Section – V

CHAPTER – 25

Canal Lining

LINING OF CANALS

CONTENTS

CHAPTER -25

LINING OF CANALS

25.1 REFERENCES

IS: 651-1980	Specification for salt glazed stoneware pipes and fittings.
IS: 1398-1982	Specification for packing paper water proof bitumen laminated.
IS:2252-1981	Specification of Mortar
IS:2508-1984	Specification for low density polyethylene films.
IS3872-1990	Code of Practice for lining of canals with burnt clay tiles.
IS:3873-1993	Code of practical for laying cement concrete/stone slab lining on canals
IS:4515-1993	Code of practice for stone pitched lining cansls.
IS:4558-1990	Revised draft for under drainage of lined canals, circulated by BiS vide DOC: RVD 13 (63) in Oct. 1993 for revision of IS: 4558-1990.
IS:4701-1990	Code of practice for earthwork on canals
IS:5256-1992	Code of practice for sealing expansion joints in concrete lining on canals
IS:5690-1990	Guide for laying combination lining for existing unlined canals.
IS:5889-1970	Specification for vibratory plate compactor
IS:7246-1974	Recommendation for use of table vibrators for consolidating concrete
IS:9451-1994	Guide lines for lining of canals in expansive soils.
IS:9698-1990	Revised draft for lining of canals with low density polyethylene film circulated by BIS vide DOC:RVD 13 (155) in Oct. 1993 for revision of IS:9698-1991.
IS:10430-1991	Criteria for design of lined canals and guidelines for selection of type of lining.
IS:10646-1992	Specification on canal lining-Cement concrete tiles
IS:11809-1994	Code of practice for lining of canals Stone Masonry
IS:12379-1992	Code of practice for lining water courses & field channels
IS:13143-1991	Specification on joints in concrete lining of canals sealing compound
CWC Report June 1987	Lining of canals in Expansive Soils
Memo No.WB MP-9 of WAPCOS	Lining of main canals and branch canals of M.P. Composite Irrigation Project

T.C. 17	Canals in expansive soils-Identification and Treatment
T.C. 1/84	Concrete lining
T.C. 20	Necessity and type of Drainage Arrangements Behind Lining
CSMRS Report	Report of CSMRS on "Guideline for use of CNS soils" issued vide No. 8120/R-1/86-CSM/356 dated 18-8-87.

CHAPTER – 25

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 kaolimite 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 montmorinolite or combination of montmorinolite 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.

(b) 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.

© 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/m2 when tested according to IS 2720 (Part 10): 1991.

(D) 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

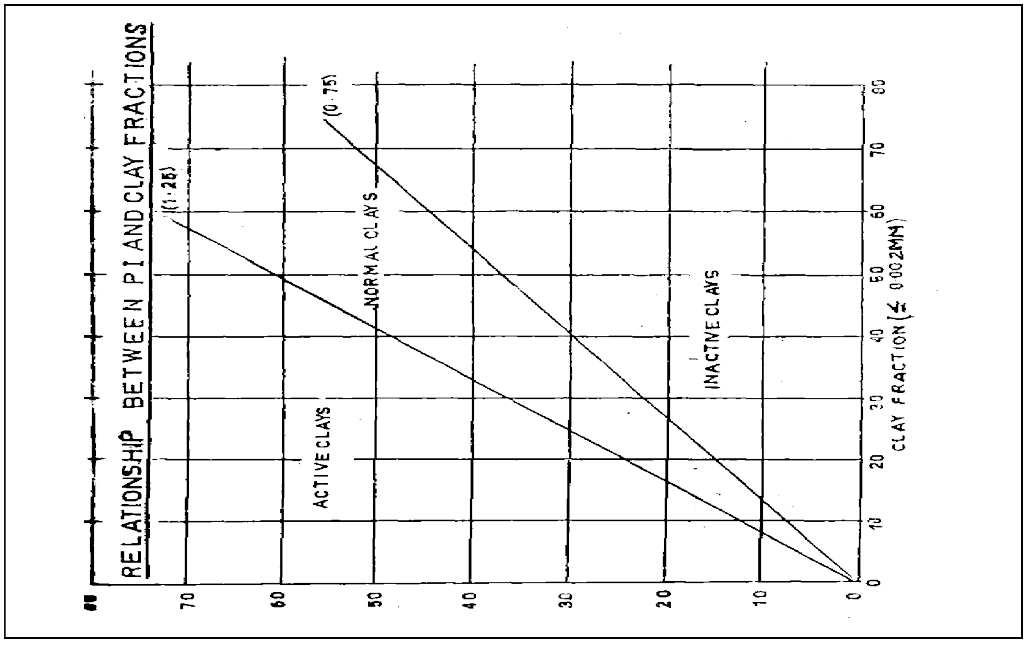


Fig 1 ACTIVITY CHART

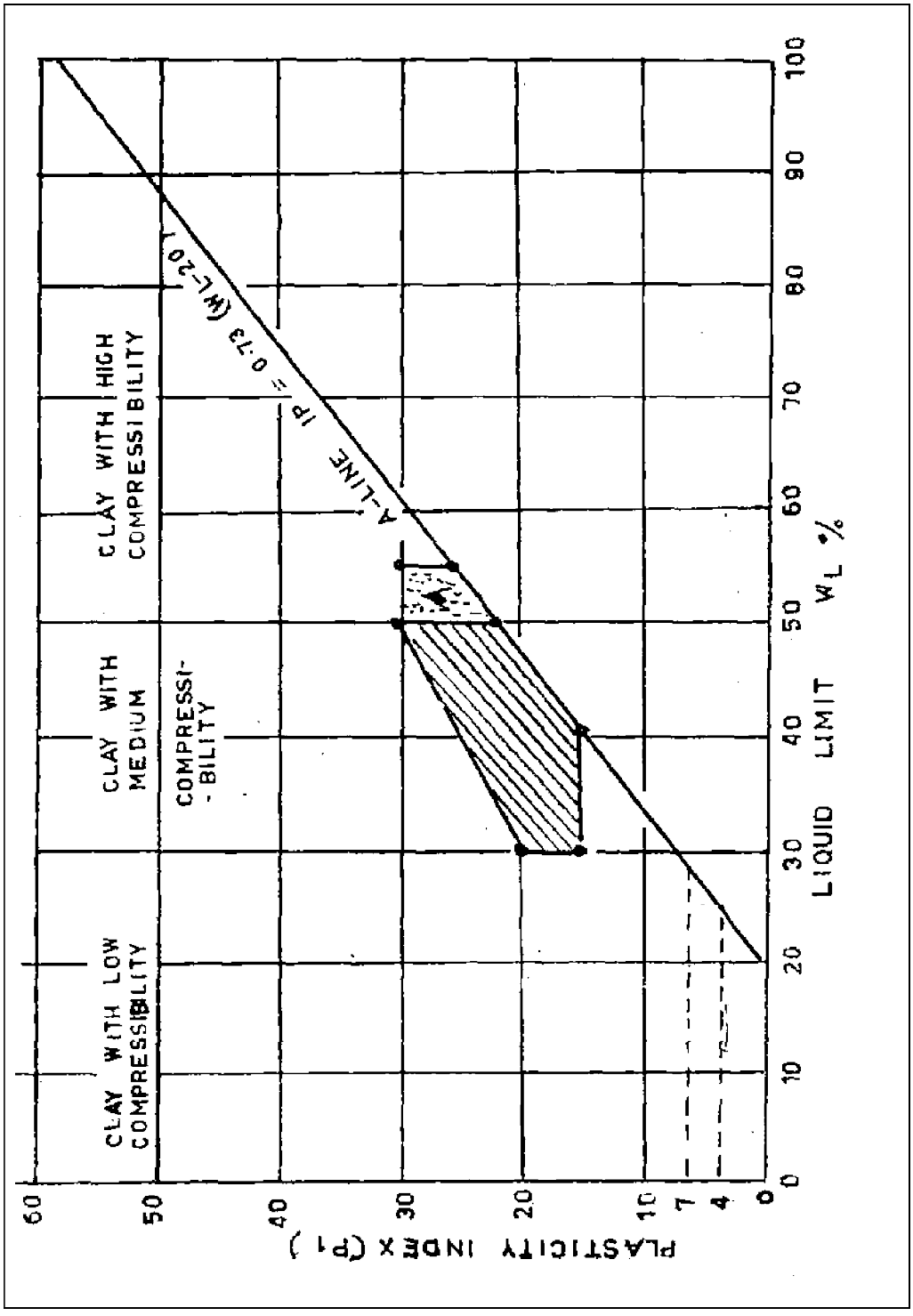


Fig 2 PLASTICITY CHART

(b) Identification using Activity Chart -

This chart (Fig.I) 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 P! 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)

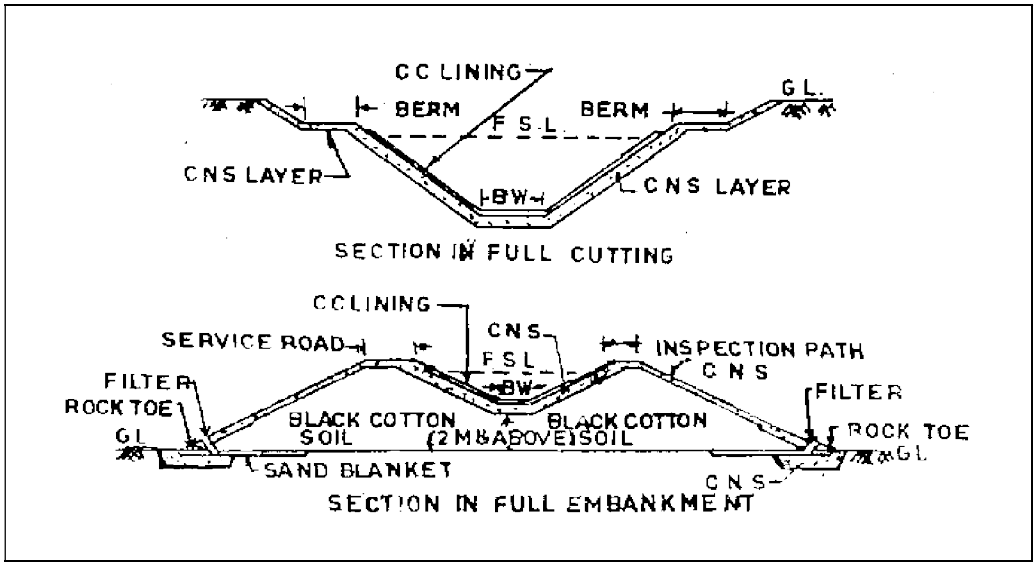


Fig. 3

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 inlayers 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 in 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

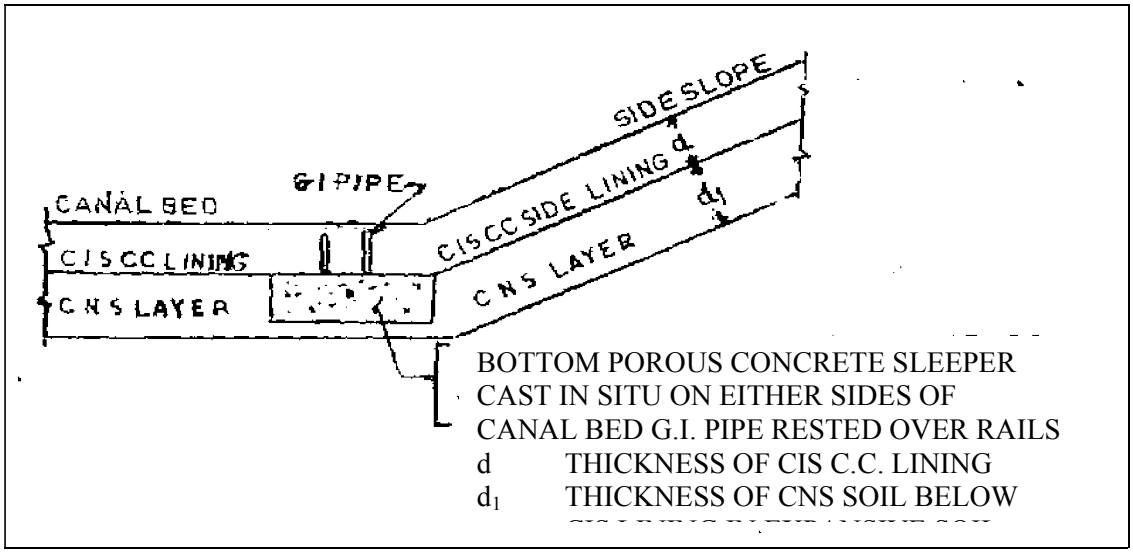


Fig.4- ILLUSTRATORY DETAIL OF BOTTOM RAILS

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 I 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 II 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/m^2. To get a good bond bitumen, bitumen and soil, crude oil at a rate of 60.5 lit/m^2 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 mururn. 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:

± 20mm on straight section

± 50 mm on tangents, and

± 100 mm on curves.

