Government of Odisha

Department of Water Resources

TECHNICAL MANUAL

Odisha Integrated Irrigation Project for Climate Resilient Agriculture (OIIPCRA)

Supported by World Bank

PROJECT MANAGEMENT UNIT (OIIPCRA)

March-2019

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1 INTRODUCTION

1.1 GENERAL

Odisha State's agriculture sector suffers from recurring natural calamities like droughts, cyclones. The poor farmers are not able to increase their leaving standards. Water for irrigating the crops is most important for farmers and crucial to the development. Climate change and its impacts in terms more frequent floods, reduction of rainy days, increasing temperature leading higher water requirement for crops, delayed monsoon, early withdrawal of monsoon is going the further add to the difficulties and constrains for sustained growth trajectory of agriculture. Water management needs to be improved in the state so that access to water for farmers throughout year increases. State is rich in water resources with 11% of India's water resources spread over 11 river basins and abundant rainfall with average total of around 1450 mm. if these resources can be managed to provide assured irrigation and access to irrigation to maximum number of farmers the growth rate in agriculture can be increased. Climate proofing of Cultivable Command Areas (CCA) by introducing soft components and system rehabilitation and modernization, augmentation as well as conjunctive use need to be given priority in our future efforts in managing irrigation in the state.

Odisha Integrated Irrigation Project for Climate Resilient Agriculture, OIIPCRA is to be implemented for building resilience to the vulnerabilities in the CCA of selected minor Irrigation and medium Irrigation projects in the state. It is proposed to be implemented in 15 districts. Based on evidence that convergence of agriculture and decentralized water management at Ayacut level can create ' resilience protocol' the OIIPCRA project with a sub-basin approach has envisioned to improve tank system efficiency and making agriculture climate smart.

1.2 RESERVOIR/ TANK BASED MINOR AND MEDIUM IRRIGATION IN ODISHA

The state has 49 completed Medium irrigation projects with created irrigation potential of 2, 80, 000.07 hectares in Kharif season and 1, 00,000.33 hectares in Rabi season. Similarly there are. Total irrigation potential created for Kharif through Minor Irrigation (Flow) projects as on December 2013 is 5, 98,231 hectares.

The potential utilized is less than the potential created. It is happening may be due to the following reasons.

- Changes in rainfall pattern that lead to inadequate and unreliable inflow into the reservoirs.
- Reduction of inflows into the reservoirs is also due to encroachment of water spread area of reservoir, rural infrastructure development interfering with the natural inflows and unplanned watershed development cutting off supply to reservoir.
- Silting of reservoir bed and feeder channels.
- Choked sluices and damaged weirs.
- Sluices with missing shutters.
- Dilapidated and weak or cut-down tank bunds.

- Poor maintenance of head-works / outlets leads to less irrigated area.
- Lack of community involvement in project management and maintenance to enforce norms and obligations.

1.3 MINOR IRRIGATION TANK PROJECT

Minor Irrigation plays an important role in providing assured water supply and prevents largely the adverse effects on agriculture because of variation of monsoon. It also plays an important role in development of agricultural production and ensuring food security and livelihood support, particularly in drought prone area and outside the command area of major / medium irrigation projects.

1.4 ADVANTAGE OF MINOR IRRIGATION TANK

Construction of Minor Irrigation Tank Projects is popular & demanding, due to

- Territorial feasibility: adaptability to all regions of the state
- Less Investment and low cost per Ha.
- Low gestation period (3-4 Years).
- Creation of Potential / Benefit in quick time.
- No Rehabilitation & Resettlement (R&R) Issue.
- Local Peoples' aspiration & involvement in Participatory. Irrigation Management (PIM) & Irrigation Management Transfer (IMT).
- Easy Operation & Maintenance (O&M).
- No special assistance required by way of foreign personnel or equipment.
- Water management is relatively simpler than in case of major and medium irrigation projects.
- Local resources can be easily and effectively be mobilized for their execution.
- They generate large amount of dispersed employment.
- Least disturbance to environment and ecology.
- Recharge of water table in the wells of village for conjunctive use.

1.5 JUSTIFICATION FOR RENOVATION OF MINOR/MEDIUM IRRIGATION PROJECT

The tanks those are the lifeline of the villages are to be sustained taking up standardization along with revival and restoration works. This approach would preserve the tanks one hand and on the other to stabilize / bridge the gap Ayacut wherever prevailing.

The measures of taking up revival / restoration works for bridging the gap/ stabilization of Ayacut are especially pertinent in the areas where no suitable sites exist or yield is exhausted for forming new tanks. The non- irrigated / gap Ayacut under the tanks in these areas, which is being brought back for irrigation, will be as productive as new irrigation potential created at relatively cheaper outlays.

1.6 ITEMS OF RENOVATION WORK

The following items of work are generally executed under repair and renovation of Minor Irrigation tank schemes. They are;

- Jungle clearance and grubbing.
- Earthwork for rehabilitation of earth dams and canal banks.
- Earthwork in excavation of foundation for canal structures.

- Filling foundation of canal structure with earth / suitable back filling material.
- Turfing of tank bund and canal section.
- Providing sand and metal layers for filter below riprap and d/s Blanket.
- Repair of rip-rap of tank bund.
- Cement concrete & RCC works both in head works& canal systems.
- Cement plaster (wherever necessary).
- Controlling devices like shutters etc.

2 COVERAGE AREA OF THE PROJECT

2.1 TYPE OF PROJECTS

OIIPCRA project will be implemented in minor irrigation project and medium irrigation project with were constructed earlier in the state. Minor irrigation projects are having Cultivable command area (CCA) from 40 Ha to 2000 Ha. Medium irrigation projects are having CCA from 2000 Ha to 10000 Ha. The projects are mostly reservoir based projects and having earthen dams. The tails of projects in different districts and the sub basins which located are described in further sections.

2.1 MINOR IRRIGATION PROJECTS

Minor irrigation projects to be covered under OIIPCRA is 538 having total CCA in Kharif as 56294 Ha of these projects are located in 15 districts of the state. District wise break up of number of minor irrigation project is given in Table 1. District wise blocks, number of MIPs, number of blocks and GPs with total CCA in Kharif and Rabi are also given in Table 1.

Table 1 District Wise Number of Minor Irrigation Projects under OIIPCRA

Sl No.	Name of District	No. of Blocks	No. of GPs	No of MIPs	CCA in Ha. (Kharif)	CCA in Ha. (Rabi)
1	Balangir	10	17	21	4,809	623
2	Balasore	5	6	6	456	-
3	Bargarh	4	19	24	2,226	279
4	Bhadrak	5	12	13	1,356	60
5	Boudh	1	8	10	755	-
6	Gajapati	1	3	3	351	121
7	Ganjam	18	172	251	18,149	722
8	Jajpur	3	3	5	598	150
9	Kalahandi	10	30	36	3,555	424

10	Kandhmal	4	6	6	452	50
11	Keonjhar	11	39	49	12,015	3,057
12	Mayurbhanj	20	82	107	11,266	1,049
13	Nabarangpur	3	3	3	125	8
14	Nuapada	2	2	2	86	-
15	Subarnpur	1	1	2	94	-
Grand Total		98	403	538	56,294	6,543

2.2 MEDIUM IRRIGATION PROJECTS

OIIPCRA project covers 8 medium irrigation projects located in five of the fifteen districts mentioned in Table 1. Name of the medium projects, districts where located, CCA in Kharif, CCA in Rabi and Names of the concerned river basin are given in Table 2.

Table 2 Proposed Medium Irrigation Projects

Sl. No.	Name of Project	District	CCA (Ha.)	River Basin
1	Ghodahada	Ganjam	7,758	Rushikulya
2	Baghua	Ganjam	8,367	
3	Daha Dam	Ganjam	6,387	
4	Sundar	Nuapada	4,633	Tel Sub-Basin
5	Upper Suktel	Bolangir	1,345	
6	Uttei	Kalahandi	9,626	
7	Kalo	Mayurbhanj	4,904	Budhabalanga
8	Balidiha	Mayurbhanj	3,832	
		Total	46,852	

2.3 RIVER BASINS

There are eleven river basins in Odisha. Under OIIIPCRA project, four river basins are covered. The total CCA in Kharif is 103145 Ha in Kharif and 6543 Ha in Rabi. Maximum projects are under Rushikulya basin with a design CCA of 41072 Ha. Locations of projects in Baitarani, Budhabalanga, Rushikulya and Tel basin are shown in figure 1 to figure 4.

Table 3 River Basin Wise Proposed Projects

Sl. No.	Name of River Basin	No of Minor/Medium projects	CCA (Kharif) in Ha.	CCA (Rabi) in Ha.
1	Baitarani Basin	94	16,941	3,479
2	Budhabalanga Basin	88	17,486	837
3	Rushikulya Basin	258	41,072	843
4	Tel Sub-Basin	106	27,646	1,384
	Grand Total	546	1,03,145	6,543

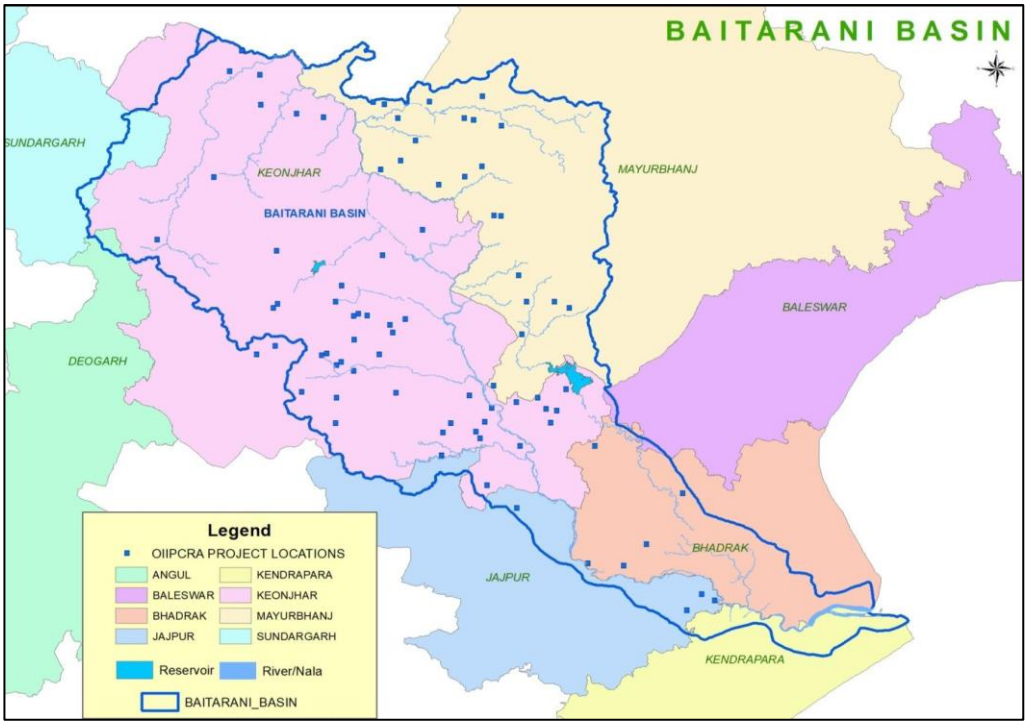


Figure 1 Baitarani Basin

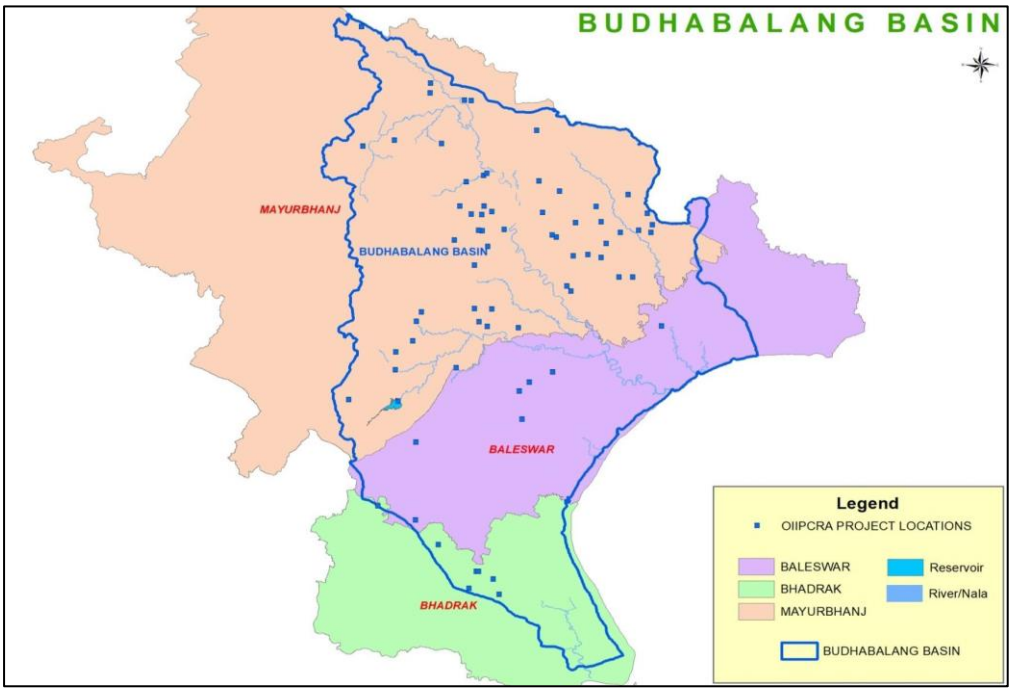


Figure 2 Budhabalanga Basin

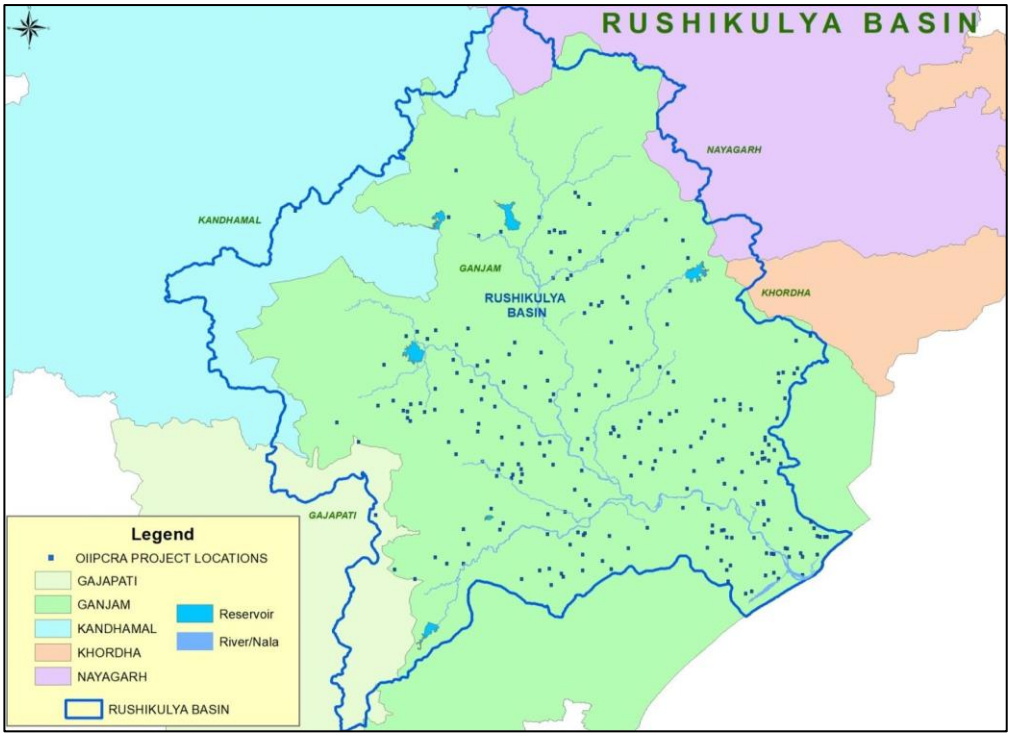


Figure 3 Rushikulya Basin

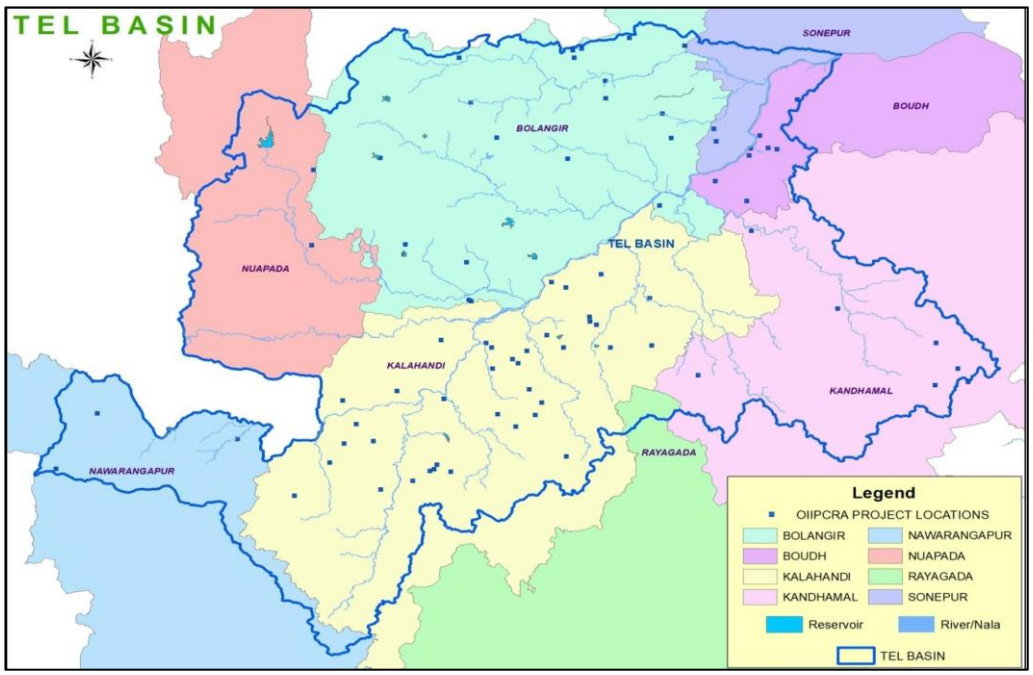


Figure 4 Tel Sub Basin

3 COMPONENTS OF MINOR IRRIGATION TANKS

The Minor Irrigation tanks consist of mainly two (2) components. Those are;

i. Head works

ii. Distribution system

3.1 HEAD WORKS

The head works of medium/minor project are constructed basically with components like;

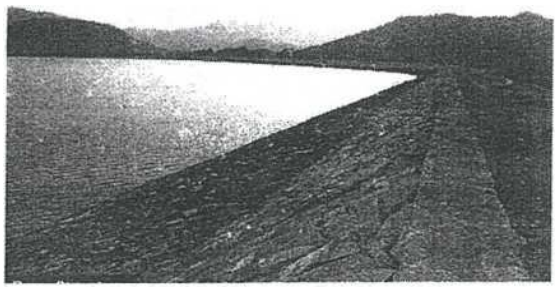
- Earth dam with Head regulator & surplus weir forming reservoir for storage of water to meet the requirement of irrigation, drinking water, pisciculture etc.

3.2 RESERVOIR

- Due to construction of the dam water impounds on its upstream.
- Water stored up to the full reservoir level (FRL) is called Gross capacity.
- Water stored below the sill level of (DSL) of the HR is called Dead storage capacity
- Water available between DSL and FRL is called live storage and is usable for irrigation and other purposes

3.3 TANK AND ITS COMPONENTS

Tanks are formed by constructing earthen dams or embankments across the stream or nala. By this way, the monsoon flows can be retained in the tank area. At the time of need, the stored water is used through regulated releases for irrigation and for other multiple uses like pisiculture, washing and bathing, rural water supply and for cattle drinking etc.



The main components of tanks are;

- Earth dam or embankment
- Tank sluices or outlets

3.3.1 Earth Dam/ Tank Bund Embankment

An earthen dam may be homogeneous or zoned type.

- Homogenous earth dam: A purely homogeneous type of dam is composed of a single kind

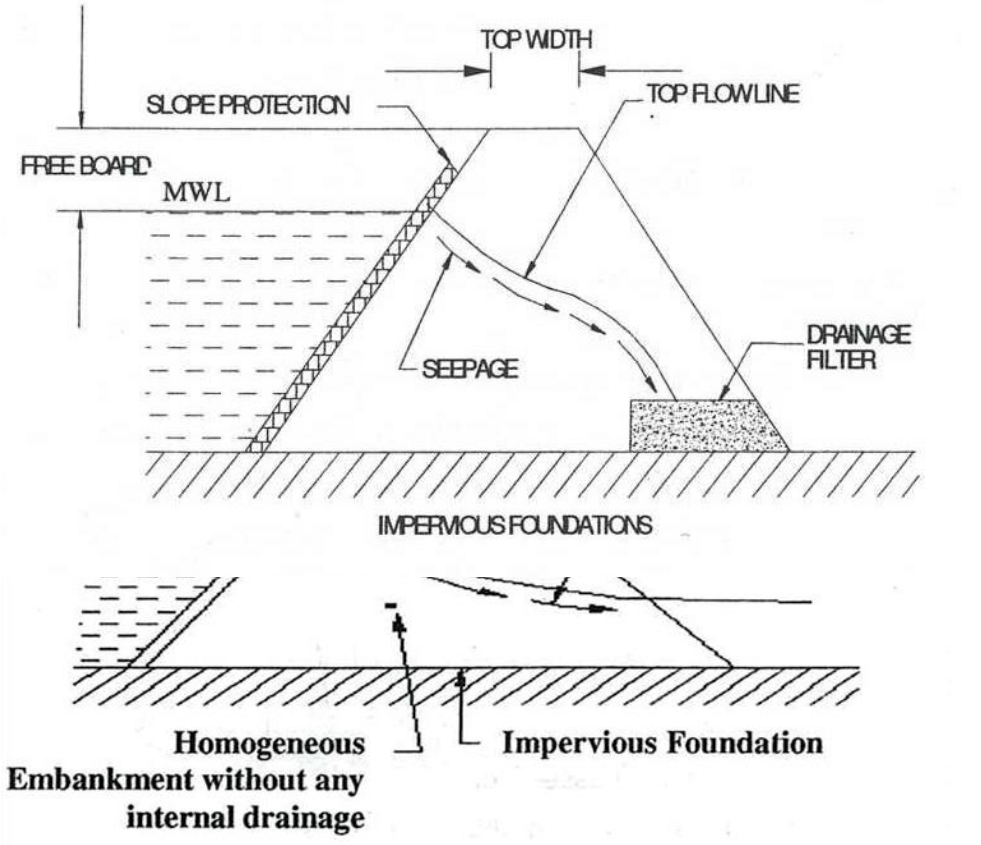


Figure 5 Homogenous Earth Dam

of material (Ref: Fig. 5&7). The purely homogeneous type of section, has now been replaced by a modified homogeneous section, in which small amount of carefully placed pervious material control the action of seepage so as to permit much steeper slopes as compared to pure homogenous dam (Ref: Fig 6)

1. Selected Earth Fill
2. Impervious Fill
3. Foundation
4. Impervious Sub-stratum
6. Rock Toe
7. Rubble Pitching
8. Toe Drain

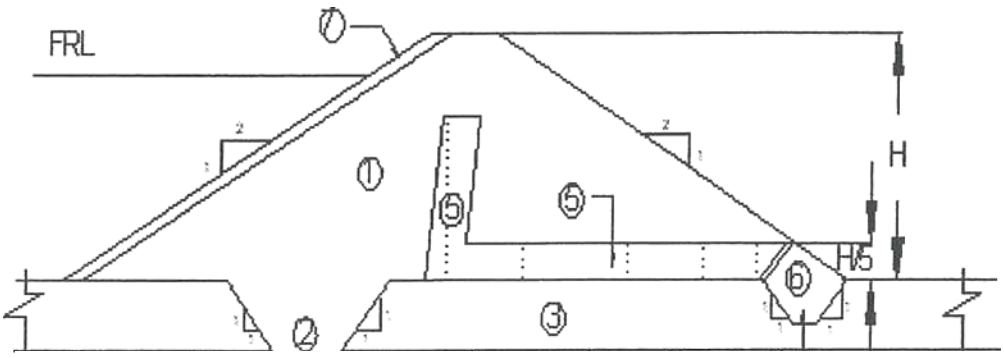


Figure 6 Modified Homogenous Earth Dam

5. Sand Filter

Zoned earth dam: Zoned earth dams are composed of a central impervious core flanked by zones of materials considerably more pervious called shells (Ref. Fig. 8).

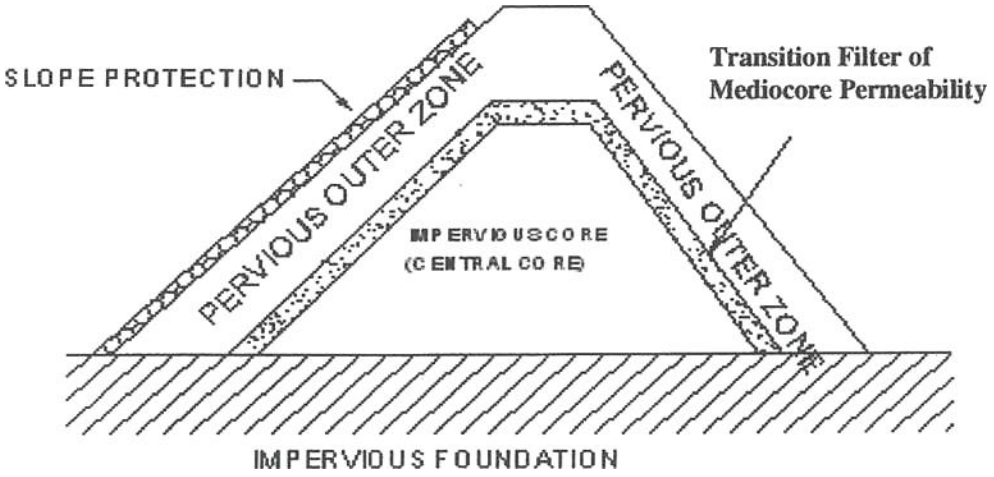


Figure 8 Zoned Earth Dam

A dam exceeding 15m in height above deepest river bed level is defined as large dam. Also a dam in between 10 m to 15 m height is termed as large dam if volume of earth dam exceeds 0.75 million cubic meters and storage exceed one million cubic meters or the maximum flood discharge exceeds 2000 m/ sec. A dam not satisfying the above criteria of large dam is termed as Small dam.

A fairly large number of earth dams constituting the tank bunds proposed to be rehabilitated under the project are 'large dams[7], being more than 15m in height.

The main components of the earth dam are described below:

1. Cut off
2. Core
3. Casing
4. Internal drainage system and foundations
5. Slope protection
6. Surface drainage
7. Impervious blanket

3.3.1.1 Functions of different components of earth dam

1. Cut off: (IS: 8414-1977)

The cut off is required,

- To reduce loss of stored water through foundations and abutments
- To prevent sub-surface erosion by piping

The type of cut off (Ref. Fig.9) should be decided on the basis of detailed geological investigations. It is desirable to provide positive cut off. Where this is not possible, partial cut off with or without upstreamimpervious blanket may be provided. Sometimes depending upon the subsoil geological

classification grouting as per IS: 8414-1977, IS: 11293 (Part-1) 1985 and IS: 4999-1991 may be done. In any case, adequate drainage arrangements may be provided on the downstream.

In case of positive cut-off, it should be keyed at least to a depth of 0.4 m into continuous impervious sub-stratum or no erodible rock formation. (Ref. Fig.9).

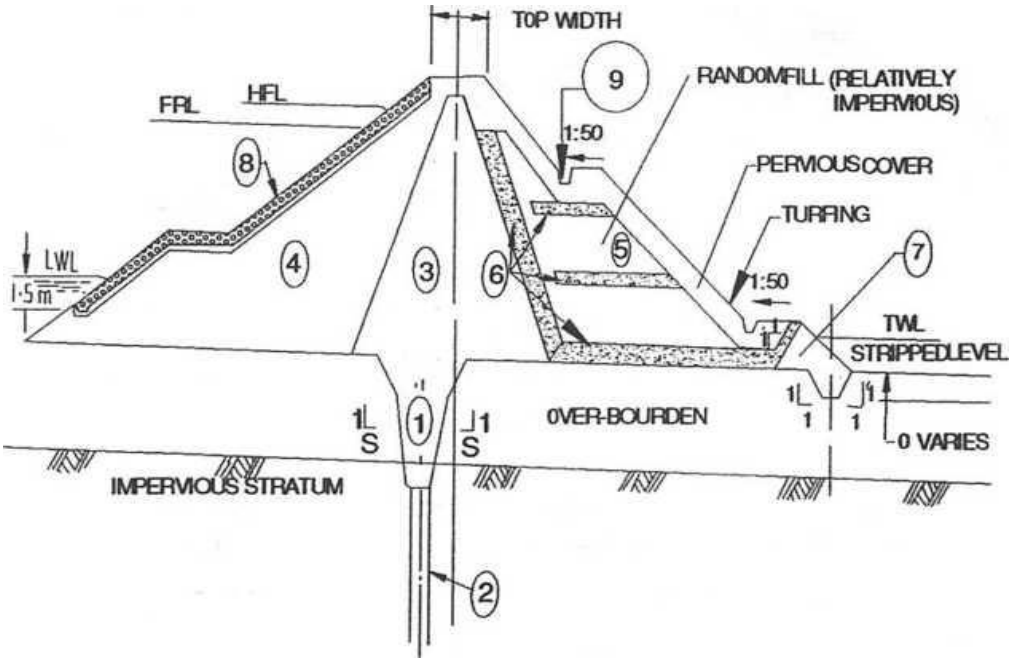


Figure 9 Earth Dam with positive cut-off

1. Positive Cut-off
2. Grout Curtain
3. Central Impervious Core
4. Upstream Casing
5. Downstream Casing
6. Inclined and Horizontal Filter
7. Rock Toe and Toe Drain
8. Riprap Filter
9. Catch Water Drain

The partial cut-off is specially suited for horizontally stratified foundations with relatively more pervious layer near top. The depth of the partial cut off. (Ref. Fig.10) in pervious alluvium will be governed by:

- Permeability of substrata
- Relative economics of depth of excavation governed usually by cost of dewatering versus length of upstream impervious blanket

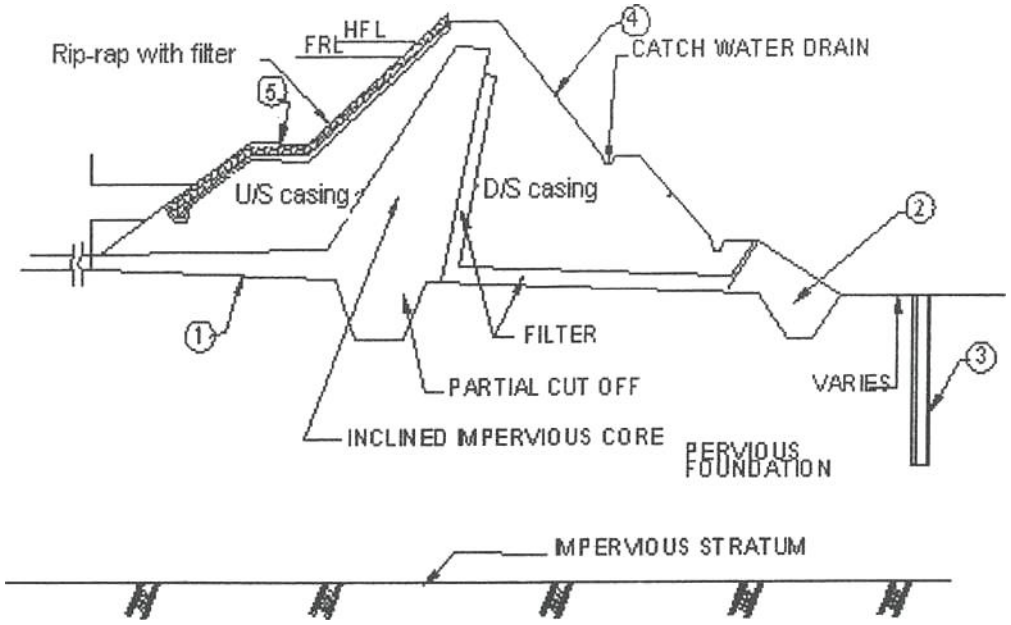


Figure 10 Earth Dam with Partial cut off

1. Impervious Blanket
2. Rock Toe and Toe Drain
3. Relief Well
4. Turfing
5. Berm

2. Core: (IS: 1498-1970)

The core (Ref. Fig.9) provides impermeable barrier within the body of the dam. Impervious soils are generally suitable for the core (IS 1498- 1970). However soils having high compressibility & liquid limit, and having organic contents may be avoided, as they are prone to swelling &formation of cracks (Such as micaceous or distomaceous fine sandy and silty soils, CH type of swelling soils, most morillonite group of soil).

3. Casing: (IS: 1498-1970)

The function of casing (Ref. Fig. 9) is to impart stability and protect the core. The relatively pervious materials, which are not subjected to cracking on direct exposure to atmosphere, are suitable for casing. Top width of dam should be provided as 4.5 m (minimum). The berms may be provided for the dam, which are more than 10 m in height. Minimum berm width may be kept as 3 m.

4. Internal drainage system: (IS: 9429-1999)

To ensure safety of dam, it is very important to handle the seepage water in the dam so as to maintain the original particles of soils in their place. The measures commonly adopted for safe disposal of seepage water through embankment dams are;

- Inclined or vertical filter (chimney filter)
- Horizontal filter
- Rock toe
- Toe drain

As far as possible locally available sand, gravel etc should be used. Inclined or vertical filter (Ref. Fig. 9) is provided just on downstream slope of core. Its thickness is kept minimum 1.0 metre. Horizontal filter collects the seepage from chimney filter & foundation, and carries to the rock toe & toe drain. Its thickness is kept minimum 1.0 metre. The standard filter criterion between filter and adjoining soil (casing or foundation) should be satisfied .In case of dam portions, where the head of water is 3 m or less it is not requiredto provide chimney filter or horizontal filter. Adequate toe protection shall however be provided. The height of rock toe is generally provided as 0.2 H, where H is the height of embankment. However minimum height of Rock toe to be kept as 1.0 meter. Rock toe is not necessary where height of embankment is 3 m or less.

The toe drain is provided at the downstream toe of the earth dam to collect seepage from horizontal filter, rock toe & through foundation and to discharge it away from the dam by suitable surface or sub surface drains. The section of toe drain should be adequate enough to carry seepage. The bed of toe drain should be given a suitable slope to lead the seepage to natural drains. Depth of toe drain is usually provided as 1.5 m with bottom width of 1 m minimum and side slopes of 1:1. For details IS 9429-1999 to be referred.

5. Slope protection

Upstream slope: The upstream slope protection (Ref. Fig. 9) is ensured by providingriprap. For design of riprap, IS 8237-1985 may be referred. A minimum of 300 mm thickriprap over 150 mm thick in two layers of filter comprising of coarse sand, coarse aggregate in equal thickness of 75mm each may be provided upto the top of dam.

Downstream slope: The downstream slope protection is ensured by turfing or riprap. It is usual practice to protect the downstream slope from rain cuts by providing suitable turfing on the entire downstreamslope from top to toe. For details of downstream slope protection, IS 8237-1985 may be referred.

6. Surface drainage

For surface drainage of downstream slope (Ref. Fig. 9) a system of open paved drains (chutes) along the sloping surface terminating in the longitudinal collecting drains at the junction of berm and slope shall be provided at 50 m c/c to drain the rain water. The section of drain may be trapezoidal having depth of 30 cm. From longitudinal collecting drain, the rain water is carried through 15-cm diameter pipes placed at 50 m c/c into paved chutes on the d/s slope. For details please refer IS: 8237- 1985. Where no berm has been provided, the open paved drains (chutes) should terminate in the downstream rock toe or toe drain.

7. Impervious blanket

The horizontal impervious blanket (fig.9) is provided to increase the path of seepage when full cut-off is not practicable in pervious foundation. The impervious blanket shall be connected to the core of the dam. To avoid formation of crack, the material should not be highly plastic.Reference may be made to IS: 1498-1970 for suitability of soils for blanket (Table 2). A 300mm thick layer of random material over the blanket is recommended to prevent cracking due to exposure to atmosphere.The impervious blanket may be designed inaccordance with IS: 8414-1977. As a general guideline, imperviousblanket with a minimum thickness of 1.0 meter and a minimum length of 5 times the maximum water head measured from upstream toe of core may be provided.

Zoning:

If only one type of suitable material is readily available nearby, a homogeneous section is generally preferred. If the available materialis impervious,a small quantity of pervious material is required as casing for protection against cracking. On the other hand if it is pervious, a thin impervious membrane is required to form a water barrier.

For other details IS: 12169 -1987 should be referred.

3.3.1.2 GENERAL GUIDELINES FOR EMBANKMENT SECTIONS

Following table gives a general guide line for fixation of embankment section.

SI. NO	Description	Height up to 5 m		Height above 5 m and up to 10 m		Height above 10 m and up to 15	
1.	Type of section	Homogeneous/Modified homogeneous section		Zoned / Modified homogeneous/Homogeneous section		Zoned / modified homogeneous / homogeneous section	
2.	Side slopes	U/S	D/S	U/S	D/S	U/S	D/S
a)	Coarse grained soil						
	(i)GW,GP,SW,SP	Not Suitable		Not Suitable		Not suitable for core, Suitable for casing zone	
		H:V	H:V	H:V	H:V		
	(ii)GC,GM,SC,SM	H:V 2:1	H:V 2:1	H:V 2:1	H:V 2:1	Section to be decided based upon stability analysis	
b)	Fine grained soil						
	(i)CL,ML,CI,MI	2:1	[2:1	2.5:1	2.25:1	-do-	
	(ii)CH, MH	2:1	2:1	3.75:1	2.5:1	-do-	
3.	Hearting zone	Not required		May be Provided		Necessary	
	a) Top width	—		3m		3m	
	b) Top Level			0.5m above MWL		0.5m above MWL	
4.	Rock toe height	Not necessary upto 3m height. Above 3m		Necessary. H/5, where H s height of embankment		Necessary. H/5, where H	

		height, lm ht. of rock toe may be provided		is height of embankment
5.	Berms	Not necessary	Not necessary	The berm may be provided as per design. The minimum berm width shall be 3 m. The berm may be provided also on the d/s slope for acilities during maintenance.

3.3.1.3 SUITABILITY OF SOIL FOR CONSTRUCTION OF DAMS

Following table describes the suitability of soil for construction of material.

Relative Suitability	Homogeneous Dykes	Zoned Dams		Impervious Blanket
		Impervious core	Pervious casing	
Very Suitable	GC	GC	SW, GW	GC
Suitable	CL, Cl	CL, Cl	GM	CL, Cl
Fairly suitable	SP, SM, CH	GM, GC, SM, SC, CH	SP, GP	CH, SM, SC,GC
Poor	-	ML, MI, MH	-	-
Not suitable	-	OL, 01, OH, Pt	-	-

GW: Well graded Gravel GP: Poorly graded Gravel

SW: Well graded Sand SP: Poorly graded Sand

GC: Clayey Gravel GM: Silty Gravel

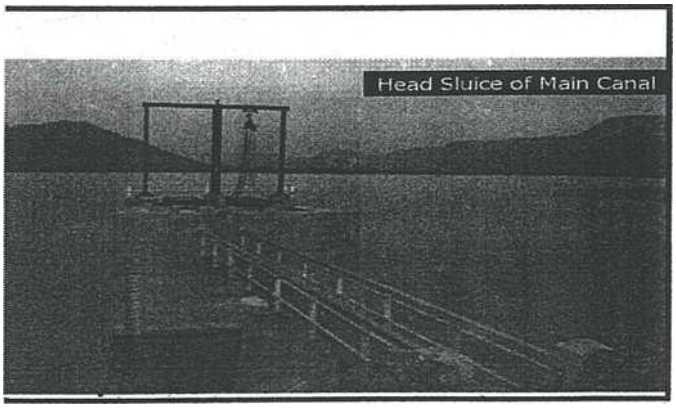
Cl: Inorganic Clays of medium plasticity CH: Inorganic Clays of high plasticity

(Viz. high swelling soils)

(Extract from Appendix A of IS 12169-1987)

3.3.2 Tank Sluice

a. Tank sluices are provided to discharge water from the tank for irrigation & other purposes.
b. These sluices may be of pipes or rectangular or arched openings passing near the base of the embankment and through the body of the embankment and carry water into the downstream channel below the embankment.
c. The sluice barrel in olden days was constructed in brick or stone masonry covered with stone slabs. Now days, Hume pipes are used for construction of such structures for better and easy maintenance.



3.3.3 Surplus escape

- In order to avoid over-topping of the tank embankment, tanks are provided with spilling arrangement for smooth escape of excess surplus water entered into the tank.
- These surplus escape arrangements may be provided in the following forms.
- In form of surplus escape weir in the body or at one end of the tank embankment. The surplus escape weir is a concrete / masonry structure with its crest level at Full Tank Level (FTL). When tank is full upto FTL, extra water is discharged over the surplus escape weir. The length or capacity of this surplus escape weir should be so designed that water level in the tank does never exceed the maximum water level (MWL). The top of the tank bund should be kept at a level, so as to provide 1.50 m free-board above this MWL. As the surplus escape weir is a masonry / concrete structure, it should be properly connected to the earthen embankments by suitable designed bank connections.
- Other arrangements like siphon spillway may also be provided as in case of earth dam projects

3.3.4 Distribution System

1. It consists of a main canal taking off from the cistern behind the bund downstream of the sluice.

It has a designed capacity for the maximum demand to be supplied in the crop season. It may have branch canals, distributaries and minors feeding the water-courses to irrigate the fields, sequentially depending upon the size of the tank and the Ayacut.

2. The distribution system have different types of structures such as;

> Drop structures(Fall).
> VRB / VRC / Road Crossings / cattle crossing / Foot bridge.
> Outlets structures with or without controlling gates.

- Cross drainage works.
    i. Super Passage
    ii. Canal Siphon
    iii. Aqueduct
    iv. Under Tunnel
    v. Drainage Siphon
    vi. Drainage Inlet and Drainage outlet (Escape)
- Head Regulator.
- Cross Regulator.
- Outlet structures with or without controlling gates.
- Measuring device.
- Proportional Distributor.

To safely carry the canal flow to the tail end as well to field channel.

3.3.5 Drop Structures (FALL)

Mainly two types of falls are used in case of minor irrigation canal system. These are:

i) Vertical drop type fall
ii) Siphon well type fall

i) Vertical drop type fall

Vertical drop type falls (Ref. Fig. no. 11) are provided when the ground slope exceeds the given slope of the channel. Vertical drop falls are quite suitable for discharge upto 15 cumecs and drop upto 1.5 m.

In case of vertical drop fall, the energy of the flowing water is dissipated by means of impact and by sudden deflection of velocity from vertical to horizontal direction. A water cushion is provided at the toe of the drop, so as to reduce the impact of falling jet and thus to save the downstream floor from scour. The water cushion is formed by depressing the floor below the d/s bed of the canal.

ii) Siphon well type fall

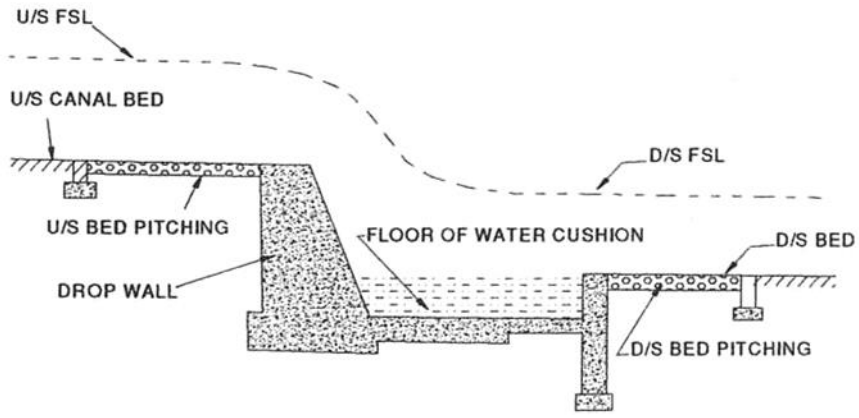


Figure 11 Vertical Drop Type Fall

This type of fall consists of an inlet well with a pipe at its bottom, carrying water from inlet well to a downstream well or a cistern. The water falls into the inlet well through a trapezoidal notch constructed in the staining of the well from where it emerges near the bottom dissipating its energy in turbulence inside the well (Ref. Fig no. 12).

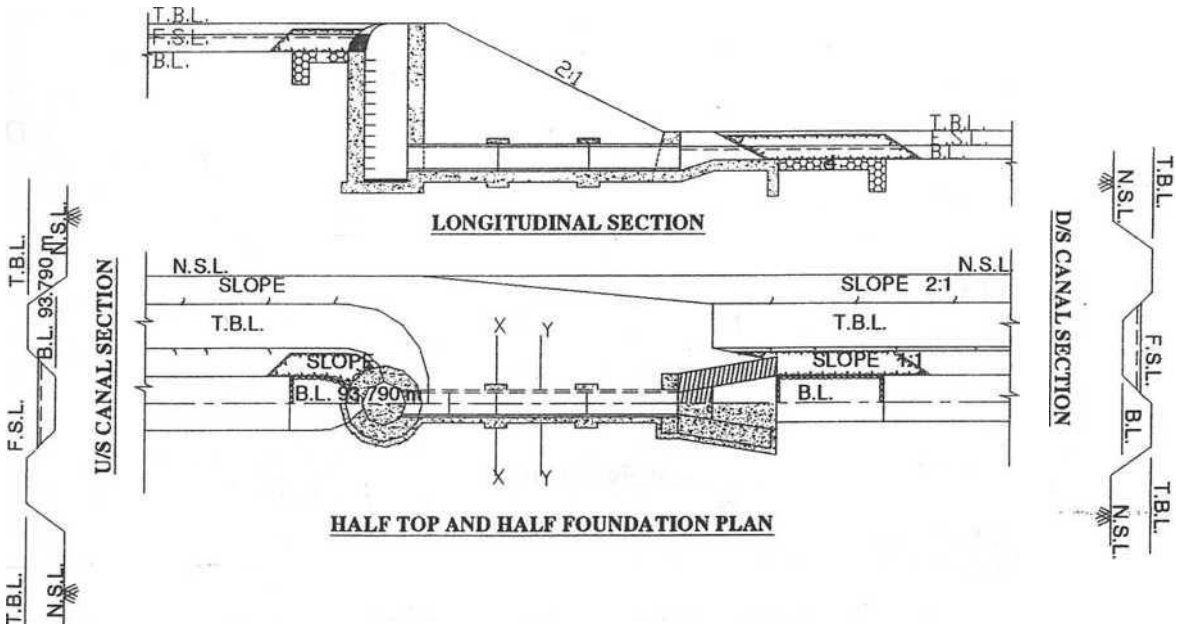


Figure 12 Syphon Well Type Fall

CAD-WM:

There is a major component in the project to improve the irrigation water distribution as CAD-WM by providing irrigation water to each 1.0 ha of sub-command area under the outlets of Minor Irrigation projects.

The project as its name appears to be climate resilient, proposed to provide CAD-WM channel system in the Minor Irrigation Projects to reduce the wastage of water percolating to ground under the out-lets and projects not having any canal system where irrigation is being provided by flooding in field-to-field.

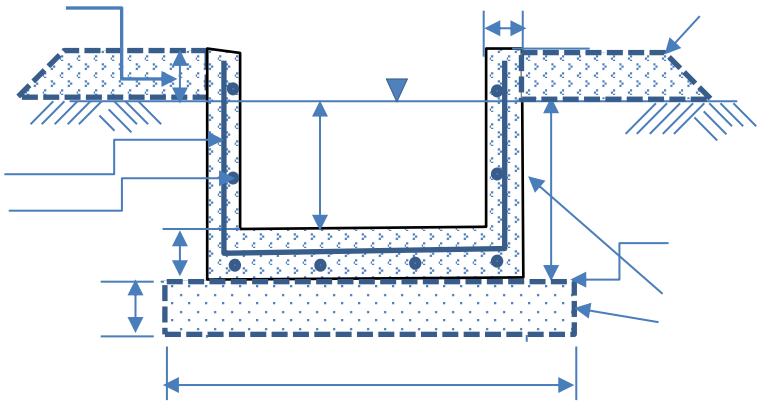
The CAD-WM was planned by creating patches of 1.0 ha sub-command in the command under each outlet. In order to achieve this without land acquisition and making almost no burden of curtailing the cultivated land of the farmers, it is proposed to traverse these channels as watercourses along the common bunds between the agriculture fields. This is required to be a slim, low-cost but durable CAD channel, which impelled the project to develop such section basing on the information and method being practiced in the state. The same was presented to the World Bank for inclusion in the estimate of the projects for implementation. But, the World Bank suggested to get it approved by the State Technical Advisory Committee for the proposed design and cost involved as the implementation of such system comprises a major chunk of the total project improvement cost in a policy decision by the State.

As such, the proposal is now submitted to the State Technical Advisory Committee for its technical verification and recommendation with suggestions to be adopted for this project.

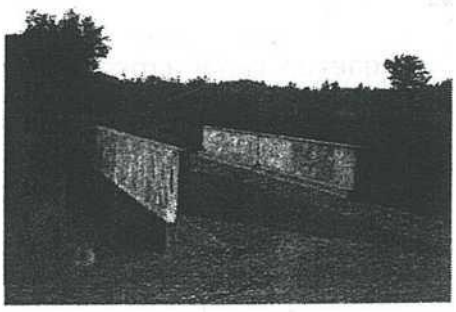
Present Proposal:

- The sizes of outlets under Minor Irrigation project vary from 4.00 Ha to 16.00 ha, some projects are not having any canal systemand irrigation is being provided by flooding in field-to-field.
- The section presently proposed is kept at 30 cm x 30 cm; are designed to carry a discharge of up to 18.4 to 26 Litre per second considering various slopes of terrain (1 in 500 to 1000).

- The projects where there is no canal system and irrigation is being provided by flooding in field-to-field, some larger size channel up to 25 to 40 LPS (for 25-40 Ha of command) is required. As such, some more sections have also been proposed in a tabular form to be chosen basing on the necessityconsideringto channel discharge. However, the section properties for construction would remain same except for the cross-section parameters.
- The Channel section proposed is rectangular in cross-section to be constructed in cement concrete by providing nominal steel reinforcement.
- The hydraulicdesign have been made adopting the Mannings' equation of flow velocity and recommended Rugosity coefficient of 'n' for concrete. From practical point of view, the 'n' value was considered at 0.020 for this section instead of 0.018 recommended for smooth surface concrete; as the value of 0.018 for concrete surface cannot be achieved in the field due to various reasons associated with the actual workmanship.
- The thickness of the concrete wall and bed will be 100 mm.
- Free board will be 50 mm to 100 mm.
- To have a working platform, a solid foundation base in M10-A40 concrete mix is provided below the channel section.
- A sample design, typical drawing, table of sections for different slopes of terrain and sample items of work contained in the estimate is enclosed for reference.



3.3.6 VRB/VRC/Road Crossing



Village road crossing is a structure, provided for better communication across the canal. Canal water runs freely below the structure

3.3.7 Outlet Structure in Canal

An outlet is a device built at the head of a water-course which connects the water-course with the distributing channel & controls the flow of water in the water course. The discharge depends upon the difference of head between the parent canal and its off-taking canal. Distribution of water is carried out by means of outlets. Typical section of a pipe outlet is depicted in Fig. No 13.

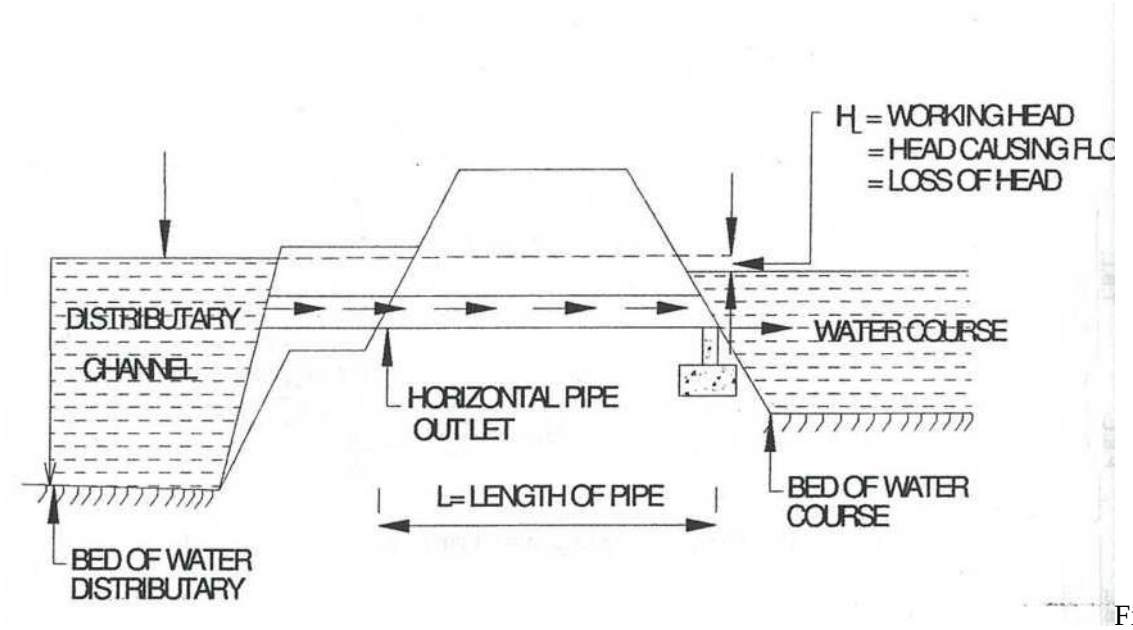


Figure 13 Canal Outlet

3.3.8 Super Passage: IS 7784 (Part-2 / Section-2) 2000

Whenever canal crosses a natural drain on its passage, it becomes necessary to disposed off drainage discharge for uninterrupted canal water supply. In case of super passage (Ref. Fig. no. 14) the drain is taken over the canal in such a way that the canal water runs freely. In such case the FSL of canal is sufficiently below the bottom of the drain trough.

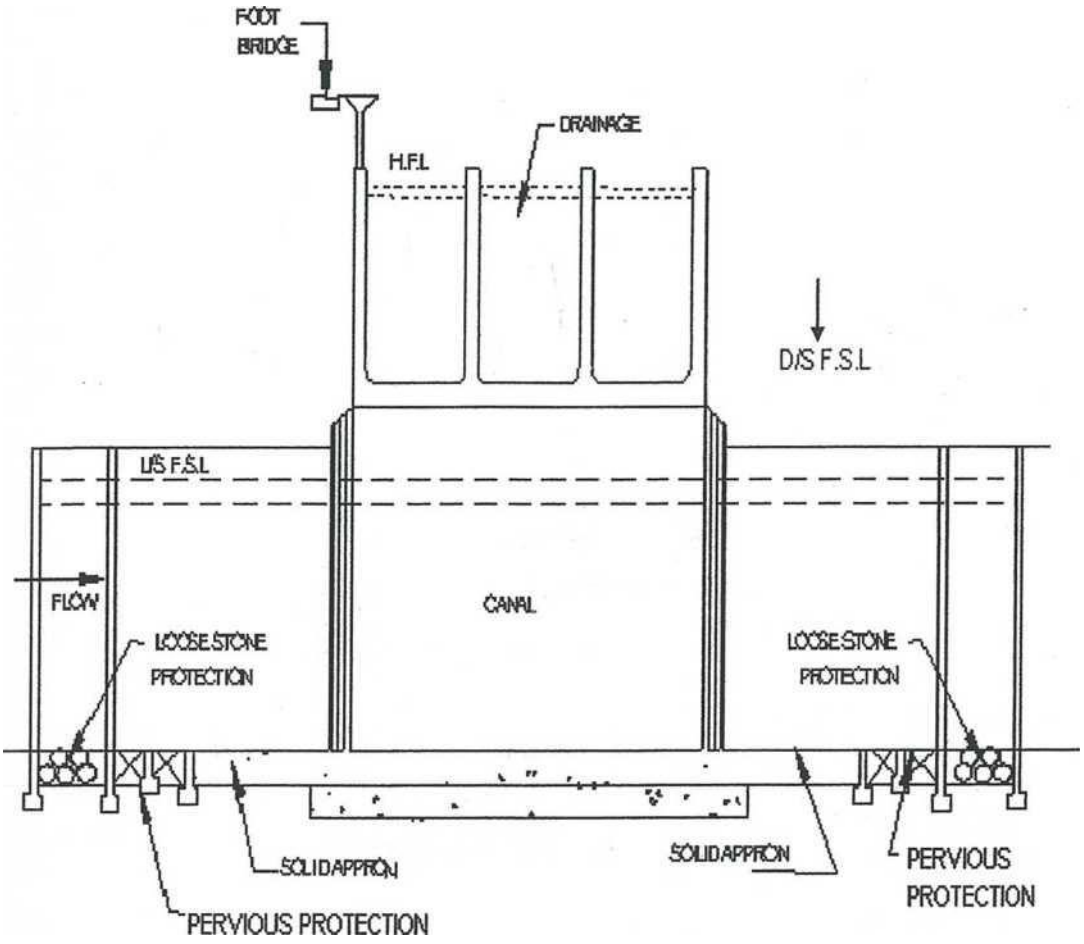


Figure 14 Super Passage

3.2.9 Canal Syphon: IS 7784 (Part-2 / Section-3) 1996

When drainage water is intercepted by the canal, and if the FSL of the canal is higher than the drainage bed, then it is disposed off by provision of syphon. In this case the canal bed is depressed & siphoned. In such case canal is usually flumed. Trouble of silting is minimized by provision of ramp at exit (Ref. Fig. no. 15)

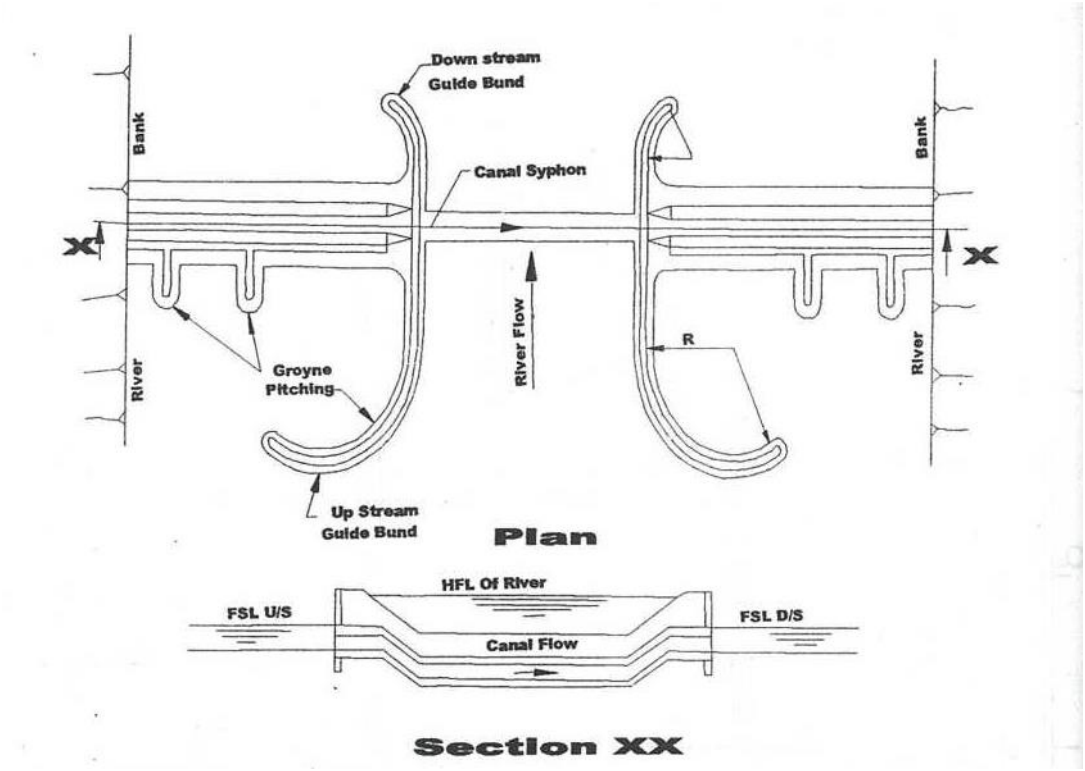
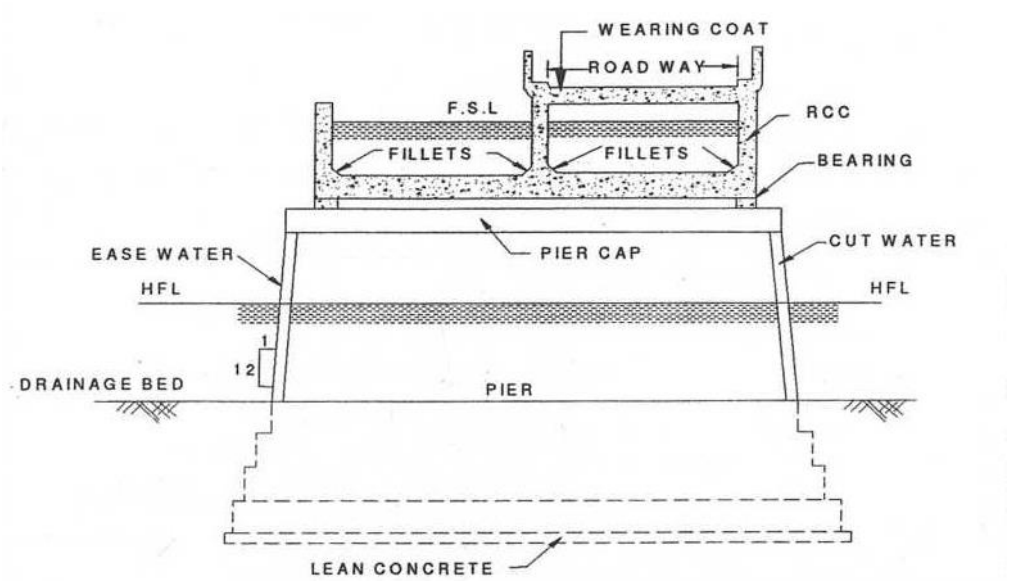


Figure 15 Canal Siphon

3.2.10 Aqueduct: IS 7784 (Part-2 / Section-1) 1995

An aqueduct (Ref. Fig. no. 16) means a channel for conveying water and it may be either above or below the ground level. In irrigation engineering, the term is confined to mean a structure carrying an irrigation channel over a drainage channel without having lower down the bed of the drainage channel for the crossing. These are suitable for crossing over small stream and where the difference of level between the bottom of the canal and high flood level of the drainage stream is small



3.3.9 under Tunnel

Figure 16 Aqueduct

When the bed level of the drainage channel is below the canal bed level and drainage water flows freely from upstream to downstream it is called drainage under tunnel (Ref. Fig. no. 17).

3.3.10 Drainage Syphons: IS 7784 (Part-2 / Section-5) 2000

When the bed level of the drainage channel has to be depressed below its natural level to pass it under the canal it is called drainage syphon (Ref. Fig. no.18).

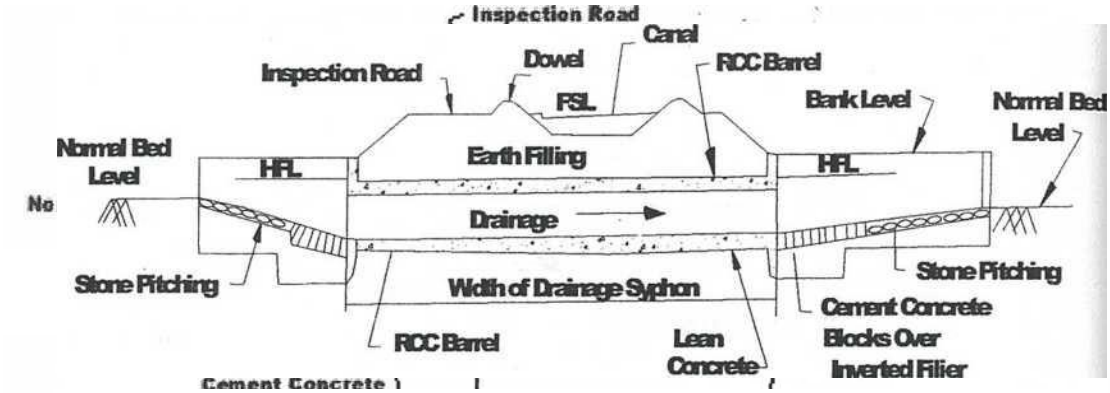
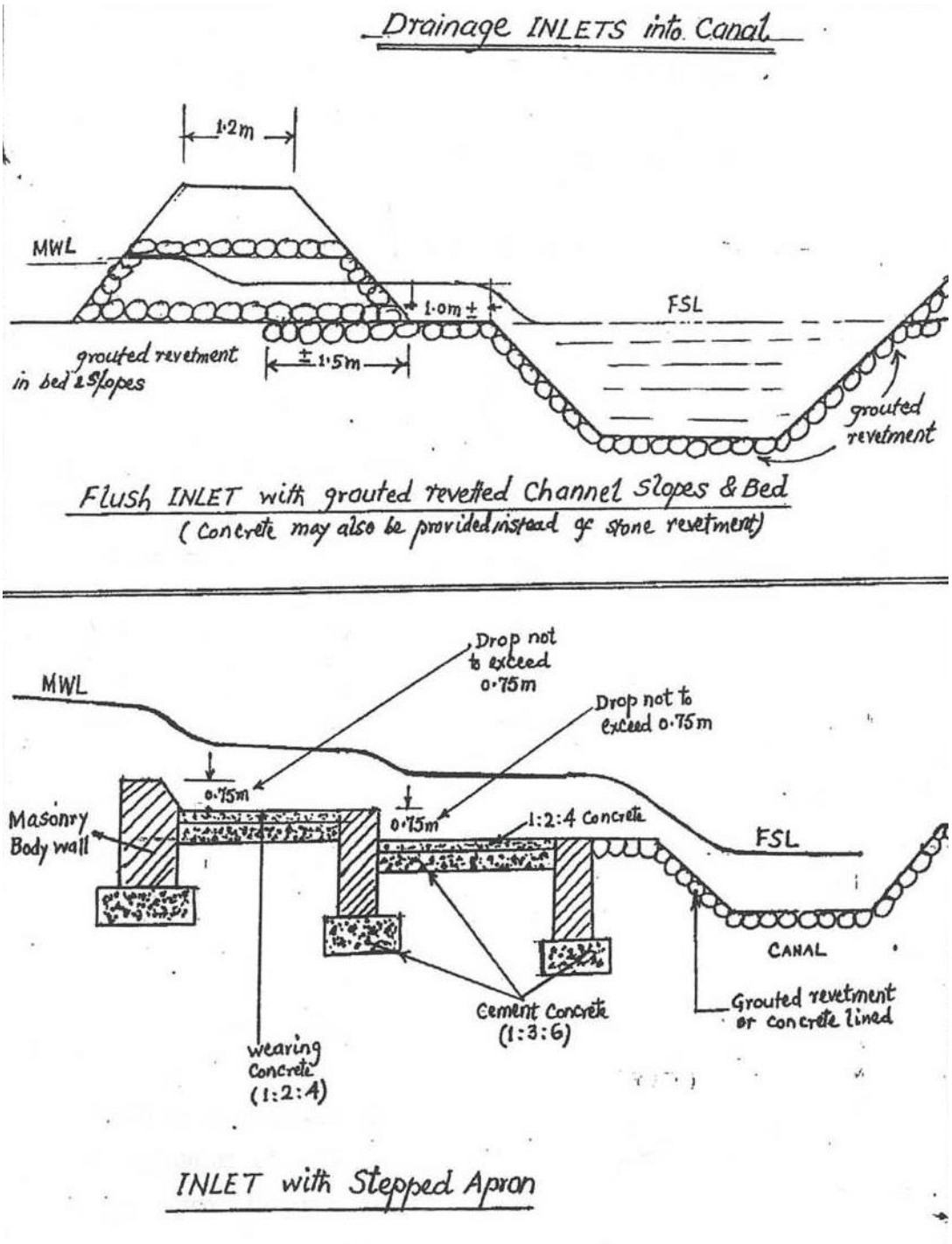


Figure 18 Drainage Siphon

3.2.13 Drainage Inlet & Drainage Outlet:(Escape):IS 7784 (Part-2 / Section-4) 1999

Drainage Inlet:-Inlet is a simple open cut with grouted revetted channel or with stepped apron or a pipe in a canal bank to admit the drainage water into the canal. It may be provided for a small drainage, if its bed level is higher than the canal FSL and it does not carry heavy silt (Ref. Fig. No 19)



Drainage Outlet: Ifthe drainage water admitted into the canal is discharged at a suitable site

Figure 19 Drainage Inlet

opposite the inlet or on the downstream, the arrangement is called "Drainage Outlet".

