Andhra Pradesh Community Based Tank Management Project

OPERATIONAL MANUAL

Volume – V(a) of VI
Technical Manual

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Irrigation & CAD Department
Government of Andhra Pradesh
OPERATIONAL MANUALS

VOLUME

I  WUA MANUAL
II SUPPORT ORGANIZATION MANUAL
III FINANCIAL MANUAL
IV PROCUREMENT MANUAL
V TECHNICAL MANUAL
VI QUALITY CONTROL MANUAL
Foreword

The Government of Andhra Pradesh has initiated the process of providing substantive and enabling role to farmers benefiting from irrigation projects for management, operation and maintenance of the irrigation infrastructure by enacting the APFMIS Act, 1997. Following this, I&CAD Department has carried out minimum rehabilitation of the M.I tanks through Water User Associations. A performance evaluation of the WUAs highlighted the need for investment in institution building to enable WUAs to take up irrigation system management responsibilities. This has now been initiated in the I&CAD Department as part of the ongoing sector reforms process under the flagship of “Jalayagnam” programme of Government of Andhra Pradesh in tune with the Mid-Term Appraisal of the X Plan and observation of the Sub-Group on Agriculture and Irrigation of the National Development Council.

I&CAD Department is already implementing a project on “Repair, Renovation and Restoration of water bodies directly linked to Agriculture” with assistance from Government of India in the districts of Ananthapur and Mahaboobnagar. To facilitate this, the engineering staff of the I&CAD Department has developed a step-by-step process guideline with support from WUAs and local NGOs. Towards scaling up of the above programme to benefit 2.5 lakh ha, it is planned to restore 3000 tanks at an estimated cost of Rs. 1000 crores with financial assistance from the World Bank and the Government of India under the AP Community Based Tank Management Project. The entire restoration work would be undertaken in three batches over a period of five years.

The Project Implementation Plan has been prepared to act as a guiding document, describing the activities of the project on spatial and temporal scale. In addition, a set of six Operational Manuals on various components have also been prepared to steer the project stakeholders in effective implementation of the project.

Commissioner,
Irrigation & CAD Department
Government of Andhra Pradesh
## INDEX

<table>
<thead>
<tr>
<th>CHAPTERS</th>
<th>CONTENTS</th>
<th>PAGE Nos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTER – 1</td>
<td>1.1 Introduction</td>
<td>1 - 2</td>
</tr>
<tr>
<td></td>
<td>1.2 Minor Irrigation</td>
<td>2 - 3</td>
</tr>
<tr>
<td>CHAPTER – 2</td>
<td>HEAD WORKS OF M.I. TANKS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.1 Tank &amp; Its Components</td>
<td>4 - 5</td>
</tr>
<tr>
<td></td>
<td>2.2 Operation and Maintenance</td>
<td>5 - 7</td>
</tr>
<tr>
<td></td>
<td>2.3 Special Repairs &amp; Maintenance</td>
<td>7 - 9</td>
</tr>
<tr>
<td></td>
<td>2.4 Common Problems in tanks &amp; Remedial Measures</td>
<td>9 - 21</td>
</tr>
<tr>
<td>CHAPTER – 3</td>
<td>STANDARD SPECIFICATIONS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.1 Earth Work</td>
<td>22 - 25</td>
</tr>
<tr>
<td></td>
<td>3.2 Concrete Work</td>
<td>26 - 32</td>
</tr>
<tr>
<td></td>
<td>3.3 Reinforcement</td>
<td>33 - 34</td>
</tr>
<tr>
<td></td>
<td>3.4 Form Work</td>
<td>34 - 35</td>
</tr>
<tr>
<td></td>
<td>3.5 Stone Masonry Work</td>
<td>35 - 38</td>
</tr>
<tr>
<td></td>
<td>3.6 Stone Pitching / Revetment / Rip-Rap</td>
<td>38 - 39</td>
</tr>
<tr>
<td></td>
<td>3.7 Provision of Protection Upstream &amp; Downstream of Structures</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>3.8 Re-sectioning &amp; Strengthening of Canal Sections</td>
<td>39 - 41</td>
</tr>
<tr>
<td></td>
<td>3.9 Canal Lining</td>
<td>41 - 43</td>
</tr>
<tr>
<td></td>
<td>3.10 Measuring Devices on Irrigation Channels / Distribution System</td>
<td>43 - 44</td>
</tr>
<tr>
<td></td>
<td>3.11 Gabion Structures</td>
<td>44 - 45</td>
</tr>
<tr>
<td>CHAPTER - 4</td>
<td>Guidelines of World Bank Mission on Engineering design, construction and</td>
<td>46 - 54</td>
</tr>
<tr>
<td></td>
<td>quality control adopted for APERP(MR) Programme.</td>
<td></td>
</tr>
<tr>
<td>CHAPTER - 5</td>
<td>Guidelines of World Bank Mission on Technical specifications, construction</td>
<td>54 - 66</td>
</tr>
<tr>
<td></td>
<td>procedures and critical equipment for preparation of cost estimates for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rehabilitation of MI Tanks.</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER – 1

1. INTRODUCTION

Andhra Pradesh is one of the major river states in India blessed with river systems of the Godavari, the Krishna, the Pennar and several other small rivers. The economy is basically agricultural and irrigation has been the mainstay since a very long time. Minor Irrigation Schemes consist of surface water flow schemes and ground water schemes. Surface flow water impoundments are tanks. Practically every village has a tank and tanks from ages are still functioning.

Minor Irrigation plays an important role in providing assured water supply and prevent to a greater extent the adverse affects on agriculture on account of vagaries of monsoon. They also play an important role in development of agricultural production and ensuring food security particularly in drought prone upland areas and outside the command areas of Major & Medium Projects.

Though the state has a cultivable area of 16.62 million Ha. Comprising as follows:

- Major & Medium Irrigation Schemes - 6.48 M.Ha.
- Minor Irrigation - 2.30 M.Ha.
- Ground Water - 5.92 M.Ha.

So far the total potential created under Minor Irrigation sector is 1.72 million Ha. (including Panchayat Raj). Irrigation Department is incharge of investigation and execution of Minor Irrigation sources in the state is having an ayacut of 1.50 M.Ha. under 11277 sources besides maintenance of these sources having an ayacut between (40 Ha. – 2000 Ha.). Tanks below 40 Ha. acres hither to under P.R.Department have been shifted to Minor Irrigation & all these small tanks are to be restored to M.I. Standards.

More than 50 percent of the tanks were formed centuries ago. Barring a few tanks formed by kakateeyas, Vijayanagara Kings, Gajapathis of Vizianagaram, Nizams and Rajahs of Wanaparthy which were earlier considered to be of super standards most of the tanks were constructed based on previous practices and thumb rules with out proper evolution of soil characteristics and other parameters like intensity of flood, fetch of wave during cyclone etc…Even after independence the same practices were continued upto 1970s. If we compare the designs now formulated by the Central Design Organization after evaluating the soil characteristics and foundations ,there will be no hesitation to say that all those tanks are substandard .Attempts were made from 1972 to 1986 to improve and rationalize the design standards for new tank formations. But the development in soil mechanics and the computer aided design made it possible by 1980s to design the Minor irrigation tanks accurately and scientifically. But the designs so formulated have turned out to be such high standards that they can very well be compared with the standards adopted by kakateeyas, Vijayanagara kings,Gajapathis of Vizianagaram, and Nizams etc, which we were hitherto thinking as of super financially viable and we may not be able to ground even a single scheme. As a compromise between the conflicting claims of economic viability and scientific design, eminent Engineer Sri T.Hanumantha Rao, then the chief Engineer, Minor Irrigation rationalized the standards considering the modern concept of economic viability and technical feasibility and issue “Guidelines for the preparation of Project Reports of New Minor Irrigation Projects” during 1986. But it should be remembered that even these standards are far shorter than the designs that are given by the Central Designs Organisation. All the minor irrigation tanks are now designed and grounded based on these guidelines. However, the tanks formed with these standards are fairly working well though in certain cases when faced with peculiar site conditions, elaborate designs are obtained from the Central Designs organization and adopted during execution. The point to be made out is that about 80 percent of the existing tanks are sub-standard and are easily vulnerable to damages for cyclones and floods. It is for this reason that we are faced with a situation where hundreds of tanks are getting breached year
after year due to floods, not to speak of innumerable other damages. But it is not uncommon that breaches occur in tanks even for normal rain fall (more than average) particularly in the regions of Rayalaseema and Telengana.

**Decline of Tanks in AP:** Tank, as an important source of Irrigation, has lost its significance during the last three or four decades. Most of the tanks in the state perform below their capacity level and the gap between the irrigation potential created and actual irrigated area under tanks has been reported at about 40 to 60 percent depending upon the rainfall during the year. In the process, area under tank irrigation has declined, which has adversely affected people who were traditionally depending for their livelihoods on tanks.

The proportion of area irrigated under tanks showed a significant decline from 39% in 1995 to 14% in 2005 in the state. Though the irrigation potential created through the tanks is estimated at 14 lakh hectares, the actual area irrigated is only about 4-6 lakh hectares. The variation in rainfall in the last decade is also one of the principle causes for the large decline.

The fall in efficiency of the tank system could be one or more of the following reasons:

b) Decrease in inflows to the tank  
c) Deterioration of physical system  
d) Poor canal system  
e) Poor water Use Efficiency

The decline in tank irrigation is now widespread turn and affecting the agricultural economy of the state. Much of the tank-fed areas are situated in the districts where there are no possibilities of providing other systems of irrigation. This loss is not only to irrigation but also to other village common use like domestic and drinking in many places. As per the estimates of the Indian Planning Commission, in the last 25 years, about 1.7 million hectares of net area under tank irrigation has been lost amounting to a capital loss of about Rs.51,000 millions.

**Bharat Nirman Project:** The Working Group for X Plan has assessed that proportionate share of minor irrigation sector at 60% of the increase in food production would require an additional irrigation potential of 8 Mha. Out of which 5 Mha is to be from ground water and 3 Mha from surface water sources. Irrigation from surface water resources of 3 Mha is to consist of 2.4 Mha from new minor irrigation schemes and 0.6 Mha from renovation of existing tanks. The project assumes greater importance in the context of the Bharat Nirman Project under which a target of 1 Mha is envisaged. The Bharat Nirman Programme also invokes the Report of the National Commission for Integrated Water Resources Development which points out that the carrying capacity of tanks has decreased over a time for a various reasons and that the restoration and renovation of tanks is a priority task.

The present project of A.P. Community based Tank Management is a sequel to the Bharat Nirman Project capturing the national framework for state projects to be proposed for World Bank assistance.

**1.2 MINOR IRRIGATION**

**1.2.1 Definition & advantages:**

As per classification of Irrigation Project, all the tanks having culturable command area upto 2000 Ha comes under MI Sector. Minor Irrigation projects can be categorized as surface irrigation projects which are of following types.

a) Construction of Tanks for surface flow irrigation  
b) Percolation tanks  
c) Construction of small Anicuts across streams  
d) Lift irrigation schemes from canals and streams
Minor Irrigation plays an important role in providing assured water supply and prevent to a greater extent the adverse effects on agriculture on account of vagaries of monsoon. They also play an important role in development of agricultural production and ensuring food security particularly in drought prone area and outside the command area of major irrigation projects.

The minor irrigation projects have definite advantage over major, medium projects enumerated as follows:

a) It has smaller capital investment and shorter gestation period
b) Unlike major, medium irrigation projects, which serve only a concentrated geographical area, the M.I. schemes can be dispersed throughout the length and breadth of the state and have a tremendous impact on development of rural economy at micro level.
c) No special assistance required by way of foreign personnel or equipment.
d) Local resources can be easily and effectively be mobilized for their execution
e) They generate large amount of dispersed employment
f) They will act as sources of famine relief
g) Water management is relatively simpler than in case of major and medium irrigation projects.
h) Low cost of maintenance when compared with major and medium projects.
i) Least disturbance to environment and ecology
j) Beneficiaries participation available
k) Life of tank is invariably multifold than designed life
l) Recharge of water table in the wells of village for conjunctive use
m) Negligible R & R issues involved

1.2.1 Need to protect the existing sources of Minor Irrigation:

At present, 1.5 million Ha is under M.I. sector in A.P. There is only a little potential left to tap the yields in view of saturation in most of the basins.

As such, the tanks which are the life line 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 / bride the gap ayacut wherever prevailing.

The measures of taking up revival / restoration works for bridging the gap/ stabilization of ayacut are specially 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 I.P. created at relatively cheaper outlays. (about 50% of the cost of new tank formation)

1.2.2. The Role and importance of Minor Irrigation Tanks in Rural Life:

In an agro based rural economy the pre-eminence of minor irrigation sources is undisputable. The rainfall being restricted to 3 to 4 months in a year, the importance of irrigation tanks for providing dependable and assured water supply to irrigation was recognized from the earliest days of civilization. A minor irrigation tank is the life line of the village. The size and prosperity of village is directly linked up to the size of a tank. The village life is closely interwoven with the tanks. The receipt of fresh inflows into the tank is a cause for celebration in the village. During some important festivals the villagers congregate on the tank bund to perform religious rites. Usually, some fruit bearing and tamarind trees etc., are grown on the tank bund and rear margin and all villagers are entitled to usufruct of these trees. The tank provides water to the village cattle during the dry months. The tank is also be centre for birds and other fauna. The babul trees grown in the foreshore lands supply food to the sheep and goats during the summer months. When the tanks dry up the silt accumulated in the tank bed is utilized by the villagers as manure in their fields. Thus, the tanks help maintain ecological balance and improves environment. This last but not the least importance of minor irrigation tanks is the replenishment of ground water, which is another importance source of drinking water as well as irrigation.
CHAPTER – 2

HEAD WORKS OF MINOR IRRIGATION TANKS

2.1 Tank and its Components

a) Usually, it is an earthen embankment comprising of selected earth constructed across a stream or a nala. The purpose is to arrest the monsoon flows in front of the bund to store water for regulated releases whenever needed, mainly for irrigated agriculture and for other multiple uses. The multiple uses may be for fisheries, washing and bathing, village water supply and for cattle drinking.

b) For the bunds stability, recently constructed bunds are provided with core walls, cut off trenches to prevent leakage and also toe drains and filters to safely carry the seepage if any away from the bunds without disturbing the soil particles of the bunds.

c) The upstream slope of the bund is normally protected against wave action / by stone revetment of about 0.30 meter thickness, with filter material underlain protecting the inner earthen material.

d) Stone edging on either side of the top width of the bund if provided will prevent erosion of the edges and to maintain the profile

e) Grade stones at the front edge on the top of the bund are fixed to maintain the longitudinal top profile and to know location points along the length of the tank bund

f) Rear slope of the earthen bund is protected by suitable grass cover (turfing) to prevent rain erosion

g) If the bund is serving as a road to connect villages across the stream, the top width is widened suitably to carry vehicular traffic.

