



MANUAL FOR LINING IN IRRIGATION CANALS IN WEST BENGAL

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GOVERNMENT OF WEST BENGAL
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Introduction

- 1.0 Lining of canals is an important feature of irrigation projects as it improves the flow characteristics and minimizes the loss of water due to seepage. Lining also helps in retention of shape of the canal. Functions of lining, apart from seepage control and retention of shape of the canal, may include but not be limited to, increased hydraulic efficiency, increased resistance to erosion / abrasion, and low operation and maintenance cost.

Relevant BIS Codes for canal lining

- 2.0 Following Codes brought out by the Bureau of Indian Standards, after finalization of the drafts by the Irrigation Canals & Canal Linings Sectional Committee, and consequently approved by the River Valley Division Council, are relevant.

Sl. No.	Title	BIS Code No.
1.	Criteria for design of lined canals and guidance for selection of type of lining (First Revision)	IS 10430: 2000 (Amended 2005 & Reaffirmed 2009)
2.	Laying cement concrete / stone slab lining on canals – Code of Practice (Second Revision)	IS 3873: 1993 (Amended 2000 & Reaffirmed 2004)
3.	Canal linings – Cement Concrete Tiles – Specification (First Revision)	IS 10646: 1991 (Amended September 2000 & Reaffirmed 2004)
4.	Under Drainage of Lined Canals – Code of Practice (Second Revision)	IS 4558: 1995 (Reaffirmed 2001)
5.	Guidelines for lining of canals in expansive soils (Edition 3.1)	IS 9451: 1994 (Reaffirmed 2004)

Apart from the above Codes, “Plain and Reinforcement Concrete – Code of Practice” (IS 456: 2000, Reaffirmed 2005) is also relevant, for cement concrete lining, particularly in regard to the environmental exposure condition, vis-à-vis minimum grade of concrete for different exposures.

Objective of the Manual

- 3.0 Selection of a particular type of lining, keeping in consideration the general requirements, as well as site specific requirements, including structural stability,

economy, availability of construction materials, machinery & equipment, skilled and unskilled labour, subsequent repairability, ability to prevent weed growth, resistance against burrowing animals, structural stability during and after construction etc., requires a judicious evaluation of various available options. The task is not easy for the field level officials due to the exercise of consultation of so many Codes / Guidelines, provision of which are mostly generalistic, applicable for the entire country and may not always be truly representatives of the special features of sub-grade soil in different districts / regions within the geographical boundary of the State. Therefore, the field level officials often have to refer the cases to the Design Wing, resulting in delay of the implementation of the projects. With a view to obviate these difficulties, this Manual has been brought out to serve as a zone / districtwise ready reckoner for the field level engineers for proper selection of type and other parameters of lining, depending on discharge capacity of canals, position of Ground Water Table (GWT), and soil characteristics. However, recommendations of the Manual would generally be applicable to the normal soil characteristics or conditions generally found in any region and the field level officials may still refer special cases involving typical problems and issues, to the Design Wing of this Department, in case of any doubt. The approach methodology, governing general guiding principles and recommendations for selection of lining in irrigation canals have been discussed in the subsequent paragraphs.

Approach methodology for preparation of the Manual

4.0 Firstly, relevant codal provisions have been perused and correlated to follow a unified approach. These have subsequently been compared with the engineering practices being followed by the Department Officials in various districts since last fifty years, keeping in view the availability of construction materials including relative merits and demerits of these materials, trend of changes in construction technology over the years and most importantly, success as well as failure stories in different areas or projects together with reasons of such success and failure. Recommendations on the basis of such comparative case studies have finally been suggested keeping in view the following considerations:

- Adherence to the spirit of the provisions / guidelines of two relevant BIS Codes and convergence of provisions with the prevailing good construction practices.
- Standardization of recommendations on the basis of following key parameters:
 - ➔ Discharge capacity of the canals;
 - ➔ General soil characteristics encountered in various zones and districts, especially permeability of sub-grade soil;

- ➔ Position of groundwater table;
 - ➔ Availability of construction materials;
 - ➔ Common difficulties faced during construction.
- Economy in design, without sacrificing stability and durability both during and post construction.

Guiding Principles for determination of type, location and parameters of lining

5.0 Following guiding principles are recommended on the basis of the approach methodology stated in Para 4.0 above.

5.1 As a general guidance and subject to results of the soil test and assessment of position of Ground Water Table (GWT) stated in Para 5.2 hereinafter, following cases may be considered for lining:

5.1.1 Canal lining only on the side slopes (canal bed excluded) may be provided,

- (a) Where there is an established history / evidence of unstable side slope, causing rapid and successive deposition of soil particles from sides into the canal bed, canal section has been enlarged or deshaped, irrespective of whether the canal is passing through full cutting, partial cutting-filling or full filling zone. However, there should be no bed lining, when bed level is below existing ground level.
- (b) Where canal is in partial cutting-filling or full cutting zone and GWT fluctuates between bank level and bed level when canal is not in operation, and subsoil is poor draining (i.e. coefficient of permeability varying from 10^{-4} cm/sec to 10^{-6} cm/sec) causing slope failure due to hydrostatic pressure.
- (c) Normally, side slope lining is to be terminated at a level not exceeding FSL plus prescribed Free Board. However, if the subgrade material on the side slope contains gravelly soil, moorum or similar unstable materials causing perpetual deposition of such materials within canal bed and if flatter side slope (2.0H : 1V or more) cannot be provided above top of lining in deep cutting zone due to space constraint or other reasons, lining in such exceptional cases may be extended upto top of bank.

Note: Surveyed and superimposed cross and long sections as detailed in Para 5.3 hereinafter, are to be presented in the DPR along with the position of GWT to and the coefficient of permeability stated in Para 5.2 hereinafter, is also to be mentioned in the DPR, to justify the necessity of lining.

5.1.2 Canal lining on bed and also on side slopes may be provided, where canal is in fully filling zone and subgrade is free draining, or closer to free draining, resulting in significant seepage and/or there is not adequate cover (at least 0.6m) to the hydraulic grade line (assumed 1:6), when the canal is running at FSL.

5.1.3 In case of inadequate cover to hydraulic grade line stated in Para 5.1.2 above, which cannot be provided by widening the embankment due to space constraint, following additional measures are recommended:

- (a) Providing 1.2m deep x 0.9m wide crated boulder sausage, with 0.3m embedment on the toe of countryside slope, with a layer of 300mm thick graded shingles / jhama khoa filter in the interface of the crated boulder and the earth of embankment, extending upto the full height of the exposed position of the crate (0.9m).
- (b) Constructing a RCC cantilever type retaining wall, in case the hydraulic grade line cuts the countryside slope of the embankment at a height of 0.9m above the existing ground level, having adequate number of weep holes at suitable spacing in two rows, and providing a layer of 300mm thick graded shingles / jhama khoa filter in the interface between the stem of the retaining wall and the earth of embankment, extending upto the full height of the stem, i.e. the height above GL where the hydraulic grade line cuts the countryside slope.

Note: Surveyed and superimposed cross and long sections as detailed in Para 5.3 hereinafter, are to be presented in the DPR along with the position of GWT to and the coefficient of permeability stated in Para 5.2 hereinafter, is also to be mentioned in the DPR, to justify the necessity of lining.

5.1.4 In case expansive soil in the subgrade is encountered in the process of soil investigation, governing principles and lining parameters should be adopted as per provision of Para 7.0, including subparagraphs thereunder.