3.4 Water Spread Area

a. The submergence water area at full tank level is known as water spread area. The quantity of the water stored between DSL & FTL (waste weir crest level) is the live storage capacity which can be drawn through the sluice.

b. Maximum Water Level (MWL) is the level up to which water can be allowed to raise without endangering the bund during floods when the waste weir is discharging.

4 DEFICIENCIES IN THE TANK SYSTEMS

4.1 DEFICIENCIES IN THE TANK SYSTEMS

The existing tank systems are suffering from a wide range of deficiencies and defects. The tank bunds comprise of earthen dams/ embankments of varying heights. A fairly large number of earth dams are more than 15 m in height, coming in the category of large dams.

The tank system deficiencies are broadly classified as:-

1. Deficiencies in tank bund and appurtenant structures.
2. Deficiencies in canal and distribution net work.

4.2 DEFICIENCIES IN THE TANK BUNDS / EARTHEN EMBANKMENTS / EARTHEN DAMS AND APPURTENANT STRUCTURES

- Some tank bunds are having thick jungle growth.
- Tank bunds are deficient of designed sections, both on upstream and downstream slopes, and also the TBI's are below the designed levels.
- Some tank bunds do not fulfill the Indian Standard (IS) requirement of Free-Board of 1.5m above MWL.
- Several earth dams exhibit 'distress features', such as: sloughing and slippages of downstream slopes at some locations; and seepages from the dam toe.
- The dam top in some embankments suffers from a large number of long and wide cracks.
- Some earth dams are prone to piping phenomenon, with substantial increase in seepage and the appearance of 'turbid seepage water' upon impoundment of water to F.R.L.
- Disturbed rip-rap on upstream slope
- Some dams are more than 100 years old and associated with complete silting of dead storage and also the silt accumulation being higher than the sill level of the head regulator (H.R.).
- Such a situation necessitates excavation of leading / approach channels year after year to feed the H.R.
- Choking of toe drains and inadequate surface drainage system
- Some earth dams, constructed through Panchayatas, are deficient both in designs and construction. The appurtenant structures are also quite deficient.
- Dam with 11.8m high in Daungia MIP (KandhamalaDistrict) is lying in a 'breached condition' since 1995, and is non-functional.
- In several dams the mechanical fixtures like steel shutters on the sluices are non-functional, the stem rods having been broken or nonexistent. In some cases, the steel frame and the hoisting arrangements do not exist.

- Some Diversion Weirs along with the downstream aprons and out flow channels are in damaged condition.
- The body walls of some masonry surplus weirs are associated with substantial leakages, indicating gradual increase in porosity of masonry.
- Besides the structural damages to some pick-up weirs, there are a number of such weirs which do not have the provision of scouring sluices.
- A large number of out-flow channels immediately downstream of surplus weirs are associated with deep erosions on both bed and banks

4.3 DEFICIENCIES IN CANAL AND DISTRIBUTION NETWORK

The canal and distribution network in the various tank systems suffer from the following deficiencies:

- The canals have lost their profiles and designed sections and by and large, in a very poor condition.
- The canals suffer from a large scale siltation.
- Some canals are associated with extensive jungle growth, both in bed, slopes, and on banks.
- Canals have lost their designed discharge carrying capacities as a result of which water does not reach the tail ends. In some canals, the water does not go beyond 60% to 70% of the respective canal length.
- The conditions of drop structures are deplorable. These masonry structures suffer from extensive damages. In some canals, almost all masonry drop structures have collapsed.
- The condition of other canal structures comprising well siphons and C.D. works etc. are also in poor condition and many have become non-functional.
- The canals passing through swelling black cotton soils suffer from severe deficiencies viz. loss of designed profile, collapse of structures, extensive crack formations, and huge jungle growth both in the canal prism as well as on canal banks.
- Inflow of uncontrolled drainage water into some of the canal systems during rains in the absence of any properly designed "Inlet Structures" causes serious damages to the canals.
- Serious damage caused to the canal systems because of nonexistence of catch water drains / existence of in adequate carrying capacity of water.
- Efficient distribution of water through the canal systems are adversely affected either due to the poor condition of the gate system or because of non-existence.
- Measuring Devices do not exist anywhere in any of the canal system.
- No proper outlets exist, a large no. of existing outlets are in damaged condition and unauthorized drawl of water arrangements from the channels are in abundance.
- Damages have occurred to the existing masonry canal troughs (wherever provided) downstream of HRs / Sluices, causing leakages of water.

4.4 Guidelines on Rehabilitation Measures

4.4.1 Tank Bunds / Earth Dams

In order to bring the deficient earthen tank bund to the specified design standard, and also to fulfil the requirement of Indian Standard in respect of free-board, the job of re-sectioning, raising , and strengthening of the embankment section shall be taken up in a methodical manner .

The following construction procedure shall be followed:

4.4.2 RENOVATION OF EARTHEN EMBANKMENTS

Raising and strengthening of earthen embankments (dam & canals) in such reaches / portions which are deficient in designed sections shall be carried out with good construction procedures. For raising earthwork on the existing old embankment, it is essential to ensure proper bonding of fresh laid soil with the old embankment so that it behaves as a homogeneous section. Placement of earth fill layers on the U/S & D/S slopes duly benched, as also on the dam top to bring the dam section to design standard. It is essential that watering to OMC condition and mechanical compaction of earth fill to 98% proctor density to be done.

Construction Procedure

- All vegetation, bushes, roots, plants etc. shall be removed from the existing portion of embankment proposed to be strengthened.
- The base shall be stripped to a depth of about 15 cm to 20 cm.
- The outer slope / inner slope shall be benched in suitable steps of about 30 cm to 45cm.
- Borrow area to furnish suitable soil for fill placement shall be identified.
- Types of soil suitable for placement comprise of: clayey gravel, silty gravel, clayey sand, silty sand, clayey soils etc.
- Density tests of borrow area soil shall be conducted. 3 or 4 tests shall be conducted with varying moisture contents to enable determination of "Maximum Dry Bulk Density (MDBD)" and Optimum Moisture Content (OMC), viz the moisture content at which the density is high.
- Earth fill shall, then be laid in layers at the placement side. Thickness of layers shall be restricted to 20 cm to 22.5 cm, in case required compacting equipments are used for compaction.
- Thickness of layer shall be restricted to 15 cm in case "Fuel- operated Vibratory Plate Compactor" is used for compaction.
- Thickness of layer shall be restricted to 10 cm in case manual compaction with improvised "Hand Rammers" is to be done.
- Water shall be uniformly sprinkled over the layer, if it is dry Rapid Moisture Meter or conventional Heating Method may be used to determine the moisture content in the layer. Fine spray nozzle or gardener's cans be used for adding water. Compaction shall, preferably, be done to 98% Proctor density (viz maximum density corresponding to OMC), in no case less than 95% proctor density.
- During placement of layers, clods & stones of size larger than 7.5 cm shall be hand-picked and removed from each layer.
- Extra width of about 30 cm or more shall be laid in each layer and compacted to ensure full compaction of designed section. The extra earth fill shall be later trimmed to the designed slope and the earth is re-used.

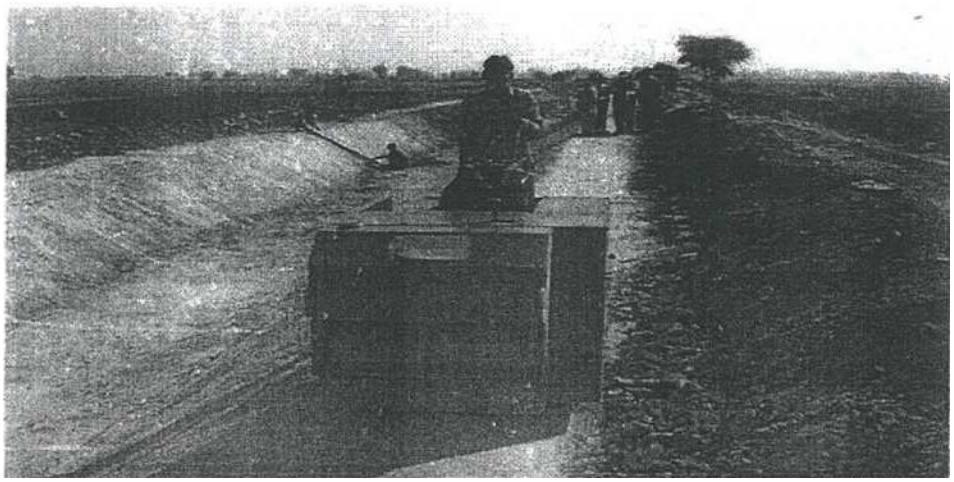


Figure 20 One Metre Wide Vibratory Roller Being Used for Earth fill Compaction

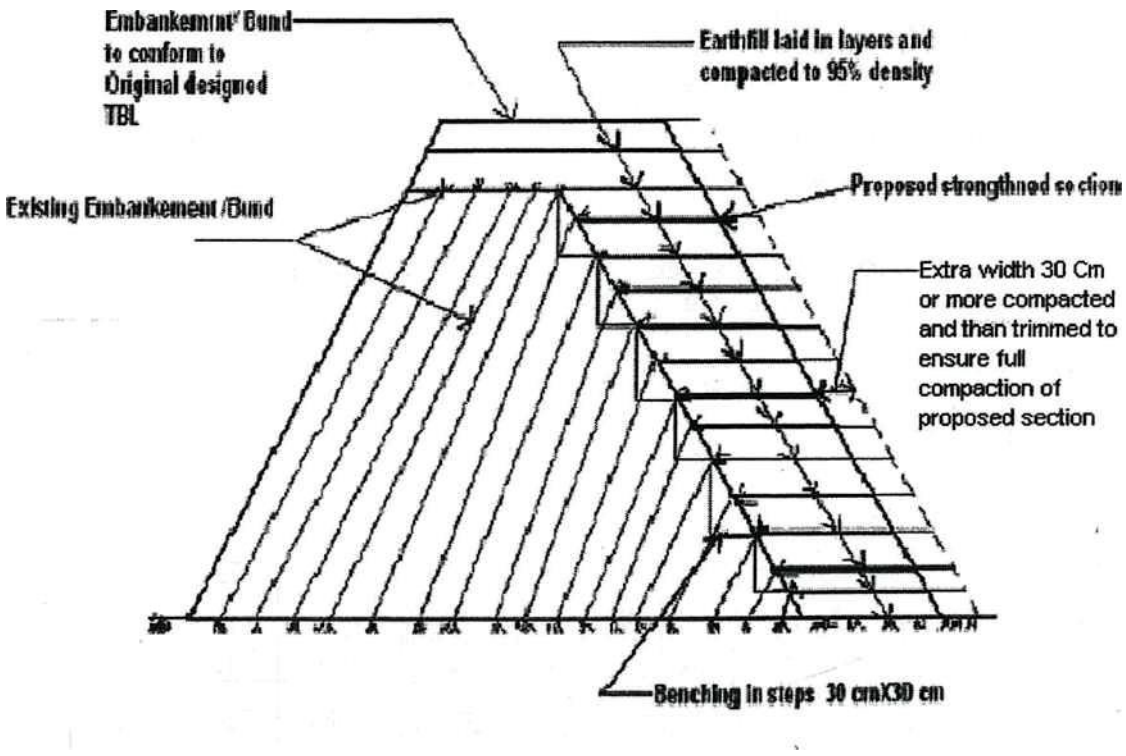


Figure 21 Raising & Strengthening of Existing Bund

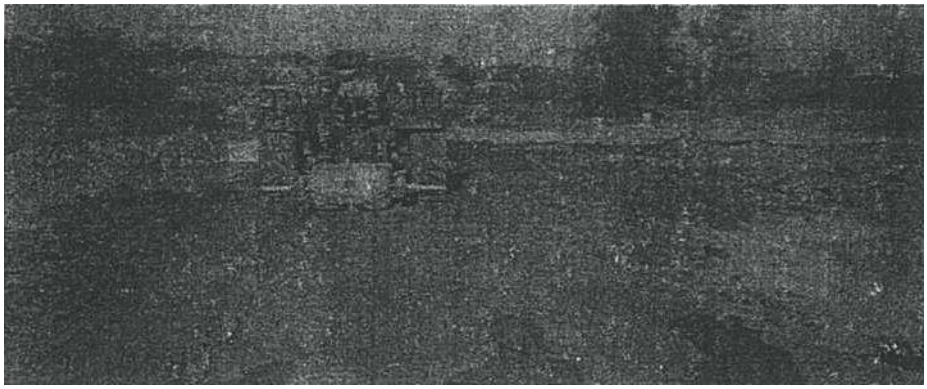


Figure 22 Roller

In case determination of Maximum Dry Bulk Density (MBD) viz; Proctor Density and Optimum Moisture Content (OMC) are sometimes not easily feasible, particularly on the jobs of strengthening of canal sections, these values may be assumed as have been outlined in Table 2 of Indian Standard, IS : 12169-1987 for calculating the compaction efficiency of the compacted earth fill layers in terms of the percentage of Proctor Density.

AVERAGE PROPOERTIES FOR DIFFERENT TYPES OF SOILS,

(TABLE 2: *Clause* 5.1.2.3 of 15:12169-1987)

Sl No.	Engineering Classification of Soil (see IS; 1498-1970*)	Average Properties of Soil				Soil constants for recommended slopes			
		MDD Kg/m3	OMC percent	Cohesion Kg/m2	Tan □	MDD Kg/m3	OMC percent	Cohesion Kg/m2	Tan □
I	GC	>1840	<15	NA	>0.60				
Ii	GM	>1830	<15	NA	>0.67				
Iii	SM	1830±16	15±04	500±500	0.58±0.07	1800	15	1100	0.60
Iv	SC	1840±16	15±04	1100±600	0.6±0.07				
v	ML	1650±16	19±0.7	900±NA	0.62±0.04				
vi	CL	1730±16	17±0.03	1200±600	0.54±0.04	1650	19	900	0.35
vii	CH	1510±32	25±1.2	1300±600	0.35±0.09				
viii	MH	1310±64	36±3.2	2000±900	0.47±0.05	1300	35	1300	0.35

*Classification and identification of soils for general engineering purpose (first revision).

(i) Longitudinal and Transverse Cracks on top of Dam:

Sometimes during hot summer months, cracks are noticed on the embankment. Due to highly clayey nature of soils used in the embankment formation of such cracks occur due to high temperature, which tend to close during colder season.

Other types of cracks are caused by unequal settlement between adjacent lengths of embankment, at junctions of earth and masonry structures, and due to non-uniform compaction to its full width in the successive layers in the embankments. The most serious cracks are those which run transversely creating a path through the core for concentrated seepage through it. In such cases immediately the Pani Panchayat should bring it to the notice of the Engineer-in-Charge.

ii) Remedial Measures for Treating of Cracks:

The following measures are to be taken promptly whenever cracks (other than the cracks associated with high temperature and which close during cold weather) are observed in the embankment:

- Find approximate depth of crack by excavating an inspection pit.
- Carry out water test through this pit and observe approximate intake of Water.
- Excavate the cracked portion in the form of a trench up to the bottom of crack and the trench be filled in 10cm thick layers of semi pervious soil duly compacted. The compaction may be done by hand rammers or pneumatic tampers or even manually by persons through their gum boots if mechanical means of compaction are not readily available (Ref. Fig. No. 23).

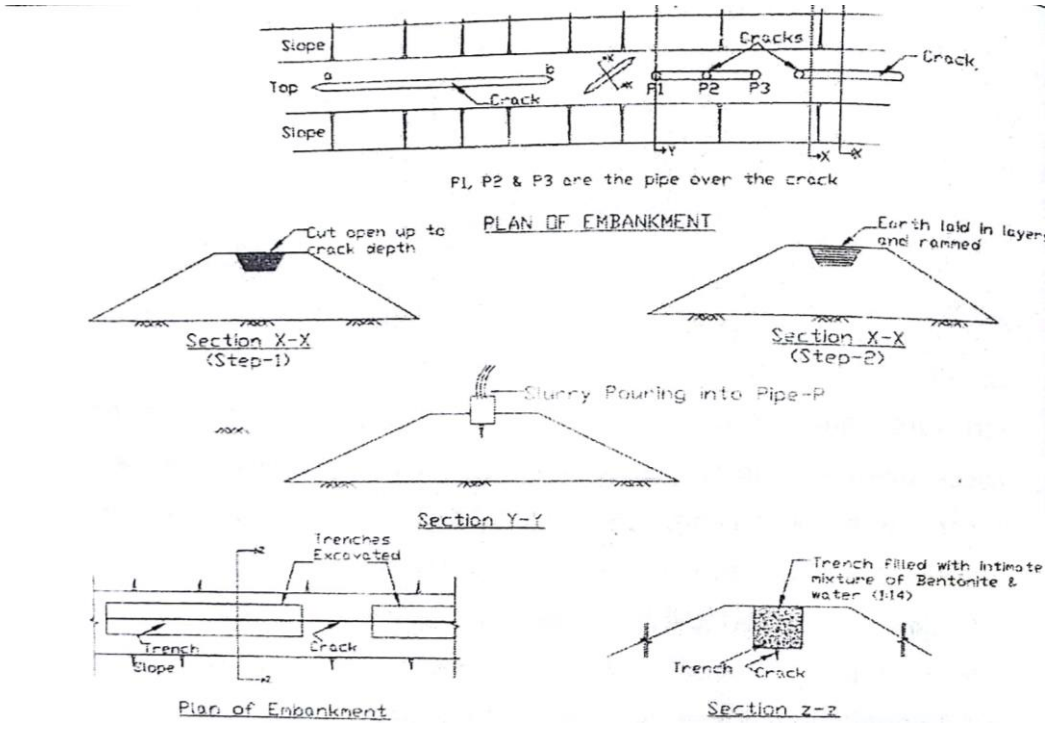


Figure 23 Treatment of longitudinal and transverse cracks

- If the depth of crack is substantial / about 0.60 m or more, "clay - cement water mix grouting maybe adopted. This is normally done through 75mm dia pipes inserted into the cracks at about 0.9m to 1.0 m spacing and pouring the fluid grout mix (clay - cement - water) in these pipes, viz., 'gravity grouting' without deploying any grout pump (Ref.Fig.23).

- Treatment of deeper cracks can also be done by excavating trenches in the cracked portions to a depth of about 0.60 m to 1.0 m range; exposing the cracks; and filling the trenches with a solution of ‘bentonite and water (1:14 ratio)’. Gradually, the bentonite will penetrate the cracks extending below the trench bottom all along their depths, filling these completely. When no solution is left in the trenches, suitable earth fill in layers should be placed and compacted well right up to the top level of embankment. There is no need of excavating the trenches right up to the bottom of cracks if these are very deep. [0.60 m to 1.0m deep trenches are o.k]. An important requirement is that the bentonite powder should be very well mixed in water and is to be kept stirring till the solution is poured in the trenches (Ref. Fig.no.23).
- Sand Slurry Method: Sometimes it is more expedient (when nothing else is available at a short notice) to treat the longitudinal and transverse cracks by pouring a well stirred mixture of fine sand and water (Say, 1:5 ratio) into the cracks manually.

(iii) Tackling Leakages & Piping Phenomenon through Tank Bund:

If clear water is coming out through a leak, the situation is not serious. However, discharge should be measured and reported immediately to the Engineer-in-charge. Regular monitoring of discharge should be introduced. Gradual / sudden increase in leakage discharge can be a cause of concern. In case the discharge is not allowed to increase further, dumping of soil and morrum on the upstream slope in a portion opposite to the leakage point maybe adopted. Even gunny bags full of soil and morrum can be dumped.

If turbid water is coming out through a leak the matter is serious and may develop into a dangerous situation of piping. The leakage discharge should be approximately estimated. Also, immediate inspection of Tank Bund should be made to discover whether any settlement, howsoever small, and any longitudinal or/and transversecracks have developed in the embankment. It should also be observed whether any 'sloughing' of embankment has occurred at any location. All these facts should be promptly communicated to the Engineer-incharge so that requisite remedial measures can be initiated well in time. Simultaneously, following actions should be taken immediately:

- Inverted filter be laid over the face where leakage of turbid water is taking place viz the inverted filter be built over the embankment slope as it is without going in for any bowel shaped excavation to lay the inverted filter. The layer of sand is to be placed against the leakage face.
- This Proposal of 'inverted filter' is to trap soil particles. The danger to a leak arises out of the removal of soil particles from the body of embankment, ultimately resulting into uncontrolled piping. The function of the filter is to arrest the movement of soil particles. It is, therefore, of utmost importance that correct filter materials are used. If after placement of inverted filter, it is observed that the turbidity of leakage water has disappeared and the leakage is of clear water, the filter has served its purpose.
- If, even after taking the above emergent action, the situation still demands lowering of water level in the tank, it should be done.

- If the leakage of water comes from the junction of earthen embankment with the foundation at the bed, the inverted filter can be placed in the portion immediately downstream of the toe in about 3.0 m length.

Figure 24 Inverted Filter

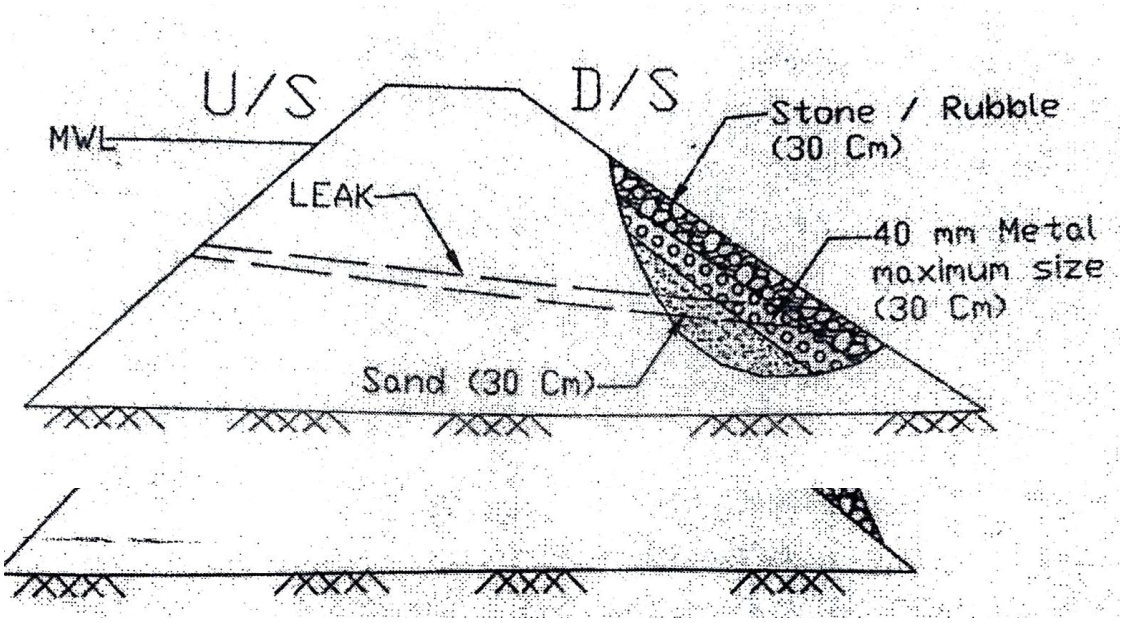


Figure 25 Inverted Filter

(iv) Long Term Remedial Measure for Piping:

When water level in the tank goes down and the tank is almost depleted and bed is exposed. A key trench of 0.9m to 1.0m depth should be excavated at the upstream toe of the embankment and impervious soil should, then be laid in layers and properly compacted. The length of this trench (covering a substantial reach u/s and d/s of the location of leakage point / points) can be determined at site. A coffer dam or a ring bund can also be constructed on the upstream side, space between ring bund and tank bund dewatered, and the work excavating key trench and filling it with impervious earth fill undertaken. There-after, the upstream slope of bund be stripped by about 20 cm and a clay blanket of about 1.25 m to 1.5 m thickness should be raised from the key trench up to M.W.L. (duly placed in layers and appropriately compacted). Stone revetment over graded filter should then be laid over the inclined clay blanket.

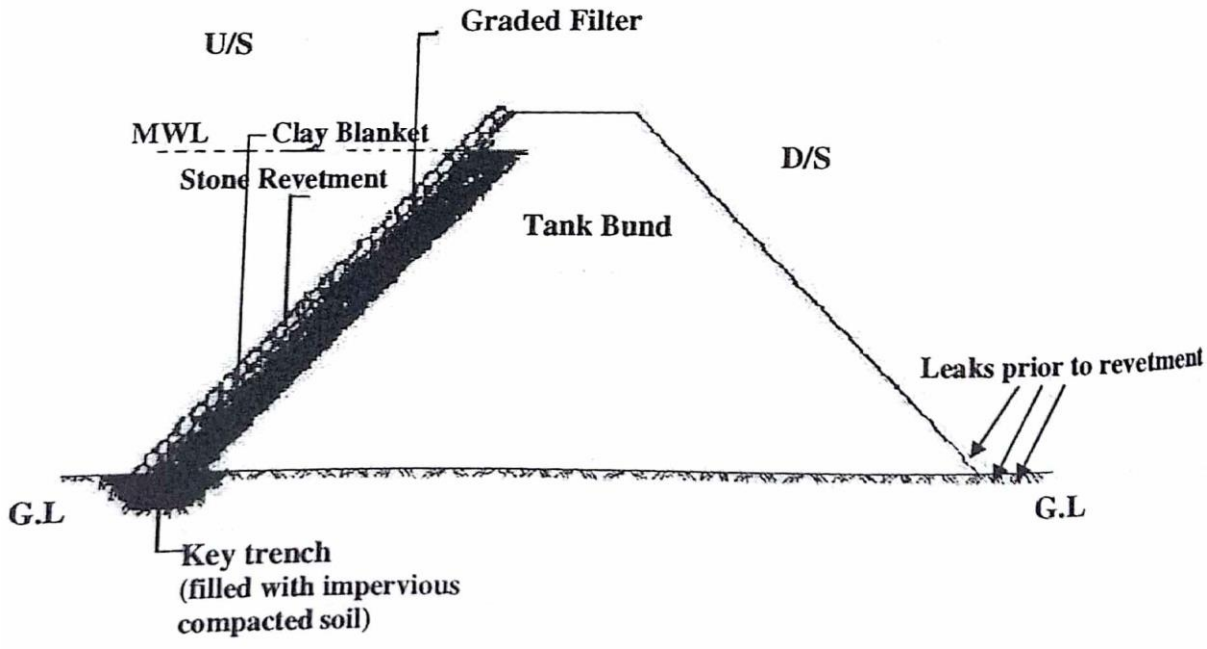


Figure 26 Clay Blanket

- Placing and laying of rip-rap shall be in accordance with clause no. 6.1, 6.2, 6.2.1 and 6.2.2 of IS: 8237-1985.
- In case of siltation of the reservoir above the sill lavel of the HR an approach / leading channel is to be excavated up to the Head Regulator in order to feed water to the canal system.

(v) Dam Safety

The field engineers are advised to obtain inputs from the Design Cell and the GoO constituted Dam Safety Review Panel in finalizing remedial measures for addressing serious distress situation affecting dam safety. Advice from Geologist should also be obtained by the field engineers to address any geo-technical problems.

(vi) Leakages from Body walls of Surplus Weirs

The body walls of masonry weirs shall be appropriately encased with M20 concrete with nominal temperature reinforcement. Steel dowels of, say 16 mm dia. shall also be drilled into the masonry section and cement grouted to promote a good bond between the old masonry and the new concrete jacket.

(vii) Mechanical Fixtures

The detailed information has been indicated in Chapter-5 of this manual.

(viii) Leakages from Wing Walls of Structures

Drilling shallow holes in the masonry and undertaking low pressure cement grouting is expected to provide good results in checking haphazard leakages. Prior to grouting, few drainage holes should be drilled to channelize water. In alternate epoxy or required chemical application be made as per necessity/ suitability.

(ix) Breached Earth Dams

Sequence-wise steps for closing of breaches

A) Preparation:

- All water should be completely cleared out of the bottom of the breach section as well as from its close vicinity.
- All soft mud / slushy soil should be removed and dense surface exposed on the bottom. A proper foundation is of paramount importance.
- All loose soils should be removed from the ends of bund on either side of breach.
- In case it is a zoned section, core trench or core wall is to be restored to its design section.
- All vegetation, bushes, roots should be removed.
- Key trench should be provided at the base.
- The existing bund on either side of breach should be cut to a flat slope, preferably, 4(H): l (v) slope.
- The cut slopes should be benched in suitable steps of +30 cm or 45 cm. Meanwhile, soil to be placed with requisite compaction in the breach section should be got classified for its suitability.

B) Placement of Earth fill and Compaction:

- Prior to placement of earth fill, all scour holes / scoured portions existing both in front and rear of the bund should be filled with good clayey soil and compacted well.
- Earth fill should be placed in suitable layers (20 cm / 22.5cm thick in case power roller is used or 15 cm thick in case fuel operated plate compactor / earth rammer is used).
- Core trench / core wall is to be filled first and compacted. Thereafter, fill placement should be carried out systematically over the whole area.
- In case of zoned section, hearting portion of embankment should always be kept one layer above the adjacent portion of casing.
- Earth fill layers in the homogenous section bund are to be compacted to at least 95% proctor density (98% will be preferable); earth fill layers in the hearting zone should be strictly compacted to 98% of proctor density.
- It is to be ensured that any gravel / stone pieces / clods of size more than 7.5 cm are picked out and removed.
- The soil in the casing zone (viz cohesion less soil) is to be compacted to a relative density of 65%.
- Slopes of the new embankment should be in conformity with the designed slopes of the bund or even somewhat flatter in special situations. An extra width of, say, 30 cm should be laid and compacted during fill placement to ensure effective compaction of full section. This extra width can be later trimmed and the trimmed earth re-used.
- The top level of newly formed bund section should be raised to an extra height above the old embankment to allow for settlement. Settlement allowance of about 2% in height must be kept.

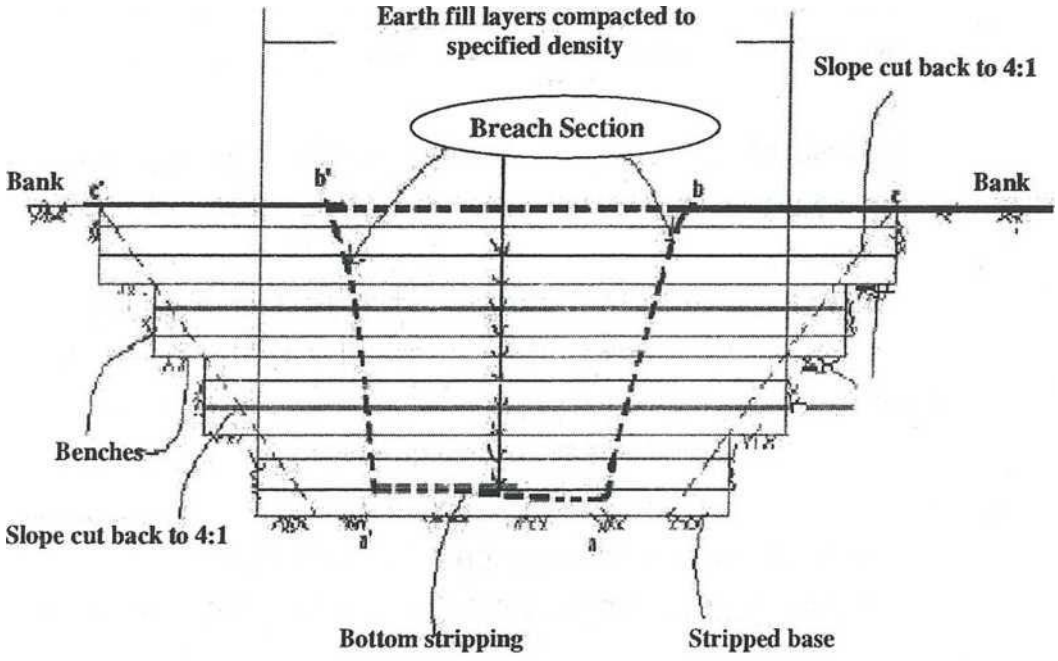


Figure 27 Breach Closing

4.4.3 Canal System

- The canals & distribution system are associated with loss of designed profiles, siltation, erosion of banks, and jungle growth and have become incapable of carrying the designed discharge. An extensive job of re-sectioning, raising, and strengthening of the channels is required to bring the system to the design standards. The detailed guideline to be adopted are
- Detailed surveys should be carried out through L-section and cross-sections to determine the quantum of re-sectioning and strengthening involved in various channels to bring those to the design standards and the quantities of earthwork estimated.
- In respect of the unlined channels which are proposed to be lined, hydraulic designs should be done to fix the requisite parameters and based thereon the quantities of earthwork needed for lined section estimated. While converting the unlined canal section into lined one, "n" value (viz; Rugosity coefficient) in Manning's formula is taken as 0.020 for concrete lining.
- Jungle growth within the canal prism and from the canal banks should be properly removed and requisite provision made in the cost estimate.
- For re-sectioning / raising / strengthening of existing canal sections, provision should be made for benching the slopes in suitable steps, earth fill placement in layers, watering and mechanized compaction with appropriate compaction equipment viz standard short width drum (± 1.0 m to ± 1.2 m), fuel operated vibratory plate compactors, pneumatic tampers etc. depending upon the site situation and availability of space. The thickness of layers will be influenced by the type of compacting equipment. For strengthening of channels, compaction should be done to 95% of Proctor density. In case of non-cohesive soils the layers should be compacted to at least 65% Relative Density.
- The soil proposed to be brought from the borrow areas should be got "classified" through relevant tests to determine its suitability for use on the strengthening of canal sections and earthen dam.
- During earth fill placement in layers, extra width of 30 cm or more is to be laid to ensure full compaction of the design section. Provision of the extra earth fill and its later trimming to the

designed slope / profile and its re-use allowing for re-handling and some loss during re-handling should be made in the cost estimate.

- In case determination of Maximum Dry Bulk Density (MBD) viz; Proctor Density and Optimum Moisture Content (OMC) are sometimes not easily feasible, particularly on the jobs of strengthening of canal sections, these values may be assumed as have been outlined in Table-2 of Indian Standard, IS: 12169-1987 for calculating the compaction efficiency of the compacted earth fill layers in terms of the percentage of Proctor Density (Ref. Table in Clause No.2.3.2).

4.4.4 Canal Structures

- A very large number of structures of various types have either collapsed or are in badly damaged condition. These are mostly in masonry construction .The situation is in worst so far as drop structures are concerned.
- All the collapsed and badly damaged masonry structures shall be replaced with new structures to be constructed in concrete with proper design.
- The partly damaged masonry structures, which are feasible of easy repairs, shall be repaired to make them fully functional. In future new structures shall be constructed in concrete to the optimum possible extent.
- The Design Cell shall also review the old designs and make improvements there-in, as warranted, to enhance their stability and functional efficiency.
- Special attention shall be given to the designs of structures which are to be constructed in the swelling black cotton soils. The Design Cell shall introduce additional needed features to counter the swelling pressures to ensure the stability of such structures.

4.4.5 Measuring Structures

- For an efficient irrigation system, it is essential to provide measuring devices in the canal and distribution network. Normally , a measuring device shall be provided downstream of : every Head Regulator ; off-take of Distributory / Minor from the Main canal / Branch canal and Sub-minor from Minor etc (Ref.Fig.no.28).
- The discharges being small, provisions of "Cut-Throat Flumes" (CTFs) as measuring devices shall prove to be very useful.
- These shall be constructed in concrete. Provision of some 'state-of-art' CTFs in fibre glass reinforced plastic mould (FRP) shall also be made.

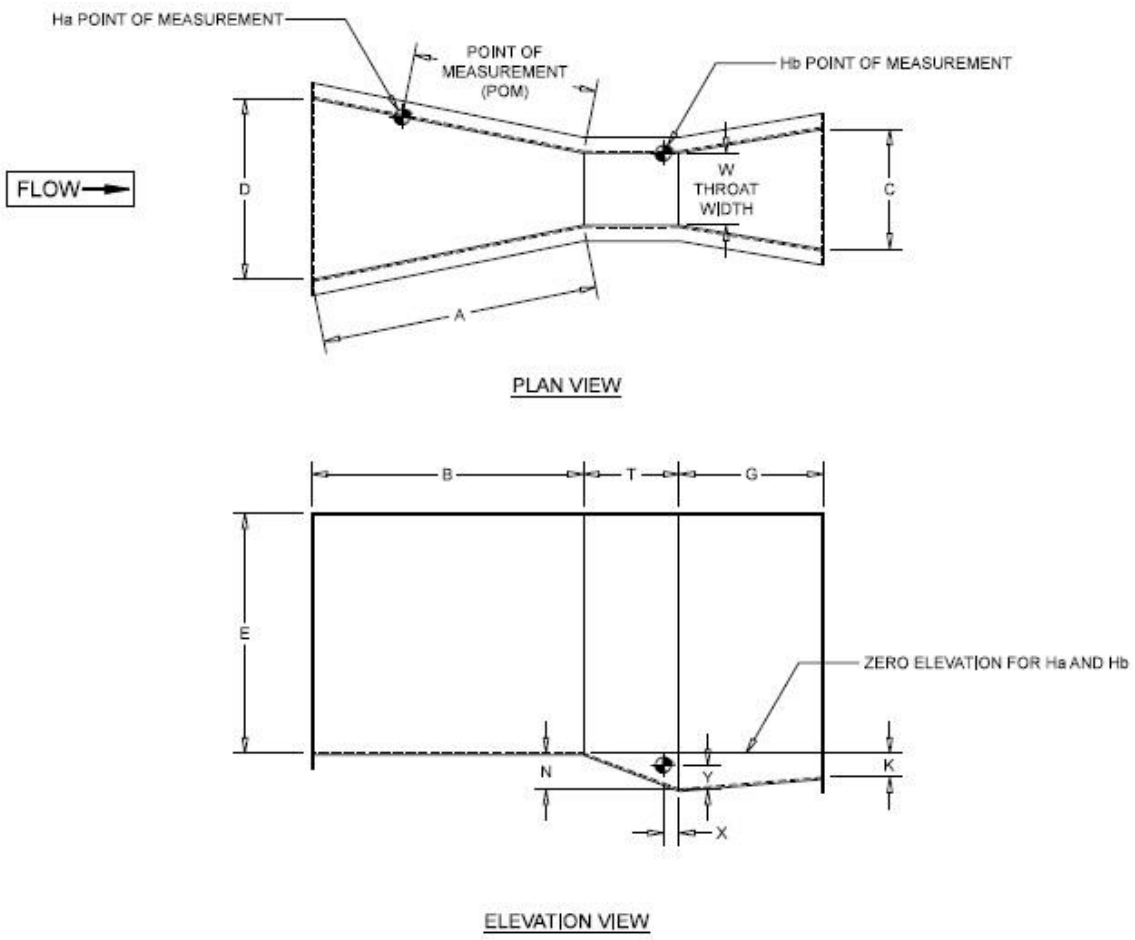


Figure 28 Parshal Flume

4.4.6 Drainage Inlets / Drainage Outlets (Escape)

- The Design Cell shall prepare typical design of "Inlets" (Ref. Fig. No.19 in Chapter-1) to be provided at relevant locations in the canal system to enable probable discharge of drain into the canal. Typical drainage Outlets / Escape has also to be designed and provided, where ever so warranted.

4.4.7 Catch water Drains

- A comprehensive survey shall be carried out to assess the condition of existing catch water drains and the adequacy there-of. Necessity of any additional drains or re-sectioning shall be determined and provided in consultation with the Design Cell.

5 SPECIFICATION OF EARTH WORK

5.1 SCOPE

Earth work consists of excavation, removal and satisfactory disposal of all excavated materials for the required construction / renovation of earth dam, its structures and distribution systems of tank project in accordance with the required specifications and confirming to the approved design and drawing. It should also include the hauling, stacking, spreading and compaction of earth for renovation of earth dams and canal embankments along with reuse of useful earth in the work and disposal of unsuitable excavated materials in the specified dumping yard in a systematic manner as per the requirement of the department.

5.2 JUNGLE CLEARANCE AND GRUBBING OF SITE

5.2.1 GENERAL

The clearing operation shall be in accordance with clauses 4.1, 4.1.1, 4.2 and 4.3 of I.S. 4701-1982 for "Indian Code of Practice for earth work in canals."

Jungle growth within the earth dam slopes, canal prism and on the canal banks should be properly removed. The clearing work includes cutting and disposing of trees up to 30 cm. girth, bushes and shrub, windfalls, logs and objectionable vegetation growth. Grubbing consists of excavation, rooting out, removal and disposal of stumps and roots.

Trees less than 30 cm girths should be cut under the item of jungle clearance and trees with girth exceeding 30 cm will be dealt under separate items. Clearance of jungles such as clearing, cutting & disposal etc. shall be subject to provision of forest values.

Where grubbing is not required, all shrubs will be cut within 7.5 cm. of the ground surface measured on the uphill side of the stump.

5.2.2 DISPOSAL OF THE MATERIALS

The disposal of cleared and grubbed material shall be in accordance with clause 4.1.1 of I.S. 4701-1982, "code of Practice for earth work on canals".

All stumps, roots, bushes, buried logs and other debris within the area required to be cleared and where grubbing is to be done, shall be burnt or otherwise completely removed from the site to the requirement.

Disposal by burning will be allowed only on specific sanction of the Engineer-in-Charge and shall be done under constant attendance until fires have been burnt out or have been extinguished to guard against

spreading of fire. In absence of approved dumping yard arrangement of the same may be made for disposal of waste materials.

5.3 EARTH WORK IN EXCAVATION

5.3.1 CLASSIFICATION OF EXCAVATED MATERIAL

All materials involved in excavation for the renovation of tank projects are as follows;

- Soil (All kinds of soil)
- Disintegrated Rock
- Hard Rock

5.3.1.1 ALL KINDS OF SOIL

This shall comprise of top soil, silt, loam, clay, mud, peat, black cotton soil, soft shale or loose moorum, mixture of both stoney earth, sand and similar material which can be excavated by pick axe and spade. Removal of stoney earth mixed with gravel and moorum etc. inter spread with boulders upto 0.014 cum size should also be covered under this category.

5.3.1.2 DISINTEGRATED ROCK

Rock type such as Laterite, Shales and Conglomerates varieties of lime stone and sand stone etc. which can be quarried / spilt mechanically or manually by / with crow bar & pick axe can be classified as disintegrated rock. In addition to this any rock in its dry state may be very hard requiring blasting but when gets wet it becomes soft and can be removed by pick axe, crow bars and spade should cover under this category of rock. Hard stone boulders having volume 0.5 to 3.0 cum mixed with D.I.rock etc., which may not require blasting for excavation, shall also be included in this item.

5.3.1.3 HARD ROCK

Hard rock requires drilling holes and blasting with explosive and cannot be removed by pick axe and crow bars or any other method.

5.3.1.4 EXCAVATION OF HARD ROCK

This shall include all rock in place, of such hardness and textures that it cannot be removed by pickaxe and crowbar or any other method until loosened by drilling, blasting and wedging. All boulders or detached pieces of solid rocks having volume greater than 3 cum. can be classified as hard rock when removed by blasting etc. Rock excavation shall be done as per relevant I.S. Codes.

The excavated rock and debris so obtained shall be carried and dumped/stacked separately with varying lead at dumping yard. The volume shall be calculated after deduction of suitable void percentages and compared and co-related with the pre-measured volume.

1.1.1.2 OVER EXCAVATION

Excavation should be done to exact designed section in all kinds of soil, D.I rock and hard rock. No over excavation will be allowed. However, in canal sections taken up in hard rock formation over excavation to the extent of 10 cm. depth on an average will be allowed and paid in respective item. In case of over excavation due to poor geological formation payments would be made for removal of such quantity only

after due approval of the competent authority.

5.4 FOUNDATION EXCAVATION OF STRUCTURES

The excavation for foundations of structures shall be done to the lines, grade, and depths shown in drawings duly observing all safety precautions including shoring / strutting / timbering. Additional excavation needed to remove unsuitable material should be done. The over excavation shall be filled with suitable soil or M7.5 concrete in soil or rock strata respectively. The foundation shall be wetted and thoroughly compacted / tamped. Suitable excavated material shall be used in the back-fill or other works. After the structure has been constructed and cured, all unsuitable material (dirt, scrap, set concrete, vegetation etc) shall be removed and placement of back-fill taken up layer by layer. The layers at OMC shall be 10 to 15 cm thick depending upon the compaction to be done by pneumatic tampers or hand rammers. Every layer shall be adequately compacted to the satisfaction of Engineer- in- charge. In case of sand filling, the area shall first be saturated with water. The sand shall be free of all impurities.

5.5 EMBANKMENT

5.5.1 NEW CONSTRUCTION OF EMBANKMENT

New construction of embankment shall be constructed to the top width and side slopes as per the design section provided. Suitable excavated material available from the canal cutting, removal of ramps and excavation for structures shall be used for construction of banks. If suitable and adequate material for constructing embankment is not available from excavations the desired materials shall be obtained from borrow area designated for the purpose.

The planning for execution should be such that all the useful excavated materials are utilized in embankment prior to utilisation of borrow earth from outside. Only suitable materials as per specification shall be excavated, loaded and conveyed to the point of placement in the embankment.

5.5.1.1 PLACING OF EARTH

a) The embankment shall be constructed with earth fill or required materials as per the provided section and specification. The fill shall be free from lenses, packets, streaks, or layer of materials differing substantially in texture of gradation from the surrounding materials. The useful excavated materials shall be classified as 'impervious[7] and 'semi-pervious'. The impervious materials should be utilized towards the water side of the embankment and semi-pervious materials towards out zone of the embankment.

(b) Construction of embankment shall begin at the toe of the fill and in no case shall embankment be widened by material dumped from the top. The material shall be placed in the earth fill in the continuous horizontal layers not more than 15 cm. in thickness after being rolled. If compaction is performed by mechanical tampers, the thickness should not be more than 15 cm, if by sheep foot / vibrator roller, or similar equipment it should not be more than 30 cm. Initially the earth in the embankment fill shall be laid in a greater width than the designed section. Adequate extra width of about 0.3m or more on either side of the embankment shall be provided so that the earth fill, up to lines of the finished slopes, shall have the required compaction. Such extra width shall be removed and utilized in the upper layers of embankment along with slope dressing. In case of lining work, the inside proud section should not be removed. Such proud section shall be made out of borrow earth from outside only.

(c) No fresh layer shall be laid until the previous layer is properly watered and compacted as per requirement. In case, the surface of the prepared foundation or the rolled surface of any layer of earth fill is too dry or smooth to bound properly with the layer of materials to be placed thereon, it shall be moistened or worked with harrow or other suitable equipment in approved manner to a sufficient depth to provide a satisfactory bonding surface before the next succeeding layer of earth fill materials is placed. If the rolled surface of any earth fill is found to be too wet for proper compaction of the layer of earth fill materials to be placed thereon, it should be raked up and allowed to dry or be worked with harrow, scarfler or any other suitable equipment to reduce the moisture content to the required amount and it shall be compacted before the next succeeding layer earth fill materials is placed.

(d) The materials shall be deposited in rows parallel to the axis and spread in the uniform layers and shall be broken clods maximum upto 5 cm. The work of spreading and compactions shall be so adjusted as not to interfere with each other in such a way that neither of the operations is held up because of non-completion of rolling and watering. The excavation and placing operation shall be that the material when compacted shall blend sufficiently to secure the best practicable degree of compaction, impermeability and stability. The surface of banking shall all time of construction be maintained true to required cross section.

(e) During construction a small transverse slope from centre towards edges should be given to avoid pools of water forming due to rains.

(f) When compaction the soil against the rock, abutment walls of masonry or concrete structures, the construction surface of the embankment shall be sloped away from the rock or masonry or concrete structures leaving a minimum distance of 0.6 m. and at an inclination of 4:1. If the foundation surface is too irregular to allow the use of large roller directly against the structure or rock out crop, the roller shall be used to compact the soil, as close to the structure or the out crop as possible and portion of the embankment directly against the rock or the structure shall be compacted with pneumatic hand tampers / rammer in thick layers. The moisture content of the earthfill placed against the rock or the structure shall be slightly above the optimum to allow it to be compacted in all irregularities of the rock and this shall be determined by the field laboratory. In placing the earth-fill under rock foundation, the foundation shall first be prepared as detailed earlier. At the time of placing of first layer of fill above the filter layer no damage should be caused by hauling machinery. The soil for the first layer shall be at moisture content sufficient to enable satisfactory bonding of the fill with the filter surface.

5.5.1.2 WEATHER CONDITIONS

Embankment materials shall be placed only when the weather conditions is satisfactory to permit accurate control of the moisture content in the embankment materials. Before closing work on embankment, in any continuous reach prior to setting of monsoon, the top surface shall be graded and rolled with smooth wheeled roller to facilitate run off. Prior to resuming work, the top surface shall be scarified and moistened or allowed to dry as necessary for resumption.

5.5.1.3 MOISTURE CONTROL

The water content of the earthfill material prior to and during compaction shall be distributed uniformly throughout each layer of materials and it shall be between (-) 2% to (+) 2% of the optimum moisture content. Moisture determination of soil as well as needle moisture determination of soil shall be carried out as per I.S. 2720- 1983.

5.5.1.4 COMPACTING EARTH MATERIALS

Where compaction of earth materials is required, the materials shall be deposited in horizontal layers and compacted as specified in this paragraph. The excavation, placing, moistening and compacting operations shall be such that the materials will be uniformly compacted to the required density throughout the required section, and will be homogeneous, free from lenses, pockets, streaks, voids, laminations or other imperfections. The earth fill placement in layers of cohesive soils shall be compacted to at least 95% proctor density; the non cohesive soils shall be compacted to at least 65% relative density.

Having decided on the filling materials to be used standard compaction test will be conducted on the materials proposed for embankment to indicate best type of equipment to be used and the moisture content at which compaction should be done, thickness of layer and number of passes etc.

5.5.2 BORROW AREA

5.5.2.1 GENERAL

All materials required for the construction of canal embankment and backfill around the structures, which are not available from canal excavation, excavation for structures or from excavation of other ancillary works shall be obtained from the approved borrow areas after stripping. In case of dam embankment earth has to be brought from the approved borrow area. The depth of cut in all borrow areas shall be designated by the competent authority and the cuts shall be made upto such designated depths only.

5.5.2.2 PREPARATION OF BOROW AREAS

All areas required for borrowing earth for embankment shall be cleared of all tree stumps, root, bushes, rubbish and other objectionable materials. Particular care shall be taken to exclude all organic matters from the materials to be placed the embankment. The cleared areas shall be maintained free of vegetable growth during the progress of the work.

5.5.2.3 STRIPPING OF BORROW AREAS

Borrow areas shall be striped of top soil, sod and any other objectionable materials to the required depth. The work may be done manually or with suitable machine. Stripping operations shall be limited only to designated borrow areas. Materials from stripping surface should be disposed of in exhausted borrow areas.

5.5.2.4 BORROW AREA WATERING / DEWATERING

a) Borrow area watering should be done wherever necessary preferably 48 hours in advance, so that materials may be carried with adequate moisture.

b) The initial content of the material in the borrow areas shall be estimated with the help of field and laboratory tests. The optimum moisture content required for the material, in any particular borrow area shall be obtained from the field laboratory test. The additional moisture requirements as determined by the laboratory test shall be introduced into the borrow areas by watering well in advance of the excavation to ensure uniformity of moisture content. To avoid formation of pools in the borrow areas during excavation and operation, drainage ditches from borrow areas to suitable outlets shall be excavated, wherever necessary. Upon exhaustion of all materials or abandoning the borrow areas, the pits shall be fully drained to ensure for no ponding of water.

5.5.3 COMPACTING EQUIPMENTS

As shown in or I.S. 4701-1982, the following earth compacting equipment may be used for compacting the soils shown against them as detailed below:

Major Divisions	Sub-Group	Suitable type of compacting equipments
Coarse Grained Soils	Well grained gravel, gravels and mixtures little or no fines.	Smooth wheel roller, Diesel road rollers of 8 to 10 tones capacity, pneumatic tyred roller
	Well graded gravel sand mixtures with excellent clay binder	-do-
	Uniform gravel with little or no fines.	-do-
	Poorly graded gravel and gravel sand mixtures little or no fines	-do-
	Gravel with fines, silty gravel, clayey gravel, poorly graded	-do-
Coarse Grained Soils sands & sandy clays	1. Well graded sand and Gravelly sands, little or no fines	Heavy vibrating Front rammer, Power rammer, Power rollers
	2. Well graded sand with excellent clay binder	-do-
	3. Uniform sand with little or no fines.	-do-
	4. Sands with fines, silty sands, clay sands, poorly graded sand clay mixtures	-do-
Fine Grained Soils : Soil having low compressibi	1. Silts (inorganic) and very fine sands rock flour, silty or clayey fine sands with slight plasticity.	Smooth wheel roller, diesel Road Rollers of 8 to 10 tones capacity, power rollers pneumatic tyred roller.
	2. Clayey silts (inorganic)	-do-
Soils having medium compressibility	1. Organic silts of low plasticity.	Sheep foot roller
	2. silty and Sandy clays (inorganic) of medium plasticity	Front rammer, power rammer
	3. days (Inorganic) of medium plasticity	-do-
	4. Organic days of medium plasticity	-do-
Soils having Higher compressibility roller	1. Micaceous or diatomaceous fine sandy & silty soils elastic silts.	Smooth wheel roller, diesel Road Rollers of 8 to 10 tons capacity power roller & pneumatic
	2. Clays (Inorganic) of High plasticity Fat clays	-do-
	3. Organic days of . high plasticity	-do-

The compacting equipment shall confirm to relevant Indian specification below.

- Smooth wheeled roller should conform to I.S. 5502-1969.
- Sheep Foot roller should conform to I.S. 4616-1968.
- Pneumatic tyred roller should conform to I.S. 5501-1969.
- Vibratory plate compactor should conform to I.S. 5589-1970.
- Vibratory roller should conform to I.S. 5500-1977.

The methods of compaction shall conform to clauses 7.2.1., 7.2.2., 7.2.3. of I.S. 4701-1982.

5.5.3.1 ROLLER DRUMS

Double drum sheet roller shall be used for compaction. Each drum of a roller shall have an outside dia. not less than 142.25 cm and shall not be less than 122 cm. in length. The space between two adjacent drums shall not be les than 30 cm and not more than 38 cm when on level surface. Each drum shall be free to pivot about an axis parallel to the direction of travel.

5.5.3.2 TAMPING FEET

The total number of feet per drum shall be 88. At least one tamping foot is to be provided for 667sq.cm of the drum surface area. The length of each tamping foot from the drum surface shall be maintained at not less than 18 cm. The cross sectional area/bearing surface area of each tamping foot shall not be less than 25.80 sq.cm, and not mare than 645 sq. cm. at plain normal to the axis shaft 15 cm from surface.

5.5.3.3 ROLLER WEIGHT

The weight of the roller when fully loaded shall not be less than 7091 Kgs and the ground pressure when fully loaded shall not be less than 40 Kgs / sqm. Appropriate equipment for hauling the roller should be used which can pull the rollers satisfactorily at a speed of 4 Km. per hour when drums are fully loaded. The space between the tamping feet shall be kept clear of material striking the drum as the same can reduce the effectiveness of the tamping roller.

5.5.3.4 ROLLING

When each layer of material has been prepared to have the proper moisture content uniformly distributed throughout the material, it shall be compacted by passing the tamping roller. The exact number of passes for each layer to obtain specific density shall be designated by field laboratory test and tests conducted on the borrowed material. The layers shall be compacted in strips over lapping not less than 0.6 M.Rolling shall commence at edges and progress, towards centre longitudinally. The rollers of loaded vehicles shall travel in a direction parallel to the axis of the canal. Turns should be made carefully to ensure uniform compaction.

5.5.3.5 TAMPING

Rollers will not be permitted to operate within 1.0 m of concrete masonry structures. In the following locations where compaction of the earth fill materials by means of roller is impracticable or undesirable the fill shall be specially compacted as specified further below.

- Portion of the earth fill in embankment adjacent to masonry structures and embankment foundation designated on the drawing as specially compacted earth fill.
- Earth fill embankment adjacent to steep abutments
- Earth fill at specifically designated locations Earth fill shall be spread in layer of not more than 15 (fifteen) cm in thickness loose and shall be mentioned to have the required moisture content as specified. When each layer of material has been conditioned to have the required moisture content it shall be compacted to be specified density by the special rollers, pneumatic / hand tampers or by other approved methods. The moisture control and compaction shall be equivalent to that obtained in the earth fill actually placed in the embankment with the specifications.

5.5.4 TESTING

Density tests shall be carried out after compacting to ascertain the state of compaction, which should be measured in terms of dry density. Standard proctor density test shall be carried out at a regular intervals (to account for variations in the borrow area materials). Not less than three tests shall be conducted to indicate variations in the standard proctor density attained in the laboratory. Density test shall be conducted from time to time at site to ascertain whether compaction is attained as specified. However, minimum for density tests shall be made per day irrespective of quantity of earth work. In case the tests show that the specified densities are not attained, suitable action shall be taken either by moisture correction or by additional rolling, so as to obtain the specified density which shall be checked again by taking fresh tests at the same location. The tests locations should be so chosen as to represent the whole layer under test. Each layer should be tested for proper compaction before a fresh layer is allowed over it.

5.5.5 SETTLEMENT ALLOWANCE

In the mechanically compacted earth fill, settlement allowance of 2% should be provided. Settlement allowance shall be calculated after embankments are subjected to natural compaction of one full monsoon rains. For short duration works, necessary adjustments are to be made to take care of natural settlement due to rains. Accordingly extra heights should be provided taking the settlement into account. The base width of the embankment shall not be increased to maintain the design slope indicated in the drawings for additional height as settlement allowance.

5.5.6 SLOPE DRESSING

The slopes of particular earth fill, which has been completed shall be dressed neatly to the designed line and grade. Extra earth works done at sides are to be dressed and reused in the embankment.

5.6 SLOPE PROTECTION

5.6.1 RIP-RAP AND COARSE GRAVEL PROTECTION

5.6.1.1 MATERIALS

The stone required for rip-rap shall be in accordance with clause 4.1 of I.S. 8237-1976 India Code of practice for protection of slopes for Reservoir embankments. The stones for rip-rap shall be hard and durable and shall not crumble on long exposure to water and air. The gravel protection shall be reasonably well graded and shall conform to clauses 5.1, 5.1.1, 5.1.2, 5.1.1.3 and 5.2 of I.S. 8237-1976. The thickness of the stone to be used in the rip rap shall be in accordance with clauses 6.3 and 6.4.1. of I.S. 8237-1976 India code of practice for protection of slopes for reservoir embankments.

5.6.1.2 PLACING

The placing and laying of rip-rap with coarse gravel protection shall be, in accordance with clause 6.1, 6.2, 6.2.1 and 6.2.2 of I.S. 8237-1985 in case of hand placed rip-rap, and in accordance with clause 7.1, 7.2, of I.S. 8237-1967, in case of dumped rip-rap.

Table 4 Minimum Thickness of Hand Placed Riprap

Expected Wave Height (Meter)	Minimum thickness (cm.)
0 to 1.5	30

1.5 to 3.0	45
Larger than 3.0	60

Table 5Recommend Rip RapThickness and Gradation

Range of wave Height (Meter)	Minimum average Rock size (cm)	Minimum Rip Rap Thickness (cm.)
0 to 1.5	30	60
1.5 to 3.0	40	75
Above 3.0	70	100

5.6.2 ROCK TOE

The rock toe along with filters shall be formed to the lines and graded. The forming of rock toe filters consists of:

- Excavation of foundation trench of rock toe
- Laying sand filters
- Laying graded metal filters and
- Forming rock toe.

5.6.2.1 FILTER MATERIALS

- The filter materials should be composed of layers of fine sand, coarse sand and hard rock aggregates of specified thickness.
- The fine and coarse sand used shall be composed of clean sand, well graded, hard siliceous material, free from injurious amounts of dust lumps of clay, soil or flaky particles, shale, alkali, loam mica or other deleterious substance. If the same brought to the site is dirty, it must be washed thoroughly cleaned with water so as to get rid of all soluble impurities. The sand shall be screened and the fine coarse stocked separately which materials shall confirm to the gradation specified hereunder.
- The aggregate of 10mm. to 75mm. size rock fragments shall consist of broken stone which are hard, dense and durable. The rock fragments shall be free of disintegrated and decomposed stone, soft flaky, salt, alkali, vegetable matter and the deleterious substance like clay, lumps etc. They should be washed clean and stacked separately as per the gradation defined hereafter.
- The gradation *of* each filter layer shall meet the following requirements with respect to the materials in the adjacent filter layer. Each successive layer of material shall be composed of particles such that the 15% size (15% smaller than and 85% larger than the dia) is more than 5 (five) times that of 15% size of the layer above.
- The requirement for grading of the filters shall be established by the field laboratory on the basis at mechanical analysis of the adjacent fill material. Mechanical analysis shall be performed on samples which have been compacted.
- The following gradation is however tentative and roughly informative.

FINE SAND -At least 15% particles should be less than 0.3 mm. to 0.5mm. in dia.

COARSE SAND - At least 15% particles should be less than 2.50mm. to 3mm. in diameter.

AGGREGATE - 10mm to 75mm rock aggregate:-

At least 15% particles should be less than 20mm. in size.

The representative samples of these filter materials should be submitted for mechanical analysis.

5.6.3 ROCK FILL

- The rock fill at the downstream toe of the bank shall be constructed to the finished lines and grades.
- The rock fill shall be placed in layers not exceeding 0.30 meter thickness at a time. The large rock fragments shall be placed on the outer faces of rock toe and shall be closely and firmly set with hand with their broadest side downwards and face normal to the finished slope. At least 25% of these stones on the outer faces should be 300 mm. in depth in normal to the slope and to be well embedded in the mass and should be laid with breaking joints as far as possible, so as to secure a firm and stable rock mass. For the sloping surface away from the embankment interstices between the adjacent stone on the slope shall be well filled with stones of the proper size and tightly wedged by wooden mallets or crowbars to ensure firm packing to result in a neat and well packed surface true to the finished slope. For earth side slope the surface stones need not be wedged with smaller stones so as to allow free drainage of the embankment. Profiles of strings and pegs should be used to ensure that rock toe is done true, straight and to confirm neatly to the designed slope throughout.
- Rock spoils and stones not less than 0.014 cum. in volume shall be dumped in the interior portion so as to claim a free draining. Properly graded fill material with the best practicable distribution prevent large unfilled spaces left within the rock mass. The inclusion of rock spoil in the mass, to the amount in excess of requirement to fill the voids between the large stones shall be permissible. The stones used should consist of sound, dense and durable rocks of reasonably well graded.

5.6.4 ROUGH STONE DRY PACKING FOR APPRONS AND REVETMENTS

The bed or slopes to receive the packing should be prepared as per the specification.

The size of the stone to be used for dry stone revetment should be of 225 mm. and 300mm thick as specified. The stone shall be perfectly sound, regular in shape, free from cracks and with their lengths equal to the thickness of the required apron or revetments. Each stone shall not be less than 0.05 cubic meter. The stone shall be obtained from the specified quarry.

The stones shall be laid closely in position on the prepared bed and firmly set with their broadest and downwards, so that they may meet all round their bases and with the top of the stone level with the finished surface of packing. The stones shall be laid with breaking joint so far as possible in the direction of the flow of water. The stones are to be placed perpendicular to the finished surface i.e.; perpendicular to the slope for revetments.

Interstices between adjacent stones shall be filled with stones of the proper size. They should be well driven with crowbars to ensure tight packing and complete filling. Such filling shall be carried out simultaneously with the placing in position of large stones.The finalwedging shall be done with the largest sized chip. Each

chip should be well driven with a hammer, so that no chip is possible of being picked up or removed by hand.

Profiles of strings and pegs are to be put up to ensure that the pitching is done true,straight and to the proper slope throughout. Revetments are in cases to be built up from the foot of the bund to be revetted. Strong toe wall or other protection should always be given to revetment as protective measures. On completion, the surfaces presented by the apron or revetment should be even throughout, free from irregularities to the required length, breadth and slope.

5.7 TURFING

The slopes of dam and canal banks should be turfed for the entire downstream slope and also on the upstream for the widths, which remain above stone pitching or lining. The soil in the said portion of the slopes loosened due to rain or occasional rise of water level and gradually eroded. To protect the soil from being subjected to such erosion the slopes are covered with compact grass-turfs as described below.

The turfing should be done with good approved quality "dub grass" sods not less than 15cm. size. Top soiling is not done for turfing in small dams and small canals. Compact dub grass is selected and sods are cut in convenient rectangular sizes 8 cm to 10 cm in depth. The sods are spread on pre-moistened slopes of dams and embankments in such a way that the edges of the sods remain in close contact. Then the sods are rammed gently until compacted and levelled and appear like one uniform blanket. The turfed area is then periodically watered until the turf survives to serve as a blanket for preventing earth from slipping.

6 TECHNICAL ASPECTS OF DPR

Based on the review of DPR of Boitalmahara and Srimal Minor Irrigation projects, certain guiding notes, skethes and photos are presented as part of the Technical manual for guidance in preparation of DPR for other Minor Irrigation Projects

6.1 DPR of BOITALUMAHARA MI Project in Bhadrak District (Rs. 11.046 Million) without CAD

(i) Renovation to Head Works Dimensioned drawings of the existing head works are not included; neither drawing of the proposed renovation works is appended in the DPR. Importantly, dimensioned drawing of the "concrete skin wall" should be appended which should depict holes drilled in the body wall filled with mortar and L-shaped anchor bars inserted in these holes to ensure effective bond between the body wall and the skin concrete. It should also depict temperature reinforcement. A typical Sketch of "concrete skin wall" is given as Attchment-1 for guidance and appropriate incorporation in the DPR. Cost of this work should accordingly be modified. The concrete skin wall should be in M20 concrete.

(ii) Reconstruction of 2 Head Regulators.Dimensioned drawings of proposed reconstruction of Head Regulators are not appended in the DPR. These should be appended for carrying out the technical review.

(iii) Conversion of Earthen Right & Left Main Canals into Cement Concrete Lined Canals (Trough Section / Trapezoidal Section).

Right Main Canal: It has been proposed to line the Right Main Canal in the reach RD 0 to 600 m. Total length of the main canal is not indicated. The agency (Odisha Construction Corporation Ltd) preparing the DPR has not brought out the existing condition of this canal. Rationale for lining only the initial 600 m reach of this canal has also not been explained. It has no where been specifically mentioned whether walk-through survey of the Right Main Canal was conducted by the agency along with the farmers / WUAs and concerned engineers to decide the extent and location of the proposed concrete lining.

Following suggestions are made in respect of the provision of concrete lining

Right Main Canal:

Free Board: A free board of 30 cm should be kept for the channels of discharge more than 0.10 cumec. The free board for channels of discharge less than 0.1 cumec should be 15 cm.

Coefficient of rugosity (n). 'n' value of 0.020 be adopted for cement concrete lining instead of 0.018 from practical considerations since the final "finish" of concrete surface cannot normally be as smooth as to afford n value of 0.018 and, furthermore, the concrete lining becomes rough in few years time and the free board gets reduced. N value for unlined reach should be 0.028. or 0.030.

Selective Lining. It shall be better to make provision for "selective lining" in the channels (main canals, branch canals, distribution system etc.) in about 15 to 20 % reaches depending upon the site conditions and availability of funds (within approved cost limits) instead of lining the whole reaches (Attachment-2). Broadly, provision of selective lining shall comprise: (i) lining in the initial head reach in about 30 m length (ii) installation of measuring device in this reach (iii) provision of lining in the balance reaches considered vulnerable and at the locations of Off-take channels /outlets / culverts/ C.D. structures / vulnerable banking reaches/bends etc (iv) provision of concrete model sections in the balance unlined reaches at about 45 m to 50 m spacing. Sketch of a typical "concrete model section" is given as Attachment-3.