Departure from established grade:

± 20mm

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 he 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 then 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)

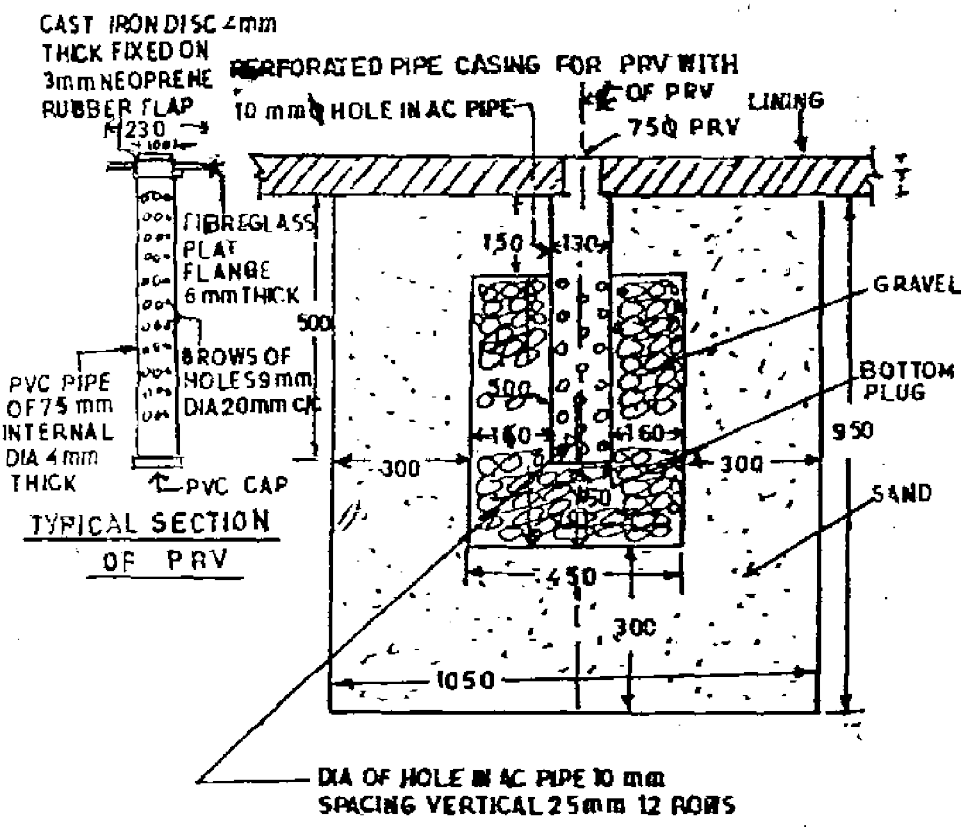


Fig. 5 TYPICAL CROSS SECTION OF POCKET FILTER WITH PRV IN BED

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 m^2 should be provided in the canal bed, while on the sides, one pressure relief for every 40 m^2 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.

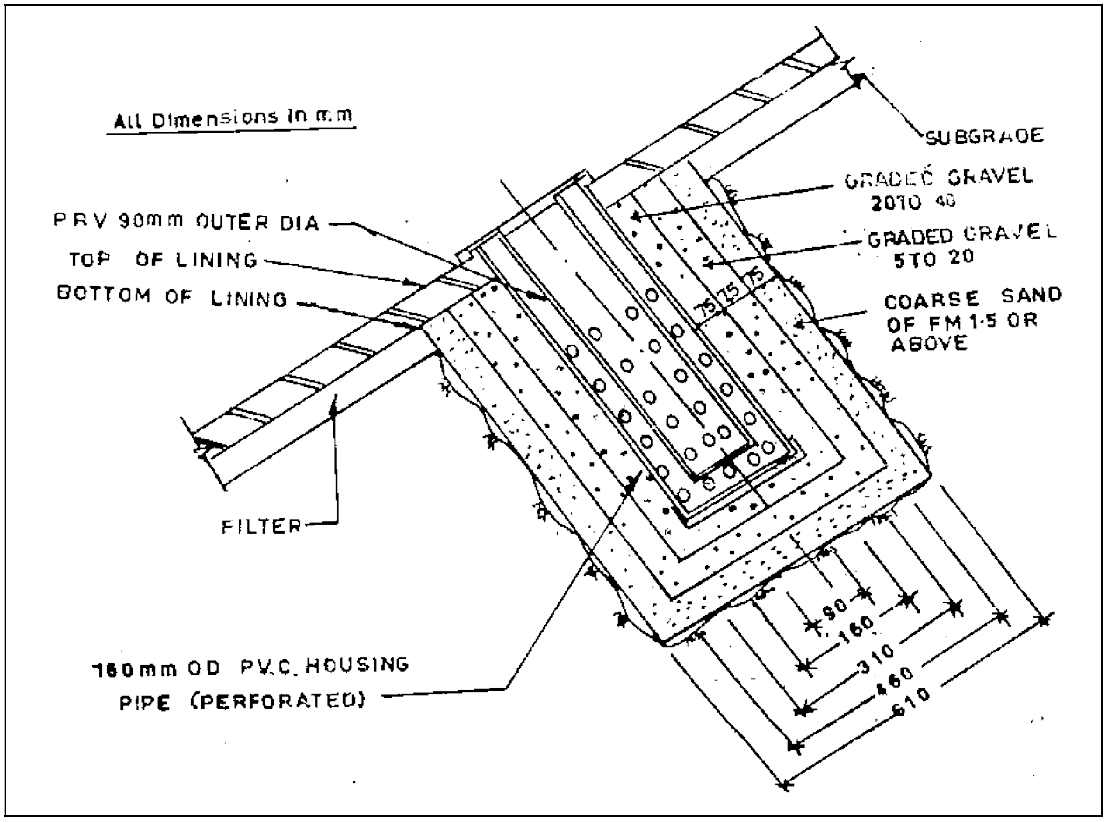


Fig. 6 PRV POCKET ON SLOPE

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.

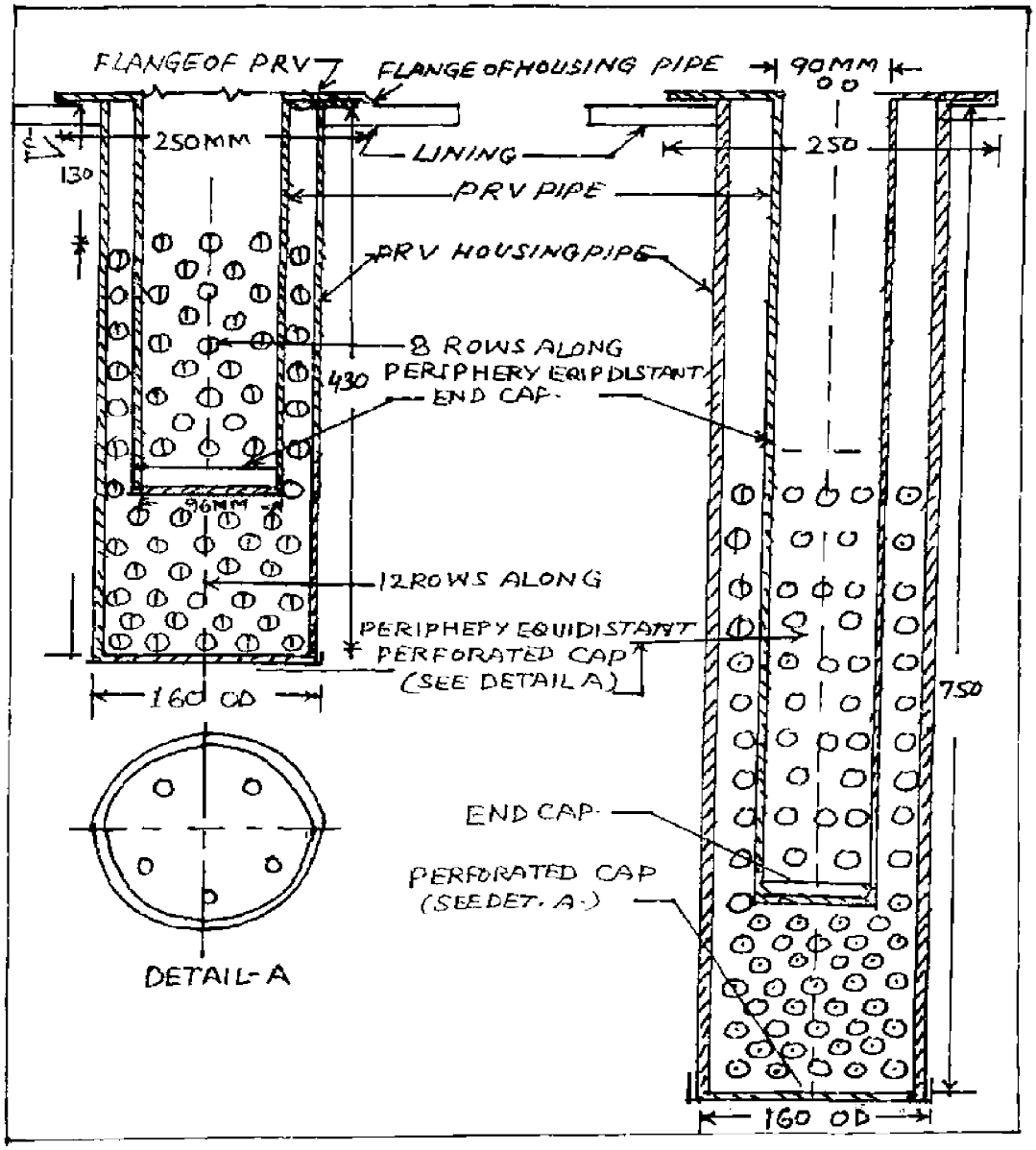


Fig. 7 DETAIL OF PERFORATION IN DRY HOUSING PIPE
(DETAIL OF PRV NOT SHOWN)