5.2 Following field tests are to be conducted and results are to be presented in the DPR wherever any stretch of canal is proposed to be lined:

- (a) Coefficient of permeability (i.e. 'k' in cm/sec) in the zone between bank top upto a depth of 2.0m below the bed level of the canal

Depending on value of 'k' the soil may be classified as subgrade free draining ($k > 10^{-4}$ cm/sec), poor draining (10^{-6} cm/sec $< 10^{-4}$ cm/sec) and practically impervious ($k < 10^{-6}$ cm/sec).

- (b) Whether the soil is expansive (swelling) in nature from bank top upto a depth of 1.0m below the bed level of the canal.

Note: Two number of soil samples are to be taken, either one in bed and the other on bank or both on the banks, having depth of bore hole extended upto 2.0m below the bed level of the canal, for each 500m or part length thereof, of continuous canal stretch to be lined for canal capacity beyond 1.50 cumec for each 1.5 km or part thereof for canals having lesser capacity. No other investigation, apart from those stated in Para 5.2(a) and

5.2(b) above is to be done. If permeability test cannot be done in-situ, laboratory test on undisturbed sample may be done.

(c) In addition to above, variation of ground water table in the proposed stretch of lining, both in the pre and post monsoon season is to be collected from the Blockwise data maintained by the State Water Investigation Directorate (SWID) wherever available and presented in the DPR.

5.3 Existing cross sections, normally at 60 m interval (which may suitably be increased upto 150m in case of continuous lining of more than 500 m length), taken upto a distance of 15m from the countryside toe of embankment, or from edge of the bank, in deep cutting zone where there is no embankment, are to be superimposed on design sections of the canal. Such cross sections are to be taken for a stretch of 120m on upstream as well as on downstream or upto the nearest fall structure, whichever is shorter. In a like manner, existing long section, superimposed over the designed long section is also to be provided for the same stretch length.

5.4 Notwithstanding the guiding principles stated in subparagraphs 5.1.1 to 5.1.4 hereinbefore, following cases may be considered for lining, subject to soil investigation and furnishing long and cross sections of the canals, in existing and designed conditions, to ensure better hydraulic efficiency, minimize losses and consequently to transport the water at the tail ends.

(a) Slope and bed lining in all canals in Purulia district, except in stretches passing through rocky zones, having capacity less than 50 cusec (approximately 1.50 cumec).

(b) Only slope lining for all canals in Minor Irrigation Schemes (having irrigation command area upto 2,000 ha), in all districts.

(c) Only slope lining for Minor / Sub-Minor Canals of Major and Medium Irrigation Projects (having command area beyond 10,000 ha and in between 2,000 ha to 10,000 ha respectively), upto a stretch of initial 50% length in the head reach from offtake head regulator of these canals, subject to the condition that capacity of the canals is less than 35 cusec (1 cumec).

Recommended parameters on lining, filter materials and bank slope (for all categories of soil other than expansive soil)

6.0 Various parameters as shown in the enclosed Drawing No. Misc/1092/1/2/18 of the Central Design Office, Irrigation & Waterways Directorate, have been recommended, which are to be selected following a step by step approach as stated below:

6.1 Type (i.e. cast-in-situ or precast) of lining, recommended thickness, plan dimension / area and Free Board (FB) above Full Supply Level (FSL) are to be determined from

Table-1, for categories of subgrade soil condition. These parameters would be independent of soil characteristics and accordingly would be the same for all projects, irrespective of the location districts. Plain Cement Concrete (PCC) lining is recommended considering the aspects of strength, durability, easier repairability and prevention of weed growth. Recommended grade of PCC is M20, considering severe exposure condition and the minimum grade of PCC required for such exposure condition as per Table-3 & Table-5 of IS 456:2000.

6.2 Depending on soil type and soil characteristics, various location districts of Major / Medium / Minor Irrigation Projects have been classified in 4 (four zones) as shown below:

Zone I : Alipurduar, Jalpaiguri, Siliguri Subdivision of Darjeeling and Uttar Dinajpur.

Zone II : Western part of Murshidabad, Purba Bardhaman, Hooghly, Howrah and northern part of Purba Medinipur.

Zone IV : Birbhum, Bankura, Paschim Bardhaman, Jhargram and Paschim Medinipur.

Zone V : Purulia

6.2.1 Recommended range of side slopes and requirement of filler materials which are dependent on soil characteristics and position of GWT are to be determined for any project falling within any district(s) and Zone(s), from Table-2. Although these parameters are not strictly related to discharge capacity of the canals, rationalization of requirement of filter has been made for smaller size canals having discharge upto 5 cumec (176 cusec) within the overall recommended range as per codal provision, based on acceptable engineering practice and past experience of successful execution of project. Some variations have also been made, in case of practically impervious subgrade, on practical considerations, with due regard to economy and durability.

6.3 There are a few parameters, which depend both on capacity of canals as well as soil characteristics and position of GWT. However, with a view to standardize such parameters to the extent feasible, optimum rationalization has been made, so as to facilitate the selection of such parameters by the field level engineers, without compromising the safety aspects. These parameters include,

- (a) toe wall at the junction of bed and slope.
- (b) top wall at top of lining.
- (c) coping slab extending into the embankment / bank from the top wall.
- (d) Longitudinal and transverse separator beams.

A ready reckoner to determine these parameters has been presented at Table-3.

Guidelines for lining of canals in expansive soils

7.0 Canals excavated in expansive soils, such as black cotton soil, pose several problems affecting stability of slopes and shape of section. To have economical sections and prevent erosion due to design velocities, it is necessary to line the canal bed and slopes. Lining materials directly placed against the expansive soils undergo deformation by heaving, disturbing the lining and throwing the canal out of commission. This deformation is traced to the characteristics of swelling and swelling pressure developed by expansive soils, when they imbibe water in their intra-layers. Adequate thickness of “Cohesive Non-swelling Soil” (CNS) material is found to resist swelling pressure and prevent the heaving of underlying soil. From experiments in laboratory and field, it is concluded that deformations may be correlated to the thickness of CNS layer and swelling pressure characteristics of expansive soil. This part lays down guidelines for the treatment of expansive soils by introduction of a CNS layer of suitable thickness between the expansive soil mass and the lining material (including filter material below) to counteract the swelling pressure and resultant deformation of the lining material on a scientific basis.

7.1 General

7.1.1 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 soils is attributed to the pressure of montmorillonite or combination of montmorillonite and illite clay minerals. A wide range of properties of expansive soils are found in India (see IS 1498: 1970 for identification and properties). The swelling pressure and free swell index tests should be done in accordance with IS 2720(Part 40): 1977 and IS 2720 (Part 41): 1977. 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 remoulded 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 full saturation level.

7.1.2 Cohesive Non-swelling Soils (CNS) for Treatment

7.1.2.1 These 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.

7.1.2.2 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.

7.1.2.3 CNS material should be non-swelling with a maximum swelling pressure of 10 KN/m² when tested in accordance with IS 2720(Part 41): 1977 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.

7.1.2.4 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.

7.1.2.5 Most moorums of laterite, laterite type and siliceous sandy clays exhibit CNS characteristics; however, some moorums 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:

Clay (less than 2 microns)	: 15% to 20%
Silt (Silt (0.06 mm to 0.002 mm)	: 30% to 40%
Sand (2.0 mm to 0.06 mm)	: 30% to 40%
Gravel (greater than 2.0 mm)	: 0% to 10%
Liquid Limit	: Greater than 30% but less than 50%
Plasticity Index	: Greater than 15% but less than 30%

7.2 Criteria for fixing the thickness of CNS layer

7.2.1 Thickness of CNS materials is related to swelling pressure and the resultant deformation, the permissible deformation being 2cm.