Left Main Canal: Comments / Suggestions outlined above for the Right Main Canal also hold good for the Left Main Canal.

(iv) Measuring Devices In Canals. Provision of one measuring device has been made in the "Quantity Statement" in respect of Right Main Canal. However, no provision has been made for a measuring device in the Left Main Canal. This omission should be looked into.

6.2 Rehabilitation of SRIMAL MIP in Kantamal Block (Rs. 13.79 lakhs) without CAD Works

This DPR envisages re-sectioning (raising & strengthening) of the existing 330 m earthen dam and re-construction of the damaged Left Head Regulator at a total cost of Rs 13.79 lakhs. Our Review comments and suggestions in respect of the work of re-sectioning of the earth dam and the re-construction of the head regulator are given below:

Re-sectioning (raising & strengthening) of Earth Dam.

Perusal of page 59 of DPR indicates a "Free Board" of only 1.0 m (TBL – MWL). The fee board should be 1.50 m. Accordingly, earth fill shall need ed to be calculated afresh.

Side slopes of the earth fill to be placed and compacted should be 2(H):1(V) as per Indian Standard IS 12169 – 1987.

Top width of the earthen dam has to be minimum 3.0 m. Presently, the top width has not been indicated in the dam section shown on page 59. (see Attachment-5)

Prior to the placement of earth fill for raising & strengthening the dam section, "serrations / benches" have to be cut in both the water side and the rear side of the dam section and the quantity of earth / soil so cut has to be included in the cost estimate. Presently, such benches / serrations have not been depicted in the dam sections shown on pages 59 to 62. Being a very important requirement (for achieving effective bond between the existing earth slopes and the new earth fill), the requisite benches / serrations must be depicted (typical sketch on such benches has been furnished to Sh B.S.S.Patro, Attachment-4)

Degree of compaction of earth fill: Degree of compaction of earth fill has been indicated to be 98 % Proctor Density on pages 59 to 62 of DPR. However, degree of compaction is indicated as 95 % Proctor density in the Item No. 6 of B.O.Q (page 29) and also in Quantity Statement (page 32 as well as in the Detailed Estimation on page 37). *This discrepancy should be rectified.* The Maximum height of the dam being 4 m, degree of compaction of the earth fill of 95 % Proctor density is considered to be adequate.

Provision of extra earth fill to the extent of about 30 cm on both the side slopes may be needed to ensure compaction of the full design section by the vibratory rollers. This extra earth fill, instead of its removal,

should then be adequately consolidated / compacted through deployment of mobile hydraulic excavator (back hoe) fitted with a steel plate (of size about 1m x 1m x 20 mm) after removal of its bucket. This shall afford availability of additional width of 0.60 m at the dam top (making the top width as about 3.6 m). The unit rate of such consolidation / compaction of the surface could be about Rs 10 /m2 (typical photo copy of such device in operation is given.

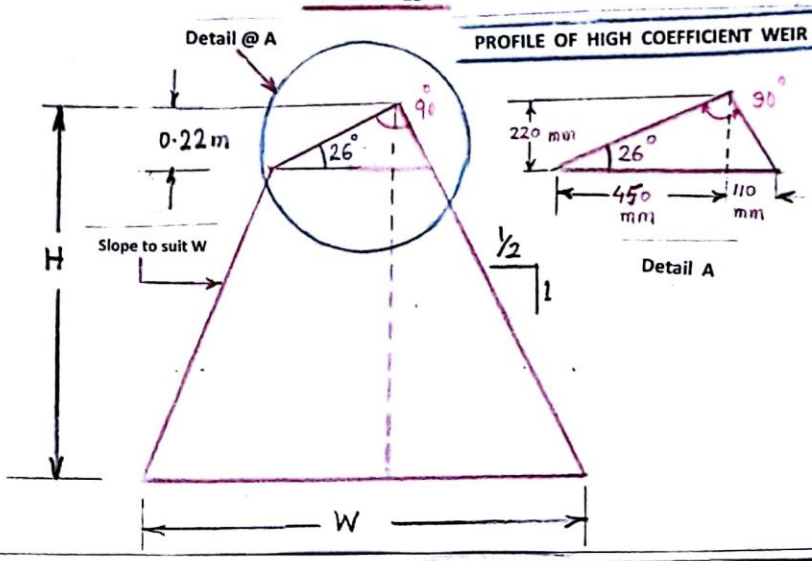
Adequacy of existing Spillway / Surplus Escape: Adequacy of existing broad crested spillway to handle the maximum design flood has not been checked and no calculations have been included in the DPR. Design Organization should be consulted in respect of the quantum of maximum design flood.

Re-construction of Left Head Regulator: Drawing of the proposed Head Regulator appended on page 64 of DPR should be got vetted from the Design Organization. It is also suggested that the earthen dam bund should be cut to 4 (H) : 1 (V) slope on both sides of the location of Head Regulator and, also, serrations / benches are to be cut in these slopes (see Attachment-6). Accordingly, requisite provision for these items should be made in the cost estimate. Provision for compaction of earth fill by vibratory tamper / earth rammer in the close vicinity of the Head Regulator structure (and of the earth fill up to about 1 m above it) should also be made besides provision of compaction of other earth fill by roller (typical Sketch of benches photos of vibratory tamper in operation is given as Attachment-7 & 8)

ANNEX -4

SKETCH - 13

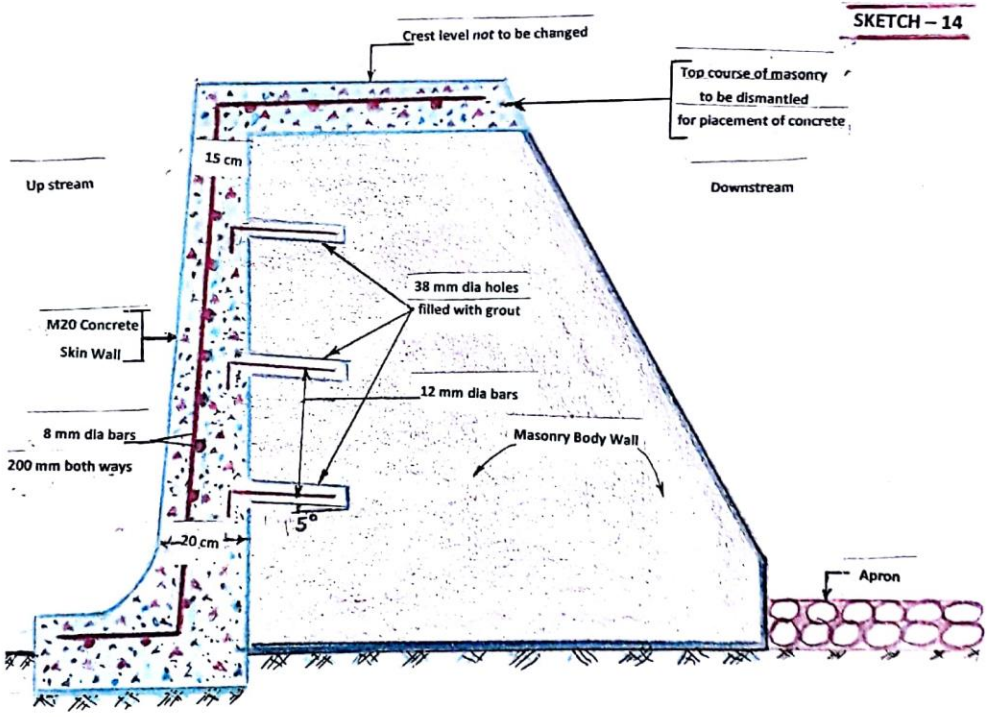
PROFILE OF HIGH COEFFICIENT WEIR



Annex – 4

Rehabilitation Of Masonry Surplus Weir through Concrete Skin Wall Treatment

SKETCH – 14



Attachment 1

Sketch 11

Annex – 3

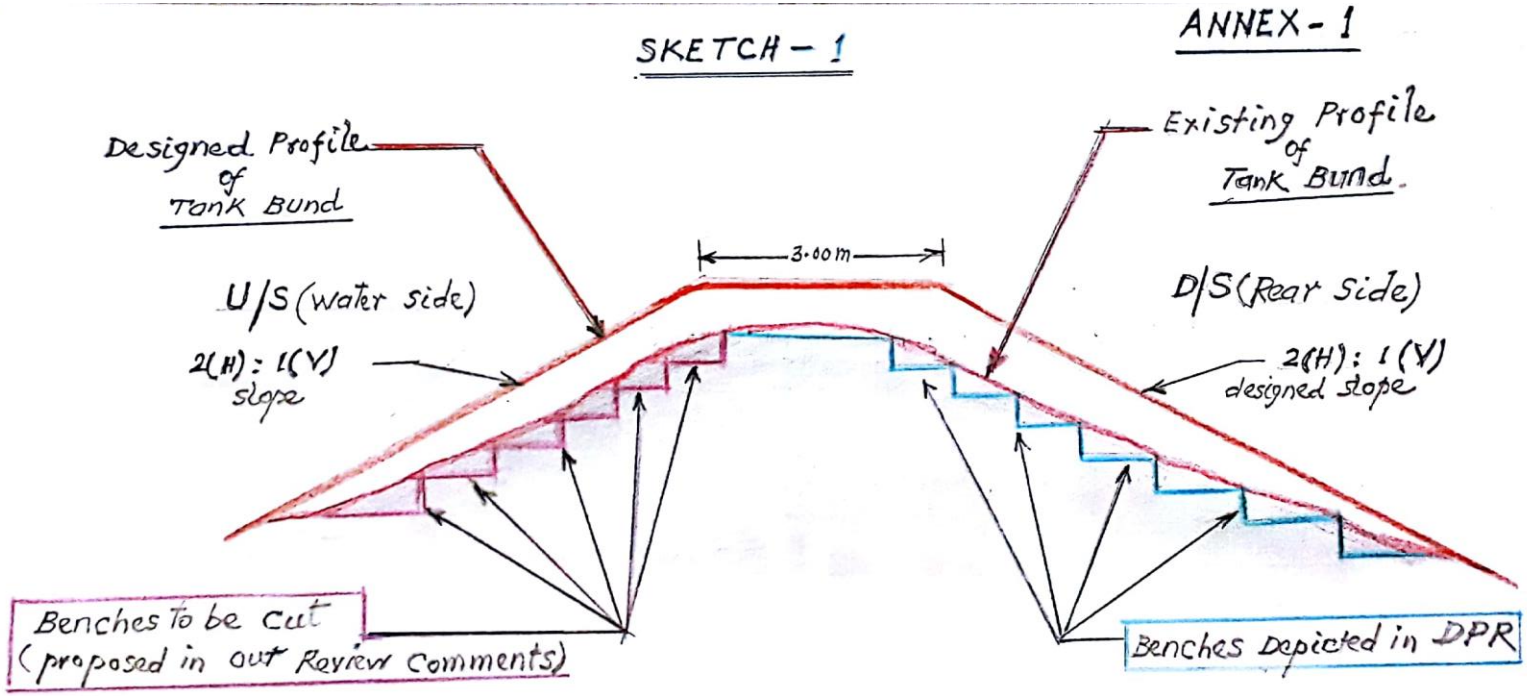
48

Attachment 2

Attachment 3

ANNEX - 1

SKETCH - 1



Cutting "Benches / Serrations" in the water side & Rear side slopes of Tank Bund prior to placement of earth fill for raising & strengthening of tank Section

Attachment 4

TABLE 1 GENERAL GUIDELINES FOR EMBANKMENT SECTIONS
(Clause 5.1.2.3)

Sl. No.	DESCRIPTION	HEIGHT UP TO 5 m		HEIGHT ABOVE 5 m AND UP TO 10 m		HEIGH	E 10m and UPTO 15 m	
i)	Type of section	Homogeneous section/Modified homogeneous section		Zones section/Modified homogeneous section/Homogeneous section		Zoned se	Modified homogeneous nogeneous section	
ii)	Slopes	*Up stream*	*Downstream*	*Up stream*	*Downstream*	*Up*		*Downstream*
	a) Coarse grained soil (GW, GP, SW, SP)	Not suitable		Not suitable		Not suita		re
	b) Coarse grained soil (GC, GM, SC, SM)	(H) (V) 2 : 1	(H) (V) 2 : 1	(H) (V) 2 : 1	(H) (V) 2 : 1	Suitable Section stability 7894-19		g zone ded based upon the accordance with IS:
	c) Fine grained soil (CL, ML, CI, MI)	(H) (V) 2 : 1	(H) (V) 2 : 1	(H) (V) 2.5 : 1	(H) (V) 2.25 : 1			
	d) Fine grained soil (CH, MH)	(H) (V) 2 : 1	(H) (V) 2 : 1	(H) (V) 3.75 : 1	(H) (V) 2.5 : 1			
iii)	*Hearting zone*	Not required	--	May be provided		Necessa		
	a) *Top width*		--	3 m		3 m		
	b) *Top level*		--	0.5 m above MWL		0.5 m ab		
iv)	*Rock toe height*	Not necessary plo 3 m. Above 3 m height, 1 m height of rock toe may be provided		Necessary H/5, where H is the height of embankment		Necessa H/5, whe embankr		e height of
v)	Berms	Not necessary		Not necessary		The berm design.		provided as per num berm width shall may be provided also on the dc during m

Attachment 5

Attachment 6

Attachment 7

Attachment 8

7 SPECIFICATION OF PLAIN AND REINFORCED CONCRETE WORKS

The concrete shall be broadly governed by the Indian Standard Code, IS 456:2000.

7.1 INGREDIENTS OF CONCRETE

The ingredients of concrete are mainly;

- Cement
- Aggregate
  - Fine aggregate (Sand)
  - Coarse aggregate
- Water
- Any other admixture as specified in IS : 9103-1999.

7.1.1 Cement

The cement used shall be any of the following and the type selected should be appropriate for the intended use:

a) 33 Grade ordinary Portland cement conforming to IS 269.

b) 43 Grade ordinary Portland cement conforming to IS 8112.

c) 53 Grade ordinary Portland cement conforming to IS 12269.

d) Rapid hardenings Portland cement conforming to IS 8041.
e) Portland slag cement conforming to IS 455.
f) Portland pozzolana cement (fly ash based conforming to IS 1489 (Part 1).
g) Portland pozzolana cement (calcined clay based) conforming to IS 1489 (Part 2).
h) Hydrophobic cement conforming to IS 8043.
i) Low heat Portland cement conforming to IS 12600.
j) Sulphate resisting Portland cement conforming to IS 12330.

OPC 43 grade and OPC 53 grade cements are commonly used, these days. For concrete exposed to the coastal environment, Portland slag cement shall be used or as directed by Engineer-in-Charge.

7.1.2 AGGREGATE

An aggregate is a general term applied to those inert or chemically inactive materials which when bonded together by cement, form concrete. Most of the aggregates used are naturally occurring aggregates such as crushed rock, gravel and sand.

7.1.2.1 CLASSIFICATION OF AGGREGATE

Depending upon the size aggregates may be divided into two groups such as fine aggregates and coarse aggregates.

a) Fine Aggregate (Sand): It shall be well graded and have a fineness modules conforming to I.S 383. It shall be tested for the presence of any organic impurities. It shall also be tested for the presence of silt & clay content. Sieve analysis shall be carried out to determine the grading and fineness modulus. Sand must be well graded with a maximum size of 4.75 mm. Well graded sand is essential to impart good workability and finish to the concrete mix. The gradation requirement of sand for concrete is indicated below:

Table 6 Mechanical Analysis of Sieving

Sieve Size	Percentage Passing for		
	Grading Zone I	Grading Zone II	Grading Zone III
10 mm	100	100	100
4.75 mm	90-100	90-100	90-100
2.36 mm	60-95	75-100	85-100
1.18 mm	30-70	55-90	75-100
600 micron	15-34	35-59	60-79
300 micron	5-20	8-30	12-40
150 micron,	0-10	0-10	0-10

Sand of zone I is the coarsest, followed by zones II, III & IV in order of coarseness. Zone IV Sand shall not be used in the concrete works. Sand shall be free of organic impurities. The cumulative percentage of silt & clay present in sand shall not exceed 3%. If moist sand is used, its "bulkage" test shall be conducted. The maximum bulkage allowed is 20%. Allowance for bulkage shall be made by adding more sand and reducing the quantity of water in the concrete mix. The allowance to be made for bulkage is tabulated below:

Table 7 Allowance for bulkage in moist sand

Bulkage determined in moist sand	Allowance to be made
Less than 5%	NIL
5 to 10%	5%
10 to 15%	10%
15 to 20%	15%

Procedures for conducting quality control tests on sand are explained in the section on Quality Control Tests. These tests include: gradation of fine and course aggregate; fineness modulus of sand; bulkage of sand; total organic impurities; and determination of silt/clay content. All these tests must be conducted and recorded at the site before allowing the aggregate to be used in work.

b) Coarse Aggregate: The coarse aggregate shall be hard and well graded to produce a dense concrete of the specified strength and consistency that will work readily into position without segregation. It shall be tested for gradation, water absorption, and also for impact and abrasion values if requisite testing equipment is available (for testing impact & abrasion). It should not absorb more than 5% water. Grading shall be accessed through sieve analysis. Coarse aggregate comprises of all aggregate particles of size more than 4.75 mm. The maximum nominal size of aggregate shall be 80 mm when used in the mass concrete. For almost all works in the OCTMP, 40 mm and 20 mm size aggregate shall be used. Aggregate of maximum nominal size of 20 mm size shall be used in the reinforced concrete works. The aggregate shall be free from silt, clay, dust and other impurities. The grading shall broadly meet the following requirement.

Sieve Size	% Passing by weight for graded aggregate of nominal size			
	40 mm	20 mm	16 mm	12.5 mm
63 mm	100	—	—	—
40 mm	95-100	100	—	—
20mm	30-70	95-100	100	—
16 mm	—	—	90-100	100
12.5 mm	—	—	—	90-100
10.0 mm	10-35	25-55	30-70	48-85
4.75 mm	0-5	0-10	0-10	0-10

The gradation test of coarse aggregate is explained with examples in the Section on Quality Control Tests.

7.1.3 Water for concrete

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, salts and organic materials. Potable water is considered satisfactory for mixing concrete. In case of doubt about the suitability of water proposed to be used, it shall be ascertained by the compressive strength as outlined below:

"Average 28 days compressive strength of at least three 15x15x15 cm concrete cubes prepared with water proposed to be used shall not be less than 90% of the average of strength of 3 similar concrete cubes prepared with distilled water." Also, the pH value of water shall be not less than 6. Accordingly, the water samples shall be tested with pH meter.

7.2 Concrete Mix

Proportioning of concrete mix in small jobs shall be done by volume batching in view of the small magnitude of works. Accordingly, measuring boxes shall be used for batching the mix ingredients. Water shall be added from a calibrated container in litres, (one litre of water weighs 1 kg). The measuring boxes shall be dimensioned corresponding to one bag of cement and knowing the bulk densities of sand and sand to be actually used in the concrete mix. Design mix concrete shall be used in all other works/jobs and proportioning shall be done by weight.

For works involving substantial quantities of concrete, design mix concrete shall be used for concrete of Grade M10, M15, M20 etc. and proportioning of concrete mix ingredients will be by weight.

a) The class of concrete or grade of concrete to be used shall be as shown on the table shown below. The concrete is classified on the basis of its compressive strength at 28 days as shown below:

Table 8 Classification of concrete on basis of compressive strength

Concrete Class / Grade	Cube strength at 28 days (kg/cm2)	Mix proportion in case design mix is not adoptable
M-20	200	1:1.5:3
M-15	150	1:2:4
M-10	100	1:3:6
M-7.5	75	1:4:8

b) Minimum Cement Content, Maximum Water -Cement Ratio & Minimum Grade of concrete for different Exposure conditions with coarse aggregate of 20 mm Nominal Mix size from "Durability considerations".

Besides the importance of 28 days compressive strength of concrete cubes (as an acceptance criteria) durability of concrete is also now a very important requirement. A durable concrete is one which performs efficiently for a very long period in the exposure environment in which it is constructed. One of the most important factors influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate etc. A low permeability of concrete is achieved by having adequate cement content, sufficiently low water-cement ratio, and by ensuring good compaction of concrete,and by adequate curing, various exposure conditions are:

SI No	Environment / Exposure	Exposure conditions
i	Mild	Concrete surface protected against weather or aggressive conditions.
ii	Moderate	Concrete surfaces sheltered from severe rain Concrete exposed to condensation and rain Concrete continuously under water. Concrete buried under ground water / non- aggressive soil
iii	Severe	Concrete surfaces exposed to severe rains Concrete surfaces exposed to alternating wetting & drying & severe condensation Concrete completely immersed in sea water and exposed to coastal environment
iv	Very Severe	Concrete exposed to sea water spray, exposed to corrosive fumes or severe freezing conditions whilst wet Concrete in contact with or buried under aggressive sub-soil/ground water.
V	Extreme	Concrete exposed to tidal waves / zone; 8i Concrete in direct contact with aggressive chemical

Concrete surfaces of concrete lined channels are exposed to alternate wetting & drying and, therefore, come under the category of "Severe conditions".

The minimum cement content, maximum water-cement ratio and minimum grade of concrete under various exposure conditions is tabulated below:

Table 9 Concrete subjected to various exposure conditions

SI No	Exposure	Plain concrete			Reinforce concrete		
		Minimum cement content (Kg/m3)	Maximum water-cement Ratio	Minimum Grade of concrete	Minimum cement content (Kg/m3)	Maximum water-cement Ratio	Minimum Grade of concrete
i	Mild	220	0.60	M10	300	0.55	M 20
ii	Moderate	240	0.60	M 15	300	0.50	M25
iii	Severe	250	0.50	M20	320	0.45	M 25/M 30
iv	Very Severe	260	0.45	M20	340	0.45	M 35
v	Extreme	280	0.40	M 25	360	0.45	M40

Adjustments to Minimum Cement Contents for Coarse aggregate otherthan 20 mm nominal maximum size:

SI No.	Nominal Maximum coarse aggregate size (mm)	Adjustment to minimum Cement Contents (Kg/m3)
i	10mm	+ 40 Kg/m3
ii	20mm	0
iii	40mm	-30 Kg/m3

Note: No reinforced concrete shall be of grade less than M 20 in respect of concrete works.

c) Consistency/workability of concrete Mix:The consistency shall be such that the concrete can be easily placed and compacted withoutsegregation of materials. The resulting concrete should be free from honey-combing. The consistency of concrete, as determined by the slump test, should be within the range 50 mm to 75 mm viz "medium degree of workability".

d) Mixing of Concrete:Concrete mix ingredients shall be mixed in a mechanical mixer. All ingredients (viz cement, sand, coarse aggregates) including water shall be thoroughly mixed together before any portion of the mixture is discharged. The ingredients shall be mixed in the mechanical mixer for at least 2 to 3 minutes. The entire quantity of water shall be put in the mixer before one-fourth of the mixing time has elapsed. The mixer shall be cleaned before commencing mixing and shall be kept free from set concrete.

In exceptional cases when the quantity of concrete is very small, the Engineer may allow hand mixing of concrete to a limited quantity. Hand mixing shall be done on a smooth and hard platform. The whole of the aggregate, sand and cement shall be turned over on the platform in a dry state at least 3 times, keeping the central portion of the heap depressed. Water from a calibrated container shall then be added gradually after which the materials shall again be thoroughly turned over in a wet state at least 3 times before taking the mix to the placement site.

e) Water-Cement Ratio: It is one of the key elements for a durable and sound concrete. Accordingly, it should be maintained at correct specified value. High durability is associated with low water-cement ratio. Co-efficient of permeability increases rapidly for water-cement ratio in concrete higher than 0.55 or 0.60. Higher permeability of concrete makes it porous, there-by, allowing easy ingress of water, carbon dioxide, sulphates and chlorides into the concrete and initiating its deterioration rapidly. Higher W/C ratio reduces the compressive strength of concrete. An excess of 10% water shall reduce the compressive strength by about 15% and an excess of 30% water in the concrete mix shall reduce the strength by about 50%.

To achieve good compaction of concrete (in narrow forms and congested reinforcement), proper mechanical vibrators (needle type vibrators) shall be deployed. Manual compaction of concrete mix (of low W/C ratio) through tamping poses problems. In such cases, workability (viz fluidity) of concrete shall need to be increased by increase in water content in the concrete mix to increase its workability/fluidity must be accompanied by a proportionate increase of cement, if strength is to be maintained. If wet or moist sand is used, increase its quantity by approximately % of bulkage and reduce the quantity of water by almost the same amount as the % of bulkage.

f) Sieve analysis of sand and coarse aggregate: It is essential that sieve analysis of sand and coarse aggregate is carried out. The natural sand gravel mixture / sand aggregate mixture should not be used by the contractor without screening and washing. The fine and coarse aggregate must be stacked separately after screening. This is an essential requirement of quality control (Ref.I.S.383).

g) Placement, compaction and curing:Before placing concrete, the site must be clear of all debris, loose material, rubbish, vegetation etc. Concrete shall be placed and compacted as soon as possible after it has been mixed with water and before the initial set of cement viz 30 minutes. Concrete shall be placed in layers of 15 cm to 30 cm for reinforced work and upto 45 cm for mass concrete. The layers shall be placed in quick succession to prevent any separation between the layers. Each layer is to be vibrated with a mechanical internal needle type vibrator. In very small works, adequate tamping shall be done for compaction of concrete.

- Concrete shall not be thrown from a height of more than 1.5 m when brought in hand baskets. When dumped or dropped from a chute, the direction of its fall shall be vertical. When concrete is to be placed more than 1.5 m below ground level, chutes shall be used. Chutes could be of semi-circular shape of wood lined inside with a sheet; or these could be semicircular sheet pieces joined together and fixed at a slope of 1 (H):2 (V). The delivery end of chute shall be as close to the placement point as possible. The chute shall be kept moist with water just prior to the delivery of concrete.
- The concrete shall be placed in convenient lifts,, varying from 60 cm to 90 cm, depending upon the capability of concrete production, placement, and compaction. Concrete surface shall be given a steel trowel finish upon completion of placement of the lift. In small jobs, the finished surface shall be manually nicked (viz made rough with a chisel or pointed steel rod) after about 6 hours of completion of placement and all laitance (viz fine mortar layer) removed and the coarse aggregate exposed. The surface be washed with water. In the construction of big bridges, culverts and other substantially bigger jobs, an air-water gun shall be used to remove the laitance. This is known as green cutting of concrete. Next lift of concrete shall then be placed over the surface thus prepared.

Curing:It is very essential to do adequate curing of concrete to enhance its durability. Inadequate curing not only reduces the strength of concrete but also increases its permeability there-by making it vulnerable to attacks by the atmospheric water, carbon dioxide etc. and making it weak. Inadequate curing causes spalling & cracking of concrete. Accordingly, exposed surfaces of concrete shall be kept continuously in a damp or wet condition by covering the same with sacks, canvas, hessian, or similar material for a period of 28 days.

h) Frequency of sampling of concrete:No. of samples to be taken from each grade of concrete shall be broadly as under:

Quantity of concrete in the work (m3)	No. of samples to be taken for testing
1-5 m3	1 No.
6-15 m3	2 Nos.
16-30 m3	3 Nos.
31-50 m3	4 Nos.
51 m3 and above	4 plus one additional sample for each additional 50m3 concrete or part there-of.

3 test specimens (viz cubes) shall be cast from each sample for testing at 28 days. Additional specimens may be cast for testing at 7 days, if so desired. The test results of sample shall be the average of the strength of 3 specimens.

• For ordinary portland cement concrete (OPC), compressive strength at 7 days is about 75% of the strength at 28 days; and the compressive strength at 3 days is about 33% of the strength at 28 days.

i) Acceptance Criteria of the Cube Compressive Strength: Any individual test result shall not be less than 80% of the strength of the respective grade of concrete viz for M20 grade concrete, the individual test strength shall not be less than 160 kg /cm2 and the average strength of all samples shall however, be not less than 200 kg/cm2.

Note: As per latest IS 456:2000 the acceptance criteria is explained below:

Assumed standard deviation: Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in Table indicated below may be assumed for design ofmix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly. However, when adequate past records for a similar grade exist and justify to the designer a value of standard deviation different from that shown in Table below, it shall be permissible to use that value.

Assumed Standard Deviation (Clause 9.2.4.2 and Table 8 of IS 456:2000)		
Grade of Concrete		Assumed Standard Deviation (N/mm2)
M 10		3.5
M 15		
M 20 M 25		4.0

NOTE: The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate grading and moisture content; and periodical checking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by 1N/mm^2.

Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following condition are met:

a) The mean strength determined from any group of four consecutive test results complies with the appropriate limits in col. 2 of Table 11 of I.S.456-2000.

b) Any individual test result complies with the appropriate limits in col. 3 of Table 11 of I.S.456-2000.

Flexural Strength

When both the following conditions are met, the concrete complies with the specified flexural strength.

a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm2.

Quantity of Concrete Represented by Strength Test Results

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches.

For the individual test result requirements given in col.2 of Table 11 of I.S.456-2000 or in item (b) of 16.2 of I.S.456-2000, only the particular batch from which the sample was taken shall be at risk.

Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3.

If the concrete is deemed not to comply pursuant to clause-16.3 of I.S.456-2000, the structural adequacy of the parts affected shall be investigated see clause -17 of I.S.456-2000 and any consequential action as needed shall be taken.

Concrete of each grade shall be assessed separately.

Concrete is liable to be rejected if it is porous or honey-combed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not been met. However, the hardened concrete may be accepted after carrying out suitableremedial measures to the satisfaction of the Engineer-in-Charge.

Characteristic Compressive Strength Compliance Requirement *(Clauses 16.1 and 16.3)* of I.S.456-		
SpecifiedGrade	Mean of the Group of 4 Non- Overlapping Consecutive Test Results in N/mm^2	Individual Test Results in N/mm^2
M-15	> f_{Ck} + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm) or f_{ck} + 3 N/mm^2, whichever is greater.	> f_{ck}'^{3} N/mm^2

M-20 or above	> f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 4 N/mm^2, whichever is greater.	> fck'^{4} N/mm^2

NOTE: In the absence of established value of standard deviation, the values given in Table of I.S. 456-2000 may be assumed, and attempt should be made to obtain results

- Mild steel and high tensile steel bars and hard drawn steel wire conforming to IS 432-(part-l) & as revised from time to time.
- High strength deformed steel bar confirming to I.S. 1786.
- Hard drawn steel wire fabric confirming to I.S.1566.
- Structural steel sections conforming to Grade 'A' of I.S 2062 & as revised from time to time.
- Cold twisted steel bars complying with the requirements of IS 1786-1966 and as amended from time to time.
- Such other reinforcement as maybe proved suitable having regard to the yield point stress, ductibility, ultimate resistance to tension and other essential properties of the completed reinforcement as produced in readiness for reinforced concrete.

Bar stock shall be periodically tested for quality from time to time during the progress of the work or when there is doubt that bar stock may not conform to the requirements of the specifications. Bar stock not meeting the requirements of the specifications shall not be used in the work. All steels to be used in work shall be tested in the laboratory to ascertain its suitability & the cost of testing charges shall be borne by this contractor.

7.3.1 CUTTING AND BENDING

- Reinforcement bars shall be of the size prescribed and shall be cut to the lengths, bent to the shapes and fixed in position shown on the drawings or as directed by Engineer-in-Charge and shall conform to IS 2502-1963 and as revised from time to time.
- Deformed bars shall not be returned after being bent and straightened unless initially bending and subsequent straightening and bending are carried out under proper approved supervision.
- Reinforcement bars shall be bent cold. Bars shall not be cooled by quenching. Bars shall not be straightened or bent in a manner that will injure or weaken the material.

7.3.2 JOINTING AND SPLICING

- Joints or splices in reinforcement bars shall be made at the position shown on the drawings. Additional joints or splices maybe permitted at positions other than those shown on the drawings

provided that the positions of joints and splices in adjacent bars are staggered and are placed as approved.

- Reinforcement bars 25 mm in diameter and larger maybe connected by butt welding provided that lapped splices will be permitted if found to be more practical than butt welding and if lapping does not encroach on cover limitations or hinder concrete or reinforcement placing.
- Deformed bars shall not be lap welded at splices except where lap welding is shown on the drawings or otherwise specifically approved.
- Butt welding of reinforcement bars shall be performed under cover from the weather and maybe performed either by the gas pressure or flash pressure welding process, or by the electric arc methods. The following requirements shall apply for all welding of reinforcement bars including butt welding and the preparation of welded reinforcement mats.
- The ends of the bars to be butt welded by gas pressure or flash - pressure welding shall be squared off by an abrasive disc-cutter. Any accumulation of dirt or oxide film formed after the cutting operation shall be removed by sand blasting or buffing prior to welding. Ends of bars to be joined by flash pressure welding shall be cleaned of all rust and projections on the end faces and for a distance of about 15 cm, from the ends, if necessary, prevent arching. Care shall be taken in aligning and separating the ends of the bars shall be matched accurately and shall be retained firmly in position during the welding operations. For pressure welding the bars shall be accurately held in position with the prescribed pressure applied prior heating and during heating and welding.
- Where bars are to be joined by electric arc welding, the weld metal shall be deposited in successive layers and each layer shall be thoroughly cleaned before the subsequent layer is deposited.
- All structural welds shall have complete fusion and freedom from imperfections. Defective pressure welded joints shall be separated by flame cutting and re-welded.
- Only operators skilled in the type of welding procedure used for the welding of reinforcement base shall be used for work.
- Welding materials and welding procedures and the workmanship of welding operators will be subject to inspection and approval at all times during the progress of the work.
- The position and dimension of lapped splices will normally be shown on the reinforcement drawings. Where splices are required for the work the following minimum overlap of spliced bars shall be used for the various sizes and grades shown. Hooks will not normally be prescribed for splices in structural grade deformed bars.

Diameter of bars in mm	Grade of Bar	Minimum length of the overlap	
		For (M-15) Concrete	(M-20) & (M-25) Concrete
8	Deformed ribbed bars	44 cm	33 cm
10	Deformed ribbed bars	55 cm	44 cm
12	Deformed ribbed bars	66cm	49 cm
16	Deformed ribbed bars	88 cm	65 cm
20	Deformed ribbed bars	110 cm	82 cm
22	Deformed ribbed bars	110 cm	83 cm
25	Deformed ribbed bars	125 cm	94 cm

32	Deformed ribbed bars	160 cm	120 cm
36	Deformed ribbed bars	180 cm	135 cm
40	Deformed ribbed bars	200 cm	150 cm

- Binding wire used shall be of soft annealed steel of 16 SWG and shall have an ultimate strength of not less than 5600 kg per sq cm and an yield point of not less than 3850 kg per sq.cm.

7.3.2.1 Nominal Cover to Meet Durability Requirements

(as per IS: 456:2000, Clause No.26.4.2, Table No.16)

Minimum values for the nominal cover of normal weight aggregate concrete which should be provided to all reinforcement, including links depending on the condition of the exposure.

Table 10 Table for Nominal Cover to meet Durability Requirements

Exposure	Nominal Concrete Cover in mm not Less Than
Mild	20
Moderate	30
Severe	45
Very Severe	50
Extreme	75

Notes:

1. *For main reinforcement up to 12 mm dia. Bar for mild exposure the nominal cover may be reduced by 5mm.*
2. *Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by (+) 10mm and (-) 0mm.*

7.4 MIXING OF ADMIXTURE

As per IS 9103 - 1999, an admixture is defined as a material other than water, aggregates, hydraulic cement additives like pozzolana orslag and fibre reinforcement used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing to modify one or more of the properties of concrete in the plastic or hardened state.

It is proposed to use Air-Entraining- Agent (AEA) as an admixture in the concrete mix to be used for cement concrete lining.

Agent Dosage: The dosage shall be approved by the Engineer-in- Charge. Normally the dosage should help in entraining 4 to 5% air in the mix.

Slump & Workability: Air-Entraining-Admixture (AEA) enables better finish and effects good workability viz. fluidity.

7.5 PREPARATION OF SURFACE FOR PLACING CONCRETE

Concrete shall not be placed until all form work required is completed, embedded parts, if any installed and checked and surfaces prepared for placing. No concrete shall be deposited until the foundation has been inspected and approved. All surface or forms and embedded materials that have become encrusted

with dried mortar or grout from concrete previously placed shall be cleaned of all such mortar or grout before the surrounding or adjacent concrete is placed.

7.5.1 DETAILED DESCRIPTION OF PREPARATION OF SURFACE FOR DIFFERENT NATURE OF WORK

Immediately before placing concrete, all surfaces of foundation on or against which the concrete is to be placed, shall be free from standing water, mud and debris. All surfaces of rock upon or against which concrete is to be placed shall, in addition to the fore going requirements be cleaned and free from oil, lubricant, objectionable coatings and loose semi batched or unsound fragment a surface of absorptive foundations upon or against which concrete is to be placed shall be moistened thoroughly and kept sufficiently wet for at least 24 hours immediately prior to placing so that moisture will not be drawn form the freshly placed concrete. The cleaning and roughening of the surfaces of the rock shall be performed by the use of high velocity air water jets, wet sand blasting, stiff booms, picks or by other effective means. Washing and scrubbing process shall be continued until the wash water collected in puddles is clear and free from dirt. In the final cleaning process, the wash water may have to be removed by sponges. If any drilled hole is left in the foundation surface which is no longer needed, the hole shall be cleaned with air water jetting and filled up completely with cement slurry.

Concrete / Masonry surfaces upon or against which concrete is to be placed and to which the new concrete is to be adhered and that it has become so rigid that the new concrete can not be incorporated by near vibration integrally with that previously placed are defined as construction joints. The surfaces of construction joint shall be clean, rough and damp but free from standing pools of water receiving the next lift. Clean up shall comprise of removal of all laitance, loose or defective concrete, castings, sand, sealing compounds if used and other foreign materials, if necessary by scrapping, chipping or by other suitable means.

The surface of construction joints shall be cleaned by use of a high pressure water jet or wet sand blasting and then washed thoroughly. The water jetting sand blasting and washing shall be performed at the last opportunity prior to the placing of concrete.

7.6 DETAIL DESCRIPTION ON PLACING OF CONCRETE

After the surfaces have been cleaned and dampened as specified, surfaces of rock and construction joints shall be covered, wherever practicable with a layer of mortar approximately 15 mm to 20 mm thick. The mortar will have the same proportions of water, air entraining agent, cement and fine aggregate as the concrete mixture which is to be placed upon it. The water cement ratio of the mortar in place shall not exceed that of the concrete to be placed upon it, and the consistency of the mortar shall be suitable for being spread uniformly and worked thoroughly to all irregularities of the surface.

In so far as it is practicable, concrete shall be placed directly in its final position and shall not be directly in its final position which may cause to flow in a manner to permit or cause segregation. Methods and equipment employed in placing concrete will ensure that aggregate is not separated from the concrete.

In placing mass concrete in a lift successive batching of concrete shall be placed in a systematic arrangement in order to avoid long explosive of parts of the live surface of a concrete layer.

In mass concrete placement, delays may occur resulting in cold joins within a lift. When placement is resumed while concrete is so green and therefore capable of ready bonding that it can be dug out with a hand pick, the usual contraction joint treatment will not be required if the surfaces are kept moist and the concrete placed against the surface is thoroughly and systematically vibrated over the entire area

adjacent to the older concrete. If the delay is short enough to permit penetration of the vibration into the lower layer during routine vibration of successive layers, the vibration will assure necessary bonding.

If from any cause, the working surface is left exposed until it has hardened to a considerable extent, it shall be left to set and cure for not less than 56 hours or longer if necessary until a strength greater than 35.2 kg/cm2 (500 psi) has been attained, before completing the lift. The surface thus, interrupted shall be given a thorough clean up as for normal lift joint surface and the work shall be commenced with a mortar layer as specified. In placing mass concrete, the exposed area of fresh concrete shall be maintained at the practical minimum by first building up the concrete in successive approximately horizontal layers to the full width of the block and to full height of the lift over a restricted area at the down streamed of the block and then continuing upstream in similar progressive stages to the full area. The slope formed by the unconfined upstream edges of the successive layers of concrete shall be kept as steep as practicable in order to keep its area minimum. Concrete along these edges shall not be vibrated until adjacent concrete in layer is placed, except that it shall be vibrated immediately when weather conditions are such that the concrete will harden to an extent the layer vibration may not fully consolidate and integrate it with more recently placed adjacent concrete.

Re-tampering of concrete shall not be permitted. Any concrete which has become so stiff that proper placing without re-tampering cannot be ensured shall be wasted.

In formed structural work concrete placements shall generally be started with an over-sanded mix containing 20 mm maximum size aggregate and an extra sack of cement per cubic meter and having in 125 mm slump placed several centimeters deep on the joints at the bottom of the form, concrete placement shall commence immediately thereafter.

If concrete is placed monolithically around opening having vertical dimensions greater than 0.6 meter or if concrete in deckses, floor slabs, beams, girdes, or other similar pats of structure is placed monolithically with supporting concrete, the following instruction shall be strictly observed.

- Placing of concrete shall be delayed not less than one hour for more than three hours at the top of opening and at the bottom of fillets under decks, floor slabs, beams, girders or other similar parts of structure.
- The last 0.6 meter of more of concrete placed immediately before the delay shall be placed with as low slump as practicable and shall be thoroughly compacted.
- The surfaces of concrete where delays are made shall be cleaned and free from loose and foreign materials when concrete placing is started after the delay.
- Concrete placed over openings and in decks floors, beams, girders and other similar parts of structures shall be placed with as low slump as practicable.
- Concrete shall be compacted maximum practicable density, in such a manner that is free from pockets of coarse aggregates and is in intimate contact with surface of forms and embedded materials. Unless otherwise permitted, all concrete shall be compacted by mechanical vibrator.

7.6.1 COMPACTION

Compaction of concrete shall wherever practicable be carried out by the use of immersion type needle vibrators. Concrete vibrators having vibrating heads of 100 mm or more in diameter shall be operated at speeds of at least 600 revolutions per minute when immersed in the concrete. Vibrators having vibrating heads less than 100 mm in diameter shall be operated at speeds of at least 7000 revolutions per minute in the concrete. Normally, form work shall be designed to provide for the insertion and

operation of mechanical vibrators in the placed concrete. Form vibrators shall be used wherever internal vibration is not possible or would be inadequate.

In compacting each layer of concrete, the vibrator shall be operated in as near vertical position and vibrating heads shall be allowed to penetrate and vibrate the concrete in the upper portion of the under lying layer. On the area where newly placed concrete in each layer joints previously placed concrete more vibration than usual shall be performed, so that the vibrator penetrate deeply at close intervals along the contacts. Layers of concrete shall not be placed until layers of previously placed have been vibrated thoroughly as specified. Contact of the vibrating head with surface of the forms shall be avoided.

During placing and until curing is completed, the concrete shall be protected against the harmful effect of exposure to sunlight, wind and rain as directed.

7.7 DETAILED DESCRIPTION ON FORM WORK

Forms shall be used wherever necessary to continue the concrete and shape it to the required lines or to ensure against contamination of the concrete by excavations or other features of the work. All exposed concrete surfaces having slopes of 2 horizontal to 1 vertical or greater shall be formed.

Form work may be of timber, steel or pre-cast concrete panels or such other suitable materials or combination of such materials. Form work shall be substantially and rigidly constructed to the shapes lines and dimensions required, efficiently propped and braced to prevent deformation due to placing, vibrating and compacting concrete, other incidental loads or to the effect of weather. If settlement or deflection of forms under the load of fresh concrete is to be expected, allowance should be made in the original construction of the forms of that the finished lines and dimensions of the structure are in accordance with those specified on the drawings.

The surfaces of form work shall be made to produce surface finishes as specified and form work joints be tight enough to prevent loss of liquid form concrete. Joints between the form work and existing concrete structures shall also be "grout tight". Form work shall be arranged to facilitate easing and removing of the various parts in correct sequence without jarring or damaging the concrete. Temporary opening shall be provided at all points necessary in the forms of facilitate clearing and inspection immediately before the placing of the concrete.

Forms shall overlap the hardened concrete in the lift previously placed by not more than 75 mm and shall be tightened against the hardened concrete so that when concrete placement is resumed, the form will not spread and allow loss of mortar at construction joints. Additional blots or form ties shall be used as necessary to hold forms tight against hardened concrete. Particular attention shall be paid in setting and tightening the forms for construction joints so as to get a smooth joint free form sharp deviations or projections.

Moulding strips shall be placed in the corners of forms so as to produce chamfered edges as required on permanently exposed concrete surface.

7.7.1 TYPE OF FORM WORK TO BE ADOPTED FOR CONCRETING WORK

Type of form work used for form sheathing and lining shall confirm with the following requirements:

Required finalization	Timber sheathing or lining	Steel sheathing or lining

FI	Any type and grade meeting the dimensional requirements of surface finish except that metal forms shall be used on surfaces of internal traverse and longitudinal joints in the dam.	Steel sheathing permitted steel lining permitted except on surface of internal transverse and longitudinal joints in the dam
F2	Common grade timber or pay sheathing or lining	Steel sheathing permitted steel lining permitted if strongly supported.
Steel sheathing denotes steel sheets not supported by a backing of timber boards. Steel lining denotes steel sheets supported by a backing of timber boards.		

Timber sheathing or lining shall be of such kind of'quality or shall be so treated or coated that there will be no chemical deterioration or discoloration of the formed concrete surfaces. The type and condition of forms sheathing and lining and the ability of forms to withstand distortion caused by placement and vibration of the concrete and the workmanship used in the form construction shall be such that the formed surfaces will conform with applicable requirement of this specification pertaining to finish of formed surfaces. Forms for concrete surfaces required to receive F2 finish shall be constructed so as to produce uniform and consistent texture and pattern on the concrete faces. Metal patches on forms for these faces will not be permitted.

The form sheathing or lining shall be so placed that all horizontal form marks are continuous across the entire surface. Where finish Fw is specified height sheathing or lining shall be placed so that the joint marks on the concrete surfaces will be in general alignment both horizontally and vertically and the form sheathing materials used for such surfaces shall be restricted on one type in any one major feature of the work.

Embedded ties for holding forms shall remain embedded and except where FI finish is permitted shall terminate not less than two diameters or twice the minimum dimension of the tie or ten millimeter, whichever is greater, i.e. from the formed faces of the concrete. Where Fl finish is permitted, ties may be cut off flushed with formed surface.

The ties shall be constructed so that removal of the ends or end fasteners can be accomplished without causing appreciable spalling, at the faces of the concrete. Recesses resulting from removal of the ends of the form ties shall be filled in accordance with the provisions of section of repair of concrete.

7.7.2 CLEANING AND TREATMENT OF FORMS

At the time concrete is placed in the forms the surface of the forms shall be free form encrustations of mortar grout or other foreign materials. Before concrete is placed, the surfaces of the forms designated to produce FI, F2 finishes shall be oiled with a commercial form oil that will effectively prevent sticking and will not stain the concrete surfaces. For timber forms, form oil shall consist of refined mineral oil suitable compounded with one or more ingredients which are appropriate for the purpose.

Care shall be taken to keep form oil out of contact with reinforcement

7.7.3 REMOVAL OF FORMS

- Except as otherwise provided in this Sub-clause, form shall be removed as soon as the concrete has hardened sufficiently to prevent damage by careful form removal thus facilitating satisfactory progress with specified curing and earliest practicable repair of surface imperfections.
- Forms on upper slopping faces of concrete, such as forms on the water sides of wraped transitions shall be removed as soon as the concrete has attained sufficient stiffness to prevent sagging. Any

needed repairs or treatment required on such slopping surfaces shall be performed at once and be followed immediately by the specified curing.

- Forms shall be removed with care so as to avoid injury to the concrete. Any concrete damage informs removal shall be repaired in accordance with the provisions of section of repair of concrete.
- The minimum intervals of time as per IS:456-2000 will generally be allowed when using ordinary Portland cement between placing concrete and striking form work but the period shall be modified in case of wet weather and also at the option of the Engineer-In- Charge.

7.7.4 FINISHING OF CONCRETE SURFACE

Allowable deviations from plumb or level and form the alignment, profile, grades and dimensions shown on the drawings are defined as "tolerance" and are to be distinguished from the irregularities in finish as described herein. The tolerances in concrete constructions are specified in the particular section. The classes of finish and requirements for finishing of concrete surface shall be as shown in the drawing. In the event of finishing not being definitely specified herein or on the drawings the finish to be used shall be as directed. Finishing of concrete surfaces shall be performed only by skilled workmen. Concrete surfaces will be tested where necessary to determine whether surface irregularities are within the limits hereinafter specified.

Surface irregularities are classified as "abrupt" or "gradual" offset caused by displaced or misplaced form sheathing or lining or from sections or by loose knots or otherwise- defective form timber will be considered as abrupt irregularities and will be tested by use of template, consisting of a straight edge or the equivalent thereof for curved surface. The length of the template will be one and half meters for testing of formed surface and three meters for testing unformed surfaces.

The classes of finishes for formed concrete surfaces are designated by one of the symbols FI & F2. Bag rubbing or sand ballasting will not be required on formed surfaces. Grouting will not be required on formed surfaces other than that necessary for the repair of surface imperfections. Unless otherwise specified or indicated on the drawings, the classes of finish which will apply are as follows:

(A) FINISH FI

This finish applies to surfaces where roughness is not objectionable, such as those upon or against which fill materials masonry or concrete will be placed, i.e. the upstream face of the structure that will otherwise be permanently concealed. The surface treatment shall be repair of defective concrete, correction of depressions, deeper than 25 mm and filling of tie rod holes. Form sheathing shall not leak mortar when the concrete is vibrated. Forms may be build with a minimum of refinement.

(B) FINISH F2

The finish is required on the permanently exposed surfaces for which other finishes are not specified, such as in outlet works and open spillways, bridges and retaining wall not prominently exposed to public view and in the galleries and audits in the structure except where FI finishes are permitted. Forms shall be built in a workman like manner to the required dimensions and alignment, without conspicuous off-sets or bulge. Surface irregularities will be measured from a 1.5m template

Uniformed surfaces which are nominally level shall be sloped for drainage as shown on the drawings or as directed. Unless the use of other slopes or level surface is indicated on the drawings, narrow surface such as tops of parapets, tops of wall and kerbs shall be slopped approximately one per 30 cm of width, broader surface such as roadways, platform and decks, shall be sloped approximately half centimeter for 30 cm of width.

7.8 REPAIRS OF CONCRETE

Repairs of concrete shall be performed by skilled workers and in the presence of an experienced Engineer. The repairs of concrete includes correction of all imperfections on the concrete surfaces with the requirements of finishing of the same on formed concrete and shall be completed as soon as practicable after removal of forms and within 24 hours. Concrete that is damaged from any cause and concrete that is honey combed, fractured or otherwise defective and concrete which because of excessive surface depressions must be excavated and builtUp to bring the surface to the prescribed lines, shall be removed and replaced by dry pack mortar or concrete as hereinafter specified where bulges and abrupt irregularities protrude outside the limits specified in the section "finishing of concrete surfaces" the protrusions shall be reduced by bush hammering and grinding so that the surfaces are within the specified limits.

7.8.1 METHODS OF REPAIR OF CONCRETE

For new works four methods are used:

(i) Dry pack method

This method should be used for holes having a depth nearly equal to or greater than the least surface dimensions, such as cone but grout inset holes, etc. and narrow slots cut for the repair of cracks. Dry pack should not be used for relatively shallow depressions where lateral restrain cannot be obtained for filling in back of considerable lengths of exposed reinforcement nor for filling holes which extend entirely through the wall, beam, etc.

(ii) Concrete replacement method

Concrete replacement should be used when holes extend entirely through the concrete sections, when holes in plain concrete are more than 1000 sq. cm in depth and holes in reinforced concrete are more than 500 sq. cm in area and deeper than the reinforcement steel.

(iii) Mortar replacement method

This should be used for the holes too wide to dry pack and too shallow for concrete replacement and for all comparatively shallow depressions, large and small which extend more deeper than for side of the reinforcement bar & nearest to the surface.

(iv) EPOXV method

A thermosetting plastic compound known as epoxy can be used as a bonding medium wherever long time curing of conventional concrete can not be assured. Also epoxy mortars of fine sand as well plain epoxy are suitable for concrete repair work and should be used whenever very thin patches are to be placed for immediate reuse of the area or where moist curing can not be effectively accomplished. Preparation for epoxy bonded repairs should in general be identical to that for other concrete repairs except that every effort should be made to provide surfaces of at least 24 hours thoroughly dry. Drying of the surface for at least 24 hours and warming to temperatures between 65° C to 80° C are essential for proper application of epoxy mortars. A wash of dilute 1:4 muriatic acid rinsing with clean water and subsequent drying is desirable where feasible. If acid wash is not feasible, preparation maybe accomplished as for other concrete repairs with final clean up being by means of sand blast method followed by air water jet washing and thorough drying. Epoxy repairs shall be carried out only by trained personnel.

7.8.2 PREPARATION OF CONCRETE FOR REPAIR

All concrete of questionable quality should be removed. It is better to remove too much concrete than too little because effected concrete generally continues to disintegrate and while the work is being done it costs but little more to excavated to ample depth. Moistening cleaning, surface drying and complete curing are of utmost importance when making repairs, which must be thoroughly bonded, water tight and permanent. Surfaces between trimmed holes should be kept continuously wet for several ours preferably over night prior to placing new concrete. Immediately before placement of the filling, the holes should be cleaned so as to leave a surface completely free of chipping dust, dried grout and all other foreign materials. A preliminary washing as soon as the chipping and trimming are complete is desirable to remove lose materials. Final cleaning of the surfaces to which the new concrete is to be bonded should be done by wet sand blasting followed by washing with air water jet for thorough cleaning and carrying with an air jet. Care should be taken to remove any loose materials embedded in the surface by chisels during the trimming and to eliminate all shiny sport indicating free surface moistures. Cleaning of steel if necessary should be accomplished by sand blasting. The prepared surface shall be approved by the Engineer-in-charge.

(i)For Dry Pack Concrete

For this method of repair, the holes should be sharp and square at the surface edges but the corners within the holes should be rounded, especially when water tightness is required. The interior surfaces of holes left by cone bolts, etc., should be roughened to developing effective bond. Other holes should be under cut slightly in several places around the perimeter. Homes for dry pack should have a minimum depth of 25 mm.

(ii)For Concrete Replacement

Preparation for this method should be as follows:

a) Holes should have minimum depth of 100 mm in new concrete and the minimum area of repair should be 500 sq. cm. for R.C.C and 1000 sq. cm for P.C.C.

b) The reinforcement bars should not be left partially embedded. There should be a clearance of at least 25 mm around each exposed bar.

c) The top edge of the holes at the face of the structure should be cut to a firmly horizontal line. If the shape of the defect makes it possible, the top of the cut maybe stepped down and continued on a horizontal line. The top of the hole should be cut to 1 to 3 upward slope from the back towards the face of the wall. It maybe necessary to fill the hole from both sides, in which case the slope of the top of the cut should be modified accordingly.

d) The bottom and sides of the holes should be cut sharp and approximately square with the face of the wall. When the hole goes entirely through concrete section spalling or feather edges shall be avoided by having chippers worked from both faces. All interior corners should be rounded to a minimum radius of 25 mm.

(iii) For mortar replacement

When mortar gun is used with this method, comparatively shallow holes should be flared outwardly at about 1:1 slope to have proper rebound. Corners within the holes should be rounded. Shallow imperfections in new concrete maybe repaired by mortar replacement of the work is done promptly after removal of the forms and while the concrete is still green. Wherever hand placed mortar replacement is used, edges of chipped out areas should be squared with the surface leaving no feather edges.

(iv)For use of Dry Pack mortar

The surface after preparing should be thoroughly brushed with a stiff mortar or grout barely wet enough to thoroughly wet the surface after which the dry pack material should be immediately packed into place before the bonding grout has dried. The mix of boding grout is 1:1 cement and fine sand mixed to a consistency like the dry pack material more than very slightly rubbery. Dry pack is usually a mix (dry volume of weight) of one part of cement of 1 1/2 part of sand that will pass a No. 16 screen. The proper amount of mixing water and proper consistency are those which will produce a filling which is at the point of rubbery when the material is solidly placed. Dry pack material should be placed and packed in layers having a compacted thickness of about 10 mm. The surface of each layer should be scratched to facilitate bonding with next layer. One layer may follow another immediately unless appreciable rubber ness develops in which case work on the repair should be delayed. The tamping should be directed at a slightly angle and towards the sides of the hole to ensure maximum compaction in these areas. The holes should not be over filled and finishing may usually be completed at once by laying the flat side of the guard wood placed against the fill and striking it several good blocks. If necessary, a few light strokes with a rag some time later may improve the appearance. Steel finishing tools should not be used and water must not be used for replacement of concrete.

7.8.3 REPLACEMENT OF CONCRETE

All procedures for replacement of concrete and by use of epoxies and curing of repairs shall be according to the provisions laid down in chapter VII repair and maintenance of concrete - Concrete Manual of the United States Bureau of Reclamation, Seventy Edition, 1963.

7.8.4 CURING OF CONCRETE

Subsequent, to laying of concrete lining and after a period of 4-6 hours depending upon ambient temperature, the lining shall be cured for at least 28 days. Curing compound may be used in place of curing by water.

7.9 TOLERANCE FOR CONCRETE CONSTRUCTION

Permissible surface irregularities or the various classes of concrete surface finishes specified in the relevant portion of the section on " finishes and finishing of concrete surfaces" are defined as finishes and are to be distinguished from "Tolerances " as described " as described in this section Deviations from the establishment lines, grade and dimensions will be permitted to the extend set-forth in this clause, provide that lesser tolerances than that tolerance set-forth in this clause maybe prescribed at site if such tolerances are considered to impair the structural action or operational action or operational function of the structure.

Where tolerances are not stated in the specifications or drawings for any individual structure of feature thereof, permissible deviations will be interpreted in conformity with the provisions of this clause.

Concrete work that exceeds the tolerance limits specified in this section shall be either remedied satisfactorily or removed.

7.10 CONCRETE LINING OF CANALS

The concrete lining in canals serves the following purposes

- Seepage loss of 'water is very much reduced and the water, thus saved, can be utilised for increasing the intensity of irrigation.
- The land by the sides of canals is saved from water logging due to rise of ground water table

because of canal seepage.

- The canal section area and the required land width for acquisition can be reduced as higher velocity in the lined canal can be allowed.
- Aquatic plant growth on the bed and slopes is prevented.
- Maintenance cost requirement is reduced as the stability of canal section is improved by lining.

The following broad guidelines may be followed in the canal reaches associated with non-expansive soils (viz; non black cotton soils) andthose associated with swelling in expansive soils.

a) Lining in non BC Soils:

- Selective protective lining to be provided immediately up stream and down stream of every structure in 2.5m reach up stream and 3.75m reach down stream of the structure where fluming of channels is involved, and in 2.5m reach both u/s and d/s of structure where fluming of channels is not involved. Toe walls must be provided at upstream and downstream ends of lining.
- Lining be provided in high banking reaches and in all such reaches as are considered "vulnerable" viz; associated with seepages, slippage of slopes and breaches etc
- Model Sections / Profile Walls of concrete (30cm x 30cm) should be provided in the balance unlined canal reach at intervals of say, 50m and at a closer spacing in curves, viz; extra Model Section / Profile Wall at the curve.

(b) Lining in Swelling BC Soils:

- Lining to be provided throughout the canal reaches passing through swelling BC soils.

Where C.C. lining is to be placed in the channels passing through the swelling black cotton soils, provision for CNS treatment of the sub-grade should be made prior to placement of lining as per Indian Standard IS 9451:1994. Thickness of CNS soil is to be in accordance with the following Tables:

Table for: Thickness of CNS layer in canal carrying less than 2 cumecs (70 cusecs).

Discharge in cumecs (cusecs)	Thickness of CNS layer in centimetres (minimum)	
	Swelling pressure of BC Soil (0.50-1.50 kg/cm^2)	Swelling pressure of BC Soil more than 1.50 kg/cm^2
1.4-2.0 (50-70)	60 cm	75 cm
0.70-1.40 (25-50)	50 cm	60 cm
0.30-0.70 (10-25)	40 cm	50 cm
0.03-0.30 (1-10)	30 cm	40 cm

Table for: Thickness of CNS layer in canal carrying more than 2 cumecs (70 cusecs).

Swelling pressure of BC Soil (kg/cm^2)	Thickness of CNS layer in centimetre (minimum)

0.50-1.50 kg/cm^2	75 cm
1.50-3.00 kg/cm^2	85 cm
3.00-5.00 kg/cm^2	100 cm

The CNS soils to be used should be non-swellings with a maximum allowable swelling pressure of 0.1 Kg/cm^2 (10 KN/m^2) when tested inaccordance with Indian Standard, IS: 2720 (Part 41)-1977 CNS soils are broadly conform to the following range:

Clay	15-20%
Silt	30-40%
Sand	30-40%
Gravel	0-10%
Liquid Limit	More than 30% but less than 50%
Plasticity Index	More than 15% but less than 30%

Soil Properties and their Influence on Design of Dams

Many dams fail due to improper assessment of effect of soil properties of borrow area and foundation soils on the stability of dams and appurtenant works. In this paper, an effort has been made to high light the different soil properties such as dispersivity and swelling pressure and their effect on dam design. This will help in safe design of dams and will reduce the number of dam failures. FIVE Annexes have been enclosed explaining soil classification including description, average properties for different type of soils, suitability of soils for construction of dams, degree of expansion of fine-grained soils and general guidelines for embankment sections.
Generally the following soil tests are conducted before designing an earthen embankment. These tests should be conducted on soils in the borrow area, foundation and existing embankment (if any).

1. Particle size distribution
2. Atterberg limits
3. In situ moisture content and density test
4. Proctor maximum dry density and optimum moisture content
5. Total soluble solids with EC, pH, carbonates, bicarbonates, and sulphates
6. Specific gravity
7. Permeability of disturbed samples and field permeability
8. Triaxial shear test for cohesion and angle of internal friction
9. Dispersivity by
   (a)Pin hole test
   (b) Crumb test
10. Free swell index
11. Swelling pressure

12. Compressibility
13. Ionic concentration of river water
14. Organic matter

Particle size Distribution:
Particle size distribution by sieve analysis (for particle size greater than 0.075 mm) and by hydrometer analysis (for particle size smaller than 0.075 mm) is carried out in order to determine percentage of components (Table 1) present in the soil.
Table 1. Grain size classification of soils:

S. No.	Soil Type	Particle size
1	Clay	Less than 0.002 mm
2	Silt	0.002 to 0.075 mm
3	Fine sand	0.075 to 0.425 mm
4	Medium sand	0.425 to 2.000 mm
5	Coarse sand	2.000 to 4.750 mm
6	Fine gravel	4.750 to 20.00 mm
7	Coarse gravel	20.00 to 80.00 mm

Grain shape varies with particle size and mineralogy. Soil grains are classified in three categories.

Bulky Grains: If the dimensions of the soil particles are about the same, as in sand and gravel, the soil grains are described as being of a bulky shape. Coarse-grained soils are bulky (except for mica).

Flaky or scale like grains: These resemble a piece of paper and are extremely thin compared to their length and breadth.

Needle like grain shape:

- Fine grained soils: These are soils more than 50% of which pass through 75 micron IS Sieve.
- Coarse grained soils: These are soils 50% or less of which pass through 75 micron IS Sieve.

Clay (Particle size less than 0.002 mm)
Clays are plastic fines. They have low resistance to deformation when wet, but when dry they are hard, cohesive masses. Clays are virtually impervious, difficult to compact when wet and impossible to drain by ordinary means. Large expansion and contraction with changes in water content are characteristics of clays. The small size, flat shape and type of mineral composition

of clay particles combine to produce a material that is both compressible and plastic. The clays having higher liquid limit are more compressible. At the same liquid limit, the higher the plasticity index, the more cohesive is the clay.
Small amount of organic matter in colloidal form in clay will result in appreciable increase in liquid limit without increasing plasticity index. Clays with high organic matter create voids through decay.

Silts (Particle size 0.002 to 0.075)

Silts are the non-plastic fines. They are inherently unstable in the presence of water and have a tendency to become quick when saturated. Quick silts are often called bull's liver by construction people. Silts are fairly impervious, difficult to compact and are highly susceptible to frost heaving. Silt masses undergo change of volume when distorted or strained in shear (the property of dilatancy). The dilatancy property together with the "quick" reaction to vibration affords a means of identifying typical silt in the loose, wet state. When dry, silt can be pulverised easily under finger pressure (i.e. very slight dry strength)
Silts differ among themselves in size and shape of grains, which are reflected mainly in the ability to compress. Higher the liquid limit of a silt, more compressible it is. The liquid limit of a typical bulky- grained, inorganic silt is about 30 percent, while highly micaceous or diatomaceous silts (so called elastic silts) consisting mainly of flaky grains may have liquid limit as high as 100 percent.
Soils containing large quantities of silt and clay are the most troublesome to the engineer. These materials exhibit marked changes in physical properties with change of water content. Dry clay is hard and suitable as a foundation for heavy loads, but may turn into a soft, highly compressive material when wet. Many of the fine soils shrink and crack on drying and expand on wetting, which may adversely affect structures founded upon them or constructed of them.

Coarse Grained Soils (Gravel & Sand)

Gravel and sand have essentially the same engineering properties, differing mainly in degree. Well-graded compacted gravel or sands are stable materials. The coarse grained soils, when devoid of fines are pervious, easy to compact, little affected by moisture and not subjected to frost action. Gravels are generally more pervious, more stable and less affected by water or frost than are sands, for the same amount of fines.
As sand becomes finer and more uniform, it approaches the characteristics of silt with a corresponding decrease in permeability and reduction in stability in the presence of water.
The soil classification based on particle size distribution and Atterberg limits have been given in Annex 1.

Atterberg Limits:

The behaviour of all soils with fines and particularly clays varies considerably with water content. Clay may be almost like a liquid or it may be very stiff depending upon its water content.
If a fine-grained soil is mixed with a large quantity of water, it is in a liquid state.
If the water content is gradually reduced, then the following apply:

Liquid limit: The limit of water content, at which soil water suspension passes from zero strength to an infinitesimal strength, is the true liquid limit.

Plastic limit: The moisture content at which the soil has a small plasticity, as determined by a standard test, is called the plastic limit.

Shrinkage limit: The moisture content, at which its further reduction will not cause a further reduction in the volume of soil, is called shrinkage limit. At shrinkage limit, voids in soil are completely filled with water.
In between plastic and shrinkage limits, the soil displays the property of semi solid. Between the plastic and liquid limits, the soil exhibits plastic behaviour.
Table 2. Moisture content variation and Atterberg limits:

STATE	LIMIT	SATURATION	VOLUME	COLOUR
Liquid state	Liquid limit Plastic limit Shrinkage limit	100%	Decreases	Dark
Plastic state				
Semi solid state				
Solid state		Decreases	Constant	Light

The liquid limit is indicative of the compressibility of the soil. Soils having a liquid limit above 45 are compressible in nature. Small amount of organic matter in colloidal form in clay will result in an appreciable increase in liquid limit without increasing the plasticity index. Liquid limit of bulky grained inorganic silt is about 30%, which may be increase to 100% for elastic silts consisting mainly of flaky grains.
If the shrinkage limit is less than 15, it is likely to develop cracks in the embankment. If it is less than 10, the soil should not be used in embankments, as the section is likely to develop extensive cracks. Soils having shrinkage limit more than 25 are also not suitable for dam construction.
The shrinkage limit should be higher than the optimum moisture content (OMC), otherwise dam section will develop cracks on moisture reduction (drying).
If the shrinkage limit of the soil is lower than the OMC, then the soil should be used for the inner core only. Outer shell shouldconsist of soils having a shrinkage limit higher than OMC.

Plasticity index: It is the difference between the liquid and plastic limits. For non-plastic soils, the plasticity index is zero. For clayey soils, the plasticity index is higher. It indicates the moisture contents over which the soil is in plastic condition. The plasticity index depends upon the clay present in the soil. The information regarding the type of clay in the soil may be obtained by considering the plasticity index in relation to the liquid limit.