2.1.1 Tank Sluice:

a) It consists of a regulating device at the head of the barrel passing though the bund at a suitable location and level to command the fields in the ayacut and connecting the main channel downstream of the bund to draw water when needed to irrigate crops

b) The regulating device may consist of a plug and rod system (known as kontha) in the old tanks or a sliding steel shutter with screw gear arrangement in the present day tanks. The regulating device is approached from the top of the bund usually in large tanks through a narrow footbridge.

c) The sluice barrel in olden days was constructed in brick or stone masonry covered with stone slabs. Later constructions have Hume pipes as an improvement against leakages and for better and easy maintenance.

2.1.2 Surplus Weir:

a) This component of the tank system located usually at the ends or rarely in the middle of the bund as an overflow section to pass off the excess floodwater safely to the stream down below without damaging the bund. The surplus weir could also be located elsewhere in the saddle in between two hillocks at the ridgeline in favorable topography. This is rare.

b) The excess flood water past the weir is carried through a properly designed and constructed channel safely away from the bund to prevent damage to the earthen bund and arrest retrogressive erosion of the bed material of the channel, behind the waste weir body wall.

c) To facilitate smooth flow of approaching floodwaters towards the weir, the upstream area of the weir is cleared for the required width and to the levels, to prevent heading up of
water that may cause overtopping of the bund.

2.1.3. Conveyance System

a) 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 watercourses to irrigate the fields, sequentially depending upon the size of the tank and the ayacut.

b) The conveyance channels have minor masonry structures such as outlets structures with or without controlling gates, cattle crossings, cart track crossings, cross drainage works crossing valleys, canal drops etc. to safely carry the channel flow to the tail end fields of the ayacut.

c) Ayacut roads are also provided to convey the agriculture produce from the fields to the access roads leading to the market nearby.

2.1.4. Water Spread Area:

a) Water spread area is defined as the extent of fore shore (submergence) water area at full tank level. The quantity of the water stored at FTL (waste weir crest level) is the total gross capacity of the tank in terms of volumetric measure. Out of this the storage below the sluice sill level (tank sluice level) is the dead storage. The difference 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”

2.2 Operation & Maintenance:

2.2.1 General:

Operation & Maintenance (O&M) is an important activity of any managerial organization made responsible to make the tank function effectively on a sustainable basis to realize the planned benefits. This activity can be broadly classified into two main types viz., (a) routine maintenance and repairs repeated every year & (b) special repairs including improvement which may be required to be done when ever situation warrants.

2.2.2 Routine Maintenance & Repairs:

2.2.2.1 Tank Bund:

This routine activity is carried out on the tank bund and its appurtenant works twice in the year, once before the monsoon period and again at the end of the monsoon. It comprises detailed inspection and rectification of defects and deficiencies.

a) Bund condition should be checked for its profiles throughout its length for any damage due to rains, movement of cattle, burrowing by rodents, crabs etc.

b) The top width level and its surface & the edgings to be checked for any distortions and rectified.

c) Longitudinal and transverse crack in the bund if any, should be checked and filled back with appropriate materials and compacted after treating the cracks with care particularly at masonry junctions like sluice and surplus weir under expert guidance.

d) Revetment on the front slope should be checked and rectified for any settlements and distortions.
e) Sluice gate and its parts should be specifically checked for smooth and effective
operation. Any missing or damaged parts should be repaired or replaced.
f) The operation of the regulating arrangements like screw gear or lifting devices
should be thoroughly checked against the operational difficulties and all moving
parts should be oiled /greased after thoroughly cleaning the surfaces. All exposed
surfaces should be cleaned and painted to prevent rusting.
g) The sluice barrel or pipe should be checked thoroughly against any damage or
leakage: Also it should be thoroughly cleaned removing all obstructions, silt and
debris deposits if found.
h) The toe drains, constructed as part of the bund should be inspected to check that
they are in good condition and not clogged with earth particles
i) If piping is noticed in any part of the bund in the downstream, flowing with turbid
water, it should be immediately attended to under expert guidance.
j) Vegetation and tree growth including - the roots in any part of the bund should be
removed completely, positively before the monsoons and after.
k) Grazing of cattle, sheep on bund and slopes should not be allowed. Grass grown
should be utilized after carefully cutting it and taken away.

2.2.2.2 Water Spread Area:
   a) Encroachments if any should be cleared & preventive measures taken against
      further encroachment.
   b) Either a contour bund or stones at intervals are to be laid along the FTL contour or
      2 to 3 rows of trees (bamboos) can be planted to prevent encroachment and to arrest
      erosion and prevent silting up of tank bed.
   c) Removal of silt every year is advised to take care of loss of storage capacity.
   d) Approach channel to the sluice point and level is to be 'cleared for easy flow of
      water.
   e) Draft approach channel to the surplus weir also to be checked for encroachment and
      vegetative growth and action taken to clear it off.

2.2.2.3. Surplus Weir :
   a) The surplus weir and appurtenant works including downstream protection works
      should be inspected to verify that the junction with the earthen bund and the flank is
      intact without any damages or dislocation or damage to sides, foundation & crest of
      the weir including the body wall all along its length. Any damage or distortions,
      cracks should be removed. The Crest of the weir or weirs should be checked to
      verify that uniform level is .maintained all along the length as per the original
      construction.
   b) The approach channel in the upstream of the weir and the draft channel in the
      downstream should be inspected to verify that they are free from obstructions
      including vegetative growth, encroachment and that no erosion or retrogression of
      ground has occurred to ensure the safe passage of flood waters.
   c) The gauge with markings near the surplus weir should be checked to verify that it is
      useful to measure the depth of flow over the weir during floods and to calculate the
      quantity of surplus water, passed each time. If there is damage it should be rectified
      before the monsoons.

2.2.2.4. Conveyance System:
   a) The main canal taking off from the sluice barrel/pipe in the downstream should be
inspected from head to tail end every time before and after each irrigation supply in the cropping season.

b) It is essential to provide measuring devices such as V – notches, cut-throat flumes, Standing Wave flumes etc., depending on the quantity of discharge carried by the respective canals. These will enable to measure the quantum of water withdrawn from the tank and also to regulate the flow to the desired requirement to prevent wastage and to conserve the precious water in the tank.

c) The section of the channel at various points both in cutting and embankment reaches should be checked for designed bed width, depth of flow and the free board provided to prevent overtopping. If any damage or distortions have occurred it should be rectified soon by carrying out the necessary earthwork before water is allowed to flow.

d) To maintain the correct longitudinal slope it is advisable to fix bed grade stones at intervals of 100 meters.

e) To maintain the correct profiles it is preferable to construct templates. Masonry/concrete at intervals of 100 meters or closer intervals as may be required.

f) Distance stones along the main canal at every 0.2 KM (2 HM) interval must be fixed on the inspection path side to determine the locations along the canal.

g) All the branching points must be constructed in masonry/concrete so that they are fixed in position. This should be combined with gate slots to regulate and distribute the flows as required in the channels. The gates could be of stone or pre-cast RCC that could it in the slots. Standardized sizes should be used to facilitate flexibility and interchanges when necessary in such locations.

h) If the channel has steeper gradients, to avoid 'scouring and damage, masonry / concrete standard drops should be constructed with gauge markings to measure the rate of flow. These will be useful to know discharges at any point and also if a constant discharge maintained at the head of the sluice, channel losses in different stretches can be assessed to facilitate regulation of flow as per requirement.

i) All turnouts (outlets) to the water course along the supply channel should be pucca in masonry / concrete with pipe openings of required size and at authorized level and locations provided with controlling devices.

j) The WUAs should operate & maintain the conveyance system including the water courses.

k) Depending upon the needs of the cultivators and the required cropping pattern in the ayacut specified by the WUAs in consultation with the irrigation engineers, WUAs may adopt any of (i) “On off” of the outlets, minors as the case may be or (ii) "Block system’ with' continuous with' constant discharge" or (iii) "variable discharge with regulation" within the capacity of the conveyance system

2.3 Special Repairs & Maintenance:

a) Apart from routine operation & maintenance activities that are carried every year, certain works involving heavy expenditure, which cannot be met from the normal revenues that accrue, need to be undertaken in exceptional circumstances. Such expenditure warranting high capital outlay are termed as capital expenditure.

b) The special circumstances are when (1) there is breach in the bund due to excessive floods which the surplus weir can not accommodate or (2) due to piping caused by rodents and crabs, causing heavy damage to masonry structures such as sluice and the canal system.

c) Deferred maintenance over a number of years and also due to continuous neglect may also warrant special repairs. Excessive silting such as what has happened to many tanks is an
example' of this nature. Desilting which needs to be done to almost all the tanks come under this category.

d) Improvements and restoration works to original condition, which is being undertaken by A.P. Community Based Tank Management Project through community participation being funded by World Bank.

2.3.1. Tank Bund Complex:

a) Bund Portion:

i. The interventions in bund to be decided by the priorities fixed during the walkthrough survey and as pointed out by the Ayacutdars.

ii. Whether position of revetment on the upstream side is in place to be checked. If dislodged provision to be made in the estimate for reconstruction with the available stones or else fresh revetment with Jelly and Sand Backing can be made.

iii. Whether turfing is provided on the downstream slope of the bund shall be noted. If it is not there the same shall be provided to avoid erosion of bund due to impact rain water.

iv. The top width shall be as per standards and downstream slope shall be as per standards.

v. The weed growth on the bund should be removed.

vi. Detailed survey shall be conducted and longitudinal and cross section should be drawn at least for every 30 metres.

vii. The quantity of embankment should be assessed by the longitudinal section and cross section, If the soil obtained by desilting is suitable for embankment the same can be used for bund portion.

viii. Proper care should be taken to compact the embankment in slope portion and over the top duly scraping the old embankment or by making grip trenches.

ix. Existence of cracks which are horizontal/longitudinal noticed if any details such as depth, width and length of crack should be collected.

x. Leakage and sweating of downstream side slope of bund noticed if any, the details of their locations should be collected.

xi. Adequacy of free board existing should be collected and checked.

b) Surplus Weir:

i. Surplus weir may be of any type either slopping apron, clear over fall or of ogee type

ii. The surplus weir may be of masonry or concrete

iii. Check whether there are any leakages in the body ‘wall or there are any damages, check whether downstream apron, coping slab are in position, check for clearance of draft channel.

iv. Joints in the masonry wall should be thoroughly cleaned and pointed using CM 1:3 mortar

v. If there are more leakages, provide a concrete skill wall on the upstream side to a thickness of 20 to 30cms with nominal reinforcement (detailed specification and methodology is explained in guide lines methodology for masonry surplus weirs).

vi. If coping slab is damaged the same should be replaced.

vii. If Apron stones are washed away provision to be made for replacement of Apron in its position.

viii. If the length of the weir as revised with maximum flood discharge is more than the existing surplus weir length, then provision should be made to increase the length of the existing surplus weir.

ix. Details of the approach channel leading to surplus weir to be examined and details of missing pitching and damages to side protections if any should be collected.
x. Details of the existing condition of wing walls upstream and downstream of the surplus weir should be collected if improvements & repairs are required such details and dimensions have to be noted.

xi. Details of existing conditions of energy dissipater on downstream of surplus works along with draft channel clearance required if any, shall be collected.

c) Sluice:
  
i. Two types of sluices. Barrel type and piped type.
  
ii. Sluices are sometimes provided with Plug & Rod or Gates (Shutters).

iii. Number of sluices, their types, their location in the bund, their sill levels, their effective working, whether the barrel is dislodged etc., should be noted.

iv. Observe whether there are any leakages, if so check whether they are inside the barrel or outside of barrel walls.

v. See whether Plug & Rod is existing or not; if not existing, replace it; if existing check for damages.

vi. Check for damages to sluice structure

vii. Check for existence of foot bridge for operation

viii. If it is a gated sluice check for leakage in gates, if so ascertain the damage and take suitable action

ix. While desilting, care should be taken to make approaches to the sluice such that water flows freely towards the sluice.

x. If the barrel is collapsed and sluice is not functioning, the bund should be cut opened in a flat slope, preferably, in 4:1 slope, barrel portion reconstructed and then embankment is redone duly keying to the old embankment.

xi. Check the condition of shutters and the screw gear arrangement.

d) Command Area:
  
i. Standing on the center of the tank bund facing the command area, the left side of us is the Left Bank and to the right side of us is the Right Bank.

ii. The alignment of the canal with respect to the designed command area is to be identified

iii. If the canal section very small, the siltation in the canal is to be removed manually & not with JCB,

iv. Critical reaches in the canal for which selected lining is to be provided, should be identified with respect to chainages.

v. Wherever cross regulators have to be constructed, their chainages are noted and accordingly provision to be made to construct cross regulators. This also fixes the bed level of the canal.

vi. Wherever cross drainage works such as Aqueduct (when the canal crosses a nala) & culvert (wherever road crosses the canal) should be identified and such structures wherever necessary should be constructed.

vii. Loss of water due to carelessness should be avoided.

viii. The designed command area should be marked in a revenue survey map.

ix. Details of existing distribution outlets, their locations and their conditions should be collected.

2.4. Common Problems In Tanks & Remedial Measures:

The common problems faced in a tank proper and remedial measures thereon are outlined as described below:
2.4.1 Tank Bund:

Bund is a very important component of the Tank structure. Generally it is built with earth of homogeneous/non homogeneous type soils depending on the availability of the materials in place. Some tanks are of composite type with earthen bunds with masonry or earthen bund with concrete surplus weirs. Generally the earthen bunds consists of top width varying from 1.5 to 5 meters with more flattened slopes with revetment on the front slopes and steep slopes with turfing on the rear slopes. The condition of the bund deteriorates due to the following reasons.

a) Dislodging of the revetment or its non existence causes water waves to hit directly on the upstream slope of the bund resulting in erosion of the bund or settlement of slope. Hence wherever noticed the upstream slope should be protected with revetment and filters. (Fig. 2.4.1 a)

![Fig. 2.4.1. a](image)

b) If down stream slopes are not provided with turfing, due to the impact of the rain water directly falling on the rear slopes causes gradual erosion of the slopes resulting in the deterioration of the bund section and ultimately causes damage to the bund. (Fig. 2.4.1 b)

![Fig. 2.4.1.b](image)

c) The trees that are allowed to grow on the Tank bunds extend their roots from one side of slope to the other side of slope. If these roots grow below the Free Board Zone, there is possibility of piping action which is very dangerous. If these piping action is left as it is, it will gradually give room for breach of the bund. (Fig. 2.4.1.c)

![Fig. 2.4.1.c](image)
d) Presence of rats/burrowing animals, causes piping action. (Fig. 2.4.1.d)

- Fig. 2.4.1.d

![Diagram of sand bags](image)

e) If the anthills that are existing on the tank bund are to be removed, to avoid cut opening of the bund, sand should be poured into the holes along with water until the holes get filled up completely. (Fig. 2.4.1.e)

- Fig. 2.4.1.e

![Diagram of bund with labels](image)

f) Sometimes the top of the bund erodes gradually due to rain falling directly on it resulting in decreasing the height and width of the bund. Wear and tear of the bund also occurs due to movement of vehicles and animals. When the bund height is reduced less than the Maximum Water Level (MWL) and due to heavy siltation. The water overflows through the bund causing failure of bund due to erosion, breach and sometimes over toppling. The bund height should be increased to a height of 1.5 m. above MWL giving sufficient free board using proper soil duly compacted after ensuring adequate grip between the existing and the new embankment. The height of the revetment also to be increased accordingly up to MWL (Fig. 2.4.1.f)
g) Cutting of downstream toe of the bund due to encroachment results in exposure of seepage gradient on the downstream slope causing collapse of the slope and breach. (Fig.2.4.1.g)

