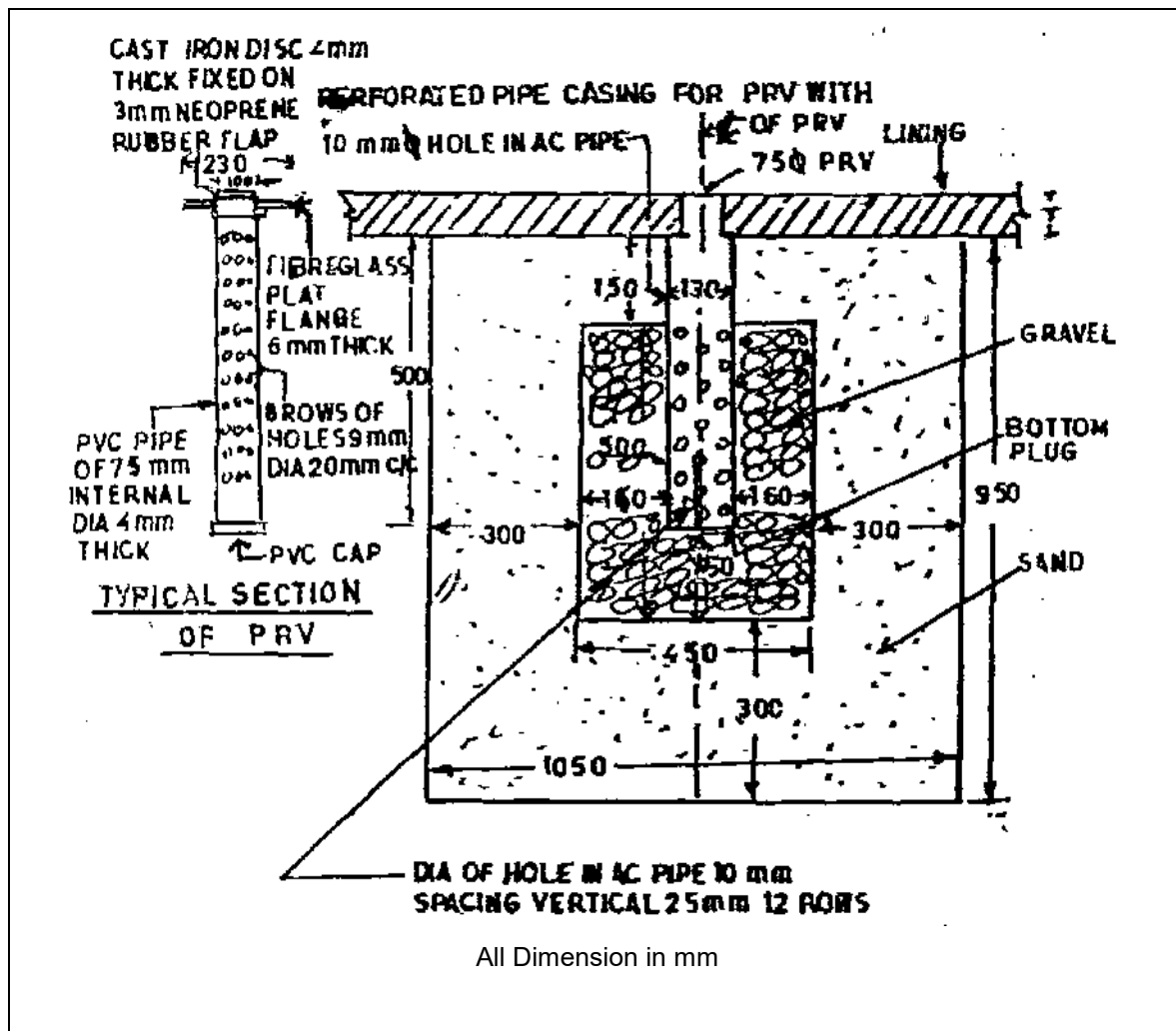


Fig. 5 TYPICAL CROSS SECTION OF POCKET FILTER WITH PRV IN BED

The size of PRVs for different conditions of water table/discharge of channel shall be provided as indicated in Table-2.

TABLE-2

Discharge upto 15 cumecs		Discharge above 15 cumecs	
Bed	Slope	Bed	Slope
-----Diameter of PRV in mm-----			
i. GWT below CBL			
50	50	100	50
ii. GWT. Above CBL			
75	50	150	50

25.4.3.1 Pocket Filter :-

The pressure release valves are provided in pockets filled with graded filter or concrete/masonry outlets with graded metal underneath the lining. The dimensions of out-let/pocket filter w.r.t to dimensions of PRV shall be as indicated in Table - 3.

Table – 3

Size of Pressure release valve		Size of outlet/pocket filter		
Diameter	Length of Strainer pipe	Length	Width	Depth
-----mm-----				
OUTLET				
150	500+ T	450	450	600
100	500+ T	450	450	600
POCKET FILTER				
75	500+ T	1050	1050	950
50	450+ T	600	600	600

Note :- “T” in col-2 of table-2 represents thickness of lining in mm.

25.4.3.2 Rows:-

Pressure release valves in pocket filter shall be provided in rows in the bed and slope of canal. The number of rows depend on bed width, depth, drainage media, size of valve and sub-grade.

However, for general guidance number of rows on the bed of canal may be such that for every 10m bed width one row shall be provided Minimum number of rows for width 10 m and above shall be two and for less than 10 m shall be one. The number of rows shall be so arranged as to be symmetrical in plan with reference to centre line of canal. On the sides in general, one row at every 4m should be provided. The first row should be about 50 cm above curve line and top row at 50 cm to 100 cm below" full supply level. If the water depth is less than 1.5 m one row should be adequate. Valves in adjacent rows should be staggered.

25.4.3.3 Spacing

For general guidance, one pressure relief valve for every 100 m² should be provided in the canal bed, while on the sides, one pressure relief for every 40 m² should be provided. However the spacing should be decided on this general consideration, keeping in view the site conditions.

25.4.3.4 Construction - Pockets shall be excavated (fig.6) with their sides as nearly vertical as possible. Pockets on slopes shall be excavated with their sides at right angles to the slopes.

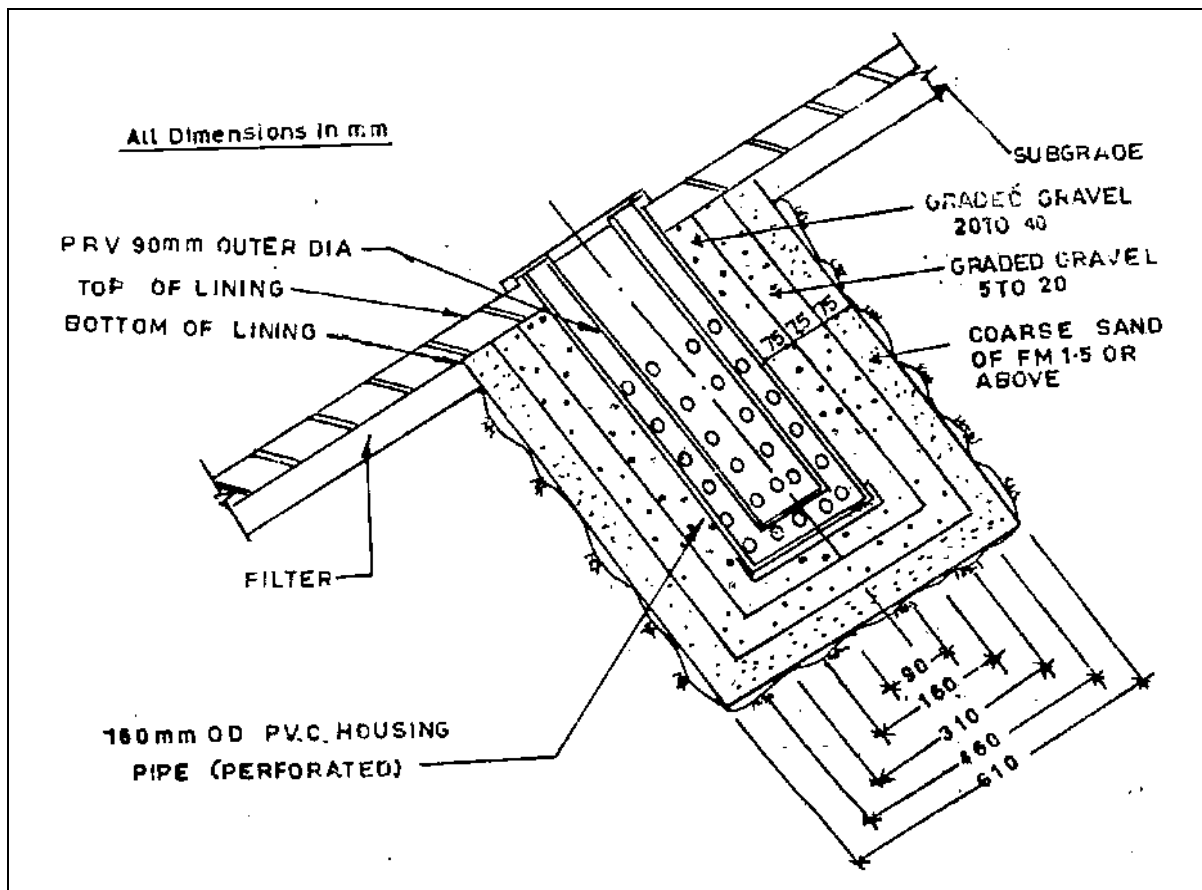


Fig. 6 PRV POCKET ON SLOPE

Any material out side the lines or required excavation which is disturbed shall be removed.

Note: - The graded filter shall be designated in such a way that there is no loss of soil particles. The gradation curve of bed material should be obtained from the sieve analysis. The 15 percent size (D15) of the layer (A) should be at least four times as large as 15 percent size of the soil and less than 4 times 85 percent size D85 of the soil. Design of the other layer should be designed in a similar way till the requirement of the filter opening is met.