Shrinkage index: The numerical difference in between plastic limit and shrinkage limit, is called shrinkage index.
In Annex 2 the suitability of soils for construction of dams based on soil classification is available for general guidance.

In Situ Moisture Content and Density:
These values indicate whether the natural/embankment soil is dense or not, and if the natural moisture content is near the OMC or not.
Extract from 'Earth Maual' by U.S.B.R.: Various criteria for quality control have been proposed. Table 3 lists suggested limits of density and moisture control based on experience gained in compacting 44

cohesive soils and 18 cohesionless soils in Bureau of Reclamation earthfill dams. In the absence of instructions to the contrary, the criteria given in this table should be used. It is recognised that the normal frequency distribution curve for any desired average value permits a small percentage of very low tests. However, because of the relatively small samples recommended to be tested, the values listed in the table as " minimum acceptable" are suggested as a basis for requiring recompaction of the area represented by lower test values.
The effect of gravel content in cohesive soils must be taken into account in control. Available data indicate that lesser percentages of density on the 4.76mm fraction basis are required for gravelly cohesive soils than for soils containing little or no gravel. This fact is reflected in Table 3.

Table 3. Criteria for control of compacted dam embankments

Type of material	% of 4.75mm & above by dry weight of total material retained	Percentages based on 4.75 mm fraction					
		15 m or less in height			Greater than 15 m height		
		Minimum acceptable density	Desirable average density	Moisture limits Wo-Wt	Minimum acceptable density	Desirable average density	Moisture limits Wo-Wt
Cohesive soils controlled by the Proctor test	0-25	95% of MDD	98% of MDD	-2% to +2%	98% of MDD	100% of MDD	2% to 0% (note 2)
	26-50	92.5% of MDD	95% of MDD		95% of MDD	98% of MDD	
	more than 50 (note 1)	90% of MDD	93% of MDD		93% of MDD	95% of MDD	
Cohesionless soils controlled by the relative density test	Fine sands with 0-25	Dd=75	Dd=90	Soils should be very wet	Dd=75	Dd=90	Soils should be very wet
	Medium sands with 0-25	Dd=70	Dd=85		Dd=70	Dd=85	
	Coarse sands and gravels with 0-100	Dd=65	Dd=80		Dd=65	Dd=80	

1. Wo -Wt is the difference between optimum water content and fill water content in percent of dry weight of soil MDD is the Proctor's maximum dry density.

Dd is relative density
(note 1) Cohesive soils containing more than 50 percent gravel sizes should be tested for permeability of the total material if used as a water barrier
(note 2) For high earth dams special instructions on placement moisture limits will ordinarily be prepared

2. Proctor Maximum Dry Density and Optimum Moisture Content
Soil compaction refers to the process of obtaining increased density of soil in a fill by reduction of its pore space by the expulsion of air. The bearing capacity of any soil usually increases with increasing dry density and decreasing moisture content. High density assures high shear strength and greater imperviousness. When a soil is submerged, its effective density is reduced and with this it's bearing capacity. The moisture content of a soil is defined as the ratio of the weight of water present in the soil to the dry weight of solid soil particles. The moisture content at which the weight of soil grains obtained in a unit volume of the compacted soil mass is maximum is called the "optimum moisture content" and the dry density so obtained is called "Maximum Dry Density" (MDD). As coarse-grained soils do not absorb the water and are not appreciably amenable to lubrication, they do not display distinct Optimum moisture content. For coarse and fine-grained soils, average values are 8 to 15 and 17 to 36 respectively as given in Annex 3. At OMC, the soil is broadly 90% saturated depending upon type of soil, meaning that about 10% of the void space is occupied by air.
Warning: The OMC should always be less than the shrinkage limit. Otherwise on exposure to sun, cracks will develop in such soil. If such soil has to be used in embankments, then it should be covered with good suitable soil, so that moisture reduction in such soils is avoided.
3. Total Soluble Salts, E.C., pH, Carbonates, Bicarbonates and Sulphates
Total Soluble Salts: These consist of sodium, calcium, magnesium, and potassium. The suitability of soil depends upon the percentage of sodium in comparison to other cations. In dispersive soils, the increased salt concentration (without an increase in sodium salt) reduces the dispersivity of the soil. A very high percentage of total soluble salts may cause failure of an embankment by formation of cavities caused by removal of salts with seeping water.
Electrical Conductivity: This measures the ability of the solution to conduct electricity and is expressed in millimhos/cm or micromhos/cm. E.C. value in millimhos/cm at 250 c can be converted to salt concentration in parts per million or milligram per litre with reasonable accuracy by multiplying by 640.
Table 4. Electical Conductivity showing severety of salt content

E.C. in miili-mhos/cm	Severity
Less than 1	Normal
Between 1 and 2	Fairly good
Between 2 and 3	High
Between 3 and 4	Very High

4.

1 miili-mhos/cm=1000 micro-mhos/cm

pH value: The pH value represents the concentration of hydrogen ions (H) in water. It is the logarithm of the reciprocal of the hydrogen ion concentration. A value of pH less than 7 indicates acidic character while pH value more than 7 is indicative of alkaline character, while 7 is neutral. Alkaline soils (pH > 7) are more prone to dispersivity.
Carbonates: of calcium and magnesium are not soluble in water. Only carbonates of alkali metals like sodium and potassium are soluble in water.
Bicarbonates: Bicarbonates are generally soluble in water. High concentration of bicarbonates may result in precipitation of calcium and magnesium bicarbonates from soil, increasing the relative proportions of sodium ions, which is harmful for stability of embankments.
Sulphates: The sulphates (principally soluble sulphates) present in soil or ground water in contact with concrete/masonry works attack the cement paste causing deterioration and disintegration. The free lime of cement acts with sulphates finally forming calcium sulphate aluminate. This compound crystallises on drying causing expansion and ultimate disintegration of concrete. As such, soils having sulphates in appreciable quantity should not be used adjoining concrete/masonry structures. If it is essential to use soils containing sulphates then suitable admixtures should be added to concrete/mortar to save them from the ill effects of sulphates.
Salt concentration is expressed in parts per million (PPM) or milligram per litre (mg/l) both units being equal.

5. Specific Gravity:
This is the ratio of weight in air of a given volume of soil solids to the weight of an equal volume of distilled water, at a given temperature.
The specific gravity of engineering soils usually varies between 2.6 to 2.8. If it is less than 2.6, it may indicate possible presence of organic matter.

6. Permeability:
The rate of movement of gravitational water through soil pores is termed the permeability of soil.
Permeability of disturbed/undisturbed soil samples should be measured in the laboratory. Permeability of foundation and embankment soils should also be measured in situ. The soils are categorised as permeable, semi permeable or impermeable as per the following limits.
Impermeable : with permeability less than 1 x 10-6 cm/sec
Semi permeable: with permeability 1x 10-6 to 1x 10-4 cm/sec.
Permeable : With permeability more than 1x 10-4 cm/sec.
The dam embankments should be impermeable. The permeability of the down stream section of embankment should not be less than that upstream.

7. Triaxial Shear Test
This is a test in which a cylindrical specimen of soil encased in an impervious membrane is subjected to a confining pressure and then loaded axially to failure.

   a. *Unconsolidated Undrained Test (Q test)*
   This is a soil test in which the water content of the soil sample remains unchanged during the application of the confining pressure and the additional axial (or shearing) force. No drainage and hence no dissipation of pore pressure

is permitted during the application of the confining pressure and then the axial load.

This test is usually performed on partly sa mostly for analysis of the stability of the earth dam under the "end of construction" condition.

b. *Consolidated Undrained Test (R test)*

Drainage is permitted after application of confining pressure so that the sample is fully consolidated under this stress. No drainage is permitted under the application of the axial load. This test is carried out with pore water pressure measurement, for obtaining effective stress values of cohesion and angle of internal friction.

The values of C and f obtained from this test, are used to check stability of the upstream slope *under the sudden draw down condition,* after the soils are fully saturated.

c. *Consolidated drained Test (S test)*

Drainage is permitted after application of the confining pressure and during the axial loading. The values of shear parameters so obtained are almost the same as the effective stress values obtained from undrained tests with pore pressure measurement.

The values of C and f obtained from this test are used to check stability of the downstream slope when the reservoir is in operation. *Generally, the 25th percentile strength values are used in the stability analysis of slopes (i.e. 75% of the samples exhibit strength values).*

2. Dispersivity:

Dispersive soils are clay soils, which are highly susceptible to concentrated leak by a process of colloidal erosion. These clays have a predominance of dissolved sodium cations in the pore water, whereas ordinary erosion resistant clay has calcium and magnesium as the dominating dissolved cations. These are eroded by a process in which the, individual colloidal clay particles go into suspension in practically stilled water. All colloidal particles carry a like electric charge, which prevents the particles from attracting each other.

Dispersivity of clayey soils is determined by two tests namely:

a. Sherard's pin hole test
b. Crumb test

These two tests should be carried out on a given sample and if the soil is found dispersive by any of the two tests, it should be categorised as dispersive.

Higher values of pH and sodium concentration and lower values of total dissolved salts promote soil dispersivity.

Soils containing the *clay mineral montmorillonite,* are prone to dispersion. Generally, dispersive clays have been red, brown, grey (some nearly white), yellow and all transitions among them. No black colour soils with obviously high organic contents have tested dispersive. All tested fine grained soils, known to be derived from in situ weathering of igneous and metamorphic rocks, have been found non dispersive as well as soils derived from lime- stone.

Salt, hydrated lime, gypsum, alum and fly ash may be used to treat dispersive soils after observing their effect on the soil in laboratory.

Dispersive soil can be used as fill material by keeping placement moisture content on the wet side (about 1%) of optimum moisture content. Such soil should be compacted in thinner layers using pneumatic

tampers to obtain a high degree of density, and permeability less than 1x10-6 cm/sec and good bond with the structure/ foundation rock. As far as possible non- dispersive soils should be used near structures and at rock interface.
With dispersive soils the frequency of density and moisture control tests should be increased. One should closely observe the compacted soil surface for cracks and take measures for prevention/correction of moisture by appropriate methods.
Effectively seal surface cracks in the foundation rock by slush grouting.

10. Free Swelling Index:
    This indicates swelling potential of fine-grained soils when water is added to them. If the free swell index of a soil is more than 100, then such behaviour may require special attention. The degree of expansion of fine-grained soils based on their properties is available at Annex 4.
11. Swelling Pressure:
    The characteristics of swelling and the swelling pressure of black cotton soils are attributed to the presence of montmorillonite or a combination of montmorillonite and illite clay minerals. Clay minerals are made of colloidal particles having diameters less than one micron. The presence of specific clay minerals is determined by an *x-ray diffraction test.*
    Degree of expansion: The fine-grained soils exhibit low to very high degree of expansion depending upon the presence of clay minerals. Based upon the Atterberg limits and free swell of a soil the degree of expansion and degree of severity is indicated in at Annex 4.
    As per IS 6186 : 1986, Bentonite, a characteristic type of fine- grained clay, is an alteration product of volcanic ash containing not less than 85 percent of the clay mineral montmorillonite.
    Black cotton soils have a predominance of the montmorillonite clay mineral. The grain size distribution and index properties of expansive soils expressed in percentages are in the following ranges.
    Gradation:

Clay	(less than 2 micron)	50 to 70%
Silt	(0.075 mm to 0.002 mm)	20 to 35%
Fine and medium sand	(2 mm to 0.075 mm)	30 to 50%
Coarse sand and Gravel	(greater than 2 mm)	Less than 10%

12. *Index Properties:*

Liquid Limit	60 to 100%
Plastic Limit	30 to 50%
Plasticity Index	30 to 40%

Shrinkage Limit	8 to 12%

13. If a high liquid limit (greater than 55 %) is accompanied by a low shrinkage limit (lower than 10) swelling pressure and free swell tests should be conducted. The swelling pressure is determined by conducting a one dimensional swelling pressure test using either fixed or floating rings on both undisturbed and remoulded soils in the partially saturated condition. Two methods are used to determine swelling pressure.
    - Consolidometer method in which the volume change of the soil is permitted and the corresponding pressure required to bring back the soil to its original volume is measured.
    - Constant volume method in which the volume change is prevented and the consequent pressure is measured. The details of the two methods are available in IS 2720 (Part XLI): 1977.

If the swelling pressure is more than 50 kPa, treatment is necessary. In canals, treatment is provided by a cover of cohesive non-swelling soils over swelling soils as per IS 9451: 1994

12. Compressibility:
    The decrease in volume per unit increase of pressure is defined as the compressibility of soils. It is measured only for undisturbed samples. Compressibility is a property of a soil pertaining to its susceptibility to decrease in volume when subjected to load. The phenomenon of compressibility is associated with a change in volume of the voids and, to a very limited extent with changes in the soil particles. Soils having only air voids will be compressed immediately upon application of load. In saturated soils, the pore pressure will increase significantly with an increase in the soil's compressibility. In general a very compressible cohesive soil will develop high pore pressure when loaded, unless there is an appreciable amount of air present. Compressibility of sand and silt varies with density. Compressibility of clay varies directly with water content and inversely with shear strength.
13. Ionic concentration in river water:
    Ionic concentration in river water below 1.2 meq/litre is considered low. River water passes through embankment. As such it may dissolve salts present in the embankment and foundation. Small quantities of calcium and magnesium salts in soil may increase dispersivity of soils and thus such reservoir water may aggravate a piping problem.
14. Organic matter:
    Even a small amount of organic matter in colloidal form in clay, will result, in an appreciable increase in liquid limit of the material, without increase in plasticity index. The tendency for soils high in organic content is to develop voids by decay while this makes them undesirable for engineering use. Soils containing even moderate amounts of organic matter are significantly more compressible and less stable than inorganic soils.
    In Annex 5, general guidance for embankment slope inclination based on soil classification and height of embankment has been provided for guidance.

CONCLUSIONS:

The inference of soil test result help in designing the earthen embankments/ dams with proper safety

measures and economy.
Following inferences need special attention.

1. S.L.(shrinkage limit) of soil should be higher than its optimum moisture content (OMC), otherwise cracks will develop upon moisture reduction below O.M.C.
2. Soils having S.L. less than 10 should not be used in dam embankment, as the dam section is likely to develop extensive cracks.
3. If S.L. is in between 10 to 15, than it is likely to develop cracks in the embankment.
4. Specific gravity of most inorganic soils is in between 2.60 to 2.80. Values less than 2.60 indicate possible presence of organic matter in appreciable quantity.
5. Permeability of the downstream portion of an embankment should be higher than the upstream portion; otherwise dam may fail on this account only.
6. The soils containing appreciable quantities of colloidal particles (less than 0.001 mm in diameter), sodium, the clay mineral Montmorillonite & illite, are prone to dispersion. Higher values of percent sodium in soil make it dispersive.
7. The dispersive soil may be used safely in dam embankment except near masonry/concrete works and near foundation rock, if the permeability of the embankment may be ensured to be 1x10-6 cm/sec or less.
8. Soils of high swelling potential are not suitable as embankment material.
9. The soils containing appreciable quantities of sulphates should not be used adjoining the concrete/masonry works. If it is essential to use, then a suitable admixture should be added to the concrete/mortar to make safe.

Method of Compaction: In small section channels, provision *for* "cut & fill method" should be made in order to achieve effective compaction. The channel section should be over excavated (to the extent governed by the CNS thickness), say, in 300 m. long reach; CNS soil be placed in layers in the full section, watered (as required) and each layer be compacted to 95% proctor density through deployment of, preferably, small drum width power roller or the standard power roller or fuel operated plate compactors (Ref. fig. No 29 & 30). This process of compaction should be continued right up to the top of designed section. Thereafter, the compacted section should be scooped out to the proposed designed section and the CNS so scoped be re-handled for use in the next 300 m. reach. Provision in the cost estimate should accordingly, be made for re-handling of scooped CNS and also some percentage of wastage during re-handling be provided.

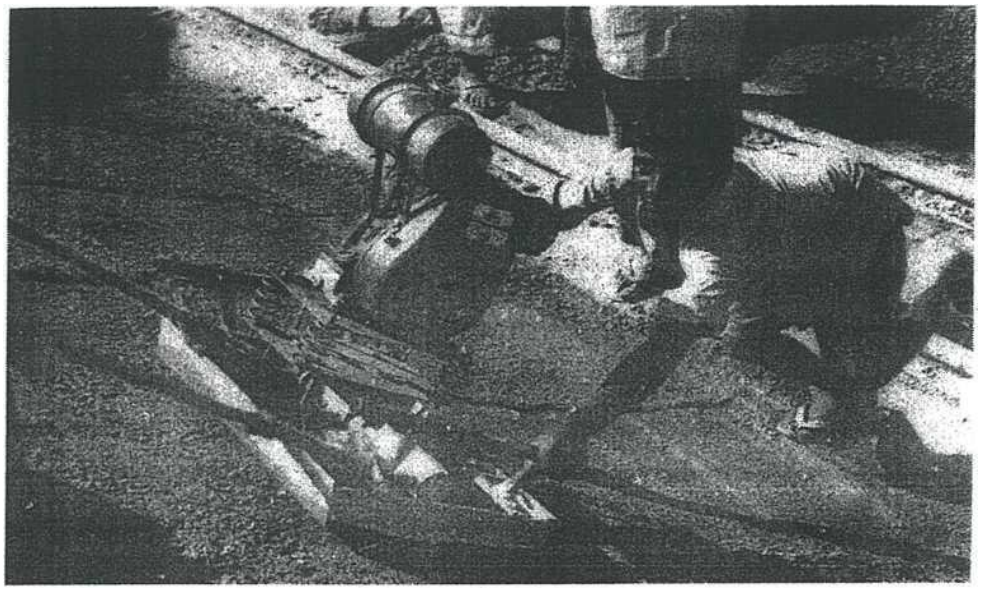


Figure 29 Plate Vibrator

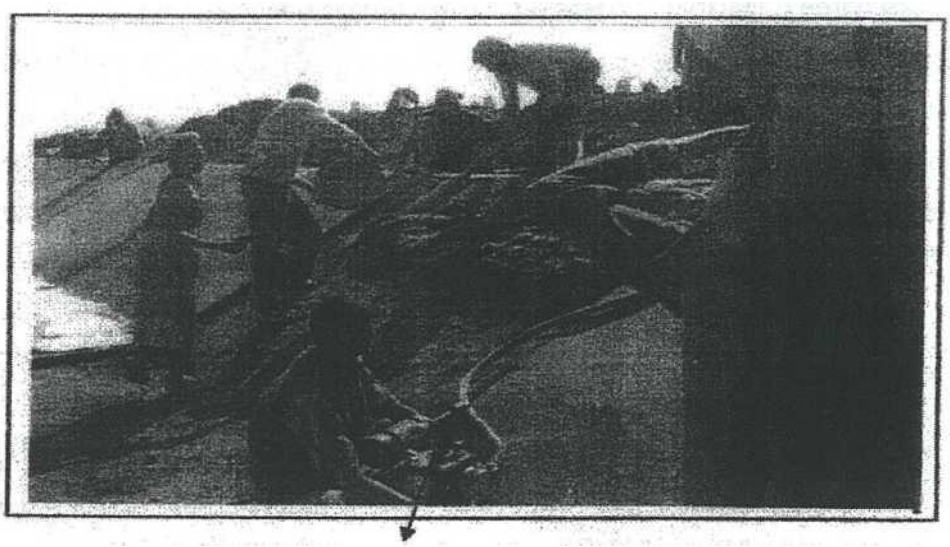


Figure 30 Engine (petrol kerosene driven)

FUEL-

OPERATED PLATE VIBRATOR FOR
CONSOLIDATION OF CC LINING ON CANAL SLOPE

Parameters of Cast-in-Situ Cement Concrete Lining:

(i) Thickness of cc lining: Thickness of un-reinforced viz plain cc lining may conform to either the Indian Standard, IS 3873-1993, or as per US Bureau of Reclamation Practice, tabulated below:

As per Indian Standard IS 3873-1993

Discharge Capacity in Cumecs (Cusecs)	Depth of water	Thickness of lining (mm)
0-5 (0-175)	0-1 m	50-60 mm
5-50(175-1750)	1-2.5 m	60-75 mm
50-200 (1750-7000)	2.5-4.5 m	75-100 mm

As per USBR Practice

Discharge Capacity in Cusecs	Thickness of lining (inches)
0-500 cusecs	2.5 inches
500-1500 cusecs	3.0 inches
1500-3500 cusecs	3.5 inches
3500-7500 cusecs	4.0 inches

The thickness of canal lining may be adopted as below:

Thickness	Channel discharging capacity
65 mm	0-5 cumecs (0-175 cusecs)
70 mm	5-14.16 cumecs (175-500 cusecs)
75 mm	14.16-50 cumecs (500-1750 cusecs)

Taking into consideration the various factors including economy and ease/practicability of placement, it may be appropriate to adopt a lining thickness of 65 mm. for channels of discharging capacity up to 175 cusecs, 70 mm for the channel discharge up to 500 cusecs and 75 mm for the channel discharge beyond 500 cusecs up to 1750 cusecs.

(ii)Cement: 43 grade or 53 grade Ordinary Portland Cement by used. In the coastal zone, Portland slag cement may be used.

(iii) Cement Content and Water - Cement Ratio: Tile concrete lining being exposed to alternate wetting and drying during its functioning and working life, comes in the category of "severe exposure condition" as per Indian Standard IS 456:2000. Accordingly, provision of cement content of minimum 250 Kg/m^3 of "durability consideration". Water cement ratio is to be restricted to not exceed the range 0.50-0.60.

(iv) Maximum Size of Coarse Aggregate: Graded coarse aggregate with the maximum nominal size (MSA) of 2.0 mm downgraded conforming to I.S:283 should be used in the concrete mix of lining.

(v) Air-Entraining Agent (AEA): Provision for using AEA in the concrete mix for cc lining should be made jn the cost estimate. Concrete mix with AEA affords more "durability" as well as "better workability (viz fluidity)" and better "finish" to the surface. Graded fine and coarse aggregates are to be used in the concrete mix and any slight deviation in the requisite grading is compensated by air-entrainment in the mix by the addition of AEA.

(vi) Contraction Joints: As an acceptable "practical thumb rule", the spacing of contraction joints should not exceed 36 times the thickness of lining in order to avoid cracking of the lining surface in between the joints.

Lining thickness (t)	Spacing of joints (36xt)
65 mm	2340 mm, say, 2.25 m
70 mm	2340 mm, say, 2.50 m
75 mm	2340 mm, say, 2.70 m

If the perimeter of canal section is 6m or less than 6m, no longitudinal contraction joint need to be provided. However, the transverse contraction joints across the canal section are to be provided irrespective of the extent of the perimeter.

(vii) Preparation of lining surface: The minor irrigation canals systems which have served for a few years after construction seldom exist in their proper section. They are eroded, silted up and disturbed by white ants etc.

The bed and inner slopes of the canal are excavated to a depth of nearly 15 cm. below the designed level. The excavated soil, if coarse grained and free from organic impurities, should be separately stacked for reuse. If the soil is fine grained it is not suitable for re-use and the unsuitable soils may be utilised on the outer slopes of the banks. The trimmed or excavated canal section is to be brought back to designed section by compacting the suitable soil available from the cutting and/or by borrowing approved soils. The approved soil in order of preference should be GW, GP, GC, GM, SC, SW, SP and SM. Wooden frames shall be made of dressed wood of thickness equal to the thickness of lining exactly to fit into the canal section. The soil to be compacted at OMC so that minimum of 95% of proctor M.D.D. is achieved. Whether cast-in-situ cement concrete lining or pre-cast concrete slab lining is to be placed, the sub-grade must be hard, well compacted and smooth prior to placement of lining. The vibrator plate device can be very effectively deployed for compaction of the subgrade. The surface irregularities (to be checked with a wooden template / straight edge) should not exceed the following limits.

a) 6.25 mm for subgrade in bed , and

b) 12.00 mm for subgrade in side slopes.

(vii) PREPARATION OF CONCRETE MIX: The material as required for good concrete with aggregate largest size not to exceed 20 mm. should be utilised. The mix should include enough well graded sand to ensure a reasonably good finish. The consistency (liquidity) of the mix for a 7.5 cm. thick canal lining should be such that the slump value is 60 to 75 mm. The slump should be 75 mm. to 90 mm. for a 6 cm. thick lining and 80 to 95 mm. for 5 cm. thick lining.

The concrete should be produced in a mechanical concrete mixer (10/7 eft or 14/10 eft or any other standard size) or in a stationary weigh batching and mixing plant. Mobile concrete mixers of various

drum capacities (± 0.50 m^3) are also available in the market for production of concrete.

Hand mixing of concrete should not be allowed except in rare exceptional circumstances and isolated cases with prior permission of Engineer-in-Charge when the quantity of concrete to be placed is very small.

(ix) Consolidation of Concrete Lining: Proper consolidation of concrete mix for the cc lining, as being placed on bed and sides is of paramount importance. Sketches of Steel Shutter Gantry are shown in Fig. No 31&32 respectively.

Use of conventional needle vibrators may puncture the sub grade surface. One of the most effective methods of consolidation comprises of deployment of "vibrator plate device:" operated by a fuel-operated motor.

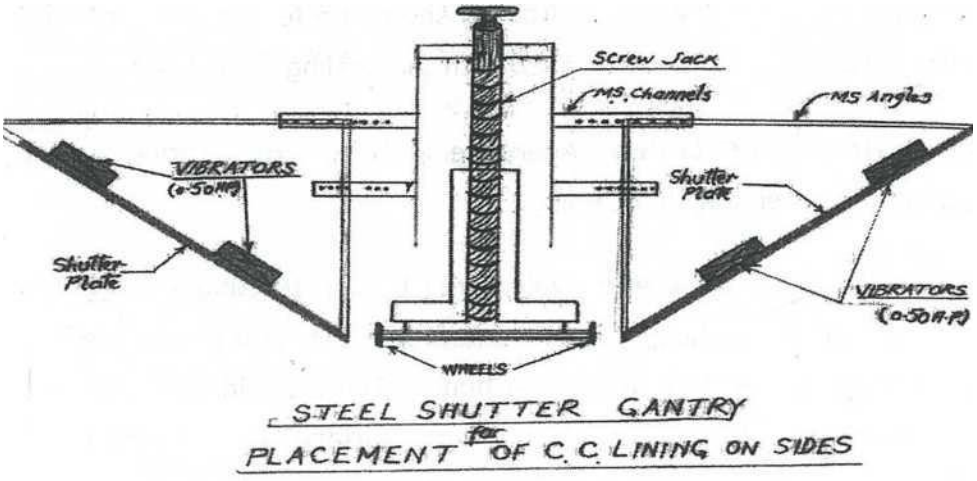


Figure 31: Steel Shutter Gantry

Cutting Grooves for Contraction Joints: Grooves should be cut when the concrete is still green plastic,

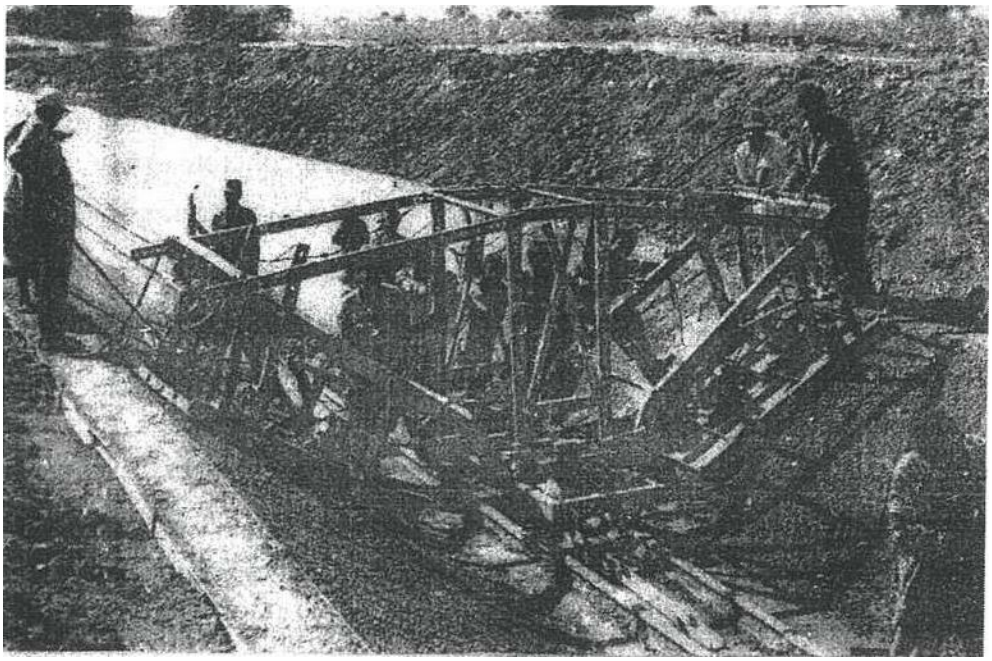


Figure 32: Steel Shutter Gantry

to be later filled with the sealing compound. The groove is normally 27 mm deep, for the cc lining

thickness of 65 mm - 75 mm range, 11 mm wide at bottom and 14 mm wide at the top. It should be filled with hot poured sealing compound conforming IS:5256-1992. After the cc lining is fully set (viz after a period of 28 days), the grooves should be fully cleaned of dirt, mortar, or grout and only then filled with the sealing compound.

(x) Curing of CC Lining: Adequate and fool-proof curing is the most vital requirement for cc lining.

The bed lining should be effectively cured by constructing small earth bunds of, say, 30 cm freight at convenient intervals and ponding water on the bed between the successive bunds. The side lining should be cured either by fully covering the concrete surface with hessian cloth rolls/gunny bags and keeping these wet with water throughout 28 days period or by application of white pigmented curing compound approved by Engineering-in-Charge.

(xi) Under Drainage: The necessity or otherwise of providing the under drainage in small channels shall be got examined by the Design Cell.

(xiii)Tolerance in CC Lining thickness: The permissible tolerance for the thickness of lining is ± 10% provided the average thickness is not less than the designed thickness.

Parameters of Pre-Cast Concrete Slabs for Lining: In case precast concrete slabs are to be used for the lining, the concrete mix for casting the slabs should be of M-I5 grade. The slabs, 30 cmx30 cm (or any other convenient size) should be of 50 mm thickness. The sub grade - is to be given a plaster layer (1:6) of 12 mm thickness duly cured with water for at least 24 hours and thereafter slabs be placed on this base layer with 6mm thick (1:2) mortar. The joints between the slabs are to be filled / pointed with 1:2 mortars and cured.

Placement of Cast-in-Situ Cement Concrete Lining:

I. Production of Concrete Mix: The concrete should be produced in a mechanical concrete mixer (10/7 eft or 14/10 eft or any other standard size) or in a stationary weigh batching and mixing plant. Mobile concrete mixers of various drum capacities (± 0.50 m^3) are also available in the market for production of concrete.

II. Hand mixing of concrete should not be allowed except in rare exceptional circumstances and isolated cases when the quantity of concrete to be placed is very small.

Placement of CC Lining: The canal sections in the proposed rehabilitation measures in the OCTMP being small, the following methodology for placement of CC lining may be adopted:

- Protective Lining U/S & D/S of Structures: Both the bed andside lining may be placed manually.
- Selective Lining in Vulnerable/ High Filling Reaches: Incase the reaches are small in length, say, upto about 100m or so, manual placement of CC lining may be done on both the bed and sides.
- Construction of Model Sections/ Profile Walls: Manual placement may be done.

Lining in long reaches in non-expansive/ expansive Soils:

Where, the cc lining is to be placed in long / fairly long reaches, the bed lining be placed manually. However, the placement of CC lining on side slopes can be mechanized through deployment of "Steel Shutter Gantry". Such gantry has steel shutters fitted with vibrators for vibration and consolidation of concrete. It comprises of a simple frame of steel channels and angles.

Normally, where the bed width is less than 2.5m, and the slant length (viz the length of side slope proposed to be lined) is upto about 2.75m mechanized placement of cc lining by the steel shutter gantries

may be adopted. This methodology offers better progress as well as good construction quality. The placement of CC lining is almost continuous. It obviates the placement of concrete in alternate panels, and, thus, eliminates the provision of concrete sleepers.

In case the slant length is upto about 3.5m a "Baby Paver" can be efficiently deployed for placement of side lining. The reach proposed to be lined should be substantially long (say ± 3 km) to deploy the Baby Paver.

The Steel Shutter Gantry provides a very convenient and speedy methodology of mechanized placement of cc lining. It is not a costly device. One such gantry may be deployed for placement of lining in, say, 1000m reach. In longer reaches, more number of gantries can be deployed.

7.11 PRE-CAST CONCRETE LINING

The laying of pre-cast concrete slab lining should confirm to IS 3873: 1993. The pre-cast concrete slabs used for lining, should be made of Ml5 grade of concrete mix. The slabs, 30 cm x 30cm (or length 0.45 to 0.90 cm , width 0.45 cm) should be 50 mm thick. The pre-cast slabs should confirm to IS 10641:1991. The sub grade is to be given a plaster layer (1:60 of 12mm thickness, duly cured with water for at least 24 hours and thereafter slabs be placed on this base layer with 6 mm thick (1:2) mortar. The joints between the slabs are to be filled / pointed with 1:2 mortars and cured.

8 SPECIFICATION FOR GATE WORKS

8.1 GENERAL

Minor Irrigation Projects are catering to the need of Irrigation of the farmers in Orissa. Very often, it is found that the optimum irrigation facilities are not achieved due to wastage of water by leakage through the gate regulating system. Field staff find difficulty to stop the wastage due to lack of technique and maintenance as well as minor repair. Under such situation, it is highly essential to provide required water supply from the reservoir / main canal to the canal systems basing on the actual requirement of the farmer / field. In order to ensure the above requirement provision of HR & CR gates are essential for the efficient service and operation of the gate. Head regulators in Minor Irrigation Project are a Water Resources development structure consisting of Rectangular / Circular R.C.C / P.C.C conduit suitably embedded in the embankment. Head Regulator shaft (Rectangular / Circular section) accommodates service and emergency gates to control discharge in to the conduit from the reservoir for Irrigation purpose as and when required by actuation of vertical lift gates. The renovation work of MIPs undertaken through the World Bank assistance includes manufacture, installation and repair of gates.

8.2 CLASSIFICATION OF GATE

Generally the gates used in irrigation projects are of three types. They are

- High Head Gate
- Medium Head Gate
- Low Head Gate

8.2.1 High Head Gate:The gates operating under 30 m and above water head are called High Head Gate.

8.2.2 Medium Head Gate:Gate which operates under a head of 15M and above, but less than 30M.

8.2.3 Low Head Gate:Gates operating under less than 15 mof water head are called Low Head Gate.

8.3 REQUIREMENT OF MIP GATES

The gates used for releasing water in Minor Irrigation Projects are generally low head slide gates. Since the gates installed in M.I.P are located in remote places, the designer intends to make the gate operational by simple manual type hoisting mechanism without any need of electricity at the site.

The design considerations of slide type gates are covered under I.S: 5620. In no case the hoisting capacity can be allowed to exceed 12 MT for manual operation.

The Principal requirement of slide gates shall be as follows:

I. These shall be reasonably water tight.

II. These shall be capable of being raised & lowered by manual hoisting mechanism.

III. These shall be rigid and reasonably free from vibration

8.3.1 TECHNICAL PROVISION:

GENERAL DESCRIPTION OF SLIDE GATES

Slide type Head Regulator Gate / Emergency gate suitable for vent size of Rectangular / Circular conduit with manually operated screw Gear Hoist & its supporting structure as mentioned below.

8.3.2 SKIN PLATES

(1) The skin plate and stiffeners shall be designed together in a composite manner for the following conditions.

a) In bending across the stiffeners or horizontal girders or as panels and

b) In bending co-acting with stiffeners and/or horizontal girders

(2) The stresses in the skin plate for conditions in (1) (a) and (b) above as panel shall be determined in accordance of Appendix-C of I.S-5620 -1985.

(3) The gates shall be designed on the basis of stresses specified under wet and inaccessible condition given in Appendix-B of IS.5620- 1985.

The permissible values of stresses in welded construction shall be the same as that for the parent material. To take care of corrosion, the actual thickness of the gate shall be at least 1.5 mm more than the theoretical thickness computed. The minimum thickness of skin plate shall not be less than 8 mm inclusive of corrosion allowance.

8.3.3 HORIZONTAL AND VERTICAL STIFFENERS AND MAIN GIRDERS

The horizontal and vertical stiffeners shall-be designed as simply supported or continuous beams depending upon the framing adopted for the gate. The spacing between main horizontal girders shall be preferably such that all the girders carry equal loads.

The end vertical girders shall be designed as continuous beams resting on Thrust Pad centre point with concentrated loads, coming from horizontal girders, at points where they meet the end vertical girders. The values of stresses so computed shall not be greater than those specified in IS: 5620-1985.

The connections of the gate to the hoisting mechanism at points other than end vertical girders shall be so made that the stress concentration particularly on the wed of the top horizontal girder is avoided and the hoisting forces shall be dispersed through suitable stiffeners to one or more horizontal girders below the top horizontal girder The extra stresses, if any, arising due to this arrangement shall be combined, with the other stresses to ensure that the permissible limits are not exceeded.

8.3.4 DEFLECTION OF GATES

Maximum deflection of the gate under normal conditions of loading shall be limited to 1/800 of the span (centre to centre of Thrust pad) IS 5620-1985 P-15.

8.3.5 THRUST PAD

The Thrust Pads shall be suitable to withstand the stresses developed due to hydrostatic loads which they will carry. The Pads shall be machined true and shall operate smoothly without undergoing any vibration or drift. The Thrust Pads shall be fixed to the gate leaf by means of counter sunk screws/bolts made up stainless steel. The holes in the bearing plates shall be suitable counter bored and when assembled, the heads of the screws/bolts shall remain 2mm below the surface of the bearing plate.

8.3.6 GUIDE AND GUIDE SHOE

For limiting lateral motion of gates, guide shoe shall be provided. The guide shoe shall be fixed to the end vertical girder of the gate and shall travel on guide rails securely embedded in the concrete of gate slot. The guide shoe shall be machined true to the desired shape and shall operate smoothly without vibrations or jerks. The guide roller/shoes shall be designed to the maximum loads to which they may be subjected during operation. A minimum of five percent of the total dead weight of the gate is recommended for the design of each guide roller.

8.3.7 SEALS AND ACCESSORIES

The side seals shall be of hollow music note type rubber seals and the bottom seals shall be rectangular type rubber seals The seals shall conform to IS: 11855-1986 "General requirements of Rubber Seals for Hydraulic gates" The seal pre-compression shall be preferably 4 mm for the single stem seals.

The tests required for measuring the properties of rubber seals shall confirm to IS-11855-1986.

The faces of side seals shall be in a common plane within l/4mm without offsets or gaps or Joints.

The bottom seals shall be of rectangular type rubber seal conforming to IS: 11855-1986.

8.3.8 SEAL SEATS, BASES. SEAL BASES

The seal seat plates shall be of high grade stainless steel. The seat plates shall be welded to the seal-seat-base plates and shall be finished smooth within a range of 1 6 to 6 3 microns The edges of seal seats shall be suitably rounded/chamfered to prevent damage to rubber seals during gate operation. The minimum thickness of seal seat plates for side seal shall be 8mm. The minimum thickness of seal seat plate for the bottom seal shall be 6 mm. The minimum width of all seal seats shall be 80mm.

8.3.9 BALLAST

Suitable Ballast in the form of dead weight shall be added if necessary for making the Gates self closing and achieving a minimum seating Pressure @2.5 KN/M length of gate. The ballast shall be in the form of Cast Iron/Pig Iron billets and shall 'be secured firmly in between the webs of the Horizontal Girders Precaution shall be taken to ensure that the ballast is not dislodged from its position during the gate operation. The effect of dead weight of the ballast on the Horizontal Girder shall be analyzed.

8.3.10 EMBEDDED PARTS

A) The Guide/Guide Channel shall be rigid and adequately anchored in concrete.

The section of the frame is so chosen that bearing pressure on concrete shall not exceed the permissible values as specified in IS: 456. The frames shall be embedded in concrete as a second stage and suitable anchors shall be provided to align the frames within the required tolerances. The thickness of the plates used for the frame shall not be less than 8mm.

B) GUIDES

Guides shall be fixed inside the gate groove. This shall be flat plate or a rail section anchored into concrete for gates.

The guide shall be suitable for the type of guide rollers or shoes provided for the gate. Suitable guide shall also be provided on the embedded parts to limit its lateral and longitudinal movements within a tolerance of 3 mm in every 3 m height with overall tolerance of 5 mm.

(C) SILL BEAM

The sill beam shall comprise of a standard rolled-I section, I fabricated girder section of structural steel conforming to relevant Indian standards specification. To the two flanges of these I-sections the bottom seal seat plate of material stainless steel shall be fixed. The machining finish of the top surface of the seal seat plate shall be within a range of 1.6 to 6.3 microns and it shall be placed flush with surrounding steel lining or concrete surface as the case may be.

8.3.11 TOLERANCE

The tolerance for the embedded parts and components of the gates shall be in accordance with Appendix-E, I.S. 5620-1985.

8.4 MANUALLY OPERATED SCREW GEAR HOIST

Manually operated Screw Hoists of capacity as designed shall be provided. The Hoist and its accessories are to be located on a Hoist platform. The Screw Hoist shall be conforming to I.S: 11228-1985 "Recommendations for Screw Hoist for Hydraulic Gates". The manually operated screw hoist shall have maximum hoist capacity of 12MT.

8.4.1 GENERAL REQUIREMENT

(1) The various components of the hoist mechanism shall be so proportioned as to take the worst load coming on individual component

(2) The stress in various components of screw hoist shall be checked for maximum power transmission in these components taking into account the permissible stresses given in IS: 11228-1985.

(3) All the hoisting machinery parts shall be checked for static as well as dynamic loads.

8.4.2 STEM

(1) There shall be one no of stem connected to the gate at the centre of span.

(2) The stem shall normally be made of mild steel or forged steel.

(3) The stem shall be provided with standard metric thread conforming to IS:4218-1976 at one end for connection with the gate. It shall normally be connected to the horizontal girders and shall be required to be tightened against a minimum of two girders. The bottom shall be provided with an additional lock nut. In case the gate does not require positive thrust for closing, pin jointing the stem to the gate may be considered.

(4) Standard square threads conforming to IS: 4694-1986 or acme threads shall be cut on the stem at the other end for transmission of power. The minimum length for which the threads may be provided shall be the sum of the following.

a) Total/lift of the gate,

b) Length of the nut in contact with the stem, and

c) Extra allowance of 300 mm (Min).

If required more than one start screw threads shall be provided in order to achieve quick linear movement.

(5) The screw stem rods shall be designed for direct tensional compressive load by taking the root diameter at the minimum cross section. The diameter so arrived at shall be checked for torsion shear stress, buckling and for combined maximum shear and maximum tensile compressive stress. Suitable

supports may be provided at intermediate points, if required. (Ref-IS-11228-1985, Section-5.2, Page-9).

5.3.1 NUTS

(1) The nut, through which the power is to be transmitted to the stem, shall generally be of a material having lesser wear resistance than the material of the stem. (Ref-IS-11228-1985, Section-5.3.1, Page-10).

(2) Square or acme threads matching with those provided on the screw stem shall be provided on the inner surface of the nut. The total number of threads to be cut on the nuts shall be calculated on the basis of the total bearing area to be provided. The bearing pressure on the threads of phosphor bronze nut shall not exceed 0.04 ultimate tensile strength (UTS). The total length of the nut shall also be governed accordingly.

(3) The number of threads provided on the basis of the bearing stress shall be checked for shear stress at the threads cross section. The minimum outside diameter of the nut shall be at least twice the minimum inside diameter. The height of the nut shall not be less than the major diameter of the stem.

8.4.3 EFFICIENCY OF TRANSMISSION (STEM)

The efficiency of the power transmission between the nut and stem shall be as per Clause 5.3.4, Page-10 of IS: 11228-1985.

8.4.4 MANUAL OPERATION

The manual operation arrangement shall be so designed that the continuous effort per man does not exceed a crank force of 100 N at 400 mm crank radium at a continuous rating of 24 revolutions per minute.

8.4.5 MATERIAL SPECIFICATION FOR HOIST

The material to be used in various components of the hoist shall conform to the relevant IS: specifications shown in Table No.-l, Page- 7 of IS 11228-1985.

8.4.6 LUBRICATION

The points of lubrication of the bearings and the journal shall be readily accessible & where necessary piped to convenient points using copper or brass pipe. Greases grooves shall be provided in the bearing surface for satisfactory distribution of the lubricant. A levered type hand compressor for forcing the lubricant to the bearings shall be provided duly equipped with couplings suitable for the industrial button type fittings.

8.5 MATERIALS

8.5.1 GENERAL

All materials used in manufacture of the equipments (gates, gate frames, Hoists & Hoist platform) shall conform to the materials stipulations in accordance with relevant Indian Standard Specifications of latest revised editions. Where any materials has not been specified, it shall be the best available for the purpose for which used considering strength, ductility and best engineering practice and shall conform to the latest applicable standard of Indian Standards institution or other equivalent Standards as approved by the Engineer-in-Charge.

8.5.2 METAL WORK FABRICATION AND MACHINE WORK GENERAL WORKMANSHIP

All work shall be performed and completed in a thorough workman like manner as per practice in the manufacture and fabrication of materials. The work, shall in all cases, be of the highest quality and carefully performed. Workmanship shall conform to the latest standards, laid down in Indian Standard Specifications.

All members shall be free of twists, bends or other deformation and all surfaces' that will be in contact shall be thoroughly cleaned before assembling. Parts shall be adjusted to line and fit and shall be firmly bolted or otherwise held securely together so that surfaces are in close contact before drilling, reaming or welding in commenced.

Minor surface imperfections can be repaired wherever possible with the prior approval of the EIC.

If weight limitations and transport clearances do not permit anchorages and miscellaneous embedded parts, they shall be fabricated into sub assemblies.

All parts of the gates, hoist shall be fabricated in accordance with the specifications. Special care in fabrication of the parts affecting strength, rigidity and water tightness of the gates shall be taken. The seal bases shall be finished after the plates have been welded to the skin plate and the finished surfaces of the seal bases shall be in the same plane within the tolerances prescribed in IS 5620-1985.

8.5.3 FITS AND TOLERANCES

Fits used for different components shall be according to the best modem shop practice. Due considerations shall be given to the special nature of function of the parts and to the corresponding accuracy required to secure proper operation. The fits shall be in accordance with Indian Standard. "Guide for the Selection of Fits (First Revision)" IS 2709-1982. The tolerances for embedded parts and components of gates shall be in accordance with relevant I S specifications.

8.5.4 SCREW THREADS

The threads for bolts and nuts shall have metric threads of International Standards Organisation and conforming to Indian Standard "ISO Metric Screw Threads Diameter Pitch Combination (First Revision) (With Amendment No.l)" 1S:4218 Part-II- 1976.

8.5.5 MACHINE FINISH

The type of finish, unless otherwise specified shall be that most suitable for the part of which it applies and shall be smooth, average or rough as defined under India Standard "Assessment of Surface Roughness (with Amendments NO.l to 3) (Reaffirmed 1979)" IS 3073- 1967 A smooth finish (three delta, that is 0.20 to 0.8 micrometers) will be required for all surfaces in surfaces in sliding/rolling contact, avenge or commercial finish (two delta, that is 1.6 to _ micrometers) for surfaces in contact where a tight joint is required and rough finish (single delta, that is 12.5 to 25 micrometers) for all other machined surfaces which are not in contact, but which require finish for dimensional accuracy.

8.5.6 FABRICATION OF STRUCTURAL STEEL

The structural steel work for the equipment covered by the specifications shall conform to the requirements of "Reamed work" and shall conform to the following requirements.

All completed members shall be free from twists, bends and open joints. Attention is called to the special nature of the work involved in the manufacture of equipments, which require close adherence to the dimensions, tolerances and finish called for.

Before being laid off or worked in any manner, structural material shall be straight without twist, bends or kinks and shall be cleared of all rust and dirt. If straightening is necessary, it shall be done by methods that will not injure or mark the materials.

8.5.7 SHEARING, CHIPPING AND GAS CUTTING

Shearing, chipping and gas cutting shall be done carefully by torch or by electric arc and all portions of the work which shall be exposed to view shall present a neat appearance.Gas cutting shall be mechanically controlled. Re-entrant cuts and copes in beams and channels shall be filleted before cutting.

8.5.8 WELDED EDGES

The edges of plates or shapes to be joined by welding shall be properly formed to suit the selected type of welding. Sheared edges of plates and shapes to be joined by welding shall be machined or chipped to sound metal before welding.

8.5.9 BENT PLATES AND SHAPES

Where bending of plates or forming shapes is required, these shall be bent to proper curvature by cold fanning. Heating and hammering to correct curvature shall not be permitted.

8.5.10 REAMED WORK

Holes in material 20 mm or less in thickness shall be sub-punched’ or sub-drilled before assembly and reamed to full size during assembly.

Holes in materials more than 20mm in thickness shall be sub-drilled 3mm smaller than the normal diameter of the rivet on bolt before assembly and reamed to full size during assembly.

Counter boring shall be done carefully to meet the requirements for clearance and fit of welded studs. Anchor bolt holes shall be punched or drilled out to full size. All holes shall be made by the following methods

8.5.11 PUNCHING

Punching of holes to full size shall not be permitted. For sub-punching, the diameter of the punch shall be 5 mm smaller than the nominal diameter of the' bolt used and the diameter of the die shall not be more than 2.50mm larger than the diameter of punch. All holes shall be cut clean without any burrs.

8.5.12 DRILLING AND REAMING

For sub-drilling, the dia meter of the drill shall be 3mm smaller than the nominal diameter of bolt used. Except where tapping is required or where tight fit bolts, ribbed bolts or dowels are to be used full size drilled or reamed holes shall not be less than 1.5mm nor more than 2.5mm larger than nominal diameter of the bolts used. Holes for ribbed bolts shall be drilled or reamed to 1.5mm less than the diameter of the ribbed shrunk of the bolts to ensure a tight fit. Reaming of sub-punched or sub-drilled holes shall be done with machines after assembly. The templates shall be used when assembled reaming is impractical. The threads will be continuous, smoothly cut and free from imperfections when tapped carefully.

8.5.13 ACCURACY OF PUNCHING, DRILLING AND REAMING

1) Before assembly: The accuracy of all holes shall be such that during assembly, a cylindrical pin 3mm less in diameter than the normal size of the holes shall be entered perpendicular to the face of the member, without drifting in not less than 75 percent of any group of continuous holes in the same plane. All holes shall pass a pin 5mm smaller in diameter than the nominal diameter of the hole.

2) During assembly: The accuracy of reaming and drilling during assembly shall be such that not less than 85 percent of any group of continuous holes in the same plane shall show on offset greater than 0.5mm between adjacent thickness of material, unless a greater degree of accuracy is called for on the approved drawings and specifications of the department.

8.5.14 WELDED STUDS

Welded studs wherever used shall be welded in place with automatic end-welding guns Templates of sufficient thickness to afford good alignment shall be used to accurately locate the studs during the welding cycle and to locate matching holes in other material. Bushing shall be used for template holes, if necessary to ensure angular alignment of the studs and location accuracy required for proper fit of parts to be assembled.

8.5.15 PATTERNS

While making patterns, care shall be taken to avoid sharp corners or abrupt changes in cross section and ample fillets shall be used. The pattern thickness as will conform to the standard foundry practice and as may "be necessary to ensure that all metal thickness of the finishedcastings shall be in accordance with the dimensions shown on the approved drawings of the department.

8.6 WELDING

8.6.1 PREPARATION FOR WELDING

Members to be joined by welding shall be cut accurate to size, and where required shall be rolled or pressed to the proper curvature in accordance with the dimensions. The edges of the members to be joined by welding shall be sheared, flame cut or surfaces shall expose sound metal, free from laminations, surface defects caused by shearing or flame cutting operations and other injurious defects. The surfaces of plates to be welded shall be free from rust, grease and other foreign matter for a distance of at least 50mm back from the edge of the weld. In assembling and during welding the components parts of built up members shall be held in place with sufficient and proper clamps or other adequate means to keep all parts in proper position. Before commencement of welding the complete programme of welding sequence to minimize stresses and distortion of the finished members of the equipment shall be done.

8.6.2 WELDING TECHNIQUE

All welding shall be performed by electric arc process using coated electrodes or other means whereby the atmosphere is excluded from the molten metal and where applicable, automatic machines with correct precision control shall be used. After being deposited, the weld shall be cleaned of slag or flux and shall show uniform section, smoothness or weld metal, feather edges without overlap and free from porosity and clinkers. Visual inspection at the edges and ends of welding shall indicate good fusion with the base metal. When weldmetal is deposited in successive layers, each layer except the last shall be penned moderately with a tool before the next layer is applied.

Particular care shall be taken in aligning and separating the edges of members to be joined by butt welding, so that complete penetration and fusion at the bottom of the joint shall be ensured. All pin holes, cracks and other defects shall be repaired by chipping or grading the defects to sound metal and re-welding. Where fillet welds are used, the member shall fit closely and shall be held together during welding. The welding rods used for manual welding shall be of heavily coated type and shall be suitable for all position welding where required. In welding, precautions shall be taken to minimize stresses due to expansion and contraction and distortion due to heat by using the proper sequence in welding i.e. by penning the welds while hot or by other satisfactory methods.

Rectification's of distortions by blows after welding shall not be permitted. The welding shall conform to Indian Standard .Code of Practice for use of Metal Arc welding for General Construction in Mild steel IS: 816-1985. All skin plate welds shall be continuous and water tight and shall develop the full strength of plate. The electrodes shall conform to the Indian Standard 'Specifications for covered Electrodes for Metal Arc Welding of Structural Steel for Welding Products other than sheets and for welding sheets (Parts-I and II)" IS: 814-1985.

8.7 CASTING

All castings shall be true to pattern and the thickness of the metal shall not vary at any point by more than 1.5mm. Care shall be taken in the foundry to cool the castings properly so that they shall not twist. All castings shall be free from cracks, large or injurious blow holes or sandholes and other blemishes. They shall have workman like finish inside angles having proper fillets and unfinished edges of bases, ribs and similar parts being neatly cast with rounded comers.

The cast parts shall- be homogenous and free from non-metallic inclusion. The surfaces which are not machined and which will be exposed after their final installation shall be such that grinding at the site is not required before painting. All castings shall be suitably heat treated.

Repairs of major defects in castings shall not be allowed, but if the 'strength and machinability of the castings can be ensured, the castings shall be rectified by welding.

8.8 ERECTION BOLTS, NUTS, WASHERS AND OTHER FASTENERS

Erection bolts, nuts, washers and other fasteners shall be furnished in the amount of 15 percent or ten bolts, nuts, washers and other fasteners whichever is grater, in excess of the nominal number of each size and length required for complete Installation of equipment.

Bolts In tension shall have a net section at root of thread 15 percent in excess of the net section required in tension.

8.9 CLEANING AND SURFACE PREPARATION

8.9.1 METHOD-A AND METHOD-B

The Method-A

The weld surface (5 shall be de-slogged and weld spatters, burrs and other 'objectionable surface irregularities shall be removed carefully. All rust, mill scale and other foreign substances shall be removed from the surfaces by scraping, chipping, vigorous wire brushing, blasting or other effective means. AH oil, grease, dirt and all other contaminants shall than be removed by the use of clean mineral spirits, xylem or white gasoline and clean wiping materials and Surface of seals shall be protected by masking tape or by other suitable means during the cleaning and painting operations.

The Method-B

The weld surfaces shall be de-staged and weld spatters, burrs and other objectionable surface irregularities shall be removed carefully. All rust, mill scale and other foreign substances shall be removed from the surfaces by scraping, chipping, vigorous wire brushing, blasting or other effective means. Care shall be taken to avoid excessive burnishing of steel. All oil, grease, dirt and all other contaminants shall than be removed by the use of clean mineral spirits, xylem or white gasoline and clean wiping materials.

In case rust forms or the surfaces become otherwise contaminated in the interval between cleaning and painting, re-cleaning shall be carried out by the same Method as herein above specified for the respective

items. Surfaces of stainless steel, Nickel, Bronze and machined surfaces adjacent to metal work being cleaned or painted shall be protected by masking tape or by other suitable means during the cleaning and painting operations.

8.9.2 PAINT MATERIALS AND COATINGS: GATE LEAF

All the surfaces (except non-ferrous surfaces and machined mating ferrous surface) of the gate, hoisting mechanism shall be applied with 2 (two) coats of ZINC RICH PRIMER followed by 3(three) coats of COAL TAR EPOXY. The zinc rich primer and coal tar epoxy paint shall generally conform to the particulars given below. The first coat of the zinc rich primer shall be applied within 4 hours of cleaning. The dry film thickness (OFT), of each coat of zinc rich primer shall be at least 50 microns. The dry film thickness (OFT) of each coat of coal tar epoxy paint shall be at least 100 microns.

ZINC RICH PRIMER

1. Purity of Zinc 94%minimum
2. Fineness 325
3. Zinc content in the paint 85% q 1%
4. Process Electrolytic
5. Curing Polyamide cured
6. Pot life at 451°C not less than 8 hours
7. OFT with thinner 50 microns/coat
8. of 2 pack system pack system
9. Volume solids corresponding to 86% zinc content 38'%
10. Covering capacity
    i. Theoretical
    ii. Practical

1. Maximum percentage of thinner for primer 10-12%
2. Epoxy content in dry film 12%
3. Mixing ratio by volume Base hardener-3:1
4. Application as recommended by manufacturers

COAL TAR EPOXY PAINT

1. OFT with thinner 100 microns/coat
2. Volume solids on OFT Not less than 67%
3. Pot life at 450c not less than 3 hours
4. Epoxy content not less than 35'% (Total Resin content more than 50%)
5. Covering capacity:

i) Theoretical As recommended

ii) Practical by manufacturers

6. Percentage of thinner 5% maximum

7. Mixing ration by volume Base hardener 2:1

8. Application as recommended by manufacturers

8.9.3 APPLICATION PROCEDURE

a) Painting shall not be done when the ambient temperature is less than 10 degrees or when relative humidity is more than 80%.

b) Primer coats shall be applied without any time lag after the surface preparation, and care shall be taken to ensure that paint is not applied to damp surfaces.

c) Painting shall be discontinued during rain and dust storm and shall not commence until the surfaces are perfectly dry and clean.

d) All materials shall be in thoroughly mixed conditions at the time of application and shall not be thinned unless otherwise specified. When paint is applied by spraying, suitable means should be provided to prevent segregation during the painting operation.

e) Any warming of the paint materials shall be performed by means of hot water bath and except as specifically provided paints shall not be heated to a temperature higher than 38°C.

f) Each coat of paint shall completely and uniformly cover the surface and shall be free from runs and sags. Each coat shall be allowed to dry or harden sufficiently as per manufacturers recommendations before the next coat is applied.

g) The detailed application procedure indicating method of preparing and applying etc. shall be evolved in consultation with the paint manufacturer.

h) Surface to be painted which will be inaccessible after installation shall be completely painted as scheduled prior to installation.

INSPECTION

The inspection of all gates and their accessories, shall be carried out in accordance with Indian Standard "Recommendations for Inspection, Testing and Maintenance of Fixed wheel and Slide Gates-Part-II-Inspection and Testing at the Time of Erection-Part-III-After Erection IS :7718 (part-II and III) unless otherwise specified.

INSPECTION AT THE TIME OF INSTALLATION

1. It shall be ensured that the beam is correctly positioned both in level and locations.

2. The parts to be embedded, that is track plates, guides, seal seats shall be checked when all these parts are in final position from bottom to top of the groove. Check shall be carried out both in location and levels, with respect to sill beam already established in position. Each part shall be checked first individually and thereafter relatively to other parts.

3. The track plates and seal seats shall be absolutely in true alignment. The alignment of track plates and seal seats shall be checked at 300mm intervals from bottom to topside of the gate opening. Alternatively, diagonal checking or any other satisfactory method can be adopted for checking, the alignments.

4. After checking track plates and seal seats on both sides it shall be ensured that they are in terms of their respective planes.

5. Guide and Guide shoes shall be checked for true location and alignment first individually and then relatively.

6. Groove corner protection angles shall be checked for true location and alignment

7. The following critical dimensions shall be checked at intervals of 300mm from bottom to top of the groove for embedded parts.

a. Center to centre distance of track plates,

b. Center to centre distance of side seal seats,

c. Face to face distance of guides,

d. Face of track plate to face of side seal seat,

e. and Face of track plate to centre line of guide,

f. Vertical distance between sill and the centre line of top seat.

1. Eccentricity provided to gate for its fine adjustment in the grooves shall not be accounted for while erecting parts to be embedded.

2. The groove concreting shall be done only after satisfying all these details. Recheck of alignment of embedded parts shall be done after concreting.

3. It shall be ensured that there is no offset of joints while extending the embedded parts.

4. All the gates shall be inspected on site before lowering them in the respective grooves Overall dimensions shall be checked to ensure that the respective gates correctly in the respective groove.

11. The following critical dimensions shall be checked at an interval of at least 300mm, wherever applicable, for gate.

a) Center-to-centre distance between Thrust Pad treads

b) Center-to-centre distance between side seals/bases,

c) Face to face distance between guide shoes/rollers

d) Face of seal base to Pad Tread, and

e) Center line of guide shoes/roller to Pad tread in zero position

12. Seals and seal base shall be checked to ensure that they are coplanar All Pads shall be adjusted to ensure that Pad treads are in their proper alignment.

13. Seal bolts shall be tightened adequately and uniformly.

14. To check the effectiveness of the seal, actual seal interference shall be compared with that provided in the design.

15. It shall be ensured that installation of the various parts of the hoisting arrangements along with gates has been done to specified location and alignment, particularly in respect of correct positioning and attachment of stem of the gates as well as hoists.

16. Connections like shaft couplings, connection of stem rods to the gates and hoists, connection of stem links, connection of hoist components to the base shall be checked.

17. It shall be ensured that intermediate supports for stem rods are provided at the required levels, and permit free movement of stem rod for the entire gate travel.

18. The hoists provided for the operation of the gate shall first be independently tested when it is not connected to the gate to ensure its satisfactory working. The hoists shall be kept running for a sufficient period so as to ensure its independent worming.

INSPECTION AFTER INSTALLATION

At an appropriate stage (As decided by the Engineer-in-Charge), after installation of the respective gates shall be tested as per the requirements and specifications. The inspection after installation shall cover following points.

(1) Drain holes in the components of the gates shall be so checked that they do not get clogged with silt causing accumulation of water in the horizontal girders.

(2) Inspection of gates shall be carried out to detect defects, if any, after erection and when the canal is full. The gate shall be operated up and down several times to measure that they function well, without vibrations.

(3) Inspection, after erection shall consist of visual inspection of exposed surfaces of embedded parts, sill beams, seal seats, gate leaves, hoisting equipments, hoists, supporting structures and checking of important dimensions. In case of inaccessible parts, necessary inspection shall be carried out with the help of divers.

(4) Inspection shall be carried out of the connections for structures of gate tightness of all fittings, soundness of all welds, leakages through gates, lubrication of all bearings, guide shoes, machinery and equipments, wear and tear, corrosion, sealing, pitting of all metal work and machinery (soundness of metal).

FIELD TESTS

Field Tests shall be for all the gates, hoists and shall include

1) Operational tests in dry

2) Operational tests with stipulated full supply level and

3) Leakage tests,

The tests will be repeated, if necessary, until they are successfully carried out to the satisfaction of the Engineer-in-Charge.

LEAKAGE TESTS

Leakage tests will be carried out with the gates lowered on to the sill. Before the observation for leakage the gates will be raised and lowered suitably in order to dislodge any debris that might have lodged in the side and bottom seals. The leakage then shall be measured and it shall not be more than the amount specified in relevant code. The tests shall be repeated if necessary.

AFTER INSTALLATIONMAINTENANCE / REPAIR

The maintenance of low head slide gates and hoist and ancillary component should be done regularly. Proper record of inspection, testing and maintenance should be kept by the officer in-charge of the work. Following maintenance work should be attended to.

1. Damaged nuts, bolts, screws etc. should be replaced. Any pitting to skin plate, horizontal and vertical stiffeners should be cleaned and filled up by welding and finished by grinding, weld joints of Major components should be checked thoroughly and defects if any noticed should be ratified by re-welding and grinding.
2. The gate, hoist and allied structures should be painted timely.
3. Rubber seals of the gate should be checked for wear and tear and damages should be repaired / replaced as considered necessary.

4. The bolts and nuts fixing the rubber seals to the skin plate should be checked for slackness and should be tightened if found loose. Damaged bolts and nuts should be replaced.
5. Lifting pin and lifting bracket brush if provided should be lubricated properly.
6. The stem of restraining arrangement and split bushes should be lubricated properly. The bolts and nuts of restraining brackets and stem flanges should be checked for slackness and should be tightened if found loose.
7. All major joints of hoist and hoist bridges / walk way bridge shall be checked for cracks etc. and shall be rectified suitably.
8. The screw rod, worm and worm wheel should be checked for worm out, damage or hair cracks to teeth etc. and should be rectified / replaced as considered necessary.
9. The thrust bearing should be opened and checked for damage to the inner / outer cones and rollers etc. and shall be rectified / replaced.
10. The chequered plates / wooden planks should be checked for rusting / damage and shall be replaced / repaired as considered necessary.
11. Emergency gate, if provided shall be maintained in the similar method.

MAINTENACE SCHEDULE

A. *Quarterly / Half Yearly Maintenance*

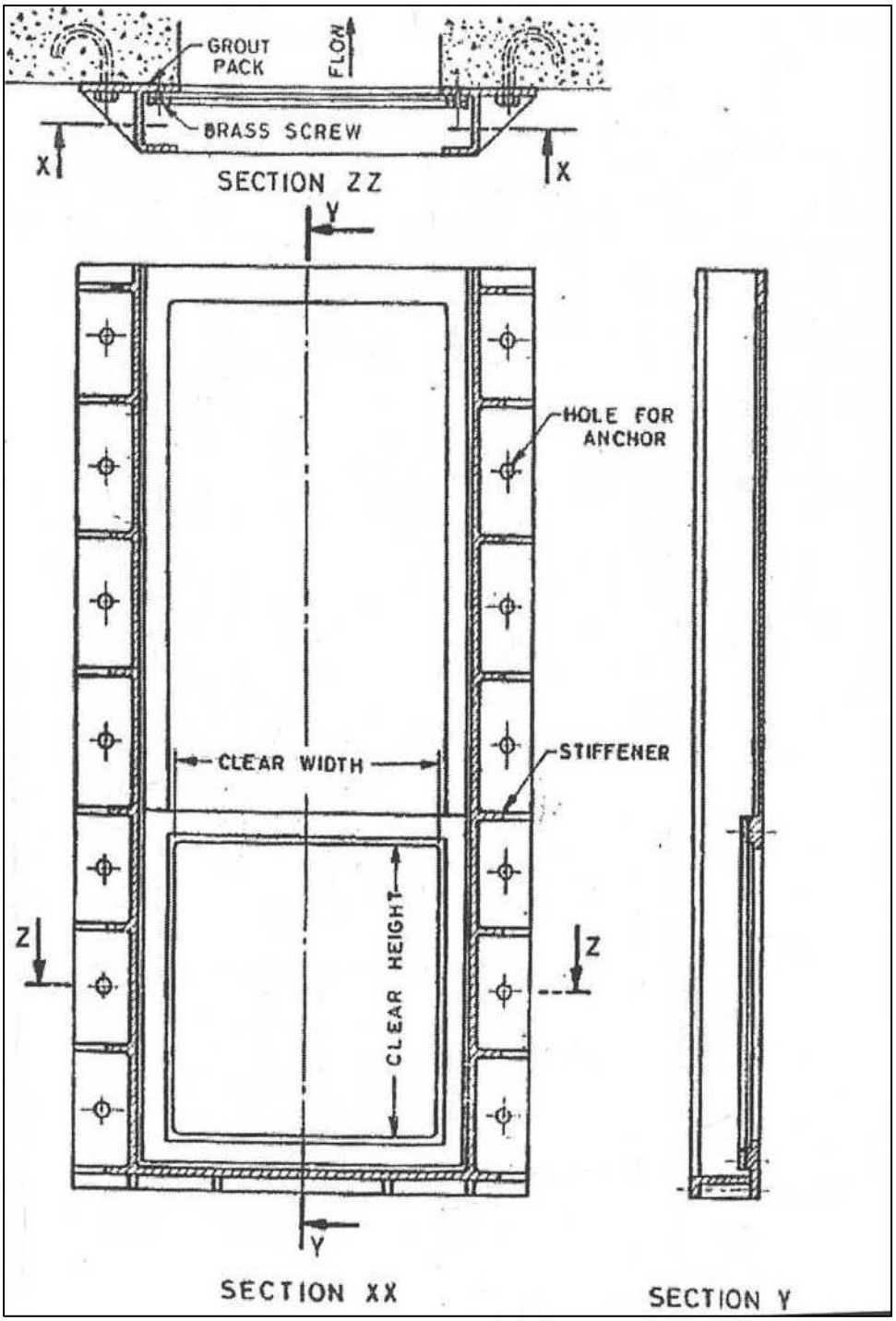
1. Stems and split bushes: The stems and split bushes should be lubricated.
2. Lifting Bracket bush and pin: The lifting bracket bush and pin should be lubricated.
3. Gear box Assembly: a)The screw rod should be lubricated.
   b) The worm, worm wheel, worm shaft and thrust bearing should be lubricated.