2.4.2. Following care should be taken in order to maintain the tank in good condition.

a) To keep a constant vigil of miscreants from damaging the bund.
b) To remove weed growth frequently without giving room for its root growth deep into the Tank Bund
c) To protect front slope with revetment some time with new stones or resetting of revetment whenever required.
d) To protect rear slope with turfing to avoid scouring action due to impact of rain directly on the slope
e) Not to give room to take soil out of the bund for other purposes.
f) Not to cut the grass on the downstream slope resulting in exposing of earthen surface
g) Not to grow trees on the tank bund
h) Not to propose structures such as temples etc., on the top of the bund
i) Not to cut the rear toe of the bund cause due to encroachment of the farmer whose land is adjacent to the bund.
j) Not to allow for the encroachment on the tank bund area.
2.4.3. Damages to bund may also take place naturally for the following reasons:

a) **Longitudinal and Transverse Cracks in Embankment:**
   - Sometimes during hot summer months, cracks are noticed on the embankment. Due to highly clayey nature of soils used in the embankment formation, such cracks occur due to high temperature, which tend to close during colder season.
   - Other types of cracks are caused by differential 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 crack are those which run transversely creating a path through the core for concentrated seepage through the core. In such cases immediately the WUA should bring it to the notice of the concerned authorities i.e. A.E. / A.E.E.

b) **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:-
     i. Find approximate depth of crack by excavating an inspection pit.
     ii. Carry out water test through this pit and observe approximate intake of water
     iii. Excavate the cracked portion in the form of a trench up to the bottom of crack and trench filled in 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.
     iv. If the depth of cracks is substantial / about 0.75m 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 1.0m spacing and pouring the fluid grout mix (clay – cement – water) in these pipes, viz., ‘gravity grouting’ without deploying any grout pump.
     v. Treatment of deeper cracks can also be done by excavating trenches in the cracked portions to a depth of about 0.75 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 0.75 m to 1.0m deep trenches are o.k. This treatment is known as bentonite grouting and is simple and effective. 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.
     vi. 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.

2.4.4. **Remedial Measures for Piping Phenomenon:**
   A) 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 order that the discharge is not allowed in increase further, dumping of soil and murrum on the upstream slope in a portion opposite to the leakage point maybe adopted. Even gunny bags full of soil and murrum can be dumped.
   B) 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, however small, and any longitudinal or/and transverse cracks 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-in-charge so that requisite remedial measures can be initiated well in time. Simultaneously, following actions should be taken immediately:

i  **Inverted filter of filter materials** should 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 bowl shaped excavation to lay the inverted filter. The layer of sand is to be placed against the leakage face.

ii  **This is illustrated in Sketch I:** Propose 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, as shown in Sketch I, is 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. (Sketch I at Page 19)

iii  Soil, murrum and stones / rock should also be dumped, if necessary, on the portion of the upstream slope of the embankment (opposite the leakage location) to be sure that leakage does not increase.

iv  If any subsistence of the embankment is noticed in some reach, earth fill should be placed, duly compacted, to achieve the designed top level to ensure the designed free board.

v  If, even after taking the above emergent action, the situation still demands lowering of water level in the tank, it should be done.

(C) **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. 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. This arrangement of key trench and inclined clay blanket is illustrated in Sketch – II. (Page 20)

2.4.5. **Sluices:**

Sluices are one of the important masonry / concrete structures in the tank component. Sluices may be one/two/three/four in numbers depending on the size and the Topography of the Command Area. Sluices may be of barrel type or piped structure facilitated with plug and rod or shutter type (in recent years) arrangements.

Precautions to be taken to inspect the controlling arrangements before the onset of mansoon for its correctness. The following are the possible problems that may arise due to improper care and needs immediate rectification.

a) Plug and rod/shutter and controlling arrangements to be kept in good condition before receiving water into the tank. This avoids leakages if any through the Sluice portion. (Fig 2.4.5.a)
b) If the leakage water is of turbid nature then there is leakage nearer the Sluice or along the sides of the Sluice barrel. This needs to be arrested by providing bund on the upstream side of the tank near the Sluice and when the tank is empty permanent repairs are to be carried out. If necessary the bund also has to be cut opened and repairs carriedout. (Fig 2.4.5.b)

2.4.6. SURPLUS WEIR (Waste Weirs)
Surplus Weirs are of three types (Fig 2.4.6)

SURPLUS WEIRS ARE OF THREE TYPES

1. SLOPING APRON TYPE
2. CLEAR OVERFALL TYPE
3. Ogee WEIR TYPE

Generally the Surplus Weirs are constructed by Size Stone masonry with deep pointing of the joints. Excess water over and above the Full Tank Level (FTL) overflows through these surplus weirs upto the maximum water level. The leakages or damages occur due to the following
reasons.

a. Damage to the pointing of the joints in the body wall which needs to be set right only after the water recedes in the tank or by putting Ring Bund all along the length of Waste Weir to make re-pointing after scraping the joints thoroughly. Some time plastering may also be done along with pointing. (Fig 2.4.6 a)

![Fig2.4.6 a](image)

b. Leakages occur through the body wall of the Waste Weir due to weak structure of masonry. In such case provision to provide a concrete skin wall (M 15 concrete) with nominal reinforcement. The thickness of the wall is generally of 200 to 300 mm. (Fig 2.4.6 b)

![Fig2.4.6 b](image)

c. If there are pot holes in the solid apron (of concrete) on the downstream of the Surplus Weir, there is possibility of leakage from the bottom of the Surplus Weir.

Even though most of the tanks have with stood for more than 100 years, it may receive the unexpected floods by itself or due to the breach of upstream tanks if the Tanks are in series, in such cases immediate arrangements to be made to report to the concerned authorities and also care should be taken to cut open the Waste Weir itself to pass the heavy floods. Subsequently repair the masonry/concrete walls immediately after the flood water recedes. This is essential otherwise it may damage the bund.

2.4.7. Closing of Breaches in Tank Bunds:

Breaches should be closed with utmost care duly observing all quality control requirements. Any non conformance to specifications would result in poor quality work which could be prone to re-occurrence of breach.

2.4.7.1. Sequence-wise steps for closing of breaches

A) Preparation:

a) All water should be completely cleared out of the bottom of the breach section as well as from its close vicinity.
b) All soft mud / slushy soil should be removed and dense surface exposed on the bottom. A proper foundation is of paramount importance.

c) All loose soils should be removed from the ends of bund on either side of breach.

d) In case it is a zoned section, core trench or core wall is to be restored to its design section.

e) All vegetation, bushes, roots should be removed.

f) Key trench should be provided at the base.

g) The existing bund on either side of breach should be cut to a flat slope, preferably, 4(h) : 1(v) slope.

h) The cut slopes should be benched in suitable steps of +30 cm or 45 cm. Meanwhile, soil to be placed in the ‘breach section’ should be got classified for its suitability.

B) Placement of Earthfill and Compaction:

a) 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.

b) Earth fill should be placed in suitable layers (20 cms / 22.5cms thick in case power roller is used or 15 cm thick in case fuel operated plate compactor / earth rammer is used).

c) Core trench / core wall is to be filled first and compacted. Thereafter, fill placement should be carried out systematically over the whole area.

d) In case of zoned section, hearting portion of embankment should always be kept one layer above the adjacent portion of casing.

b) 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 compacted to 98% of proctor density.

e) It is to be ensured that any gravel / stone pieces / clods of size more than 7.5 cm are picked out and removed.

g) The soil in the casing zone (viz cohesion less soil) is to be compacted to a relative density of 65%.

h) Slopes of the new embankment should be in conformity with the designed slopes of the bund or even some what flatter in special situations. An extra width of, say, 20 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.

i) 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.

Methodology of closing breach is illustrated in Sketch – III.( Page No. 21 )

2.4.8. Leakage in Canals:

Wherever Canals are taken up through full embankment without proper compaction there is possibility of damage to the Canal through heavy seepage and cause wastage of water. Some times there will be loss of Crops too.

In banking reaches associated with seepages, selective lining can be led both in the bed and sides, duly constructing toe walls at the commencement as well as at the ends of the selective lining.

Cross drainage works should be constructed wherever required to see smooth flow of water in the Canal.

Note: In case of emergencies, it is always advisable to inform the experts who can guide the WUAs in a better manner and deal with the situations appropriately. Also the District Collectors of the concerned districts should be informed about the possible damage that may cause in case of
occurrence of breach.

Before the onset of monsoons it is always advisable to keep stock of empty cement bags and sand for putting emergency Ring Bunds.
INVERTED FILTER

TANK BUND

U/S

D/S

LEAK

OUTERMOST LAYER OF RUBBLE 300MM THICK
(SIZE = 12 CM TO 20 CM)

30 CM THICK LAYER
(METAL OF MAX 40 MM SIZE)

LEAK OF TURBID WATER

SAND (5MM MAX SIZE)
(45 CM THICK LAYER)
U/S KEY TRENCH & INCLINED CLAY BLANKET

U/S

M/WL

Inclined Clay Blanket

Graded Filter

Stone revetment

TANK BUND

D/S

Leaks (prior to revetment)

Key Trench (filled with impervious soil duly compacted)
Methodology of closing Breach

Earthfill layers compacted to specified density

Breach section

Slope cut back to 4 H: 1 V and remove the earth from portion abc

Bank

Bench

Slope cut back to 4 H: 1 V and remove the earth from a'b'c' portion

Bottom stripping

Stipped base

Earth filling in Breached section

(Refer comments)
CHAPTER – 3.0

STANDARD SPECIFICATION

3.1. EARTH WORK

3.1.1. Excavation :

A) General :

a) All excavation shall be carried out to the lines, grades, levels shown on the drawings and as directed by the Engineer.

b) All permanent excavation shall be trimmed to the specified lines and slopes. In case there is over excavation beyond the specified lines and levels, the same shall be filled with suitable soil, laid in layers duly moistened and compacted.

c) In very small jobs, compaction of earthfill may be done manually by hand rammer. An hand rammer may consist of a wooden block, say, 20 cm x 15 cm x 15 cm with a wooden handle fixed to it. Mechanized compaction shall be done on all other jobs.

d) Care shall be taken to ensure that the soil below and beyond the lines of all excavation is preserved in a sound condition.

e) In case of excessive over excavation on slopes, the same can be filled with lean concrete 1: 6 : 12 or with stone masonry instead of filling with soil and compacting it. Over excavation on the bed can be conveniently filled with soil, laid in layers, and compacted.

f) The bottom and side slopes of excavation against which concrete is to be placed or masonry is to be laid, shall be finished accurately and should be well tamped and moistened prior to placement of concrete and laying of masonry.

g) Moistening of sub-grade shall be done with the gardener's can to ensure gentle and uniform spray of water and without the formation of any cuts or puddle.

h) In case of soft or hard rock strata, all weathered or partly decomposed pieces of rock shall be removed.

B) Stability of Slopes:

During the excavation as well as fill placement, stability of slopes has to be ensured, being of paramount importance. During re-sectioning of earthen channels, the slopes both in cutting and fill sections should remain stable. Likewise, the earthen embankments should have stable side slopes. In case the canal is to be lined with concrete or masonry, the side slopes shall be such that no earth pressure is exerted over the back of the lining.

For general guidance, recommended side slopes are tabulated below from consideration of slope stability:

3.1.1(b) TABLE: Recommended Side Slopes

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Type of Soil</th>
<th>Side Slopes (Horizontal: Vertical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>Loose sandy soil</td>
<td>3 : 1</td>
</tr>
<tr>
<td>ii)</td>
<td>(Average sandy soil/sandy gravelly soil)</td>
<td>1 : 1 to 1.5:1 (in cutting) 1.5 :1 to 2: 1 (in embankment)</td>
</tr>
<tr>
<td>iii)</td>
<td>Murrum - gravel mixed soil</td>
<td>1 : 1 to 1.5:1 (in cutting) 1.5:1 to 2:1 (in embankment)</td>
</tr>
<tr>
<td>iv)</td>
<td>Clayey Soils</td>
<td>2 : 1 to 2.5:1 (in embankment) 1.5:1 to 2:1 (in cutting)</td>
</tr>
<tr>
<td>v)</td>
<td>Rocky Soils</td>
<td>0.25 : 1 to 0.50 : 1</td>
</tr>
</tbody>
</table>
The above slopes are for depth of cutting and height of embankment upto 5.0 m. The clayey soils, when wet, shall have stable slopes of 2.5:1, since these soils are prone to slips when wet. In any case, the slope should not be steeper than 2:1. As a matter of fact, side slopes 2:1 are considered stable for all types of soil in embankment upto a height of 5.0 m. In case of clayey soils for embankment height of more than 5.0 m (upto 10 m), side slopes of 2.5:1 shall be the stable slopes. Flatter side slopes, 3.5:1, shall be needed in case of swelling black cotton soils.

C ) Strengthening of Earthen Embankments:

Raising and strengthening of earthen embankments 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 freshly laid soil with the old embankment so that no leakage takes place at the junctions.

(i) Construction Procedure:

a) All vegetation, bushes, roots, plants etc. shall be removed from the existing portion of embankment proposed to be strengthened.
b) The base shall be stripped to a depth of about 15 cm to 20 cm.
c) The outer slope / inner slope shall be benched in suitable steps of about 30 cm to 45 cm.
d) Borrow area to furnish suitable soil for fill placement shall be identified.
e) Types of soil suitable for placement comprise of: clayey gravel, silty gravel, clayey sand, silty sand, clayey soils etc.
f) 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 maximum.
g) 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 standard "Power Roller" is used for compaction.
h) Thickness of layer shall be restricted to 15 cm in case "Fuel-operated Vibratory Plate Compactor" is used for compaction.
i) Thickness of layer shall be restricted to 10 cm in case manual compaction with improvised "Hand Rammers" is to be done.
j) Water shall be uniformly sprinkled over the layer, if it is dry. Rapid Moisture Meter 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 95% Proctor density (viz maximum density corresponding to OMC), as explained above.
k) During placement of layers, clods & stones of size larger than 7.5 cm (viz. 3 inches) shall be hand-picked and removed from each layer.
l) Extra width of about 15 cm shall be laid in each layer and compacted to ensure full compaction of designed section. The extra earthfill shall be later trimmed to the designed slope and the earth re-used.

(ii) Quality Control Tests & Documentation: Standard Proctor Density Test shall be conducted once in the "borrow area". Density test shall be made in each layer and/or one test for every 150 m$^3$ of earthwork placed and compacted. These tests are to be properly documented in a permanent page-numbered register.

D) Borrow Pits:

As far as possible, all suitable soil from the excavations shall be used in backfill of structures and in the raising / strengthening of embankments. In case sufficient quantity of suitable soil is not available from such excavations, the balance quantity shall be brought from the "borrow areas/borrow pits", duly approved by the Engineer.