[illegible]

25.4.3.4.1 Graded filter meeting the requirements as shown in the above figure shall be carefully placed and compacted to form an even bedding upto the elevation of the bottom of canal lining. The gravel shall be clean and well graded.

25.4.3.4.2 Any suitable material such as tar paper shall be placed over the entire surface of the broken rock or gravel fill to prevent water from concrete entering the fill:

Pressure relief valves should be provided on the longitudinal/transverse drains (see fig.9) and on slopes, if there are no transverse drains. The PRV may be provided in pockets filled graded filter underneath the lining. Pockets may be square with sides 800 mm or cylindrical with diameter 600 mm.

Pockets on slopes should be excavated with their sides at right angles to the slope. The PVC perforated housing pipe for the PRV should be 750 mm long for sides and 430mm long for bed and should conform to class-2 of IS 4985-1988. It should be placed in the centre of the pocket. Graded filter as shown in fig.6 should then be carefully placed in the pocket and compacted to form an even bedding for canal lining. Perforations in the housing pipe should be as shown in fig. 7.

25.4.4 Longitudinal And Transverse Drains

25.4.4.1 (a) Longitudinal drains

The section of the drain should be trapezoidal with bottom width 500 mm, depth 525mm and with suitable side slopes. The drain should be carefully filled up to the bottom of the lining with graded filter as shown in fig.8 and properly compacted so as to form an even bedding for lining. The pipe may be asbestos cement pipe or PVC pipe. It should be perforated. Usually 150mm dia pipes are used. The perforations/holes should be 12mm in diameter and should be done by drilling. On an average there should be a minimum of 100 perforations/hole per meter length of pipe and the perforations/hole in adjacent rows should be staggered. The pipe should be properly surrounded with suitable filter. Care should be taken that the filter does not get clogged during lining.

25.4.4.1.1 (b) Transverse drains

Transverse drains, Where necessary, should be provided in the bed and on the side slopes upto ; free board level. Section of transverse drains should be same as of longitudinal drains shown in fig. 8. The drain should be carefully filled up to the bottom of the lining with graded filter as shown in fig. 8 and properly compacted so as to form an even bedding for lining. The pipe may be asbestos cement pipe or PVC pipe. It should be perforated. Usually 150mm dia pipes are used. The perforations/holes should be 12mm diameter and should be done by drilling. On an average there should be a minimum of 100 perforations/hole per meter length of pipe and the perforations/holes in adjacent rows should be staggered. The pipe should be properly surrounded with suitable filter. The arrangement showing drains and PRV locations is given in fig.9.

25.4.4.1.2 Spacing of Drains

Spacing of longitudinal drains shall be as indicated in Table - 4.

Table – 4

Canal bed width	No. of drains
Less than 10 m	One central drain
10m and upto 20m	Two toe drains
Above 20 m and upto 30m	One central and two toe drains
30 m and above	One for every 10 m width arranged symmetrically with the centre line of canal.

25.4.4.1.3 The spacing of transverse drains shall be at every 10-15 meters depending on sub-grade.

25.4.4.2 Rows - Criteria for fixing the number of rows shall be same as given in 25.4.3.2

25.4.4.3 Outlets - Outlets shall be provided through suitable concrete boxes collecting water from drains with pressure relief valves on the top of the boxes shown in Fig. 10. These boxes shall be of precast cement concrete, open at the top and with a circular cross section. The inner diameter and depth of boxes shall be about 450 mm and 600 mm respectively. These boxes shall be filled with graded filter material.

25.4.4.3.1 Spacing Of Outlets - On each drain exit, a pressure relief valve shall be provided at a spacing of 100m or as specified. Outlets on adjacent drains shall be staggered.

25.4.4.4 Construction Of under Drains With Open Joints

Trenches for under drains shall be excavated to not less than the dimensions specified in para 25.4.4.1 with the sides of the trenches as nearly vertical as practicable. Any material outside the lines of required excavation for trenches which is disturbed shall be removed.

Broken rock or gravel shall be carefully placed and compacted to form an even bedding, up to the invert level of pipe or drain and so as not to disturb the pipe after being laid and to hold it securely in position. The pipe or drain shall be laid nearly in the centre of trenches with partially open uncemented joints. The entire trench outside the pipe shall be filled with broken rock or gravel graded filter up to the elevation of the bottom of the concrete canal lining. Broken rock or gravel used in back filling trenches for under-drains shall be clean and well graded with sizes from 4.5 mm to 12.5 mm.

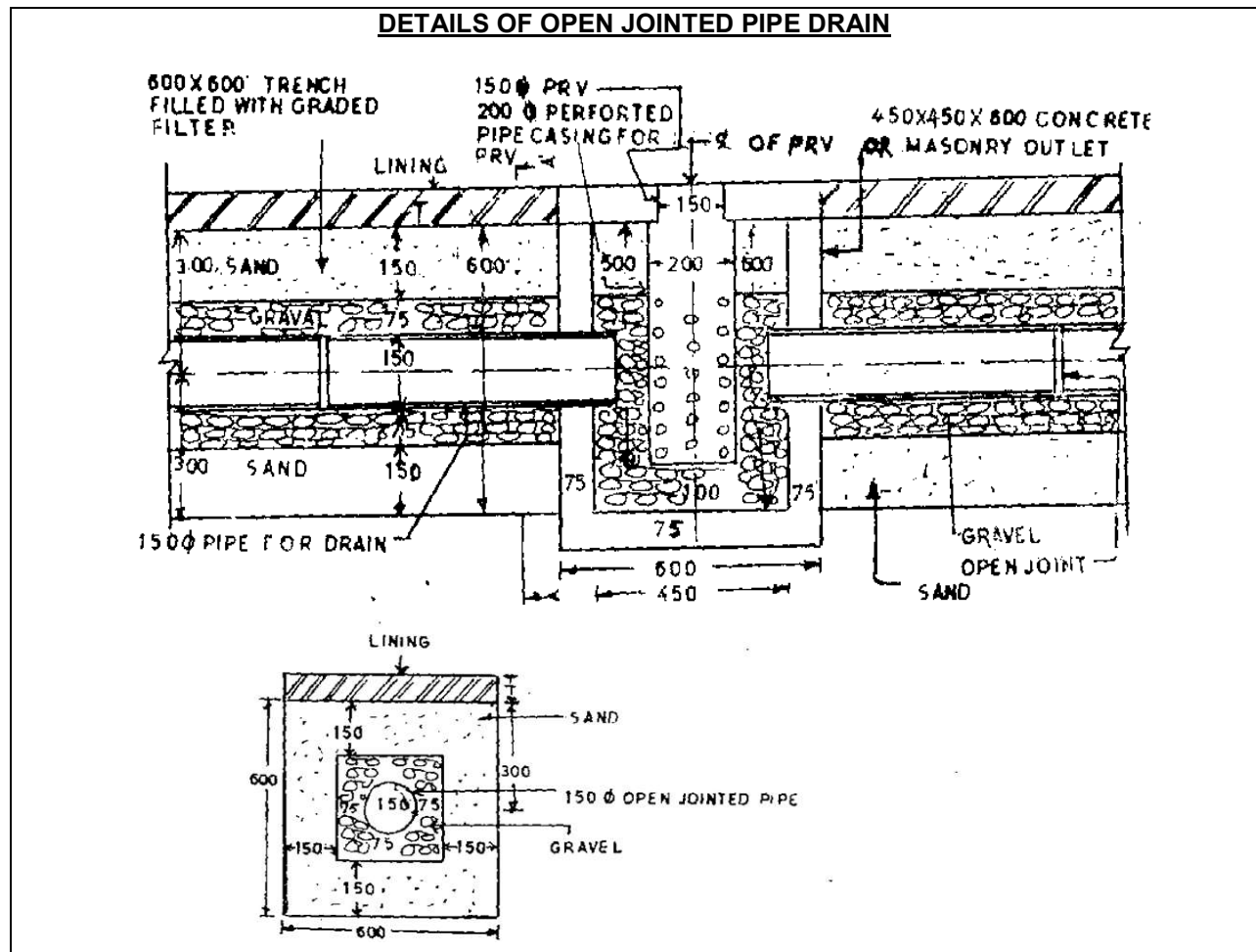


Fig. 10 DETAILS OF OPEN JOINTED PIPE DRAIN

Any suitable material, such as tar paper shall be placed over the entire surface of the broken rock; and gravel fill to prevent water from 'concrete entering the fill in case of cast in-situ concrete lining.

25.4.5 Under Drains For Clayey Sub-Grade - For clayey soil a 7.5 cm or as specified thick layer of sand or suitable filter material shall be provided underneath the lining. Rows of pipes with open joints in gravel filled trenches with outlets as specified at 25.4.4.3 shall be provided. Other details of drains, outlets and construction shall be according to paras 25.4.4.1, 25.4.4.3 and 25.4.4.4.

25.4.6 Under drainage For CNS Material :-

Where ever cohesive non Swelling (CNS) layer is provided, the permeability of CNS layer will decide drainage provisions considering CNS layer as sub-grade. Provisions of CNS layer be made in accordance with para 25.3.1.4

25.5 USE OF POLYETHYLENE FILM UNDER RIGID SURFACE LINING OF SOIL COVER

25.5.1 General:

"A plastic membrane of low density polyethylene film of suitable thickness may be used below the concrete lining in sides and in beds where the subgrade of the lining is of pervious materials like murum etc., so as to prevent absorption of water in subgrade from green concrete, during placement on the subgrade. However, the Superintending Engineer shall decide whether the polyethylene film shall be used or not in the case of every individual work"

25.5.2 Film

25.5.2.1 The low density polyethylene film should conform to IS 2505-1984 and be of nominal thickness not less than 150 microns (thickness to be designed based on type or sub grade and water depth) and should be black in colour.