7.2.2 Guidelines for choosing the thickness of CNS materials required for balancing the different swelling pressures is given in Table below. Slopes should be in accordance with IS: 10430: 2000.

<i>Thickness of CNS Layer, for canal carrying capacity less than 2.0 Cumec</i>		
Discharge in Cumec	Thickness of CNS Layer in mm (Min)	
	Swelling Pressure 50 to 150 KN/m ²	Swelling Pressure more than 150 KN/m ²
1.40 to 2.00	600	750
0.70 to 1.40	500	600
0.30 to 0.70	400	500
0.03 to 0.30	300	400

<i>Thickness of CNS Layer, for canal carrying capacity 2.0 Cumec and more</i>	
Swelling pressure of soil KN/m²	Thickness of CNS Layer in mm (Min)
50 to 150	750
150 to 300	850
300 to 500	1000

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

7.3 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 expansive soil and the filter material, below the lining. The thickness of CNS layer should be measured perpendicular to the surface of expansive soil.

7.3.1 Canal in cutting

7.3.1.1 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 15cm thickness. Care is also 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 steps:

- (a) Subgrade may suitably be excavated 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 moistures should be added to CNS material.
- (d) CNS material should be compacted in layers 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) Filter material over CNS material should be provided followed by laying of PCC (M20) lining units.
- (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 20cm. However, full design thickness behind the lining should be continued at least 100 cm above the top level of the lining (illustrator arrangement shown in Figure-1).
- (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.
- (j) It is necessary to stack the excavated soil away from the cuts to prevent it inducing slips by surcharge.

7.3.2 Canal in embankment (filling)

The construction should be carried out in the following steps:

- (a) Proper moisture should be added to CNS material and expansive soil.
- (b) Expansive soil and CNS material above ground level should be compacted simultaneously, in layers, with appropriate equipment to ensure proper density.
- (c) The CNS materials 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 preferably either with sheep foot rollers or 8 to 10 ton ordinary rollers.
- (d) Provision of drainage filter should be made to minimize external/internal erosion. A rock toe with inverted filter may also be provided at either end of canal bank, if required. As an alternative to rock toe, provisions of Para 5.1.3 (a) & (b) may also be followed.
- (e) Special care is required to be taken to provide internal drainage for the banks, having bed filling of 2 metres or more.

- (f) For both the cuts and banks, paved surface drains should be provided at the berms etc., 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) Moorum (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.

7.3.3 Similar procedure should be followed for canals in partial cutting and embankment.

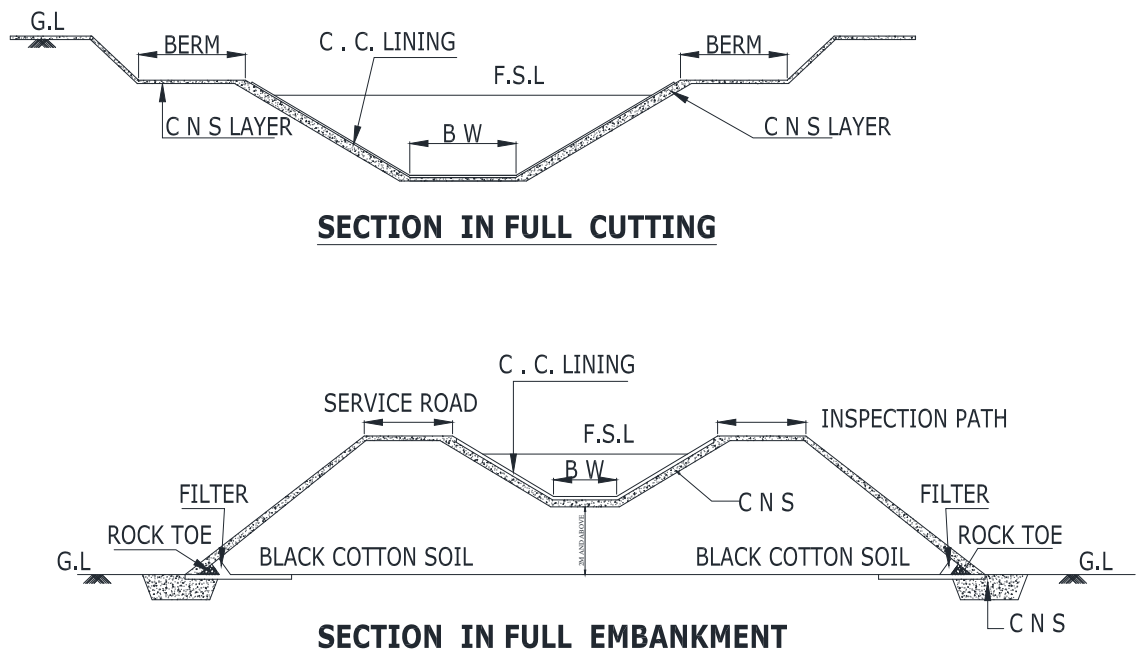


Figure – 1

7.3.4 Pride

7.3.4.1 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 be placed for the sides and bed, in addition to design thickness. 20cm 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.

7.3.4.2 For cutting in soft material where the CNS backfilling is not required the best method is to leave the cutting 20cm 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.

7.4 Lining

The lining should be plain cement concrete, cast-in-situ or precast, depending on recommendations of Table 1.0. All round gap of 6mm in case of precast lining and 12mm for cast-in-situ needs to be provided, as Gaps in case of precast lining are to be kept open and not to be sealed or packed. However, gaps between cast-in-situ lining panels are to be packed with bajrees / stone chips of 5.6mm size. Polythene sheets (100 µm) placed below the cast-in-situ lining are to be cut at joint locations between two adjacent units, after casting, so as to expose the filter below. These apart, holes are to be kept in both precast and cast-in-situ lining for better under-drainage, as stated in Para 7.6 below.

7.5 Side slopes, termination level of lining and other parameters like toe wall, top wall, coping slab, longitudinal and transverse separator beams.

Recommended side slope should be 1.5:1 in the range of 1.75:1 for cutting and upto top of lining and in the range of 1.5:1 to 2:1 for filing and beyond the top of lining. Other parameters should be as per Table 3.0.

7.6 Filter and Under-drainage

A layer of 200mm thick medium sand (Grading Zone-II as per IS: 383-1970) is to be provided as filter in between the bottom of lining and top of CNS layer. PVC pipes, 30mm dia for precast lining and 50mm dia for cast-in-situ lining, top flush with the finished surface of lining, with full embedment in filter and partial embedment in the CNS layer, upto $2/3^{\text{rd}}$ of full depth of the CNS layer, are to be laid in the centre of the each or alternate panels, depending on canal capacity both longitudinally and transversely in bed as well as in slope. The pipes are to be packed with 22.4mm bajrees or 20mm nominal grade stone aggregates.

7.7 Drawing No. Misc/1092/2/2/18 of the Central Design Office, Irrigation & Waterways Directorate may be referred to for various details.

7.8 In case of any doubts of determination of CNS materials and other precautions to be taken during lining in expansive soil, the filed level officials may consult the Central Design Office.