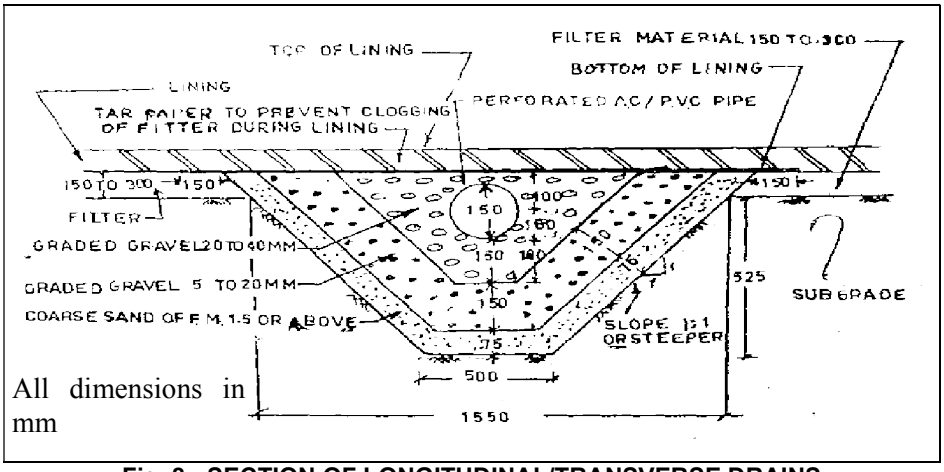
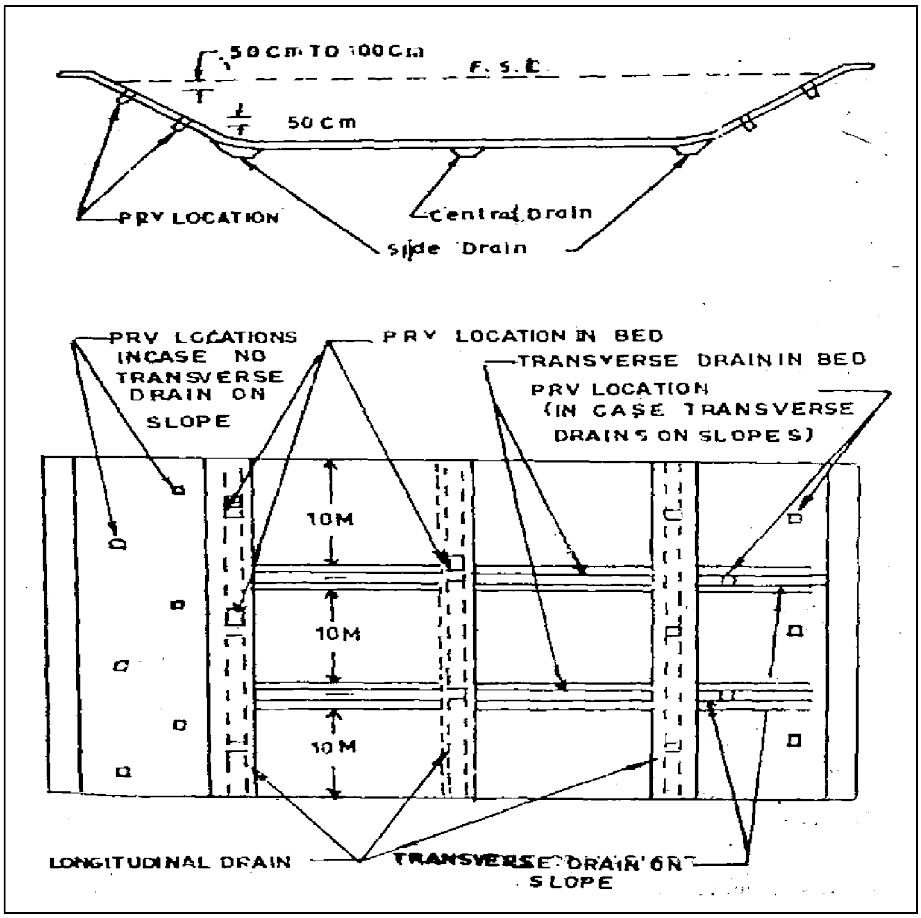


Fig. 8 : SECTION OF LONGITUDINAL/TRANSVERSE DRAINS
(pressure relief value not shown)



(Fig. 9) ARRANGEMENT SHOWING DRAINS AND PRV LOCATIONS

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 held 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.

DETAILS OF OPEN JOINTED PIPE DRAIN

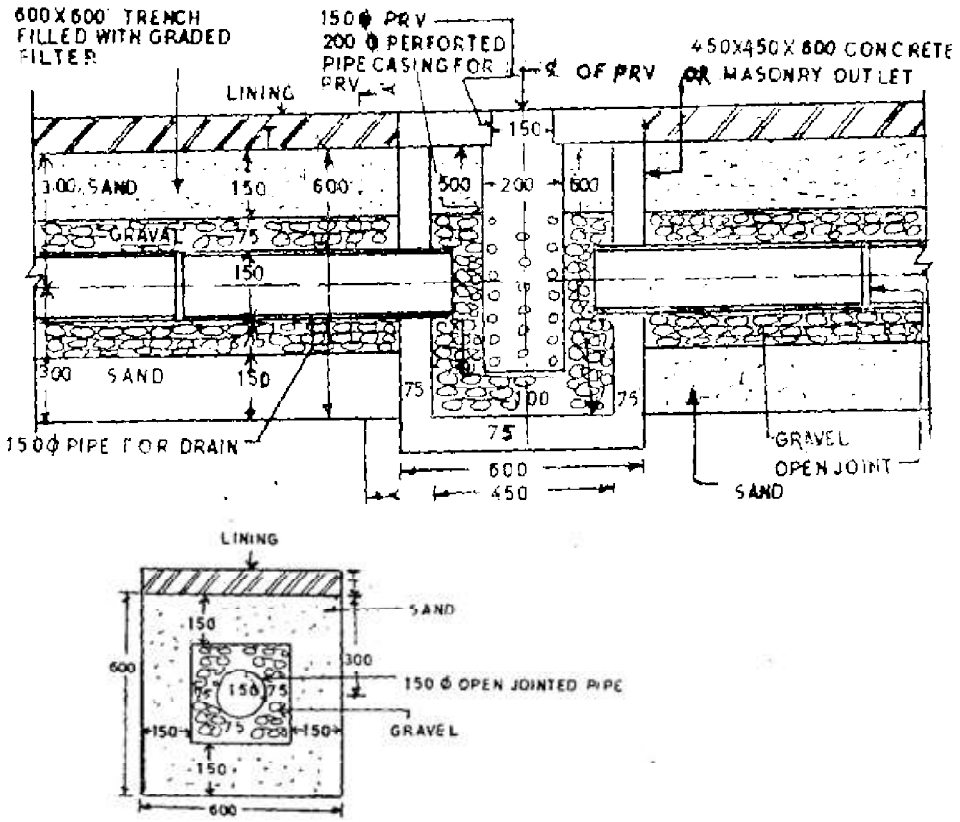


Fig. 10 DETAILS OF OPEN JOINTED PIPE DRAIN

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 para25.3.1.4

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.

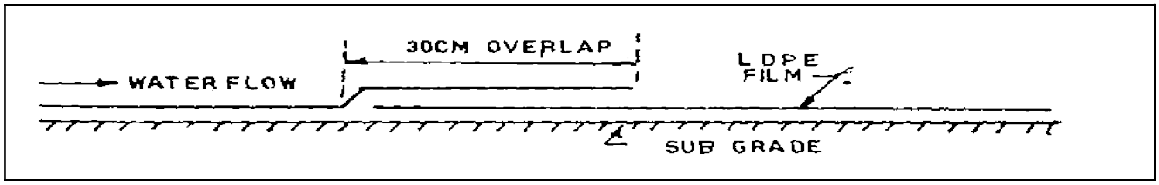


FIGURE 11 (i) Simple Overlap

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.

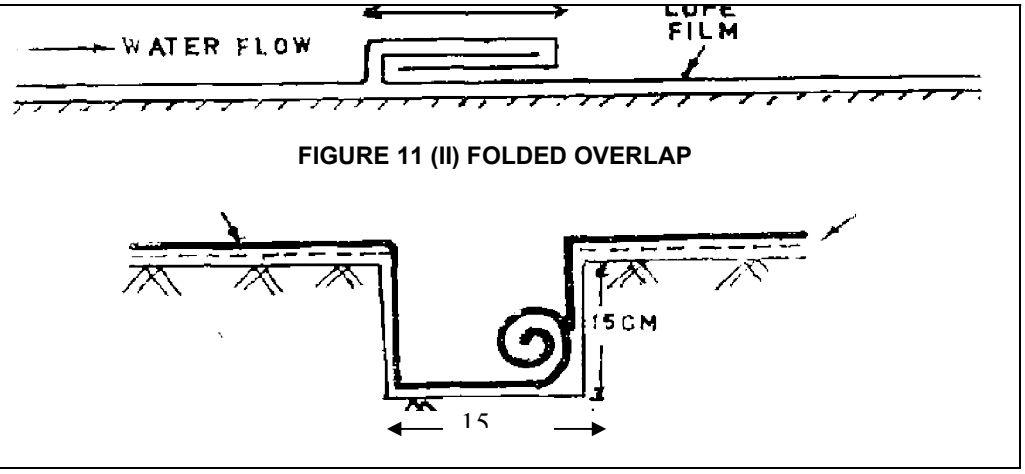


FIGURE 11 (II) FOLDED OVERLAP

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 100^0C. 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.

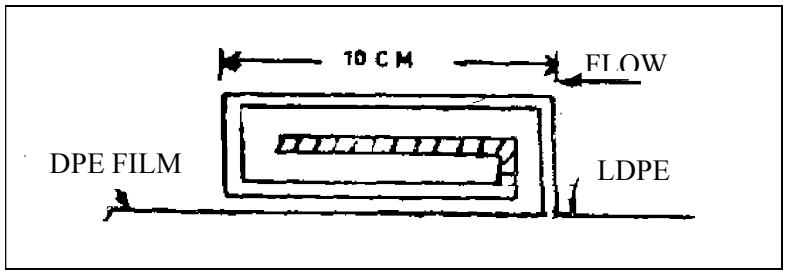


Fig 11 (iv) Jointing by hot Bitumen

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.

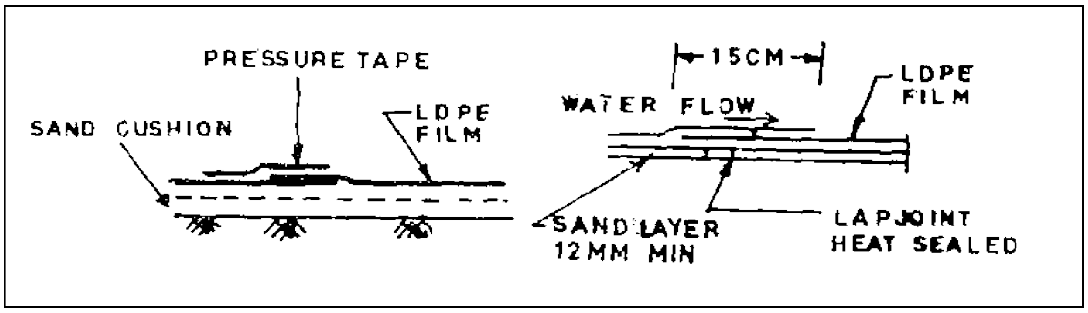


FIG. 11 (v) OVERLAP JOINT WITH PRESSURE TAPE

FIG 11 (vi) HEAT STEALING 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 stump 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	± 20 mm on straight reaches, 50 mm on partial curves or tangents
b)	Departure from established grade	± 20mm on small canals
c)	Variation on concrete lining thickness	± 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. upto2 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.