The film shall be uniform in colour texture and finish. The material shall be substantially free from pin holes and undispersed raw materials, streaks and particles of foreign matter, There shall be no other visible defects, such as holes, tears or blisters. The edges shall be free from nicks and cuts visible to unaided eye.

The film shall be furnished in the form of flat, sheet or rolls or in the form of flat tubing or in any other specified form as agreed to the suppliers & the purchaser. The film shall be free from any objectionable colour.

25.5.2.2 Grades - The film shall be classified according to the optical properties, impact strength and slip, ' Each grade shall be designated by a set of 3 numerals.

The first one will indicate optical property. The second impact strength and the third slip property. Wherever numeral 'zero' is used, it shall mean the material has not been tested for that particular property.

For typical properties the numeral 1 shall mean low clarity, numeral 2 normal clarity and numeral 3 high clarity. For impact strength numeral 1 shall indicate low impact strength, numeral 2 normal impact strength and numeral 3 high impact strength. For slip property numeral 1 shall denote low slip, numeral 2 medium slip, numeral 3 high slip and numeral 4 shall mean extra high slip.

Example: -

Grade 001 - This shall mean that the film has not been tested for optical properties and impact; strength and it is of low slip.

Grade 210 - This shall mean that the film is of normal clarity, low impact strength and slip has not been tested.

Grade 314 - This shall indicate that the film of high clarity, low impact Strength and extra high slip.

25.5.3 Preparation of Sub-Grade

25.5.3.1 The sub-grade preparation shall be as per provisions under para 25.3. Additional requirement for this shall be as detailed hereunder.

25.5.3.1.1 Kankar or any sharp angular material shall be removed to provide reasonable smooth sub-grade. Any weeds roots and vegetation that may damage the film shall be removed.

25.5.3.1.2 If the reaches are weed infected suitable anti-weed treatment of the sub-grade May be done to discourage weed growth under the film The weedicides should be selected with utmost care specially where the canal water is used for drinking/bathing purpose and should not be harmful

After completion of the spraying of weedicides and before taking up the next activity a period of 24 hours should be allowed for penetration of chemicals into the soil.

25.5.3.1.3 A layer of fine sand of thickness 12mm to 25mm should be provided over the subgrade (in bed only) to facilitate working conditions over the film As there is no bond between concrete & LDPE film, the canal profile should not be smoothened (with a layer of sand etc) as the undulations will form keys& prevent sliding tendency of concrete.

25.5.4 Laying Technique

25.5.4.1 The film shall be laid over the sub-grade prepared below the designed bed level to the extent of cover thickness in strips perpendicular to water flow depending upon the width of the film, width of the bed & perimeter of the section Longitudinal joints should be avoided.

25.5.4.2 The film shall be spread loosely over the sub-grade so that it shall attain the contours of sub-grade and compensate for thermal variation during the day. It recommended that an extra length of 3.5 percent, over the length of the film required for spreading over bed and side slopes should be provided to take care of thermal variations during the day.

As polyethylene film is likely to be affected by very high temperature about 45°C obtaining in summer days it would be advisable to avoid laying of the film under such high temperature. In case it is necessary to continue the work on hot days as well working should be restricted to morning hours only.

25.5.4.3 Adjacent layers of film sheet should be laid in such a manner that the width of an overlap should be adequate and the overlap should point downstream.

The film sheets should be jointed using of the method described in 25.5.4.3.2 to 25.5.4.5.3.

25.5.4.3.1 Jointing of film sheet

There are various methods of jointing adjacent lengths of film sheet to avoid leakage along the joints. The suitability of a particular method depends on prevailing site conditions.

25.5.4.3.2 Simple over lapping

The method of over lapping is shown in Fig. 11 (i). The simple over lap should not be less than 30cms for earth cover and 15cms for hard cover. Since the simple over lap is prone to leakage it is least preferred, yet it can be adopted for small channels.

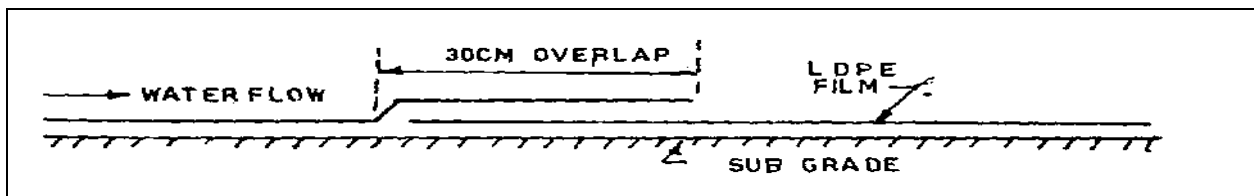


FIGURE 11 (i) Simple Overlap

25.5.4.3.3 *Folded overlapping*

The methods of folded over laps are generally used in practice. The first type is the simple folded over lap as showing in Fig. 11 (ii). In this the fold should not be less than 7.5 cms. In the second type folded over laps are embedded in a trench having a minimum width of 30 cms and depth of 15 cms as shown in Fig. 11 (iii). After the over lapping the trench should be filled with excavated material or cement concrete and coping provided over it.

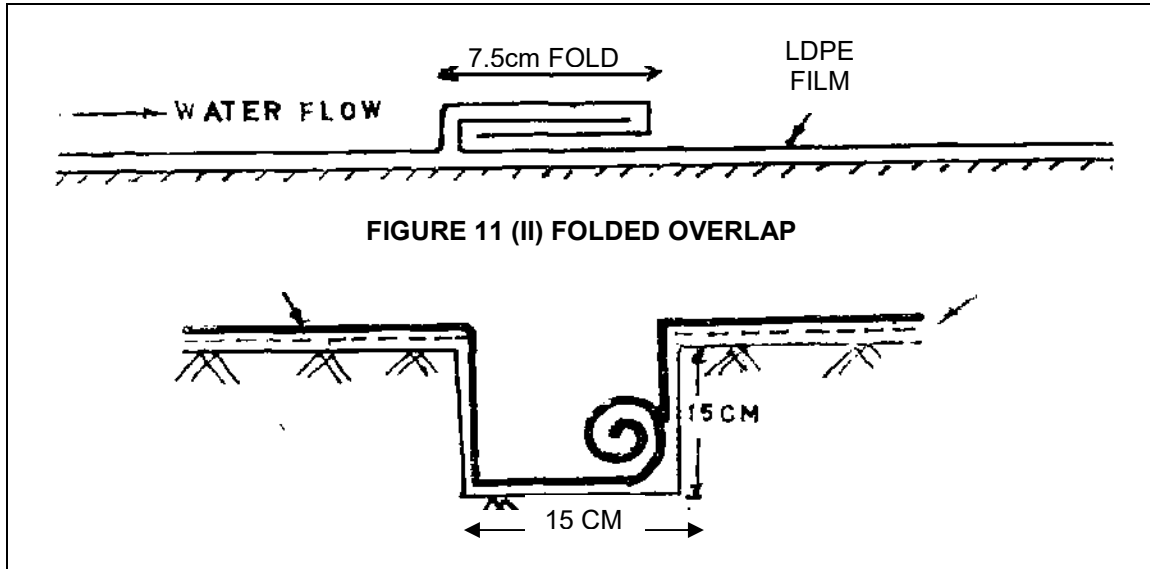


FIGURE 11(iii) FOLDED JOINTS EMBEDDED IN A TRENCH TO FACILITATE LINING

25:5.4.3.4 *Jointing by hot bitumen*

The film sheet can also be jointed by a coat of bitumen. Bitumen the grade 85/25 and 80/100 in the ratio of 2:1 should be heated at a temperature around 100°C. Heated bitumen can be tested on a small piece of film sheet so that overheated bitumen may not damage the film. After ascertaining the appropriateness of the temperature, apply a thick coat of tested bitumen on a 10 cm area along the width of both the sheets and fold them as shown in Fig. 11 (iv) and cover the same with brick masonry profiles (Dhamalies) at a suitable interval depending upon the width of the film which should come directly over this joint at a regular intervals, in order to ensure a better joint of the film sheet. Using, damaged fill sheet is not recommended. However, this method has been found convenient for repairing punctures in the film at site itself. In case of big holes, pieces of sheet should be pasted from both sides.

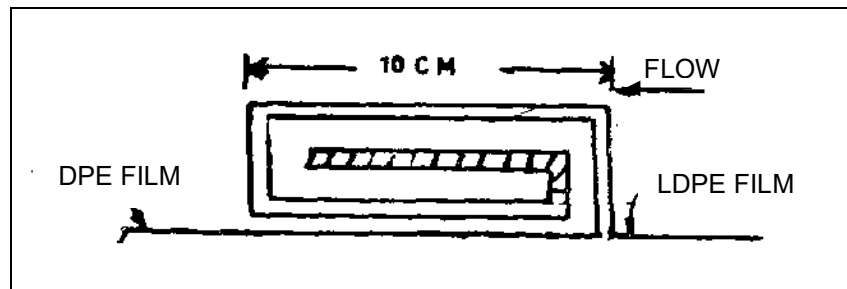


Fig 11 (iv) Jointing by hot Bitumen

25.5.4.3.5 Sealing by adhesive tapes

Adjacent lengths of film sheet can also be jointed with suitable adhesive tapes as shown in Fig. 11 (v) Hydrostatic pressure and the over-layer is sufficient to make the over lap practically water tight. However in the areas where high temperature exists (40° - 50°C) during summers and with passage of time under submerged conditions, the joints may open up. Soil particles creeping into the joint while laying may also lead to leakage.