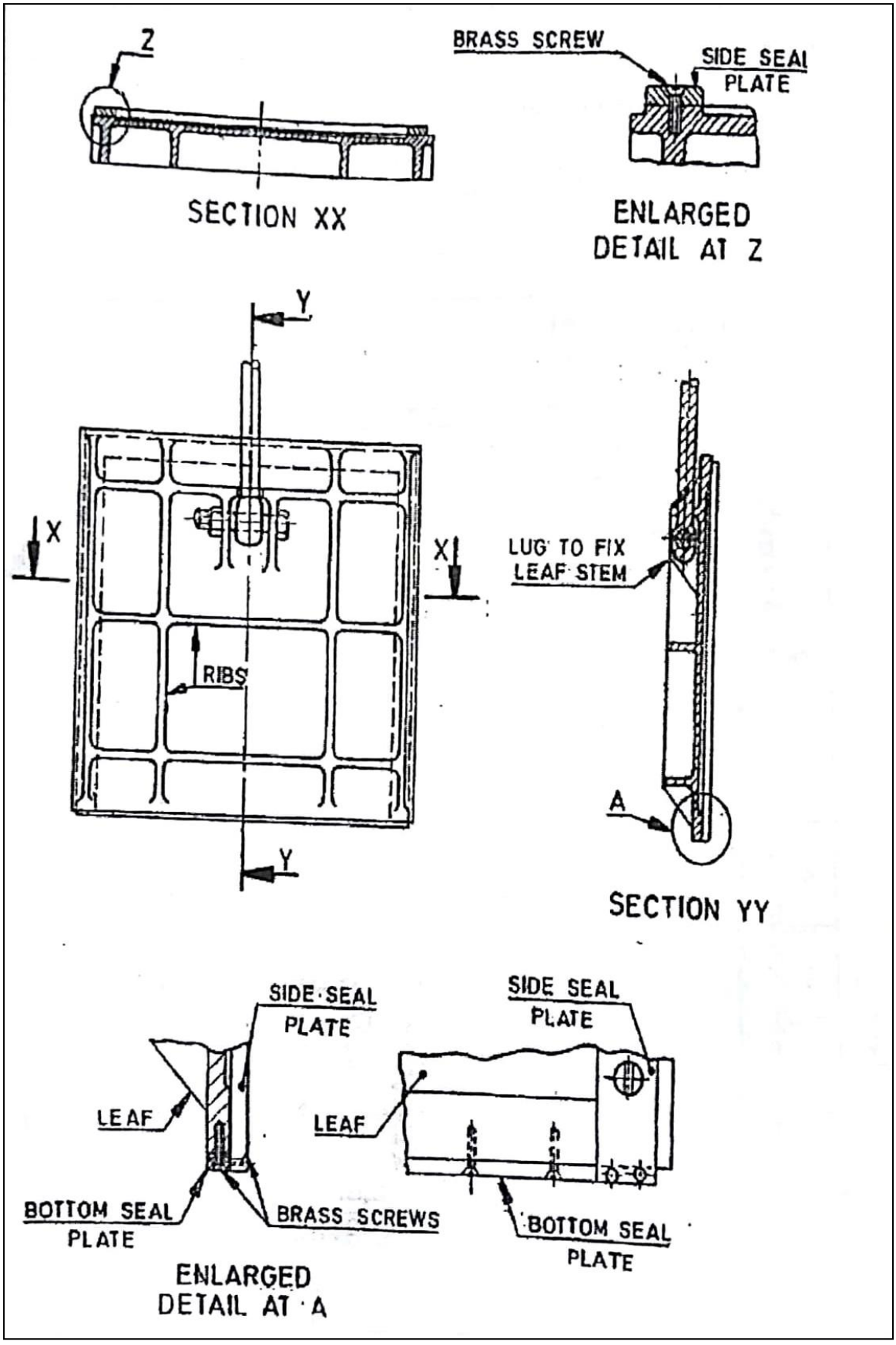
B. *Yearly Maintenance*

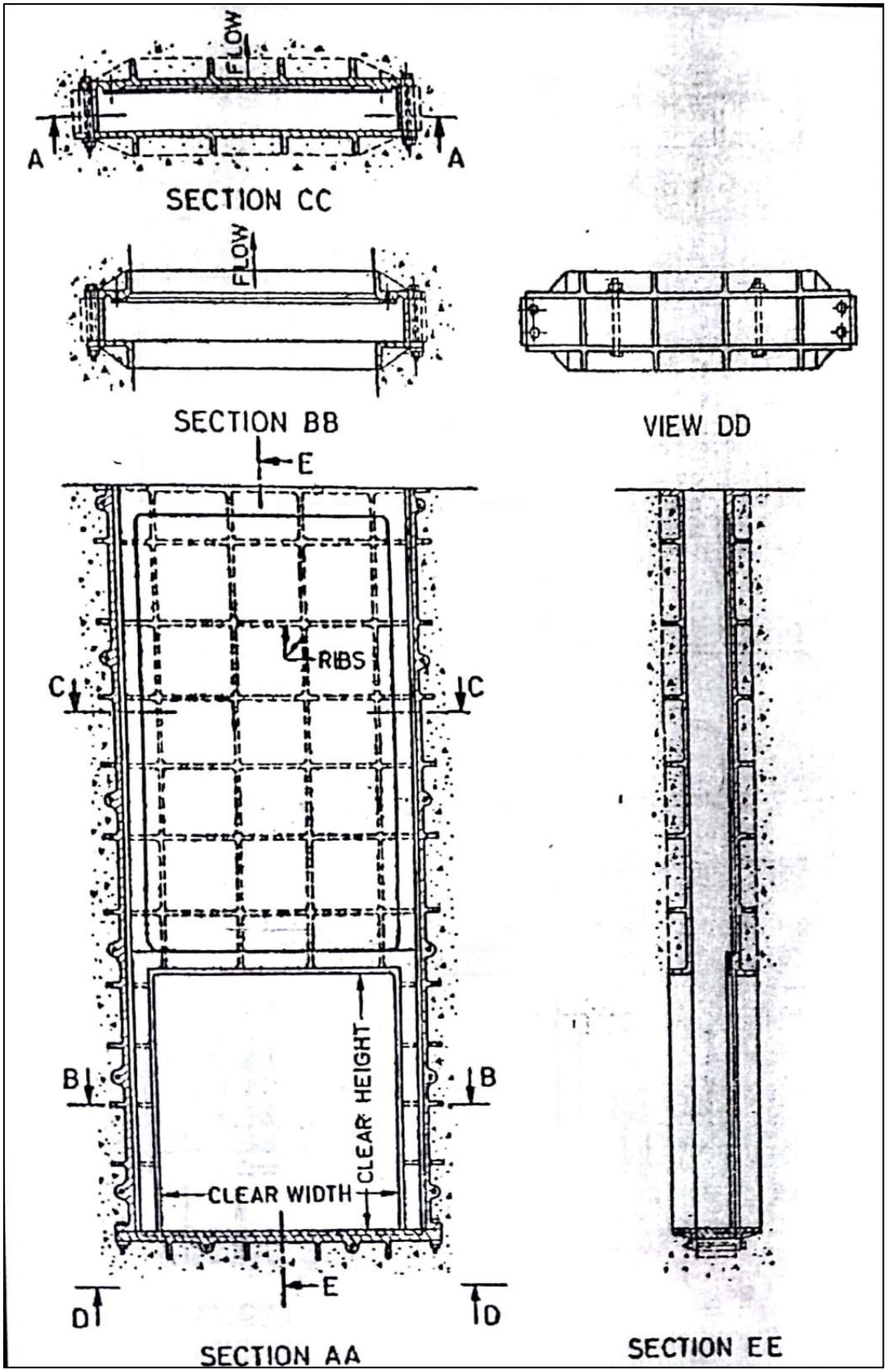
1. Grease shall be applied to guide, wheel track.
2. All bolt nuts should be checked for slackness and shall be tightened if found loose.
3. The rubber seals should be checked for deformation and damage etc. shall be repaired / replaced.

PAINTING OF GATES: Painting of gates is essential to prevent rusting, scaling and corrosion since the gates are exposed to Sun, Rain and Air. Brass plates, stainless steel flats and rubber seals shall be cleaned only and shall not be painted. Before painting the surface must be perfectly cleaned by wire brush. The surface shall be free from moisture, dust, oil grease, rust etc.

Item		Paints recommended
1	Gate leaf upstream side	Anti corrosive black bituminous paint (H.D) Coal tar epoxy base.
2	Gate leaf downstream side	Anti corrosive black bituminous paint (L.D) Coal tar epoxy base.
3	Gear box, Gear box support frame hoist bridge and walkway bridge.	a) Primary coat red-oxide. b) Final coat-Aluminium / Enamel paint.


GROUT PACK
FLOW
BRASS SCREW
X
X
SECTION ZZ
Y
HOLE FOR ANCHOR
STIFFENER
CLEAR WIDTH
CLEAR HEIGHT
Z
Z
Y
SECTION XX
SECTION Y


Z
SECTION XX
BRASS SCREW
SIDE SEAL PLATE
ENLARGED DETAIL AT Z
Y
X
X
RIBS
Y
LUG TO FIX LEAF STEM
A
SECTION YY
SIDE SEAL PLATE
LEAF
BOTTOM SEAL PLATE
BRASS SCREWS
ENLARGED DETAIL AT A
SIDE SEAL PLATE
LEAF
BOTTOM SEAL PLATE


FLOW
A
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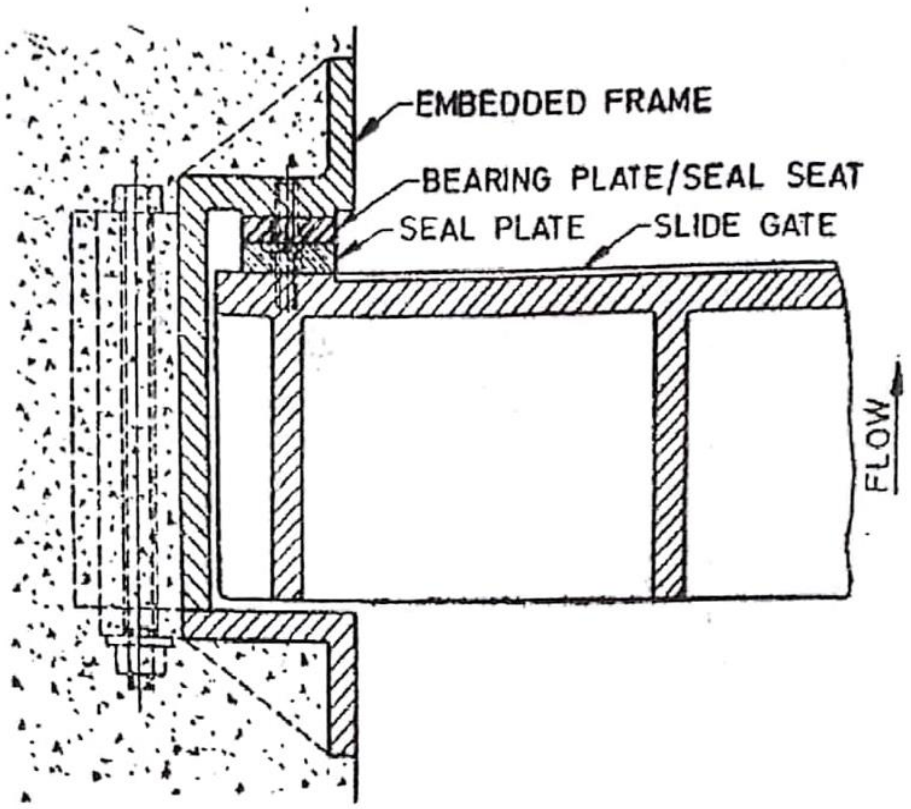
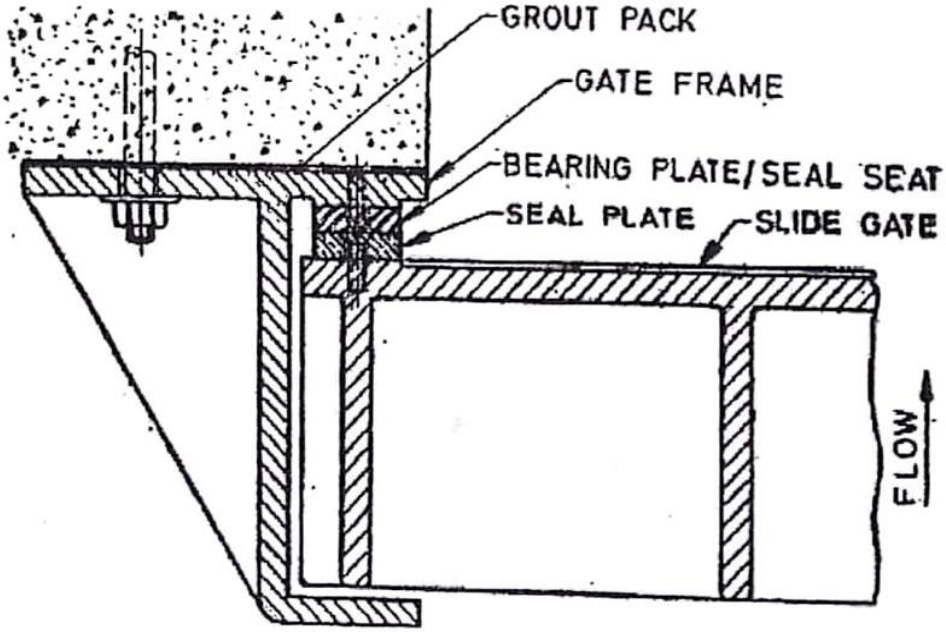
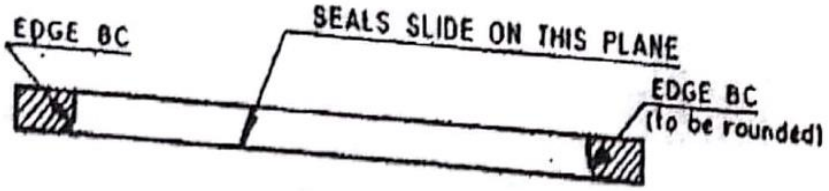
SECTION EE



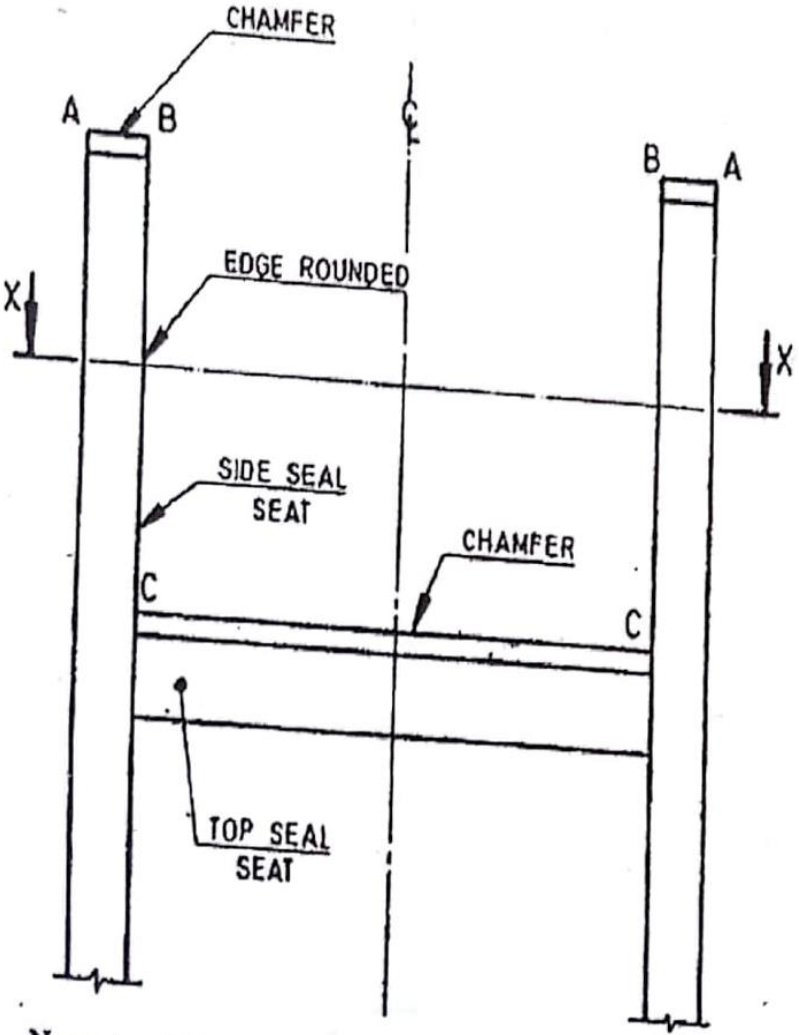
Typical Slot Section Detail Showing Low Head Slide Gate and Emmbedded Frame



Typical Slot Section Detail Showing Low Head Slide Gate and Full Face Gate Frame

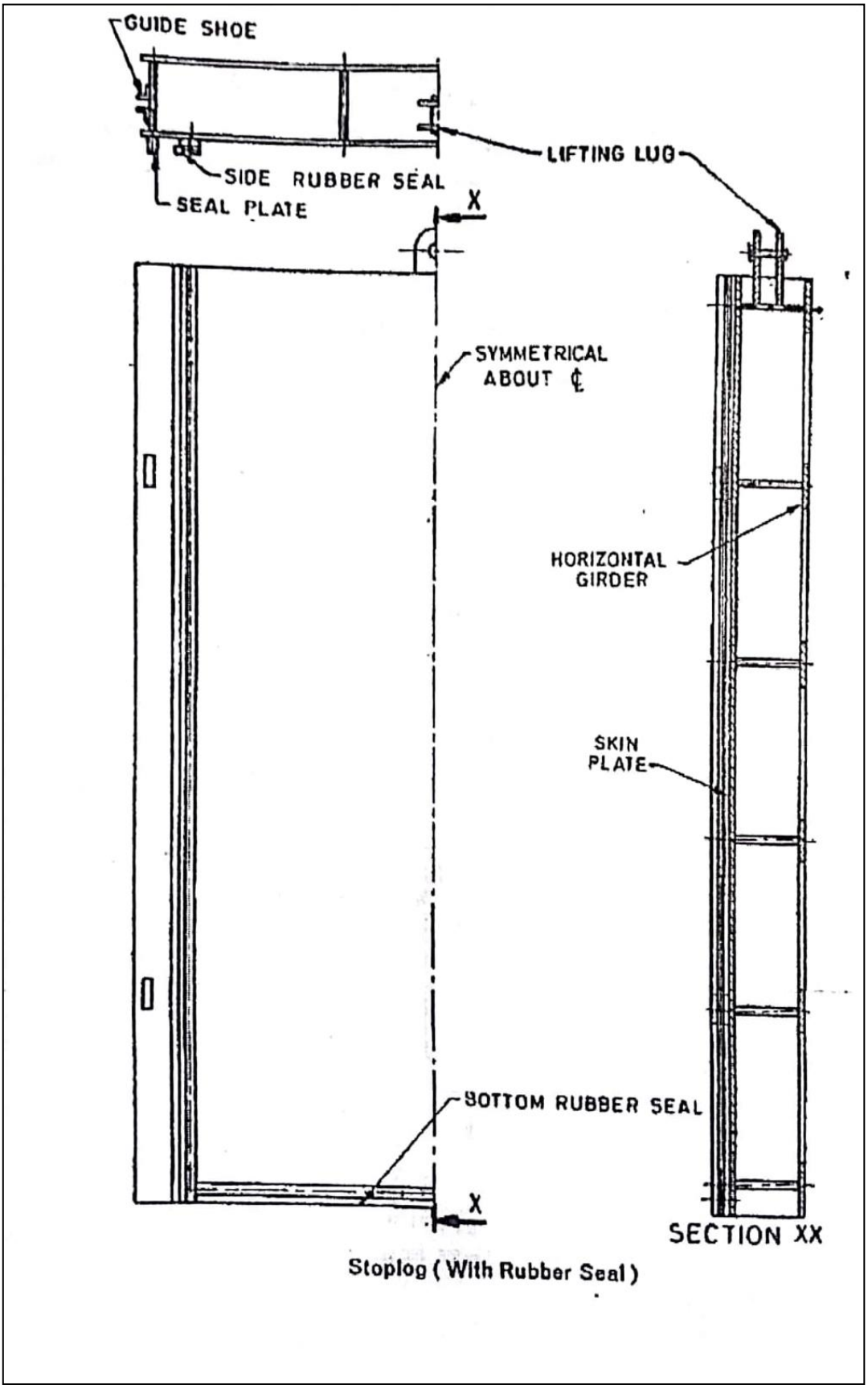


SECTION XX

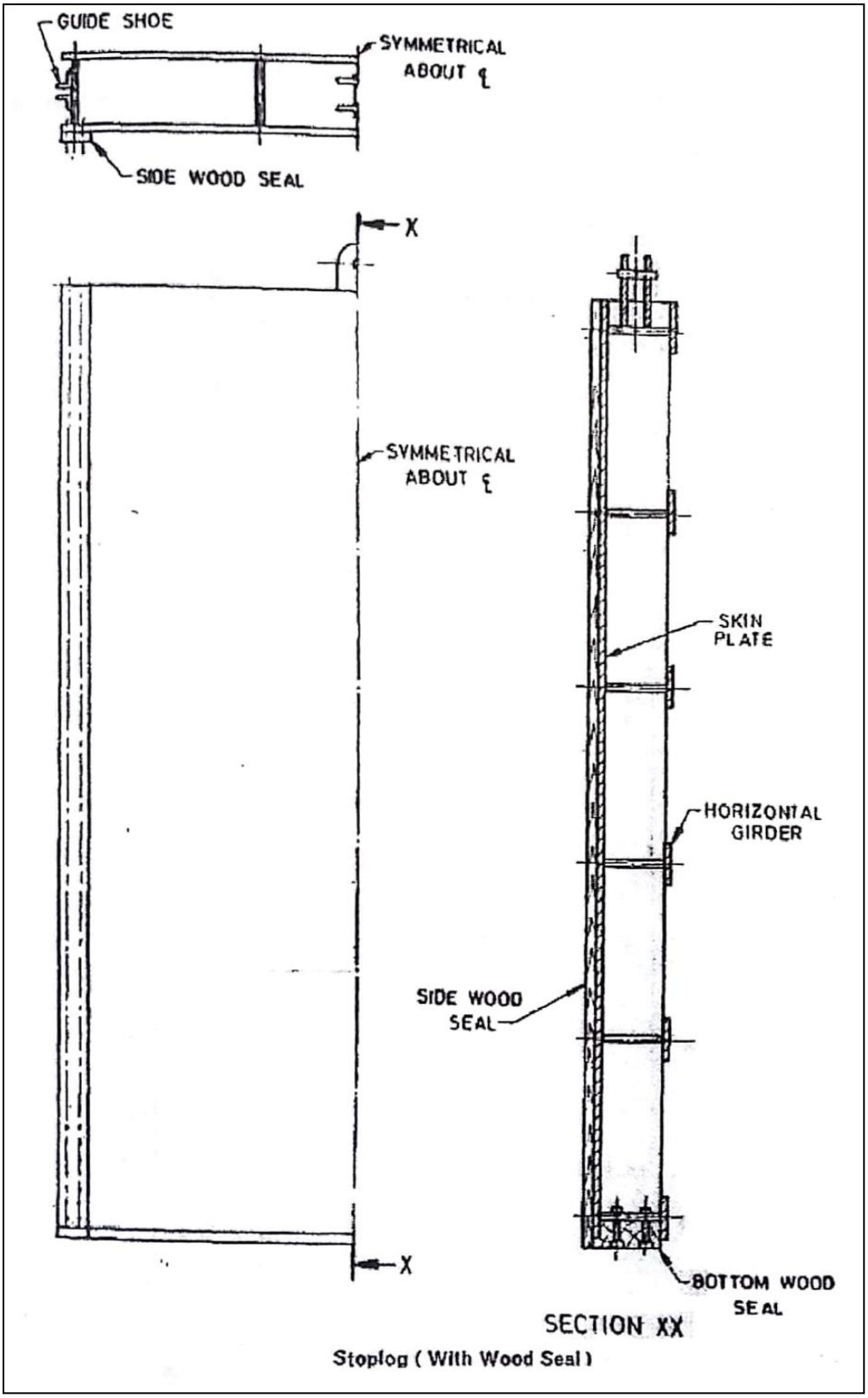


NOTE 1 — Edges *AB* and *CC* to be chamfered.

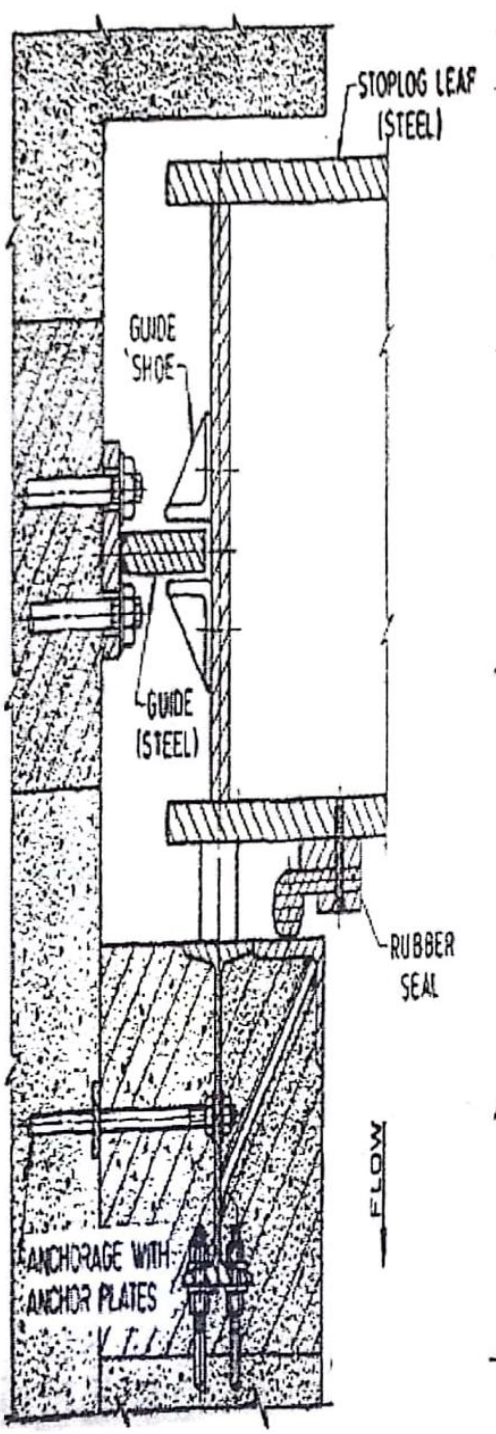
NOTE 2 — Edges *BC* to be rounded.



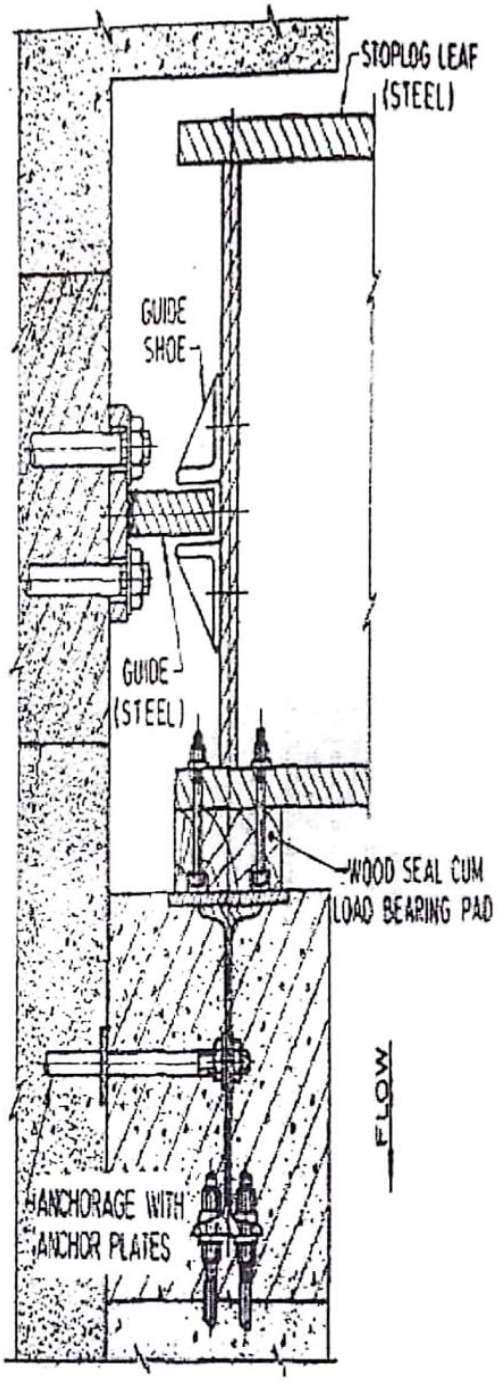
Stoplog (With Rubber Seal)



Stoplog (With Wood Seal)



Details of Rubber Seal



Details of Wood Seal

9 GROUND WATER EXTRACTION AND CONJUNCTIVE USE

9.1 WATER WELL BASICS

In this project, ground water extraction structure and conjunctive use of surface water and ground water is proposed to be taken up. Basics of well, construction of wells, selection of pumps, conjunctive use of water balance are discussed in this chapter.

Water well is a hole, shaft, or excavation used for the purpose of extractingground water from the subsurface. Water may flow to the surface naturally after excavation of the hole or shaft. Such a well is known as a flowing artesian well. More commonly,water must be pumped out of the well.Most wells are vertical shafts. Some basic information about water wells helps understand principles of effective well construction when they work with a driller, engineer or farmers for well drilling and maintenance. Components of a water ell is given in figure 33

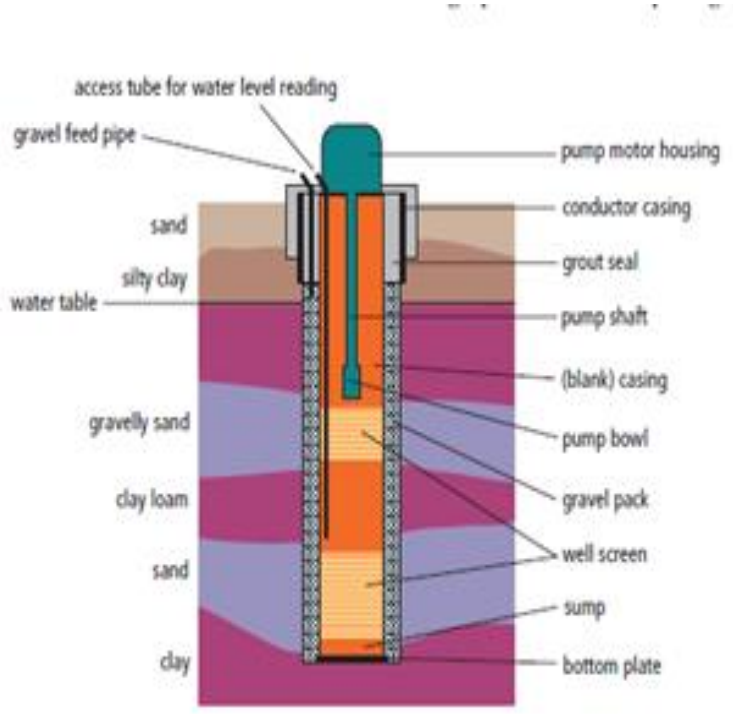


Figure 33 Components of a well

9.2 Drilling a Well: Overview

The process of designing and constructing awater well begins with selection of the project command area Concerned finds a suitablelocation to meet the specified purpose of thewell and a preliminary design is established.Once the drilling rig is set up, the drillingprocess itself may last from a few hours (for ashallow, small-diameter well) to several days(for a deep, large-diameter well). Appropriate

materials(screen, casing, gravel) can then be orderedin a timely fashion prior to the final drilling.Once the well bore is drilled, the drillerinstalls well casing and well screens and fillsthe annulus around the casing with a gravel(filter) pack and the appropriate cement andbentonite seal to prevent water from leakingbetween uncontaminated and contaminatedaquifers or from the land surface into the well(bentonite is a special type of clay used toseal against water leaks). Then the drillerdevelops the well (see Well Development),implements an aquifer test, completes thesanitary seal of the well head. Proper design, construction,development, and completion ofthe well will result in a long life for the well(as long as half a century or more) and efficientwell operation.

The purpose of the screen is to keep sand and gravel from the gravel pack out of the well while providing ample water flow to enter the casing. The screen should also be designed to allow the well to be properly developed. Slotted, louvered, and bridge-slotted screens and continuous wire wrap screens are the most common types. Slotted screens provide poor open area. They are not well suited for proper well development and maintenance, and are therefore not recommended. Wire wrap screens or pipe-based wire wrap screens give the best performance. The additional cost of wire wrap screens can be offset if you only install screen sections in the most productive formations along the bore hole. The purposes of the blank well casing between and above the well screens are to prevent fine and very fine formation particles from entering the well, to provide an open pathway from the aquifer to the surface, to provide a proper housing for the pump, and to protect the pumped groundwater from interaction with shallower ground water that may be of lower quality. The annular space between the well screen, well casing, and borehole wall is filled with gravel or coarse sand (called the gravel pack or filter pack). The gravel pack prevents sand and fine sand particles from moving from the aquifer formation into the well. The gravel pack does not exclude fine silt and clay particles; where those occur in a formation it is best to use blank casing sections. The uppermost section of theannulus is normally sealed with a bentonite clay and cementgrout to ensure that no water or contamination can enter theannulus from the surface. The depth to which grout must beplaced varies by county. At the surface of the well, a surface casing is commonlyinstalled to facilitate the installation of the well seal. Thesurface casing and well seal protect the well against contaminationof the gravel pack and keep shallow materials from caving into the well. Surface casing and well seals are particularly important in hard rock wells to protect the otherwise open, uncased borehole serving as a well.

9.3 Well Design Objectives

- Highest yield with minimum drawdown
- Good quality water with proper protection from contamination
- Sand-free water
- Long lifetime (>50 years)
- Reasonable short term and long term costs

During drilling, drillers must keep adetailed log of the drill cuttings obtainedfrom the advancing borehole.Note that a copy of all well log information should be given to the person whopays for the drilling job. The Department of Water Resources keeps copies of all welllogs and has a large collection of past well logs. These can be requested by a wellowner if the original records are unavailable. The well log contains important informationabout construction details and aquifer characteristics that can be used later fortroubleshooting well problems.

9.4 Well Development

After the well screen, well casing, and gravel pack have been installed, the well isdeveloped to clean the borehole and casing of drilling fluid and to properly settle thegravel pack around the well screen. A typical method for well development is to surgeor jet water or air in and out of the well screen openings. This procedure may takeseveral days or perhaps longer, depending on the size and depth of the well. A properlydeveloped gravel pack keeps fine sediments out of the well and provides a cleanand unrestricted flow path for ground water.

Proper well design and good well development will result in lower pumpingcosts, a longer pump life, and fewer biological problems such as iron-bacteria andslime build-up. Poorly designed and underdeveloped wells are subject to more frequentpump failures because sand and fines enter the well and cause significantlymore wear and tear on pump turbines.

Poorly designed and underdeveloped wells also exhibit greater water level drawdownthan do properly constructed wells, an effect referred to as poor well efficiency.Poor well efficiency occurs when ground water cannot easily enter the well screenbecause of a lack of open area in the screen, a clogged gravel pack, bacterial slimebuild-up, or a borehole wall that is clogged from incomplete removal of drilling muddeposits. The result is a significant increase in pumping costs. Note that well efficiencyshould not be confused with pump efficiency. The latter is related to selection of aproperly sized pump, given the site-specific pump lift requirements and the desiredpumping rate.

Once the well is completed and developed, it is a good practice to conduct anaquifer test (or pump test). For an aquifer test, the well is pumped at a constant rate orwith stepwise increased rates, typically for 12 hours to 7 days, while the water levelsin the well are checked and recorded frequently as they decline from their standingwater level to their pumping water level. Aquifer tests are used to determine the efficiencyand capacity of the well and to provide information about the permeability ofthe aquifer. The information about the pumping rate and resulting pumping waterlevels is also critical if you are to order a properly sized pump.

Once the well development and aquifer test pumping equipment is removed, itmay be useful to use a specialized video camera to check the inside of the well fordamage, to verify construction details, and to make sure that all the screen perforationsare open.

9.5 Borewell Submersible Pump

Water scarcity is a common problem in most parts of Odisha due to erratic rainfall pattern and in adequate availability surface water in Minor and Medium irrigation projects for throughout the year cropping. This calls for the extraction of ground water as an approach for conjunctive use in irrigation projects. In order to extract water from the earth, it is important to install borewell submersible pumps. Borewell Submersible pump is a pump that is completely submerged in water and is sealed in an air-tight manner.

Submersible pumps consist of an AC electric motor, impeller, diffuser, cable guard, submersible electric cable. Borewell pumps are put in a bore (cylindrical hole) dug in earth and is connected to electrical supply for operation. A submersible pump lifts water to the ground level by conversion of rotary energy of the impeller into kinetic energy of water. Water is sucked into the pump where it is pushed/lifted by the rotation of impeller through the diffuser.

9.5.1 Borewell

Key factors to keep in mind while selecting bore well submersible pumps:

Borewell Size: It is the diameter of the hole that is dug to put the submersible. A user can opt for a pump with lesser outer diameter size than the bore well size but he should avoid the reverse, as it will not fit.

Head: It is the height to which a pump can lift water. Depending on the size of house and the water table of the area of installation, the customer should select the best model. The depth at which the pump has to be put plus the height at which storage tank is located is the total head. It is measured in ft. or metres.

Outlet/Delivery Size: It is the diameter of the pipe through which water is ejected from the pump set. It should match the size of the pipe connected to our storage tanks. It is generally measured in Inches or mm.

Discharge Rate: It is the measure of amount of water pumped per minute. In case the area is big, we need a pump with greater discharge. It is measured in Litre per minute/hour.

Stage: All the pumps have an efficiency chart and selecting the correct stages of submersible pump, based on motor rating and head, is a vital step as it maximizes efficiency.

Cooling system: Bore well pumps come with both oil filled motor and water filled motor. In water filled motor the coolant is water and it can be refilled again and again making it a better option than the oil version where the coolant cannot be replenished. Oil filled variants are cheaper than water filled ones.

Material of Construction: This factor doesn't affect the performance or application of pump, but if one is looking for a product that has longer life, they should go for pumps with Noryl impeller and CI motor body.

9.5.2 Advantages of a Borewell Submersible Pump:

Self- Priming: As these pumps are totally submerged in water, they do not need to be primed. It also avoids any air bubble in the pump set which may damage the inner lining of the pump.

Enhanced Efficiency: As these pumps are submerged in water, it doesn't need to spend a lot of power in extracting water from source. The pressure of water enables the movement of water in the pump.

Better Water Availability: Since the water is extracted directly from the earth and not from municipal supply, a user can anytime switch ON the pumps and fill his/her storage tank. It avoids the hassles of storing water only at certain hours in a day.

Non Return Valve (NRV): This valve ensures that there is no back-flow of water at the outlet.

These pumps come in both single and three phase models depending on the rating of the motor. Special care should be taken while installing the pump in the bore because if it is not completely enclosed by water, it may cause overheating of the motor winding, reducing the longevity of the product.

9.6 Conjunctive use of water

Conjunctive use of water relates to the combined use of ground and surface water Due to the augmented water source, higher water reliability can be achieved. Conjunctive use therefore functions as a buffer for periods of water scarcity. The idea of this management approach is to use surface water when the water table is high and change to groundwater when the water table is low. This technique might be especially important as a buffer function for mitigating impacts of climate change, such as increased heat and drought.

Advantages

- Improved security of water sources
- Protection of the groundwater level

- Reduced environmental impact
- Increase of agricultural productivity

1.1.1 Basic design principles

- Recharge: when the water table is high, the use of surface water is to be maximised. The recharge of groundwater can be enhanced artificially by surface water recharge and subsurface water recharge.
- Recovery: During dry season, water is drawn from groundwater resources (for possible measures to draw groundwater, see groundwater sources).

It is important to keep recharge and recovery in balance (see also water balance estimation). However, as there are usually several users (e.g. farmers) relying on the same water source, individual use may lead to overexploitation of groundwater. This is a widespread problem, because conjunctive use often occurs unplanned and by default. To enhance the benefits of this practice, better coordination between the users is needed, which is part of conjunctive water management discussed below (WORLD BANK 2006).

Conjunctive water management is an improved form of conjunctive use. Additional to the combined use of surface water and groundwater, components of groundwater management tools, such as water balance estimation and water resources assessment, are added. In comparison to conjunctive use, conjunctive water management helps to better manage water use between different parties, leading to well-prepared recharge and recovery phases and therefore to a lower probability of harming groundwater sources.

Today, conjunctive water management is less frequently implemented than conjunctive use, because of lacking institutions or coordination mechanisms

9.7 General (Water Balance Estimation)

Water balance estimation is an important tool to assess the current status and trends in water resource availability in an area over a specific period of time. Furthermore, water balance estimates strengthen water management decision-making, by assessing and improving the validity of visions, scenarios and strategies.

9.7.1 Advantages

Conducting water balance estimation provides you with a comprehensive understanding of the water flow system and water resources in your area. It is a very complex work process and needs to be done by qualified experts (or at least supported by experts) and this requires considerable time and resources.

9.7.2 Who Is Involved?

Almost everyone is influenced by the water balance estimates because they are often central elements of awareness raising campaigns. Stakeholders directly involved in decision making may require more detailed information about the water available. Given that water balance analysis should be based on a needs assessment, everyone is involved in determining the outputs that are needed. The process of producing water estimates is best undertaken by experienced specialists or by staffs who have undergone training and have access to specialist support.

9.7.3 What Is a water Balance Estimation?

In the natural environment, water is almost constantly in motion and is able to change state from liquid to a solid or a vapour under appropriate conditions. Conservation of mass requires that, within a specific area over a specific period of time, water inflows are equal to water outflows, plus or minus any change of storage within the area of interest. Put more simply, the water entering an area has to leave the area or be stored within the area. The simplest from of water balance equation is as follows:

Factsheet Block Title

$P = Q + E \pm \Delta S$

Factsheet Block Body

Where, P is precipitation, Q is runoff, E is evaporation and ΔS is the storage in the soil, aquifers or reservoirs.

In water balance analysis, it is often useful to divide water flows into 'green' and 'blue' water. 'Blue' water is the surface and groundwater that is available for irrigation urban and industrial use and environmental flows. 'Green' water is water that has been stored in the soil and that evaporates into the atmosphere. The source of 'green' water is rainfall or 'blue' water has been used for irrigation.

A Water Balance Analysis Can Be Used to:

Assess the current status and trends in water resource availability in an area over a specific period of time.

- Strengthen water management decision-making, by assessing and improving the validity of visions, scenarios and strategies.

Water balance estimates are often presented as being precise. In fact, there is always uncertainly, arising from inadequate data capture networks, measurement errors and the complex spatial and temporal heterogeneity that characterises hydrological processes. Consequently, uncertainty analysis is an important part of water balance estimation as is quality control of information before used.

When the data sources are imprecise, it is often possible to omit components that do not affect changes. For example, it is possible to omit storage from an annual water balance if year-on-year storage changes (such as reservoirs) are negligible.

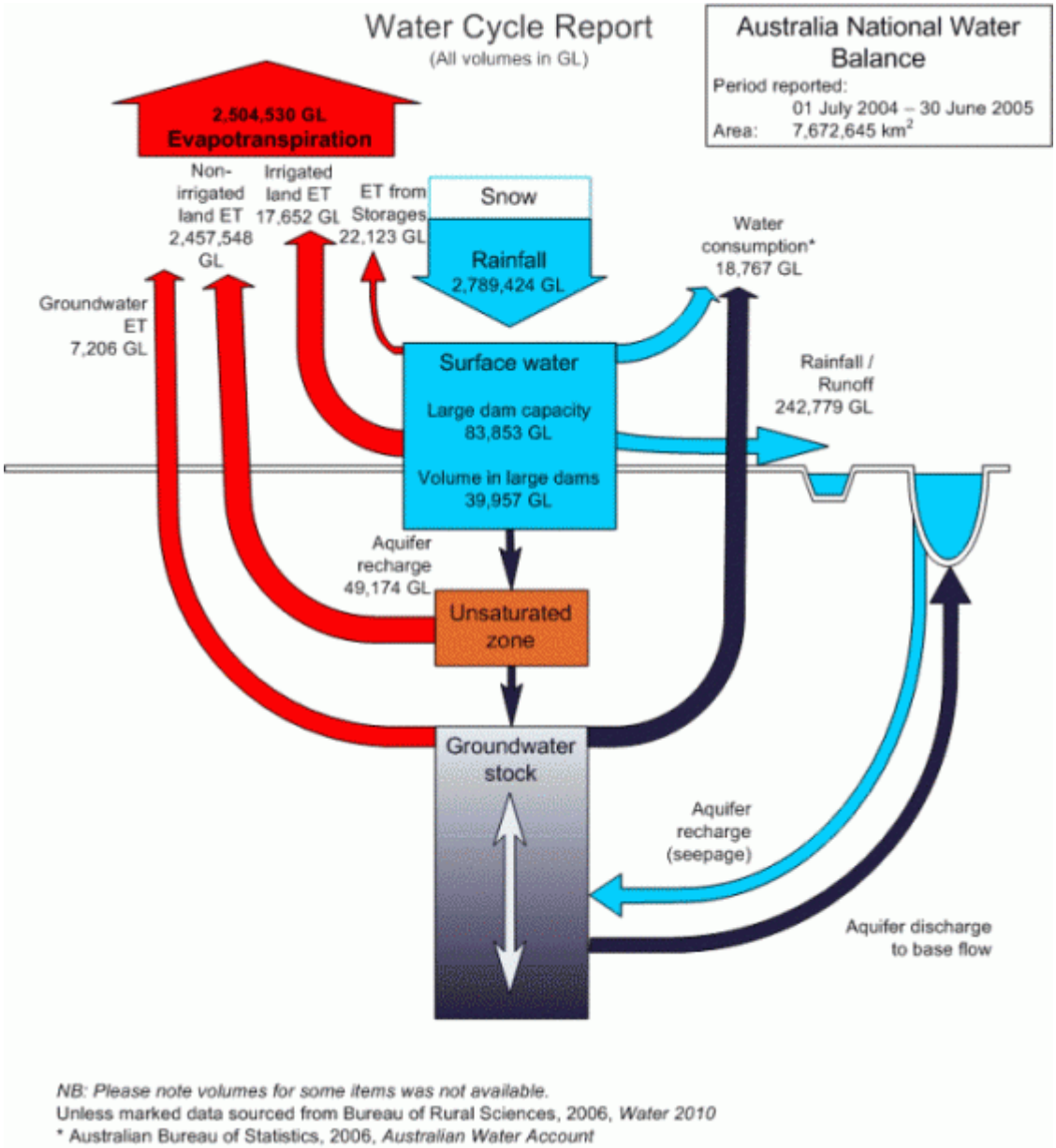
Some common problems that occur when water balance estimations are made include:

- Temporal and spatial boundaries are not defined.
- The quality of input data is poor.
- Double counting of water flows when water flows within an area added to water flow exiting area.
- Inappropriate extrapolation of field level information to a larger scale. Many hydrological relationships are scale dependent (e.g. runoff as a proportion of rainfall is almost always higher at smaller spatial and temporal scales).
- Intuition (often based on popular myths) is used rather than good quality information.
- The storage term(s) of the water balance is omitted.

Political or other pressures result in unreliable estimates that have been manipulated.

9.8 Materials and Resources

Techniques for carrying out water balance estimation range from very simple 'back of the envelope' estimates to highly complex computer-based models. A sound knowledge of hydrological processes of a prerequisite of water balance estimation. It is often advisable for a project or programmes to employ the services of a specialist to produce water balance estimates or, at the very last, to provide specialist advice as and when it is needed. Access to a quality-controlled information base is a good starting point for water balance estimation.



9.8.1 Methods

Step 1

Define boundaries of the area of interest and period over which water balance is to be made.

Step 2

Undertake a needs assessment of the water balance information that is required among stakeholders. This should be used as a starting point for listing and defining the water balance components that are of particular interest.

Step 3

Produce a simply schematic diagram that shows storage, inflows and outflows from the area of interests. Use the diagram as a basis for drafting a water balance equation. Check that no components are missing and that is no double counting of flows or storage.

Step 4

Identify a source(s) of quality-controlled information. Ensure that the information is relevant to the area and time period you are interested in.

Step 5

Carry out uncertainty and sensitivity analysis on this information. If there are inadequacies in the information (almost always the case), redefine the boundaries of the water balance and/or modify the water balance equation.

Step 6

Produce water balance estimates in a format that is useful for visioning, scenario building and planning with the community.

Step 7

Control these estimates regarding their quality before they are disseminated, using quality control methods described in this chapter.

Step 8

Disseminate findings to stakeholders in a form that they can understand. One tool with which you can carry out a professional water balance analysis is the WEAP (Water Evaluation and Planning) Tool.

9.8.2 Applicability

Water balance techniques, one of the main subjects in hydrology, are a means of solution of important theoretical and practical hydrological problems. On the basis of the water balance approach, it is possible to make a quantitative evaluation of water resources and their change under the influence of people's activities. The study of the water balance structure of river basins, forms a basis for the hydrological substantiation of projects for the rational use, control and redistribution of water resources in time and space.

Tank Command Water Productivity WP (t)

The gross volume of water depleted from the tank storage (Sd) or the equivalent depth (Sd') in cm, over the crop growth season forms the base (denominator) for productivity calculations.

WP (t) = Y/Sd ---------- (15)

where,

Y = the overall tank command yield in tonnes

Sd = depleted volume of water from tank storage, ha.cm or Million cubic metres

Sd' = equivalent depth in cm of water depleted from tank storage

10 COMMAND AREA DEVELOPMENT-CAD PLANNING

10.1 Introduction

The chak or outlet command is a basic unit for irrigation management in the command of Minor, distributory or any other parent channel. Therefore, establishing layouts of the chaks in the command of a given channel is the first step of the planning process. For this purpose, the contour map of the command of minor or distributory to the scale of 1:2000 (1:4000 if command is very big) with contour interval of 0.2 or 0.3 m should be available.

Before the design of the minor and the chaks can be taken up, it is necessary to carry out detailed surveys and investigations. The data so collected has to be analyzed so that the design is appropriate to the field situation.

10.2 Unit for Design:

The smallest unit for design will be a minor serving a group of outlets. This will ensure that the field conditions of the adjoining chaks (command of an outlet) are reflected in the design. If the minor is too large, serving, say, more than 20 outlets, the design can be proposed in two or more parts so that only 10 to 12 outlets are considered at a time. However, to ensure that the adjoining topographical conditions are taken into consideration, in such cases, at least one outlet on each side of the minor should be included in each part of the design so that there is an overlapping area (The design of a chak should not be done in isolation, without consideration of the adjoining chaks). The term 'Chak System' is used to indicate primary unit of design.

10.2.1 Sill Levels:

After survey, design and construction of distributories and minors, tentative locations and sill levels of the outlets shall be fixed after joint inspection of Construction and CAD organizations. As far as possible outlets shall be located at the upstream of the drops. The sill levels of the outlet shall be taken at or near the bed of the distributory or minor. The locations and the sill levels of the outlets so fixed, will be supplied by the Construction wing to the Command Area Development Authority. The Construction Organization shall also fix stone indicating the sill levels and the locations of the outlets on site. The survey and investigations for a chak system will be taken up after the sill levels of all the proposed outlets in the chak system are provided by the construction organization.

10.2.2 Farmers:

In canal irrigation, unlike in well irrigation, water that is supplied at the Government outlet is to be shared equitably by all the beneficiary farmers. This involves understanding and cooperation. Therefore, the number of beneficiaries has to be reasonably small. Generally, 10 to 15 beneficiaries can be organized for water sharing. If the number exceeds 20, it becomes practically un-manageable. Therefore, the farmers organization at the outlet will have always to be at the focal point. Suggestions from the farmers organization regarding alignment of F.C., tentative locations of turnouts, requirement and tentative location of graded bunds be sought. Details of the individual holding (pot hissa) in the

chak system should be obtained so that the number of farmers under each outlet is known at the time of design. The boundaries of the individual holding should be marked on the village maps.

10.2.3 Soils:

The soil conditions in a chak affect the design of the water delivery system and land shaping in many ways.

(a) Channel Gradient: Fine Textured soils (Black Cotton Soils) and other clayey soils are easily erodible and hence the gradients of channels in such soils have to be relatively flat. In Coarse Textured (murumy) soils, steeper gradients can be allowed without affecting the stability of the channel bed and depth of water in the channel for diverting water in the field.

(b) Rate of flow: For efficient application of water on the farm the rate of flow has to be controlled according to the character of the soil. Generally in Fine Textured soil (Black Cotton Soils) the rate of flow has to be smaller than in Coarse Textured (murumy) soil.

(c) Land Forming: If the depth of soil is shallow, care has to be taken while designing the land forming work. Some soil cover is necessary even after land forming.

(d) Field Drains: Field drains have not only to carry excess water during irrigation but also to drain the excess run-off during the rainy season. In fine textured soils area, there is likely to be more runoff from rain than in medium and coarse textured soils area. Capacity of the drainage system will have to be varied to suit these variations.

(e) Structures: Design of structures in Fine textured (black cotton) soil is quite different from that in coarse (murumy) soils. The costs also vary accordingly.

The data about soil conditions should therefore be collected and the area in each chak roughly demarcated into different portions as coarse textured or fine textured soil etc. survey number wise, for designing of the water delivery system. The individual farm maps for land shaping should show whether the soils are shallow (less than 22.5 cm), medium (22.5 cm to 45 cm) or deep (45-90 cm) and very deep (more than 90 cm).

For land shaping, data regarding soils is necessary. For this purpose at least five trial pits should be taken, four at the four corners of the farm and one at the centre. The trial pits should have a depth of 1.0 m or should reach coarse-grained soil whichever is earlier. In case of difficulty in taking trial pits, 100 mm diameter auger holes can be taken. Soil samples should be collected at every 0.15 m depth of soil from the top or part thereof and tested for texture. Soil texture refers to the relative proportion of various groups of soils grains in a soil mass. These fractions are called “Soil separates” or “Soil fractions”. The International Soil Science Society (I.S.S.S.) System for soil separates may be adopted as given in Table 14.1 below:

Table 11Classification of soil separates, I.S.S.S. System

S.No.	Soil Separate	Diameter Range (mm)
1	Coarse sand	2.00 - 0.20

2	Fine sand	0.20 - 0.02
3	Silt	0.02 - 0.002
4	Clay	Below 0.002

The soil texture can be determined by simple field classification methods and the soils are classified in the following 5 broad groups. For many purposes, the complete details of soil textural classes are arranged into groups as shown below:

General Soil Textural Group	Basic Soil Textural Classes
A) Coarse textured soils	Sandy, loamy sands
B) Moderately coarse textured soils	Sandy loam
C) Medium textured soils	Loam ,silt loam ,silt
D) Moderately fine textured soils	Clay loam ,sandy clay loam, silty clay loam
E) Fine textured soils	Sandy clay ,silty clay ,clay

10.2.4 Field Method of determining soil texture:

Determination of soil texture in the field is made mainly by feeling the soil with fingers and noting the feel as grittiness, stickiness, slipperiness, plasticity, etc. This requires skill and experience. For high accuracy, the texture determined in field by surface feel should be checked against laboratory analysis. The basis of field determination of soil texture by surface feel is explained below:

i) When felt between fingers, the sand particles in soil feel gritty or in case of very sandy samples, these can be seen by naked eye.

ii) The feel of the silt is soft and floury when dry, and is slippery or soapy when moist; but does not stick to the fingers.

iii) The clay when felt between thumb and fingers, is sticky if moist, plastic enough to form a flexible ribbon when pressed.

Thus by means of different feels among the sand, silt and clay, the soil textural class is estimated. However, errors are expected due to presence of organic matter gypsum, calcium carbonate, coarse fragments, soluble salts, etc. The individual textural class can be identified as described below.

Take a handful of soil free from coarse fragments and moist in condition. Rub the soil between thumb and fingers and ask yourself three question, viz.

a) Is the soil gritty?

b) Is the soil silky, slippery and soapy?

d) Is the soil sticky and plastic?

If the soils are equally gritty, silky and sticky, then the soils are 'loam' in texture. If in all the feelings, grittiness is more dominant, soils are 'sandy loam' in texture. If stickiness is much more dominant as compared to other two feelings, soils are 'silt loam' in texture. If stickiness is much more pronounced than grittiness and silkiness, soil is 'clay loam' in texture. If it is only silt, silky feeling is present and dominant, whereas other two feelings are almost absent. If the silkiness and stickiness are equally dominant and grittiness absent, then 'silty clay' is estimated. If grittiness and stickiness is equally and dominantly felt and slippery feeling absent, the texture is 'sandy clay'. If loam texture is felt, but sand and clay are felt equally high, it is 'sandy clay loam' texture. Similarly in loam texture if both clay and silt are felt dominant the texture is estimated as 'silty clay loam'. Thus, it is an approximate key to identify soil texture in the field, but should always be supported by laboratory analysis, skill and experience. For ready reference, steps to be followed in field classification are presented in Figure 34.

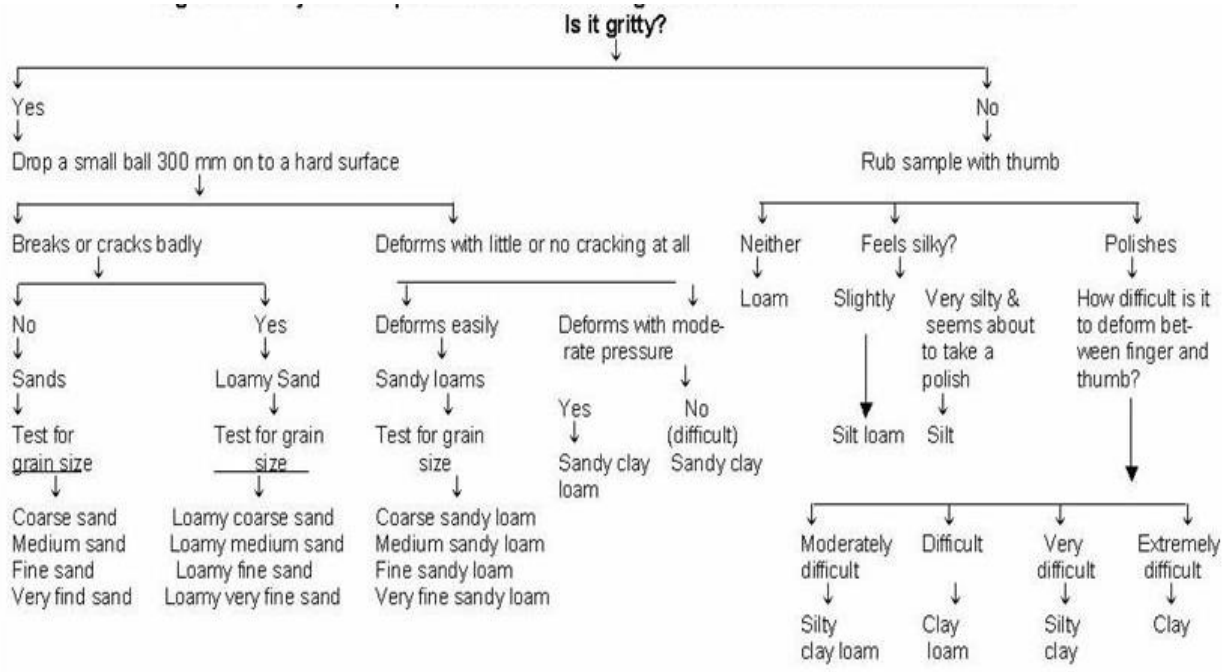


Figure 34 Systematic procedure for determining the soil texture of a moist mineral soil

10.2.5 Other Facilities:

For the given chak system, data about the following should be collected and should form a part of the design report:

(a) Roads

(b) Distance to nearest market

(c) Present area under well irrigation and number of wells

(d) Present area under lift irrigation and bandhara irrigation.

10.2.6 Crops:

Data of the present crops grown in each chak should be presented in the design report. The data can be obtained from the village records.

10.2.7 Surveying and Mapping:

Accuracy required for the design of community items is different from that required for the individual items of land forming. Separate surveys are therefore carried out for the two works.

10.2.8 Survey for Community Items:

For design of community items, maps are required in the scale of at least 1:1000 to 1:1250, with contours having an interval of 0.2 m to 0.3 m. Such contour maps can be produced either by Aerial Survey or Ground Survey.

(a) Aerial Survey: From rectified prints of aerial photographs, contour maps can be prepared by control survey on the ground. The survey of India provides the contour maps after aerial photography as well as ground control. Such maps are generally adequately accurate. This however requires planning many years in advance. The survey of India can also provide rectified prints from aerial photographs. With complimentary ground survey, accurate contour maps can be produced by the Land Development Divisions.

(b) Ground Survey: The procedure followed presently is to have a grid survey with block levels on 15m X 15m grid. From these, contour maps with an interval of 0.2 m to 0.3 m can be prepared. The procedure is adequate for the design of community items. The survey should however be carried out for the entire chak system. The closing of the benchmarks with reference to the outlet sill levels provided by the Construction Organization is most important. The design should not proceed unless this factor is satisfied. From this survey, contour maps with a contour interval of 0.2 m to 0.3 m should be prepared. However, taking into consideration the requirement of scale for the contour map of the chak and the contour map of the chak system, plotting for these two maps will be separately done as under:

For the map of the chak system the grid levels at 30 m. interval (omitting alternate levels) will be plotted on a scale of 1:2000 or 1:2500 and the contours drawn with 0.3 m interval. (If the command is big the map of chak system may be prepared to the scale of 1:4000 or 1:8000 and contours of 0.4 m or 0.6 m interval). For the contour map required for the individual chak, the entire grid levels will be considered (at 15 m interval) and contour map will be prepared with 0.2 m to 0.3 m contour interval to a scale of 1:1000 or 1:1250.

The above maps should be superimposed on village maps and following aspects be marked on it.

1) Alignment of Distributory / Minor / Subminor

2) Location of outlets with sill level and other structures on Distributory / Minor / Subminor

3) Un command portion

4) Gat number wise type of soil

5) Ridges, vallies, Nallas, depressions or ponds, hillocks, Goothan, Hutments

6) Location of existing wells

7) Trees and permanent structures.

After the survey, a tracing of the contour map of the chak / chak system with the signatures of the surveyor and the plotter and the Agricultural Supervisor / Junior Engineer, thereon should be prepared.

10.3 Layout of Chaks:

Following factors are considered for finalizing chak boundaries and total layout of chaks.

i) Topography (Ridges, vallies, local depressions, high patches, etc.)

ii) Maximum permissible area which can be irrigated in peak rotation by a prescribed discharge in a given flow period

iii) Maximum length of field channel

iv) The number of farmers to be served

v) Other factors like village boundary, road/railway lines, etc.

10.3.1 Topography:

Mark vallies, local depressions, gullies, natural drains, high patches, ponds, gaothans, roads, railway lines, village boundaries etc. in different colours on the contour plan so as to limit the boundary of the Chak to natural drain / village boundary / road / railway lines.

10.3.1.1 Maximum Permissible Chak Size:

The chak size plays an important role in the efficient scheduling of irrigation. It is the area served by an outlet. It depends mainly on discharge of the outlet, flow period, crop pattern and peak irrigation water requirements. For example, the Government of Maharashtra has standardized the capacity of the field channels at 30 l/s. Previously, the flow period in most of the projects used to be 12 days in a rotation period of 14 days. Now the flow period of 6 days in a rotation period of 14 days is adopted for chak design. With the discharge of 30 l/s and the flow period of 6 days in a rotation, the only variable factor in determining the chak size is the peak net irrigation requirement. Net irrigation requirement (NIR) based on modified Penman Method is worked out for crops as per the approved project-cropping pattern. This is generally the NIR at root zone (expressed in mm) considering effective rainfall and the special needs of different crops. Since the water is released at outlet head, the net irrigation requirement at outlet head has to be determined. This can be computed by applying efficiency factors, from field to turnout and from turnout to outlet. The field application efficiency (root zone to the turnout) depends on preparation of land, irrigation methods and the flow rate. It normally varies from 70% to 80%. With the developed lands and good irrigation method, 75% application efficiency can be achieved and may be adopted. The conveyance losses in field channel depend on length of field channel, soil strata, channel condition, type of lining, distribution of fields along the length of the channel which determine running time of each unit lengths of field channel, etc. However, average conveyance efficiency of field channel from the turnout to the out let may be taken as 85%. The efficiency from root zone to outlet is therefore 75% x 85% = 63.75%. The efficiency figures can be modified if specific data is available. The net irrigation requirement for every fortnight of year is calculated for the project crop pattern. Based on

this, the master statement of crop water requirement is prepared. The maximum value of the irrigation water requirement is then adopted for the determination of chak size.

One such sample calculation is presented in Table given in the end of this lecture.

As per Table Fortnightly Peak Net Irrigation Requirement for the given

crop pattern is in the 26th fortnight (17/12 to 31/12) and is 46610 m^3 per 100 ha of I.C.A.

NIR = 46610 m^3 for 100 ha of ICA

i.e. 466.10 m^3/ha of ICA

Assuming field application efficiency of 75% and average conveyance efficiency of field channel as 85%, the overall efficiency between outlet and root zone works out as 75% x 85% = 63.75% i.e. 0.6375.

NIR at outlet head = (466.10/0.6375) = 731 m^3

Water delivered at outlet

At the rate of 30 lps (108 m^3/hr) = 108 m^3 x 6 days (flow period) x 24 hrs

= 15552 m^3

Chak Size (ha of I.C.A.) = (15552/731) = 21.27 ha

If intensity of irrigation (ICA/CCA) for project under consideration is Say 80% then

Chak Size (ha of C.C.A.) = (21.27/0.8) = 26.58 ha.

Maximum chak size for the project is say 25 ha.

10.4 Length of Field Channel:

Excessive length of field channel results into more conveyance losses and complaints from tail Enders about non-receipt of desired discharge. Therefore, the maximum length of field channel in one stretch from outlet generally should not be more than 1000 m (1 Km).

10.4.1 Number of Farmers:

In canal irrigation, the water that is supplied at the Government outlet is to be shared equitably by all the beneficiary farmers. This involves understanding and cooperation and therefore the number of beneficiaries has to be reasonably small. Generally 10 to 15 beneficiaries can be organized properly for water sharing. The number of beneficiaries in a chak will depend upon the sizes of the holdings. Where the average size of holding is smaller, the chak size may be adjusted such that the maximum number of beneficiaries should not exceed 30.

10.4.2 Other Considerations:

As far as possible the chak should lie in one village only. Similarly roads, railway lines should be considered while fixing chak boundaries. As far as possible chak boundaries may be restricted upto road/railway line in order to avoid crossings. Considering above-mentioned factors the boundaries of the chaks be fixed and layout of chaks in the whole command of a given canal be finalized. The cost economics of OFD works should also have bearing while finalizing the chak area and layout.