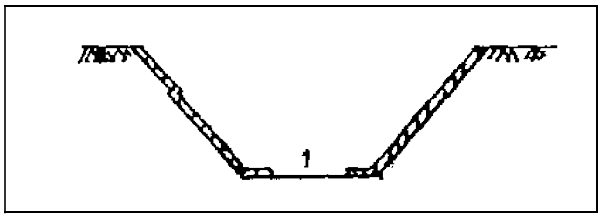


Fig. 12 Sides Cast First

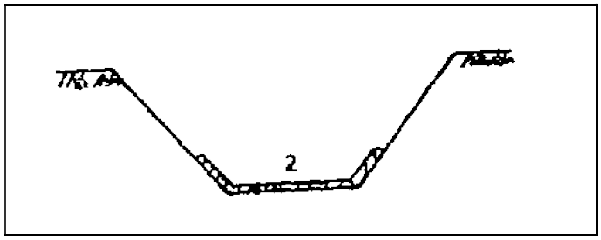


Fig. 13 Bed Cast First

25.6.3.6.2 ***Mechanical Placing of Concrete***

Concrete for slip-form should be air entrained to provide a more workable and slipabe 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

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 vide 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 intercepts 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 foil mortar and availability of sufficient number of tiles should be ensured before starting the work Arrangement for proper soaking of the files shall be made.

25.6.4.3.3 The subgrade should then be uniformly soaked with water without 1 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 filed 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.

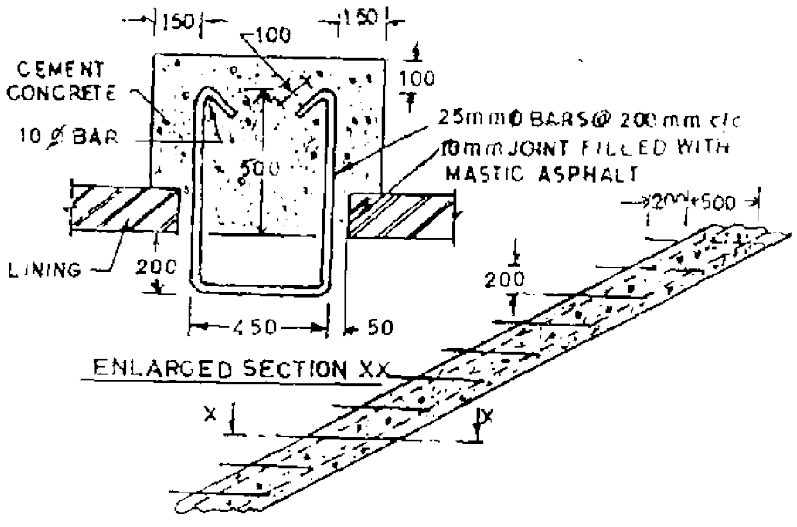
25.6.5 Safety Ladders

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



ALL Dimensions in mm

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.

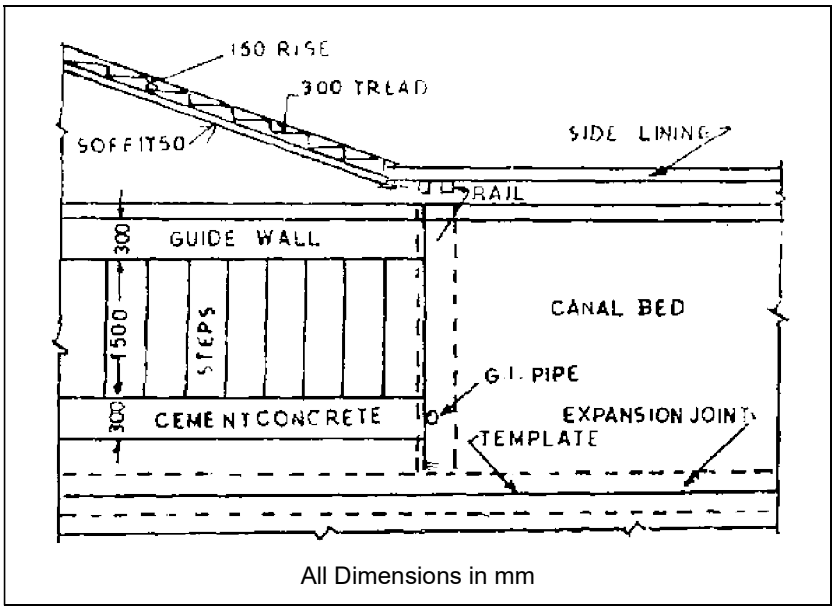


Fig. 15 Details of Steps

25.7 PRECAST CEMENT CONCRETE LINING

25.7.1 Manufacture: The precast cement concrete tile will be compressed Mechanically at the time of manufacture so as to achieve higher strength stipulated in this standard. The cement used in the manufacture of tiles shall conform to IS: 269:1989, IS:455:1989 or IS:1489-1991. Fine aggregates and coarse aggregates shall conform to IS:383-1990. The size of the coarse aggregate shall be not more than 20mm. Pozzolana conforming to IS:1344-1990 or IS:3812-1992 may also be used as aggregate. The potable water shall be used for mixing concrete and curing.

25.7.2 Dimensions

25.7.2.1 The nominal dimension shall be as below:

500 mm x 500 mm x 250 mm, 400 x 400 mm, 300mm x 300mm and 250 mm x 250 mm.

25.7.2.1.1 Each these shall be manufactured in the thickness 60, 50 and 40 mm.

NOTE- However other size than these given in 25.7.2.1 may also be manufactured if specifically required by the user.

25.7.3 Tolerance

In length and breadth shall be 3 mm and thickness shall not be less than the specified value.

25.7.4 Shape

the tile shall have its all sides at right angles to the faces.

25.7.5 Flexural Strength of Manufactured Tiles.

When tested according to the method given at Annex. II minimum breaking load per cm length of tile shall not be less than 41 kg for 60 mm, 29 kg for 50 mm and 18 kg for 40 mm tiles thickness.

25.7.5.1 Marking

25.7.5.1.1 Each tile shall be suitably marked as under:

a) Source of manufacture, and

b) Size with thickness.

25.7.5.1.2 The tiles may also be marked with the Standard Mark.

25.8 FLAG STONE LINING

25.8.1 Shaping & Size - Each flag stone shall be rectangular or square in shape and of uniform thickness. The stone slab should conform to IS-128-1988 or IS-3622- 1993 of length 0.45 M to 0.9 M width 0.45 M and thickness 35 to 50 MM

NOTE- The size (length and width) of stone slab may vary. But at least one dimension shall be as specified above, so that the longitudinal joints run continuous and parallel.

25.8.2 Physical Characteristics

Flag stone slabs shall be sound, clean, hard and tough. It shall be free from sand holes, weathered portions, adhering, flaws, cracks, soft seams and other inherent defects due to subsequent weather effects. The slabs shall be quarried fresh from the quarry in all cases and only the slabs conforming to requirements of theses specifications shall be brought to work site for use.

The physical properties of the flag of the stone shall be as below :-

S.No.	Characteristics	Requirements	Method of testing (Ref.to IS)
1.	Moisture absorption after 24 hrs. immersion in cold water.	Not more than 2.5 percent by weight	IS: 1124-1990
2.	Transverse strength	Not less than 7N/MM	IS:1121-1993
3.	Resistance to wear	Not greater than 2mm, on the average and 2.5mm on any individual specimen.	IS: 1704-1960
4.	Durability	Shall not develop signs of spalling disintegration or crack.	IS:1126-1990

25.8.3 Dressing Of Slabs

The sides shall be chisel dressed vertically roughly to a depth of 10 mm. Beyond this depth the sides shall be dressed slightly splayed so as to from an inverted shaped joint with the adjoining flag stone.

25.8.4 Preparation Of Sub-Grade

The subgrade shall be prepared as per provisions laid down under para 25.3 as applicable.

25.8.5 Profiles

Flag stone profiles of lining at right angle to the center fine of the canal shall be prepared at suitable intervals. Mortar shall be uniformly spread over the subgrade (15 ± 5 mm, to accommodate tolerance in slab thickness) and the stone shall be properly laid in bed at right angle to the centre fine of the canal while on the side slopes they shall be laid parallel to the centre line. Enough number of profiles both in bed and slopes shall be laid each day so mat when the work is started next day me marks shall be already in position.

25.8.6 Laying

25.8.6.1 Flag stones shall be cut, dressed and finished to the size and shape mentioned in para 25.8.1 and 25.8.3 or any other size found convenient in handling or as per site conditions and as directed by Engineer-in-Charge. Half size flag stone mentioned in para 25.8.1 shall also be made available for breaking joints at me time of placing them m position.

25.8.6.2 Stones and other construction materials shall be carted and stacked at convenient intervals along the canals to avoid excessive lead and handling of materials.

25.8.6.3 For lowering the flag stone in canal bed, wooden or iron chute of width suitable for flag stones and sides 7.5 cm high shall be used. Flag stone shall not be lowered by sliding m the surface of previously completed fined section of the canal. At the bottom of the chute one or two earth filled bags should be kept to prevent the stones from breaking by hitting hard canal bed.

25.8.6.4 The laying of flag stones shall be started only when atleast 35 m length of canal with subgrade is properly dressed to receive fining. Necessary arrangements for proper soaking of flag stone slabs, mortar mixing arrangements and sufficient number of flag stones shall be made available before starting me work.

25.8.6.5 Where Ground Water is high, the water table shall be lowered to atleast 30 cm below the sab-grade by dewatering.

25.8.6.6 The subgrade shall men be uniformly soaked with water without making it slushy to ensure hot water penetrates generally to a depth to about 300 mm m sandy soil and about 150 mm in other soils. Wetting of subgrade shall continue in advance of laying of tiles so that the soil does not absorb moisture of cement mortar (1:5 mix) laid on me subgrade for laying the flag stone.

25.8.6.7 Before placing a flag stone at least 15 ± 5 mm, thick fairly stiff cement mortar of 1:5 mixes shall be laid on the subgrade prepared as above/polyethylene sheet by covering the area to be occupied by each flag stone. Mortar shall not be spread in advance. It shall be ensured that each flag stone obtains an area of contact with the mortar of not less than 90%. The bottom of the flag stone shall be cleaned with a wire brush and surface made wet just before placing it in position. The joints between adjacent flag stone shall have a width not exceeding 20 mm at exposed face. Mortar in the joint shall also be placed at the time of laying each flag stone as a simultaneous operation and well grouted into it. Cement mortar for joints should be fairly stiff on 1:5 mix.

25.8.6.8 **Curing** - On completion of laying and from the next day, the lining shall be kept wet by sprinkling water over it keep the mortar well wetted.

On the next day the surface shall be kept wet and joints of the stone slab shall be carefully tested. Hollow joints shall be raked to a depth of 12 mm. loose mortar removed from sides and top of stone slabs and the joints properly refilled. Any loose stone slab shall be removed and relaid. Curing of mortar joints after laying should be ensured for 14 days. Satisfactory curing can be achieved by covering the joints with soaked gunny bags and keeping the same wet for 14 days.

25.8.6.9 The completed lining shall be checked for level with wooden templates and spirit levels.

25.8.6.10 The horizontal embedment of lining into the embankment at the top of lining in the case of flag stone lining shall be done with cast-in-situ 6 cm thick cement concrete 1:3:6. The embedment shall extend atleast 20 cm into the earthen embankment.