Procedure: The following broad guidelines shall be followed in respect of opening of the
borrow pits:

a) No borrow areas shall be taken on roads, village tracks etc.

b) No borrow pits shall be dug within 3 m of the toe of canal embankment.

c) The top layer of earth having grass, roots, vegetable matter of any kind, and any undesirable material shall be stripped to a suitable depth, say, about 7.5 cm or so. Moisture content of soil in the borrow area shall be determined either by "oven or stove drying method" or by using "Rapid Moisture Meter".

d) Borrow areas shall be moistened / watered when observed moisture content is less. Depth of borrow pits be restricted to, preferably, 0.50 m.

e) Density tests of soil in the borrow area shall be conducted by either the "Core Cutter" or the "Sand Replacement" methods to determine maximum dry bulk density.

f) In Case, determination of maximum dry bulk density (MDBD) and optimum moisture content (OMC) is not easily feasible, these shall be assumed as per the following Table (as per United States Bureau of Reclamation Guidelines):

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Soil Classification</th>
<th>Average properties of Soil</th>
<th>MDBD</th>
<th>OMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Clayey Gravel</td>
<td>&gt;115 lbs/ft³</td>
<td>&lt; 14.7%</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Silty Gravel</td>
<td>&gt;114 lbs/ft³</td>
<td>&lt; 14.5%</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Clayey Sand</td>
<td>(115 ± 1) lbs/ft³</td>
<td>(14.7± 0.40)%</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Silty Sand</td>
<td>(114 ± 1) lbs/ft³</td>
<td>(14.7± 0.40)%</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Clayey Soils</td>
<td>(108 ± 1) lbs/ft³</td>
<td>(17.3 ± 0.30)%</td>
<td></td>
</tr>
</tbody>
</table>

The symbol > denotes …….. greater than, & < denotes ……….. less than.

Thus, in the absence of any tests, the following values may be adopted:

For clayey sand / silty : MDBD = 114 lbs/ft³ or 1800 kg/m³ & OMC = 14% sand/clayey gravel/silty gravel

For clayey soils (other than fat: MDBD = 107 lbs/ft³ or 1650 kg/m³ & OMC= 17% clays or swelling black cotton soils)

g) Layers can be laid and compacted at about + 2% of OMC depending upon the atmospheric conditions and nature of soils. The above values of MBD may be assumed as "Proctor Density" and the actual "in-place field densities" after compaction of earthfill (placed in layers) shall, preferably, be 95% MBD's.

h) After the use of borrow area has been finally discontinued, the overburden and any other unsuitable material previously laid aside shall be replaced in the pits, spread and leveled. The sides of borrow pits shall be graded and the whole area shall be left in a tidy state to the satisfaction of the Engineer. This is in the context of "environmental requirements". To avoid formation of pools in the borrow pits, drainage ditches from borrow pits to the nearest outlets/depressions shall be excavated. The objective being to ensure proper drainage.

E) Construction of New Embankment:

The procedure is the same as has been outlined above in para (c) above in respect of the raising/strengthening of existing embankments. Principal focus shall be on "compaction of earthfill, which is of paramount importance for long-term integrity and sustainability of the embankment. Turfing shall preferably be done on slopes to prevent formation of rain-cut and gulleys. If the embankment is for storage of water, the water side slope shall be provided with stone revetment and the down stream slope shall be turfed with the locally available grass / shrubs.

Compaction of cohesive soils (viz clayey sand, silty sand, clayey gravel, silty gravel, clayey soils etc) shall be done to 95% proctor density. In respect of cohesion less soils (sandy soils, sandy gravelly soils) compaction shall be done to 65% relative density with the addition of
sufficient water in each layer and compacted by mechanical tampers / power rollers / vibratory plate compactors or by hand rammers (if the quantum of work involved is small). As outlined in para (d) above, the values of Maximum Dry Bulk Density (MDBD) and optimum Moisture Content (OMC) for soils brought from borrow areas may be assumed (in the absence of conducting the requisite tests). The field in-place density tests of compacted layers shall be 95% of the Proctor density assumed values of MDBD. Rapid Moisture Meter is used for quick on-site determination of moisture content in the earthfill layers. Sprinkling of water be done, if necessary, to bring the moisture content within about + 2% of OMC.

F) Back-filling:

It is a very important item of work and is required to be carried out through systematic procedure conforming to acceptable quality standard.

**Procedure:**

a) No back-filling behind walls and structures shall be commenced until and unless the work has been completed, inspected, and approved by the Engineer.

b) The area to be back filled shall be fully cleared of all objectionable material, like vegetation, spill-over concrete, spill-over mortar, vegetation, scrap, stones & any other debris.

c) Back-fill soil to be used shall be approved by the Engineer. The soil shall neither be too wet nor too dry. If too wet, it shall be allowed to dry; and if too dry, water shall be added.

d) The back-fill soil shall not contain any dead vegetation and clods or material of more than 7.50 cm size. Such over-size material shall be hand-picked and removed.

e) Back-filling shall be commenced only after the specified curing of structure (against which back-fill is to be placed) has been completed. All wooden or steel scrap be removed from the back-fill area.

f) Back-fill soil shall be placed in layers and such layers shall be brought up evenly around the structure. Thickness of each layer is to be restricted to 15 cm in case mechanical tampers / fuel-operated vibratory plate compactors are used for consolidation. In case manual compaction through hand rammers is to be done, the thickness of layer is to be restricted to 10 cm. The hand rammers shall, preferably, be about 3 kg in weight. Various types of hand rammers can be made locally. Such rammers may comprise of: wooden blocks (of, say, 20 cm by 15 cm by 15 cm provided with a wooden handle); or a circular cast iron base plate with an iron handle; or steel channels/I-section beams welded together with a steel handle etc.

g) Each layer shall be well consolidated before the next layer is placed. Compaction of back-fill to 90% maximum dry density shall be reasonably adequate. (Refer to be assumed values outlined in para (d) above).

h) The back-fill layer in the immediate vicinity of the structure shall be compacted by hand rammers, say, in a width of about 30 cm, beyond which fuel-operated vibratory plate compactors can be used for compaction, if available, to avoid any damage to structure.

i) Where the back-fill soil to be used is cohesion less (sandy/sandy gravelly etc.) each layer be fully saturated with water and consolidated to a bulk density of about 1900 kg / m³.

j) It is to be ensured that the procedure outlined above is meticulously followed and that the soil is not dumped haphazardly against the structure and is not allowed to remain loose.
3.2. CONCRETE WORKS

3.2.1 The concrete mix shall consist of cement, graded fine and coarse aggregates, water, well mixed in a mechanical mixer, duly maintaining the specified water cement ratio (W/C), and consolidated well after placement at site. Only when the quantity is very small, and in exceptional cases, hand mixing of concrete mix ingredients shall be allowed by the Engineer.

3.2.1 (i) Cement:
Cement shall be procured from reputed manufacturers. It shall be of Grade M43 or M53. A certificate should be obtained from the manufacturer about its essential characteristics such as: initial setting time, final setting time; fineness; 28 day compressive strength, soundness, consistency; sulphate content etc.

Ordinary Portland Cement (OPC) shall normally be used on all works. Sulphate resisting cement or Portland Slag cement (with slag content more than 50%) shall be used in such situations, which in the opinion of the Engineer, are exposed to sulphate attack. It has been experienced that the Portland slag cement (with slag content of more than 50%) exhibits better sulphate resistant and chloride resistant properties.

3.2.1 (ii) Concrete Aggregates:

a) Fine Aggregate (Sand): It shall be well graded and have a fineness modules of 2.2 to 2.8. 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:

**Mechanical Analysis of Sieving**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage Passing for</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grading Zone I</td>
</tr>
<tr>
<td>10 mm</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>90-100</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>60-95</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>30-70</td>
</tr>
<tr>
<td>600 micron</td>
<td>15-34</td>
</tr>
<tr>
<td>300 micron</td>
<td>5-20</td>
</tr>
<tr>
<td>150 micron,</td>
<td>0-10</td>
</tr>
</tbody>
</table>

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 reinforced 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 mix. The allowance to be made for bulkage is tabulated below:

**TABLE**

<table>
<thead>
<tr>
<th>Bulkage determined in moist sand</th>
<th>Allowance to be made</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5%</td>
<td>NIL</td>
</tr>
<tr>
<td>5 to 10%</td>
<td>5%</td>
</tr>
<tr>
<td>10 to 15%</td>
<td>10%</td>
</tr>
<tr>
<td>15 to 20%</td>
<td>15%</td>
</tr>
</tbody>
</table>
Procedures for conducting quality control tests on sand are explained in the section on Quality Control Tests. These tests include: gradation; fineness modulus; bulkage; organic impurities; and determination of silt/clay content. All these tests must be conducted and recorded.

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 assessed through sieve analysis. Course 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 EIRP, 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.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing by weight for graded aggregate of nominal size</th>
</tr>
</thead>
<tbody>
<tr>
<td>63 mm</td>
<td>100 95-100 30-70 - - - - - -</td>
</tr>
<tr>
<td>40 mm</td>
<td>95-100 100 - - - - - -</td>
</tr>
<tr>
<td>20 mm</td>
<td>30-70 95-100 100 - - - - - -</td>
</tr>
<tr>
<td>16 mm</td>
<td>- - 90-100 100 - - - - - -</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>- - - - - - - - - - - -</td>
</tr>
<tr>
<td>10.0 mm</td>
<td>10-35 25-55 30-70 40-85 - - - - - -</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>0-5 0-10 0-10 0-10 - - - - - -</td>
</tr>
</tbody>
</table>

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

3.2.1 (iii) 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 atleast three 15 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.

3.2.1 (iv) Concrete Mix:

i) 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 mass.

ii) Measuring boxes/gauge boxes for volumetric batching of cement, fine and coarse aggregates are illustrated in sketch A. The wooden measuring boxes may be dimensioned as 30cm X 30cm X 37.25 cm to hold one bag of cement equivalent to 1.2 cubic feet volume. To add measured quantity of water, water containers are calibrated as shown in sketch A. Such wooden measuring boxes/gauge boxes should also be deployed for the preparation of cement mortar to be used in the masonry construction and plastering jobs. (Sketch ‘A’ at Page No.28)
Volumetric batch mixing of concrete mix ingredients by measuring boxes.

**NOTES**

- The Measuring Box shall be made to hold ONE BAG of cement.
- One Bag of cement weighs 50 kgs.
- In volume, one Bag of cement is equivalent to 1.2 cubic ft.
- The dimensions of Measuring Box may be:
  Length x Width x Height
  14.5 inches x 12 inches x 12 inches
  or 372.5 mm x 300 mm x 300 mm
  (to form a volume of 1.2 cft)

**Calibrated water containers**

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

<table>
<thead>
<tr>
<th>Concrete Class / Grade</th>
<th>Cube strength at 28 days (kg/cm²)</th>
<th>Mix proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 25</td>
<td>250</td>
<td>1 : 1 : 2</td>
</tr>
<tr>
<td>M20</td>
<td>200</td>
<td>1 : 1.5 : 3</td>
</tr>
<tr>
<td>M 15</td>
<td>150</td>
<td>1 : 2 : 4</td>
</tr>
<tr>
<td>M 10</td>
<td>100</td>
<td>1 : 3 : 6</td>
</tr>
<tr>
<td>M 7.5 (lean concrete)</td>
<td>75</td>
<td>1 : 4 : 8</td>
</tr>
<tr>
<td>M 5.5 (lean concrete)</td>
<td>50</td>
<td>1: 6: 12 (approx.)</td>
</tr>
</tbody>
</table>

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.

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:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Environment / Exposure</th>
<th>Exposure conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>Mild</td>
<td>Concrete surface protected against weather or aggressive conditions.</td>
</tr>
<tr>
<td>ii</td>
<td>Moderate</td>
<td>Concrete surfaces sheltered from severe rain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete exposed to condensation and rain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete continuously under water.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete buried under ground water / non-aggressive soil</td>
</tr>
<tr>
<td>iii</td>
<td>Severe</td>
<td>Concrete surfaces exposed to severe rains</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete surfaces exposed to alternating wetting &amp; drying &amp; severe condensation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete completely immersed in sea water and exposed to coastal environment</td>
</tr>
<tr>
<td>iv</td>
<td>Very Severe</td>
<td>Concrete exposed to sea water spray, exposed to corrosive fumes or severe freezing conditions whilst wet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete in contact with or buried under aggressive sub-soil/ground water.</td>
</tr>
<tr>
<td>v</td>
<td>Extreme</td>
<td>Concrete exposed to tidal waves / zone; &amp;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concrete in direct contact with aggressive chemical</td>
</tr>
</tbody>
</table>
Concrete surfaces of concrete lined channels are exposed to alternate wetting & drying and, therefore, comes 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>
<thead>
<tr>
<th>S. No.</th>
<th>Exposure</th>
<th>Plain concrete</th>
<th></th>
<th>Reinforce concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum cement content (Kg/m³)</td>
<td>Maximum water-cement Ratio.</td>
<td>Minimum Grade of concrete</td>
</tr>
<tr>
<td>i)</td>
<td>Mild</td>
<td>220</td>
<td>0.60</td>
<td>M10 (1:3:6)</td>
</tr>
<tr>
<td>ii)</td>
<td>Moderate</td>
<td>240</td>
<td>0.60</td>
<td>M 15 (1:2:4)</td>
</tr>
<tr>
<td>iii)</td>
<td>Severe</td>
<td>250</td>
<td>0.50</td>
<td>M20 (1:1.5:3)</td>
</tr>
<tr>
<td>iv)</td>
<td>Very Severe</td>
<td>260</td>
<td>0.45</td>
<td>M20 (1:1.5:3)</td>
</tr>
<tr>
<td>v)</td>
<td>Extreme</td>
<td>280</td>
<td>0.40</td>
<td>M 25 (1:1:2)</td>
</tr>
</tbody>
</table>

Adjustments to Minimum Cement Contents for Coarse Aggregate other than 20 mm nominal maximum size:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Nominal Maximum coarse aggregate size (mm)</th>
<th>Adjustment to minimum Cement Contents (Kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>10mm</td>
<td>+ 40 Kg/m³</td>
</tr>
<tr>
<td>ii)</td>
<td>20mm</td>
<td>0</td>
</tr>
<tr>
<td>iii)</td>
<td>40mm</td>
<td>-30 Kg/m³</td>
</tr>
</tbody>
</table>

Note: No reinforced concrete shall be of grade less than M 20. In respect of concrete works in EIRP, it may be adequate to assume "Severe" environment / exposure conditions. In this context, the minimum cement contents and maximum W/C ratio work out to be:

<table>
<thead>
<tr>
<th></th>
<th>Plain Concrete</th>
<th>Reinforced Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement content (Kg/m³)</td>
<td>250</td>
<td>320</td>
</tr>
<tr>
<td>Max water-cement ratio</td>
<td>0.5 to 0.6</td>
<td>0.45 to 0.50</td>
</tr>
<tr>
<td>Grade of concrete</td>
<td>M 15 / M 20 (1:1.5:3)</td>
<td>M 25 (1:1:2)</td>
</tr>
<tr>
<td></td>
<td>viz compressive strength at 28 days should be 150 / 200 kg/cm²</td>
<td>Viz the compressive strength at 28 days should be 250 kg/cm²</td>
</tr>
</tbody>
</table>

Cubes should be tested of concrete mixes with above minimum cement contents and water-cement ratios. If the 28 days compressive strength achieved work out to be 150/200 kg/cm² & 250 kg/cm² respectively, it is OK, otherwise increase the cement content.
In view of adoption of volumetric batching, the concrete mixes may involve higher cement content than the "designed mixes" based on proportioning of mix ingredients by weight. It may be adequate to increase the cement contents by about 10% (viz to increase the tabulated cement contents by about 10%). Cement content in the concrete mixes shall be such as would meet the durability requirements. Any excessive cement used in the mixes would be un-economical, besides causing thermal cracking.

e) **Consistency/workability of concrete Mix:** The consistency shall be such that the concrete can be easily placed and compacted without segregation 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 atleast 2 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. 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 atleast 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 atleast 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%.