10.4.3 Alignment of Water Courses and Field Channels:

After the layout of the chaks is prepared, the locations of the outlets, jointly decided by the concerned Organizations are marked on the contour plan. Following aspects may be considered while finalizing the location of the outlet.

i) The outlet to be located upstream of drop/fall on parent channel

ii) The FC should command the area within short distance (Say within 15m)

iii) As far as possible it should not cross borrow pit

iv) To avoid the road crossing on F.C., if possible, the location of the outlet should be taken d/s of the road.

If these locations are not suitable for the layout obtained earlier, changes are made by relocating the outlets and increasing the number where necessary.

The sill level (of the outlet) should be taken at or near the bed of the minor or distributory, so that the outlet can draw its full discharge of 30 l/s even when the minor is flowing half full. From the sill level, the bed level of the field channel near the outlet is obtained.

The alignment of the field channel is then marked along high ground so that it can command maximum area. As far as possible, it should be taken along the boundary of a holding so that the field is not artificially divided by the channel. The field channels will be aligned either along the ridge so that irrigation can be done on both sides or along the contour with irrigation only on one side, depending upon topography. The field channel should be marked down to each individual holding. It should be ensured that the turnout can be placed in the holding it serves and near the boundary. While marking the alignment of the field channel, it should be seen that the channel can command the fields included in the design. For this purpose preferably the water level in the field channel be kept as 15 cm higher than the ground, it is designed to serve.

A field channel must necessarily tail into a drain (natural or otherwise). In any case F.C. should not be used as a tail of minor or distributory.

In case, the field channel is being aligned on a sloping ground leaving some area above the field channel as uncommanded, then it is obligatory to provide a catch water drain along-side the field channel on the upstream side. It should terminate in a natural gully.

The marking of the alignment should be done by the SDO. The locations of the outlets and the alignments of the field channels should then be marked on site and verified by the Agricultural Supervisor/Junior Engineer and also by the SDO (and so certified) before the plans are submitted by SDO to DO for approval. The beneficiaries should also be consulted and their suggestions, if found suitable, may be incorporated. After these are approved, the location of the outlets can be finally informed to the Construction Organization so that the construction can proceed. If required, a joint inspection should be carried out by Executive Engineer of Construction Organization and the Divisional Officer of a Land Development Division. The approval of the Divisional Officer will be accorded on the plan (tracing on cloth/paper), on which locations of outlets and the alignments of field channels are shown, in ink.

10.5 Chak Water Delivery System – Channel Design

10.5.1 Introduction

Assured and timely irrigation water supply to each farm is the basic need for maximizing the agricultural production per unit area of irrigated land in command area. Properly designed and constructed water delivery system only can function efficiently and help to achieve above target. The system should be such that it will supply adequate water efficiently even at peak demand period upto farthest and highest location of each individual farm in command area under the outlet. The system should also be economical.

10.5.2 Elements of chak water delivery system:

Chak is the area under outlet. Following are the elements of the delivery system.

1) Channel for conveyance of water – to convey water from outlet to farm head.

2) Control structures – to control water distribution and velocities.

3) Crossings - for transportation facilities.

10.5.3 Channels for conveyance:

Channels for conveyance include watercourse and field channel upto farm gate. Equalizer is channel within the farm for internal distribution by the farmer. Field channels convey water from outlet to each farm gate. Watercourse is initial part of field channel near outlet which is dead channel not serving command area.

10.5.4 Planning of Field Channel:

Field channels form the tertiary distribution network in the canal system. These are the last link in the water delivery system of an irrigation network. The planning and design of field channels are, therefore, key issues, which determine the success of an irrigation project. Since the reliability of water supply and credibility of irrigation engineers is dependent on these issues, it is necessary to attend to planning and design of field channels, carefully and judiciously.

10.5.5 Data and maps for planning:

For planning of field channels in particular, following data and maps are necessary:

a) Contour maps of chak to the scale of at least 1:1000 to 1:1250 with contours having an interval of 0.2m to 0.3m. This map shall also show gut numbers and the field boundaries of gut numbers. The natural drains and nallas occurring within the chak shall also be marked on this map.

b) Statement showing names of beneficiaries and their gut numbers with respective ownership area.

c) Type of soil in chak command, as assessed in district soil survey maps. If these maps are not available type of soil shall be decided by taking trial pits.

10.5.6 Field verification of field channel alignment:

Layout and alignment of the field channel network within the chak is obtained as already described in Lec -15, "Chak layout and alignment of field channels." This layout and alignment of the field channels shall be verified on the field, before detailed survey and actual design of field channels is taken up in hand. This is necessary to accommodate the changes in ownership or division of ownership etc. The field verification of field channel layout helps to modify the alignment to avoid fruit bearing and any other trees or newly dug wells etc. on the F. C. alignment. Secondly, F. C. alignment may also be discussed with beneficiaries / members and office bearers of Water Users' Association related to the chak. This will be in line with participatory irrigation management and minimize the divergent views taken by beneficiaries during actual construction / taking over the area for management by the W.U.A.

10.5.7 Detailed survey along the alignment of F.C.:

Before the actual design of field channels is taken up in hand, the longitudinal section is run along the alignment recording spot levels at 30m interval. Cross section across the alignment may be taken at 60m interval and at the location of turnouts. The cross section may extend adequately on either side to judge the sill levels of turnouts, with respect to area it has to serve. The L section for each segment of field

channel is surveyed separately, with appropriate survey equipments. Trial pits, if necessary, be taken along the alignment of F.C. to access the soil variation and depth of black cotton soils.

10.5.8 Design of field channels:

The design of field channels envisages design of following three aspects,

a) Discharge

b) Cross section

c) Bed gradient

10.5.9 Design discharge of field channel:

The design prescription for the discharge of field channel varies from State to State. The planning commission has prescribed a range of 30 to 70 lit/sec depending upon the type of soil and crops to be served. In Odisha mostly the prescribed design discharge for field channel is 30 l/s

Cross section of field channel:

A trapezoidal cross section of field channel is most suitable for unlined field channels. The design parameters to design a trapezoidal cross section for unlined field channel are as follows:

a) Bed width (B),

b) Side Slope (Z:1, Horizontal : Vertical)

c) Rugosity coefficient (N)

d) Free board (FB)

e) Top width in banking (T)

Typical cross section of unlined field channel is shown in fig 35.

Figure 35 Typical cross section of unlined field channel

a) Bed width (B):

The bed width of field channel governs the total cross sectional area of field channel to be constructed i.e. it governs the earthwork quantities. It also governs the depth of water flow in the field channel i.e. it governs the driving head at turnout and also the velocity of flow in the field channel. Thus, this is an important dimension from economic as well as hydraulic design point of view. Minimum bed width of 30cm shall be provided in unlined field channel, which caters above requirements. But in very flat topography, this can be increased.

b) Side slope (Z: 1, Horizontal: Vertical)

The side slopes for the unlined field channel cross section are designed according to structural stability of soils through which field channel passes. The recommended side slopes in accordance with type of soil are given in Table 12.

Table 12Side slopes recommended for unlined field channels

Sr. No.	Type of soil	Side slope (Horizontal : Vertical)
1.	Fine Texture Soil (Black cotton soil)	2½ : 1
2.	Medium Texture Soil (Clay loam)	1½ : 1
3.	Coarse Texture soil and soft murum	1½ : 1
4.	Hard Murum	1 : 1

c) Rugosity coefficient (N):

Rugosity coefficient (N) is characteristic of the condition and type of contact surface. For unlined field channels, recommended values of rugosity coefficient (N) are given in Table 13.

Table 13Recommended values of N for field channel

Sr.No.	Type of surface	Recommended values of rugosity coefficient (N)
1	Earthen channel	0.04
2	Earthen channel with grass Soddling	0.04
3	Rock cuts Hard murum	0.04

4	UCR masonry lining OR Brick masonry lining	0.03
5	RCC half round pipe lining	0.022

d) Free board (FB):

Free board is a vertical distance between full supply depth (Y) and the top of retaining banks for field channel. This is necessary for preventing overtopping of banks under unprecedented conditions. For field channel in banking, the minimum free board of 30cm should be kept. For field channels in cutting, the minimum free board shall be about 15 cm to 20 cm, lesser free board may be adopted for field channels in cutting in murum. In case of field channels with R.C.C. half round pipe lining / UCR masonry lining minimum free board shall be 10 cm to 15cm.

e) Top width of section in banking (T):

The field channel cross section may be in full banking or in partial banking – partial cutting. The top width of banking section in such cases may be minimum 0.3 m and may increase upto 0.45 m in accordance with height of banking. Since, the seepage losses through banking are more, the height of banking may not be more than 1.0 m in any case.

10.5.10 Hydraulic design of field channels:

The field channels are designed as unlined, open channels to have a uniform flow. The hydraulic design of field channel is an iterative process to arrive at design discharge with an appropriate bed gradient which generates permissible, non erdodible velocity and results in minimum requirement of drop/falls structures. To determine the bed gradient to suit these requirements, is the key issue in the hydraulic design of field channel. The bed gradient (S) of field channel is the ratio of its vertical drop (H) for a length (L) of channel.

The gradient for each segment of field channel is designed separately. The gradient of field channel should give non-erodible velocity and adequate depth of water to provide sufficient driving head at each turnout to serve maximum area of every farm in the command with minimum land shaping. The maximum permissible gradient consistent with the maximum permissible velocities, shall be adopted wherever required so that the number of drop structures is minimized. To minimize the number of drop structures or falls, ground slope be adopted in the first trial as bed gradient. To obtain the best fit bed gradient for the given segment of field channel, following points are adhered to,

10.5.10.1 Non-erodible velocity:

The velocity in the unlined field channel has to be non-erodible. Hence, the permissible velocities have been recommended in the Table 14 for design purposes.

Table 14Permissible velocities in unlined channels in different soils

Sr.No.	Type of Soil Permissible	Velocity (m/s)

1.	Silt	0.45
2.	Black cotton soil (Fine texture soils)	0.5
3.	Clay loam	0.65
4.	Soft murum	0.8
5.	Grass sodded section	0.9
6.	Hard murum	1.0

10.5.10.2 Depth of water flow:

The gradient governs the depth of water-flow in the field channel and the depth of water flow in the field channel near turnout with reference to highest ground level in the farm governs the driving head for efficient water distribution through turnout. Hence, the field channel bed gradient should be such that it would evolve a field channel elevation near turnout to get a minimum driving head of 15cm.

10.5.10.3 The design process:

The commonly accepted formula for the hydraulic design of an open channel is Manning's formula as given below:

$$V = \frac{R^{\frac{2}{3}} S^{\frac{1}{2}}}{N}$$ Where,

V = Velocity of flow (m/sec.)

R = hydraulic mean depth = m.

A = Cross sectional area of water flow (m^2).

P = Wetted perimeter (m)

S = Bed Gradient

N = Rugosity of coefficient

The typical trapezoidal cross section of unlined field channel is shown in fig. The dimensions are decided in accordance with the discussions.

For the first trial,

1. Assume the natural ground slope along the F C alignment, to be the bed gradient (S) of field channel in that segment, and

2. Assume full supply depth of flow = Y meters. The cross sectional parameters in the Manning's formula are as below:

B = Bed width of field channel.

Y = Full supply depth

Z = Side slope of trapezoidal cross section of field channel.

A = Wetted cross section area = *(B + Z * Y) * Y*

P = Wetted perimeter = $B+2*Y*\sqrt{1+Z^2}$

R = hydraulic mean depth = $\frac{A}{P}$ m

N = Rugosity of coefficient

S = Bed gradient of field channel

= the natural ground slope in that segment (In the first instance of trial)

Then, using Manning's formula,

V = velocity of flow = $\frac{1}{N}R^{\frac{2}{3}}S^{\frac{1}{2}} m/\sec$

This trial would be successful & finally accepted for design if,

a. Q is nearly equal to 0.03 cumec.

b. V is within permissible, non-erodible range of velocity for soil type specified in Table.

c. Y, the full supply depth of flow near turnout is at-least 15cm higher than the ground level in the command of respective turnout. If there is no turnout to be served in the field channel segment, this criteria may be relaxed. If any of these requirements, is not fulfilled, next trial with appropriate depth of flow and bed gradient is conducted as above till the hydraulic and structural requirements of field channel design are satisfied. The calculated values are tabulated table 15 to 17 in the end of this lecture for 30 lps discharge and for different side slopes and for N values of 0.022, 0.03 and 0.04.

9.2.4 Longitudinal section of field channel:

The longitudinal section of field channel is finalized as given below. This will facilitate minimum drops/fall or zero drops which will reduce the cost of structure.

1. Plot the ground profile of field channel (main or branch) on L - Section sheet.

2. Mark turnout positions on the L-Section.

3. Divide the whole length of field channel into different reaches/segments having more or less uniform ground slope and workout respective ground slopes.

4. Mark outlet sill level of outlet at the start of FC / WC.

5. Decide bed gradient to be provided to FC / WC. As far as possible natural ground slope be adopted as bed gradient to minimize number of drops / falls. However, care should be taken that bed gradient should neither result in the velocity more than the permissible, nor it should result into full supply depth

less than 15cm if turnout is to be served at that chainage. If there is no turnout in a particular reach and strata is hard, bed gradient as steeper as possible (limiting it to natural ground slope) may be adopted even if the full supply depth in F.C. is less than 15cm provided the velocity is within permissible limits.

6. Too many changes in slopes are avoided to ease of construction and better hydraulic conditions.

7. Start marking F.C. bed profile considering designed bed gradient. If the bed gradient is flatter than the ground slope fall / drops will have to be proposed. The location of fall and its depth (bed fall) may be decided considering following guidelines:

a. Fall / drop should not be located U/s of turnouts.

b. The bed level U/s of fall / drop should at least be 10cm in cutting.

c. The depth of drop i.e. bed fall will be governed by the requirement of downstream turnout. Therefore considering downstream turnout, mark the bed profile from downstream turnout going upstream. If necessary more than one fall will have to be provided to avoid excessive height of drop. (i.e. 1 m).

d. Standardized fall / drop designs are available. Where actual bed fall required is different than standard design, the fall as per actual requirement be provided, however the design of next higher fall be adopted (e.g. if fall of 0.4m is necessary, provide 0.4m drop, but the design of 0.45m drop be adopted)

e. Try to provide a sloping bed drop (rapid) wherever F.C. is passing through hard strata like hard murum or soft rock etc. and no turnout is to be served.

DIVISION BOXES

Division boxes are used to divide or direct the flow of water between two or more canals or ditches. Water enters the box through an opening on one side and flows out through openings on the other sides. These openings are equipped with gates (see Fig. 36).

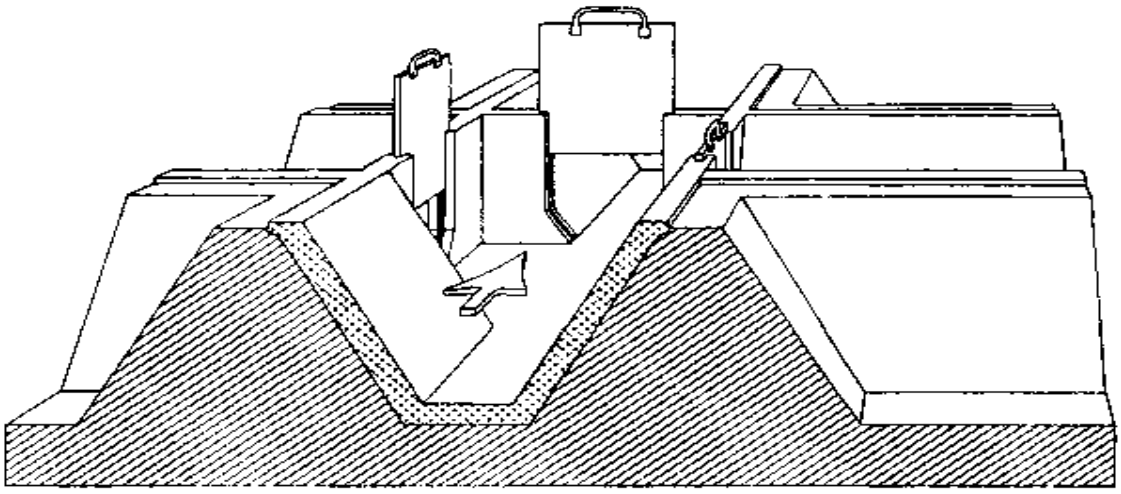


Figure 36A division box with three gates

10.5.11 Departure from designed alignment:

To attend better hydraulic functioning of field channels, it is necessary to give the accurate markout as per design and follow the same during construction with proper vigilance. The following tolerances may be accepted in case of construction of field channel during execution:

20 mm on straight section

50 mm on tangents

100 mm on curves

Departure from designed gradient: 20mm

In case of drops, division boxes, turnouts, crossings, the tolerance can be ±20 mm in elevation.

In case of measuring devices, the tolerance can be ± 5mm in elevation and ±5 mm in dimension.

Table 15Design of Field Channel for 30 lps discharge and bed width of 30 cm and n = 0.022

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(sqm)	m		m/s	cumec
0.3	0.094	1.5	100	0.022	0.041454	0.638922	0.064881	0.733264	0.030397
0.3	0.113	1.5	200	0.022	0.053054	0.707427	0.074995	0.571096	0.030299
0.3	0.126	1.5	300	0.022	0.061614	0.754299	0.081684	0.493641	0.030415
0.3	0.135	1.5	400	0.022	0.067838	0.786749	0.086225	0.443215	0.030067
0.3	0.143	1.5	500	0.022	0.073574	0.815594	0.090209	0.408547	0.030058
0.3	0.15	1.5	600	0.022	0.07875	0.840833	0.093657	0.382401	0.030114
0.3	0.156	1.5	700	0.022	0.083304	0.862466	0.096588	0.361387	0.030105
0.3	0.162	1.5	800	0.022	0.087966	0.884099	0.099498	0.344805	0.030331
0.3	0.166	1.5	900	0.022	0.091134	0.898522	0.101427	0.329275	0.030008
0.3	0.171	1.5	1000	0.022	0.095162	0.916549	0.103826	0.317288	0.030194

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(sqm)	m		m/s	cumec
0.3	0.09	2	100	0.022	0.0432	0.702492	0.061495	0.707514	0.030565
0.3	0.107	2	200	0.022	0.054998	0.778519	0.070644	0.548779	0.030182
0.3	0.119	2	300	0.022	0.064022	0.832184	0.076932	0.474299	0.030366
0.3	0.128	2	400	0.022	0.071168	0.872433	0.081574	0.427123	0.030397
0.3	0.135	2	500	0.022	0.07695	0.903738	0.085146	0.393109	0.03025
0.3	0.141	2	600	0.022	0.082062	0.930571	0.088185	0.367349	0.030145
0.3	0.147	2	700	0.022	0.087318	0.957404	0.091203	0.34782	0.030371
0.3	0.151	2	800	0.022	0.090902	0.975293	0.093205	0.330102	0.030007
0.3	0.156	2	900	0.022	0.095472	0.997653	0.095697	0.316748	0.030241
0.3	0.16	2	1000	0.022	0.0992	1.015542	0.097682	0.304637	0.03022

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q

(m)	(m)	1 in	1 in		(sqm)	m		m/s	cumec
0.3	0.086	2.5	100	0.022	0.04429	0.763124	0.058038	0.680726	0.030149
0.3	0.103	2.5	200	0.022	0.057423	0.854672	0.067187	0.530713	0.030475
0.3	0.1132	2.5	300	0.022	0.065996	0.909601	0.072554	0.456121	0.030102
0.3	0.1215	2.5	400	0.022	0.073356	0.954298	0.076869	0.410528	0.030115
0.3	0.129	2.5	500	0.022	0.080303	0.994686	0.080731	0.379394	0.030466
0.3	0.134	2.5	600	0.022	0.08509	1.021612	0.08329	0.35362	0.03009
0.3	0.139	2.5	700	0.022	0.090003	1.048538	0.085836	0.334031	0.030064
0.3	0.144	2.5	800	0.022	0.09504	1.075464	0.088371	0.318582	0.030278
0.3	0.148	2.5	900	0.022	0.09916	1.097004	0.090392	0.304925	0.030236
0.3	0.152	2.5	1000	0.022	0.10336	1.118545	0.092406	0.293561	0.030342

Table 16Design of Field Channel for 30 lps discharge and bed width of 30 cm and n = 0.03

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(m^2)	m		m/s	cumec

0.3	0.1103	1.5	100	0.03	0.051339	0.697692	0.073584	0.584823	0.030024
0.3	0.1324	1.5	200	0.03	0.066015	0.777375	0.08492	0.455002	0.030037
0.3	0.147	1.5	300	0.03	0.076514	0.830016	0.092183	0.392411	0.030025
0.3	0.1583	1.5	400	0.03	0.085078	0.870759	0.097706	0.353286	0.030057
0.3	0.1675	1.5	500	0.03	0.092334	0.90393	0.102148	0.325499	0.030055
0.3	0.1753	1.5	600	0.03	0.098685	0.932053	0.105879	0.304335	0.030033
0.3	0.1823	1.5	700	0.03	0.10454	0.957292	0.109204	0.28763	0.030069
0.3	0.1885	1.5	800	0.03	0.109848	0.979646	0.112131	0.273842	0.030081
0.3	0.194	1.5	900	0.03	0.114654	0.999477	0.114714	0.262133	0.030055
0.3	0.199	1.5	1000	0.03	0.119102	1.017505	0.117053	0.252051	0.03002

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(m^2)	m		m/s	cumec
0.3	0.1047	2	100	0.03	0.053334	0.768233	0.069425	0.562559	0.030004
0.3	0.1249	2	200	0.03	0.06867	0.85857	0.079982	0.437179	0.030021

0.3	0.1383	2	300	0.03	0.079744	0.918496	0.08682	0.377031	0.030066
0.3	0.1484	2	400	0.03	0.088565	0.963665	0.091904	0.339152	0.030037
0.3	0.1568	2	500	0.03	0.096212	1.001231	0.096094	0.312502	0.030067
0.3	0.1638	2	600	0.03	0.102801	1.032536	0.099562	0.292099	0.030028
0.3	0.17	2	700	0.03	0.1088	1.060263	0.102616	0.275937	0.030022
0.3	0.1756	2	800	0.03	0.114351	1.085307	0.105363	0.262703	0.03004
0.3	0.1806	2	900	0.03	0.119413	1.107668	0.107806	0.251495	0.030032
0.3	0.1852	2	1000	0.03	0.124158	1.12824	0.110046	0.241885	0.030032

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(m^2)	m		m/s	cumec
0.3	0.1004	2.5	100	0.03	0.05532	0.840671	0.065805	0.542822	0.030029
0.3	0.1192	2.5	200	0.03	0.071282	0.941912	0.075678	0.421342	0.030034
0.3	0.1316	2.5	300	0.03	0.082776	1.008688	0.082063	0.363125	0.030058
0.3	0.141	2.5	400	0.03	0.092003	1.059308	0.086851	0.326598	0.030048

0.3	0.1486	2.5	500	0.03	0.099785	1.100235	0.090694	0.300676	0.030003
0.3	0.1552	2.5	600	0.03	0.106778	1.135778	0.094013	0.281137	0.030019
0.3	0.161	2.5	700	0.03	0.113103	1.167012	0.096916	0.265617	0.030042
0.3	0.1662	2.5	800	0.03	0.118916	1.195014	0.09951	0.252878	0.030071
0.3	0.1708	2.5	900	0.03	0.124172	1.219786	0.101798	0.242058	0.030057
0.3	0.1749	2.5	1000	0.03	0.128945	1.241865	0.103832	0.232686	0.030004

Table 17Design of Field Channel for 30 lps discharge and bed width of 30 cm and n = 0.04

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(m^2)	m		m/s	cumec
0.3	0.1285	1.5	100	0.04	0.063318	0.763313	0.082952	0.475114	0.030083
0.3	0.1535	1.5	200	0.04	0.081393	0.853452	0.09537	0.368716	0.030011
0.3	0.1702	1.5	300	0.04	0.094512	0.913665	0.103443	0.317822	0.030038
0.3	0.1829	1.5	400	0.04	0.105049	0.959455	0.109488	0.285869	0.03003
0.3	0.1934	1.5	500	0.04	0.114125	0.997314	0.114433	0.263335	0.030053

0.3	0.2022	1.5	600	0.04	0.121987	1.029042	0.118544	0.246118	0.030023
0.3	0.21	1.5	700	0.04	0.12915	1.057166	0.122166	0.232481	0.030025
0.3	0.217	1.5	800	0.04	0.135734	1.082405	0.1254	0.221289	0.030036
0.3	0.2232	1.5	900	0.04	0.141687	1.104759	0.128252	0.211786	0.030007
0.3	0.229	1.5	1000	0.04	0.147362	1.125671	0.13091	0.203686	0.030015

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(m^2)	m		m/s	cumec
0.3	0.1213	2	100	0.04	0.065817	0.84247	0.078124	0.456487	0.030045
0.3	0.1441	2	200	0.04	0.08476	0.944435	0.089746	0.354069	0.030011
0.3	0.1593	2	300	0.04	0.098543	1.012411	0.097335	0.305179	0.030073
0.3	0.1706	2	400	0.04	0.109389	1.062946	0.102911	0.274297	0.030005
0.3	0.1801	2	500	0.04	0.118902	1.105432	0.107562	0.25268	0.030044
0.3	0.1881	2	600	0.04	0.127193	1.141209	0.111455	0.2362	0.030043
0.3	0.195	2	700	0.04	0.13455	1.172067	0.114797	0.223031	0.030009

0.3	0.2015	2	800	0.04	0.141655	1.201135	0.117934	0.212411	0.030089
0.3	0.207	2	900	0.04	0.147798	1.225732	0.120579	0.203249	0.03004
0.3	0.2121	2	1000	0.04	0.153603	1.24854	0.123026	0.195419	0.030017

bed width	normal depth	side slope	bed gradient	n	Area	P	R	V	Q
(m)	(m)	1 in	1 in		(m^2)	m		m/s	cumec
0.3	0.1158	2.5	100	0.04	0.068264	0.923602	0.073911	0.439914	0.03003
0.3	0.137	2.5	200	0.04	0.088023	1.037768	0.084819	0.340981	0.030014
0.3	0.151	2.5	300	0.04	0.102303	1.11316	0.091903	0.293711	0.030047
0.3	0.1615	2.5	400	0.04	0.113656	1.169704	0.097166	0.263987	0.030004
0.3	0.171	2.5	500	0.04	0.124403	1.220863	0.101897	0.243724	0.03032
0.3	0.1776	2.5	600	0.04	0.132134	1.256405	0.105169	0.227228	0.030025
0.3	0.184	2.5	700	0.04	0.13984	1.29087	0.10833	0.21457	0.030005
0.3	0.19	2.5	800	0.04	0.14725	1.323181	0.111285	0.204347	0.03009
0.3	0.195	2.5	900	0.04	0.153563	1.350107	0.113741	0.195486	0.030019

0.3	0.2	2.5	1000	0.04	0.16	1.377033	0.116192	0.18811	0.030098

10.6 Flow Measuring Devices for Field Channels

10.6.1 General

In any irrigation systems, there should be a commitment to deliver a specific amount of water in a specific time to the irrigators. This means flow volume is assured. Not only the management staff should be able to measure the stream flow rate, but also the irrigator should be able to verify that the promised stream flow (30 lps. in Maharashtra) is being delivered to him. This facility can create a confidence in the minds of farmer towards the system. Reasonable accurate water measurement is also necessary to ensure proper delivery schedules, to determine the amount of water delivered and to estimate or detect the conveyance losses. It also helps in field trials and evaluation of actual irrigation efficiencies, etc.

A measuring device is, therefore, fixed in the initial reach of the field channel system of every chak. The device should be located on a 10 to 20 m straight reach. If a drop is available in this portion, it can be combined with the measuring device.

If Self-Regulated (SR) outlet is used to deliver the water, separate measuring devices may not be necessary as this outlet delivers almost constant discharge (upto 10% variation) under given modular range.

A good measuring device indicates the discharge with preferably single guage reading and it should be reasonably accurate within the given range of discharge. The device should not be unduly sensitive to changes in the type of flow and levels of upstream and downstream, particularly the approach velocity in the upstream and some silting or erosion on the downstream.

For small discharges the above conditions are satisfied by the following measuring devices:

a) V-notch

b) Cut-throat flume

c) Replogle flume.

If drop/fall is available, V-Notch is suitable device. If not, Replogle Flume may be selected, as it is easy to construct, low in cost. The Cutthroat flume if available in pre-fabricated form can also be used provided setting is properly worked out and executed.

10.6.2 V-Notch:

Generally 90° V-notch is quite often used to measure small discharge (say upto 30 to 40 lps) in field channels where falls are available. The downstream water level must be at least 15 cm below the vertex or crest of the notch. This implies an available drop of about 45 to 50 cm. Advantages of V-notch are its low cost and ease in construction. Figure 37 shows the fixing of 90° V-notch in field channel.

19.1.1 Discharge Formula:

The Kindsvater-Shen formula for thin plate V-notch is:

$$Q = Ce.\frac{8}{15}\tan\frac{\alpha}{2}\sqrt{2g}.H^{5/2}$$

Here α is the angle of notch. For a 90° notch the formula becomes,

$$Q = Ce.\frac{8}{15}\sqrt{2g}.H^{5/2}$$

In which

Q = discharge in cumec

Ce = Co-efficient of discharge, and

H = effective head, m = h + kh

(For a 90° notch, kh = 0.85 mm, or 0.085 cm)

g = 9.81 m/s^2

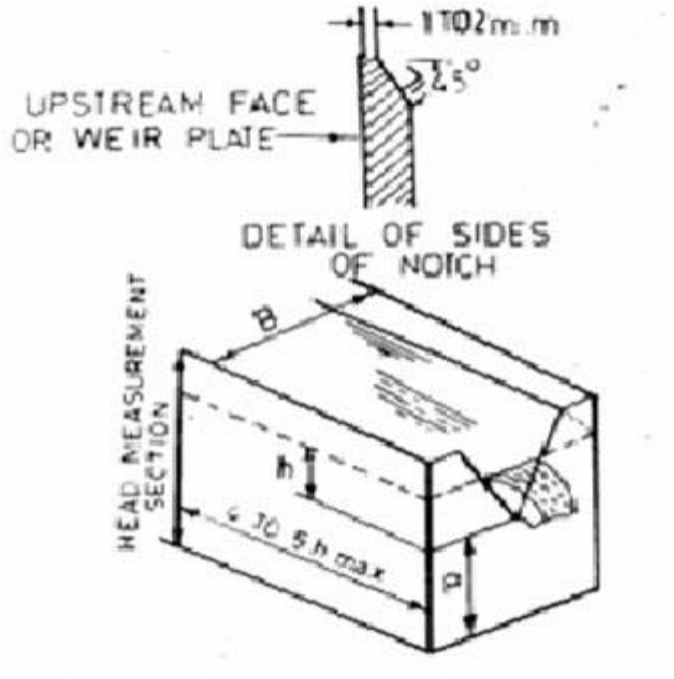


Figure 37 Sharp crested 90^O V notch

For a 90° notch, the co-efficient of discharge Ce is a function of two variations h/ p and P/B.

In which,

P = height of the vertex of the notch above the channel bed

B = Width of the approach channel

h = head above the vertex of the notch measured at a distance 4 to 5 times h_{max} u/s of the notch

For a 90° V-notch, the value of co-efficient of discharge Ce varies from 0.58 to 0.61 with following limitations.

a) h/p should be limited from 0.2 to 2.

b) p/B should be limited from 0.1 to 1

c) h should not be less than 6 cm

d) p should be nearly 10 cm

e) The nappe should be fully ventilated.

In general, the approach channel should be smooth, straight and rectangular for a reach not less than 20 times h_{max}, when B/h_{max} is less than 3 and/or h_{max}/p is greater than 1 (which is generally the condition).

Table-18 gives the discharge for head h varying from 6 cm to 30.5 cm for a 90°V-notch taking Co-efficient of discharge Ce equal to nearly 0.68 (for greater accuracy, refer IS-9101 – 1979. For a flow range of 30 to 70 lps in 90°V-notch, the depth of flow should be 21.5 to 30.5 cm. "Liquid Flow Measurement in Open Channels using Thin Plate Weirs" and establish the exact value of Ce for the given condition of the setting).

Precaution must be taken to see that the weir plate is truly vertical after installation and at equal distance from channel sides. The plate should be firmly embedded either in concrete or masonry. The edges of the notch should be rounded smoothly so that small eddies are not formed near the weir. The sharp-edge is chamfered on down-stream side.

Table 18Discharge Table for Sharp - Crested 90º V notch

Head	Discharge	Head	Discharge	Head	Discharge	Head	Discharge
H (cm)	(lps)	h (cm)	(lps)	h (cm)	(lps)	h (cm)	(lps)
6.0	1.3	12.5	7.7	19.0	21.7	25.0	43.2
6.5	1.5	13.0	8.5	19.5	23.2	25.5	45.4
7.0	1.8	13.5	9.3	20.0	24.7	26.0	47.6
7.5	2.2	14.0	10.2	20.5	26.3	26.5	49.9
8.0	2.6	14.5	11.1	21.0	27.9	27.0	52.3
8.5	3.0	15.0	12.1	21.5	29.6	27.5	54.8
9.0	3.4	15.5	13.1	22.0	31.4	28.0	57.3
9.5	3.9	16.0	14.2	22.5	33.2	28.5	59.9

10.0	4.4	16.5	15.3	23.0	35.0	29.0	62.6
10.5	5.0	17.0	16.5	23.5	37.0	29.5	65.3
11.0	5.6	17.5	17.7	24.0	39.0	30.0	68.1
11.5	6.2	18.0	19.0	24.0	39.0	30.5	71.0
12.0	6.9	18.5	20.3	24.5	41.0		

10.6.3 Cut-Throat Flume:

Cut-throat flume have been developed to over come the difficulties experienced in construction of the Parshall flumes. The shape of Parshall flume especially its bottom, presents some problems of construction in the interior places, where good workmanship is not available. In Cut-throat flume, there are only two sections, a converging inlet section and a diverging outlet section. The floor of the flume is horizontal. Since the flume has no longitudinal throat portion, it is named "Cut-throat Flume". Advantages of the Cut-throat flume over Parshall flume are:

- Ease of construction
- Angles of convergence and divergence remain the same for all size
- The rating of intermediate sizes can be developed from the available rating equations.
- It gives nearly as accurate measurements as Parshall flume in free flow condition for smaller throat widths (5% errors).

The diagrammatic sketch of the Cut-throat flume is shown in Figure 38. L is the total length of the flume. W is the throat width, L_1 and L_2 are the length of converging and diverging sections and La and Lb are the upstream and downstream gauge locations. Cut-throat flume is recognized by its throat width W and length L. In field channels 10x90 cm and 20x90 cm flumes can be used which can measure a discharge upto 54 lps and 115 lps respectively under free flow condition. In Table 19 various dimensions for 10x90 cm and 20x90 cm cut-throat flumes are given. However, in order to minimize the problem of head loss and afflux it is advisable to use 20x90 cm flume. The total height of the flume from bottom may be restricted to 35 cm for economy.

Table 19Dimensions for 10x90 cm & 20x90 cm Cut-Throat Flumes

Throat WidthW (cm)	L(cm)	L_1(cm)	L_2(cm)	L_a(cm)	L_b(cm)	B(cm)
10	90	30	60	20	50	30

20	90	30	60	20	50	40

For both 10x90 cm and 20x90 cm Cut-throat flume, free flow limit (h_b/h_a) is 65.3%, it is observed that cut-throat flumes are not suitable for measurements of discharges under submerged flow conditions i.e. for h_b/h_a more than 65%. However, in order to compute discharges under submerged flow condition, a submerged flow equation is proposed in literature. It still needs full rectification.

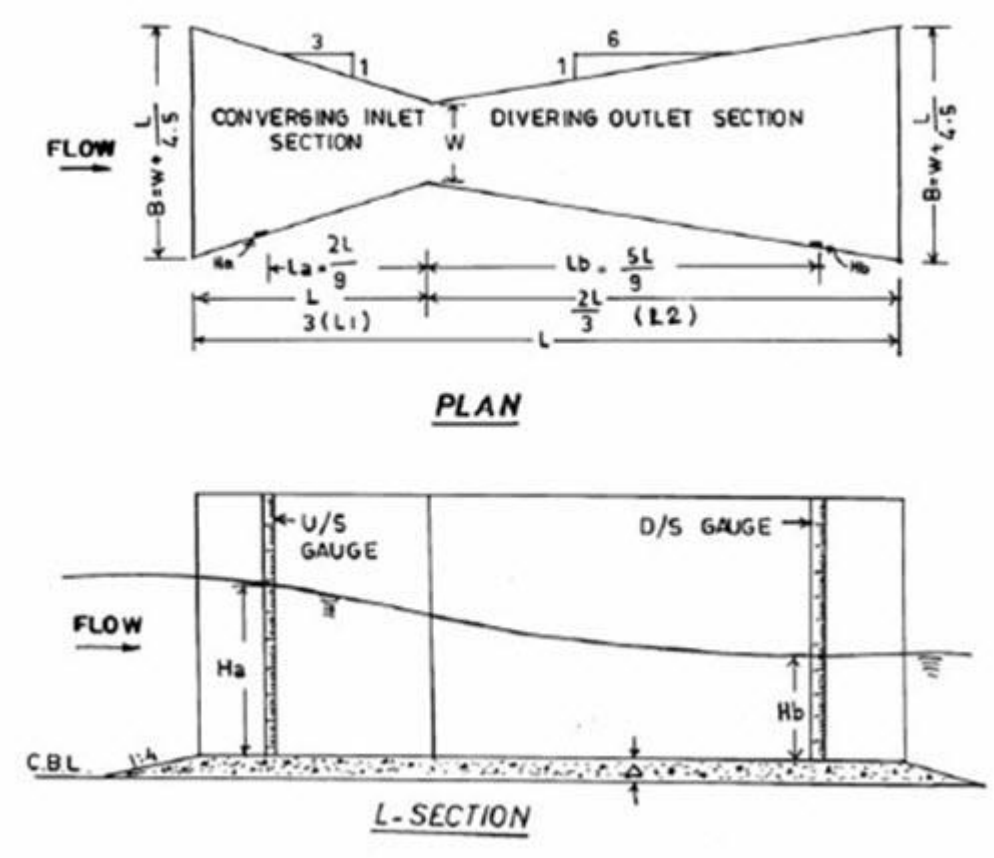


Figure 38 Schematic of Cut throat flume

The discharge equation under free flow conditions is as below:

$Q = C\ Ha^n$

Where,

Q is discharge in m^3/sec.

H_a is upstream gauge reading in m.

C is discharge coefficient and n is exponent depending upon flume length.

The value of discharge coefficient C is calculated as:

$C = K.W^{1.025}$

K is coefficient depending upon length of flume and W is throat width in m.

For 90cm long flume value of exponent n and coefficient K are 1.843 and 3.89 respectively.

Table 20Free Flow Discharge for 10x90 cm and 20x90 cm Cut-Throat Flumes

Upstream Head Ha (cm)	Discharge (lps)		Upstream Head Ha (cm)	Discharge (lps)	
	10 x 90 cm	20 x 90 cm		10 x 90 cm	20 x 90 cm
5.0	1.5	3.0	20.5	19.8	40.3
5.5	1.8	3.6	21.0	20.7	42.1
6.0	2.1	4.2	21.5	21.6	44.0
6.5	2.4	4.8	22.0	22.5	45.9
7.0	2.7	5.6	22.5	23.5	47.8
7.5	3.1	6.3	23.0	24.5	49.8
8.0	3.5	7.1	23.5	25.5	51.8
8.5	3.9	8.0	24.0	26.5	53.9
9.0	4.3	8.6	24.5	27.5	55.9
9.5	4.8	9.8	25.0	28.5	58.1
10.0	5.3	10.7	25.5	29.6	60.2
10.5	5.8	11.7	26.0	30.7	62.4

11.0	6.3	12.8	26.5	31.8	64.6
11.5	6.8	13.9	27.0	32.9	66.9
12.0	7.4	15.0	27.5	34.0	69.2
12.5	8.0	16.2	28.0	35.2	71.5
13.0	8.5	17.4	28.5	36.3	73.9
13.5	9.2	18.7	29.0	37.5	76.3
14.0	9.8	19.9	29.5	38.7	78.8
14.5	10.5	21.3	30.0	39.9	81.3
15.0	11.1	22.6	30.5	41.2	83.8
15.5	11.8	24.1	31.0	42.4	86.3
16.0	12.5	25.5	31.5	43.7	88.9
16.5	13.3	27.0	32.0	45.0	91.5
17.0	14.0	28.5	32.5	46.3	94.2
17.5	14.8	30.1	33.0	47.6	96.9
18.0	15.6	31.7	33.5	48.9	99.6

18.5	16.4	33.3	34.0	50.3	102.3
19.0	17.2	35.0	34.5	51.7	105.1
19.5	18.0	36.7	35.0	53.0	107.9
20.0	18.9	38.5	35.5	54.4	110.8

For free flow condition, discharge equation for 10x90 cm flume will become.

$Q = 0.3672\ Ha^{1.843}$ (M.K.S. units)

Discharge equation for 20x90 cm flume under free flow condition will be:

$Q = 0.7473\ Ha^{1.843}$ (M.K.S. units)

For better accuracy, upstream head H_a should be restricted to 0.4 L i.e. 36 cm. Free flow discharge tables for 10x90 cm and 20x90 cm cut-throat flume are given in Table.

Regarding gauge locations, in Cut-throat flume u/s gauge is located in converging section at a distance equal to 2L/9 measured along the axis of the flume from the throat. The d/s gauge is located in the diverging section at a distance 5L/9 from the throat.

19.2.1 Computation of Discharge for Submerged Flow Condition:

Discharge equation for submerged flow condition (Hb/Ha)100>65%) through a Cut-throat flume is

$$Qs = \frac{Cs(Ha - Hb)^n}{(-\log_{10} S)^{Ns}}$$

Where,

Qs = discharge under submerged flow condition in m^3/s,

Cs = Submerged flow discharge coefficient,

Ha = U/s head in m

Hb = D/s head in m

n = free flow exponent depends upon flume length L,

S = Actual submergence in fraction = (Hb/Ha)

Ns = Submerged flow exponent depends upon flume length L,

$Cs = Ks\ W^{1.025}$

Ks = Submerged flow coefficient depends upon flume length L and,

W = Throat width in m.

Submerged flow discharge equation for a given Cut-throat flume of size W x L can be developed similar to as for free flow conditions. However, it is observed experimentally that accuracy of flow measurement by using Cut-Throat flume is doubtful under submerged condition and hence not discussed. It is also advised to avoid submerged flow condition in Cut-throat flumes as far as possible. Example 1 explains how to establish submerged flow discharge equation for a given flume size W x L and then to compute discharge for observed gauge readings i.e. Ha and Hb.

Example 1:

Establish submerged flow discharge equation for 20 x 90 cm Cut-throat flume and compute discharge if measured gauge readings are as below:

Ha = 20.0 cm Hb = 16.0 cm.

Solution:

Flume size under consideration is 20 x 90 cm. For flume length 90 cm,

n = 1.843

Ns = 1.483

ks = 2.15

W = 20 cm = 0.2 m.

$Cs = Ks\ W^{1.025} = 2.15 \times 0.2^{1.025} = 0.413$

Submerged flow discharge equation for flume size 20 x 90 cm is:

$$Qs = \frac{Cs(Ha - Hb)^n}{(-\log_{10} S)^{Ns}}$$

Calculation of discharge if Ha = 20.0 cm and Hb = 16.0 cm

S = (16/20) = 0.8 (Submerged flow condition)

Put values of Ha, Hb and S in the submerged flow discharge equation, Ha = 20.0 cm = 0.2 m. Hb = 16.0 cm = 0.16 m.

$$Qs = \frac{0.413\ (0.2 - 0.16)^{1.843}}{(-\text{Log}_{10}0.8)^{1.483}} = 0.0349 m^3/S$$

Qs = 34.9 l.p.s.

19.2.2 Upper Limit for U/s Head Ha and Submergence S:

For flow measurement through a Cut-throat flume, the u/s head Ha should not exceed 0.4 x L and submergence should not be more than 95%.

19.2.3 Setting of Cut-Throat Flume for Free Flow Condition:

It is convenient to use Cut-throat flumes for free flow condition. Setting (Δ) of the flume means the height of sill (leveled floor of the flume) above the canal bed level. Setting (Δ) is calculated for the

maximum discharge, Q max, supposed to flow in the canal. Setting involves the selection of appropriate flume size also.

Steps involved in computation of setting (Δ) are:

i) Select the flume size

ii) For Q max and selected flume size, find Ha required for free flow condition from discharge table.

iii) Find max. value of Hb for free flow to occur i.e. Hb = free flow submergence limit X Ha.

iv) At this limiting condition, the water surface at d/s gauge location coincides with the normal depth line i.e. Yn i.e. full supply depth in channel

v) Then setting $\Delta = Yn - Hb$

vi) Depth of flow in the u/s of the flume, D will be : $D = Ha + \Delta$

vii) Afflux caused by the flume Δh will be; $\Delta h = D - Yn$.

viii) For afflux Δh, check whether sufficient free board is available or not in the u/s of the flume if sufficient free board is not available select the bigger size flume and repeat the steps.

As it is likely that flume may settle down in due course of time, or there may be vegetation growth and silting in the d/s side (which may increase the submergence) it is the practice to set the flume little bit higher than the setting (Δ) worked out.

19.2.4 Location of the Flume:

i) The flume should not be placed too near the off – taking point because the afflux caused due to the installation/construction of flume may decrease the driving head at head regulator or out-let head. In any channel the distance of Cut-throat flume from off-taking point should be calculated taking into account the afflux, back water length and allowable decrease in driving head.

The length of backwater profile can be computed by direct step method given in any standard book on Open Channel Flow. However, an approximate method for computation of length of backwater profile in small canals is given below:

$L = (KX/S)$

Where,

L = length of backwater profile = distance of flume from off-taking point in m.

K = a coefficient = 1.5 to 1.9

X = depth u/s of flume – allowable depth d/s of off-taking point in m

S = bed slope of the canal.

Allowable depth d/s of off-taking point can be determined by knowing the water surface level u/s of off-taking point and minimum driving head required between parent channel and off-taking channel. (Ref. P.W.D. Hand Book, Volume II (1960). Govt. of Maharashtra, Page 685)

At the planning stage, if topography allows, afflux due to flume can be accommodated at d/s of flume by lowering the bed level of field channel. This will allow to install the flume not far away from the outlet.

ii) Flume should be installed/constructed in a sufficient straight reach.

Example 2:

Set a cut-throat flume 10 x 90 cm to measure a discharge of 30.0 lps flowing in a field channel with normal depth 18.0 cm. Make a comparative study with flume size 20 x 90 cm also.

Solution:

Q = 30.0 lps and Yn = 18.0 cm. (i.e. normal full supply depth)

i) from free flow discharge table for flume size 10 x 90 cm and discharge 30.0 lit/sec,

Ha = 26.0 cm

ii) For flume length 90 cm submergence transition.

St = 65.3% or 0.653

iii) Maximum value of d/s head Hb for the free flow condition to exist.

Hb = St x Ha = 0.653 x 26.0 = 17.0 cm.

iv) Height of sill (flat bottom) above canal bed,

setting Δ = Yn – Hb = 18.0 – 17.0 = 1.0 cm.

v) Depth u/s of flume,

D = Ha + Δ = 26.0 + 1.0 = 27 cm.

vi) Affux Δ H = D - Yn = 27.0 – 18.0 = 9.0 cm.

The comparative study of 10 x 90 cm and 20 x 90 cm flume sizes for free flow condition in the field channel under consideration is made in the table below:

Steps	Particulars	Flume size	
		10 x 90 cm	20 x 90 cm
i)	U/s head Ha	26.0 cm	17.5 cm
ii)	Transition Submergence St (fraction)	0.653	0.653
iii)	D/s head Hb = St x Ha	17.0 cm	11.5 cm
iv)	Setting Δ = Yn – Hb	1.0 cm	6.5 cm
v)	U/s depth D = Ha + Δ	27.0 cm	24.0 cm

vi)	Afflux Δ H = D – Yn	9.0 cm	6.0 cm

Important Points:

i) Cut-throat flumes have the advantage over Parshall flumes in the layout of the structure i.e. the floor is flat bottom which facilitates the construction or fabrication simple. Cost of the flumes also reduces considerably.

ii) As the angle of convergence (3:1) and divergence (6:1) are same for all flume sizes, even if in the construction the throat width is different than designed, there is a flexibility of using the same flume with modified discharge tables.

10.6.4 Replogle Flume:

Replogle flume is broad crested weir, having a sill and ramp with slope 3:1 (3 Horizontal to 1 vertical). Profile and cross section of Replogle flume are given in Figure 39. The sides of the channel are also the sides of the flume. In the Figure, different abbreviations used are follows:

d = constructed depth of channel:

D1 = upstream water depth,

F1 = actual free broad,

Y1 = gauge reading,

L = sill length,

ΔY1 = Loss of head caused by the flume,

S = sill height,

dm = normal depth of flow,

Ramp length = 3xS = Three times the sill height (ramp length),

B1 = channel bottom width,

B3 = Channel width at sill level or sill width and

Z = channel side slope.

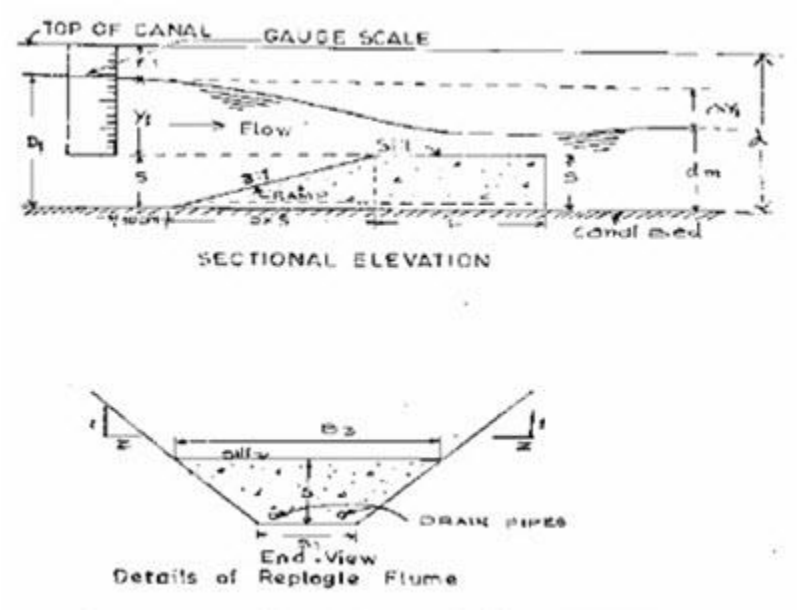


Figure 39 Details of Replogle flume

The gauge is located at a distance of 30 cm upstream of the ramp and its Zero must coincide with the sill level. The discharge equation, which consists critical flow area and critical depth is complicated due to the trapezoidal shape of flow area and hence is not given here. However, in Table 21, discharge are given for corresponding gauge (Y1) for three sets of sill heights (S) and sill lengths (L) for a channel with bottom width of 30 cm and side slopes 0.5 : 1, 1 : 1, 1.5 : 1 and 2 : 1.

Modular Limit:

The sill height (S) is the most important design dimension for which the flume is very sensitive. Replogle flume operates satisfactorily upto 85% submergence i.e. the downstream water head should not be more than 85% of the upstream water head, both measured above the sill level. In other words loss of head ΔY1 should be least 15% of the gauge reading Y1. Care must be taken that the sufficient free board is available to accommodate upstream depth D1 (d1 = s + Y1) for the maximum designed discharge.

Table 21Discharge for Replogle Flumes in Field Channels

Discharge Q (lps)	Gauge Reading Y1 (cm)			
	0.5:1.0	1.0:1.0	1.5:1.0	2.0:1.0
6	3.8	3.0	2.5	2.2
8	4.5	3.6	3.1	2.7
10	5.2	4.2	3.5	3.1
12	5.9	4.7	4.0	3.5
14	6.5	5.2	4.4	3.8

16	7.0	5.6	4.8	4.2
18	7.6	6.0	5.1	4.5
20	8.1	6.5	5.5	4.8
22	8.6	6.8	5.8	5.1
24	9.0	7.2	6.1	5.4
26	9.5	7.6	6.5	5.7
28	9.9	7.9	6.8	5.9
30	10.4	8.3	7.0	6.2
32	10.8	8.6	7.3	6.4
34	11.2	8.9	7.6	6.7
36	11.6	9.3	7.9	6.9
38	12.0	9.6	8.1	7.2
40	12.3	9.9	8.4	7.4
42	12.7	10.2	8.6	7.6
44	13.1	10.4	8.9	7.8
46	13.4	10.7	9.1	8.0
48	13.8	11.0	9.4	8.2
50	14.1	11.3	9.6	8.5
52	14.4	11.5	9.8	8.7
54	14.7	11.8	10.1	8.8
56	15.1	12.0	10.3	9.0
58	15.4	12.3	10.5	9.2

60	15.7	12.5	10.7	9.4

Advantages:

− Simple in construction and cheap in cost

− No upstream approach transition is required as the section of the flume is same as the section of the channel

− Modular limit (free flow limit) is higher (upto 85%) the Parshall flume and Cut-throat flume.

Replogle Flume for Field Channels:

Recommended size of Replogle flume for the measurement of discharge in field channels (Bottom width B1 = 0.3 m) is with sill S as 0.2 m and sill length L as 0.5 m. The discharge table, for channel side slopes 0.5:1.0, 1.0:1.0, 1.5:1.0, 2.0:1.0 and is given in Table-21.

Construction:

Replogle flume can be constructed either in masonry or in concrete. But care must be taken to provide accurate side slopes throughout the length of flume, finishing, curing, etc. the sill height (S) should not change more than 1 percent. Wall Mounted Gauge scale is mounted on the sidewall of the channel at the prescribed location. As sidewalls of the channel are inclined, scale should be either calibrated to read vertical depths, or correction factor should be applied.

10.7 Lining watercourses and field channel

10.7.1 General

A watercourse, as defined in the Northern India canal and drainage act, means any channel which is supplied with water from a canal but which is not maintained at the cost of the state government and all subsidiary works belonging to any such channels. The watercourses pass through the common land and are maintained by the farmers. Field channels carry water to the individual fields from the watercourse. In irrigated rice areas of the south, however, field channels are normally absent and the conventional practice is to irrigate from field to field .the overflow from the upper field irrigates the adjoining lower field and so on successively.

10.7.2 OBJECTIVES OF LINING

1) To control seepage

2) To prevent water logging

3) To increase the capacity of canal

4) To increase the command area

5) To protect the canal from the damage by flood

6) To control the growth of weeds.

10.7.3 ADVANTAGES OF LINING

1) It reduces the loss of water due to seepage and hence the duty is enhanced.

2) It controls the water logging and hence the bad effects of water logging are eliminated.

3) It provides smooth surface and hence the velocity of flow can be increased.

4) Due to the increased velocity the discharge capacity of a canal is also increased.

5) Due to the increased velocity, the evaporation loss also be reduced.

6) It eliminates the effect of scouring in the canal bed.

7) The increased velocity eliminates the possibility of silting in the canal bed

8) It controls the growth of weeds along the canal sides and bed.

9) It provides the stable section of the canal.

10) It reduces the requirement of land width for the canal, because smaller section of the canal can produce greater discharge.

11) It prevents the sub-soil salt to come in contact with the canal water.

12) It reduces the maintenance cost for the canals.

10.7.4 DISADVANTAGES

1) The initial cost of the canal lining is very high. So, it makes the project very expensive with respect to the output.

2) It involves much difficulties for repairing the damaged section of lining.

3) It takes too much time to complete the project work.

4) It becomes difficult, if the outlets are required to be shifted or new outlets are required to be provided, because the dismantling of the lined section is difficult.

10.7.5 TYPES OF LINING

The following are the different types of linings, which are generally recommended according to the various site conditions.

1) Cement concrete lining

2) Pre-cast concrete lining

3) Cement mortar lining

4) Brick lining

5) Boulder lining

10.7.6 CEMENT CONCRETE LINING

This lining is recommended for the canal in full banking. The cement concrete lining in widely accepted as the best impervious lining. It can resist the effect of scouring and erosion very efficiently. The velocity of flow may be kept above 2.5m/sec. It can eliminate completely growth of weeds. The lining is done by the following steps,

10.7.6.1 Preparation of sub-grade

The sub-grade is prepared by ramming the surface properly with a layer of sand (about 15cm). Then slurry of cement and sand (1:3) is spread uniformly over the prepared bed.

10.7.6.2 Laying of concrete

The cement concrete of grade M is spread uniformly according to the desired thickness ((generally, the thickness varies from 100mm to 150mm). After laying, the concrete is tapped gently until the slurry comes o the top. The curing is done for two weeks. As the concrete is liable to get damaged by the

change of temperature, the expansion joints are provided at appropriate places. Normally no re-inforcement is required for this cement concrete. But in special cases a network of 6 mm diameter rods may be provided with spacing 10 cm center to center.

10.7.7 PRE CAST CONCRETE LINING

This lining is recommended for the canal in full banking. It consists of pre-cast concrete slabs of size 60cm´60cm´5cm, which are set along the canal bank and bed with cement mortar (1:6). A network of 6mm diameter rod is provided in the slab with spacing 10cm center of center. The proportion of the concrete is recommended as 1:2:4. Rebates are provided on all the four sides of he slab so that proper joints may be obtained when they are placed side by side the joints are finished with cement mortar (1:3). Expansion joints are provided at a suitable interval.

The slabs are set in the following sequence

The sub- grade is prepared by properly ramming the soil with a layer of sand. The bed is leveled so that the slabs can be placed easily.

The slabs are stacked as per estimate along the course of the canal. The slabs are placed with cement mortar (1:6) by setting the rebates properly. The joints are finished with cement mortar (1:3).

The curing is done for a week.

10.7.8 CEMENT MORTAR LINING

This type lining is recommended for the canal fully in cutting where hard soil or clayey is available. The thickness of a cement mortar (1:4) is generally 2.5cm. The sub-grade is prepared by ramming the soil after cutting. Then, over the compacted sub-grade, the cement mortar is laid uniformly and the surface is finished with neat cement polish. The lining is impervious, but is not durable. The curing should be done properly.

10.7.9 BRICK LINING

This lining is prepared by the double layer brick laid with cement mortar (1:6) over the compacted sub-grade. The first class bricks should be recommended for the work. The surface of the lining is finished with cement plaster (1:3). The curing should be done perfectly.

This lining is always preferred for the following reasons,

1) This lining is economical.
2) Work can be done quickly.
3) Expansion joints are not required.
4) Repair work can be done easily.
5) Bricks can be manufactured from the excavated earth near the site.

However this lining has certain disadvantages,

1) It is not completely impervious.
2) It has low resistance against erosion.
3) It is not so much durable.

10.7.10 BOULDER LINING

In hilly areas where the boulders are available in plenty, this type of lining is generally recommended. The boulders are laid in single or double layer maintaining the slope of the banks and the bed level of the canal. The joints of the boulders are grouted with cement mortar (1:3). Curing is necessary in this lining too. This lining is very durable and impervious. But the transporting cost the material is very high. So, it cannot be recommended for all cases.

Manning's N value for different types of lining:

The Rugosity co-efficient to be used in the design of dimensions of lines channel are tabulated below.

Table 22Recommended values of N for field channels

S.No.	Types of surface lining	N
1.	Half round RCC spun pipes	0.024
2.	Pre-moulded PCC trapezoidal sections or PCC soil cement slabs or Shahabad stone or concrete cast in situ	0.025
3.	UCR Masonry	0.03

11 POST CONSTRUCTION EMERGENCY PREPAREDNESS

11.1 TANK BUNDS/EARTHEN CHECK DAMS

The personnel in charge of maintenance of structures/works, particularly Tank Bunds, Earthen Check Dams should have some basic knowledge on the common types of emergencies and practical methods of remedial measures to save the structures from imminent failure.

The following are some of the common types of emergencies and the remedial measures to address them effectively:

11.2 LONGITUDINAL AND TRANSVERSE CRACKS IN THE EMBANKMENT

Sometimes during hot summer months, cracks are noticed on the embankment. Due to clayey nature of soil used in the construction of embankment, such cracks occur due to high temperature, which tends to close during colder season.

Other types of cracks are caused due to differential settlement between adjacent lengths of embankment; at junctions of earth and masonry / concrete structures due to non uniform compaction (to its full width) of the successive layers of earth fill. The most serious cracks are those which run transversely creating a path across the embankment for the passage of seepage water. Longitudinal cracks are also a cause of concern.

Remedial Measures for Treatment of Cracks: The following measures should be taken promptly whenever cracks (other than the cracksassociated with high temperature and which close during cold weather) are observed in the embankment:

- Find approximate depth of crack by excavating an inspection pit.
- Excavate the cracked reaches in the form of a trench up to the bottom of crack.
- Fill each trench with good soil/semi pervious soil in layers of 10 cm thickness duly compacted manually with hand rammers. Compaction can be done even by persons by tamping with their gum boots put on their feet.
- If the depth of cracks is substantial, say about 60 cm or more, "clay-cement-water mix" injection method may be adopted. This is done by driving pipes into the cracks at about 90 cm spacing and then manually pouring the fluid mix of clay - cement - water into the pipes. The fluid mix of cement, clay, and water is prepared in a bucket, stirred well, and then pored into pipes.
- Treatment of deep cracks is most effectively done by excavating trenches in the reaches (having cracks) to a depth of about 60 cm : exposing the cracks at the bottom of trenches ; and then filling trenches with a solution of very fine clay power, known as "bentonite" (which is easily

available in the market) and water. Proportioning of bentonite powder and water should in the range of 1:14 viz 1 part of bentonite powder and 14 parts of water. This mixture should be prepared in a bucket and thoroughly stirred and then poured into trenches. Gradually, the bentonite - water mix solution will penetrate into the cracks right to their bottom, filling these completely.

- When no solution is left in the trenches, suitable soil should be placed in layers in the respective trenches and eachlayer compacted well with hand rammers right up to the top of embankment.
- • Sometimes, it is more expedient to treat the longitudinal and transverse cracks by pouring a well stirred mixture of fine sand and water directly into the cracks. Proportioning of sand - water mixture is generally 1 : 5 viz one part of sand and 5 parts of water.

The above mentioned remedial measures are broadly illustrated (fig no.40) below

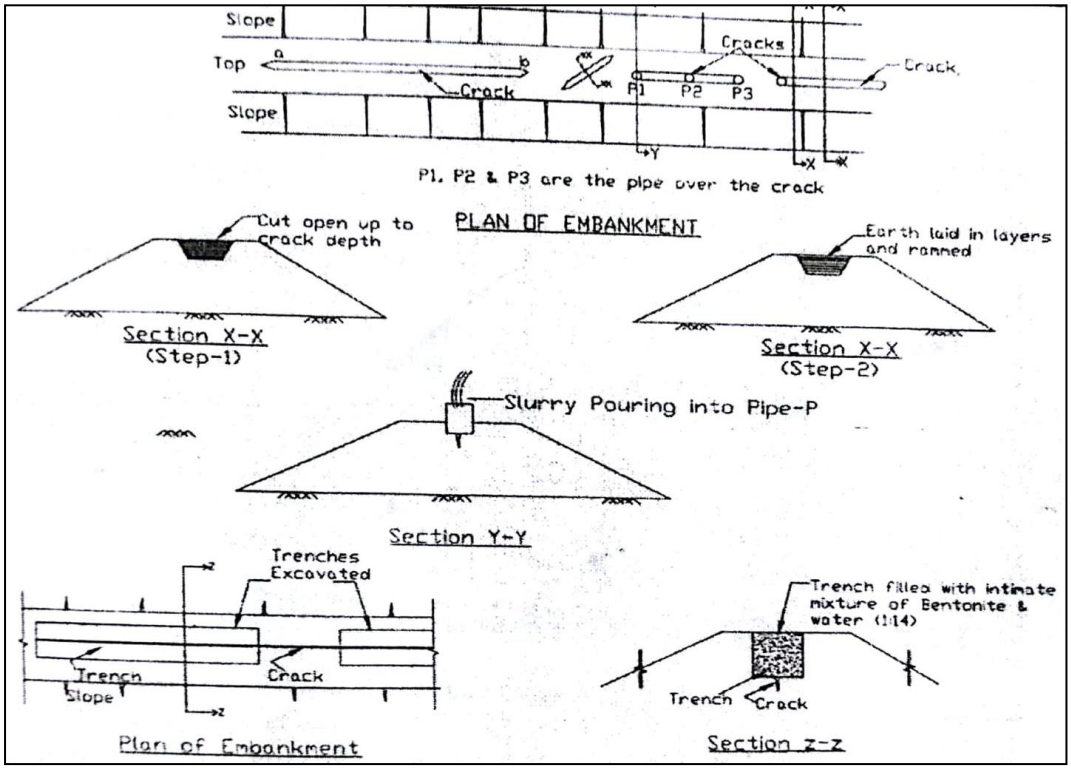


Figure 40 Treatment of longitudinal and transverse cracks

11.3 TACKLING A LEAK THROUGH AN EARTHEN CHECK DAM / TANK BUND:

When leakage is observed on the downstream face of the earthen embankment, the following actions should be immediately taken to deal with the leak. If turbid water is coming out of leak the matter is serious and may develop into a dangerous situation.

- *If the leakage is small:* A bowel shaped excavation should be made in the downstream slope and a filter consisting of sand, gravel or metal and stone / rubble should be placed in the bowel. The sand layer is to be deposited against the leakage face.

This technique of placement of "Inverted Filter" is illustrated in the (Fig no.41) below.

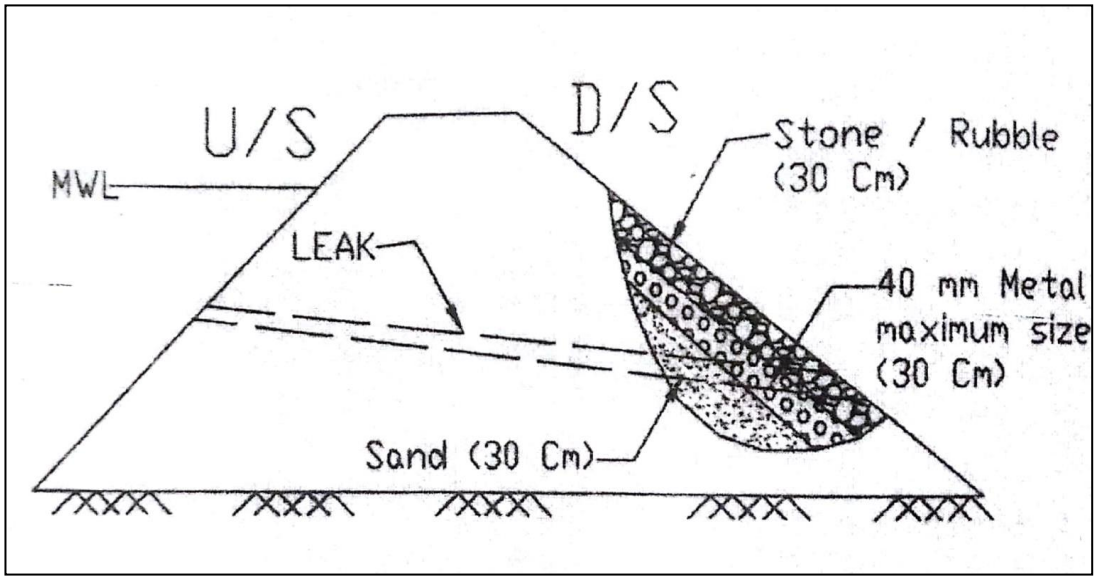


Figure 41 Inverted Filter

If the leakage is substantial or when the bowel shaped excavation in the downstream is not considered feasible or safe: No bowel shaped excavation is made in the downstream slope and the "Inverted Filter"should be placed directly on the slope after removing any vegetation etc. from the slope.