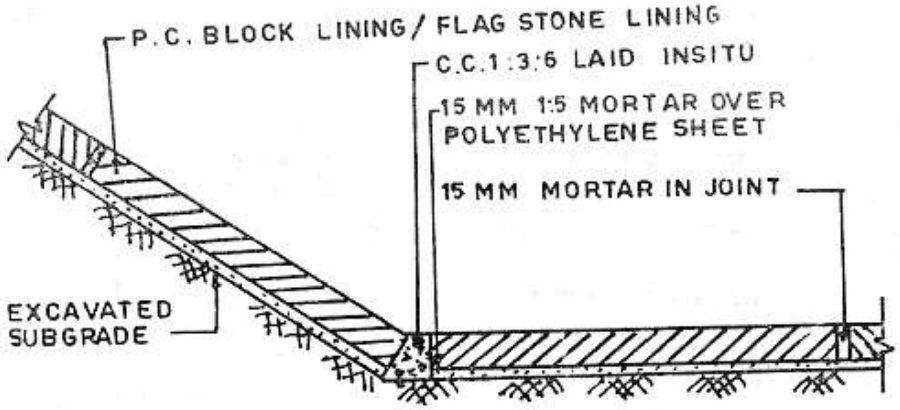


Fig. 16 P.C. Block Lining Detail Of Bed With Side

25.8.6.11 The trapezoidal junction of blocks in the bed and the side slope shall be facilitated by placing a small quantity of concrete in wedged shape as shown in fig. 16.

25.9 BURNT CLAY TILE LINING

25.9.1 Layers of Tiles for Bed and Side Slopes - The lining shall consist of single tile lining or double tile lining as specified by the Engineer-in-Charge (see Fig. 17). The tiles used for lining of canals shall conform to IS:3367-l993 and shall be of class 105, class 75 as specified. The average compressive strength shall not be less than 105 kg/cm2 for class 105 and 75 kg/cm2 for class 75.

25.9.1.1 Bed

25.9.1.1.1 Single Tile Lining - This shall consists of single layer of burnt clay tiles laid on about 10 mm thick 1:5 cement mortar on the well dressed sub-grade (see Fig. 17 A). Joints shall be well filled with mortar of the same consistency. Joint shall than be raked to 12 mm depth and after that not less than 20 mm thick cement plaster 1:3 shall be laid on it, which shall be given smooth finish. The mortar shall be laid on 6 m lengths, the lengths being laid alternatively. The total thickness of lining shall be not less than 80 mm. The thickness of joints shall not exceed 10 mm.

25.9.1.1.2 Double Tile Lining - This shall consist of double, layer of tiles, with a sandwiched layer of cement mortar, laid in accordance with para 25.9.1,2

Note :- However, the first layer of tiles in the canal bed may be allowed to be replaced by 75 mm thick 1:3:6 brick-bat cement concrete with necessary modifications in the rates of tile items. This change shall be allowed only to the extent required for utilising the broken tiles accumulated on the site due to normal breakages during the course of the work.

25.9.1.2 Side Slopes, Double Tile Lining - The sides shall consist of double layer of tiles with not less than 15 mm thick sandwiched layer of cement mortar of 1:3 mix. The first layer of tiles shall be laid on about 10 mm thick 1:5 cement mortar spread on compacted sub-grade dressed to specified slope. The joints shall be filled with mortar of the same consistency. The first layer of tiles shall be covered with 1:3 cement plaster not less than 15 mm thick on the top of which second layer of tiles shall be laid in about 5 mm. thick 1:3 cement mortar except for the bottom one metre length before its junction with single tile lining in the bed. The last metre in such-case shall be joined to the single tile lining m the bed by laying 1:2:4 cement concrete in half metre width and by laying 1:3 cement mortar in the rest half. Total thickness of lining masonry shall be not less than 130 mm (see Fig. 17 A and 17 B).

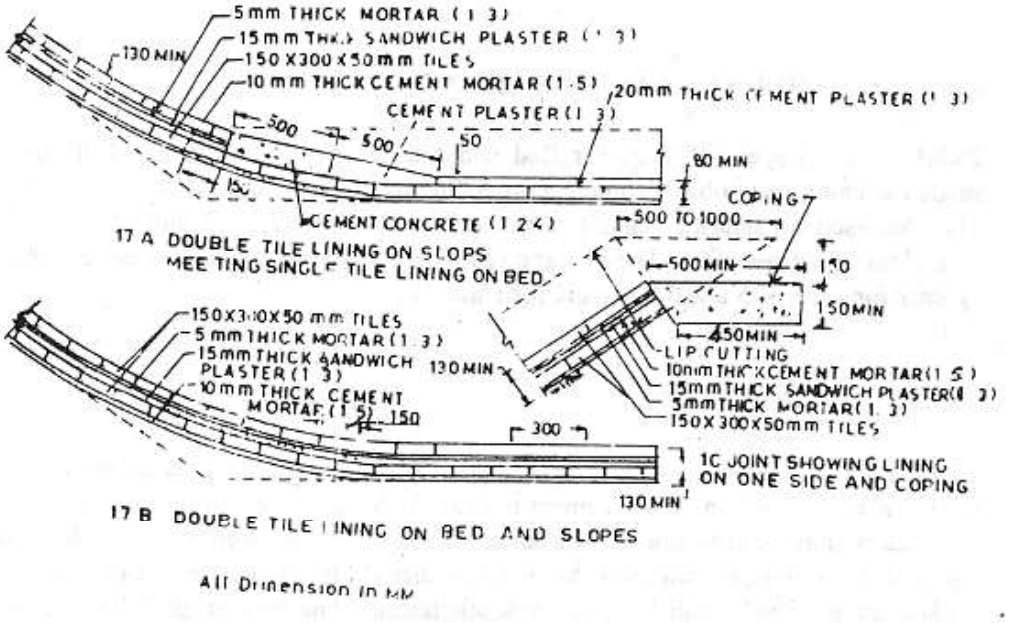


Fig. 17 Typical Sketch Of Canal Lining With Burnt Clay Tiles

25.9.2 Thickness

25.9.2.1 The thickness of joints shall not exceed 10 mm.

25.9.3 Mix For Cement Mortar

The following proportion for cement mortar shall be used for lining works. However, the mortar shall conform to IS:2250-1981.

(a)	For 10 mm thick cement mortar sub-grade	1:5 By Volume
(b)	Mortar for masonry of first layer of tiles	1:5 By Volume
(c)	For 15 mm thick sandwich cement and sand plaster	1:3 By Volume
(d)	For 5 mm thick cement and sand mortar and for tile masonry for, top layer	1:3 By Volume
(e)	For20 mm thick cement and sand plaster over the layer of tiles for single tile lining in bed.	1:3 By Volume

The use of pozzolana and other admixture including water-proofing compounds may be permitted, if approved by the Engineer-in-Charge. The pozzolana shall conform to the relevant Indian Standard.

25.9.4 Top Coping

To check the leakage of rain water behind the lining in sides, not less than 150mm, thick cement concrete coping of Grade M-100 conforming to specifications given under chapter 7 & 16 or of a double layer of tiles with a mortar mix specified for slopes (see para 25.9.3) shall be provided horizontally on the top of the fining (see Fig.17). The width of the coping at the top shall not be less than 350 mm.

25.9.5 Preliminary Work

25.9.5.1 Preparation of subgrade - The sub-grade shall be prepared as per provisions laid down under para 25.3 as applicable.

25.9.5.2 Hump- Humps of concrete of masonry about 150 nun high shall be provided where necessary in the bed of the canal at every 300 m intervals, to ensure that during short closures the bed of the canal does not dry and thus does not expose the plaster to direct rays of sun which may otherwise result in formulation of cracks.

25.9.5.3Soaking Of Tiles

Arrangements shall be made by those engaged in the work and be regulated mat tiles properly soaked in water for at least two hours are available for carrying out the work during each day.

25.9.6 Laying Of First Layer Of Tiles-First And Second Day Programme

25.9.6.1 The fining shall be started only when at least 35 m length of canal with subgrade is properly dressed to receive lining. Necessary arrangements and sufficient number of tiles be made available before starting the work.

25.9.6.1.1 Where spring level is high the water table shall be lowered to at least 30 cm below the subgrade by de-watering.

25.9.6.1.2 The sabgrade shall then be uniformly soaked with water without making it slushy to ensure that water penetrates to a depth of about 300 mm in sandy soil and about 150 mm in other soils. Wetting of subgrade shall continue m advance of laying of tiles so that the soil does not absorb moisture from 10 mm thick mortar laid on the subgrade for laying the layer of tiles.

25.9.6.1.3 Single tile profiles of lining parallel to centre line of the canal shall be prepared at suitable intervals. Mortar shall be uniformly spread over the subgrade and the tiles shall be properly laid in position quickly after that. Care shall be taken to see that the vertical joints are completely filled with mortar. The tiles shall be laid m bed at right angles to the centre line of the canal while on me side slopes they shall be laid parallel to the center line.

25.9.6.1.4 Enough number of profiles both in the bed and slopes shall be laid each day so that when the work is started next day the marks shall already be in position. Construction points or panels at suitable width each bed and sides shall be perfectly rolled, levelled and laid with profiles every day to receive lining of the first layers of tiles on the next day.

25.9.6.1.5 Tiles shall be firmly embedded in mortar. Hollows, if any, shall be rectified by relaying the defective portions with fresh mortar.

25.9.6.2 Curing And Correction - Thud And Fourth Day Programme -

On the third day the layer of tile shall be kept wet by sprinkling water over it, to keep the mortar well wetted on the fourth day, the surface shall be kept wet and joints of the tile masonry shall be carefully tested. Hollow joints shall be raked to a depth of 12 mm, loose mortar removed from sides and top of tiles and joints properly refilled. Any loose tile shall be removed and relaid.

25.9.6.3 Laying Cement Mortar Layer-Fifth Day Programme

25.9.6.3.1 Cement plaster of 1:3 mix shall be laid on the completed portion of the bed. To ensure proper thickness of mortar being laid and to achieve perfect -level in spreading of cement mortar L-shaped wooden frame of 1m x 1.5 m made of 20 mm, thick wooden plankings, shall be used. The plaster shall be well pressed while laying so that any excess of water or air locked into pores is driven out, thereby exercising uniform plaster over the layer of tiles. The surface of the plaster shall be finished even and smoothness after lightly sprinkling it with pure cement. This ensures a smooth hard surface thus checking the erosion of the surface of the plaster by water action.

25.9.6.3.2 For Double Tile Lining - When double tile lining is to be laid either on bed or side slopes, not less than 15 mm thick sandwiched layer of 1:3 cement sand mortar shall be laid by using L-shaped wooden frames of 1m x 1.5 m made of 15 mm, thick wooden plankings. This shall be done to ensure that correct thickness of 50 mm, is obtained over the whole surface. The plaster shall be well pressed while laying so that any excess of water or air locked into pores is driven out, thereby providing uniform plaster over the first layer of tiles. The upper side of the plaster shall be made rough for proper bond with the upper layer of tiles by means of fibre brushes or brooms. Wire brushes and nails shall not be used for the purpose.

25.9.6.3.3 The cement sand plaster shall be kept well wetted on the sixth day.

25.9.6.4 Laying Top Layer Of Tiles-Seventy Day Programme

25.9.6.4.1 The top layer of tiles in case of double tile lining shall be laid in 1:3 cement mortar about 5 mm thick. This layer of tiles shall be laid firmly and properly to proper levels in beds and correct slopes on the sides with joints not more than 10 mm thick.

25.9.6.4.2 Tiles used on the top layer shall be the best and laid with great precaution. Vertical joints shall be laid flush with cement mortar and no cement pointing shall be done on top of the tiles. The completed lining shall be checked for level with wooden templates and spirit levels.