Preparation of subgrade, laying of lining, filter and other related issued

8.0 Relevant provisions may be perused in the BIS Code referred in Para 2.0 hereinbefore, and in Paragraphs 2.3.2.3, 2.7.1, 2.7.2, 2.7.3, 2.7.4, 2.7.8, 2.7.9 and 2.7.10 of the Unified Schedule of Rates of Irrigation & Waterways Department, and also Schedule of Rates of Public Works Department, for taking the supply rates of medium sand, bajree, stone chips and river grits comprising 12.6 or 5.6mm down coarse stone aggregates. Labour charges for laying the filter may be collected from the USoR of the Irrigation & Waterways Department (including addenda & corrigenda).

Conclusion

9.0 It would be evident from the foregoing discussions and recommendations that lining in irrigation canals in West Bengal, which are already under operation since decades, should be done after adequate field investigation. Considering the facts that there is little scope of redesigning the existing canals and some amount of seepage loss may always be allowed from the point of view of indirect benefit arising out of recharge of groundwater, selection of stretches for lining should be judicious and based on adequate justification. Any departure from the recommendations must be got approved by the Central Design Office, Irrigation & Waterways Department.

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Size, thickness and type of lining for all zones and all categories of sub-grade and soil condition (Refer to Figure-1)

(Drawing No. Misc/1092/1/2/18 of the Central Design Office, Irrigation & Waterways Directorate)

Table 1.0

Capacity of canal		Thickness of PCC Lining (M20)		Recommended Plan dimension / area		Remarks	Recommended free Board above FSL upto top of lining
Cumec	Cusec	Cast-in-situ (mm)	Precast (mm)	Cast-in-situ	Precast		
1	2	3	4	5	6	7	8
0 to 5	0 to 176	65	65	<i>Bed:</i> In between Plan area : 0.25 m ² to 1.00 m ² Max. dimension : 1.00 m Min. dimension : 0.50 m <i>Sides:</i> : Same as above	<i>Bed:</i> Plan area : 0.20 m ² Max. dimension : 0.50 m Min. dimension : 0.40 m <i>Sides:</i> Same as above	1. Panel size of cast-in-situ and precast lining should conform to Col.5 & Col.6 respectively. 2. Precast lining preferred in both bed and on side slopes.	0.30 m (upto 1 cumec) 0.60 m (1 to 5 cumec)
5 to 50	176 to 1766	75	75	<i>Bed:</i> In between Plan area : 1.00 m ² to 4.00 m ² Max. dimension : 2.00 m Min. dimension : 1.00 m <i>Sides:</i> : Same as above	<i>Bed:</i> Plan area : 0.25 m ² Max. dimension : 0.55 m Min. dimension : 0.45 m <i>Sides:</i> Same as above	1. Panel size of cast-in-situ and precast lining should conform to Col.5 & Col.6 respectively. 2. Cast-in-situ lining preferred in bed and precast lining preferred on side slopes. 3. 1 No. 30 mm dia hole spaced centrally may be kept in each unit of precast lining unit for handling.	0.75 m
50 to 250	1766 to 8828	90	90 (in slope Only)	<i>Bed:</i> In between Plan area : 4.00 m ² to 6.25 m ² Max. dimension : 2.50 m Min. dimension : 2.00 m <i>Sides:</i> : Same as above	<i>Bed:</i> Plan area : – Max. dimension : – Min. dimension : – <i>Sides:</i> Plan area : 0.25 m ² Max. dimension : 0.55 m Min. dimension : 0.45 m	1. Panel size of cast-in-situ and precast lining should conform to Col.5 & Col.6 respectively. 2. Precast lining is not recommended in bed. 3. Choice of type of lining on side slope, i.e. cast-in-situ or pre-cast, would depend on site conditions. 4. 1 No. 30 mm dia hole spaced centrally may be kept in each precast lining unit for handling.	0.75 m
250 to 500	8828 to 17655	125	–	<i>Bed:</i> In between Plan area : 6.25 m ² to 9.00 m ² Max. dimension : 3.0 m Min. dimension : 2.5 m <i>Sides:</i> : Same as above	<i>Bed:</i> Plan area : – Max. dimension : – Min. dimension : – <i>Sides:</i> – : –	1. Panel size of cast-in-situ and precast lining should conform to Col.5 & Col.6 respectively. 2. Precast lining is not recommended in bed or side slope.	0.90 m

Note: As stated in Para 2.3.2.3 of the Unified Schedule of Rate (USoR) of the Irrigation & Waterways Department, a layer of thick polythene sheet (100 µm) is to be placed below the cast-in-situ lining, before casting to prevent clogging of filter. If the sheet is continuous, it must be cut at joint locations after casting, so as to fully expose the sand filter below.

Recommendations on side slope and requirement of filter below lining in bed and on sides depending on the sub-grade characteristics (other than expansive soils) and position of water table (Refer to Figure-1)

(Drawing No.Misc/1092/1/2/18 of the Central Design Office, Irrigation & Waterways Directorate)

Table 2.0

Zone	Districts covered	Soil type	Sub-zone	General description of soil	Recommended side slope for depth of cutting / height of embankment (H:V)		Position of Groundwater Table	Requirement of filter	Arrangement for pressure release
1	2	3	4	5	6		7	8	9
I.	<ul style="list-style-type: none"> • Jalpaiguri • Siliguri Subdivision of Darjeeling • Uttar Dinajpur 	Mainly Terai – Teesta alluvial	–	Soil comprising fine sand, admixture of sand, silt and clay, i.e. sandy silt / silty sand/ clay sand / clay silt, permeability considered to be in the range of 10^{-4} cm/sec to 10^{-6} cm/sec (poor draining).	Case – A	Range	Below canal bed / between canal bed & FSL / above FSL	<p>A(I) Medium sand (Grading Zone-II as per IS: 383-1970) of 150mm thick layer for canals of capacity upto 5 cumec (176 cusec).</p> <p align="center"><i>or</i></p> <p>A(II) Medium sand (Grading Zone-II as per IS: 383-1970) of 200mm thick layer for canals of capacity beyond 5 cumec (176 cusec).</p> <p align="center"><i>or</i></p> <p>B. UV stabilized polypropylene non-woven 300 gsm geotextile filters for all canal capacities.</p> <p><u>Note:</u> From economic point of view and also to facilitate laying of lining blocks, use of medium sand is preferred to geotextile filter. However, geotextile filters may be used for reasons to be recorded in writing.</p>	<p>A. <i>For precast lining</i> 6mm all round gaps between adjacent pre-cast units, not to be sealed or packed.</p> <p>B. <i>For cast-in-situ lining</i></p> <p>1. 12mm all round gaps between adjacent panels, to be packed with river grits (5.6mm down).</p> <p>2. 50mm dia PVC pipe, top flush with finished surface of lining and upto 300mm embedment in virgin ground, fully packed with 22.4 mm down bajrees, to be laid at the centre of alternate panels, upto 50 cumec canal capacity and in each panel, beyond that capacity, both longitudinally & transversely, in bed and on side slopes.</p>
				Cutting & upto top of lining	1.5 : 1 to 1.75 : 1				
				Case – B	Range				
				Filling and beyond top of lining	1.75 : 1 to 2 : 1				
				<p><u>Note:</u> Appropriate slope to be selected within the ranges stated above. Flatter slope preferable for stability.</p>					

Special Note: Normally lining is to be terminated on slope at a level equal to FSL + Free Board. In deep cutting and high filling zone (height exceeding 4.5m), cases may arise where slope beyond the top of lining cannot be flattened due to space constraint. If the subgrade material is loose sandy / fine silty type in such cases and if there is evidence / history of perpetual deposition of such soil particles into canal bed from the unlined upper portion, lining may be extended upto the top of canal bank in exceptional cases, subject to prior approval of the concerned Chief Engineer.