This technique is illustrated in the (Fig no.-42) below:

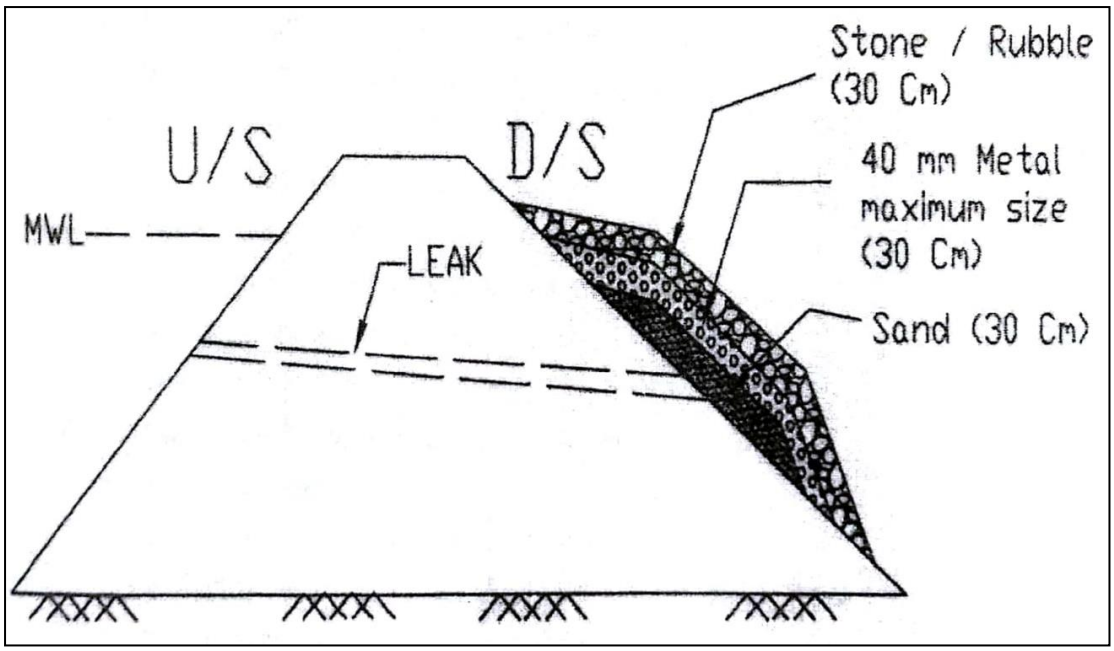


Figure 42 Inverted Filter

Purpose of "Inverted Filter" Purpose of filter is to trap the soil particles. The "turbid" type of leakage is a sure indication of the removal of soil particles from the body of earthen embankment, and if no remedial measure is taken, the leakage could turn into an uncontrolled flow, and would cause breach of the embankment. Thefunction of filter is to arrest the movement of soil particles. If after the filter is placed, the turbidity of leakage water disappears and even if clear water continues to flow, the filter has fully served its purpose.

If the leakage of water comes from the junction of earthen embankment with the foundation at the bed, the inverted filter can be placed in the portion immediately downstream of the toe in about 3.0 m length.

12 EQUALITY CONTROL & QUALITY ASSURANCE

12.1 SCOPE

Execution of works in OIIPCRA are to be done to the recognized standards through meticulous implementation of quality control and quality assurance parameters associated with the prescribed technical specifications indicate below:

12.2 FOUNDATION PREPARATION FOR EARTH WORK

- The working area shall be cleared off all growths like plants, bushes, light, vegetations and grass etc.
- The base should be properly ploughed and be prepared with proper watering for laying approved quality of earth.
- The placing of approved quality of earth should be in conformation with relevant I.S Code and chapter 2 and chapter 3 of this manual and the degree of compaction achieved shall be checked in a routine manner minimum to 95 proctor density.

12.3 FOUNDATION PREPARATION FOR CONCRETE STRUCTURES

- The proposed foundation area for the concrete structure shll be cleaned of all growth and stripped to designed level/hard surface as directed by the Engineer in-charge. The suitability of foundation be in conformation with approved drawing, water loss test of the sub soil and the safe bearing capacity of the soil shall be tested and passed by the Engineer-in charge for laying the concrete.
- The concrete shall be laid in conformation with relevant I.S. Code and chapter - 4 of this manual.
- Green cutting of concrete by air-water jet and suitable measures for bonding of concrete between two faces and adjacent layers shall be properly done as directed by the Engineer-in-Charge.
- Grouting and suitable anchoring as per the necessity at the site of work shall be done as directed by the Engineer-in-Charge and in conformation to the relevant I.S. Code.

12.4 QUALITY OF FILTER MATERIALS

- Filter materials as per requirement in the approved drawing shall be provided in confirmation with I.S. 9429-1980. The said materials be tested in therecognized quality control laboratory in conformity to the relevant Indian Standard Code.

12.5 QUALITY OF STONE FOR RIP-RAP

- The rip rap stone should be collected from the approved quarry satisfying all the required criteria

indicated in I.S. 8237-1985 and all other relevant Indian Standard Codes.

- The approved quality of stone shall only be used and laid compactly with staggered joints and so interlocked that they shall be keyed together with minimum of joint space. The rock fragments and spalls shall be driven by hammer into interstices to wedge the rip rap in place.

12.6 QUALITY CONTROL OF TURFING WORK

- All the work executed shall be protected by providing turfing confirming to the approved specifications of the department. The turfing shall be executed as per the relevant section of chapter-3 of this manual and ensure its survival.

12.7 QUALITY OF PLAIN AND REINFORCED CONCRETE

- All the ingredients for the concrete works should be tested and shall be used if satisfies all required parameters indicated in I.S Code No.383:1970 and Chapter-4 of this manual.
- Before executing the concrete works care shall be taken in finalising the design mix/volumetric mix as per the quantity of concrete works are involved.
- Proper care should be taken for applying air-water jetting over the previous layer of concrete in order to remove the thinsurface of laitance for proper bonding between two layers. An illustrative sketch of air-water gun is shown in fig. 43.
- OK card system shall be introduced in all works. This shall ensure compliance of technical specification and shall promote construction quality. Formats of OK cards for various key items of works are appended in Annexure-7 (c).
- The execution of canal lining works in swelling black cottons soils and non black cotton soils should be executed confirming to the relevant clauses of chapter-4 of this manual. Over and above since the curing of concrete work plays a vital part in developing its required strength, proper care should be taken for adequate curing throughout the 28 days period or by application of white pigmented curing compound approved by the Engineer-in-Charge.

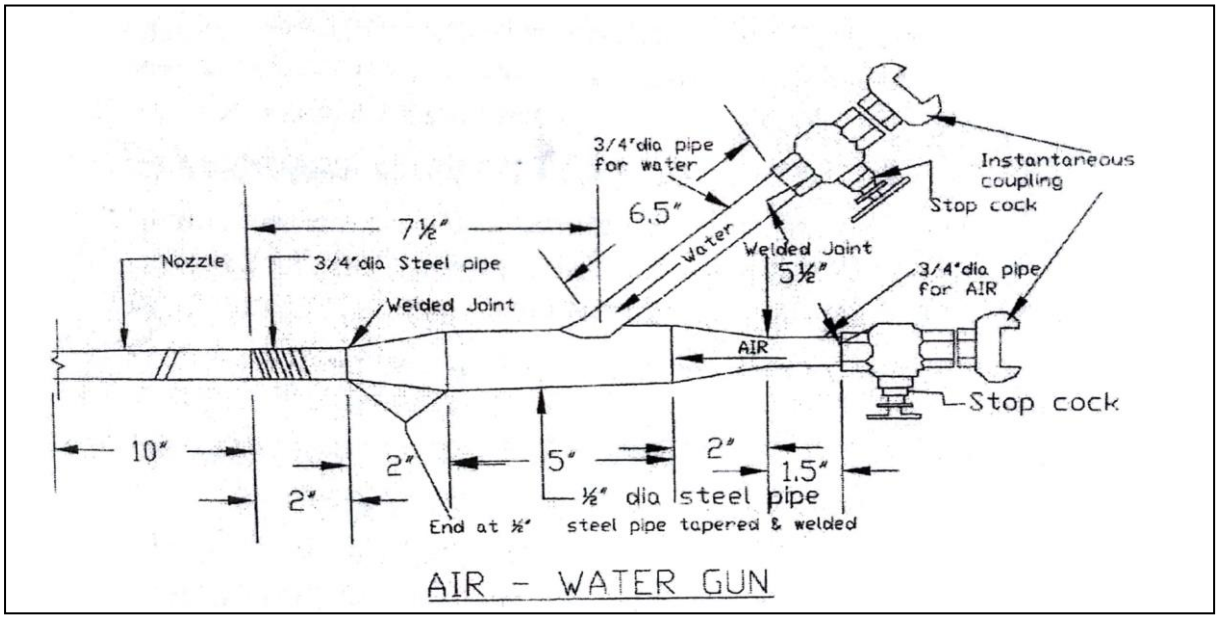


Figure 43 Air - Water Gun

12.8 QUALITY CONTROL TESTING EQUIPMENTS

- In order to achieve the required degree of quality of different works under taken by Orissa Community Tank Management Project all construction materials required to be used shall be tested in the laboratory and approved by the competent authority prior to the execution of work.
- All the required tests of materials shall be done by the testing equipments in the quality control laboratory.
- Some of the equipments required for use of such tests are indicated in Annexure - 7 (a).

12.9 FREQUENCY OF TESTING

- In order to monitor the quality of all the works of Orissa Community Tank Management Project the quality tests are to be conducted periodically and documented. The frequency of tests shall be decided by the Engineer-in-Charge of the work. However, the frequency of tests normally adopted for concrete work is enclosed in Annexure - 7 (b).

12.10 MODE OF TESTING

- The quality of materials / finished item of works shall be periodically conducted and recorded in the appropriate register for their documentation. Most of the materials shall be tested in the departmental laboratory and the results there of indicating their suitability shall be forwarded to the field functionaries for records.
- Similarly the materials collected at the site of work shall also be tested prior to its use and also during the execution.
- All such test results shall be recorded in OK Card (which should be always available at the work site) and documented for verification of the inspecting officers.
- Such recordings in OK Card shall be maintained in the respective model OK Cards.
- The observations and the deficiencies indicated during the course of execution of works should immediately be complied by the concerned field officers and intimated all concerned prior to executing any further works.
- Third party quality monitoring shall also be adopted for avoiding any inadvertent lapses.

12.11 Third Party Quality Control Arrangements

In view of the immunity and the vast spread-out nature of works, it is considered essential to introduce " Third Party Quality Control / Quality Assurance Mechanism" to adequately supplement the departmental organization on Quality Control and Quality Assurance and to ensure that all works are executed to acceptable construction quality standards, duly conforming to the contract technical specifications. The Third Party Quality Control / Quality Assurance system shall also independently conduct the needed Quality Control Tests on soils, materials and relevant inputs / outputs, check the workmanship of finished item of works, determine the adequacy of the mobilization of men and material / equipment by the contractor and promptly bring out any deficiency or defect in the works to the notice of the Engineer- in-Charge for facilitating quick rectification etc. The Third Party consultancy shall also bring out a "booklet" on monthly basis indicating the Quality Control tests done during the previous month compliance of defects brought out and the status of projects etc.

12.12 De-siltation of Tanks

Some tanks are very old. The Narayan Sagar MIP is reported to have been completed during 1889 (viz 118 years back). Similarly, Jagataghai MIP was completed during 1865,viz 143 years back. The Pani Panchayat members intimated that the reservoirs of these 2 tanks had been filled with silt to a level higher than the cill levels of Head Regulator, and that they had to excavate a leading channel every year to feed water to the respective HR of these tanks. In all such cases, the project engineers should undertake contour surveys to asses the position of silt deposition above the cill level (viz above live storage) and then work out the quantity of silt requested to the only essentially removed to ensure uninterrupted feeding of Head Regulator. Removal of silt below the Dead storage is not to be allowed under the OCTMP. The Chief Engineer should presently decide as to how much silt is to be essentially removed only from the live storage to feed the H.Rs.

12.13 Routine Quality Control tests

12.13.1 Tests on Sand:

Sand is an important ingredient of the "Mortar Mix" as well as of the "Concrete Mix". It is greatly influences the strength of these mixes. It is, therefore, of paramount importance that the sand to be used is free from impurities, silt, and clay. A well graded sand with a maximum size of 4.75 mm should be used in the mortar and concrete mixes to achieve good workability and strength.

Sand should be tested for the presence of silt & clay content as well as for the presence of any organic impurities. If moist of west sand is used, bulkage test is to be conducted. Sieve analysis should be carried out of determine the grading and fineness modulus of sand.

Procedures for Test:

- Silt & Clay Content in sand. The permissible limit for the presence of silt or clay content in sand is 3%.

Take certain amount of air-dray sand in a colourless graduated glass of transparent plastic cylinder. Add sufficient quantity of water till the sand is totally submerged. Shake vigorously and add 10 ml (milli-litre) of 5% alum solution. Allow about 2 to 3 hours for settlement of silt/clay sediment. Conduct this test even without the alum solution if it is not readily available. In that case, more time, say 5 to 6 hours may be needed for settlement.

Note down the levels

Let H - top level of silt / clay sediment above sand, say, at 90 ml mark and h=top level od sand, at 88ml mark. Hence-silt & clay content % in sand =H-h/hxl00, Or, 90-88/88x100=2.27%.

Sand is O.K. since the silt / clay content is less than 3%.

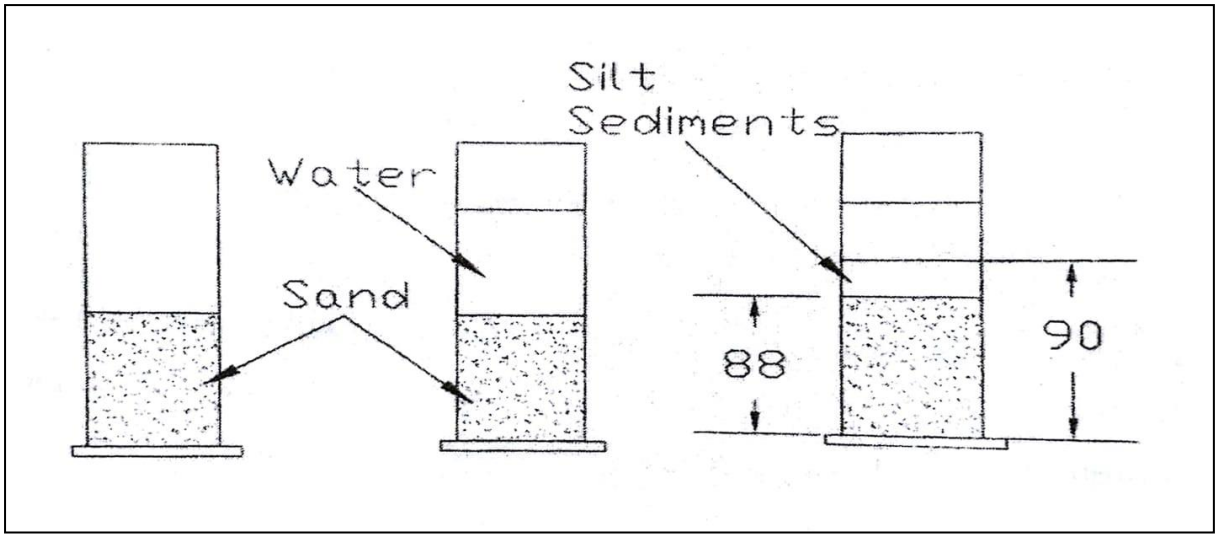


Figure 44 Test on silt or clay content in Sand

Bulkage of Moist Sand. The maximum permissible limit of bulkage is 20%. Take a certain amount of sand from the moist sand sample in a graduated glass or transparent plastic cylinder. Note down the level mark, say, H. Next, pour water to completely submerge the sand and shake it. Allow it to stand for about: 2 hours. Note down the new level mark of sand, say h. The sand level goes down after submergence.

Let H level mark of moist sand in cylinder = 80ml and h level mark after complete submergence of sand in water = 70 ml. Hence, %age of bulking of sand = 80-70/70x100=14.3%.

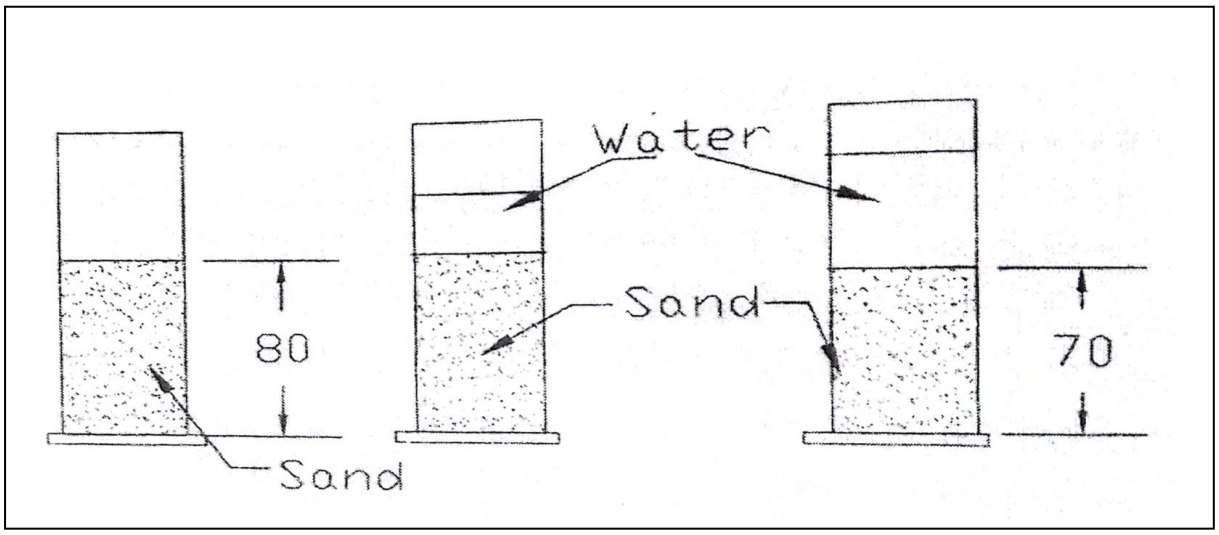


Figure 45 Test on Bulkage of Moist Sand

14.3% of extra volume of sand is required to be added in the concrete or mortar mix to compensate for this bulkage of moist sand. The water content would be.

Organic Impurities in Sand: The sand is tested for the presence of any injurious organic compounds in natural sands which are to be used in cement mortar or concrete.

Take a 350 ml capacity graduated clear glass bottle. Fill it up to 75 ml mark with 3% solution of Sodium Hydroxide in water. Pour sand gradually (as received without drying) until the sand reaches 125 ml. mark. Add more solution (viz 3% solution of sodium hydroxide in water) till 200 ml mark is reached. Put stopper in the bottle and shake vigorously, and then allow it to settle for 24 hours.

Observe the colour carefully.

A clear colour indicate nil presence of any organic impurities: so sand is O.K.

A straw colour indicates non-objectionable organic compounds: so sand is O.K.

A dark colour indicates presence of harmful organic impurities: so sand is to be washed and re-tested for acceptance and use.

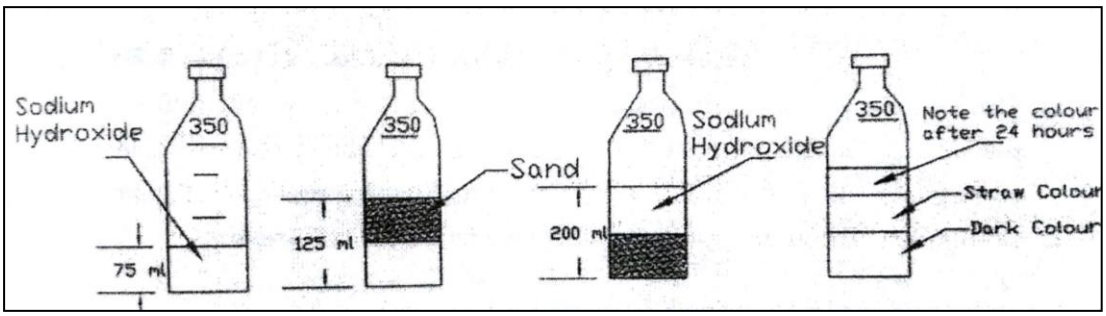


Figure 46 Test on Organic Impurities in Sand

Fineness Modulus & Grading of Sand by Sieving:The air-dry sample is weighed and sieved successively on standard sieves of sieve size: 4.75 mm. 2.36mm, 1.18mm, 600 microns, 300 microns and 150 microns. Each sieve should be shaken separately for a period not less than 2 minutes, and with a varied motion, backwards and forwards, left to right circular and with frequent jarring. On completion of sieving, the material retain on each sieve should be weighed. A fine camel hair brush may be used on the 150 micron and 75 micron sieves to prevent choking of apertures/openings of these sieves.

Example: Weight of air dry sample = 2kg (2000g).

Sieve size	Weight retained	% Wt. retained	Cumulative %retained	% passing
4.75 mm	—-	—	—	100
2.36 mm	9 gm	0.45	0.45	99.55
1.18 mm	35 gm	1.75	2.20	97.80
600 micron	616 gm	30.8	33.00	67.00
300 micron	1175 gm	58.75	91.75	8.25
150 micron	140 gm	7.00	98.75	1.25
Pan	25 gm			
		Total	226.15	

Thus, Fineness Modulus = 228.15/100 = 2.26

The column: "% passing" a above determines the grading of sand. As per Indian Standard IS:383, the grading of the above sand sample corresponds to Zone III, which is O.K. The Table given in IS:383 on Grading of sand to be used in concrete works is outlined below:

Indian Standard IS: 383 on Grading Zones of Sand.

IS Sieve	*Percentage passing for* Grading Zone-I	Grading Zone-11	Grading Zone-Ill	Grading Zone-IV
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Note: Zone-IV sand should not be used for reinforced concrete works.

Sand of, preferable, fineness modulus 2.2 to 3.2 should be used in concrete works.

Grading of Sand for masonry Works:

IS Sieve size	Percentage passing by weight
4.75 mm	90-100
2.36 mm	70-100
1.18 mm	40-100
600 micron	5-70
300 micron	0-15
150 micron	0-15

12.13.2 Tests on Soils:

• Determination of Moisture Content in Soil Sample by Rapid Moisture Meter.

The Rapid Moisture Meter provides a quick on-site determination of moisture content in the soil sample. It uses a chemical, calcium carbide, and 6 gm of soil sample is taken for analysis. The gauge of Moisture Meter is calibrated to indicate the moisture content based on the wet weight of soil, and it is then converted to the dry weight of the soil. The range of moisture content measured by the Moisture Meter is up to 25% and the operating instructions accompany the instrument.

Let the reading on the Moisture for a particular soil sample be .....W

Hence, the weight of dry soil in the sample will be 100-W

Thus, the Moisture content in terms of dry weight

• Determination of Moisture Content in Soil Sample by Conventional heating method.

Take a container and weigh it. Put the soil sample in it and take weight. There-after, heat the container (having the soil sample) on a stove, or on fire.Observe the weight of the container having the soil dried on stove/fire.

Example of Calculations:

Weight of container..... We gm
Weight of container with wet soil sample..... Ws gm
Weight of container with soil sample fully dried..... Wd gm
Thus, weight of moisture present in soil sample..... Ws-Wd gm
And, weight of dry soil ..... Wd-We gm
Hence, moisture content of soil in terms of %
of dry soil.....Ws-Wd/Wd-Wc x 100

• Determination of Dry Density of Soil Core Cutter Method.

Equipment and Material:

- Cylindrical core cutter of steel, 10 cm internal diameter, 12.74 cm high, giving a volume of 1000 cc.
- Steel dolly 25 mm high, 10 cm internal diameter of wall thickness of 7.5 mm.
- Steel rammer of circular face, 50 mm dia and 2.6 kg wt.
- Sieves of size 20 mm and 4.75mm.
- Steel rule; spade/pick axe; knife.
- Weighing balance and weights.

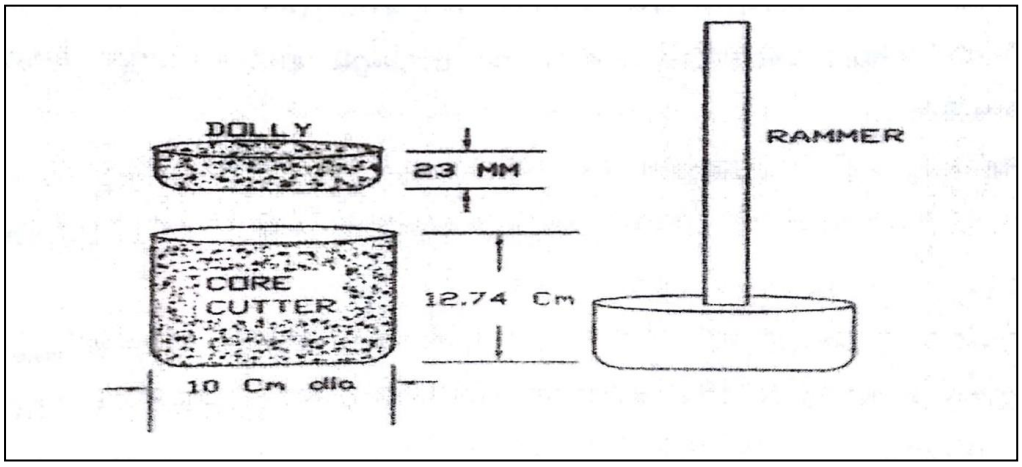


Figure 47 Test on Dry Density of Soil (by Core Cutter Method)

Procedure of Testing:

- Find the weight of Core Cutter, without Dolly, correct to 0.01 gm.
- Expose a small area (on the compacted layer of soil to be tested), say 300mm square. Put the Dolly on top of Core cutter and drive the assembly into the soil with the help of Rammer, until the top of Dolly protrudes about 15mm above the surface. Dig out from the surrounding soil. Take out the Dolly and lift the Cutter and trim flat the end of Cutter.
- Find the weight of Core Cutter full of soil.

Example of Calculations:

Weight of Core Cutter	=	We gm (1058 gm)
Wt. of Core Cutter and Wet Soil	=	Ws gm (3027 gm)
Wt. of wet Soil ..... Ws-Wc = 3027-1058	=	1969 gm
Volume of Core Cutter..... = Vc cc	=	1000 cc

Thus, Wet Bulk Density of Soil (Yw) = Ws-Wc / Vc x 1000 kg/m3

=1969 kg/m3 or 1.97 gm/cm3

Moisture content in soil = m%, say 14% (as to be determined from Rapid Moisture Meter or through conventional heating method).
Hence, Dry Bulk Density of soil (yd) =
100xYw/100 + m = 1969x100/100+14=1727 kg/m3 or 173g/cm3

Proctor Density: The maximum dry bulk density (DBD) corresponding to the optimum moisture content (OMC) is known as Proctor Density. It is determined through laboratory testing.

Compaction Efficiency of compacted layer * 1OO Proctor Density.

The earth fill placed in layer should be compacted to at least 95% Proctor density. The portable Electronic Nuclear Density Testing Equipments and its accessories are shown in Fig. No.48

12.13.3 Test on Concrete

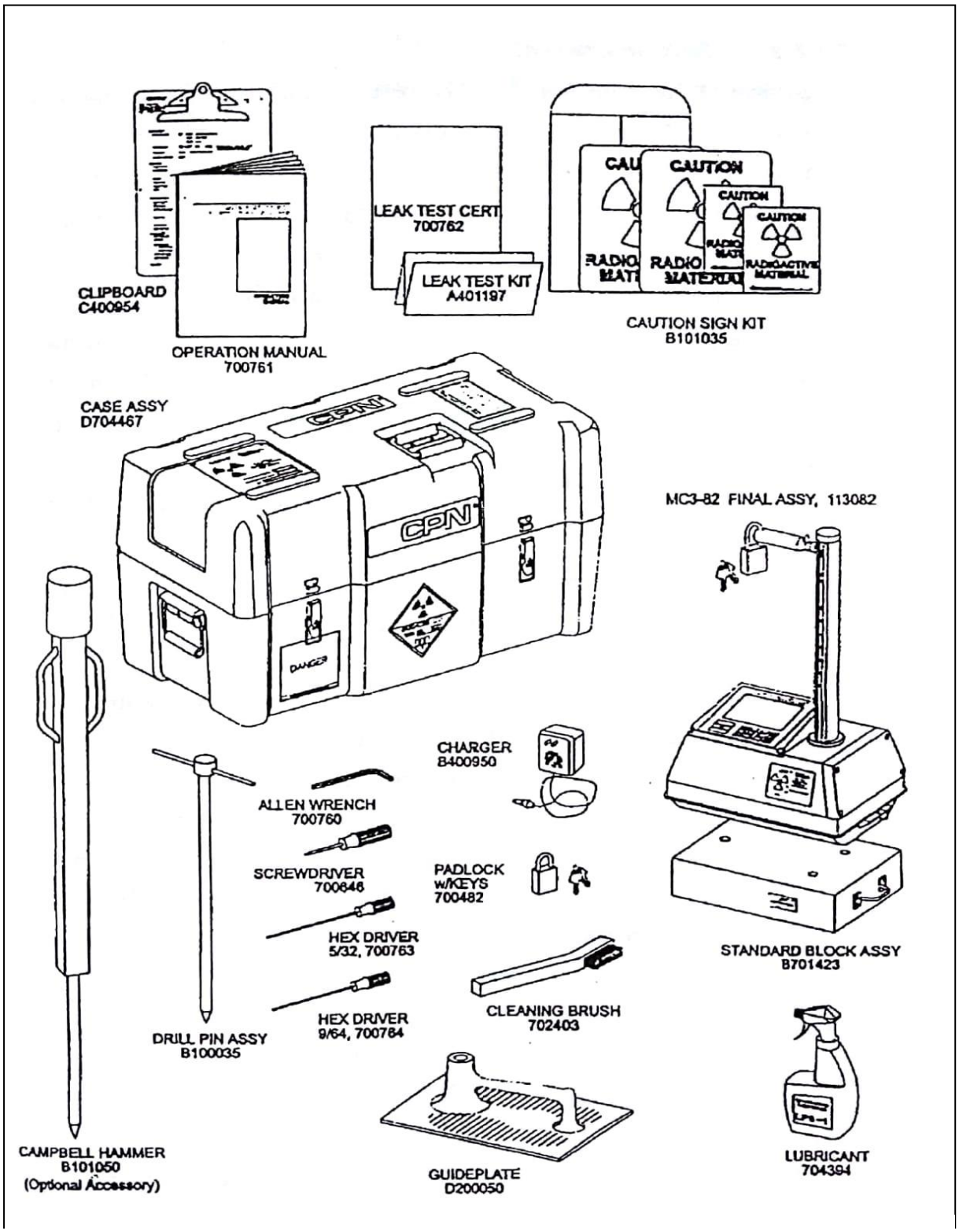


Figure 48 Portable Electronic Nuclear Density Testing Equipments

*Slump Test Concrete:*This test is used to determine the workability/fluid of concrete in the field. All

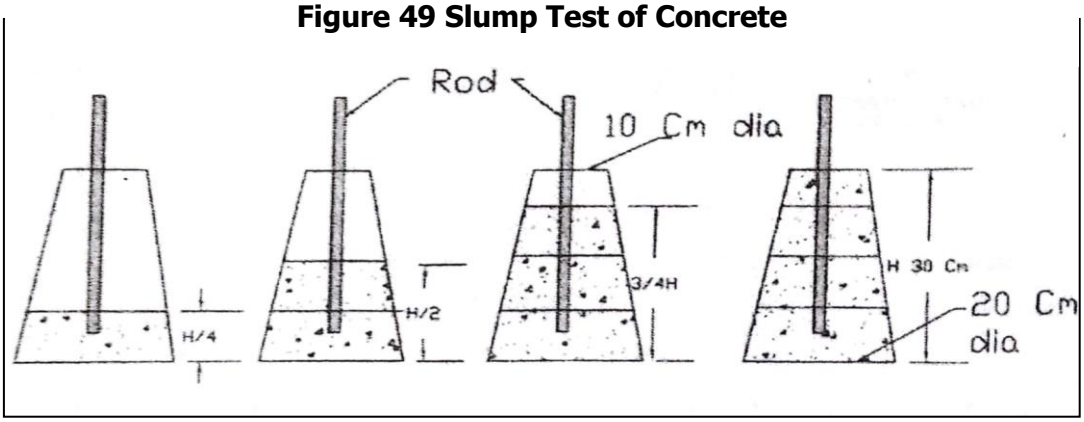
aggregate of size more than 40 mm size is to be removed before undertaking the rest.

Apparatus: It comprises a steel mould in the form of a truncated cone with the base of 20 cm diameter, the upper portion of 10 cm diameter and 30 cm in height. It is open at both ends and is fitted with handles for lifting the mould. It is provided with a base plate, 45 cm square and 5 mm thick. A tamping rod of 16 mm diameter and 60 cm long is provided with the apparatus for rodding/tamping of concrete.

Test Procedure: The mould is thoroughly cleaned before commencing the test.

- The mould is placed on the base plate. If base plat is not available, the mould can be placed on a smooth, hard, and non absorbent surface.
- The mould and base plate is slightly moistened with water.
- The mould is filled in 4 layers, each layer being approximately l/4th height (one fourth) height of the mould. Each layer should be tamped with 25 stokes of the tamping rod. In the second and the subsequent layers, the tamping rod should penetrate into the underlying layer. This is illustrating below in Fig. No. 49.

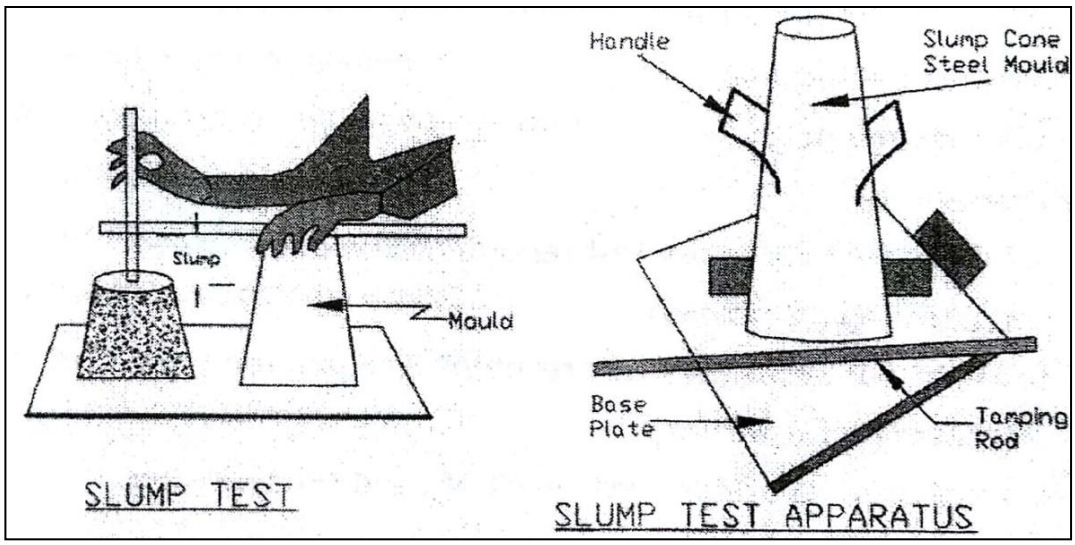
Figure 49 Slump Test of Concrete



- Alter the top layer has been tamped, the concrete, the concrete should be struck off level with a trowel/tamping rod.

- The mould should, then, be raised vertically slowly and carefully. This allows the concrete to subside. The "slump" or subsidence of concrete is measured from the straight edge held across the top of mould. This is depicted below in Fig. No.50.

Figure 50 Mould & Slump Test Apparatus



12.14 DOCUMENTATION

12.14.1 GENERAL

The objective of documentation is to collect, process and 'record all Quality Control and testing activities generated in the base and field laboratory work for reference at a later stage.

In addition to the above, Photographic and video recording of daily construction activities shall also be kept for future analysis. Computerized system shall be adopted for storage of data and its analysis.

The various tests, conducted at the investigation stage, construction stage and post construction stage shall be chronologically recorded for documentation purpose as detailed below.

7.13.1.2 INVESTIGATION STAGE

(1) Location Map

(ii) Foundation Characteristic.

a. Drilling and Log-hole data
b. Water Loss test result
c. Test reports of foundation soil (Engineering properties)

(iii) Construction material survey

a. Borrow area map
b. Quarry map
c. Summary of Laboratory test reports of Borrow area soil. (Engineering properties)
d. Summary of Laboratory test result of rock and rock products (Engineering properties)
e. Summary of Laboratory test result of sand (Engineering properties)

7.13.1.3 CONSTRUCTION STAGE

a. Execution Drawings
b. Project report (including revised report, if any)
c. Contract documents.

d. Geotechnical report and mapping.
e. Details of grouting and post water loss test.
f. Details of cut-off (as per actual execution)
g. Gradation curve for filters for earth dam.
h. Statistical evaluation reports on moisture content and density of earth fill.
i. Summary of test result of cement.
j. Summary of test result of coarse aggregate.
k. Summary of test result of fine aggregate
l. Summary of test result of rock.
m. Water quality test result.
n. Alkaline reactivity test result.
o. Statistical evaluation report.
    i. Standard deviation of concrete strength
    ii. Co-efficient of variation
    iii. Control Chart for concrete strength
    iv. Control chart for cement strength.
    v. Test report on cores of concrete and masonry mortar.
p. Records and certificates of calibration of measuring and testing equipments.
q. Photography and Video recording.
r. Inspection reports.
s. Non-conformance report
t. Corrective action records.
u. Computerized information.

12.5 GENERAL SPECIFICATION INNDIAN STANDARDS

The terms the India Standard Specification herein after referred to as BIS as used therein means the relevant Bureau of Indian Standard codes with all amendments published up to the date of Submission of tenders. A statement of relevant BIS are given below.

LIST OF INDIAN STANDARDS

Sl. No.	Short Title	B.I.S Number
I.	CEMENT	
1.	Specification to ordinary Portland cement 33 grade (4th Rev)	269-1989
2.	Specification to ordinary Portland cement 43 grade (First Rev)	8112-1989
3.	Specification to ordinary Portland cement 43 grade (First Rev)	12269-1987
4.	Specification for Portland Pozzolana Cement	1489-1976
5.	Portland Slag Cement (Fourth revision)	455-1989
6.	Method for physical tests for hydraulic cement (Reaffirmed 1980)	4031-1968
7.	Method of Chemical analysis for hydraulic cement (First revision)	4032-1985
8.	Rapid hardening Portland cement	8041-1978
II.	AGGREGATES	
1.	Specification for coarse and fine Aggregates from natural source for concrete (Second Revision)	383-1970
2.	Specification for sand for masonry mortars	2116-1965
3.	Method of Tests for aggregates for concrete	2385-1969 (Part- I to Part- VIV)
4.	Standard sand for testing of cement (First revision) with amendment 1 and 2 Reaffirmed 1980	650-1966
5.	Methods for sampling of aggregates for concrete	2430 -1969
6.	Method of test for determining aggregates impact value of soft coarse aggregates	5640-1970
III.	STEEL	
1.	Code of practice for bending and fixing of bars	2502-1963
2.	Specification for cold worked steel deformed bars for concrete reinforcement	1786-1979
3.	Code of practice for welding of MS Bars used for reinforced concrete construction.	2751-1966

4.	Code for practice for use of Metal are welding for general construction of mild steel	818-1989
5.	Deformed bars for concrete reinforcement hot rolled mild steel and medium tensile steel (Revised)	1139-1966
Sl. No.	Short Title	B.I.S Number
6.	Recommendations for detailing of reinforcement in reinforced concreted works	5525-1969
7.	Specification for Mild Steel and medium tensile steel Bars for Concrete reinforcement.	432-1966(Part I)
8.	Code for practice for safety and health requirement in Electric and Gas welding and cutting operations	818-1968
9.	Code for practice for fire precautions in welding and cutting operation.	3016-1965
10.	Measurement of building and Civil Engineering works, method part VIII steel work and iron work	1200-1974 (Part VIII)
11.	Code of procedure for manual or metal ARC and welding of Mild steel	823-1964
12.	Specification for filler rods and wires for gas welding	1278-1972
13.	Recommendations for welding cold worked steel bars for reinforced concrete construction	9417-1979
14.	Hard drawn steel wire fabrics for concrete reinforcement	1566-1982
IV.	CONCRETE	
1.	Method of Measurement of building and Civil Engineer work Part-II cement concrete works.	1200-1968 (Part-II)
2.	Code of practice for plain and reinforced concrete	456-2000
3.	Methods of tests for strength of concrete	516-1959
4.	Code of practice for laying in situ cement concrete lining on canals	3873-1993
5.	Specification for Admixtures for concrete	9103-1979
6.	Method of Test for Autoclaved cellular concrete products.	6441-1972-73 (Part-I to IX)

7.	Method of Sampling and Analysis of concrete	1199-1959
8.	Specification of Batch type concrete mixtures (Second Revision)	1791-1968
9.	General requirements for Concrete Vibrators immersion type	2505-1980
10.	Specification for concrete vibrating tables	2514-1963
11.	Specification for fly ash for use as pozzolana as admixture for Concrete	3812-1981 (Part-II)
12.	Specification for Portable swing weigh batch for concrete (single and double bucket type)	2722-1964
13.	Code of practice for installation of joints in concrete pavements	6509-1972
14.	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures	457-1957
15.	General requirement for concrete vibrator screed board type (First revision)	2506-1985
Sl. No.	Short Title	B.I.S Number
16.	Code of practice for concrete structures for shortage of liquids	3370 (Part-1 to 4)
17.	Code of practice for use of immersion vibrator for consolidating concrete (First revision)	3558-1983
18.	Method for testing performance of batch type concrete mixer	4634-1968
19.	Form vibrators for concrete	4656-1968
20.	Concrete batching and mixing plant	4925-1968
21.	Ready mixed concrete (Second revision)	4926-1976
22.	Code of practice for sealing joints in concrete lining on canals	5256-1992
23.	Vibrating plate compactor	5889-1970
24.	Concrete transit mixer and agitator	5892-1970
25.	Concrete pavers	7245-1974
28.	Concrete slump test apparatus	7320-1974

29.	Method of making curing and determining compressive strength of accelerated cured concrete test specimens.	9013-1978
30.	Specification for admixtures for concrete (First Revision)	9103-1999
V.	EARTH WORK	
1.	Method of Measurement of building and Civil Engineering Works Part I, Earthwork.	1200-1969 (Part-I)
2.	Code of practice for Design installation, observation and Maintenance of uplift pressure pipes for Hydraulic structures on permeable foundation.	6532-1972
3.	Safety code for excavation works	3764-1966
4.	Code of practice for protection of slope for Reservoir embankment	8237-1985
5.	Code of practice for earth work on canals	4701-1982
6.	Guidelines for lining of canals in expansive soils	9451-19
7.	Method of test for soils Part-II Determination of water concrete	2720-1973 (Part-II)
8.	Method of test for soils Determination of water content dry density relation using light compaction.	2720-1974 (Part-VII)
9.	Method of test for soils determination of dry density of soils in place by the sand replacement method	2720-1974 (Part-XXVIII)
10.	Method of test for soils determination of dry density of soils in place by the core cutter method	2720-1975 (Part-XXIX)
11.	Classification and identification of soils for general	1498-1970
12.	General requirement for black hold drilling rigs	7209-1974
13.	Safety code for working with construction machinery	7293-1974
14.	Code of practice for stability analysis of earth dams	7894-1975
Sl. No.	Short Title	B.I.S Number
15.	Guidelines for design of under seepage control measures for earth and rock fill dams	8414-1977

16.	Filtration media sand and gravel	8419-1977(Part-I)
17.	Guidelines for design of large earth and rock fill dams	8826-1978
18.	Under drainage arrangements of lined canals.	4558-1995
19.	Pre-cast cement concrete stables for canal lining	3868-1966
20.	Methods of tests of soils	2720 (Part-1 to X)
21.	Method of sampling and preparation of stabilized soils for testing	4332 (Part-I of 1967)
22.	Test in over burden	5529 (Part-1 of 1969)
VI.	OTHER SUBJECTS	
1.	Safety code for scaffolds and ladders part I scaffolds	3696-1966
2.	Safety code for scaffolds and ladders Part 2 ladders.	3696-1966 (Part-II)
3.	Recommendation s on stacking and storage of construction materials at site.	4082-1977
4.	Plywood for general purposes (Second revision amendment 1 to 3)	303-1975
5.	Test Sieves	460-1985
6.	Code practice for under drainage of lined canals (2nd revision)	4558-1995
7.	Code of for practice for in situ permeability test	5529 (Part-1 & 2)
8.	Structural steel (Standard quality) (with amendment No.1 to 3)	IS: 226-1975
9.	Hard drawn steel wires (Third revision)	IS: 432-1982 (Part-II)
10.	Concrete pipes (with and without reinforcement) (2^{nd} revision)	IS: 458-1971
11.	Code of practice for laying of concrete pipes	IS: 783-1959
12.	Specification for mild steel tubes, tubular and other wrought Steel fittings Part-I mild steel tubes (fourth revision) (With Amendments No. 1 to 5)	IS:1239-1979
13.	Hard drawn steel wire fabric for concrete reinforcement (Second revision)	IS: 1566-1982

14.	Asbestos cement pressure pipe (Second revision)	IS: 1592-1980
15.	Preformed filler for expansion test in concrete payment and structures (non extruding and resilient type)	IS: 1838-1961
16.	Cast iron detachable joints for use with asbestos cement pressure pipes.	IS:8794-1978
17.	Structural steel (Fusion welding quality) (Second revision)	IS: 2062-1980
Sl. No.	Short Title	B.I.S Number
18.	Code of practice for laying of cast iron pipe (With amendment No. I)	IS: 3114-1965
19.	Methods of testing for concrete pipes	IS 3597-1966
20.	Rubber sealing rings for gas mains water mains and sewers	IS: 5382-1969
21.	Centrifugally cast (spun) iron low pressure pipes for water gas and sewage (First revision)	IS: 6163-1978
22.	Code of practice for laying of asbestos cement pressure pipes	IS: 6530-1972
23.	Cast iron detachable joints for use with asbestos cement pressure pipes	IS: 8794-1978
24.	Other Publications: Ministry of shipping and transport Specification for Road and Bridge works	No. 7900
VII.	STONE PITCHING AND LAUNCHING APRON	
1.	Methods of test for determination of strength properties of natural building stone	IS: 1121-1975(Part-1 to 4)
1.	Method of test determination of true specific gravity of natural building stone (First revision)	IS: 1122-1974
2.	Method of identification of natural building stone (Ist Revision)	IS: 1123-1975
3.	Method of test for determination of water absorption apparent specific gravity and porosity of natural building stone (1st revision)	IS: 1124-1974
4.	Method of test for determination of weathering of natural building stones (First revision)	IS: 1125-1974
5.	Method of test for determination of durability of natural building stone (First revision)	IS: 1126-1974
6.	Recommendations for dimensions and workmanship of natural building stones for masonry work (First revision)	IS: 1127-1970

7.	Recommendation of dressing of natural building stone (1st. revision)	IS: 1129-1972
8.	Sand for plaster (First revision)	IS: 1542-1977
9.	Code of practice for construction of stone masonry	IS: 1597-1967
10.	Rubble stone masonry	IS: 1597-1967(Part I to II)
11.	Method for determination of resistance to wear by abrasion of natural building stones (First revision)	IS: 1706-1972
12.	Sand for masonry mortars (First revision)	IS: 2116-1980
13.	Code of practice for preparation and use of masonry mortars (First revision)	IS: 2250-1981
14.	Stone facing	IS: 4101-1967(Part-I)
Sl. No.	Short Title	B.I.S Number
15.	Method of test for determination of water transmission rate by capillary action through natural building stones	IS: 4121-1967
16.	Method of test for surface softening of natural building stones by exposure to acidic atmospheres	IS: 4120-1967
17.	Methods of test for determination of permeability of natural building stones (First revision)	IS: 4348-1973
18.	Method of test for toughness of natural building stones	IS: 5218-1969
19.	Gujarat State, Section 2, Engineering properties of building stones	IS: 7779-1975 (Part1/Sec.2)
20.	Recommendation practice for quarrying stones for construction purpose.	IS: 8881-1977

In addition to the relevant BIS code, the specifications prescribed and guidelines issued by Central water Commission Standard Specifications shall also be followed where BIS specifications are not available.

13 Classification of Minor irrigation Projects in OIIPCRA

13.1 Satellite data

In the current study, Satellite data have been used for the analysis, which are described below:

13.2 Elevation

Cartosat Digital Elevation Model (DEM) will be used to get the elevation information over the entire basin and to delineate the basin and sub-basins. Cartosat-1 is a unique stereoscopic mission with the capacity of acquiring along track stereo images with fixed B/H ratio. The satellite was launched aboard PSLV-C6 on May 5, 2005 from SDSC Sriharikota by Indian Space Research Organization (ISRO). Cartosat-1 data is used widely by National and International community for applications related to infrastructure, urban Development, Forestry, Watershed analysis etc. The DEM data is distributed by National Remote Sensing Centre (NRSC) through its portal Bhuvan. Spatial resolution of the DEM is 30 m.

13.3 Land Use Land Cover (LULC)

Land use land cover (LULC) describes the appearance of the landscape and is generally classified by the amount and type of vegetation, which is a reflection of its use, environment, cultivation and seasonal phenology. Land cover is other essential influences on runoff.

13.4 Methodology

Green project: A Minor Irrigation Project (MIP) is called a 'green project' if it is not adversely impacted by the existing upstream tanks/ponds/reservoir or MIP and also does not adversely impact the downstream MIP.

The methodology to identify the green project is divided in two parts (see figure 3):

- Part A: Watershed Delineation
- Part B: Analysis of the Dependency of tank

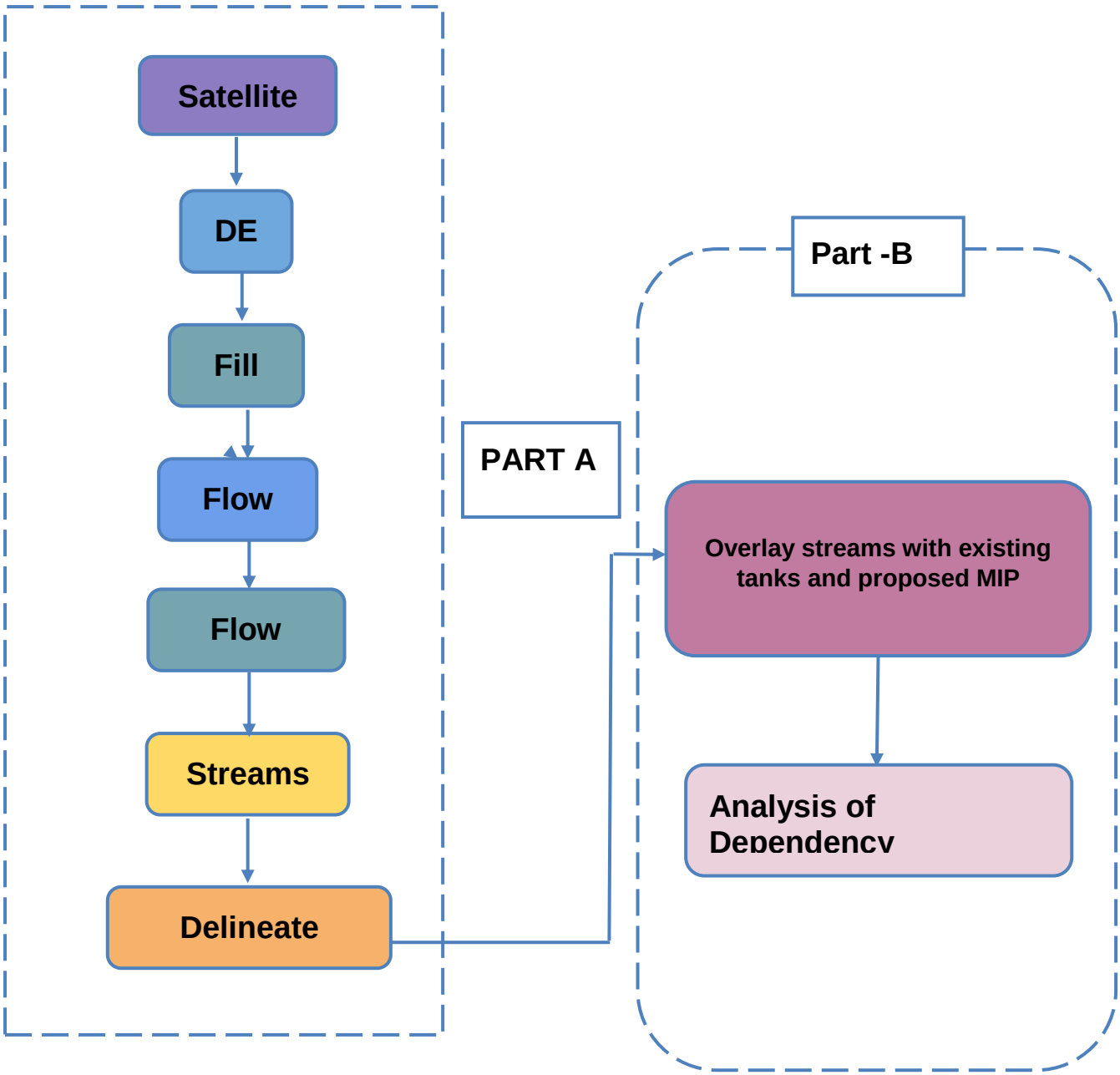


Figure 1: Methodology employed in the study

13.4.1 Part A: Watershed delineation

Watershed is the area of land from which streams drains all the water in it to the nearby water body. Watershed combines with the other watershed to form the streams, rivers and bigger water bodies. Watershed has been delineated from the Cartosat-1 DEM using GRASS GIS. Natural flow routes and their charging sub-catchments were delineated using GRASS GIS (https://grass.osgeo.org/) and outlets were identified in the Project area. The Cartosat DEM is filled by identifying and removing the sinks (Sinks are low elevation areas in digital elevation models (DEMs) that are completely surrounded by higher terrain) if present. Based on the direction of the steepest descent in each cell, flow direction is measured (see figure 4). The D8 flow method is adopted for the computation of flow direction. In this method, the flow is from each cell to its steepest down-slope neighbour. The output of the Flow Direction tool run with the D8 flow direction type is an integer raster whose values range from 1 to 255. By providing a threshold value, the pixels contributing to that pixel is delineated and identified as basins.

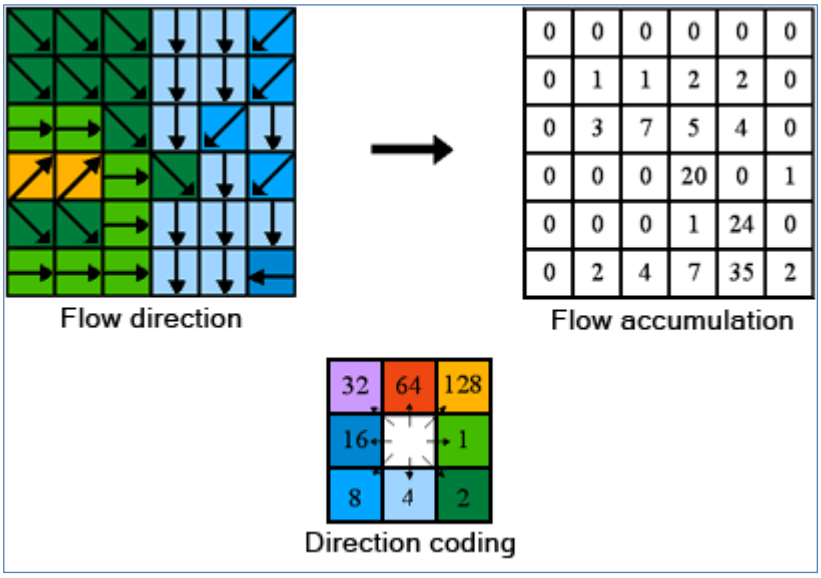


Figure 2: Description of the D8 algorithm used for the calculation of flow direction and flow accumulation

13.4.2 Part B: Analysis of dependency

The delineated stream-network in the part A will be overlaid over Google Earth images to visually identify the existing upstream tanks/ponds/reservoir/MIP or proposed MIP in the upstream and downstream. There were two kind of MIPs in the current project:

1. Tank/reservoir
2. Diversion weir

A tank is classified as a 'green project', if no tank is present in its upstream side and downstream side (up to a higher order stream). A diversion weir is classified as 'green project', if no tank was present in its upstream side. All the minor tanks/ponds which major influence did not have hydrologically can be ignored. If in a diversion project, significantly large catchment area was available to provide the water to MIP, it can be classified as 'green project.'

NOTE: The complete analysis is embedded in Hydrology assessment of OIIPCRA report.

ANNEXURE – I

THE DETAILS OF TECHNICAL SPECIFICATION FOR QUALITY CONTROL

THE DETAILS OF TECHNICAL SPECIFICATIONS:

1.0 DISCHARGE RECORDS

The Hydrological data, pertaining to the canal and the streams crossing the canal furnished in the relevant report and drawings, are for information of bidders and contractors. It should be noted that the data used in preparing these particulars were recorded at locations different from the work site. The Government (i.e. Govt. of Orissa) does not guarantee the reliability or accuracy of any of the data, shall assume no responsibilities for any conclusions or interpretations that may be made from them. The

contractor shall undertake at his expense such studies as are necessary to assess the reliabilities and accuracy of the information presented in the Data.

SETTING OUT OF WORK

Permanent bench marks shall be fixed at suitable location connecting permanent bench marks fixed by Survey of India. Temporary Bench Marks shall be set up by the Department at every 0.5 Km intervals at convenient locations along the canal to serve as reference levels. The contractor shall establish additional reference Bench Marks as may be needed at his own cost for facilitating the setting out and taking levels for measurement of work, with the approval of the Engineer-in-charge. The bench mark shall be marked on a concrete pillar 30 cm. (L) x 30 cm (B) x 75 cm (H) which shall be embedded 55 cm into firm ground and projecting 20 cm above the ground. The Bench Mark pillar shall be constructed in plain cement concrete of M-10. The pillar shall be protected from being disturbed. The RL of bench marks shall be conspicuously carved and painted on the pillar. (Conforming to the relevant I.S.Code)

Before starting any work and during execution (if required), the contractor shall erect reference bench marks, reference lines and check profiles at convenient locations as per the direction of the Engineer-in-charge. The centreline of the canal and the reference line for all alignments for demarcation purpose shall be laid by dug-belling on the ground. The reference line shall comprise the base line properly dug-belled on the ground with the numbered concrete/ masonry RD pillar suitably spaced.

Centre line of the canal shall be marked by fixing pillar/ stone at suitable intervals. Profiles of the canal in filling and in moderate cutting shall be marked at suitable intervals in straight reaches and in curves. A reference line shall also be marked on ground away from the outer edges of cutting and filling with pillars at suitable intervals for future reference.

To ensure correctness of execution, the edges of cutting and the outer toe lines of canal in filling should be marked by fixing pillars or pegs at suitable intervals or by dug- belling.

The check profiles shall be located 15 m apart or longer as directed by the Engineer-in-charge to serve as a guide for execution of all slopes and steps to the elevations and profile(s) indicated in the approved drawings. All important levels and all reference points with respect to bench marks and reference shall be fixed and co-related by the contractor as per directions of the Engineer-in-charge.

The zones of full cutting section, full filling section, partial cutting and filling section shall be separated by conspicuous demarcation in the field.

The curves stipulated in construction drawings shall be carefully laid in the field by adopting approved method of curve layout. The curves shall be marked on the ground by fixing pegs at very closer intervals and joining the peg points by dug-belling to a suitable depth.

The locations of different structures indicated in construction drawing shall also be clearly marked on the ground along the alignment of the canal. The control structure locations of off-taking canals shall also be clearly demarcated, so that unnecessary excavation or filling at these locations can be avoided.

The spoils dumping zones shall clearly be demarcated in the field. These zones should be at least 2 m beyond the location of catch water drains.

To ensure accuracy in execution of cutting, the canal embankment, spoil banks and the structures, their layout shall be given in an appropriate manner with pegs and pillars suitably placed in relation to outer dimensions of these elements.

All materials and labour for setting out works including construction of reference bench marks, reference lines, check profiles and surveys as may be required at the various stages of construction, shall be made by the contractor at his own cost. The cost of such works shall be deemed to have been included in the cost of items in schedule.

CLEARING AND GRUBBING

CLEARING AND LEVELING SITE.

The portion of the right-of-way where required for constructing the work under these specifications shall be cleared of all trees, bushes, rubbish and other objectionable materials. Trees designated by the Engineer-in-charge shall not be cut and shall be protected from injury. Such cleared materials shall be disposed-off as provided in the sub-paragraph 3.2.3 below or removed from the site of work before the date of completion of the contract as approved by the Engineer-in-charge. The clearing operation shall be in accordance with clauses 4.1., 4.1.1., 4.2 and 4.3 of IS: 4701-1982 Indian code of Practice for earth work in canals. Surface boulders, either loose or partly embedded in the ground will have to be removed and stacked as directed.

GRUBBING.

The area described or shown on the relevant site plan shall be cleared of all obstructions, loose stones, non-required materials and rubbish of all kinds. All brushwood shall be cleared and the roots grubbed up. Trees to be preserved will be designated by the Engineer-in-charge. No trees shall be cut down and removed without the instructions of the Engineer-in-charge. Those which are cut down shall be grubbed up. The same remarks apply to jungle clearance.

The products of the clearing shall be stacked in such place and manner as may be ordered by the Engineer-in-charge and the ground shall be left in a perfectly clean condition. All products of the clearing shall be the property of Govt. and shall be disposed- off as per the direction of the Engineer-in-charge.

All holes or hollows, whether originally existing or produced by digging up roots shall be carefully filled up with earth, well rammed to the design density and levelled off as directed.

PREPARATION OF BED

Ant-hills shall be completely dug out before earth work is started. Loose stones and digging of ant-hills involved in the preparation of bed. The contract rate for the earth work shall be deemed to include all the work to be done in accordance with this clause. In cases where the work of preparation of bed is rather extensive, the Engineer-in-charge will usually provide a separate schedule item of such preparation, but in the absence of such schedule provision, the contractor shall understand that his tender rate is inclusive of all such work without extra charge.

The contractor shall therefore examine the site before tendering and provide for all items to be done under this earth work tender rate. Old bunds will be benched or sloped as directed by Engineer-in-charge before addition of earth. The benches shall be 450 mm x 450 mm unless other sizes are specified

(Refer page-35/Chapter-2 of Technical Manual, OCTDMS). The benches or slope shall be inspected by the Engineer-in-charge or engineer designated for the purpose and approved before new earth work is keyed into them.

DISPOSAL OF CLEARED AND GRUBBED MATERIAL

The disposal of cleared and grubbed materials shall be in accordance with clause 4.1.1 of IS 4701-1982 code of practice for earth work on canals. All waste materials to be burnt shall be piled neatly and when in suitable condition shall be burnt completely to ashes. Pilling of waste material for burning shall be done at such a location and in such a manner as would not cause any fire risk in cleared area. Suitable materials and equipments for prevention and suppression of the fire shall be kept available at all times.

The materials to be disposed off shall be buried.

USE OF WATER

WATER FOR DUST ABATEMENT

The contractor shall procure and apply water for dust abatement.

Water applied for dust abatement will not be eligible for payment. The cost of procuring and applying water including all expenses for all means of conveying water to the point of use, their collection, usage, and all other incidental expenses will not be paid separately including creation of source of water and the cost shall be deemed to have been included in the concerned unit price bid in the bill of quantities of the contract for the relevant finished item of work for which water for dust abatement is required.

So also the cost of procuring and applying water required for the works shall be included in the price bid in the bills of quantities for the items of work for which the water is used.

PREWETTING OF CANAL PRISM AND ADJACENT AREAS

The contractor shall furnish all labour, materials and equipment and shall procure and apply water required for pre-wetting the areas under canal and embankment.

Water applied for pre-wetting areas as detailed above will not be eligible for payment. The cost of procuring and applying water including all expenses for all means of conveying the water to the point of use, their collection, usage and all incidental charges shall be included by the contractor in the concerned unit price bid in the bill of quantities for that item of work where the water shall be used and no separate payment for the same will be made.

SITE DRAINAGE

CROSS DRAINAGE

The contractor shall handle all flows from natural drainage channel intercepted by the work under these specifications, perform any additional excavation and grading for drainage as directed and provide and maintain any temporary construction required to by- pass or otherwise cause the flows to be harmless to the work and property. When the temporary construction is no longer needed and prior to acceptance of the work the contractor shall remove the temporary construction and restore the site to

its original condition as approved by the Engineer-in-charge.

In addition to cross drains, longitudinal drains may be considered necessary for proper drainage. The drainage system consisting of network of cross and longitudinal drainage system will be led into out-fall drains to prevent stagnation of water at the place of construction. The drains shall be constructed to the section designed and shall be either open or filled up with material to ensure free flow of water without clogging of the filled materials.

The cost of all works and materials required by this paragraph shall be included by the contractor in the unit prices quoted in the bill of quantities and no separate payment will be made for the same.

DRAINS

In connection with excavation for the canal and structures, the contractor shall perform excavation for the construction of drains, beam drains and chutes and any other drains as directed by the Engineer-in-charge.

The location, grades and sections of the drains shall be as shown on the drawings and or as directed. Measurement of excavation for the above drains will be made to the lines shown in the drawings or as directed. Payment for excavation for the above drains, channels and embankment will be made at the unit price bid in the bill of quantities for execution of canal, which unit price shall include the cost of placing the materials in embankment or otherwise disposing of the excavated materials and all work necessary to maintain the work in good order during construction.

BERM DRAINAGE AND DOWEL BANKS

Berm drainage, including drainage along the berm and banks of the canal and longitudinal berm drains shall be constructed where shown to dimensions and grades on the drawings or as directed.

The surface of the berm shall be sloped transversely and dowel banks shall be made along with sides of the banks and berm where shown on the drawings and elsewhere where directed. The dowel banks may be made by balding of material in place, following completion of a canal reach. The size and section of the dowel banks will be decided by the Engineer-in-charge according to the suitability.

No direct payment will be made for constructing Dowel banks and sloping berms and cost thereof shall be included in the unit price per cubic meter bid in the bill of quantities for construction for canal embankment including reconstructing and remodelling.

MONSOON DAMAGES

Damages due to rain or flood either in cutting or in banks shall have to be made good by the Contractor till the work is handed over to the department. The responsibility for de-silting and making good the damages due to rain or flood rests with the contractor. No extra cost is payable for such operations and the contractor shall therefore, had to take all necessary precautions to protect the work done during the construction period.

REMOVAL OF SILT AND WATER

Accumulated silt and water in the canal and structures for the works partly done by the contractor in current or previous seasons should be removed and no extra payment will be made, for such removal of silt and water. This unit rate of excavation is deemed to include cost of removal of such

silt and water.

PROCEDURES FOR MEASUREMENT

Before commencement of work, initial levels to indicate existing ground levels, shall be taken at 30 m intervals longitudinally along the alignment of the canal. The level points transversely along the cross sections shall be at the maximum of 5 m intervals in flat ground and 3 m in undulating terrain. The cross sections shall be extended beyond the limit of work to a suitable distance and minimum 5 m beyond the toe lines of slopes on both the sides. The interval stipulated shall be made closer depending on the topography or any stipulation made by the Engineer-in-charge.

All initial levels shall be recorded in ink in authenticated level books issued by the Engineer-in-charge and shall be signed by the Junior Engineer/ Assistant Engineer when he records the levels with due acceptance of the same by the contractor. The Assistant Engineers and Executive Engineers shall exercise checks strictly in accordance with the codal provisions.

Actual construction works shall not be allowed to start unless the above formalities are fulfilled.

The level shall be recorded in the presence of the contractor or his authorized agent. The contractor or his authorized agent shall sign each page of the level book/ field book in token of acceptance. These cross sections shall form the basis of all future measurements and payments. Each dimension shall be measured to the nearest 0.01m, areas shall be computed to nearest 0.01sqm. Volume shall be computed to nearest 0.01 cubic m.

ROLLERS AND OTHER COMPACTING EQUIPMENT

As shown in Appendix C or IS 4701 – 1982 the following compacting equipment may be used for compacting the soils shown against them as detailed below.