25.9.7 Inspection

Daily inspection of the work shall be carried out at the site and joints found empty shall be localised and thereafter filled properly and relaid, if necessary. The results of inspection may be kept in proper log book.

25.9.8 Curing

Work done on each day shall be kept thoroughly wet for curing. In case of single tile lining, subsequent to laying of cement plaster layer and after 24 to 36 hours; and in case of double tile lining after laying the second layer of tiles, the lining shall be cured for at least 28 days. For bed, this may be done by constructing 150 mm deep earthen bunds across the bed so that a small depth of water shall stand on the upstream of the bunds and curing assured.

The curing of side slopes shall be done by constructing masonry drains with deep holes or perforated pipes on the coping at the top of the lining or by using sprinklers.

25.9.9 Maintenance During Laying

During the progressive construction of lining the labours shall walk on foot-paths of planks provided for the purpose. Walking on layer of tiles, finished plastered surface or the lined portion of the canal unless properly set and cured for a period of 15 days, shall not be permitted. Such irregularities may cause dislodgement of tiles resulting in pervious lining.

25.9.10 Safety Ladders

Safety ladders shall be constructed in canal lining where shown on the drawings or as directed by the Engineer-in-Charge.

25.10 BOULDER LINING FOR CANALS

25.10.1 Specification For Stones For Lining

25.10.1.1 Stones used for lining should be rounded or subangular river cobbles or blasted rock pieces with sufficient base area to be stable.

25.10.1.2 An the stones should have reasonably uniform size with dimensions as given in Table 6. depending upon the canal capacity.

25.10.13 Individual stone should he sound, hard and durable and should be such that they will be able to sustain weathering and water action. They should be free from laminations, soft spots, cracks, seams and other defects.

NOTE - The help of tests and requirements given in Table-7 for stone may be taken in making a judgment of the suitability of stones for canal lining.

Table - 6 Dimensions of Stones and Thickness of lining

(Para 25.10.1.2)

Thickness of Lining mm	**Average Dimension Along the Longest Axis in mm**
150	150
225	225
300	300

NOTES-

1**,** A maximum tolerance of 10 percent is permissible in the thickness of lining and the dimensions of stones.

2. Lining's safe velocity may be adopted as 1.5 m/sec.

Table 7 Requirements for Stones

(Para 25.10.1.3) (Note)

Test	Requirements
Specific (apparent) gravity when tested according to the method given in IS: 1126:1974	Greater than 2.5
Soundness (Sodium sulphate method)when tested according to IS: 1126:1974	Less than 10 percent loss of weight after 5 cycles

25.10.2 Preparation Of Sub-Grade

The sub-grade should be prepared according to Para 25 - 3.

25.10.3. Laying

25.10.3.1 Sub-grade (both bed and slope) for the canal should be divided into compartments by stone masonry or concrete ribs. The Compartments should have dimensions of not more than 15m along the centre line of me canal The spacing of ribs across the centre line should be so chosen as to divide the canal bed and dope symmetrically about the centre line and in such a manner that ribs are provided at the junction of the slope and bed and of the upper extremity of the slope. The ribs along the slope of the bank should be continuous (see Fig. 18)

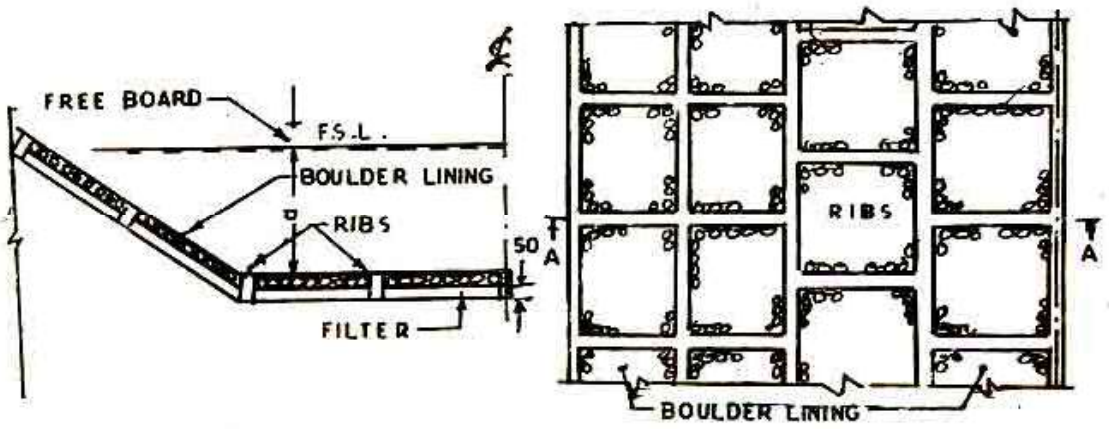


Fig. 18 Illustratory Layout Of Pitched Lining For Canal

25.10.3.1.1 If stone masonry ribs are used, the stones should meet the requirements specification 25.10.1.3.

25.10.3.1.2 If concrete ribs are used they should be made of Grade M 10 concrete in accordance with IS:456:1991.

25.10.3.1.3 Ribs should be rectangular in cross-section with width equal to the dimension of stone along its longer axis as specified in 25.10.1.2 and depth equal to the depth of lining plus thickness of filter.

25.10.3.2 A 15 cm thick layer of filter material, where required, should be laid in compartments formed by ribs. Filter material should be in accordance with the requirements specified in 25.10.4.

25.10.3.3 Stone, should be carefully hand packed in the compartments. The placing method should be such as to ensure a reasonably smooth surface and uniform thickness.

25.10.3.3.1 Spaces between the stones should be minimised. Such spaces should be wedged with spalls of suitable size to avoid filter material being washed out Such filling should immediately follow the placing of stones.

25.10.4 Filter

25.10.4.1 Filter material where required, should be free from flakes, soft particles, shale, organic matter of other deleterious substances.

25.10.4.2 Filter should satisfy the criteria

i) $\frac{\text{D15 (Filter)}}{\text{D15 (Base)}} > 4 \text{ and } < 20$

ii) $\frac{\text{D15 (Filter)}}{\text{D85(Base)}} < 5$

25.10.4.2.1 Where a large difference exists between the grading of the free draining material and of the soil to be retained, it may be necessary to use more than one layer of filter material, each progressively larger in grain size but satisfying the filter criteria given in 25.10.4.2. with respect to the adjacent lower layer.

25.10.4.3 Construction of Filter

25.10.4.3.1 The sub-grade, before placing the filter, should be firm and compacted suitably, wherever necessary according to IS:3873-1993.

25.10.4.3.2 Clean filter material should have sufficient water content (3 to 10 percent) during placement and placement should be such that segregation is prevented.

25.11 STONE MASONRY LINING FOR CANALS

25.11.1 Preparation Of Subgrade

25.11.1.1 Preparation of the subgrade should be done in accordance with para 25.3.

25.11.2 Laying

25.11.2.1 The stones should be of dimensions mentioned in Table 8 and should have specific gravity not less than 2.5 when tested according to IS:1122-1993 and soundness not less than 10% loss of weight after 5 cycles when tested according to IS: 1126-1990.

soundness not less than 10% loss of weight after 5 cycles when tested according to IS:1126-1990.

Table 8 : Dimensions of Stones and Thickness of Lining

(Para 25.11.2.1)

S.No.	Canal Capacity cumecs	Thickness of lining mm	Average Dimension along the longest axis mm	Minimum Dimension at any section mm
i)	0 to less than 10	150	150	75
ii)	10 to less than 100	225	225	110
iii)	100 and above	300	300	150

Note : Tolerance upto 10 percent is permissible in the thickness of lining and the dimensions of stones.

25.11.2.2 The stone should be laid on lime mortar (1:2) or cement mortar 1:3 over a bed of minimum 12 mm thick lime/cement mortar. The joints shall be pointed with similar mortar.

25.11.2.3 The lining should be started after at least 35m length of canal sub-grade is properly dressed to receive lining. The sub-grade should be uniformly soaked with water, without making it slushy, to ensure that water penetrates to a depth of about 300 mm in sandy soil and about 15° mm in other soils. Wetting of subgrade should continue in advance of laying of stone slabs so that the soil does not absorb moisture from the mortar placed on the subgrade for laying of the stone masonry layer.

25.11.2.4 If the water table is high it should be lowered to at least 300 mm below the subgrade.

25.11.2.5 The subgrade should be divided into compartments by stone masonry or concrete ribs of size not less than 300 mm x 150 mm. The compartments should have dimensions of not more than 15°m along the centre line of the canal. The spacing of ribs across the centre line should be selected in such a manner so as to divide the canal bed and slope symmetrically about the centre line, so that ribs are provided at the junction of the slope and bed and at the upper extremity of the slopes. If stone masonry ribs are used, the stone should meet the requirements given in 25.11.2.1

25.11.2.6 Pressure relief arrangements should be done according to para 25.4.

25.11.2.7 Single stone profiles of lining, parallel to centre line of the canal, should

with their length at right angles to the cater line of the canal, while on the side slopes they should be laid parallel to the center line.

25.11.2.8 Stone should be firmly embedded in mortar. Hollows, if any, should be rectified by relaying the defective porticos with fresh mortar.

25.11.2.9 On completion of laying and from the next day, the lining should be kept wet by sprinkling water over it to keep the morter well wetted, on the next day, the surface should be kept wet and joints of the stone masonry should be carefully tested. Hollow joints should be raked to a depth of 12 mm, loose mortar removed from sides and top of stone and the joints property refilled. Any loose stone should be removed and relaid.

25.11.2.10 The completed fining should be checked for level with wooden templates and spirit levels.

25.12 WATER COURSES AND FIELD CHANNELS LINING

25.12.1 General

25.12.1.1 The shape of the lined water-course may generally be rectangular, trapezoidal or semicircular. Following are the types of lining:

a) Brick/tile lining

b) Composite cement concrete and brick masonry lining

c) Cement concrete in-situ/precast lining

d) Stone slab/stone masonry fining, and

e) LDPE film with rigid cover.

25.12.1.1.1 Earthwork in Non-compaction Zone - it shall be free from shrubs, clods and shall be laid in 150 mm thick layers. Measurements shall be made as in the case of filling and 10 percent deductions may be allowed from actual measured cubical contents. The outer side slope shall depend upon the type of soil and height of the fin.

25.12.1.2 Compaction of Earthwork Under Bed :- Earth-work shall be laid under the bed in 75mm thick layers and compacted with steel tampers or by other mechanical means at optimum moisture content.

Note:- This type of earthwork shall be applicable for fin at the back of vertical wall only. For other sections, the earthwork shall be m accordance with IS:4701-1982.

25.12.1.3 **Soil Survey** - It is to know the type of soil moisture content and dry density attainable along the entire length of water-course or earthen channel

25.12.1.4 **Up Cutting** - After the compaction, the water course/field channels are cut to the final section by removing the extra soil from the bed and from the inner slopes of the banks.

25.12.1.5 **Alignment and Layout** - Construction bench marks shall be provided at an interval of 100 m with double levelling. The centre line of the water course/ field channel to be marked on pegs at an interval of 6 to 10 m apart longitudinally and shall be so fixed that their tops indicate the correct bottom level of the bed fining.

25.12.1.6 **Slope** - The bed slope of the lined section of the water-course to be adopted is fixed with regard to the designed full supply level at the head of the watercourse, the critical level of the field to be irrigated from the water-courses or the branch under consideration subject to the minimum limit of slope of 1.5 cm/100 m length, as far as possible. The permissible tolerance for finished bed level of water-course shall not be more than 1 cm as compared to the designed level

25.12.1.7 In case of problematic soils, suitable engineering measures shall be taken.

25.12.1.8 Free Board - 7.5cm of free board shall be provided above the calculated full supply level

25.12.1.9 Sub-grade - The surface over which lining is to rest is called sub-grade. It is to be perfectly true in profile in accordance with the cross-section of the watercourse so as to form a firm compacted bed for the lining.