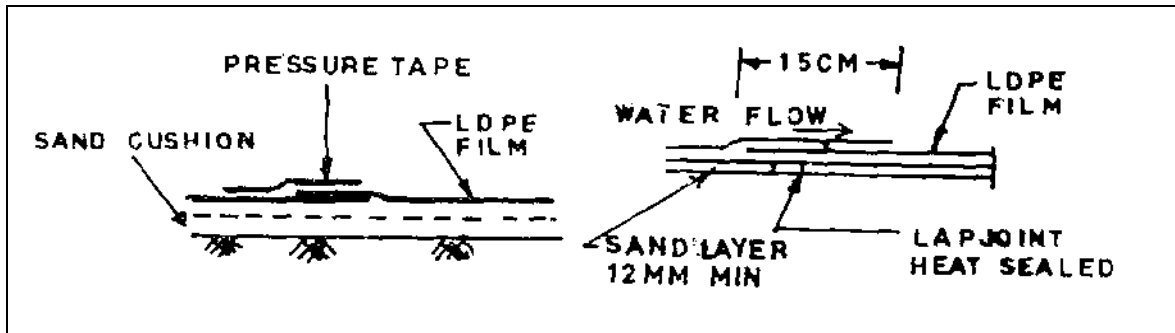


FIG. 11 (v) OVERLAP JOINT WITH PRESSURE TAPE

FIG 11 (vi) HEAT SEALING OF JOINTS

25.5.4.3. Heat sealing:

As shown in Fig. 11 (vi) the overlap joints can be heat sealed with a hot iron. The temperature of the iron should be adjusted and maintained at 150°C and pressed on the film sheet joint overlap for 4 seconds for a 150 micron film thickness sheet. For every 50 micron increase in the film sheet thickness the time would be increased by one second. To avoid the risk of film/sheet sticking to iron a poly-tetra-fluoroethylene (PTFE) impregnated glass cloth or Teflon sheet or Cellophane sheet should be placed between the film and the iron.

Note- Heat Sealing is the most effective of all the methods.

25.5.4.3.7 In all type of joints the overlap should be kept normal to the flow and should point downstream of the canal.

25.5.4.4 Film sheet should be spread on well prepared subgrade and should be held in position at two extremities of the bed by placing excavated earth on it, while two ends of film sheet are being loosely held over the embankment.

25.5.4.5 Extra length of film sheet should be placed in trench at embankment top and covered with earth. The embankments may be then raised to designed level.

25.5.4.5.1 Excavated earth should be placed over the film sheet to build up the canal section. The earth layer should be compacted by using light rollers and manual templates. It may be so arranged that earth from over- excavation of an adjacent section be used for covering tile film sheet in the earlier section. Thus, by the time earth cover is provided in one section, the adjacent section is ready to receive film sheet lining.

25.5.4.5.2 The film/sheet on the bed should be covered first. To avoid any damage to the film/sheet a layer of earth, free from gravel or granular material should be laid and compacted over the film.

25.5.4.5.3 The remainder of the earth cover should be spread in 15 cm layers, watered and compacted using light rollers or manual templates.

25.5.4.6 Connection To Structures - In case of structures in lined channels film should be embedded in the solid structure, i.e. R.C.C/masonry by about 15 cm to provide impermeable layer. This film should be protected by a layer of 50 mm to 100 mm thick cement concrete.

25.5.5 Top Cover

The top cover may be an earth layer of suitable thickness (25.5.5) or of pre-cast Concrete Tiles, in-situ Cement Concrete, Stone Slab (see 3873:1993), or burnt clay tile (see 1 S:3872-1992)

Earth Cover

- (a). For canals with velocities less than or equal to 0.6 m/s, minimum thickness of cover over the film sheet should not be less than 30 cm in bed and 60 cm on the sides.
- (b). For canals with velocities more than 0.6 m/s, the film/sheet on the bed should have a rigid cover against possible bed erosion. For sides the cover should be of any rigid type.
- (c). Side slopes should be designed in accordance with the stability requirements with lining in position. Side slopes not steeper than 1.5: 1 are recommended.
- (d). If the cover material contains Kanker or sharp angular material, a cushion layer 7.5cm thick of sieved earth (free from Kankar, etc.) may be provided over the film sheet:
- (e). To prevent effect at the water line, Kankar or gravel of stone aggregates of size 4 to 5 cm may be spread over the cover prior to compacting, using light roller or manual ramming.

25.5.5.1 In case of cement concrete lining the concrete should be so placed that the aggregates do not puncture the film sheet.

25.5.5.2 For a better bond between the smooth surface of film sheet and rigid cover lining, cement slurry may be sprayed over the film sheet before placing the rigid lining.

25.5.5.3 Do's and Don'ts for Geomembrane For Canal Lining.

- (1) Keep the rolls in original packing prior to actual use of laying and see at the time of delivery that the rolls are packed properly.
- (2) Apply uniform pressure while thermal welding (heat sealing) the film sheet.
- (3) Don't leave unpacked rolls exposed to over prolonged periods or preferably store them indoors.
- (4) Don't rough-handle or drag rolls, as the film sheet may get damaged in the process.
- (5) Don't let workers walk on the film sheet while the lining operation is in progress to avoid puncturing of the film sheet, in case this is unavoidable, they should walk barefoot.
- (6) Don't slide cover material like bricks etc. on film/sheet to avoid damage and displacement.
- (7) Don't use hooks for lifting the rolls.

25.6 CAST IN SITU CEMENT CONCRETE LINING

25.6.1 Cement Concrete

Cement concrete of specified mix shall be provided at places as shown in the drawings. The specifications for cement concrete shall be in accordance with the one laid down in relevant specifications for Chapter 7 and 16.

25.6.2 Preparation or Sub-Grade

The sub-grade preparation shall be as per provisions under para 25.3 as applicable.

25.6.3 *Laying of Concrete Lining*

25.6.3.1 Slump - For hand-placing and for placing with the light machines where concrete is screeded from bottom to the top of the slope, the consistency shall be such that the concrete will barely stay on the slope. A slump of 60 to 70mm shall be generally allowed. For heavier longitudinally operating slip-form machines, a slump of 50 mm at the laying point shall be permitted. To have a close control of consistency and workability of the concrete the slumps of concrete shall not vary by more than 20 mm which would otherwise interfere with the progress and quality of the work.

25.6.3.2 **Thickness**

The thickness of lining should be fixed depending upon the nature of the canal requirement, namely hydel channel or irrigation channel, full supply depth and channel capacity. Hydel channel should have a greater thickness than channels meant for irrigation because of draw down effects and where closure for repairs may not be useful. Deeper channels should have a greater thickness than shallow depth channels. Minimum thickness of canal lining based on canal capacities are given in Table 5.

Table 5. Thickness of In-situ Concrete Lining

Capacity of canal (1) (cumes)	Depth of water (2) (m)	Thickness of lining (3) (mm)
0 - 5	0 – 1	50 - 60
5 - 50	1 - 2.5	60 - 75
50 - 200	2.5 - 4.5	75 - 100
200 - 300	4.5 - 6.5	100 - 120
300 - 700	6.5 - 9.0	120 - 150

NOTE - If surface deterioration in freezing climate is expected, these thicknesses may be increased. The lining will not be subjected to external hydrostatic earth pressures or uplift caused by expansive clays on frost heave.

25.6.3.3 Tolerance in Concrete Thickness, Alignment and Grade

- | | | |
|----|--|--|
| a) | Departure from Established alignment | \pm 20 mm on straight reaches, 50 mm on partial curves or tangents |
| b) | Departure from established grade | \pm 20mm on small canals |
| c) | Variation on concrete lining thickness | \pm 10 mm provided average thickness is not less than specified thickness. |

25.6.3.4 **Mixing**

Concrete should normally be mixed in a mechanical mixer.

25.6.3.5 **Transporting** : The specification given under para 7.4.4 of Chapter 7 & 16 shall apply

25.6.3.6 Placing

Placing of concrete should not be started until all form work, installation of parts to be embedded and preparation of surfaces upon which concrete is to be laid have been completed. All absorptive surfaces against which concrete is to be laid should be moistened thoroughly so that moisture will not be withdrawn from freshly placed concrete. The surfaces however, should be free from standing water and mud and 1:3 cement slurry shall be spread over the moist subgrade before placing concrete to prevent absorption of water from concrete making it spongy. A plastic membrane of low density polythene film of suitable thickness may be used below the concrete lining in sides and in beds where the subgrade of the lining is of pervious materials like murum etc, so as to prevent absorption of water in subgrade from green concrete, during placement on the subgrade. The approved film is to be laid on the neatly well dressed subgrade, and fixed in the subgrade so as to prevent displacement during the placement of the concrete. The use of polythene sheets is for achieving better ultimate imperviousness of the lining as a whole. The following properties of L.D.P.E. film are given as guidelines with deviation to the extent of (plus or minus) 10 percent.

1) Tensile strength	17.5 N/mm ²
2) Tear resistance	9.5 N/mm ²

NOTE - Till better materials are developed, use of LDPE film of appropriate strength and resistance against slippage of tunnel may be adopted as a second line of defence against embankment failure and as a seepage barrier particularly in high capacity channels of relatively bigger depth.

In case filter material is to be provided over subgrade to take care of different hydrostatic pressure and draw-down in canals, designs of coarse filter material blanket immediately in contact with lining would be necessary. To make such filter blanket effective and to prevent ingress of concrete into it, before placement of concrete, polythene sheet should be placed over the filter blanket. All concrete should be placed directly in its final position within 20 minutes of mixing. Concrete should not be dropped from excessive height and free fall should, be kept to a minimum to avoid segregation. Construction should be continued until satisfactory construction joint is made. Concrete should not be placed faster than the placing crew can compact properly.

25.6.3.6.1 Hand Placing

Hand placing of concrete should normally be adopted where cheap labour is available.

25.6.3.6.1.1 Depending upon the construction method and arrangement of concreting, the sequence of placing concrete either on the sides or the bed should be decided. It is preferable to place concrete on the sides first if the concreting equipment and the construction materials like aggregate, sand etc. are kept on the canal bed. This will prevent the bed from getting spoiled by the subsequent concreting operations for the sides. Other things being equal placement for bed first should be preferred.