Major Division	Sub-group		Suitable type of compacting equipments.
1. Coarse Grained Soils	1.	Well Grained Gravel, gravel and mixtures of little or no fines.	Smooth wheel roller, Diesel road rollers of 8 to 10 tones capacity, pneumatic tyred roller and vibrating smooth wheel roller.
	2.	Well graded gravel sand mixtures with excellent clay binder	Smooth wheel roller, Diesel road rollers of 8 to 10 tones capacity, pneumatic tyred roller and vibrating smooth wheel roller.
	3.	Uniform gravel with little or no fines.	-do-
	4.	Poorly graded gravel and gravel sand mixtures little or no fines.	-do-

	5.	Gravel with fines, silty gravel, clayey gravel poorly graded gravel sand clay mixtures.	-do-
2. Coarse Grained soils, Sand & sandy clays.	1.	Well graded sand and Gravely sands, little or no fines.	Heavy vibrating plate Frog rammer, pneumatic rammer and power roller.
	2.	Well graded sand with excellent clay binder.	-do-
	3.	Uniform sand with little or no fines.	-do-
	4.	Sands with fines silty sands, clayey sands, poorly graded sand clay mixtures.	-do-
3. Fine Grained Soils, Soil having low compressibility	1.	Silts (in organic) and very fine sands rock flour, silty or clayey fine sands with slight plasticity.	Smooth wheel roller, diesel Road Rollers of 8 to 10 tones capacity, power rollers, and pneumatic tyred roller.
	2.	Clayey silts (inorganic)	-do-
4. Soils having medium compressibility	1.	Organic silts of low plasticity	Sheep Foot Roller
	2.	Silty and sandy clays (Inorganic of medium plasticity.)	Frog rammer, pneumatic rammer, padded vibratory roller.
	3.	Clays (inorganic of medium plasticity)	-do-
	4.	Organic clays of medium plasticity.	-do-
5. Soils having higher compressibility	1.	Micaceous or diatomaceous fine sandy and silty soils, elastic silts.	Smooth wheel roller, diesel Road Rollers of 8 to 10 tones capacity and pneumatic tyred roller.
	2.	Clay (Inorganic)	-do-
	3.	Organic clays of high plasticity.	-do-

The compacting equipment shall confirm to relevant India specification below.

1. Smooth wheeled roller should conform to IS 5502-1969
2. Sheep Foot roller should conform to IS 4661-1968
3. Pneumatic tyred roller should conform to IS 5501-1969
4. Vibratory plate compactor should conform to IS 5889-1970
5. Vibratory roller should conform to IS 500-1970

The methods of compaction shall conform to clause 7.2.1, 7.2.2.7, 2.3 of IS 4701-1982

Unless otherwise specified compaction shall be done by mechanical compactors like standard sheep foot roller hauled by dozer or tractor. While specifications below provide that equipment of particular type and size is to be used, the use of improved compaction shall be encouraged. Tamping rollers used for compaction of earth fill shall conform to the following requirement.

2.0 CEMENT

Cement shall conform to clause 5.1 to 5.1.3 of IS 456-2000 for the purpose of specifications. Cement used shall be any of the following with the prior approval of the Engineer-in-charge.

a. 33 grade Ordinary or low heat Portland cement conforming to IS: 269-1989
b. Rapid hardening Portland cement conforming to IS: 8041-1990
c. Portland slag cement conforming to IS: 455-1989
d. Portland Pozzolana cement conforming to IS: 1489-1991
e. 43 grade ordinary Portland cement conforming to IS: 8112-1989
f. 53 grade Ordinary Portland cement conforming to IS: 12269-1987

The provisions of this paragraph apply to cement for use in cast in place concrete required under these specifications. Portland cement required for items such as concrete pipes, pre-cast concrete structural members and other pre-cast concrete products for grout and mortar and for other items provided for, under appropriate paragraph of these specifications covering items for which such Portland cement is required.

The contractor shall make his own arrangements for the procurement of cement to required specifications required for the work. Transportation from the place of supply to the batching plant shall be in weather-tight rail cars, trucks, conveyors and other means, which will protect the cement completely from exposure to moisture. Immediately upon receipt at the jobsite, bulk cement shall be stored in dry, weather tight, properly ventilated bins until the cement is batched. The bins shall be emptied and cleaned by the contractor when so directed by the Engineer-in-charge. However, the intervals between required cleaning will normally be not less than 6 months. Each shipment of bagged cement shall be stored separately so that it may readily be distinguished from other shipment and shall be stored in a dry enclosed area protected from moisture. Storage of materials shall be as described in IS: 4082-1996 (IS recommendation on staking and storage of construction materials at site). To prevent under-aging of bagged cement after delivery, the contractor shall use bags of cement in the chronological order in which they were delivered to the job site. All storage facilities shall be subject to approval of the Engineer-in-charge.

ACCEPTANCE OF CEMENT.

Cement shall be supplied by the contractor according to clause 10.1 of IS: 269-1989.

ACCEPTANCE OF POZZOLANA:

Pozzolana added to the concrete as an admixture shall be sampled and tested as per IS: 9103-1999.

RECOVERY OF COST OF CEMENT IN WASTED CONCRETE ETC:

The cost of cement used in wasted concrete in replacement of damaged or defective concrete and extra concrete required because of over excavation and in concrete placed by the contractor in excavations intentionally performed to facilitate the contractor's operation shall be borne by the contractor himself. No extra payment shall be made to the contractor for such additional quantity.

ADMIXTURES

The contractor shall use air-entraining admixtures as directed by the Engineer-in-charge. Admixtures shall be of uniform consistency and quality and shall be maintained at the job site at uniform strength of solution. Admixtures shall be batched separately in liquid form in containers capable of measuring at one time the full quantity of each admixture required for each batch. Chemical admixtures, which harm the quality and strength of concrete, shall not be used in the concrete.

WATER

The water used in making and curing of concrete mortar and grout shall be free from objectionable quantities of silt, organic matter, injurious amounts of oils, acids, salts and other impurities etc. as per IS specification 456-2000.

The Engineer-in-charge will determine whether such quantities of impurities are objectionable. Such determination will unusually be made by comparison of compressive strength, water requirement, time of set and other properties of concrete made with distilled or very clean water and concrete made with the water proposed for use. Permissible limits for solids when tested in accordance with IS: 3025-1964 shall be as tabulated below:

PERMISSIBLE LIMITS FOR SOLIDS IN WATER

1. Organic solids : Maximum permissible limit 200 mg/l.
2. Inorganic solids : 3000 mg/l.
3. Sulphate (as SO_4) :400 mg/l.
4. Chlorides (as Cl) :2000 mg/l for plain concrete work and 500 mg/l for RCC work.
5. Suspended matter : 2000 mg/l.

The pH value of water shall generally be not less than 6 (six).

If any water to be used in concrete mortar or grout is suspected by the Engineer-in-charge of exceeding the permissible limits for solids, samples of water shall be obtained and tested by the Engineer-in-charge in accordance with IS: 3025-1964.

3.0 SAND (FINE AGGREGATE)

The term sand is used to designate aggregate most of which passes 4.75 mm IS Sieve and contains only so much coarser material as permitted in clause 4.3 of IS: 383-1970. Sand shall be predominantly natural which may be supplemented with crushed sand to make up deficiencies in the natural sand grading.

All sand shall be procured by the contractor from approved sources. Sand as delivered to the batching plant shall have uniform and stable moisture content. Determination of moisture content shall be made as frequently as possible; the frequency for a given job being determined by the Engineer-in-charge according to weather conditions following IS: 456-2000.

QUALITY:

The sand shall be clean, dense, durable, uncoated rock fragments as per IS: 383-1979. Sand may be rejected if it fails to meet any of the following quality requirements:

- FINENESS: The fineness modulus of sand shall be between 2.20 to 3.20.

- ORGANIC IMPURITIES IN SAND:

  Colour, no darker than the specified standard in clause 6.2.2.of IS: 2386 Part II 1963 (Indian Standard method of test for aggregates of concrete Part II estimation of deleterious materials and organic impurities)

  Sand shall be screened before use. If sand brought to site is not clean, it must be washed clean in water. Fine draft sand or sea sand or sand containing saline impurities shall on no account to be used.

- SODIUM SULPHATE TESTS FOR SOUNDNESS:

  The sand to be used shall pass Sodium or Magnesium Sulphate accelerated test as specified in IS: 2386(Part-V) 1963 for limiting loss on weight.

- SPECIFIC GRAVITY:

  The sand to be used shall have minimum specific gravity of 2.4

- DELETERIOUS SUBSTANCE:

  The amount of deleterious substances in sand shall not exceed maximum permissible limits prescribed in table-1, clause 3.2.1 of IS: 383-1970 (Indian Standard Specification for coarse and fine aggregates form natural source for concrete) when tested in accordance with IS: 2386-1963.

GRADING

The sand as batched shall be well graded and when tested by means of standard sieves, shall conform to the limits given in table-4 of IS: 383-1970 and shall be described as fine aggregates, Grading zones, I, II, III and IV. Sand complying with the requirements of any of the four grading zones is suitable for concrete. However, sand conforming to the requirements of grading zone IV shall not be used for reinforced cement concrete work.

Sieve analysis of natural sand shall conform to the following limits of gradation.

I.S. Sieve size	Percentage of passing on Sieve		
	Grading Zone-I	Grading Zone-II	Grading Zone-III
4.75 mm	90-100	90-100	90-100
2.36 mm	60-95	75-100	85-100
1.18 mm	30-70	55-90	75-100
600 micron	15-34	35-59	60-79
300 micron	5-20	8-30	12-40
150 micron	0-10	0-10	0-10

It is recommended that the sand conforming to grading zone-I to III is suitable for use.

COARSE AGGREGATES:

For the purposes of these specifications, the term "Coarse Aggregate" designate clean well graded aggregates, most of which is retained on 4.75 mm. I.S: Sieve and containing only so much finer materials as permitted for various types described under clause 2.2. of IS: 383-1970. Coarse Aggregate for concrete shall consist of uncrushed stone, or crushed stone and partially uncrushed and crushed stone.

Coarse Aggregates for concrete shall be procured by the Contractor from the approved quarries. The contractor shall, unless otherwise specified in the tender notice and subsequently on this basis in the contract, be responsible for payment of seignorages, quarry fees etc. on all materials.

Coarse aggregates as delivered to the batching plant shall generally have uniform and stable moisture content. In case of variations, clause 9.2.3 of IS 456-2000 shall govern during batching.

QUALITY

The coarse aggregate shall consist of naturally occurring (crushed or uncrushed) stones, and shall be hard, strong, durable, clear and free from veins and adherent coating, and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious materials. Coarse aggregate not conforming to any of the following requirements, shall be rejected

- LOS ANGLES ABRASION TEST

  The abrasion value of aggregates when tested in accordance with the method specified in IS: 2386 (Part IV)-1963 using Los Angles machine, shall not exceed 30% for aggregates to be used in concrete for wearing surface and 50% for aggregates to be used in other concrete.

- AGGREGATE CRUSHING STRENGTH TEST

  Aggregates crushing value, when determined in accordance with IS: 2386 (Part IV)-1963 shall not exceed 45% for aggregates used for concrete other than wearing surface and 30% for wearing surfaces. As an alternative to the crushing strength test of aggregates, impact value shall be found out with the method specified in IS: 2386 (Part IV)-1963. The aggregates impact value shall not exceed 45% by weight for aggregates used for concrete for other than wearing surfaces and 30% by weight for concrete for wearing surface such as runways roads and

pavements.

- SOUNDNESS TEST

  The coarse aggregates to be used for all concrete works shall pass a Sodium or Magnesium Sulphate accelerated soundness test specified in IS: 2386 (Part V)-1963 and the average loss of weight after 5-cycles shall not exceed the limits specified in clause 3.6 of IS: 383-1970.

- SPECIFIC GRAVITY

  The coarse aggregates shall have specific gravity of 2.60 minimum.

- DELETORIOUS MATERIALS

The maximum quantity of deleterious materials in coarse aggregates shall not exceed the limits specified in Table of I.S: 383-1970 when tested in accordance with IS: 2386-1963.

SEPARATION

The coarse aggregates shall be separated into nominal sizes during production of the aggregates. Just prior to batching, the coarse aggregates shall be re-washed by pressure spray and finish screened on multi-desk vibrating screen capable of simultaneously removing undersized and over sized aggregate from each of the nominal aggregate. Aggregates entering the batches occur during intermittent batching then a dewatering screen will be required after the finish screens to remove the excess free moisture. Finish screens shall be mounted over the batching plant or on the ground adjacent to the batching plant. Finish screens shall be so mounted that, the vibration of the screen will not be transmitted to the batching bins or scales and will not affect the accuracy of the weighing equipment in any other manner.

The method and rate of feed for finish screening shall be such that, the screens are not over-loaded and result in a finished product, which meets the grading requirements of these specifications. Coarse aggregate shall be fed to the finish screens in a combination of alternations of nominal sizes, which will not cause noticeable accumulation of poorly graded coarse aggregates in any bin. The finish-screened aggregates shall pass directly to the individual batching bin in such a manner as to minimize breakage. Below 2.36 mm. materials passing through the finish screens shall be wasted unless it is routed back through a sand classifier in a manner, which causes uniform blending with the natural sand being processed. Water from finish screening shall be drained in such a manner as to prevent aggregate wash water from entering the batching bins and weighing hoppers washing and finish screening requirements shall be subject to approval by the Engineer-in-charge.

Coarse aggregates for concrete shall be separated into various nominal maximum sizes specified in the relevant paragraph. Separation of the coarse aggregate into the specified sizes after finish screening shall conform to the grading requirements specified in Table-2 of IS 383-1970 when tested in accordance with IS: 2386 (Part II)-1963 (Method of test for aggregates for concrete part I) particles size and shape.

Coarse aggregate for mass concrete may be separated as previously herein specified. Separation of the coarse aggregates into the various sizes shall be such that when tested in accordance with IS 2386 (Part I) 1963 shall conform to the requirements specified in Table 3 of IS 383 – 1970.

Sieves used in grading tests shall be standard mesh sieves conforming to IS 460 (Part I) 1978 (specification for test sieves part I wire cloth test sieves)

4.0 PRODUCTION OF SAND AND COARSE AGGREGATE

Sand and coarse aggregate for concrete and sand for mortar and grout shall be obtained by the contractor from the approved sources. The approval of deposits by the Engineer-in-charge shall not be construed as consisting of the approval of all or any specified materials taken from the deposits and the contractor will be responsible for the specified quality for all such materials used in the work.

Tests performed on samples of sand and coarse aggregate obtained from the approved sources mentioned in the contract documents indicates that they are generally suitable. Well in advance of their usage on the works, the contractor shall have his own testing of materials and satisfy himself that they conform to the specification mentioned here in for use in the works.

No separate payment will be made for such tests. If sand and coarse aggregate are to be obtained from a deposit not previously tested and approved by the Engineer-in-charge, the contractor shall submit representative samples for pre-construction test and approval not less than 60 days before the sand and coarse aggregates are required for use. Each sample shall approximately consist of 100 Kg. of material. In addition to pre-construction tests for the approval of deposits, the Engineer-in-charge may test the aggregates for their suitability during their processing. The contractor shall provide such facilities as may be necessary for procuring representative samples free of cost at the aggregate processing plant and at the batch plant or mixing platform.

However, use and development of any such deposit shall be subject to the approval by the Engineer-in-charge. Any royalties (seignorages or other charges) required for the materials taken from deposits either owned by the State Government or controlled by the Department of Mines and Geology, Govt. of India or owned by any other person shall be paid by the contractor.

DEVELOPING AGGREGATE DEPOSITS

If the deposit is owned by the State Govt. and controlled by the department of Mines and Geology, the portion of the deposit used shall be located and operated so as not to detract the usefulness of the deposit or any other property of the Government and so as to preserve, in so far as practicable, the future usefulness or value of the deposit. The contractor shall carefully clear the area of deposit from which the aggregates are to be produced, free from trees, roots, bushes, sods, solid unsuitable sand, gravel and other objectionable matter. Materials including stripping, removed from deposits owned by the Government, controlled by the Director of Mines and Geology, Government of India, and not used in the work covered by these specifications shall be disposed-off as directed.

Due to the overall construction programme, it is quite likely that more than one contractor may elect to use of the sources named in the contract document. The contractor shall be responsible for co-ordinating his work such that it does not interfere with the operations of other contractors who are also using any given source.

5.0 CEMENT CONCRETE LINING

Canal lining shall be done using mechanised steel shutter gantries/ manual placement concrete as per the dimensions of the cause to be lined. Plain cement concrete of M-15 grade, with the maximum size of aggregate of 20mm shall be laid on the bed and slopes of the canal sections as shown on relevant drawings. The thickness of lining shall be as indicated in in the drawing for both in bed and slopes of the canal. If during construction it is found necessary to alter the canal section and side slopes without altering the thickness of lining, the contractor shall be informed in writing of such changes.

The equipment and operation for concrete lining includes foundation trimming, sub-grade

preparation, concrete production and delivery from point of production, placement of concrete, compaction of concrete, curing and other associated activities. Supporting the placement of the canal lining shall be matched with the lining equipment' capability in case of mechanical placement, so as not to impede the specified placement rate of lining operation. The overall equipment deployment shall be such as to ensure the completion of canal lining within the scheduled period specified in the contract.

During the preparation of sub-grade for canal lining, the proud earth work should be properly trimmed to achieve the designed profile of the sub-grade. This excavation for trimming for base preparation of lining shall be carried out immediately prior to laying of the lining, but in no case the time interval should exceed 3 days in normal weather and 2 days in adverse weather conditions.

The scope of work also includes the following:

i. Dewatering the canal section for preparing the base and laying concrete for lining.
ii. Providing steel safety ladders/ concrete steps at required intervals or as directed.
iii. Providing under drainage arrangements consisting of porous plugs in case provided in the drawing.
iv. Providing specified filter materials of approved quality.
v. Providing contraction/ expansion joints.

CLEARANCE OF SITE

Area proposed for lining of the canal as a whole shall have to be cleared of all objectionable materials, stumps, roots, bushes, and rubbish. Such materials, from clearing operation shall be disposed-off from the working area clear of work site as per direction of the Engineer-in-charge.

PREPARATION OF SUB-GRADE FOR CONCRETE LINING.

Provision of this paragraph shall apply to the preparation of sub-grade on which concrete lining is to be placed.

a. The work of trimming the canal section up to the bottom of concrete lining/ bottom of filter materials to be provided as the case may be and preparing sub-grade for concrete lining includes removal of proud from the slope and bed of the canal. The trimming operations is to be carried out manually or by machines (Trimmer) of adequate capacity immediately prior to laying of the lining but in no case the time interval between trimming and laying should exceed 3 days in normal weather and 2 days in adverse weather conditions. Wherever rock is over excavated, the item of trimming and preparation of sub-grade includes filling the over excavated portion with suitable semi pervious materials, watering and compaction and trimming up to bottom level of the concrete lining. All along the canal alignment the rain cuts on inner slope of the banks shall be filed up with approved excavated materials and shall be compacted adequately to required line and grade & level. The material required for filling the over excavation in rock and rain cuts, if not available during excavation in soils to be done under this item, shall be hauled from stock piles or borrow area to be arranged by the contractor and placed in position.

TOLEARANCE IN PREPARATION OF SUB-GRADE

Tolerance level shall not exceed 6.5mm on bed and slopes. Excavated profile provides the final

base for lining and tolerance departure from lines shown on the drawings shall be as indicated here below:

± 20 mm on straight section.

± 50 mm on tangents.

± 100 mm on curves.

Departure from levels shown on the drawings.± 20 mm

The above tolerance shall be negotiated gradually through smooth transition in a length of 50 m. No over-run in concrete quantity shall be paid to the contractor.

MEASUREMENT AND PAYMENT

Measurement and payment for trimming and preparation of sub-grade shall be made on area basis of number of square meters of the canal prism trimmed over which the concrete lining is to be placed. Payment shall be made at the unit bid price in the bill of quantities. The rate shall include cost of labour, equipments, watering, compaction of bed and sides and all incidental works as necessary to complete the work as per the specifications and also dewatering of the canal sections where required.

SELECTED BEDDING MATERIALS

The selected bedding material in the case of bed and sides of canal profile in normal soils shall be graded filter material compatible with sub grade materials and thoroughly compacted. In case of expansive soils, cohesive non swelling (CNS) soil will be used for bedding. The thickness of CNS layer shall be designed according to swelling pressure of soil or as directed by the Engineer-in-charge. The bedding materials shall generally be provided conforming to following gradation and index properties.

LINING IN NON-BLACK COTTON SOILS

- Selective protective lining to be provided immediately upstream and downstream of every structure for 2.5m upstream & 3.75m downstream of the structure where fluming of channel is involved, and for 2.5m reach both u/s & d/s of structure where fluming of channel is not made. Toe walls must be provided at upstream and downstream ends of lining.

- Lining be provided in high banking reaches and in all such reaches as are considered “vulnerable” viz; associated with seepage, slippage of slopes and breaches etc.

- Model Sections/ Profile Walls of Concrete (as depicted in the sketch) should be provided in the balance portion of the unlined canal.

LINING IN SWELLING-BLACK COTTON SOILS:

- *Lining to be provided throughout the canal reaches passing through swelling B.C. soils. In such case, provision for CNS (Cohesive non-swelling) treatment of the sub-grade should be made prior to placement of lining as per IS: 9451-1994. The thickness of CNS layers to be placed normal to the canal bed and slopes shall be in accordance as under:*

Table :Thickness of CNS layer in canal carrying (IS 9451)

Discharge less than 2.0 Cumecs

Discharge in Canal up to 2.0 Cumecs.		Min^{m} Thickness of CNS layer in cm for Swelling pressure of BC Soil	
Cumecs	Cusecs	0.50 – 1.50 kg/cm^2	More than 1.50 kg/cm^2
1.4 – 2.0	50 -70	60 cm	75 cm
0.7 – 1.4	25 – 50	50 cm	60 cm
0.3 – 0.7	10 – 25	40 cm	50 cm
0.03 – 0.3	1 – 10	30 cm	40 cm

Table :Thickness of CNS layer in canal carrying

Discharge 2.0 Cumecs and above.

Swelling pressure of BC Soil in kg/cm^2	Min^{m} Thickness of CNS layer in cm
0.50 – 1.50	75 cm
1.50 – 3.00	85 cm
3.00 – 5.00	100 cm

GRADATION & INDEX PROPERTIES

The CNS soils to be used should be non-swelling with a maximum allowable swelling pressure of 0.1 kg/cm^2 (10 KN/ m^2) when tested in accordance with Indian standard, IS: 2720 (Part- 41) – 1977. CNS soils are to be broadly conforming to the following range:

GRADATION:	INDEX PROPERTIES
Clay : 15 – 20 %	Liquid Limit : More than 30% but less than 50%
Silt : 30 – 40 %	Plasticity Limit: More than 15% but less than 30%
Sand : 30 – 40 %	
Gravel : 0 – 10 %	

Note: *Provision for mechanized compaction of CNS soil layers to at least 95% proctor density should be made.*

METHOD OF COMPACTION:

In small sectioned channels, provision for "fill & cut method" should be made in order to achieve effective compaction. The channel section should be over excavated (to the extent governed by the CNS thickness) say, in a reach of convenient length; CNS soil be placed in layers in the full section, watered (as required), and each layer is to be compacted to at-least 95% proctor density through deployment of, preferably, small width powered drum rollers or standard power rollers or fuel operated plate compactors or rig-mounted steel plate machine. This process of compaction should be continued right up to the top of designed section. There-after, the compacted section should be scooped out to the proposed design section and the CNS so scooped shall be re-used in the next 300m reach. Provision in the cost estimate should accordingly be made for re-handling of the scooped out CNS and also some percentage of wastage during re-handling is provided.

Note: *This procedure should also be followed for the re-sectioning and strengthening of channels (involving compaction of earth fill other than CNS fill) not passing through B.C. soils.*

PARAMETERS OF CAST-IN-SITU CEMENT CONCRETE LINING:

THICKNESS OF C.C.LINING: Thickness of un-reinforced viz: plain C. C. lining may conform to either the Indian Standard IS: 3873 – 1993 or US Bureau of Reclamation Practice as tabulated below:

Table 5C: THICKNESS OF C.C.LINING as per IS: 3873 – 1993

Discharge Capacity in Cumecs (Cusecs)	Depth of Flow in m	Thickness of CC lining in mm
0 – 5 (0 – 175)	0 – 1.0 m	50 – 60 mm
5 – 50 (175 -1750)	1.0 – 2.5 m	60 – 75 mm
50 – 200 (1750 – 7000)	2.5 – 4.5 m	75 – 100 mm

Note: *Taking into consideration the various factors including economy and ease/ practicability of placement & durability consideration it may be appropriate to adopt a lining thickness of 75 mm for channels of discharging capacity up to 175 cusecs.*

CEMENT:

For area other than coastal, 43 Grade or 53 Grade Ordinary Portland cement is to be used. In the coastal zones, Portland slag cement may be used.

CEMENT CONTENT AND WATER-CEMENT RATIO:

The concrete lining being exposed to alternate wetting and drying during its functioning or working life, comes in the category of " severe exposure condition" as per Indian standard IS: 456 – 2000. Accordingly, provision of cement content in the concrete mix is to be not less than 250Kg/M^3 is made in the cost estimate of C. C. lining from "durability consideration". Water Cement ratio is to be restricted to the range from 0.50 – 0.60. The M15 concrete mix to be used in the lining should be the

design mix which would indicate actual the cement concrete to be used per cubic meter of concrete.

MAXIMUM SIZE OF COARSE AGGREGATE:

Graded coarse aggregate with the maximum nominal size (MSA) of 20 mm down to IS grading should be used in the concrete mix of lining.

AIR ENTRAINING AGENT (AEA):

Provision for using AEA in the concrete mix for C. C. lining should be made in the cost estimate. Concrete mix with AEA affords more" durability" as well as "better workability (viz: fluidity)" and better "finish" to the surface.

Graded fine and coarse aggregates are to be used in the concrete mix and any slight deviation in the requisite grading is compensated by air-entrainment in the mix by the addition of AEA.

CONTRACTION JOINTS:

As an acceptable thumb rule, the spacing of contraction joints should not exceed 36 times the thickness of lining in order to avoid cracking of the lining surface in between the joints.

Table : SPACING OF CONTRACTION JOINTS

Lining thickness in mm (t)	Spacing of Joints (36 x t)
65 mm	2340 mm, say 2.30 m
70 mm	2520 mm, say 2.50 m
75 mm	2700 mm, say 2.70 m

Note: *If the perimeter of canal section is equal to or less than 9.0 m, no longitudinal contraction joints need to be provided. However, the transverse contraction joints across the canal section are to be provided irrespective of the extent of the perimeter.*

CONSOLIDATION OF CONCRETE LININGS:

Proper consolidation of concrete mix for the C. C. linings, as being placed on bed and sides is of paramount importance.

Use of conventional needle vibrators may puncture the sub grade surface. One of the most effective methods of consolidation comprises of deployment of "vibratory plate device" operated by a fuel operated tiny motor.

CUTTING GROOVES FOR CONTRACTION JOINTS:

Grooves should be cut when the concrete is still green/ plastic, to be later filled with the sealing

compound. The groove is normally 27mm deep, for the C. C. lining thickness of 65 mm – 75 mm range, 11 mm wide at bottom and 14 mm wide at the top. It should be filled with hot/ poured sealing compound conforming to IS: 5256 – 1992. After the C. C. lining is fully set (viz: after a period of 28 days), only then the grooves have to be filled with the sealing compound after cleaning of dirt and mortar or grout from the grooves.

CURING OF CC LINING:

Adequate and fool-proof curing is the most vital requirement for CC Lining.

The bed lining should be effectively cured by constructing small earth bunds of say, 30 cm high at convenient intervals and impounding water on the bed between the successive bunds. The sloped lining surfaces should be cured either by fully covering the concrete surface with Hessian cloth rolls/ gunny bags and keeping these wet with water throughout 28 days period.

UNDER-DRAINAGE:

A convenient method of the under-drainage is the provision of "porous concrete plugs" of 75 mm dia and 250 mm to 300 mm length in bed and side slopes underlain by graded filter of size 300 mm x 300 mm or 350 mm x 350 mm. One plug can be provided in the bed and one plug in each side slope at a distance of d/3 (one third of FSD) from the bed in alternate panels (viz: at a spacing of 4.5 m to 5.0 m). The porous plugs should be composed of one part of cement and four parts of coarse aggregate of size not more than 20 mm. No sand is to be used. Only so much water is used as is required to produce a paste to coat the aggregate without filling the voids. The porous plugs, after requisite curing, are becoming porous and free draining.

The porous concrete after curing shall be pervious and free draining type. As soon as the concrete hardens (i.e. it attains final setting) it should be sprinkled with water and kept moist for at least 14 days. The compressive strength of the porous concrete at 7 days as determined by tests on 15cm dia x 30 cm height cylinders should not be less than 70 kg/ cm2 and the porosity shall be such that, water shall pass through a slab of concrete 30 cm thick at a minimum rate of 500 ltr/min/sqm of the plug with a constant 10 cm depth of water on the slab.

TOLERANCE IN C. C. LINING THICKNESS:

The permissible tolerance for the thickness of lining is ± 10%, provided the average thickness is not less than the designed thickness.

MATERIALS

All materials including cement, fine aggregate and coarse aggregate, water admixture and steel shall be as specified in Section 4.2 for concrete.

6.0 CAST IN SITU CONCRETE LINING

The work shall generally conform to IS 3873-1993. All concrete for lining shall be governed by IS 456-2000. The concrete shall be of controlled grade with suitable admixtures of approved air entraining agents using well graded aggregates with maximum size of aggregates of 20 mm/ 12 mm as per specification. Due to change in design mix, if it becomes obligatory to use lean/ richer mix, the

contractor shall comply with the same. In case of leaner mix the department shall deduct the cost of cement from the bill of the contractor at the issue price of cement for short consumption of cement and no other compensation on this account shall be allowed. In case of richer mix the contractor shall be paid for the extra cement used at the issue price of cement.

PRODUCTION OF CONCRETE MIXES:

The concrete should be produced in a mechanical concrete mixer of any standard size or in a stationary weigh batching & mixing plant. Mobile concrete mixers of various drum capacities (0.5 cum or more) are also available in the market for production of concrete.

Hand mixing of concrete shall not be allowed except in rare exceptional circumstances and isolated cases when the quantity of concrete to be placed is very small.

For price adjustments, the amount so recoverable/ payable shall be deducted/ added to the value of the work done. Design mix and actual cement required shall be communicated from time to time to the contractor in writing by the Engineer-in-charge.

TRANSPORTATION OF CONCRETE

a. Transportation shall be handled from the place of mixing to the place of final deposition as rapidly as practicable by use of equipment such as transit mixers which shall prevent initial setting, segregation and loss of any of the ingredients. It shall be transported and compacted in its final position within 30 minutes of its discharge from the mixer unless carried in properly designed agitators operating continuously where this time shall be within 2 hours of the addition of cement to the mix and within 30 minutes of its discharge from the agitator.
b. If segregation occurs during transport, the concrete shall be remixed before being placed after observing the time requirements as above.

PLACING AND COMPACTION

Concrete shall be placed only in the presence of a duly authorized representative of the Engineer-in-charge. Concrete shall be placed and compacted before initial setting time and shall not be subsequently disturbed. Placing of concrete shall not be started until all form work installation of parts to be embedded if any and preparation of surface upon which concrete is to be laid have been completely inspected by the Engineer-in-charge. All absorptive surfaces against which concrete is to be laid shall be moistened adequately so that moisture shall not be withdrawn from freshly placed concrete. The surfaces, however, shall be free from standing water and mud etc.

MANUAL PLACING OF CONCRETE LINING

a. For small reaches of canal lining involving small quantity and small lining sections of lining be placed manually. Alternatively, steel shutter gantries can also be used for mechanised lining of the slopes.

b. Concrete shall be placed in all cases as neatly as practicable in its final position and shall not be caused to flow in a manner to permit segregation. Excessive separation of the coarse aggregate caused by allowing the concrete to fall freely from too great a height or at too great an angle from the vertical shall not be permitted and where such separation would otherwise occur. The contractor shall provide suitable means to convey the concrete without allowing such separation.

FINISHING.

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

b. The surface of concrete finished against form shall be smooth and be free from projections, honey combing and other objectionable effects. Immediately on removal of forms, all ridges or lips shall be removed and undesirable local bulging on exposed surfaces shall be remedied by tooling and rubbing.
c. Repairs to concrete surface and additions where required shall be made by cutting regular openings into the concrete and placing fresh concrete to the required lines. Chopped openings shall be sharp and shall not be less than 75 mm in depth.

CURING.

MEMBRANE CURING.

In case membrane curing is to be adopted, following specifications be followed:

a. These specifications cover curing of concrete using membrane forming compound to retard the loss of water during the early hardening period and to reduce the temperature rise in concrete exposed to radiation from the sun. This compound shall be suitable for use as curing media for fresh concrete and for further curing of concrete after removal of forms or after initial moist curing.
b. Concrete of canal lining on slopes including key at the top and curved portion at the bottom of the slope of canal shall be cured with liquid membrane forming white pigmented curing compound which shall form water retaining surface to achieve the desired effect of water curing at 28 days. The curing compound shall be white pigmented of approved qualify conforming to ASTM-C-309-81 Type-2.
c. White pigmented compound (Type-2) shall consist of finely divided white pigments and particle solids, ready mixed for immediate use without alteration. The compound shall present a uniform white appearance when applied uniformly to a fresh concrete surface at a specified rate of application. It shall be of such consistency that it can be readily applied by spraying to provide uniform coating at temperatures above 4 degree Centigrade. If two coats are to be applied then it shall be applied at an interval of approximately one hour. They shall adhere to freshly placed concrete that has stiffened or sufficient to resist marking during the application and to damp hardened concrete and shall form a continuous film when applied at the specified rate of application. When dry the covering

shall be continuous flexible and without visible breaks or pin holes and shall remain as unbroken film for at least 28 days after application. It shall not react and should not have deleterious effect on concrete.

d. The compound shall meet with the requirement of water retention test as per ASTM designation C-150-80 .The loss of water in this test shall be restricted to not more than 0.55 Kg/ M2 of exposed solution of exposed surface in 72 hours.
e. The white pigmented compound (Type–2) when tested as specified in accordance with method E-97 of ASTM shall exhibit a day light reflectance of not less than 60% of that of magnesium oxide.
f. It shall fulfil the requirement of drying time when tested in accordance with ASTM C-309-81. The compound applied shall be dry to touch in not more than 4 hours. After 12 hours, it shall not be tacky or track-off (peel off) concrete when walked upon nor shall it impart a slippery surface.

TESTING OF CURING COMPOUND.

a. The liquid membrane forming curing compound to be brought in the manufacture's original clear containers. Such container shall be legibly marked with the name of the manufactures the trade name of the compound the type of compound and class of vehicle/ solids the nominal percentage of volatile material and batch or lot number. The lot number will be assigned to the quantity of compound mixed sampled and tested as single product. The manufacturer shall exercise the care in filling the container so that all are equally representative of the compound produced.
b. Curing compound to be used on site shall be got tested at least 14 days in advance so that the result of water retention tests reflectance test, drying etc. are available before it can be permitted for use. All of the filled containers represented by the approved sample shall then be sealed to prevent leakage substitution or dilution. The Engineer-in-charge or authorized representative should mark each container represented by the samples with a suitable identification mark for later identification and correlation and shall be kept in store with double lock arrangements. One key shall be kept with the contractor and the other with Engineer-in-charge. Random samples shall be collected from every batch of the compound. Frequency of random sampling shall be done as directed by the Engineer-in-charge. The contractor shall provide samples and labour for collecting samples free of cost. Testing shall be carried out by the department.

METHOD OF APPLICATION OF CURING COMPOUND.

The compound shall be sprayed using mechanical sprayer of approved design to ensure uniform and continuous membrane on the concrete surface. The coverage shall be at the rate specified by the manufacture or at the rate of 4 to 5 m. per litres. Field trials shall be conducted to decide effective coverage rate which depends upon surface finish. With a view to ensure through and complete coverage approximately on half of the compound for a given area should be applied by moving the spray gun back and forth in one direction and the remaining half at right angles to this direction. In case the application is still not found uniform the contractor shall have to apply the second coat as and where directed by the Engineer-in-charge. If a second coat is to be applied it should be applied approximately after an interval of one hour. The curing compound shall be applied as soon as the bleeding water or shine disappears, leaving dull appearance. Equipment for

spraying curing compound shall be of pressure tank type (5 to 7 kg/cm2) with provision of continuous agitation. A curing jumbo with multiple travelling spray guns shall be provided for effective spray. Spraying on concrete lining shall be done in such a way that the green concrete is not disturbed or damaged or any foot impressions left. Necessary schemes on spraying by mechanized means shall be got approved from the Engineer-in-charge. However, in emergency for very small areas (Patches) it can be applied with wire or bristle brush. Such compounds shall be used on the work only after production of test results and approval of the schematic plan on spray curing compounds. Adequate care shall be taken to prevent any movements on cured surface up to 28 days after application of curing compound. Under unavoidable circumstances created by non availability or short supply of specified curing compound, the contractor shall be allowed to resort to water curing of concrete lining on slopes after obtaining prior approval of the Engineer-in-charge in writing. Such water curing shall be carried out in accordance with the following specification.

WATER CURING.

The surface of invert of the canal shall be kept continuously moist by covering it completely with wet burlap as soon as the concrete has hardened sufficiently. The burlap shall be kept continuously wet by spraying water for at least 12 hours. Thereafter curing by impounding shall be resorted to. The concrete to be cured with water shall be kept wet by impounding for at least 14 days. Water lost by evaporation shall be replenished periodically to keep the surfaces continuously submerged under water. The period of 14 days specified above shall be increased to 21 days when Pozzolana has been used in the concrete as part of replacement of cement.

When the curing of concrete in the canal bed is not found satisfactory the Engineer-in-charge may ask the contractor to resort to membrane curing.

TESTING OF CONCRETE AND ACCEPTANCE OF WORK:

SAMPLING PROCEDURE AND FREQUENCY:

a. Sampling Procedure: A random sampling procedure shall be adopted to ensure that each concrete batch has a reasonable chance of being tested i.e. the sampling should be spread over the entire period of concreting and should cover all mixing units.
b. Frequency: The minimum frequency of sampling of concrete of each grade shall be in accordance with the following.

Quantity of concrete in cum	Number of samples.
1 to 5	1
6 to 15	2
16 to 30	3
31 to 50	4
51 to above.	4 plus one additional sample for every 50 cum of part thereof.

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

TEST SPECIMEN:

Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking form work or to determine the duration of curing or to check the testing cubes cured by accelerated methods as described in IS 901-1978. The specimen shall be tested as described in IS: 516-1956.

TEST STRENGTH OF SAMPLES:

a. The test strength of the sample shall be the average of three specimens. Individual variation shall not be more than 15% percent of the average.
b. Contractor shall provide necessary unskilled labour and facilities for collection of samples cores etc. and shall remain present at the time when the samples, cores etc. are taken. Testing shall be carried out at the testing laboratories set up at the site or at any other laboratory that the Engineer-in-charge may decide upon and the results given thereby shall be considered as correct and authentic and acceptable to the contractor. All testing charges will be borne by the department.

ACCEPTANCE CRITERIA

Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following condition are met:

a) The mean strength determined from any group of four consecutive test results compiles with the appropriate limits in col 2 of Table below.

b) Any individual test result complies with the appropriate limits in col 3 of Table below).

Flexural Strength

When both the following conditions are met" the Concrete complies with the specified flexural strength.

a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3N/mm2•

b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm2•

Quantity of Concrete Represented by Strength Test Results

- The quantity of concrete represented by a group of four consecutive test results shall include the batches from which .the first and last samples were taken together with all intervening batches.
- For the individual test result requirements given in col2 of Table below or in item(b) of 5.6.4.2, only the particular batch from which the sample was taken shall be at risk.
- Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m'.

If the concrete is deemed not to comply pursuant to 5.6.4.3. the structural adequacy of the parts affected shall be investigated and any consequential action as needed shall be taken.

Concrete of each grade shall be assessed separately.

Concrete is liable to be rejected if it is porous or honey-combed. its placing has been interrupted without providing a proper construction joint. There in for cement has been displaced beyond the tolerances specified. or construction tolerances have not been met. However. the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the engineer in-charge.

TABLE: Characteristic Compressive Strength Compliance Requirement		
Specified Grade	Mean of the Group of 4 Non-Over lapping Consecutive test results	Individual test results in N/mm^2
M15	>fck + 0.825x established standard deviation (rounded off to nearest to 0.5 Nlmm1) or fck. +3 N/mm^2 whichever is greater	$>fck^{-3}$ N/mm^2
M20	> .fck., +0.82S x established Standard deviation (rounded above off to nearest tot 0.5 N/mm2) or >fck +4 N/mm^2whichever is greater	$>fck^{-4}$ N/mm^2

7.0 INSERTION OF PVC CRACK-INDUCING JOINTS.

a. The transverse and longitudinal PVC (Polyvinyl Chloride) strips shall be provided with the shapes confirming to dimensions shown on the drawing. The finished PVC crack inducing joints shall be extruded from virgin Pigmented, Plasticised Polyvinyl chloride (PVC). The PVC crack inducing joints shall be dense homogeneous free from holes and other imperfections. The cross section of the PVC crack inducing joints shall be uniform along its length and thickness shall be symmetrical transversely. Tolerance for dimensions in overall length and width shall be 5% and thickness 10%. The finished PVC crack inducing joints shall meet the following requirements:

Sl.No	Characteristics	Unit	Values
1.	Tensile strength	Kg/Cm2	116 Minimum
2.	Tear Resistance	Kg/Cm2	49 Minimum
3.	Stiffness in Flexure	Kg/Cm2	24.6 Minimum
4.	Accelerated extraction		
	a) Tensile Strength	Kg/Cm2	105 Minimum
	b) Ultimate elongation	Kg/Cm2	250 Minimum
5.	Effect of alkali (7 days)		
	a) Weight measure	%	0.25 Maximum
	b) Weight decreased	%	0.10 Maximum
	c) Hardness change	Point	1.50
6.	Effect of alkali (28 days)		
	a) Weight increase	%	0.4 Maximum
	b) Weight decrease	%	0.3 Maximum

	c) Dimension change	%	1.1

b. Weight of the PVC strip shall be a minimum of 460gm/meter for the longitudinal strip and a minimum of 420 gm/meter for the transverse strip.
c. The above determination shall be made in accordance with the specification of C.W.C. in vogue. The surface finish of PVC strips shall be mat finish and of white colour.
d. Contractor shall arrange for getting the finished PVC crack inducing joint tested in recognized Test Laboratories by the Government. The manufacturers shall furnish test sample of PVC crack inducting joints in 30 cm. length reel, free of cost. Each sample shall be marked with the number of the reel from which sample is obtained and with certificate that the samples are from the reels to be furnished.
e. It is mandatory for the manufacturer of the PVC strips from whom the contractors shall procure PVC strips to have a full-fledged testing laboratory in the factory to enable pre-despatch testing of the products. Test reports from Government test laboratory shall also be binding on the manufacturer based on samples drawn by the Engineer-in-charge from consignments received at site. The contractor shall get the sample of PVC strip approved by the Engineer-in-charge. He shall furnish the name of manufacturer the details of the in-house testing arrangements with the manufacturer and shall also furnish a test report from the in-house testing facilities along with the sample.

PLACING

a. The PVC crack inducing joints shall be inserted in the concrete lining when concrete is plastic. The longitudinal PVC crack inducing joints shall be inserted before the transverse PVC cracks inducing joints is inserted. The PVC crack inducing joints at edges shall be plastered in position fixed with longitudinal channels by clips or such other arrangement prior to lying of concrete. The PVC crack inducing joints shall be inserted in position in concrete lining as shown in drawings. The insertion of the longitudinal and or transverse PVC crack inducing joints at the predetermined locations of joints requires special attention to ensure proper location (depth is especially important) plumb installation and consolidated concrete around the PVC crack inducing joints. The longitudinal PVC crack inducing joint includes a cellular upper fin. The inspection fin shown on the drawings shall be comparatively thin and shall remain above the top surface of lining. It is important that top of the upper fin be at or near the concrete surface. The manner of installation shall include mechanical vibration that produces through consolidation of the concrete around the crack inducing joint and provides a continuous contact between the concrete and all surfaces of the crack inducing joints. The longitudinal crack inducing joint shall be fed into the fresh concrete from reels mounted in front of the pavers through guides and tension rollers so placed as to ensure proper depth and orientation of the crack inducing joints. Installation of transverse crack inducing joint shall be made by suitable joint inserted contrivance capable to insert into freshly placed concrete lining.
b. At intersection of longitudinal and transverse joints containing PVC crack inducing joints the top vertical members of the longitudinal crack inducing joints shall be removed for 10 to 15 cm. in width without pulling the crack inducing joint from the concrete lining and transverse crack inducing joint shall be placed within the notch so formed. Depression of the longitudinal cracks inducing joint below the specified positions in the concrete shall be permitted at intersection only to the extent necessary to place the transverse crack inducing joint to the specified depth. However, tolerances and concrete consolidation requirements of the preceding paragraph shall apply at intersections.
c. The manner of making the intersections shall produce transverse and longitudinal crack inducing joints and provide a nearly continuous weakened plan normal to the lining surface in both directions

through the intersection.

JOINTS.

In RCC lining construction, joints shall be provided to accommodate expansion and contraction of the concrete or to provide continuity between the breaks in construction work. Joints shall be provided as shown on the drawings or as directed by Engineer-in-charge. The depth of joints to be cut in the bed of the canal as well as on slope shall be as specified in the drawings. The joints are not to be filled with sealants but only to be cut at specified intervals. The sealants shall be filled in joints later but before functioning of canal. The tools to be used by the contractor for providing joints shall be got approved from Engineer-in-charge.

TOLERANCES IN EXECUTION OF LINING.

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

b. Tolerance for lining shall be permitted within the following limits.

i)	Departure from established alignment:	± 20 mm on straight reaches. ± 50 mm on tangents. ± 100 mm on curves.
ii)	Departure from established grade:	± 20 mm on straight reaches.
iii)	Variation in concrete lining thickness:	± 10 mm of lining thickness provided average thickness is not less than specified.

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

DEWATERING.

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

MEASUREMENT AND PAYMENT:

PLAIN CEMENT CONCRETE LINING:

a. Measurement shall be on the basis of square meter/cum of plain concrete lining and payment shall be at the unit rate bid in bill of quantities for concreting works. Payment for lining shall be made for the thickness shown on the drawings and on square meter/cum basis of the area/volume including key on both sides. The thickness of lining as shown in the drawing shall be maintained by setting of

paver machine in relation to final sub-grade on which lining is to be laid. The thickness shall be cross checked by (i) volume of concrete placed and area covered (ii) use of probe when concrete is being placed and (iii) coring if required. Any overrun in quantity of concrete in lining shall not be paid to the contractor.

b. The unit rate for lining shall include cutting of grooves for crack inducing joints to specified depth in panels as directed by the Engineer-in-charge including cost, carriage, royalty and taxes of all materials with all leads, lifts, mixing, form work, conveying, placing, compacting, finishing, curing and also dewatering during placing of concrete lining as required.
c. The unit rate of lining shall also include the cost of producing samples and cost of all incidental work needed to make the cracks inducing joints cost of all operation equipment labour tools, etc. required for carrying out this work.

8.0 SAFETY LADDERS:

Safety ladders should be constructed in canal lining as directed by the Engineer-In-Charge. 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 ladders may be provided at a spacing of about 300 m, the ladders being provided alternatively on either side.

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

Typical details of safety ladders are illustrated in the approved drawing.

MEASUREMENT AND PAYMENT:

Safety ladders shall be measured by weight of M.S. bar. Payment therefore shall be made at the unit rate in schedule of quantities. The rate shall include the cost, carriage, taxes for providing and fixing the ladders as indicated on the drawings.

9.0 CANAL LINING USING CEMENT CONCRETE SLABS

Lining of canals with pre-cast cement concrete slabs shall be adopted for rehabilitation of the damaged pre-cast slab lining in canals or new lining in the old or new canals or in places as shown in the drawings or as directed by the Engineer-in-Charge.

PREPARING FOUNDATION

The provisions detailed in the paragraph 5.3 shall apply.

MODEL (PROFILE) SECTIONS OR TEMPLATES

Model sections or templates of cement concrete M-15 shall be constructed in the bed and sides of the canal to the required sections with the top of model section level to the finished surface of the lined section of the canal portion. The spacing of the model sections shall be 15 meters in straight reaches and 7.5 meters in curved reaches. The exposed face of the model sections constructed with cement concrete M-15 or shall be plastered with cement mortar as shown in the drawing or as directed by the Engineer-in-Charge. The dimensions of the model sections will be the given in the drawings or as directed by the Engineer-in-Charge.

Suitable super elevation in curved reaches shall be given after the approval of the Engineer-in-

Charge.

Since the model sections are to be used as reference for excavation and trimming of sub grade for the lining and for laying accordingly, finishing the lining of the required grade and profile, it should be constructed with in a tolerance limit of 30 mm in a length of 3 meters. Model sections beyond the permissible tolerance will be removed and redone by the Contractor at his own expense.

PRECAST SLABS

Mix for the slab shall be of cement concrete M-15 using 20mm hard machine broken stone aggregates. The face of the slab shall be square or rectangular. The dimensions of the slab shall be 45 cm x 30 cm x 5 cm or 22.5 cm x 30 cm x 5 cm. Toe wall blocks shall be 15 cm x 20 cm x 30 cm or as directed by the Engineer-in-charge. The permissible tolerance on length and width shall be + 5 mm. The difference in length of two diagonals of slab shall be not more than 4.5 mm. The thickness shall not be less than the specified value. The permissible tolerance on thickness shall be ±2.0 mm. The slabs shall be either with all its sides right angles to the faces or with two of its sides bevelled at a particular angle to the faces or as directed by the Engineer-in-Charge. The bevelled slabs shall be provided with tongues and grooves as per paragraph 6.1.2.1 of I.S. 3860- 1966.

The slabs shall have minimum flexure strength as specified in I.S. 4060-1968.

CASTING OF SLAB

EQUIPMENT

Manufacturing of slabs required for lining shall be done in the casting yard using concrete mixers for mixing, steel moulds and table vibrators. They shall be cured in curing ponds. The casting yard with the required infrastructure shall be constructed by the Contractor at his cost.

The measuring boxes for the ingredients shall be accurate and maintained in serviceable conditions. The concrete mixer shall conform to I.S. 1971-1968.

The table vibrators to be used shall conform to I.S. 2514-1963. For all sizes of vibrating table, the height of the table top from the ground level shall be sufficient to allow for easy placing and removal of the moulds and shall not exceed 0.75 meter. The capacity of vibrating table shall be indicated for the effective vibration by the maximum weight in tones of the mould plus the concrete in the mould.

The frequency of vibration for the table operating at its maximum load capacity shall be between 3000 to 6000 cycle per minute. The vibration acceleration of the table operating at its maximum load capacity shall not be less than four times the acceleration due to gravity. The minimum frequency of the table under loaded state for determining the acceleration shall not be less than 3000 cycles per minute.

The reduction in amplitude of the table while operating from 'zero load' to full load condition shall not exceed 25%.

A source for giving copious water, required for mixing, casting and curing concrete shall be provided at the Contractor's cost. Sufficient numbers of steel moulds of required size with necessary base plates shall be procured by the Contractor.

The payment shall be for finished work and the payment includes all materials, equipment, machinery, casting yard and all other inputs including water supply etc. complete.

CASTING AND CURING

Prior to the batching operation, steel moulds and base plates shall be cleared of all dirt and well-oiled on all surfaces and kept ready for placement of concrete. The table vibrator and concrete mixer should be checked to ensure that they are in working condition. Cement, sand and aggregate shall be fed in to the mixer after measuring each volumetrically in required proportion. Required water shall be added while the ingredients are fed into the drum from the hopper. The mixing time shall not be less than two minutes and unloading of the mixed concrete to the platform shall be done only after the steel mould and the table vibrator are ready to receive concrete. The concrete shall be laid in the oiled steel moulds and vibrated using vibrating table with a frequency of not less than 3000 cycles per minute and the vibrating time shall not generally be less than 20 minutes for 10 sqm of slab of size of 5 cm thick and 30 minutes for 10 sqm in the case of 7.5 cm thick slab.

After the specified vibration period is completed, the slab shall after finishing the top surface be allowed to cure under polythene sheet of wet sack for 24 hours. After the lapse of 24 hours the slabs shall be cured in curing ponds for 7 days. Before placing the slab in the curing ponds care shall be taken to finish the top surface smooth and after 7 days of immersed curing under water, the slabs shall be cured with sprinkling water for next 21 days covering the slab with straw, gunny etc., for keeping the surface always moist.

LAYING OF SLABS

The slabs shall be removed to the canal site for lying only after they are cured for the prescribed period. While loading, transporting and unloading at the site, care shall be taken to prevent any damage to the slab. Slabs which are with rough damaged surfaces or with broken corners or cracks or with irregular edges shall not be allowed to be used in lining.

The laying slab shall be commenced after completing the preliminary works namely preparing the bed construction of model sections or templates, trimming the surface to the bottom line of lining as specified in paragraph 5.12.2 and 5.12.3.

The slabs shall be laid on finished surface true to line and grade using model sections as a guide starting from the bottom layer, the joints shall be filled in with cement mortar of mix 1:3 to the full depth of joint, the width of the joint shall not exceed 12 mm. The joint should be flush pointed in cement mortar 1:3. Curing shall be done for a period not less than 14 days. Any portion of the work not in line or grade, joints not packed with mortar and not cured for the prescribed period shall be removed and redone at the Contractor's cost.

10.0 MEASUREMENT AND PAYMENT

The measurement for the toe wall will be in cubic meter in the case of toe wall built cement concrete blocks. The lining work slabs be measured in square meter.

The unit price bid in the bill of quantities shall include cost of all materials including water, labour and charges for manufacture conveyance, laying furnishing, and casting. Payment shall be made at unit price in the bill of quantities including manufacture and laying of slabs etc. complete.

DESCRIPTION

This work shall consist of supplying and laying live sods on the slope and other locations as ordered by the Engineer in accordance with the following specifications.

MATERIALS

The sods shall consist of a dense well rooted growth of permanent and desirable grasses.

Indigenous to the general locality where it is to be used, and shall be practically free from weeds or undesirable grasses. At the time the sods is out. The grass on the sod shall have a length of approximately 2 inches (if longer, the grass shall be cut to approximately this length and the sod shall have been raked from debris.

The sod shall be cut in uniform strips cot larger than it is convenient for handling and transport. The thickness of the sod shall be as uniform as possible approximately ¾ inch or more depending on the nature of the sod, so that practically all of the dense root system of the grasses will be retained but exposed in the sod strip and so that the sod can be handled without undue tearing or breading.

In the event the sod which is to be cut is in a dry condition, so as to cause crumbling or breaking during cutting operations, the contractor at his own expense, shall at least 12 hours before cutting the sod, apply water to the same in sufficient quantity to provide a well moistened condition of the sod to the depth to which it is to be cut.

Top soil of the area to be turfed shall consist of soil adapted to the sustenance's of plant life.

CONSTRUCTION METHOD

PREPARATION OF THE EARTH BED

All areas desired to be covered with sod shall be fine dressed to required contour, to an extent such that the finished work after laying sod with necessary top soil incorporated in the bed will be in accordance with required lines, grades, slopes and cross section.

The area to sodden shall be free from stones, roots or other undesirable foreign materials. The soil of the area to be sodden shall be loosened to a depth of approximately not less than and top soil shall be spread evenly over the prepared bed to a depth of 2 inches and the clods and lumps shall be broken down to provide a uniform texture to the soil.

Placing the sod

The earth bed upon which the sod to be placed shall be moistened to the depth, manipulated, if naturally not sufficiently moist, and the sod after the same has been cut and shall be properly protected and sprinkled with water until placed be laid in horizontal strips beginning at the bottom of the slopes and working onwards, when placing sods the length to the strips shall be laid at right angles to the direction of flow of water. Sods shall be laid so that the joints caused by abutting ends of sods strips were not continuous, each sod strip shall be so laid to about against the strip previously laid.

As the sod is being laid shall be firmly and lightly tamped with suitable wooden or metal tampers to press the sod into the underlying soil. After tamping, the sod shall present a smooth even surface free from bumps or depressions, at such point. Where water will start flowing over a sodden area the upper edge of the sod strip shall be turned into the soil and layer of earth placed over this, which earth shall be thoroughly compacted to conduct the surface water over the upper edge of the sod. No sods shall be laid during the dry months of March to July.

WATERING

The sod shall be thoroughly watered immediately after placing and shall be kept thoroughly wet for a period of at least seven days after laying and shall be maintained in a satisfactory condition.

METHOD OF MEASUREMENT AND PAYMENT

Measurement of turfing shall be made after full and satisfactory growth of the turfing. The unit

and price shall contain all the specification as mentioned in the tender schedule.

Sod shall be measured by units of 100 square meters and will be paid for at the contract unit price of 100 square meter/ square meter of sod in place which shall include all operation for preparing the earth bed, for furnishing, placing, top dressing and watering the sod and for all labour, equipment, tools and incidentals necessary to complete the work in accordance with contract.

QUALITY CONTROL/ QUALITY ASSISTANCE

The contractor shall establish quality control laboratory/laboratories at work site/sites for testing of soils, material, cement, concrete, water & other relevant inputs/outputs.

In addition to the deployment of conventional "core cutters" for determination of density of compacted earth fill layers, the contractor /the engineer-in-charge may also deply "Non-Nuclear Density Device" for rapid on-site determination of compaction parameters for expediting compaction of earth fill.

6OK card system shall be introduced by the engineer in charge for all works to ensure enforcement of specification of execution of works for promotion of construction quality. This system shall be meticulously implemented by the contractor and maintained by the contractor/ quality control engineers.

ANNEXURE - II

LABORATORY EQUIPMENT

SOIL

1	Grain size Analysis	Mechanical stirrer, Analytical Balance, 80 mm, to 20mm set of sieves + 4.75mm, 6mm, 425 micron, 75 micron, Lid and Receiver suitable for 20cm dia sieves
2	Atterberg Limit	Liquid Limit Device, Casagrande grooving tool and Gauge Block, Cone Penetrometer
3	Specific Gravity	Pycnometer, Hot Plate, Analytical Balance
4	Field Density and Moisture Content	Core cutter 4" dia, Spatula Hammer, Pan Balance .
5	Permeability	Permeability Apparatus, G.!. Tray, Rammer.
6	Triaxial Shear	Triaxial Shear Machine suitable for testing soil samples of 3B mm dia x 76 mm long, sample extractor, Pan Balance, Enamel Plate
7	Shrinkage Factor	Shrinkage Dish, Spatula, Straight Edge. Glass Cup. Glass Plate, 425 micron sieve. Mercury. Desiccators
8	Standard Proctor Compaction	Proctor Mould. Rammer, G.I. Tray, Oven. Sieves. 50mm-.20mm & 4.75 mm. Sample Extruder Proctor Penetrometer (Spring type)
9	Moisture Content.	Moisture Meter.
10	Consolidation	Consolidation Apparatus. Consolidometer set of weights to give a pressure of 10Kg/Cm2
11	Swell	Swell Test apparatus.
12	Relative Density.	Core cutter (100mm dia x 175 mm long), Sand pouring cylinder apparatus. Relative Density apparatus. Vibrating Table
13	Unconfined Compressive strength	Unconfined compressive strength Machine.
14	Plate Bearing Test.	Plate Bearing Test Apparatus.

CEMENT

CHEMICAL TEST

i	AlkaJies	Flame Photometer.
ii	Minor. Major Oxides by Calorimeter	Spectro- photometer.
iii	Chloride.	Potentiometer. Silver Electrode Calomel. Reference Electrode, salt bridge
iv	General.	Water Distillation still. Oven. Hot Plate. Balance (Accuracy-i0.0002 gm), Muffle Furnace (up to 1200 °C), Platinum crucibles, conductivity Bridge. PH meter.sample divider for Powders Physical

PHYSICAL TEST

i	Fineness	Blaine's Apparatus, Stop Watch
ii	Soundness	Le Chatelier Mould. Hot water bath. Autoclave, Length comparator. Moulds. 25 x 25 x 250mm.
iii	Consistency and Setting time Initial and Final	Vicat apparatus. Mould, setting time needles and plunger
iv	Compressive Strength	Compression Testing Machine (50 tonne), Vibrating Machine, Mould 50 sg. cm area.
V	Heat of Hydration.	Calorimeter, Beckman Thermometer
vi	Drying Shrinkage	Length comparator, flow Table
vii	General	Stop Watch, Timer, Temperature Controlled oven, Humidity Chamber, Incubator, Physical Balance (Accuracy 0.001 gm.). Control Room (Temperature controlled curing tanks, set of standard sieves, lid and receiver.

AGGREGATE

(a)	General	Electric Driver, Hot Plates, set of standard sieves, lid and receiver, Balance 10 kg (Accuracy 11m.), 100 Kg (Accuracy 100 gm.), 250kg (Accuracy 0.5 Kg). Scoop, Enamel Trays, Balance. Showel Compression Testing .Machine (200 tonne), Crusher and Ball Mill. Providing Rings 1,5,25,50,100 tonne.
ii	Crushing Value	Crushing apparatus
iii	Impact Value	Aggregate Impact test machine
iv	Abrasion Value	Loss Angels Machine
v	Alkali Aggregate Reactivity	Reaction Containers
vi	Flakiness & Elongation Indices	Apparatus for measuring flakiness and Elongation Indices
vii	Unit Weight Containers	Minimum Capacity of Measures Max. Size of coarse aggregates (mm.) — Capacity of measures (Cum.) 2.5 — 6 37.5 — 11 50.0 — 14

		75.0	28
		114.0	71
		152.0	99
	Sampling Stand	Reffler sample Divider	
	Specific Gravity & Absorption	Pycnometer	

CONCRETE

FRESH CONCRETE		
i	Air Content	Air-meter
ii	Vibration.	Internal vibrator, Table vibrator
iii	Temperature Measurement	Metallic Thermometer
iv	Mix Proportions	Equipment as IS. 1199 for determination of constituents
WORKABILITY TEST		
i	Slump Test	Slump cone Apparatus
ii	Compaction Factor Test	Compaction Factor Apparatus
iii		
iv		
HARDENED CONCRETE		
i	Compression Flexural Tension Bending and Brineel's Hardness Test	Universal Testing Machines ; with accessories (Cap. 100 Tonne)
ii	Capping of Cylinders	Capping Moulds
iii	Mixing of concrete	Laboratory concrete mixer
iv	Testing of curing compounds	Reflectance Meter
SPECIAL TESTS:		
i	Microscopy	Optical Microscope, Grinding and polishing, Equipment
ii	Core Testing	Core Drilling machine, Rock cutting machine, Thermal conductivity apparatus, Permeability apparatus.

SI. No.	Name of Test.	Frequencies	Purpose	Test designated (Indian Standard)
f A) Coarse Aaareaates:				
1.	Sieve Analysis Flakiness & Elongation Index.	One test for every 150 cum or less.	to know the gradation of materials & percentage of various sizes of the constituents.	I.S-2386- Part-I-1963.
2.	Specific gravity, Bulk density, moisture content &. absorption	-do-	to utilise the data for mix design computation	I.S-2386- Part-III-1963.
3.	Soundness (Sodium sulphate method)	-do-	To assess the quality of materials	I.S-2386- Part-V-1963.
4.	Abrasion, Impact, Aggregate crushing value.	-do-	-do-	I.S-2386- Part-IV-1963.
5.	Organic impurities	-do-	-do-	I.S-2386- Part-II-1963.
6.	Alkali reactivity (Chemical method)	Twice in one season	to know the innocuous or Deleterious nature of aterials.	lS-2386-Par-VII
7.	Petrographic examination.	Twice in one season	To know the deleterious constituents & silt of	IS-2386-Part- -VIII 1963

(B) Fine Aggregates:				
1.	Screen Analysis	One test for every 150 cum of sand used in concrete	To know the grain size 8i the fineness modulus of the sand	I.S-2386- Part-I-1963.
2.	Unit weight & bulkage	-do-	To utilize the data for mix design	I.S-2386- Part-III-1963.
3.	Organic impurities	-do-	To assess the	I.S-2386- Part-II-1963.
			quality of materials	
4.	Soundness	-do-	To assess the quality	I.S-2386- Part-V-1963.
5.	Specific gravity, moisture content &	-do-	To utilize the data for mix design	I.S-2386- Part-IV-1963.

Cement

1.	Fineness test	One test for each brand of cement used during the working season preferably at 3	To know the quantity of cement used in the construction	I.S-4031- 1988
2.	Normal consistency	-do-	-do-	-do-
3.	Setting time	-do-	-do-	-do-
4.	Soundness	-do-	-do-	-do-
5.	Compressive strength	-do-	-do-	-do-
6.	Chemical analysis	-do-	-do-	I.S-4032- 1988

Finished Concrete

1.	Slump Test	One test in each shift or at frequent intervals to check the workability	To check the workability of concrete / water cement ration	I.S-1199- 1959
2.	Compressive strength	-do-	To know the strength of concrete	I.S-516- 1959
3.	Percentage cement content	One test in each shift or at frequent intervals	To determine the % of cement used in construction	I.S-1199- 1959

LIST OF REFERENCE

BOOKS AND MANUALS

1. Quality Control and Field Instruction Manual -1 & P Deptt. Govt, of Orissa.
2. Hand Book on Specifications and Field test, Deptt. of Water Resources.

3. U.S.B.R. Earth Manual.
4. U.S.B.R. Concrete Manual.
5. Design of small dams U.S.B.R.
6. Soil and foundation Engineering by Bharat Sing & Mr. Shamshere Prakash.
7. Earth and Earth Rock Dams by Mr. Bharat Sing & H.D. Sharma.
8. Soil Mechanics and foundation Engineering by Mr. B.C.Punima.

INDIAN STANDARD CODE OF PRACTICE

Sl. No.	I.S. Code No.	Title
1	1498-1970	Classification and identification of Soils for general Engineering Purpose.
2	2720 (Part-I-1983)	Preparation of dry Soil samples for various tests.
3	2720 (Part-3-Section-I-1980)	Determination of Specific gravity of Fine grained soils
4	2720 (Part-3-Section-1980)	Determination of Specific gravity of Fine, medium & Coarse grained soils.
5	2720 (Part-2:1983)	Extermination of water content
6	2720 (Part-4:1985)	Grain size Analysis
7	2720 (Part-5:1985)	Determination of liquid & Plastic Limit.
8	2720 (Part-28:1974)	Determination of dry density of soil in place, by the sand replacement method.
9	2720 (Part-29:1975)	Determination of dry density of soil in place, by the core-cutter method.
10	2720 (Part-33:1971)	Determination of dry density of soil in place by the ring and water replacement method.
11	457:1957	General construction of plain and reinforced concrete for dams and other massive structures
12	456:1978	Code of practice for plain and reinforced concrete
13	4031 (Part-l:1988)	Method of physical tests for hydraulic Cement. Determination of fineness by dry sieving
14	4031 (Part-3:1988)	Determination of soundness of hydraulic Cement

15	4031 (Part-4:1988)	Determination of consistency of standard cement paste.
16	4031 (Part-5:1988)	Determination of initial and final setting times
17	4031 (Part-6:1988)	Determination of Compressive Strength of hydraulic Cement
18	2386 (Part-1) :1963	Method of test for aggregates for Concrete, particle size and shape
19	2386 (Part-2) :1963	Estimation of deleterious materials and organic impurities
20	2386 (Part-3) :1963	Determination of specific gravity, density, voids, absorption & bulking of aggregates
21	2386 (Part-5) :1963	Soundness of aggregates
22	10262 -1982	Recommended guidelines for concrete mix designs
23	9103 -1979	Specification for admixtures for Concrete
24	383 -1970	Specification for Coarse & Fine aggregates from natural sources for concrete
25	4701-1982	Code practice for earth work on canals
26	5256-1992	Code of practice for sealing expansion joints in concrete lining of canals first revision.
27	9451-1985	Guidelines for lining of canals in expansive soils first revision.
28	9429-1980	Code of practice for drainage system for earth and rock fill dams
29	8237-1985	Code of practice for protection of slope for reservoir embankments (first revision).
30	8414-1977	Guide lines for design of under seepage control measures earth and rock fill dams (with amendment No.l).
31	5620-1985	Recomandations for structural Design criteria for Low Head Slide Gate.
32	11228-1985	Recomandations for Design of Screw Hoists for Hydraulic Gates.