25.12.2 **Procedure For Lining**

24.12.2.1 **Earthwork**

25.12.2.1.1 **Excavation -** The centre line shall first be pegged out and marked with DAG BEL or dimension lines as per designed L-section of channel All curves shall be properly laid down and the line indicating the top of the cutting or the toe of the embankments shall then be set out. These lines shall be ascertained from the X-section of the existing ground work and finished work. Reference pegs shall also. be driven into the ground.

25.12.2.1.1.1 Before commencing construction work, complete profiles of the compacted portion of the bed and embankments indicating finished section shall be set up at 150 metres apart or at such intervals as required due to the physical condition. These profiles shall be 3 metres in length along the alignment. Ends of the profile banks shall be stepped so that proper bond shall be achieved with earth fill laid afterwards. When the side slope in existing surface is more than 1:4, the ground shall be trenched or stepped to have Solid embankments. Manual excavation in cutting for channels shall be carried out in 0.6m to 1.5m lifts. Special precautions shall be taken to ensure that

excavation may be drained properly to prevent accumulation of water or formation of rain cuts. No excavated material shall be placed within 0.9 m from the edge of any trench. All gangways, paths and steps shall be kept within the section so that their removal in the end leaves the section true to design. In case of deep excavations, proper shuttering shall be done to avoid collapsing of trench.

25.12.2.1.1.2 Borrow pits shall be used for obtaining soils for earthfills only where absolutely unavoidable. No borrow pits shall be dug within 5 metres of the final section of the embankments, after making due allowance for future development. All borrow pits shall be dug to maximum depth of 0.3 m only.

25.12.2.1.1.3 All mud, slush and decay or other vegetation shall be excluded from the filling and clods of broken earth. The filling shall be placed in continuous horizontal layers of 75 mm thickness for hand compaction. Water shall be sprinkled on each layer and thoroughly rammed before the next one is laid. Filling shall be started from the outer edges working towards the centre in slightly concave layers and dressed to the desired cross-section of the channel. Earthfills shall be free from lenses, pockets, streaks or layers of material differing in texture. No filling shall be commenced without the permission of the Engineer-in-Charge.

25.12.2.2 Brick Lining - Bricks required for brick work shall be according to the specifications laid in IS 1077-1992 and shall be soaked m clear water immediately before use -for one hour or till the complete cessation of air bubbles, whichever is later. They shall be kept free from sand and silt. The bricks shall be laid in English bond with frogs upward. Half or cut bricks should be used only where required near the end of the walls (see Fig. 19)

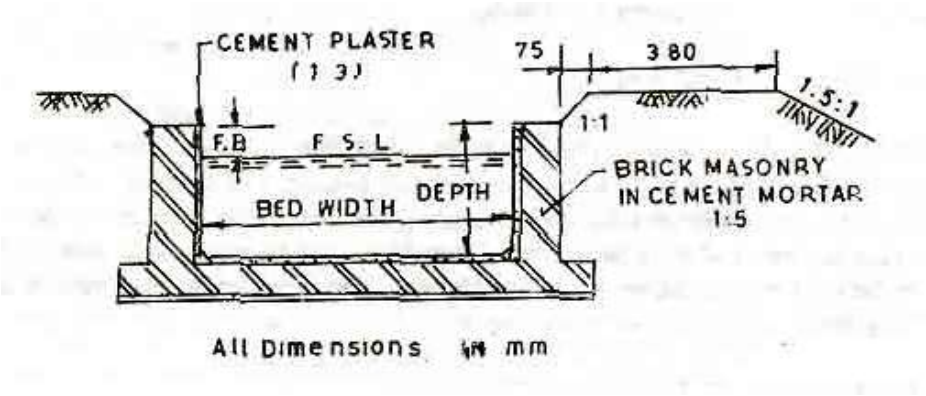


Fig. 19 Typical Brick Masonry Section

25.12.2.2.1 Section of the Side Walls - The width of the side walls shall be 115 mm for height upto 450 mm (6 courses). For height of the side walls of 525 mm (7 courses), the first course shall be of one full brick, that is, 225 mm width and 75 mm height. The width of the remaining six courses of the side

wall shall be 115 mm. For the height of side wall of 600 mm (8 courses), the first two courses shall be of full bricks, that is, the width will be 225 mm and the height will be 150 mm. The width of the remaining 6 courses win be 115 mm (see Fig.20)

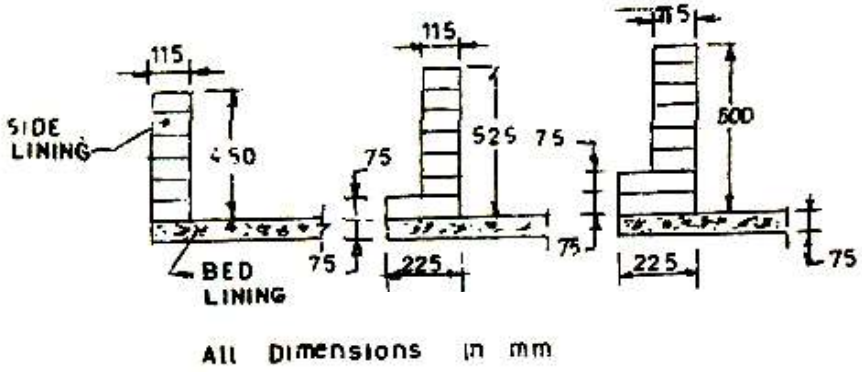


Fig. 20 Typical Section Of Side Walls

25.12.2.3 Composite Cement Concrete and Brick Masonry Lining - Following are the two methods for carrying out the lining work:

a) A bed of 50 mm thick 1:3:6 cement concrete is laid over 100 microns LDPE film conforming to IS:9698-1990. Side walls are constructed in brick masonry in 1:4 cement sand mortar (without plaster). The inside and top of these vertical walls should be finished with 10 mm thick 1:3 cement sand plaster (see Fig. 21).

b) Brick masonry in 1:5 cement sand mortar (with plaster) or 1:4 cement sand mortar (without plaster) on the sides and 5 cm thick 1:3:6 cement concrete in the bed should be laid over 1.5 to 2.0 cm thick subgrade of slate pieces/100 microns LDPE film.

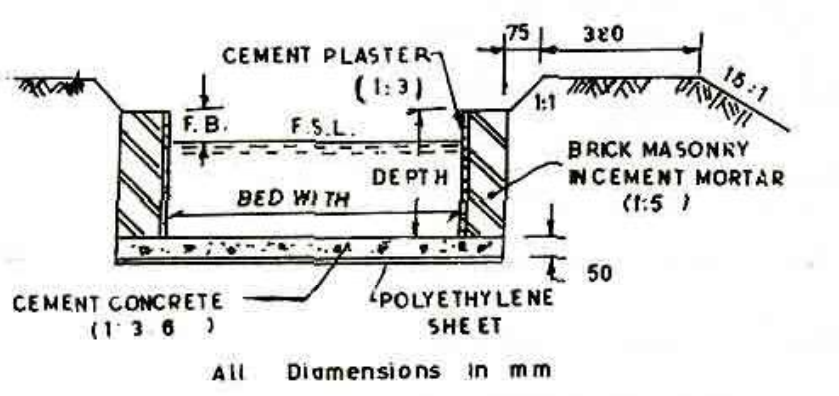


Fig. 21 Typical Cement Concrete And Brick Masonry Section

25.12.2.4 Cement Concrete Lining- 50 mm thick 1:3:6 cement concrete should be laid m the bed over a 100 micron LDPE film. The vertical side walls should be constructed with 75 mm thick 1:3:6 cement concrete. In case LDPE film is not being used, 75 mm thick 1:3:6 cement concrete shall be laid (see Fig.22).

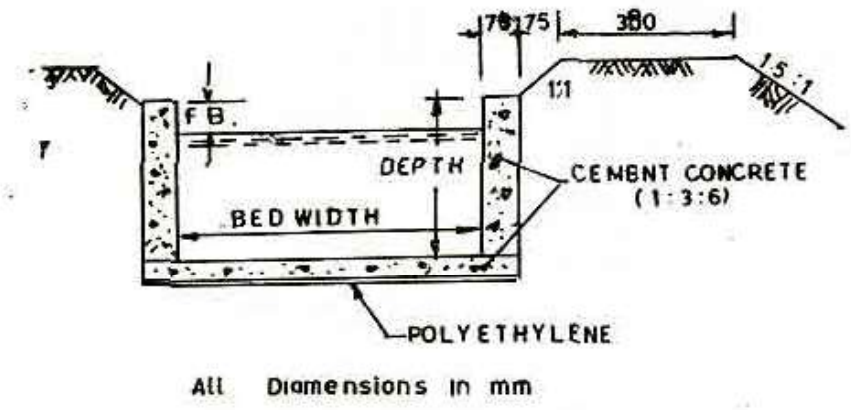


Fig. 22 Typical Cement Concrete Section

25.12.2.5 Stone Slab/Stone Masonry Lining

25.12.2.5.1 Stone Masonry Lining - Stone shall be free from laminations, soft spots, etc. Stone masonry should be laid in 1:2:8 mortar (1 cement: 2 lime : 8 stone dust) 1:5 (1 Cement :5 sand mortar). The joints should be raked and pointed with 1:3 cement mortar (see Fig.23)

25.12.2.5.2 Stone Masonry Lining - stone slab used for the bed shall have thickness of 25 mm. Stone dab should be laid in 1:2:8 mortar (1 cement: 2 lime : 8 stone dust) or 1:5 (1 cement : 5 sand mortar). All the joints shall be raked and pointed. Masonry on the sides shall be laid m 1:2:8 cement Bme/l:4 cement sand mortar. The remaining courses of side walls may be laid m 1:4 cement sand mortar,

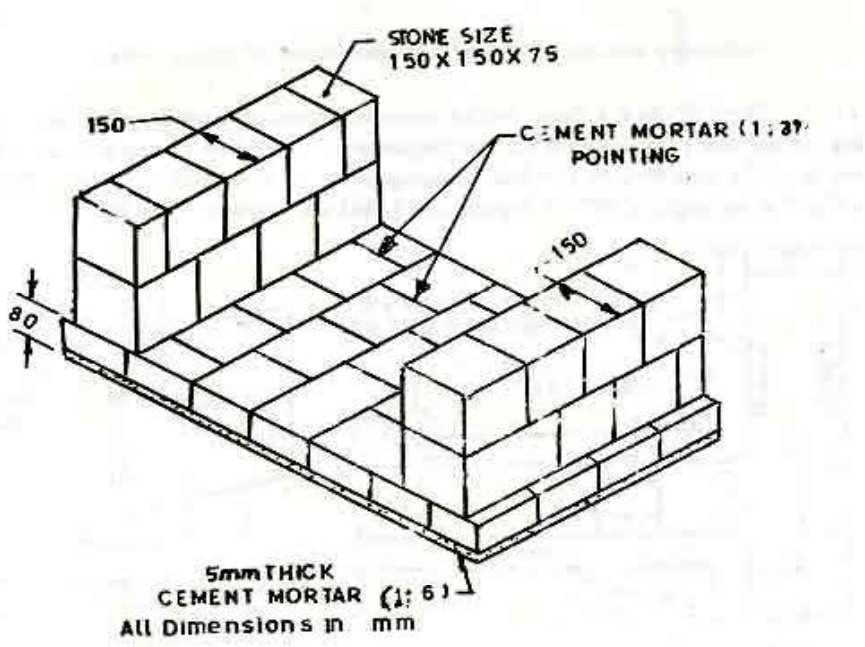


Fig. 23 Stone Masonry Lining

25.12.2.6 **Pre-Cast Cement Concrete Lining** - It shall be in accordance with para 25-7

25.12.2.7 **Strength Development** - Strength development is an important requirement before masonry/concrete is loaded to the full extent. The rate of construction shall synchronize with the development of strength, particularly in weak mixes. Extreme care shall be taken by putting the earth work behind the lining. Initially about 50 percent of the quantity of earthwork or upto 75 percent of the height shall be done. After a couple of runs of water in the lined water-course, the remaining earthwork may be completed and dressed.