Table 2.0 (Contd.)

Zone	Districts covered	Soil type	Sub-zone	General description of soil	Recommended side slope for depth of cutting / height of embankment (H:V)		Position of Groundwater Table	Requirement of filter	Arrangement for pressure release
1	2	3	4	5	6		7	8	9
II.	<ul style="list-style-type: none"> • Western part of Murshidabad • Purba Bardhaman • Hooghly • Howrah and • Northern part of Purba Medinipur 	Mainly Vindhya alluvial	A.	Soil comprising admixture of sand, silt and clay, i.e. sandy silt / sandy clay / clay silt, permeability considered to be closer to 10^{-6} cm/sec (poor draining).	Case – A	Range	Below canal bed / between canal bed & FSL / above FSL	<p>A(I) Medium sand (Grading Zone-II as per IS: 383-1970) of 150mm thick layer for canals of capacity upto 5 cumec (176 cusec).</p> <p style="text-align: center;"><i>or</i></p> <p>A(II) Medium sand (Grading Zone-II as per IS: 383-1970) of 200mm thick layer for canals of capacity beyond 5 cumec (176 cusec).</p> <p style="text-align: center;"><i>or</i></p> <p>B. UV stabilized polypropylene non-woven 300 gsm geotextile filters for all canal capacities.</p> <p><u>Note:</u> From economic point of view and also to facilitate laying of lining blocks, use of medium sand is preferred to geotextile filter. However, geotextile filters may be used for reasons to be recorded in writing.</p>	<p>A. <u>For precast lining</u> 6mm all round gaps between adjacent precast units, not to be sealed or packed.</p> <p>B. <u>For cast-in-situ lining</u></p> <p>1. 12mm all round gaps between adjacent panels, to be packed with stone chips (5.6mm).</p> <p>2. 50mm dia PVC pipe, top finish with finished surface of lining and upto 300mm embedment in virgin ground, fully packed with 20 mm nominal graded stone aggregates, to be laid at the centre of alternate panels, upto 50 cumec canal capacity and in each panel, beyond that capacity, both longitudinally & transversely, in bed and on side slopes.</p>
				Cutting & upto top of lining	1.5 : 1				
				Case – B	Range				
				Filling and beyond top of lining	1.5 : 1 to 2 : 1				

Special Note: Normally lining is to be terminated on slope at a level equal to FSL + Free Board. In deep cutting and high filling zone (height exceeding 4.5m), cases may arise where slope beyond the top of lining cannot be flattened due to space constraint. If the subgrade material is loose sandy / fine silty type in such cases and if there is evidence / history of perpetual deposition of such soil particles into canal bed from the unlined upper portion, lining may be extended upto the top of canal bank in exceptional cases, subject to prior approval of the concerned Chief Engineer.

Table 2.0 (Contd.)

Zone	Districts covered	Soil type	Sub-zone	General description of soil	Recommended side slope for depth of cutting / height of embankment (H:V)		Position of Groundwater Table	Requirement of filter	Arrangement for pressure release
1	2	3	4	5	6		7	8	9
IV.	<ul style="list-style-type: none"> • Birbhum • Bankura • Paschim Bardhaman • Paschim Medinipur • Jhargram 	Mostly red laterite	–	Soil comprising sand, moorum, silt and often silty clay, permeability generally varies from 10^{-4} cm/sec to 10^{-6} cm/sec (poor draining).	Case – A Cutting & upto top of lining	Range 1.5 : 1	Below canal bed / between canal bed & FSL / above FSL	<p>A(I) Medium sand (Grading Zone-II as per IS: 383-1970) of 150mm thick layer for canals of capacity upto 5 cumec (176 cusec).</p> <p style="text-align: center;"><i>or</i></p> <p>A(II) Medium sand (Grading Zone-II as per IS: 383-1970) of 200mm thick layer for canals of capacity beyond 5 cumec (176 cusec).</p> <p style="text-align: center;"><i>or</i></p> <p>B. UV stabilized polypropylene non-woven 300 gsm geotextile filters for all canal capacities.</p> <p><u>Note:</u> From economic point of view and also to facilitate laying of lining blocks, use of medium sand is preferred to geotextile filter. However, geotextile filters may be used for reasons to be recorded in writing.</p>	<p>A. <u>For precast lining</u> 6mm all round gaps between adjacent precast units, not to be sealed or packed.</p> <p>B. <u>For cast-in-situ lining</u></p> <p>1. 12mm all round gaps between adjacent panels, to be packed with stone chips (5.6mm).</p> <p>2. 50mm dia PVC pipe, top finish with finished surface of lining and upto 300mm embedment in virgin ground, fully packed with 20 mm nominal graded stone aggregates, to be laid at the centre of alternate panels, upto 50 cumec canal capacity and in each panel, beyond that capacity, both longitudinally & transversely, in bed and on side slopes.</p>
				Case – B Filling and beyond top of lining	Range 1.5 : 1 to 2 : 1				
				<u>Note:</u> Appropriate slope to be selected from the ranges stated above. Flatter slope preferable for stability.					

Special Note: Normally lining is to be terminated on slope at a level equal to FSL + Free Board. In deep cutting and high filling zone (height exceeding 4.5m), cases may arise where slope beyond the top of lining cannot be flattened due to space constraint. If the subgrade material is loose sandy / fine silty / moorum type, in such cases and if further there is evidence / history of continuous deposition of such soil particles into canal bed from the unlined upper portion, lining may be extended upto the top of canal bank in exceptional cases, subject to prior approval of the concerned Chief Engineer.

Table 2.0 (Contd.)

Zone	Districts covered	Soil type	Sub-zone	General description of soil	Recommended side slope for depth of cutting / height of embankment (H:V)		Position of Groundwater Table	Requirement of filter	Arrangement for pressure release
1	2	3	4	5	6		7	8	9
V.	• Purulia	Gravelly soil	–	Sandy soil mixed with moorum and gravel, occasionally with silty clay. Permeability varying from 10^{-4} cm/sec to 10^{-6} cm/sec but occasionally more than 10^{-4} cm/sec (poor to fine draining).	Case – A Cutting & upto top of lining	Range 1.5 : 1	Below canal bed / between canal bed & FSL / above FSL	A(I) Medium sand (Grading Zone-II as per IS: 383-1970) of 150mm thick layer for canals of capacity upto 5 cumec (176 cusec). <i>or</i> A(II) Medium sand (Grading Zone-II as per IS: 383-1970) of 200mm thick layer for canals of capacity beyond 5 cumec (176 cusec). <i>or</i> B. UV stabilized polypropylene non-woven 300 gsm geotextile filters for all canal capacities. <u>Note:</u> From economic point of view and also to facilitate laying of lining blocks, use of medium sand is preferred to geotextile filter. However, geotextile filters may be used for reasons to be recorded in writing.	A. <u>For precast lining</u> 6mm all round gaps between adjacent precast units, not to be sealed or packed. B. <u>For cast-in-situ lining</u> 1. 12mm all round gaps between adjacent panels, to be packed with stone chips (5.6mm). 2. 50mm dia PVC pipe, top finish with finished surface of lining and upto 300mm embedment in virgin ground, fully packed with 20 mm nominal graded stone aggregates, to be laid at the centre of alternate panels, upto 50 cumec canal capacity and in each panel, beyond that capacity, both longitudinally & transversely, in bed and on side slopes.
				Case – B Filling and beyond top of lining	Range 2 : 1 to 2.5 : 1				

Special Note: Normally lining is to be terminated on slope at a level equal to FSL + Free Board. In deep cutting and high filling zone (height exceeding 4.5m), cases may arise where slope beyond the top of lining cannot be flattened due to space constraint. If the subgrade material is loose sandy / fine silty / moorum or gravelly type, in such cases and if further there is evidence / history of continuous deposition of such soil particles into canal bed from the unlined upper portion, lining may be extended upto the top of canal bank in exceptional cases, subject to prior approval of the concerned Chief Engineer.