As brought out in the Table under Para (iv) (b), above, Water/Cement ratio for 1:2:4 (M 15 grade) be kept as: 0.60, that of 1:1.5:3 (M 20 grade) as 0.50; and that of 1:1:2 (M 25 grade) as 0.45. To maintain such W/C ratio and 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 rodding poses problems. In such cases, workability (viz fluidity) of concrete shall need to be increased even by sacrificing the compressive strength some what since inadequate compaction could cause air voids and honey-combing in the concrete, which is not at all a desirable features. An 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) 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.

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
Concrete shall be placed in layers of 15 cm to 30 cm for reinforced work and up to 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 rodding 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 semi-circular 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 thereby 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:

<table>
<thead>
<tr>
<th>Quantity of concrete in the work (m³)</th>
<th>No. of samples to be taken for testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5 m³</td>
<td>1 No.</td>
</tr>
<tr>
<td>6-15 m³</td>
<td>2 Nos.</td>
</tr>
<tr>
<td>16-30 m³</td>
<td>3 Nos.</td>
</tr>
<tr>
<td>31-50 m³</td>
<td>4 Nos.</td>
</tr>
<tr>
<td>51 m³ and above</td>
<td>4 plus one additional sample for each additional 50 m³ concrete or part thereof.</td>
</tr>
</tbody>
</table>

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 (1: 1.5:3), the individual test strength shall not be less than 160 kg/cm³. The average strength of all samples shall however, be 200 kg/cm³.
3.3 REINFORCEMENT

3.3. Tested quality of steel reinforcement bars shall be used. The Contractor shall furnish test certificates of steel to be used in the works. Reinforcement of the shape, size/dimensions shown on the drawings shall be used.

3.3.1 Cutting, Bending, and Binding of Reinforcement:

a) Reinforcement steel bars shall conform accurately to the dimensions given in the bar bending schedule shown on the relevant drawings.

b) Bars shall be bent cold to the specified shape and dimensions by a bar bender by hand or power to attain the proper shape and specified radius of bends.

c) Bars bent during transport and handling shall be straightened before being used. The bars shall not be heated to facilitate bending.

d) Reinforcement bars available from any rejected reinforced concrete shall not be used.

e) The radii of bends in main reinforcement bars shall not be less than 4 times bar diameter for plain mild steel bars or 6 bar diameters in deformed bars. Radii of bends for stirrups shall not be less than twice the dia of round bar.

f) Where reinforcement bars are bent aside at the construction joints, and, afterwards bent back into their original positions, it shall be ensured that at no time is the radius of bend less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Also care shall be taken that concrete around the bars is not damaged.

3.3.2 Placing of Reinforcement

a) Before the reinforcement is placed, the surface of all bars shall be cleaned of rust, loose mill scale, dirt, or any objectionable matter.

b) All bars shall be placed in exact position shown on the drawing, and shall be securely held in position by binding wire, and by using metal chairs, concrete spacers at sufficiently close intervals. Pieces of broken stone, or brick, or wooden block shall not be used.

c) Wire for binding reinforcement shall be soft mild steel of 16 gauge (1 mm dia) Special care shall be taken to prevent any displacement of reinforcement during concreting.

d) It must be ensured that "Concrete Cover", as indicated in the drawing is provided. All bars protruding form concrete and to which other bars are to be subsequently spliced and which are likely to be exposed for a long period shall be given a coat of neat cement grout.

3.3.3. Minimum distance between individuals bars: Horizontal distance between 2 parallel main reinforcement bars shall usually be not less than the greater of the following:

i) diameter of the bar if diameters are equal;

ii) diameter of the larger bar if the diameters are unequal;

iii) 5 mm more than the nominal maximum size of coarse aggregate.

Size of coarse aggregate may be reduced around congested reinforcement.

• Wherever, there are 2 or more rows of bars, the bars shall be vertical in line and the minimum vertical distance shall be 15 mm or two-thirds of the nominal maximum size of coarse aggregate, or the maximum size of bars, whichever is greater.

• Where it is necessary to splice reinforcement, the splices shall be made by "lapping" duly tied by the binding wire. Normally, reinforcement bars of 25 mm or less are lapped. Reinforcement bars of 28 mm in diameter and larger may be "connected by "butt welding". However the Engineer may allow splicing by "lapping" if found to be more practical than "butt welding" and if "lapping" does not encroach on cover limitation or hinder concrete placement.

• Tolerance on placing of reinforcement: The reinforcement shall be placed within the following tolerances:-

(i) for effective depth - 200 mm or less = ± 10 mm

(ii) for effective depth - more than 200 mm = ± 15 mm
Tolerance for nominal cover: Actual concrete cover shall not deviate from the specified nominal cover by + 10 mm. The actual cover shall not be less than the specified cover in any case, viz “zero-tolerance”. That is, the cover can be more but in no case less than the specified cover.

Nominal Cover: It is the designed depth of concrete cover to the reinforcement. Minimum values for the nominal cover to be provided to all reinforcement, corresponding to the various exposure conditions is outlined below:

<table>
<thead>
<tr>
<th>Exposure Condition</th>
<th>Minimum Nominal Concrete Cover (in mm) (viz. cover to be not less than)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>20mm</td>
</tr>
<tr>
<td>Moderate</td>
<td>30mm</td>
</tr>
<tr>
<td>Severe</td>
<td>45mm</td>
</tr>
<tr>
<td>Very Severe</td>
<td>50mm</td>
</tr>
<tr>
<td>Extreme</td>
<td>75mm</td>
</tr>
</tbody>
</table>

Important: Nominal cover or cover thickness is the single most important "durability parameter”. The provision of sufficient cover of concrete to the reinforcement is the most important aspects of preventing corrosion of reinforcement. Of course, the concrete has to be dense, well vibrated, and well cured. It is of utmost importance that the Engineer or his representative checks the cover of reinforcement when it has been erected to be sure that it conforms to the cover specified in drawing/specifications. Furthermore, it is to be checked that spacers/steel chairs are adequately provided to ensure that the cover is not disturbed during concrete placement. Any reduction in cover shall cause early determination of concrete, thereby, reducing the useful life of the structure.

3.4. FORM WORK

a) The formwork shall conform to the shapes, lines and dimensions of structures shown on the drawings. Where the concrete finished surface is exposed, the formwork shall be of good quality and free of any gaps. The condition of formwork influences not only the appearance of the structure, but also reflects its quality & workmanship in construction. The use of good timber formwork and the steel formwork enhances the appearance of concrete. It should be recognized that it is not economical to use poor quality formwork. Too often, any savings from the use or injudicious re-use of poor quality timber formwork are negated by time consuming manual labour in repairs and final dressing of structure to an acceptable appearance.

b) The contractor shall furnish the details of proposed formwork to the Engineer for his approval. The formwork should either be of good quality timber (with a smooth inner surface free from any gaps) or of steel.

c) The face of the formwork which is to be in contact shall be thoroughly cleaned, and treated with form oil (or any suitable release agent). The form oil shall be applied so as to provide a thin uniform coating to the forms, without coating the reinforcement. It is needed for easy stripping of formwork after the concrete has been placed.

d) Formwork shall be sufficiently rigid by the provision of ties and bracings to withstand the pressure resulting from concrete placement and vibration without deflection of the formwork. Suitable struts or stiffeners shall also be used to make the formwork sufficiently strong to prevent any displacement or sagging of the formwork.

e) The formwork, after it is erected, shall be critically checked for its tightness. If the forms are not tight, there will be a loss of mortar from the concrete, which shall result in "honey-combing" or a loss of water, which will cause sand streaking/sand pockets in concrete.

f) No concrete shall be placed in the formwork till the Engineer or his representative has inspected it and given OK signal to proceed with concrete placement.

g) Use of internal vibrators for compaction of concrete requires that the forms are strong. Full
rigidity of forms is of paramount importance, as else bulging may occur by the pressure of concrete during its placement.

h) To ensure that no ugly off-sets occur at the horizontal construction joints between the successive lifts of concrete, the formwork should be fitted snugly against the top of concrete in the previous lift and securing it so as to remain in tight contact during the concrete placement. The anchoring shall be done by using ample number of ties and bolts above and within a few centimeters of the construction joint. Formwork shall overlap the hardened concrete in the lift previously placed by about 50 mm. This will ensure that the construction joints are smooth and free from sharp deviations and projections.

i) Occasionally, spalling of concrete may occur from the face of the concrete when formwork is removed. This is often caused by rough spots on the formwork where mortar adheres strongly enough to overcome the tensile strength of the green concrete. It is essential that such areas on the, forms are cleaned and then covered with suitable form oil.

j) Wire brushing of timber formwork shall be done regularly to remove the set mortar. The forms required to be re-used more than once shall be maintained in a good condition and shall be regularly cleaned and repaired before re-use.

k) The forms shall be stripped only after the concrete has achieved adequate strength. Following guidelines shall be adopted for stripping of the forms:

<table>
<thead>
<tr>
<th>Type of Formwork</th>
<th>Minimum Period before Stripping of Formwork</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sides of beams, walls, columns</td>
<td>16 - 24 hours</td>
</tr>
<tr>
<td>Forms from beneath the slabs (spanning upto 6m)</td>
<td>14 days</td>
</tr>
<tr>
<td>Forms from beneath the slabs (spanning above 6 m)</td>
<td>21 Days</td>
</tr>
<tr>
<td>Props to slabs (spanning upto 4.5 M)</td>
<td>7 Days.</td>
</tr>
<tr>
<td>Props to slabs (spanning above 4.5 M)</td>
<td>14 Days</td>
</tr>
</tbody>
</table>

3.4.1. Quality Assurance of Formwork: A good quality formwork shall ensure good concrete finish without any bulging, depressions, protrusions, hollow sand pockets, or honeycombing. The Engineer or his representative shall critically check the formwork and pay special attention to the following items:

- a) Preparation of surface of forms; smoothness; removal of set mortar/concrete;
- b) Alignment of forms;
- c) Form oil application to forms;
- d) Adequacy of the provision of ties, struts, bracing to assess the rigidity of forms;
- e) Tightness of formwork;
- f) Overall cleanliness from within the formwork prior to placement of concrete;
- g) Final O.K. for concrete placement.

3.5. STONE MASONRY WORKS

3.5.1. The stones used for masonry shall be of hard variety and free from decayed and weathered portions, flaws and cracks. The size of stones shall be such that at least 75% stones are not less than 15 cm in any direction (though 20 cm shall be preferred) and weighing not less than about 25 Kg to 30 Kg each. It shall be better to test few sample stones for water absorption. A stone when kept immersed in water for 24 hours shall not absorb more than about 5% water of its weight. The stones and quarry from where the stones are to be brought shall be subject to the approval of the Engineer. The types of masonry construction shall conform to the drawings viz. 1:5; or 1:4; or 1:3 (cement-sand proportions by volume).

3.5.1.1. Cement: Specifications of cement are the same as of concrete works. Cement shall be obtained by the contractor from reputed manufacturers. He shall obtain the requisite test certificate from the manufacturer or their agent and furnish the same to the Engineer. Cement shall, preferably, be of grade 40 or more.
3.5.1.2. **Sand**: It shall be washed and screened and the maximum size of particles being limited to 4.5 mm. It shall be free from organic impurities as well as silt and clay. It shall not have silt & clay more than 3% by weight. If moist/damp sand is used, its bulkage be determined and allowance made in the mortar, as has been explained in the item of concrete works. Grading of sand for masonry work shall conform to the following:

Grading of sand for masonry work

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>% passing by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75 mm</td>
<td>100</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>90 - 100</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>70 - 100</td>
</tr>
<tr>
<td>600 micron</td>
<td>40 - 100</td>
</tr>
<tr>
<td>300 micron</td>
<td>5 - 70</td>
</tr>
<tr>
<td>150 micron</td>
<td>0 - 15</td>
</tr>
</tbody>
</table>

3.5.1.3 **Water**: It should be free from objectionable quantities of silt, organic matter, and other impurities. Potable water is suitable. pH value water shall not be less than 6, and acceptable range is 6 to 9.

3.5.2. **Job – specific specifications and Procedure for Construction of stone Masonry structures / Walls:**

a) The Cement mortar shall consists of cement and sand, mixed in specified proportions given in the drawings and bill of quantities.
b) Cement and sand shall be mixed by volume; water shall be added from a calibrated container. Due allowance is to be made of bulkage of sand if moist sand is used. The mortar shall be mixed intimately in a mechanical mixer to the maximum possible extent. Mixing time shall be 2 ½ minutes to 3 ½ minutes after the addition of water.
c) In exceptional circumstances, when the work is of small magnitude, hand mixing may be allowed by the Engineer. This shall be done on a smooth water tight platform large enough to allow efficient mixing and turning over of the ingredients before and after adding water. Mixing platform shall be such that the water does not flow out. Dry sand and cement shall first be mixed thoroughly and water then added gradually and mixing continued until mortar of required consistency is obtained.
d) Consistency of mortar (viz workability/fluidity) shall be in the range of the water cement ratio of about 0.6.
e) The first batch of mortar at the commencement of work with any mix shall be made richer by mixing 10% more cement over and above that required for the particular mix.
f) The stones shall be absolutely free from dirt and well cleaned and washed before being laid.
g) Only such quantity of mortar shall be prepared at a time as could be completely used up in masonry within 30 minutes of mixing. Mortar that remains unused for longer period than 30 minutes or becomes stiff or set shall not be used. It shall be rejected and wasted.
h) After the foundation is prepared, a full mortar bed shall be placed of about 12 to 15 cm thickness. The stones shall be laid by hand with specified mix of mortar.
i) The stones are to be wetted and surface dry while being laid. The stones shall be solidly bedded in mortar with close joints. No joint shall exceed about 37 mm (viz 1.5 inches) nor shall be less than 12 mm in thickness. Chips of stones and rock spalls shall be "hammer wedged" into the big interstices (viz. gaps) between stones, wherever necessary, to give maximum density to the masonry. No hollow space is to be left.
j) Every stone shall be set flush in mortar, shaken and hammered down by a mallet to sink into the mortar bedding layer. Spalls/chips to be used shall be carefully selected to fit tightly into the interstices between the larger stones.
k) Additional mortar to be added to fill the intervening space between larger stones shall be well worked by a trowel and a steel bar of about 12.5 m diameter and 0.60 m long to ensure proper mixing and bonding with the bottom mortar layer. Putting chips/rock spalls into the intervening space between the stones shall not be done before filling it with mortar and
shaking it down to the full depth. Flat chips shall not be laid at the top. These shall be driven with ends vertically down: Header and Stretchers shall be inserted.
l) Next mortar layer about 12 cm to 15 cm thickness shall be laid and process of laying stones continued as here-to-fore.
m) Mortar content: The mortar content in one cubic metre of masonry is expected to range between 0.37 m³ to 0.43 m³; the average being assumed to be 0.40 m³, viz 40%. The actual consumption of mortar shall be recorded from day to day. A variation of + 3% may be allowed. Variation of more than 3% on the lower side (viz. lower than 37%) shall not be allowed, being violation of specifications. Variation of more than 3% on higher side shall be at the cost of the contractor.
n) The masonry shall be raised in courses, and the next course shall not be laid earlier than 24 hours after laying of the previous course. A maximum of 0.60 m high masonry can be allowed to be raised in a day. Each course is carefully plumbed and checked for verticality..
o) The top surface of each course shall be wire brushed to remove excess mortar and keep the surface rough to ensure good bond with the next course of masonry.
p) Curing of masonry: Curing of masonry shall commence after about 4 to 8 hours of construction (depending upon weather condition and atmospheric temperature) and water sprayed gently. All exposed surface of masonry shall be kept moist for a period of 14 days.
q) Note: Joints on the exposed face of all stone masonry shall be neatly finished. The mortar in the joints of stone masonry shall be raked (viz removed) to a depth of 25 mm to 30 mm, washed with water and cleaned of all loose mortar. Thereafter, the joints shall be filled with cement mortar of 1:2 proportion viz 1 part of OPC and 2 parts of sand by volume or of 1:3 proportion.