25.12.3 **Testing**

25.12.3.1 The lining work constructed as explained in 25.12.2 shall be tested for leakage by filling the lined portion with available water. The points where some leakage is indicated shall be marked. These shall then be treated by raking and filling the joints on both sides of the side fining properly, wherever possible.

25.12.4 **Turnout For Nakka**

25.12.4.1 It is a structure capable of diverting the entire stream of water from the water-course to the chaks or from the field channels. These channels shall be strong because the farmers have tendency to dig and use earth around this structure to control leakage at gate point and thus unknowingly weaken the structure.

25.12.4.2 Following .are the two most common types of nakka plates:

a) **Steel Nakka** - Steel nakka plate is provided with handles (one or two depending on the size) and a chain with angle piece at the end having split sicks which is embedded into the masonry of the nakka structure so as to avoid pilferage. The steel nakka is fixed at an angle of 60°. A typical steel nakka is shown in Fig.24.

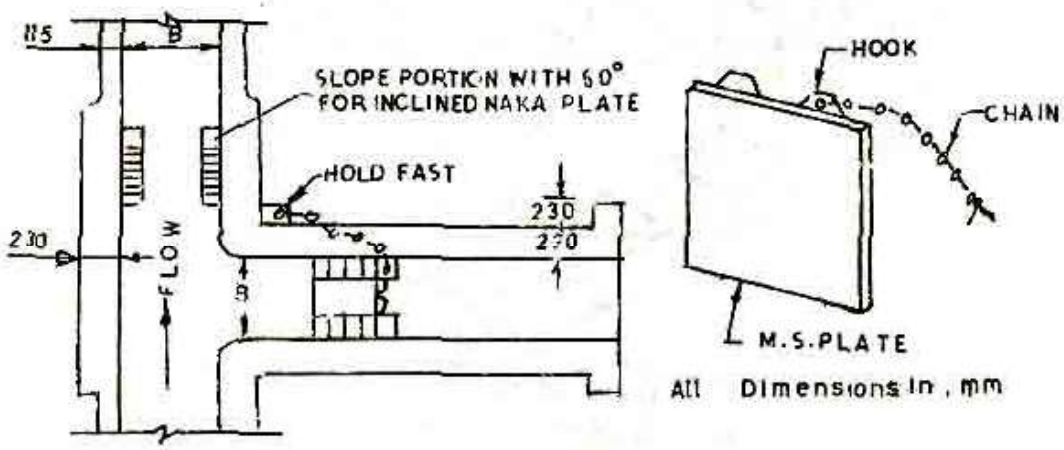


Fig. 24 Typical Design Of M.S. Plate Nakka Structure

b) **Circular Nakka** - It consists of a panel and a lid. The panel is fixed into the masonry of nakka structure at an angle of 60°. The lid is fixed into the panel after a couple of rotary motions. This is a water tight arrangement and practically no earth is required to control the seepage. A typical circular nakka is shown in Fig.25.

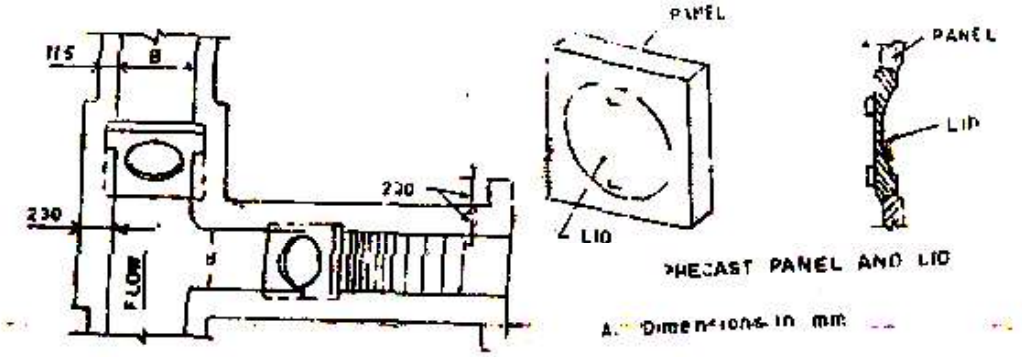


Fig. 25 Typical Design Of CIRCULAR Nakka Structure

NECESSITY AND TYPE OF DRAINAGE ARRANGEMENT

SUB-	GWT ELOW ANAL BED LEVEL CUTTING	REACHES	FILLING	REACHES	GWT ABOVE CANAL CUTTING	REACHES
1	2		3		4	
	I. Discharge above 15 cumec :					
(i)	Freedraning	---------- no drainage arrangement is necessary ----------			----------	
(ii)	Poorly	---------- no drainage arrangement is necessary ----------			------	
(iii)	draining	---------- no drainage arrangement is necessary ----------			----------	
	II. Discharge between 0.3 cumec to 3.0 cumec :					
(i)	Freedraning	---------- no drainage arrangement is necessary ----------			Bed : Longitudinal drain (LD) with pressure release valve (PRV) in pocket filter (PF) at15 m interval. Slope: PRV in PF at 15 m interval	
(ii)	Poorly draining	---------- no drainage arrangement is necessary ----------			Bed : LD with PRV in PF at 10.0m interval.	
(iii)	Impervious/rocky	---------- no drainage arrangement is necessary ----------			Bed : Sand filter and LD with PRV in PF at 10m interval. Slope: Sand filter from FSL evtended upto	
	III. Discharge between 0.3 cumec to 15 cumec :					
(i)	Freedraning	---------- no drainage arrangement is necessary ----------			Bed: LD with PRV in PF at 10 m Interval Slope: PRV in PF at 10 m Interval.	
(ii)	Poorly draining	Bed : LD with PRV in PF at 15m interval. Slope : TD from FSL connecting to LD in bed at 15 m interval.	Bed : Sand filter with PRV in PF at 15m interval. Slope : (i) Cutting portions-sand filter from FSL extending upto bed. (ii)Filling portion (a) draning – No arrangement		Bed: LD with PRV in PF at 10 m Interval Slope : TD from FSL connecting to LD at 10m Interval	
(iii)	Impervious/rocky	Bed : Sand filter and LD with PRV in PF at 15m interval. Slope : Sand filter from FSL extending up to bed	Same arrangement as indicated in III (ii) column-3		Bed : Sand filter and LD with PRV in PF at 10m interval Slope : Sand filter from FSL extending up to Bed	

(Continued……..)

1	2	3	4
iv	**Discharge above 15 cumecs :**		
(i)	Freedraning	---------- no drainage arrangement is necessary ----------	Bed : Longitudinal pipe drain (LPD) with PRV in outlet at 10.0m interval. Slope : Transverse drain (TD) from FSL connected to LPD at 10.0 m
(ii)	Poorly draining	Bed : LPD with PRV in outlet at 15m interval. Slope : TD from FSL connected to LPD at 15.0 m interval.	Bed : LPD with PRV in outlet at 15m interval. Slope : TD from FSL connected to LPD at 15.0 m interval.	Bed : LPD with PRV in outlet at 10.0m interval. Slope : (TD) from FSL connected to LPD at 10.0 m interval.
(iii)	Impervious/rocky	Bed : Sand filter and LPD with PRV in outlet at 15m interval. Slope : Sand filter from FSL extending up to bed	Same arrangement as indicated in IV (ii) column 3	Bed : Sand filter and LPD with PRV in outlet at 10m interval. Slope : Sand filter from FSL extending up

Notes:

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(i) In case canal is passing through bunded paddy field the operative rainy season water level may cause hydrostatic pressure to build up against the lining in canal slopes. Therefore, if the hydraulic gradient line with an assumed 6:1 slope from the field adjoining the canal cuts the canal side slop more than 30 cms above the canal bed, drainange arrangement applicable for WT above CBL shall be provided even

(ii)Highest ground water table (GWT) available in a year shall be considered for providing drainage behind lining.

(iii)In case of GWT below CBL but perched ground water table above CBL, drainage arrangement as indicated in deep cutting for impervious /rocky subgrade shall be provided

(iv)PRV in slope shall be staggered with reference to bed.

(v) Explanation of abbreviations :-

(i)	GWT	-	Ground Water Table	(v)	LD	-	Longitudinal drain
(ii)	CBL	-	Canal bed level	(vi)	TD	-	Transverse drain
(iii)	PRV	-	Pressurerelease valve	(vii)	LPD	-	Longitudinal pipe drain
(iv)	PF	-	Pocket filter	(vii)	FSL	-	Full supply level

ANNEXURE - II

TEST FOR FLEXURAL STRENGTH OF MANUFACTURED TILE

(Para 25.7.5)

A-l SAMPLE

A-1.1 For ascertaining {he conformity to the requirements for flexural strength test, one tile from each lot of 500 shall be selected at random and tested.

A-2.1 Lot shall be considered conforming to the requirements of the flexural strength test if the sample passes the requirements of the test. In case it fails to satisfy the requirements of the test, two more tiles shall be selected at random from the same lot and tested for the requirements of flexural strength If any of these two tested fails to satisfy the strength requirements the lot shall be rejected.

A-2 TEST

A-2.1 The specimen shall be immersed m potable water for 24 hours and then taken out and wiped dry.

A-2.2 The specimen shall be placed horizontally on roller bearers 150 mm apart with their length parallel to bearers. The load shall be applied at mid-stand by means of steel bar parallel to the bearers. The length of the bearers and that of the loading bar shall be longer than the length of the specimen and their contact shall be rounded to a diameter of 25 mm. A plywood packing 3 mm thick and 25 mm wide shall be placed between the specimen and the loading bar. The loading bar and the bearers shall be self-aligning (see Rg.26)

A-2.3 Starting from zero, the load shall be increased steadily and uniformly at the rate not exceeding 2 kg/cm length (measured along with the bearers) per minute up to the load specified in 25.7.5. which shall be maintained for at least 1 minute. There shall not be any visual crack in the tile.

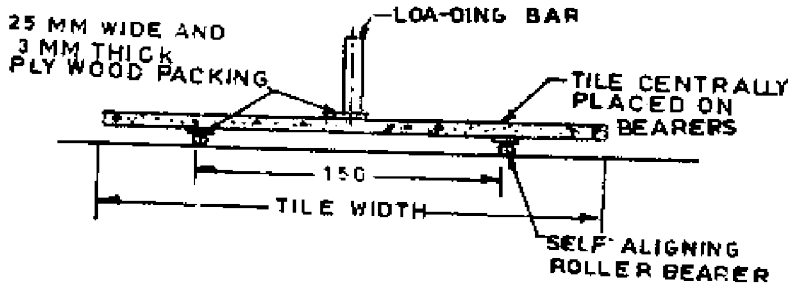

Fig. 26 Method Of Test For Flexural Strength Of Tile

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