**Dimensions of toe wall, top wall, coping slab from top wall, longitudinal and transverse separator beams
(Refer to Drawing No. Misc/1092/1/2/18 of the Central Design Office, Irrigation & Waterways Directorate)**

Table 3.0

Capacity of canal		Toe wall dimensions		Dimensions of top wall & horizontal coping slab extending from top wall into the embankment / bank				Dimensions of transverse & separator beams in bed and on side slope and also longitudinal separator beam in bed		Dimensions of longitudinal separator beams on slope		Remarks
Cumec	Cusec	b _w	D _w	b _T	D _T	L _C	t _C	b _b	D _b	b _s	D _s	
0 to 1.5	0 to 50	250	450	200	300	300	100	200	300	200	300	D _T & D _b may be reduced by 50mm if geotextile filter is used.
1.5 to 5.0	50 to 176	300	450	200	300	400	100	250	300	250	300	D _T & D _b may be reduced by 75mm if geotextile filter is used.
5.0 to 50	176 to 1766	350	600	250	350	550	125	250	350	250	350	D _T & D _b may be reduced by 100mm if geotextile filter is used.
50 to 250	1766 to 8820	400	600	300	400	600	150	300	400	300	400	D _T & D _b may be reduced by 150mm if geotextile filter is used.
250 to 500	8820 to 17655	450	600	300	450	650	150	300	450	300	450	D _T & D _b may be reduced by 200mm if geotextile filter is used.

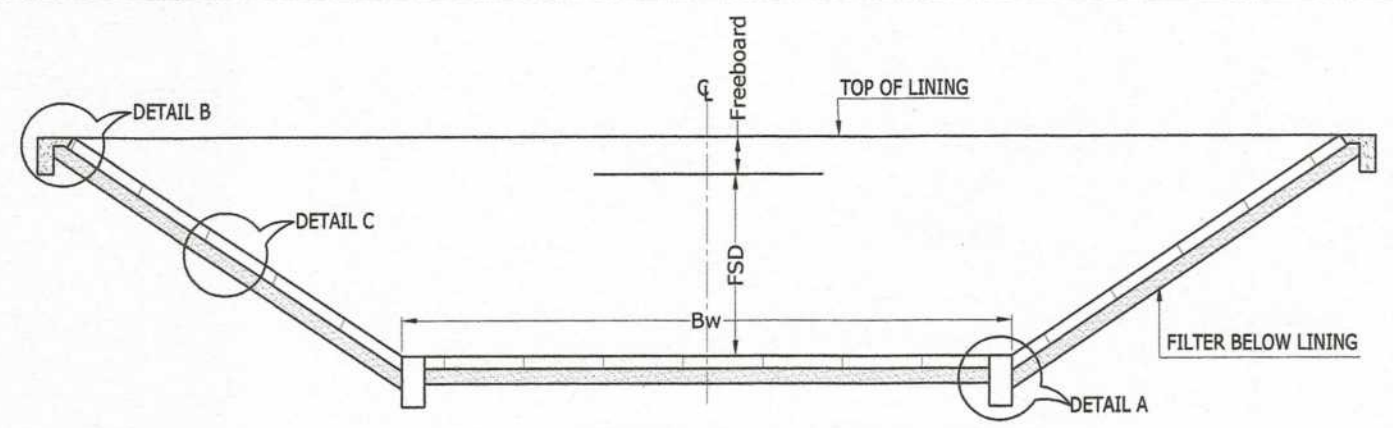
- Note:**
1. Longitudinal separator beam should be used only in the bed of canals, to divide the bed width in minimum number of more or less equal panels having width 30m or less, in case the designed bed width is more than 30m.
 2. Spacing of transverse separator beams, both in bed and also on slope, should generally be 30m c/c/, except at the stretch having bends, where smaller spacing may be used.
 3. In case height of lining on side slope exceeds 4.5m, the total height may be segregated in minimum number of more or less equal sized panels, each having height 4.5m or less, by providing a longitudinal separator beam along the slope.

DRAWING SHOWING PARAMETERS OF LINING AND APPURTENANT IN ALL KINDS OF SUB-GRADE OTHER THAN EXPANSIVE SOIL

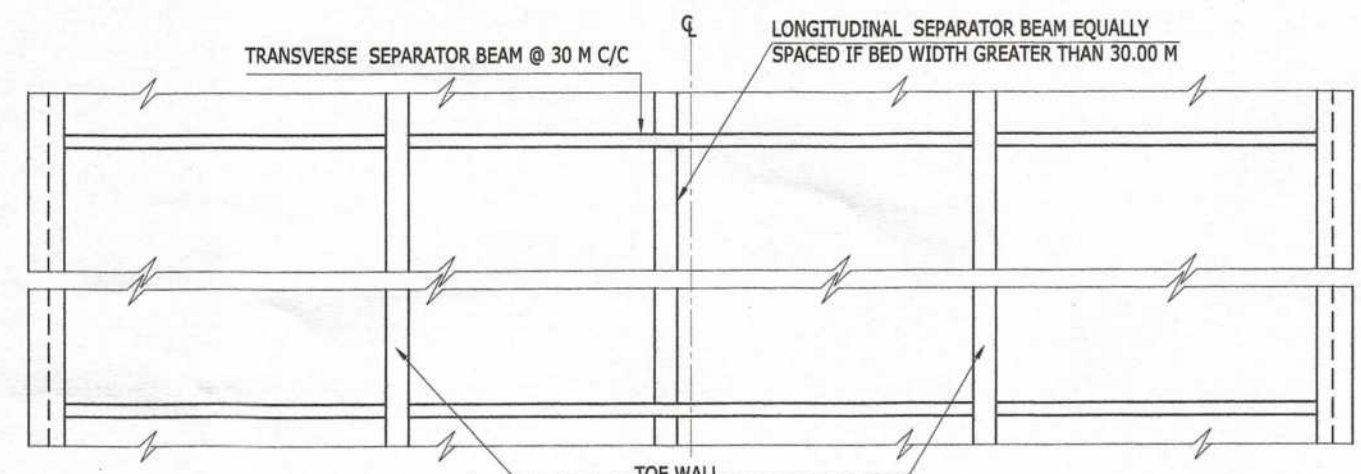
DRG. NO. -MISC/1092/1/2/18	DATE- 25-04-2018	SHEET - 1/2
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DRAWN BY.	<i>[Signature]</i> 25/04/18	<i>[Signature]</i> 25/04/18	<i>[Signature]</i> 25/04/18
T. K. MANDAL HEAD D/MAN	D. ROY CHOUDHURY DEPUTY DIRECTOR (HYD) CENTRAL DESIGN OFFICE	AMIYA BERA DEPUTY DIRECTOR (STRUC) CENTRAL DESIGN OFFICE	T. R. BARUA DIRECTOR CENTRAL DESIGN OFFICE