3.5.2.1 Quality Control Tests: Compressive strength tests of mortar cubes shall be conducted. A minimum of 3 test specimens shall be made from each type/class of mortar (viz 1:5; 1:4; 1:3) and tested for their 28 days strength. The acceptance criteria of compressive strength of 1:5; 1:4; 1:3 mortar types is 50 Kg/cm²; 75 Kg/cm²; and 100 Kg/cm² respectively.

3.5.3 Important Requirements of Masonry Construction:
a) Clean the old masonry surface prior to starting of new masonry with wire brush.
b) Do not place mortar which is too fluid viz which bleeds excessively.
c) Prepare the mortar with sand and not with gravel.
d) Surface of masonry shall be rough to secure good bond between the successive courses/layers of masonry.
e) Prepare the mortar, preferably, in a mechanical mixer, and only such quantity of mortar shall be prepared at a time as can be completely used within 30 minutes.
f) Provide contraction joint at intervals of 15 meters.
g) In the masonry walls, against the back-fill, provide 100 mm dia weep holes at above 1.5 m intervals, both vertically and horizontally in a staggered way (or as shown in the drawing) with inverted filters on the back-fill side in an area of 400 mm x 400 mm. Weep holes could be PVC pipes of 10 cm diameter.
h) Cure the masonry for 14 days.
i) Not more than 0.60 m high masonry be raised in a day.
j) Record the actual consumption of mortar in the construction of masonry every day. For a good masonry, average consumption of mortar per m³ of masonry shall be 0.40 m³ viz 40% with a variation of + 3%.
k) Proper gauge boxes shall be used in proportioning of cement and sand by volume. Volume of cement may be reckoned on the basis of 0.034 m³ per bag of cement of 50 kg viz 1.20 cubic ft per bag.
l) Mode of Mixing:  

<table>
<thead>
<tr>
<th>First stage</th>
<th>Second Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 % requirement of water</td>
<td>Balance Quantity of Sand</td>
</tr>
<tr>
<td>50 % requirement of sand</td>
<td>Balance Quantity of water</td>
</tr>
<tr>
<td>Full quantity of cement</td>
<td></td>
</tr>
</tbody>
</table>
In Mechanical mixing in Mixer, the mixing time shall be at least 2 ½ minutes; and in manual mixing, it may be extended to 3 ½ minutes. The first batch of mortar at the commencement of work with any mix shall be made richer by mixing 10% more cement.

3.6. STONE PITCHING/REVETMENT / RIP-RAP

3.6.1 It is a common practice to use stone revetment/pitching/rip-rap for the protection of channel banks, river banks and also in short reaches upstream and downstream slopes of earthen dams/embankments.

In order that the stone pitching/revetment/rip-rap remains stable, durable and functional following guidelines/requirements should be implemented:

a) The quality of stones shall be as outlined in item no. 5 (Stone Masonry Works). Stones bigger than 20 cm shall be preferred.

b) The subgrade/slopes on which stones are to be laid shall be smooth and well consolidated. Under no circumstances shall the stones be placed on a loose subgrade.

c) Compactor or hand rammers shall be used for compaction of the subgrade; a thorough consolidation is needed to avoid any subsequent settlement of stones which could cause collapse of pitching.

d) A graded filter 150 mm to 300 mm thickness shall be provided on the subgrade prior to placement of stones by hand. In small protection works, up to a height of 5 m, the graded filter of 150 mm thickness is adequate and for the height exceeding 5 m, the filter shall be 300 mm thick.

e) In the 150 mm thick filter, 75 mm shall consist of sand layer to be laid first on the subgrade followed by 75 mm stone jelly (viz natural or crushed rock of 10 to 20 mm size) laid over sand layer. In the 300 mm thick filter, each layer shall be of 150 mm thickness.

f) Purpose of graded filter is to prevent possible loss of soil particles from the subgrade. If soil loss occurs, it may cause slippage of stones.

g) The filter layers laid on the slopes shall be adequately moistened with water and consolidated. A very convenient and effective method of compaction is to use the thick stem of a date palm tree. (Sketch on Page No. 76)

h) Three or four person can go on consolidating the filter layers (duly moistened with water) on slopes with stems of the date tree. The process of hand placement of stones, commencing from the bottom, shall then be taken up.

i) To prevent the sliding of the revetment/pitching on the slopes, a toe protection shall be invariably provided in the form of a key or trench/toe wall. The key or trench shall be excavated to a depth of at least 1.5 times the thickness of pitching and the stones shall be laid in this trench and firmly bedded into the slope and adjoining stones. The width of trench could be, say 2 times the thickness of pitching.

j) Revetment shall be properly anchored to the subgrade both at the upstream end where it commences and also at the downstream end where the revetment ends by providing keys into the slopes. (Sketch on Page No.70)

k) The gaps between stones shall be filled with angular rock spalls through hammer-wedging to securely fix these in place tightly. The thickness of pitching or revetment is taken at right angles to the subgrade surface.

l) If mortar revetment is to be provided (viz stones bonded together with cement-sand mortar of 1:3 or 1:4 proportion) it shall not be constructed in a continuous or monolithic manner. It shall be divided into panels of 3m x 3m and weep holes shall be provided in each panel (with an inverted filter 400mm x 400mm at the back) for free drainage of water from the subgrade.

m) Reference be made of the following Table for broad guidance:
3.7. PROVISION OF PROTECTION UPSTREAM & DOWNSTREAM OF STRUCTURES

3.7.1. It is essential to provide protection in short reaches both upstream and downstream of structures to avoid any damages occurring to the structures through flow of water. The types of protection include: dry stone revetment; stone masonry walls; grouted stone revetment; concrete lining on slopes; or concrete walls. The designers shall decide the type of protection (or selective protection, as it is called) proposed to be provided depending upon the availability of requisite material and overall economy.

3.7.1.1. The extent of selective protection shall conform to the following broad guidelines:

(a) Where "fluming" of channels is involved:
   (viz upstream and downstream of falls, aqueducts, siphons, superpassages etc.)
   i  Small channels/Distributaries: Extent of selective protection may be in 3 m reach upstream and in 5 m reach downstream of structures, or as decided by the Design Wing.
   ii Branch canals: Extent of selective protection may be in 5 m reach upstream and in 7.5 M reach downstream of structures, or as directed by the Design Wing.

(b) Where "fluming" of channels is not involved (viz bridges, super-passages where fluming is not involved).
   i  Small channels/Distributaries: Extent of selective protection may be in 3 m reach both upstream and downstream of structures.
   ii Branch canals: Extent of protection shall be in 5 m reach both upstream and downstream, or as decided by the Design Wing.
   iii Except for the dry stone revetment. any other type of protection from amongst the types outlined above can be provided.
   iv In each case, toe walls must be provided at upstream and downstream. Bed protection shall also be provided.

3.8. RE-SECTIONING & STRENGTHENING OF CANAL SECTIONS

3.8.1. Presently, almost all irrigation channels are in bad shape. The channels have lost their design profiles, banks have eroded, beds are silted, and channel sections have widened in several reaches. Following Action Points are to be implemented and requisite provisions made in the cost estimates:

a) Jungle growth in the channel prism be removed. Detailed surveys be carried out; L – sections and Cross – Sections be plotted; and the quantum of earth work needed for re-sectioning & strengthening of channel sections to bring these to the designed profiles determined. This is an essential step. Detailed Surveys have still to be undertaken by the field engineers.

b) For re-sectioning / raising / strengthening of existing earthen channel sections, provision is to be made for benching the slopes in suitable steps, earth fill placement in layers, watering, and mechanized compaction with appropriate compaction equipment
(Viz 8 – 10 T Power Roller, 1 m wide Power Roller, or Fuel – Operated Vibratory Plate Compactors) depending upon the site situation and availability of space.

c) In case of non-cohesive soils, the layers are to be compacted to 65 % Relative Density. Compaction of earthwork is of paramount importance.

d) Provision for regrading the channel banks be made and a cross slope, say 1:80, provided towards the rear side.

e) In Small Section Channels, provision for “cut & fill method” may be made in order to achieve effective compaction, as is outlined below. “The channel section is excavated, say, in 500 m long reach; earth fill is placed in layers in the full section, watered (as required), and each layer compacted to 95 % Proctor Density through deployment of 8 – 10 ton Power Roller, vibratory Power Roller / 1 m wide drum Vibratory Power Roller. This process of compaction is continued right up to the top of designed section. There – after, the compacted section is scooped out to the proposed designed section and the scooped earth re-handled for use in the next reach taking into account some wastage during re-handling.

f) Where CC lining is to be laid in the channels passing through the swelling black cotton soils, provision for CNS treatment of the sub-grade is to be made prior to placement of lining as per Indian Standard IS 9451: 1994. Thickness of CNS material is to be in accordance with the following tables.

### 3.8.1.1. Table 1 A: Thickness of CNS layer in canals carrying less than 2 Cumecs (70 Cusecs)

<table>
<thead>
<tr>
<th>Discharge Cumecs (Cusecs)</th>
<th>Thickness of CNS layer in Centimeters (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Swelling pressure of BC Soils (50 – 150) Kn/m²</td>
</tr>
<tr>
<td>1.4 – 2.0 (50 – 70)</td>
<td>60 cm</td>
</tr>
<tr>
<td>0.7 – 1.4 (25 – 50)</td>
<td>50 cm</td>
</tr>
<tr>
<td>0.3 – 0.7 (10 – 25)</td>
<td>40 cm</td>
</tr>
<tr>
<td>0.03 – 0.3 (1 – 10)</td>
<td>30 cm</td>
</tr>
</tbody>
</table>

### 3.8.1.2. Table 1 B: Thickness of CNS layer in canals carrying more than 2 Cumecs (70 Cusecs)

<table>
<thead>
<tr>
<th>Swelling pressure of BC Soils Kn/m² (Kg/cm²)</th>
<th>Thickness of CNS layer in Centimeters (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 – 150 (0.5 – 1.5)</td>
<td>75 cm</td>
</tr>
<tr>
<td>150 – 300 (1.5 – 3.0)</td>
<td>85 cm</td>
</tr>
<tr>
<td>300 – 500 (3.0 – 5.0)</td>
<td>100 cm</td>
</tr>
</tbody>
</table>

The CNS soils have to be non-swelling with a maximum allowable swelling pressure of 10 Kn/m² (0.10 Kg/cm²) when tested in accordance with Indian Standard, IS : 2720 (Part 41) – 1977.
CNS soils are to broadly conform to the following range:

- Clay = 15 – 20 %
- Silt = 30 – 40 %
- Sand = 30 - 40 %
- Gravel (of size greater than 2mm) = 0 – 10 %
- Liquid Limit = More than 30% but less than 50%
- Plasticity Index = More than 15% but less than 30%

**Note:** In order to assess the extent of provision of CNS in the cost estimates for the treatment of sub-grade in swelling BC soils, it is essential to determine the swelling pressure. Accordingly, a ‘crash program’ needs to be launched for getting the representative soil samples tested for their swelling pressure from the soil testing laboratories. Cost estimates can be firmed up only if the “Swelling Pressures” are got determined and borrow areas for obtaining CNS soil are identified. Provision for mechanized compaction of CNS soil layers to at least 95 % proctor Density, though 98 % would be preferable is to be made in the cost estimates.

### 3.8.2. Model Sections in Unlined channels:

In the irrigation channels proposed to be left Un-lined, “model sections” of either stone masonry or concrete (± 30 cm x 30 cm) should be provided at intervals of say, 50 m, and at closer spacing in curved reaches. (The spacing be decided in consultation with the Chief Engineer).

### 3.8.3. Excavation of Tank Bund for Reconstruction of Irrigation Sluices:

When any irrigation sluice is to be re-constructed, portion of earthen embankment on either side of the sluice is required to be removed right up to the bottom of the sluice / sluice barrel. Provision should be made in the cost estimate for excavating the existing embankment to a slope of at least 3 (H): 1 (V) on either side of the sluice, benching of the excavated slope; and finally compaction of earth fill placed in layers to specified density after the new sluice is constructed. Effective bonding of new earth fill with the previous one is of paramount importance.

### 3.9 CANAL LINING

#### 3.9.1. Design of Cement Concrete Lining:

The lining is to be cast – in situ un-reinforced cement concrete lining. Thickness of lining may conform to either the Indian Standard, IS 3873 – 1993 or as per the US Bureau of Reclamation practice, tabulated below.

#### 3.9.2. Thickness of Un-reinforced concrete lining

a. **As per US Bureau of Reclamation Standard / Practice.**

<table>
<thead>
<tr>
<th>Discharge in cusecs</th>
<th>Thickness of lining (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 500 Cusecs</td>
<td>2 ½ inches</td>
</tr>
<tr>
<td>500 – 1500 Cusecs</td>
<td>3 inches</td>
</tr>
<tr>
<td>1500 – 3500 Cusecs</td>
<td>3 ½ inches</td>
</tr>
<tr>
<td>3500 – 7500 Cusecs</td>
<td>4 inches</td>
</tr>
<tr>
<td>7500 – 20,000 Cusecs</td>
<td>4 ½ inches</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Discharge capacity Cumecs (Cusecs)</th>
<th>Depth of water (m)</th>
<th>Thickness of lining (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5 (0 – 175)</td>
<td>0 – 1 m</td>
<td>50 – 60 mm</td>
</tr>
<tr>
<td>5 – 50 (175 – 1750)</td>
<td>1 – 2.5 m</td>
<td>60 – 75 mm</td>
</tr>
<tr>
<td>50 – 200 (1750 – 7000)</td>
<td>2.5 – 4.5 m</td>
<td>75 – 100 mm</td>
</tr>
<tr>
<td>200 – 300 (7000 – 10500)</td>
<td>4.5 – 6.5 m</td>
<td>90 – 100 mm</td>
</tr>
<tr>
<td>300 – 700 (10500 – 24500)</td>
<td>6.5 – 9.0 m</td>
<td>120 – 150 mm</td>
</tr>
</tbody>
</table>

Taking into consideration the various factors including economy and ease/practicality of placement, it may be appropriate to adopt a lining thickness of 70 mm for channels of discharging capacity up to 175 cusecs and 75 mm for discharge beyond 175 cusecs to 1500 cusecs.