25.6.3.6.1.2 The concreting of the sides and bed should be done in alternate panels. The panel width should vary from 2 to 3 m. In no case should the panel width exceed more than 3 m. as wider bays require unwieldy vibrators for compaction. The construction joints should be either parallel or perpendicular to the direction of flow. In case the full supply depth is high, construction joints along the direction of flow to divide the length of the panel should be provided. For this purpose wooden rafters should be used. The succeeding panels should be laid at an interval of one day). If the sloping-length is less than 2.5 to 3 metres, concrete should be placed in one operation over the entire length. In case of deeper canals where the sloping length is more it should be suitably divided (say for a length of about 2 metres) in each alternate panel so as to prevent appreciable downward flow of concrete.

The bays/panels should be formed by proper form work of M.S. channels laid all around the bay. The channels should be firmly spiked to the subgrade so that no movement takes place at the time of concreting and vibration. The depth of the M.S. channels should correspond to the required thickness of concrete lining. The concrete should be dumped in the bay from bottom to top and then spread all over the bay uniformly and to the required thickness guided by the channels. The spread

concrete should then be compacted properly and thoroughly by means of mechanical or screed vibrators. An improvised plate vibrator operated by high horse power engine and a winch for moving the vibrator up the inclined slope should be made use of for proper compaction. When width of panel is less i.e. upto 2 m manual operation of vibrators is possible and may be permitted. In no case the concrete should be compacted by tamping. The compacted surface should be true to the required side slope. Before re-Using the channel forms, they should be thoroughly cleaned and well oiled. Care should be taken while placing and vibrating the concrete that, the sub-grade in the adjacent bays does not get spoiled. **25.6.3.6.1.3**

For bed lining the procedure for laying the concrete on the canal beds should be same as that for side lining except the operations specifically required on sloping surfaces. The compaction should be done by means of a heavy screed vibrator moving on the side channels.

25.6.3.6.1.4 In order to test the effectiveness of vibration, permeability and strength of concrete cores at suitable places from the side as well as from the bed concrete should be taken.

25.6.3.6.1.5 In-situ sleepers in case of bed, and precast in case of sides, should be provided under the joints. The sleepers should be 20 cm wide and 15 cm deep. The sleepers should be placed centrally below the joint. Concrete used for sleepers should be of the same grade, as for lining. Alternatively brick sleepers 225 x 150 mm with 1:4 mortar may be used. Concreting near the joints should be done with utmost care so as to avoid segregation and collection of loose pieces of aggregate along the form work which may later result in honey combing.

25.6.3.6.1.6 Concreting near the junction of the side concrete and bed concreting should be done such that both should rest firmly against each other to resist any back-kick from external hydrostatic forces (see Fig. 12 and 13) The sketches indicate the procedure for formation of junction of the sides with bed depending upon the sequence laying concrete i.e. sides first and vice-versa.

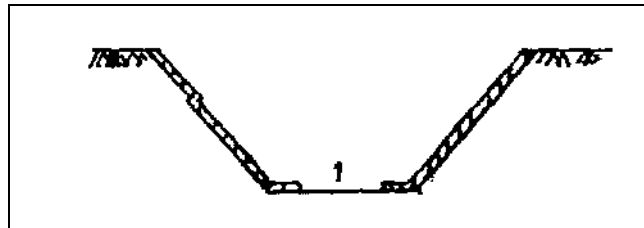


Fig. 12 Sides Cast First

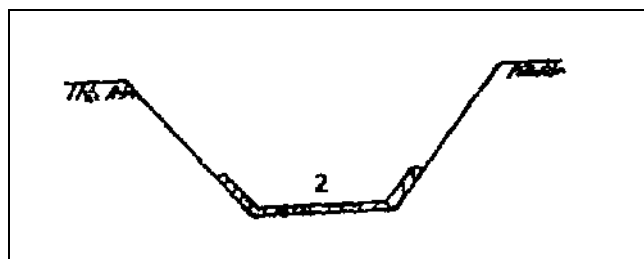


Fig. 13 Bed Cast First

25.6.3.6.2 Mechanical Placing of Concrete

Concrete for slip-form should be air entrained to provide a more workable and slipable mix. Percentage of air should as follows:

Maximum Aggregate Size mm	Air Percent by Volume
10	8.0
12.5	7.0
20	6.0
25	5.0
40	4.5

Air entraining agents will always be used in concrete by means of slip- form paving machine for entraining air.

a) Sub grade guided slip-form

This should be used for lining small to moderate size canals. The slip-form should be supported directly on the subgrade and operated longitudinally along it, concrete should be screeded on the bed along the canal and on the sides from bottom to top.

(b) Rail guided slip-form

They are adopted for larger canals of considering length. Slip-forms supported on rails placed along both berms of the canals should be operated .longitudinally. Concrete should be spread uniformly on the bed longitudinally and on the sides from bottom to top.

25.6.3.6.3 Procedure for laying concrete in Panels

The concrete of lining in panels shall be placed in the manner prescribed in para 25.6.4.3.1 or 25.6.4.3.2 as specified.

25.6.3.7 Finishing

The surface of concrete finished against forms should be smooth and should be free from projections, honeycombing and other objectionable defects. Immediately on the removal of forms, all unsightly ridges or lips should be removed and undesirable local bulging on exposed surfaces should be remedied by tooling and rubbing. Repairs to concrete surfaces and additions, where required, should be made by cutting regular openings into the concrete and placing fresh concrete to the required lines. The chipped openings should be sharp and should not be less than 70 mm in depth. The fresh concrete should be reinforced with wire mesh extending to the full depth of the slab and chipped and trowelled to the surface of the openings. The mortar should be placed in layers not more than 20 mm in thickness after being compacted and each layer should be compacted thoroughly. All exposed concrete surface should be cleaned of impurities, lumps of mortar or grout and unsightly stains.

25.6.3.7.1 The concrete should be finished to an even and smooth surface free from pockets, voids or exposed aggregates. This should be obtained by careful use of a long- handled steel trowel. Any remaining roughness or rough spots shall be rendered smooth, without any time interval after laying the concrete, with cement mortar of 1:3 proportion.

25.6.3.8 Curing

Subsequent to laying of concrete lining and after a period of 12 hours or as earlier as warranted by site conditions, the lining should be cured for at least 28 days.

25.6.3.8. Bed lining

Twelve hours after laying of concrete, small bunds longitudinal and cross-wise consisting of earth materials or lean mortar (1:15) should be laid for a height of 8 cm for the purpose of curing. Water will be kept always ponded in these bunds for 28 days continuously.

25.6.3.8.2 Side Lining

The panel in which concreting is done on the previous day should be covered with burlap or empty cement gunny bags,

For the purpose of curing, water tank of 5000 liters capacity should be placed on a platform at the edge of service road at the rate of one for 500 m length of lining, which should be kept filled with water with arrangement of outlet and flexible hose of at least 300 m length. Water should be continuously sprinkled on the gunny bags or hessian cloth keeping them wet for 28 days. Sprinkling shall be done during night time also. The curing of side slopes may be done by constructing masonry drains with weep holes or perforated pipes on the coping at the top of lining or by sprinklers.

25.6.3.8.3 Surface Drainage

The top of the side lining concrete should be keyed into the Subgrade both in cutting as well as banking by taking it horizontally for a width of about 300 mm. This key would prevent direct entry of surface rain water behind the lining. The top surface of the key should be finished with downward slope of 1 in 10 or so towards the canal. A day after completion of concreting of all panels between two templates, concreting of key slab should be done. Concurrently with the curing operation, surface drainage arrangement of the bank such as construction of keys, bank surface slope away from the lining and construction of longitudinal drain on the outer edge shall be completed. This is necessary to prevent surface and subgrade erosion and consequent damage to lining.

25.6.4 Joints**25.6.4.1 Expansion Joints**

These should not be provided except where a structure intersects in the canal. The details are given in relevant Indian Standards covering such structures.

25.6.4.2 Construction Joints

Construction joints form a work link in the lining and deterioration is generally noticed at such joints. Besides joints are potential seepage points for the canal water. As such number of joints should be kept to the minimum and great care should be taken to obtain well compacted and smooth concrete surface at joints. To ensure a good surface the shuttering should be smooth, cleaned, well oiled and rigidly fixed at site. Besides different mechanisms for compaction of concrete in lining, tamping with iron bar near the joint surface gives better results.

To cater for initial shrinkage and cracks, concreting should be done in alternate panels or bays. The panel size for the bed and slope of the canal should be adopted as given in 25.6.3.6. A 25 cm wide L.D.P.E. film of 150 micron thickness should be placed on the top of sleepers, provided to support construction joints. The top of film and side of panel should be applied with primer conforming to IS:3384-1985. This sheet acts as an intercept for seepage through the joint. In case lining is laid by mechanical paver, PVC water stops are placed at joints along with the concreting. The water stops in such a case should be provided at a spacing not more than 4 meters centre to centre.

25.6.4.3 *Laying of Precast Concrete Tiles.*

25.6.4.3.1 The tile should conform to IS: 10646: 1991.

25.6.4.3.2 The lining should be started only when at least 35 m length of canals subgrade is properly dressed to receive lining. The arrangement of mortar and availability of sufficient number of tiles should be ensured before starting the work. Arrangement for proper soaking of the tiles shall be made.

25.6.4.3.3 The subgrade should then be uniformly soaked with water without making it slushy to ensure that water penetrates to a depth of about 300mm in sandy soil and about 150 mm in other soils. Wetting of subgrade should continue in advance of laying of tiles so that soil does not absorb moisture from the mortar laid on the subgrade on laying the layer of tiles,

25.6.4.3.4 Single tile profile of lining parallel to central line of the canal should be prepared at suitable intervals. Mortar (1:3) should uniformly be spread over subgrade for a minimum thickness of 12 mm and the tiles should be properly laid in position quickly. It should be ensured that vertical joints are completely filled with mortar. The tiles should be laid in bed with their lengths at right angles to the central line of the canal while on the other side slopes they should be laid parallel to the central line.