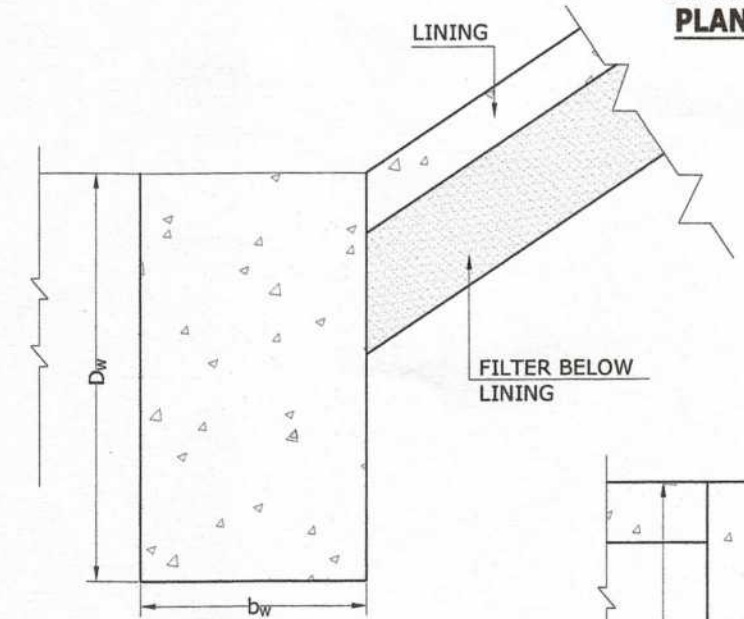
REFERENCE: - NO. $\frac{416-I}{I-4M-98-11}$ DATED 20.09.2017 AND COMMUNICATED VIDE NO. $\frac{416/I(11)-I}{I-4M-98-11}$ DATED 20.09.2017



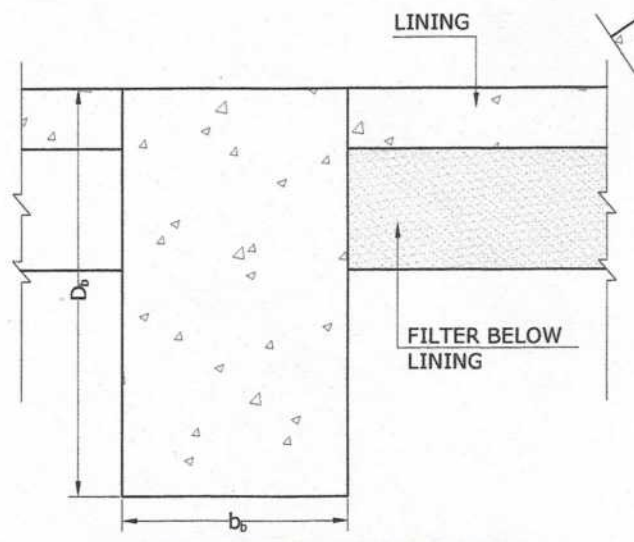
TYPICAL CANAL SECTION UP TO TOP OF LINING



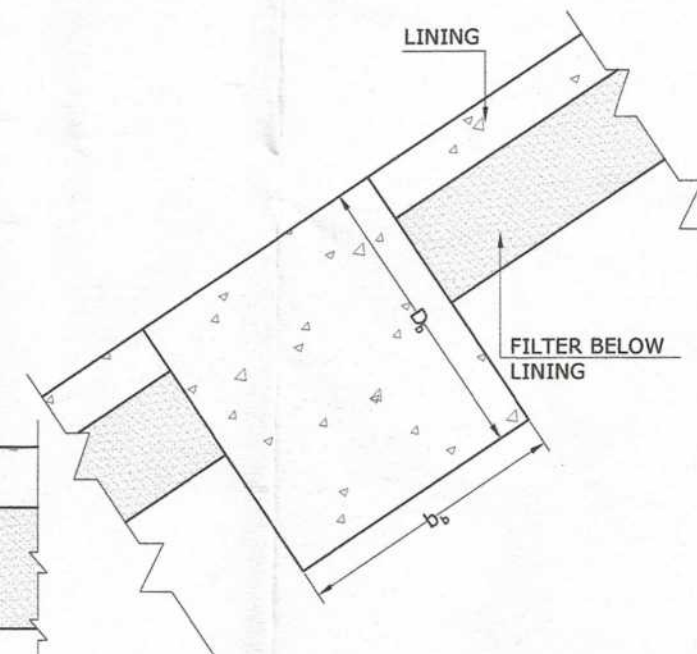
TOE WALL PLAN



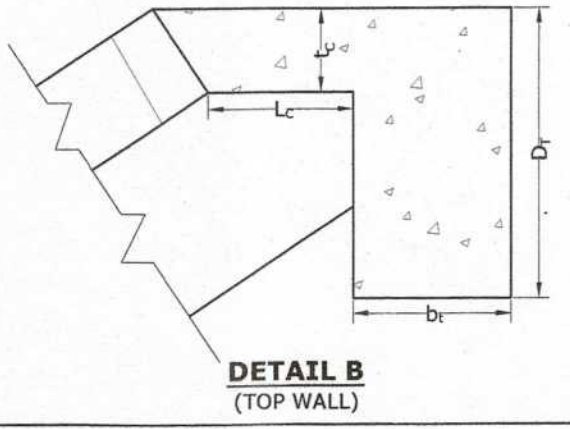
**DETAIL A
(TOE WALL)**



TYPICAL SECTION OF TRANSVERSE SEPARATOR BEAM AT BED AND ON SLOPE & LONGITUDINAL SEPARATOR BEAM IN BED



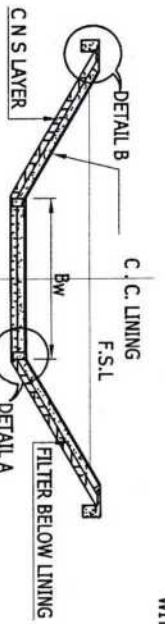
**DETAIL C
(LONGITUDINAL SEPARATOR BEAM ON SLOPE. REFER NOTE 5)**



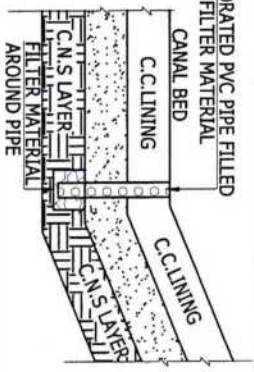
**DETAIL B
(TOP WALL)**

NOTES:

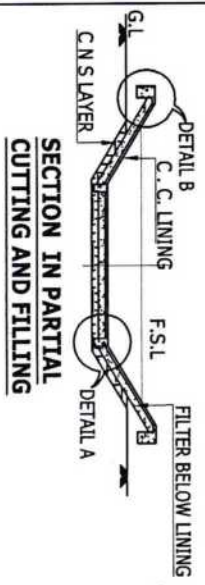
1. REQUIREMENT OF LINING AND FILTER WOULD BE GOVERNED BY PARAGRAPHS 5.0, 6.0, AND 7.0 OF THE MANUAL ALONG WITH SUB-PARAGRAPHS THEREUNDER.
2. FOR THICKNESS, PLAN DIMENSION AND FREEBOARD OF CAST-IN-SITU & PRECAST LINING REFER TABLE 1.0 OF THE MANUAL
3. FOR RECOMMENDED SIDE SLOPE OF LINING & FILTER MATERIAL BELOW LINING IN DIFFERENT ZONES HAVING DIFFERENT TYPES OF SOIL, REFER TABLE 2.0 OF THE MANUAL
4. FOR LINING IN EXPANSIVE SOIL, REFER TO PROVISIONS OF PARAGRAPH 7.0 OF THE MANUAL ALONG WITH SUB-PARAGRAPHS THEREUNDER.
5. IN CASE DEPTH OF LINING EXCEEDS 4.5 M, SUCH DEPTH MAY BE SEGREGATED IN MINIMUM NUMBER OF EQUAL PROPORTIONS EACH HAVING HEIGHT OF 4.5 M OR LESS BY PROVIDING A LONGITUDINAL SEPARATOR BEAM ALONG THE SLOPE AS SHOWN IN DETAILS 'C'
6. FOR VALUE OF DIFFERENT DIMENSIONS SHOWN IN THIS DRAWING REFER TABLE 3.0 OF THE MANUAL



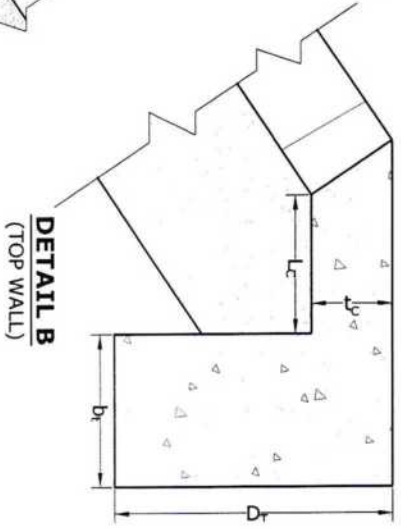
SECTION IN FULL CUTTING



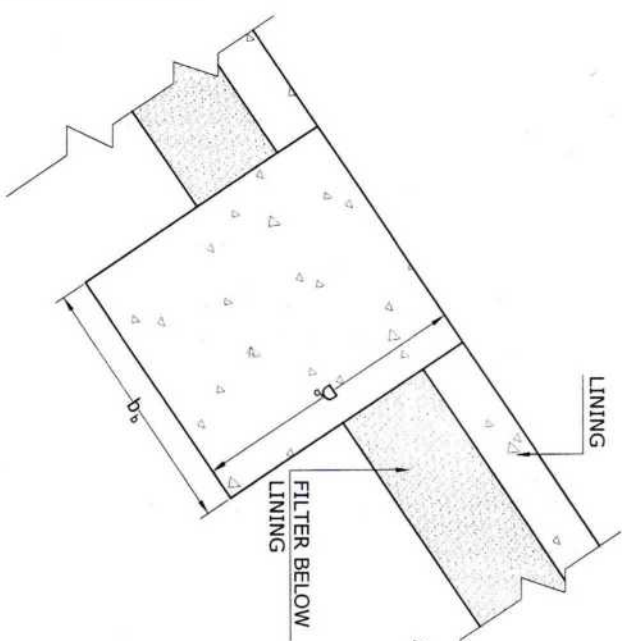
ILLUSTRATED DETAILS OF UNDER DRAINAGE IN CNS LAYER



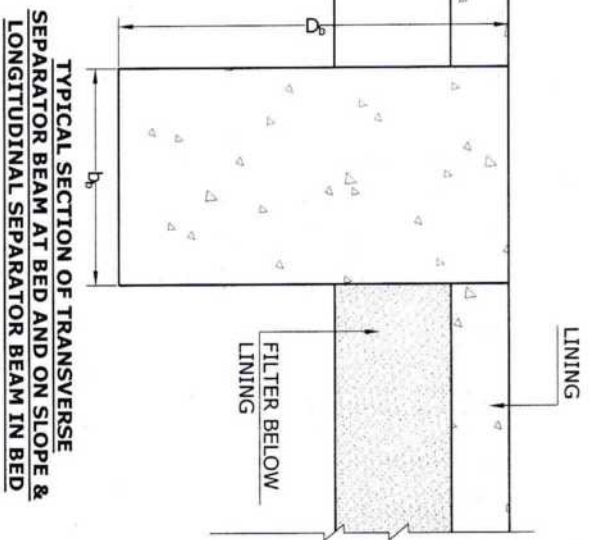
SECTION IN PARTIAL CUTTING AND FILLING



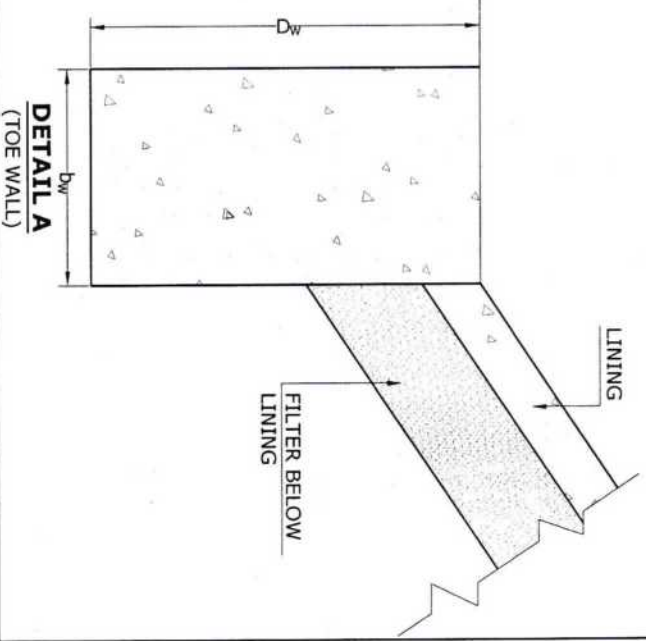
DETAIL B (TOP WALL)



DETAIL C (LONGITUDINAL SEPARATOR BEAM ON SLOPE. REFER NOTE 5)



TYPICAL SECTION OF TRANSVERSE SEPARATOR BEAM AT BED AND ON SLOPE & LONGITUDINAL SEPARATOR BEAM IN BED



DETAIL A (TOE WALL)

GOVERNMENT OF WEST BENGAL
 IRRIGATION & WATERWAYS DIRECTORATE
 CENTRAL DESIGN OFFICE
 1ST FLOOR, JALSAMPAD BHAWAN, SALT LAKE, KOLKATA- 700091

DRAWING SHOWING PARAMETERS OF LINING AND APPURTENANT IN EXPANSIVE SOIL

DRG. NO. -MISC/1092/2/2/18	DATE- 25-04-2018	SHEET - 2/2
DRAWN BY. T. K. MANDAL HEAD D/MAN	<i>D. Roy</i> D. ROY CHOUDHURY DEPUTY DIRECTOR (HYD) CENTRAL DESIGN OFFICE	<i>Amita Bera</i> AMITYA BERA DEPUTY DIRECTOR (STRUC) CENTRAL DESIGN OFFICE
	<i>T. R. Barua</i> T. R. BARUA DIRECTOR CENTRAL DESIGN OFFICE	

FOR NOTES AND DIMENSIONS REFER SHEET NO 1/2