3.9.3. Cement:

43 Grade or 53 Grade Ordinary Portland Cement conforming respectively to Indian Standard, IS 8112 and IS 12269 is to be used.

3.9.4. 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, provisions of a minimum cement level of 250 kg / m$^3$ of concrete mix be made in the cost estimate of CC lining from “durability consideration”. Water Cement ratio is to be restricted to not exceed the range, 0.55 – 0.60.

3.9.5. Maximum size of Coarse Aggregate:

Graded coarse aggregate with maximum nominal size (MSA) of 20 mm, down graded to IS grading is to be used in the concrete mix for 70 mm – 75 mm thick CC lining.

3.9.6. Air Entraining Agent (AEA):

Provision for using AEA in the concrete mix for CC lining, be made in the cost estimate. Concrete mix with AEA affords more “durability”, as well as better “workability (viz. fluidity)” and better “finish”.

Graded fine and coarse aggregate 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 adding AEA.

3.9.7. Contraction Joints:

As a thumb rule, the spacing of both the longitudinal and transverse contraction joints should not normally exceed 36 times thickness of lining to avoid cracking of the lining surface in between the joints.

<table>
<thead>
<tr>
<th>Lining thickness (t)</th>
<th>Spacing of joints (36 x t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 mm</td>
<td>2520 mm, say 2.5 m</td>
</tr>
<tr>
<td>75 mm</td>
<td>2700 mm, or 2.7 m</td>
</tr>
<tr>
<td>100 mm</td>
<td>3.60 m, better to keep 3.0 m spacing</td>
</tr>
</tbody>
</table>

If the perimeter of canal section is less than 6.0 m, no longitudinal contraction joints are to be provided. However, transverse contraction joints across the canal section are to be provided irrespective of the extent of perimeter.
3.9.8. Consolidation of concrete:

Proper consolidation of concrete mix for CC lining, as being placed, is of paramount importance. One of the most effective methods comprises of deploying a “vibratory plate device”, operated by a fuel – operated motor. Such a device can also be used for compaction of the sub-grade of small section channels.

3.9.9. Cutting Grooves for Contraction Joints:

Grooves should be cut to the specified size when the concrete is still plastic. At the time of filling of the grooves with the sealing compound, these should be thoroughly cleaned of all dirt, mortar, or any set grout.

3.9.10. Curing of lining:

Curing is the most vital requirement in the cement concrete lining. Any slackness in curing or in adequate curing shall weaken the lining and cause its early deterioration / cracking. Fool – Proof curing is a MUST. In case adequate water – curing of both the bed and side lining is assured, it is ideal. Alternatively, provision should be made for curing of bed lining by water (though construction of small height earthen bunds and ponding water) and the curing of side CC lining by application of “membrane – forming curing compound” to ensure fool – proof curing.

The curing compound should be white pigmented of approved quality conforming to ASTM – C – 309 – 81 Type – 2. This should meet the requirement of water retention test as per ASTM designation C – 158 – 80. Loss of water in this test is to be restricted to not more than 0.55 Kg / M2 of exposed surface in 72 hours.

3.9.11. Application of Curing Compound:

Curing compound is to be applied as soon as the bleeding water or shine on the concrete surface disappears, leaving dull appearance. This is when there is no longer free moisture on the surface. If applied too early, the free moisture will prevent the compound from forming a moisture – proof film. If applied too late, some of the moisture will have already been lost that should have been retained. The proper time range will vary from about 30 minutes to 2 hours after placement of lining depending upon humidity and temperature. Uniform coverage of curing compound is very important. A good skill is needed when it is to be hand sprayed with a nozzle. The dosage of curing compound, sprayed on the lining surface with a nozzle, is 1 litre for about 3.75 M2 of surface area of lining.

Note: - The sub-grade on which lining is to be placed must be well consolidated, hard, and smooth. Any surface irregularities should be within the tolerance limits (Viz. not more than 6.5 mm on slopes and 12.5 mm on bed).

3.10. MEASURING DEVICES ON IRRIGATION CHANNELS/DISTRIBUTION SYSTEM

3.10.1. Presently, there is no measuring structure on any of the canal distribution network. The existing sluice structures are not calibrated to indicate the quantum of flow in the off-taking channels. Neither there is any measuring device downstream of the Regulating Division Dams.
3.10.2. Provision of CTF (Cut – Threat Flumes) in fibre glass reinforced plastic (FRP) material with “hold fasts” to be embedded in the concrete structures should be made in the cost estimates. Such a flume has engraved gauge marking in centimeters as well as in litres per second.

3.10.3. A large number of CTFs have been constructed in the SRBC distribution system of AP III project. Designs / Drawings and data on cost estimates be obtained from SRBC engineers.

3.10.4. A measuring structure be provided at off takes of distributaries from the main canal / branch canal and minors from the distributory.

3.11. GABION STRUCTURES

3.11.1. Construction of “gabion structure” proves very effective in earth control, and soil conservation. Gabions can be very usefully used in stream training works and for controlling erosion of earth. Where the outflow channel downstream of a weir poses a serous problem of slippages of earth, gabion retaining wall provides a practical solution to control such slippages.

3.11.1.1. Specifications:
3.11.1.2. ASTM Designation:
A 975 – 97 outlines the standard specifications of “double twisted hexagonal mesh gabions”. Particulars about the mesh type and wire diameter of Zinc Coated gabions are given in Sketch 3 (Page 71).

3.11.1.3. Definition of Gabion:
It is a double twisted Zinc coated wire mesh container of variable sizes, uniformly partitioned into internal cells or diaphragms, inter – connected with other similar units, and filled with stones at the work site to form “flexible, permeable, monolithic structures such as retaining walls, revetments etc.

The gabion shall be fabricated “Maccaferri” type or equivalent supplied by an approved / reputed manufacturer.

The stones used should have a minimum size of not less than the mesh width, as shown in Sketch 3. D is the distance between the axes of the twists.

3.11.1.4. Important Points in Gabion Works:
a) Stones to be used shall be of good quality viz hard & free from soft seams or of any disintegration features.
b) Stone size shall range from about 200 mm to 300 mm. Stone size of 350 mm shall be preferable.
c) Use of small stones shall be restricted to the maximum feasible extent of fill the voids between bigger stones. Such small stones shall have a minimum size of not less than D, where D is the specified mesh width.
d) The Gabions and Mattresses shall be flexible galvanized gabions with the mesh panel wire of 3.0 mm dia, and shall be Maccaferri type or equivalent, and shall be procured from reputed agencies.
e) Foundation for each Gabion shall be free from depressions and protrusions. Any depressions are to be filled with suitable soil / gravel, moistened and consolidated. The protrusions are to be struck and leveled. Tolerance for surface irregularities shall not exceed ± 6.25 cm.
f) The Gabions shall be divided into cells by diaphragms, whose length shall not be more than the width of the gabions. Diaphragms shall be provided at not more than 1.0 m interval.
g) Where more than one layer of Gabions is to be laid, these be placed with a minimum step of 0.15 m between the faces of the lower and upper Gabions Boxes. In high walls, a step of 0.50 M shall be appropriate.
h) All Gabions shall be connected to each other along corners with – Lacing, the wire to be passed through each mesh making a double twist every other mesh.

i) Careful attention shall be given to the filling operation to ensure that the stones are placed evenly in the baskets with minimum voids in between. Smaller stones shall be hammer wedged into the voids. All external stones shall be of big size, preferably of 200 mm – 300 mm size range.

j) The stone to be used for the top layer of Gabion Boxes shall have a flat surface to ensure that the wire does not rest on sharp corners of stone if these are not flat.

k) Bracing wires shall be used as per Manufacturer’s instructions in the Brochure.

l) A Gabian shall not be completely filled until the adjacent basket has been half filled in order not to cause displacements / bulging during filling.

m) Before filling, adjacent baskets shall be secured together with steel lacing wire, duly galvanized.

n) Gabion walls shall have a vertical face, not exactly Vertical, but shall be given a slight angle to the vertical (Say 1.0 horizontal to 10.0 Vertical). This shall be achieved by sloping the foundation accordingly. This shall take care of the effect of back-fill pressure & also of the settlement/consolidation of the foundation. (Sketch Page No. 72)
CHAPTER – 4.

Guidelines on Engineering Design, Construction and Quality Control:

4.1. The Minimum Rehabilitation of minor irrigation schemes cover earth dams/bunds, sluices including shutters, surplus weirs, irrigation channels including structures there-on and feeder channels. In view of the large scale spread-out of works in 17 districts of 3 regions, it is essential that the implementation of remedial measures conforms to acceptable standards and that there is optimum uniformity in the adoption of technical specifications for execution of rehabilitation works in the various regions. The objective should be to make the respective components safe and of improved functioning capability within the Specified permissible funds by carrying out the rehabilitation to the extent considered absolutely essential through judicious prioritization of works. Whatever rehabilitation/repair work is to be done it should be in accordance with acceptable standards and specifications and in this context the following broad guidelines are listed, which can be supplemented with the relevant Indian standards' wherever needed or - considered necessary:

4.1.1. Strengthening/Rehabilitation of Earth Dams/Bunds

4.1.2. Preparation:

a) For raising earthwork on the old embankment, care shall be taken to ensure proper bonding of the freshly laid soil with the old embankment. Accordingly, all bushes, vegetation, roots, trees etc. from the existing portion of embankment proposed to be raised are to be removed.

b) The base shall be stripped to a depth of 20 cm.

c) The requisite slopes of existing embankment shall be benched in steps of 30 cm /45 cms, preferably 30cm

4.1.3. Placement of Earthwork and Compaction:

a) Being homogeneous section, proper type of soils, (GC, OM, SC, SM, CL soils) shall be used. Accordingly, representative samples of soils proposed to be used as earth-fill shall be first got tested from APERL, Hyderabad or other reputed institution for their suitability. CDO shall also be apprised of the test results for review and advice, if any. Use of any other soils be done only after approval from CDO. Grain size analysis for classification be got done to know the classification of soils 'proposed to be placed in the embankment. This is very important.

b) Earth-fill shall be laid in suitable layers not exceeding 30 cm for power roller compaction. Clods shall be broken to 7.5 cm. Any roots,' grass and rubbish shall be removed from the fill. Cobbles/gravels/boulders of size more than 7.5 cm shall also be removed.

c) In case initial water content in the soil is less than the optimum moisture content, water shall be uniformly sprinkled over the freshly laid layer before compaction.

d) Compaction of earth-fill layer shall be done by 8-10 Ton Power Roller. Following criteria for control of compaction be adopted.

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>% of+ No.4 fraction by dry wt. of total material</th>
<th>Minimum acceptable density (D)</th>
<th>Desirable average Density (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohesive Soils controlled by the Proctor test</td>
<td>0-25</td>
<td>D=95</td>
<td>D=98</td>
</tr>
<tr>
<td></td>
<td>26-50</td>
<td>D=92.5</td>
<td>D=95</td>
</tr>
</tbody>
</table>
Or a general acceptance criteria of 95% of Proctor density at OMC be adopted.

a) Where space is not sufficient for deployment of Power Roller for compaction, earth-fill be laid in layers of 15 cm and compacted either by the fuel operated bed compactor.
b) In-situ field density test of each layer shall be taken.

4.1.4. Revetment and Gravel Cover

a) After the waterside slope of embankment is trimmed, 300mm/225mm thick revetment be laid over 300 mm/225 mm thick gravel cover.
b) 150 mm thick gravel cover be provided over the top of embankment (if needed) for movement facility.

4.1.5. Tests and Frequency of Testing on Soils

<table>
<thead>
<tr>
<th>Test</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Proctor Test</td>
<td>One test per day for individual Borrow Area</td>
</tr>
<tr>
<td>Field Density &amp; Moisture Content</td>
<td>One test for every 1500 m3 of earthwork and, at least one test in each layer laid on embankment.</td>
</tr>
</tbody>
</table>

4.1.6. Register to be Maintained:

A register shall be meticulously maintained to list the above tests and the test results including the actual compaction efficiency obtained in each layer. It shall also list the results of grain size analysis on classification of soils indicating the type of soils determined to be suitable for placement in the earth-fill.

4.2. Irrigation Channels:

4.2.1. Earth Sections

a) Channels shall be restored to the designed earthen sections in optimum possible reaches.
b) Where banking is involved, the earthfill be appropriately compacted by fuel operated bed compactor to impart stability and durability to the banks. Alternately pneumatic tamper be used for compaction.
c) It shall be appropriate to construct Model Sections in RR stone masonry (+.60m width) at suitable intervals, say, one at every curve and at 50 to 75 m intervals in straight reaches. This shall be highly useful in maintaining the profile of the earthen channels.

4.2.2 Lined Sections - Selective Lining:

Channels shall be lined only in such locations/reaches where it becomes absolutely essential as dictated by the site conditions. Such selective lining shall be taken up only with the concurrence of the concerned Executive Engineer who shall also approve the hydraulic design as well as the type and design of lining.

4.2.2.1 Plain Cement Concrete Lining:

Thickness of lining. It shall be provided as per following Table:
<table>
<thead>
<tr>
<th>Channel Discharge</th>
<th>Thickness of Lining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1.5 m / sec</td>
<td>65 mm</td>
</tr>
<tr>
<td>1.5 m3 / sec up to 15m3 / sec</td>
<td>75 mm</td>
</tr>
<tr>
<td>15 m3 / sec and more</td>
<td>100 mm</td>
</tr>
</tbody>
</table>

a) **Cement level**: From durability consideration, cement level shall be 250 kg/m³ of concrete, viz the mix design shall be higher than M10 concrete (between M 10 and M15).

b) **Subgrade for lining**: The sub-grade shall be duly compacted and moistened before placement of lining.

c) **Side slopes**: In the locations where unlined reaches are proposed to be converted into lined ones. (for selective lining), the side slopes be preferably kept as 1.5:1 but not less than 1.25:1.

d) **Coping**: Horizontal concrete coping or key shall invariably be provided at the top of lining.

e) **Concrete placement**: Conventional concrete placement (viz. manual placement) shall be in alternate panels of up to 3m in length. Maximum size of graded coarse aggregate shall be restricted to 20 mm.

f) **Sand**: It shall be clean and free of silt, clay etc. It should not have injurious amount of organic impurities. Fineness modulus shall not be less than about 2.2. Recognizing that sand is a very important constituent of concrete mix, as well. As of cement mortar, field staff (Work Inspector/Assistant Engineer/Assistant Executive Engineer) shall do the following test to determine suitability of sand:

g) **Quick Colour Test** to be conducted by field engineers at site to determine the suitability of sand in respect of any injurious amount of Organic impurities.

h) Sand shall be tested with 3% solution of caustic soda, called. colour test. 

i) A colour less liquid shall indicate clean sand free from organic matter. 

j) A straw coloured liquid indicates presence of some organic matter but not enough to be objectionable. 

k) A dark colour means that the sand contains injurious amount and, accordingly, it is not to be used unless it is washed and a re-test shows that it is satisfactory.

l) **Bulkage of sand**: Bulkage of wet sand shall not be more than 20%

m) **Curing of lining**: Utmost importance shall be given to water curing of lining Bed lining be cured through ponding of water by providing small earth bunds. For curing of side lining, gunny bags be placed on slopes and kept wet. 28 days curing is desirable but the first 14 days of curing is very critical and must be ensured without any interruption whatsoever.