Tiles should be firmly embedded in mortar. However, if any, should be rectified by relaying defective portion with fresh mortar. The tiles should be laid over a minimum of 12 mm thick cement mortar and having aggregate less than 6 mm to bring overall fineness modulus less than 2. Hollow joints should be raked and pointed with the same mortar. The thickness of joint should be not exceed 12 mm.

25.6.4.3.5 Slab should be firmly embedded in mortar. Hollows if any should be rectified by relaying the defective portions with fresh mortar.

25.6.4.3.6 On completion of laying lining should be kept wet by sprinkling water over it to keep the mortar wet. On the next day, the surface should be kept wet and joints should be carefully wetted. Hollow joints should be raked to a depth of 12 mm, loose mortar removed from sides and top of tiles and the joints properly refilled. Loose tiles should be removed and relaid. Curing of Mortar joints after laying shall be ensured for 14 days. Satisfactory curing can be achieved by covering the joints with soaked gunny bags (burlap) & keeping the same wet for 14 days.

25.6.4.3.7 The complete lining should be checked for level with wooden templates and spirit level.

25.6.5 *Safety Ladders*

25.6.5.1 Safety ladders should be constructed in canal lining as directed by the Engineer-in-Charge.

25.6.5.1.1 Safety ladders consisting of ladder rungs should be constructed in canal lining about 30 m. upstream of the point where the canal enters some underground structure. In other reaches safety ladder may be provided at a spacing of about 300 m. the ladders being provided alternatively on either side.

25.6.5.1.2 Ladder rungs should be smooth, round mild steel bars, galvanised or coated with coal tar after installation.

25.6.5.2 Typical details of safety ladder are illustrated in Fig. 14

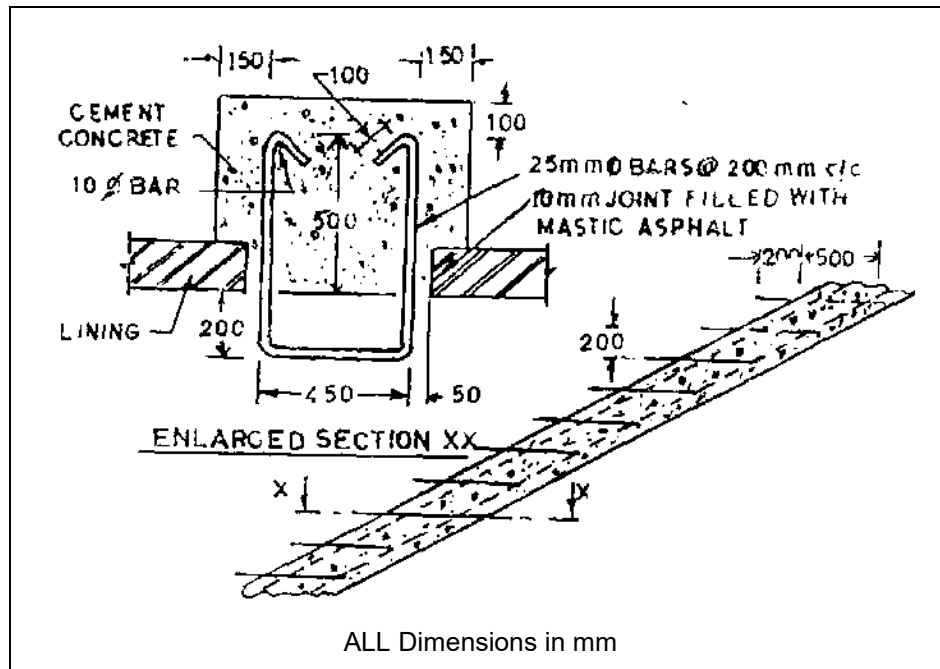


Fig. 14 Details of Safety Ladders

25.6.5.3 As all alternative to safety ladders tops of rise 150 mm, tread 300 mm and 1500 mm wide may be provided in plain cement concrete of grade M-10 at a spacing of 300 m centre to centre (staggered) on either side of canal. Details of the steps are illustrated in Fig.15.

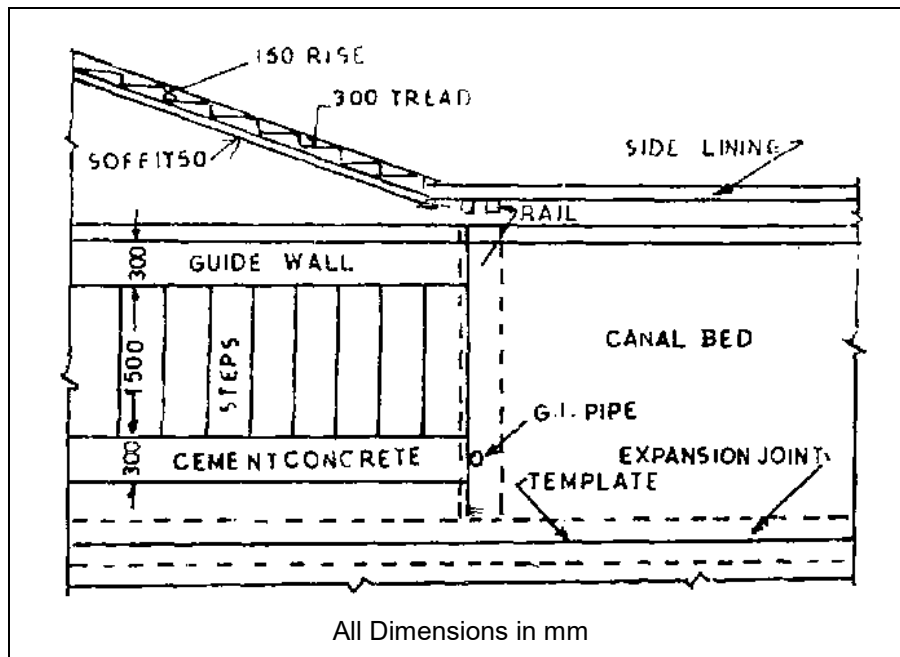


Fig. 15 Details of Steps

25.7 Clearing site

The area proposed for lining the canal as a whole shall have to be cleared of all objectionable material. Any waste material obtained from such site clearance shall be disposed off in a manner directed by the Engineer-in-Charge. The cost of this operation shall be deemed to have been covered under the rates quoted for canal lining.

25.8 Trimming the canal section and Preparation of Sub grade for Concrete Lining**25.8.1 General.**

(a) The provisions of this paragraph applies to the preparation of subgrade upon which concrete lining is to be placed.

(b) The work of trimming the canal section upto the underside of concrete lining and preparing subgrade for concrete lining includes excavation, prepares the base for lining shall be carried out by machine (trimmer) of adequate capacity to match with the paving machine used for lining with insertion of PVC strip immediately prior to laying of the lining but in no case the time interval should exceed 3 days in normal weather and 2 days in adverse weather conditions. Wherever, rock is over excavated the item of trimming and preparation of sub-grade includes, filling the over excavated portion with suitable semi-perivious material, watering, compaction and its trimming upto underside of the concrete lining. Ail along the canal alignment the raincuts on the banks shall be filled up with approved excavated material and shall be compacted adequately to required line and level. The material required for filling the over excavation in rock and raincuts if not available during excavation in soils to be done under this item shall be hauled from stockpile and placed in position. The bed and side slopes shall be trimmed to the required section by using trimmer machine. The canal bed and slopes shall be dressed, watered and compacted by suitable : oilers and slope compactors.

(c) If at any point material has been excavated beyond the pay line required to receive the concrete lining the excess excavation shall be refilled in horizontal layers with selected material moistened. If required and compacted using rollers and slope compactors. Where placing and compacting bedding material is on a sloping foundation. The layers may be placed parallel to the surface of the foundation. If at any point the foundation material is disturbed or loosened during the excavation process or otherwise it shall be moistened, If required and thoroughly compacted by tamping, rolling or other approved methods to form firm foundations for placing the concrete lining.

(d) Immediately prior to placing the first lift of bedding material, the surfaces of the excavation and embankment to receive the material shall be adequately wetted to a depth of 15cm or to impermeable

(e) After the canal prism has been shaped to a reasonably true and even surface as described above, bedding material shall be placed on adequately wet surfaces in layers of 15cm. maximum thickness to bring the bedding material to a height where it can be trimmed to form a true and even surface upon which the concrete for lining is to be placed. Each layer of bedding material shall be moistened and thoroughly compacted.

(f) At the end panels of existing lining against which lining is to be placed under these specifications, all loose material shall be removed and all voids beneath the existing lining shall be refilled and thoroughly compacted.

(g) Suitable material trimmed from the canal shall be. used to complete canal embankments or to construct road embankments or for back fill around structures or to deposit bedding material. Where material suitable for bedding as determined by the Engineer-in-Charge is encountered during trimming operations and cannot be placed in one continues operation, such material shall be stockpiled along the right of way where designated by the Engineer-in-Charge.

25.8.2 Tolerances:

Excavated profile provides the final base for lining and tolerances i.e. departure from established alignment shall be as indicated.

- + - 20mm on straight section
- + - 50mm on tangents
- + - 100mm on curves
- + - 20mm Departure from established grade.

The above tolerance shall be negotiated gradually through smooth transition in a length of 50M.

25.8.3 Measurement and Payment.

Measurement for payment for the trimming and preparation of subgrade shall be made on square meter of the surface of the canal prism trimmed over which concrete lining is to be placed. Payment shall be at the unit rate mentioned in schedule G. The rate includes cost of labour; equipments, backfilling both for bed & sides if required, watering, compaction of bed and sides and all incidental works to complete the work as per specifications and also dewatering of the canal sections where required.

25.9. Cast in Situ Concrete Lining.**25.9.1 General.**

The work shall conform to IS : 3873-1978. The concrete shall be of controlled grade with suitable admixtures of approved air entraining agents, using well graded aggregates with maximum size of aggregate of 40mm. Ordinary Portland Cement, or portland Pozzolana Cement shall be used at the rate of 221.75 Kg/M3 concrete. However due to change in design mix, if it becomes obligatory to use linear/ richer mix, the Contractor shall comply the same without any extra cost. In case of linear mix, the Deptt. shall deduct the cost of cement from the bill at the base price of Rs. 2400/- (Rs. Two thousand for hundred only) per tonne of cement at work site including handling etc. for short consumption of OPC/PPC. In case of richer mix, the contractor shall be paid for the extra cement used at the base price Rs. 2400/- (Rs Two thousand four hundred only) per tonne of cement at work site including handling for price adjustments, the amount so recoverable payable will be deducted added in 'R' the value of the work done and price adjustment will be made in accordance with Clause 32-A. Design mix and actual cement level required shall be communicated from time to time to the contractor in writing by the Engineer-Charge.

25.9.2. Batching.

(a) The contractor shall provide such means and equipments as are required to accurately determine and control and relative amounts of the various materials including water, cement admixture, sand and each specified size of coarse aggregate required for the concrete. Such means and the equipment and its operation shall be subject, at all times, to the approval of the Engineer-in- Charge. The quantity of cement fly ash (if required), sand and each size of coarse aggregate entering each batch of concrete shall be determined by weighing and the quantity of water required shall be determined by volumetric measurement.

(b) The measuring and weighing equipment shall operate within the limits of accuracy specified. Standard test weights and other auxiliary equipments required for checking their satisfactory performance shall be provided by the Contractor.

(c) The equipment shall be capable of controlling the delivery of material for weighing or volumetric measurement so that the combined in accuracies in feeding and measuring during normal operation do not exceed 1 % for water and 3% for all aggregates, Periodical tests shall be made at least once in every two weeks in the case of equipment for measuring water, cement and admixtures

and at least once in every month in case of equipment measuring sand and coarse aggregate. However, this shall not obviate any surprise checking and testing at any time as desired by the Engineer-in-Charge. Repairs, replacement, or adjustments of equipment shall be made as necessary in order to secure, satisfactory performance.

(d) The Weighing equipment shall conform to the requirement of IS : 2722-1964 and the batching and mixing plant to the requirement of IS : 4925 -1968.

25.9.3 Mixing.

(a) Concrete shall be mixed in a mechanical mixer and shall be as dense as possible plastic enough to consolidate well and stiff enough to stay in place on the slopes.

(b) Mixing shall be continued until there is uniform distribution of the materials and the concrete is uniform in colour and constancy. The time of mixing shall be as shown in table 1 of IS : 457 -1957 is produced below shall be matched with the lining equipment capability so as not to impede the specified placement rate of each lining operation.. The over all equipment deployment shall be such as to ensure the completion of canal lining within the schedule period specified in the contract.

(c) Concrete when deposited shall unless otherwise specified have a placement temperature of not less than 4.5°C and not more than 32°C.

(d) Concrete shall be deposited and spread on the bed and sides of the canal as indicated on the drawings. Concrete may be so laid as to facilitate placing, vibrating, finishing and curing operations. The side lining concrete on sides of canals shall be screeded up the slope, while the concrete is being vibrated ahead of the screed. Concrete required for keys as shown on the drawings shall be laid integrally along with the side lining.

(e) Alternately, the Contractor can select to use longitudinally operating self aligning, slip form machine with built in vibrators attached to the side forms so as to effectively compact and finish the slope and bed concrete.

(f) The joints shall be formed by inserting PVC strips if provided in green concrete.

25.9.4. Finishing.

(a) All exposed concrete surfaces shall be cleaned of impurities, lumps of mortar or grout and unsightly stains. The finished surface shall be even, smooth and free from pockets and equivalent to the obtainable by effective use of a long handle steel trowel. Where the surface produced by lining machines meet the specified requirements, no further finishing operation will be required. Surface irregularities, when tested with a straight edge of 1.5 meter length shall not exceed 6mm in canal bed for bottom slab and 12mm in the laid on side slopes.

(b) Concrete of canal lining on slopes including key at the top and curved portion at the bottom of the slope of canal shall be cured with liquid membrane forming white pigmented curing compound which shall form water retaining surface to achieve the desired effect of water curing at 28 days. The curing compound shall be white pigmented of approved quality conforming to ASIM-C-309-81.

(c) Repairs to concrete surface and additions where required shall be made by cutting regular openings into the concrete and placing fresh concrete to the required lines. Chipped openings shall be sharp and shall not be less than 75mm in depth.

25.10. Curing.

25.10.1 General

The concrete lining on slopes including curvatures portion at junction of slope and bed lining shall be cured with liquid membrane forming curing compound in accordance with specifications given in para 4.10.2. The concrete lining in canal bed shall be cured with water in accordance with the specifications given in para 4.10.3. if water curing of lining in the canal bed is not carried out to the

satisfaction of the Engineer-in-Charge as per specifications. The contractor shall be directed to switch over to liquid membrane forming curing compound for curing for which no extra payment shall be made to the contractor.

All equipment, material, etc. needed for curing and protection of concrete shall be at hand and ready for installing before actual concreting begins. Detailed plans, methods and procedures whereby the various phases of curing and protection shall be firmly established, shall be settled and got approved in writing from the Engineer-in-Charge sufficiently in advance of the actual concreting. The equipment and method proposed to be utilized shall provide for adequate control and avoid interruption of damage to the work of other agencies.

25.10.2 Membrane Curing.

(a) These specifications cover curing of concrete using membrane forming compound to retard the loss of water during the early hardening period and to reduce the temperature rise in concrete exposed to radiation from the sun. This compound shall be suitable for use as curing media for fresh concrete and for further curing of concrete after removal of forms after initial moist curing.

(b) White pigmented compound (Type-2) shall consist of finely divided white pigments and vehicle solids, ready mixed for immediate use without alteration. The compound shall present a uniform white appearance when applied uniformly to a fresh concrete surface at a specified rate of application. It shall be of such constituency that it can be readily applied by spraying to provide uniform coating at temperatures above 4°C. If two coats are to be applied then it should be applied at an interval of approximately one hour. They shall adhere to freshly placed concrete that has stiffened of sufficient to resist marking during the application and to damp hardened concrete and shall form a continuous film when applied at the specified rate of application. When dry, the covering shall be continuous, fixable and without visible break or pin holes and shall remain as unbroken film at least 28 days after application, it shall not react deleteriously with the concrete.

(c) The compound shall meet with the requirement water retention test as per ASTM designation C-156-80. The loss to water in this test shall be restricted to not more than 0.55 kg./m² of exposed surface in 72 hours.

(d) White pigmented compound Type 2, when tested as specified in accordance with method E-97 of ASTM shall exhibit a day light reflectance of not less than 60% of that of magnesium oxide.

(e) It shall fulfill the requirement of drying time when tested in accordance with ASTM C-309-81. The compound applied shall be dry to touch in not more than 4 hours. After 12 hours it shall neither be tack nor tack off (peel off) concrete when walked upon nor it shall impact a slippery surface.

(f) Testing

i(a) The liquid membrane forming curing compound to be brought in the manufacturer's original clear containers. Each container shall be legibly marked with the name of the manufacturer, the trade name to the compound, the type of compound and class of vehicle, solids, the nominal percentage of volatile material.

(b) The surface of concrete finished against form shall be smooth and free from projections, honey combing and other objectionable defects, immediately on removal of forms all unightly or shall be removal undesirable local bulging on exposed water shall be removed by looking and tubing and batch or lot number. The lot numbers will be assigned to the quantity of compound mixed, sampled and tested as single product. The manufacturer shall exercise the care in filling the container so that all are equally representative of the compound produced.

(ii) Curing compound to be used on site shall be got tested at least 14 days in advance so that the result of water refluations tests, reflectance test, drying etc. are available before it can be permitted for use. All of the filled containers represented by the approved sample shall then be sealed to prevent leakage, substitution or dilution. The Engineer-in-charge or his authorized representative should mark each container represented by the samples with a suitable identification mark for later identification and correlation and shall be kept in store with double lock arrangements. One key shall be kept with the Contractor and the other with Engineer-in-charge. Random samples shall be collected from every batch of the compound frequency random sampling shall be as directed by the Engineer-in-charge.

25.11 Testing of Concrete and Acceptance of Work

25.11.1 General

Testing of concrete shall be carried out at the cost of the Deptt. by the Laboratory Division on representative samples taken at the site of laying the concrete in accordance with relevant Indian Standard Specification.

25.11.2 Sample Procedure and Frequency

(a) Sampling Procedure: A random sampling procedure shall be adopted to ensure that each concrete batch has a reasonable chance of being tested, i.e. the sampling should be spread over the entire period of concreting and should cover all mixing units.

(b) Frequency: The minimum frequency of sampling of concrete to each grade shall be in accordance with the following.

Quantity of concrete m ³	Number of Samples
1 to 5	1
6 to 15	2
16 to 30	3
31 to 50	4
51 and above	4 Plus one additional sample for each additional 50m ³ or part thereof.

Note: At least one sample shall be taken during each shift.

25.11.3 Test Specimen

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes, such as to determine the strength of concrete at 7 days or all the time of taking form Work, or to determine the duration of curing or to check the testing cubes cured by accelerated methods as described in IS : 9018 -1978. The specimen shall be tested as described in IS: 518 -1959.

25.11.4 Test Strength of Sample

(a) The test strength of the sample shall be the average of three specimens, individual variation shall not be more than 15 percent of the average.

(b) Contractor shall provide necessary unskilled labour and facilities for transport for collection of samples, cores etc and shall remain present at the time when the samples, cores etc. are taken. Testing shall be carried out at the testing laboratories set up at the site or at any other laboratory that the Engineer-in-charge may decide upon and the results given thereby shall be considered as correct and authentic and acceptable to the Contractor. The Contractor shall be given access to all operations and tests that may be carried out as aforesaid. All testing charges are to be borne by the SSNNI.

25.11.5 Acceptance Criteria

(a) The average strength of the group of cubes cast for each day shall not be less than the specified cube strength for the work. About 20 percent of the cubes cast of each day may have values less than the specified strength provided the lowest value is not less than 85% of the specified strength.

(b) In case the concrete does not conform to the accepted criteria for strength as specified above, the Engineer-in-charge reserves the right to reject the work proved by him. Whenever necessary for the purpose of obtaining economy, workability, density, impermeability, durability or strength on account of variation in the quality and gradation of aggregates of other materials the Engineer-in-charge, in consultation with Laboratory Division, shall after testing, make necessary changes, and will not be entitled to any compensation on account for such changes.

25.12 Joints

In canal lining contraction joints shall be provided to accommodate expansion and contraction of the concrete or to provide continuity between the breaks in construction work. Joints shall be provided as shown on the drawings or as directed by Engineer-in-charge. Normally, in plain cement concrete lining joints shall be provided at 4m centre, whereas in case of RCC lining joints shall be provided in PVC joints in plain cement concrete lining shall be as per para 12.0 The reinforcement shall be discontinued at joint.

25.13 Tolerance

(a) The intent of this paragraph is to establish tolerance that are consistent with modern construction practice yet be governed by the effect that permissible deviations will have upon the structural action or operational function of the structure. Deviations from the established, lines, grades and dimensions shall be permitted to the extent set forth herein below provided that the Deptt. reserves the right to diminish the tolerance set forth herein if such tolerance impairs the structural action or operational function of the lining.

(b) Tolerance for lining shall be permitted within the following units :-

(i) Departure from established alignment	20mm on straight reaches
	50mm on tangents.
(ii) Departure from established grade	100mm on curves
	20mm on straight reaches
(iii) Variation in concrete lining thickness	provided average thickness of
	each day's placement is not less than specified thickness.

Any departure from alignment or grade shall be uniform and no corrections in alignment be made in less than 50m. No over run in concrete quantity shall be paid to the Contractor:

25.14 Dewatering

In canal reaches where subsoil water is met with above, the canal bed level, dewatering shall be resorted to any continued during preparation of sub grades, providing under drainage arrangement and placing of concrete for lining till such period the concrete attains necessary strength. No separate payment shall be made for dewatering operations, as the same is deemed to have been included in rate of related item in Schedule G.

25.15 Measurement and Payment**(i) Plain Cement Concrete Lining**

(a) Measurement will be on the basis of square meter of plain concrete lining and payment will be at the unit rate quoted in Schedule G. Payment for lining will be made for the thickness shown on the drawing and on square meter basis of the surface area in bed and on sides including keys. The thickness of lining shall be determined by setting of paver machine in relation to final sub grade on which lining is to be laid. The thickness shall be cross checked by (i) volume of concrete placed and area covered (ii) use of probe when concrete is green and (iii) coring if required any over in quantity of concrete in lining shall not be paid to the contractor.

25.16 Safety Ladders**25.16.1 General**

The contractor shall construct the concrete steps along the canal near the structures. Steps shall be constructed in concrete M-10 grade as shown in the drawings or as directed by the Engineer-in-charge.

25.16.2 Measurement and Payment

Safety ladders shall be measured by numbers. Payment therefore will be made at the unit rate quoted in Schedule- G. The rate includes the cost of providing and fixing the ladder as indicated on the drawings.

25.17 Pressure Relief Values**25.17.1 General**

(a) Vertical non metallic (PVC) pressure relief valves of 50mm dia and 150mm dia as shown on the drawing shall be provided and fixed in position, The item included excavating pits and refilling the same with filter materials, where necessary, as per drawing or as directed by the Engineer -in-charge.

(b) The vertical pressure relief valves shall be procured by the Contractor at his own cost as per requirements. The valves shall be procured only after the make is got approved. These valves shall be fixed bed as well as in slopes as per the drawings supplied by the Deptt, or as per the instructions of the Engineer-in-charge. Filter material to be used shall be of approved quality of sand and gravel in required gradation, Graded filter as shown on the relevant drawings, shall be carefully placed and compacted to form an even bedding upto the elevation of bottom of canal lining. Tar paper of any other suitable material-, approved by the Engineer-in-charge shall be placed over the surface of the gravel fill to prevent water from concrete entering the fill. The under drainage arrangements shall be in conformity-with IS: 4558 -1983 in general.

(c) As an alternative to graded filter around PRV, geofabric of approved quality and design shall be used without any extra cost to the Deptt.

25.17.2 Measurement and Payment

Measurement and payment for the pressure relief valves shall be made on the basis of numbers at the unit rate in Schedule G. The rate shall include the cost of providing and fixing pressure relief valves, excavating and refilling pits, inclusive of materials and labour required therefore as per drawings and all incidental operations necessary to execute the work as per the specifications.

25.18 Insertion of PVC Crank inducing Joints.

25.18.1 (a) The transverse and longitudinal PVC (Polyvinyl Chloride) strips shall be provided with the shapes conforming to dimensions shown on the drawing and off white 'in colour.

The finished PVC strips shall be extruded from virgin, pigmented, plasticized polyvinyl chloride (PVC). The PVC strips shall be dense, homogeneous, free from holes and other imperfections. The cross section of

the PVC strips shall be uniform along its length and thickness shall be symmetrical transversely. Tolerance for dimensions in overall length and width shall be 5% and in thickness 10%. The finished PVC strips shall meet the following requirements.

No.	Characteristic	Values
1.	Tensile strength	Kg/cm ² 116 Minimum
2.	Ultimate elongation	% 300 Minimum
3.	Tear Resistance	Kg/cm ² 49 Minimum
4.	Stiffness if flexure	Kg/cm ² 24.6 Minimum
5.	Accelerated extraction	
	(a) Tensile Strength	Kg/cm ² 105 Minimum
	(b) Ultimate elongation	Kg/cm ² 250 Minimum
6.	Effect of alkali at 7 days	
	(a) Weight increase	0.10 Minimum
	(b) Weight decrease	% 0.10 Minimum
	(c) Hardness change point	± 5
	Effect of alkali at 28 days	
	(a) Weight increase	% 0.4 Minimum
	(b) Weight decrease	% 0.3 Minimum
	(c) Dimension change	% ± 1

Weight of PVC strip shall be a minimum of 460 g/m for the longitudinal strip and a minimum of 420g/m for the transverse strip.

(b) The above determination shall be made in accordance with the specifications of Central Water Commission, Govt. of India in value. The surface finish of PVC strips shall be mat finish, and off white in colour.

(c) Contractor shall arrange for getting the finished PVC strips tested in recognized testing Government Test Houses. The Contractor shall furnish test same of PVC strips in 30 cm length reel and free of cost also shall bear testing cost. Each sample shall remarked with the number of the reel from which sample is obtained and with certification that the samples are from the roots to be furnished

(d) It is mandatory Diamancatory for the manufacturer of the PVC strips, from whom the contractors procure PVC strips, to have a full fledged testing laboratory in the factory to enable pre-dispatch testing of the products, as in the event of laboratory test reports being received after a few weeks, showing substandard values. It would not be possible to remove the material embedded in concrete. Test reports from Government test houses shall also be binding on the manufacture based on sample drawn by the Engineer-in-charge and sent for testing to Government test house, from consignments received at site. The Contractor will got the sample of PVC strip approved by the Engineer-in-charge. He will furnish the name of manufacture, the details of the in-house testing all arrangements with the manufacturer and will also furnish a test report from the in-house testing facilities along with the sample.

25.18.2 (a) The PVC strips shall be inserted in the concrete lining when concrete is plastic. The longitudinal PVC strips shall be inserted before the transverse PVC strips is inserted. The PVC strips at edges shall be placed in position fixed with longitudinal channels by clips of such other arrangement prior to laying of concrete. The PVC for crack inducing joints shall be inserted in position in concrete lining as shown in the drawing. The insertion of the longitudinal or transverse PVC for crack including joints at the predetermined locations of joints requires special attention to ensure location (depth is especially important), plumb installation and consolidated around the PVC for crack inducing joint. The longitudinal final PVC strips include a cellular upper fin. The inspection fin shown on the plate shall be comparatively thin and shall remain above the top surface of lining it is important that top of the upper be at or near the concrete surface. The manner of installation shall include mechanical vibration that produces thorough consolidation of the concrete around the crack inducing joint and provides a continuous contact between the concrete and all surface of the cracks inducing joint.

(b) At intersections between longitudinal and transverse joint containing PVC strips, the top vertical member of the PVC of the longitudinal crack inducing joints, shall be cut or plugged & removed for 10 to 15cm. in width without pulling the PVC from the concrete lining and transverse crack inducing joint shall be placed within the notch so formed. Depression of the PVC of the longitudinal crack inducing joint from the concrete lining and transverse crack PVC of the longitudinal crack inducing joint below the specified positions in the concrete will be permitted at intersection only to the extent necessary to place the PVC of the transverse crack inducing joint to the specified depth. However, tolerances and concrete consolidation requirements of the preceding paragraph shall apply at intersections.

(c) The manner of making the intersection shall produce reasonably dense fit between transverse and longitudinal crack including joints and provide a nearly continuous weak end plane normal to the lining surface in both directions through the intersection.

25.18.3 Measurement and Payment

(a) Measurement will be on the basis of running meter of PVC strip joints provided as per requirements and as directed by the Engineer-in-charge. The payment will be at unit into quoted in Schedule G.

(b) The unit rate for PVC strip joints includes providing and fixing PVC for crack inducing joints 10 specified depth in panels as directed by the Engineer-in-charge costs of all material inducing wastage, equipments, labour, tools, transport with all leads and lifts, finishing and also dewatering where required.

25.19 Strip Drain and Under Drainage Arrangements

25.19.1 General

(a) Excavation of strip drain longitudinal and transverse drain shall be done to the correct lines, grades and sections as shown in the drawings. The excavated material shall be disposed off as per instructions of the Engineer-in-charge.

(b) Open joint along with pipe shall be placed in portion in the longitudinal and transverse drains and connected to pr. relief valve chambers as per layout shown on the relevant drawings.