**Note**: Porous concrete plugs of 100mm dia may be provided in each panel of 3m width, as Under drainage, wherever considered necessary.
4.2.3. Tests and Frequency of Testing:

<table>
<thead>
<tr>
<th>Test</th>
<th>Frequency of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 ) Sand</strong></td>
<td></td>
</tr>
<tr>
<td>(i) Sieve analysis for fineness modulus and gradation.</td>
<td>One test for every 150 m³ (or less) sand to be used in concrete mix.</td>
</tr>
<tr>
<td>(ii) Bulkage of sand</td>
<td>One in a shift or for every consignment.</td>
</tr>
<tr>
<td>(iii) Organic impurities in sand.</td>
<td>One in a shift or for every consignment.</td>
</tr>
<tr>
<td><strong>2 ) Coarse Aggregate</strong></td>
<td></td>
</tr>
<tr>
<td>Screen analysis for gradation</td>
<td>One test for every 150 m³ (or less aggregate to be used in concrete mix.</td>
</tr>
<tr>
<td><strong>3 ) Water for suitability of use in concrete.</strong></td>
<td>One test from each source of water in a working season.</td>
</tr>
</tbody>
</table>

In addition, slump tests of concrete be taken regularly.

4.2.4. Register to be maintained:
A register shall be maintained to list the above tests and their results.

4.2.5. R.R. Masonry Lining (20 cm/25 cms) in cement mortar

Stones

a) Stones to be used for lining shall have a reasonably uniform size with the designed dimensions and shall conform to specifications. Stones shall be brought from the quarries approved by the Engineer.

b) Individual stones shall be sound, hard, and durable and capable of sustaining weathering and water action. Those shall be free from laminations, soft spots, seams, and other defects. When immersed in water for 24 hrs, the stones shall not absorb water more than about 5% of their dry weight.

4.2.5.1. Laying of Stone Lining:

a) Both bed and slopes of the channel shall be divided into panels for laying stone masonry. The panels shall have dimensions of, preferably, not more than 10m along and across the centre line of channels (minors/distys). This may be increased to 15 m for bigger capacity channels.

b) While laying the stones, care shall be taken to lay binder stones of size 20 cm x 20 cms x 60 cms or 22.5 cms x 22.5 cms x 60 cms on either side of expansion pint joint at 10.0m/15.0 meters centers.

c) To guard the lining from building up of pore-pressure that may cause damage to the lining in gravelly soils, porous no-fine concrete slabs (of size 20 cm x 20 cm x 20 cm) be provided in stone masonry. In small channels, such a slab be provided at half the full supply depth at 5m centers. No-fine concrete shall consist of 1 part of cement and 4 parts of coarse aggregate of maximum size not exceeding 20 mm. No sand shall be used. To guard the lining from any pore pressure in cohesive soils, perforated pipes of 75 mm dia be provided with a filter (of sand, gravel) backing. (CDO be consulted for specific
provision of above under-drainage arrangement) consist of 1 part of cement and 4 parts of coarse aggregate of maximum size not exceeding 20 mm.

d) Cement-Sand mortar shall be used within 30 minutes of the preparation of mortar.
e) Hand mixing of mortar shall be done on smooth water-tight plat form, (if mechanical mixer cannot be deployed).
f) Field colour test of sand shall be done for presence of any organic impurities. Maintain good line and grade viz. workman ship, while laying the masonry.
g) Horizontal coping (or key) shall be laid at the top of lining.
h) Water curing shall be done for at least 7 days.

4.2.6. Masonry Guide Walls:

Stone masonry guide walls in CM 1:5 over the lean concrete foundation shall be considered for construction only in specific locations where there seems to be no alternative due to peculiar site conditions.

To achieve the objective of minimum rehabilitation of Irrigation Channels conforming to acceptable engineering principles, careful decision shall need to be taken on the adoption of a particular type of lining or a combination of types of lining from amongst the three types of lining outlined above depending upon the site situations. The type and extent of such “Selective Lining”, shall be decided, by the respective Superintending Engineer of the region taking into account all the relevant factors. It shall be appropriate to restore the channels to the designed earthen sections to the optimum extent possible.

Note: In case of expansive soils associated with swelling pressures, full CNS soil treatment shall be done as per Indian Standard, IS : 9451-1994.

4.2.7 Surplus Weirs:

The surplus weirs suffer from one or a combination of the following types of damages:
Damage to pointing of joints in the body wall leakages through the bottom of weir and leakages through the body wall of weirs; pot holes in the solid apron; and damage to the talus portion etc.

Broad guidelines on repairs to these damages are outlined below:

4.2.7.1. Damage to Pointing of Joints:

a) All loose mortar shall be removed from the affected joints.
b) Raking of all such joints shall be done to a depth of 25 mm.
c) The joints shall be thoroughly cleaned with Water (or air jet).
d) Prepare the cement-sand-water mortar of specified grade on a smooth water tight. platform making sure that no foreign material gets mixed with mortar nor the mixing water flows out. Dry sand and cement shall be mixed thoroughly by turning over to get a mixture of uniform colour. Water, shall then be added, gradually and mixing continued until mortar of required consistency of 90 to 100 mm is obtained.
e) Keep the cleaned up and raked up joints moist for about 2 to 3 hours before filling
f) these with the wet mortar
g) Ensure that the wet mortar is used to fill up the joints within 30 minutes of its mixing.
h) Proper pointing of joints be done.
i) Curing of the joints done for 7 days.

4.2.7.2. Leakages through Weir:

In case the weir suffers from appreciable leakages from the body wall, it may be appropriate to provide either external plastering or skin wall of concrete to the upstream body wall of weir.

4.2.7.3. External plastering: After the hollow Joints in masonry are duly filled up as per guidelines outlined in (a) above, these be kept moist (viz., cured for 72 hours) and the following steps taken to apply external plastering.
a) Roughening of surface of body wall shall be done to improve the bond of plaster.
b) The surface shall be moistened sufficiently.
c) Plaster of 20 mm thickness and of specified grade shall then be applied to the surface from top and worked down. The mortar shall be stiff enough to cling to the surface and hold when laid.
d) At the end of the day, the plaster shall be kept in a clean horizontal or vertical line.
e) When recommencing the work on next day, the edges of old plaster shall be scrapped clean and wetted and treated with cement slurry before the new plaster is laid adjacent.
f) Water-curing of plastering shall be done uninterruptedly for 14 days.
g) Any cracks which appear on the surface and all such portions which sound hollow when tapped or found soft or otherwise defective shall be cut in rectangular shape and redone

4.2.7.4. Concrete Skin Wall:

Provision of concrete skin wall shall provide a water-tight barrier and stop all leakages through the weir. Typical construction of this wall is illustrated in the enclosed sketch (Page No.54) and its salient features are outlined below:

- grade of concrete : M15 (with 20 mm maximum size of aggregate
- thickness of concrete : 200 mm(150mm for smaller heights, say upto 1.5m)
- thickness of concrete : 300 mm (200mm for smaller heights) at bottom
  - reinforcement in skin wall : 8 mm dia at 200 mm centres in both directions
  - anchor bars : 16 mm dia (as shown in sketch)

The skin wall shall be anchored with top of weir by removing the top one layer of existing stone. The wall is to be placed below upstream ground level/apron level to a depth of 450 mm (or 600 mm) and width of 600 mm (or 900 mm) throughout the length weir, depending upon the height of weir. The shape of crest shall not be changed.

Specifications:

a) Joints in the existing masonry be raked to a depth of 25 mm.
b) Roughen the surface through manual chipping or pneumatically operated tool.
c) Keep the surface after raking of joints and roughening of surface wet for 72 hours prior to placement of skin concrete (M15)
d) A coat of cement slurry with cement – mortar mix (1 : 2.5) with water-cement ratio of 0.70 be applied over the masonry surface, with joints thoroughly packed.
e) 50 mm dia holes be drilled in the masonry and clean holes by air-water jet.
f) Cement sand mortar (1:2) with water cement ratio of about 0.33 shall be pushed into the drill holes while the holes are still wet after cleaning. Then 16 mm dia steel anchors be pushed in. Drill holes for anchors shall have an inclination of 5 degrees with the horizontal downwards into the body wall.
g) Concrete placement shall be done in convenient lifts and deploying good shuttering. Slump of concrete may be in the range of about 50 nun and needle vibrators used for consolidation.
h) Curing of concrete wall be done for 28 days.
i) In cases where the leakages are through the bottom of weir, the provision of skin wall may not be taken to the full height of the weir, but be restricted to about 0.60 m to 2 m. Fine-tuning or any modifications if considered necessary be got done through.

4.2.8. Damage to Apron:

In case the damage to the apron consists of only few pot holes and the rest of the apron is generally alright, it shall be appropriate to clean the pot holes, chip the sides wherever necessary and fill up these with plain cement concrete of M 7.5 grade (equivalent to 1 : 4 : 8) duly consolidated. In the context of the minimum rehabilitation concept such treatment is considered to be adequate.
4.2.9. Irrigation Sluices:

a) Repairs to the damaged irrigation sluices their improvements shall be accorded the 'top priority'. This shall also include replacement of existing plugs with screw gear-operated steel shutters.

b) Designs of proposed gangways /RCC platform or structures to facilitate easy approach for operation of sluices shall be prepared and got approved from CDO or the special design circle. Mechanical components shall be got reviewed and approved from the mechanical wing of CDO.

c) In case the situation is such that repairs to the whole of sluice barrel is contemplated, it shall require 'open cut' of embankment / earthen dam on either side of the barrel in order to expose the entire length of barrel. Cutting shall be done in suitable benching at \( \frac{1}{2}:1 \) or flatter slope if so warranted.

d) After the repairs to damaged masonry sluice barrel have been carried out and water-cured for 14 days, the open cut portion of the embankment shall be taken up for filling with approved soil. Layers of soil not more than 15cm thickness shall be laid, and compacted with either with 'fuel-operated bed compactors' or 'pneumatic tampers' to the specified density of 95% at OMC. High-quality job is to be done in such situations.

4.2.10. Construction Quality Control and Quality Assurance:

Construction quality implies that the jobs be done to recognized standards through meticulous implementation of quality control and quality assurance parameters associated with the prescribed technical specifications and design. The proposed 'minimum rehabilitation of minor irrigation schemes' involves works to be carried out in 2,934 tanks located in 17 districts. Rehabilitation of 2798 tanks is proposed to done by direct contracting (the cost of each tank-being less than Rs.1.2 M) and the balance 186 tanks through NCB procedure (the cost of each tank being more than Rs.1.2M recognizing that the job network is of a very wide spread-out, it is of paramount importance that a practical and result oriented quality control / quality assurance mechanism is established to ensure that whatever rehabilitation is done should be durable and sustainable. In this context the following suggestions are made

4.2.11. O.K. Card System:

It provides a very useful mechanism for enforcement of specifications and achieving quality construction. Each work is subdivided into various activities in proper sequence of construction and are listed in chronological order of occurrence on the O.K.Card. Broadly an OK Card is a condensed form of specifications and essential requirement for achieving requisite workmanship and quality level of output. This system is in use on AP III project and is proving very useful. According to the OK Card system should be introduced forthwith on the rehabilitation of minor irrigation schemes as well. Likewise, O.K. Cards other works be prepared. Essential requirements relating to this system proposed for implementation the minor irrigation schemes are listed below:

a) Entries in the OK Card shall be in English as well as in the local language (Telugu)

b) First column in the OK Card against the various activities shall be filled by Work Inspector(WI). The second column shall be initiated by Assistant Engineer/Assistant, Executive Engineer with his dated signature against all the items. In case of absence of WI the first column shall be left blank, but AEI AEE shall fill the second column.

c) Authorization of commencement of any activity and/or OK of any activity shall be governed by the OK recorded by AE/ AEE-in the OK card.

 d) Deputy Executive Engineer shall record his observations / comments on OK Card during his visits to the Work.

e) Executive Engineers/Superintending Engineers during their inspection of works shall check these cards and record their comments, if any, on them.

f) **OK Card for each component shall be in duplicate, so that one card is given to the**

52
WUA.

g) After the particular part of the Work is completed, the OK Card related there of, shall be filed in the Office of Executive Engineer, as a permanent record.

h) **Work Inspectors:** It shall be appropriate to effectively involve Work Inspectors both on construction and quality control of works. It is agreed with GOAP that through deployment, adequate number of Work Inspectors' shall be shifted to minor irrigation schemes. It will be good if for every tank there is one Work Inspector.

i) **Mobile Testing Laboratory System:** Laboratory system forms a very important link of the project organization for quality control / quality assurance. It shall be highly expedient and result-oriented if 6 metador vans are procured by GOAP and converted into 'mobile testing laboratories duly equipped with essential testing equipment. Each region shall have two such mobile labs under the respective Superintending Engineers. This shall enable quick on-the-spot testing of inputs and outputs (viz. soils, aggregates, concrete, compaction etc:) and shall help in expediting the job as well.

j) **Technical Consultant:** For ensuring effective construction supervision as well as quality control, it is agreed that 18 technical consultants (say retired superintending engineer/senior executive engineer), one each for 17 districts where the minimum, rehabilitation works are proposed in the tank schemes and one at the state level in the office of the Chief Engineer (Minor Irrigation), having requisite expertise and aptitude be recruited and posted to work during the working season (December to July). The technical consultant shall visit the works in the concerned region and oversee both the construction and quality control aspects of works. He shall also conduct requisite tests with the help of testing equipment available in the mobile laboratory. He shall get any deficiency observed by him duly set right He shall furnish his 'observation and action-taken report' to the concerned S.E./C.E. Towards the end of the working season, the Technical Consultant shall compile a comprehensive report covering maintaining of OK Cards maintaining of embankment register implementation of guidelines and specifications no of various tests conducted and the test result obtained a summary of his field visits to works, his observations and comments and status of their compliance by field engineers and his overall assessment of the quality of work. This report shall also be sent to the Chief Engineer.

k) **Training:** In respect of rehabilitation of works on earthen dams/bunds field tests on classification of soils, proposed to be brought from borrow areas for placement on bunds, are extremely important. In this context, soil experts from APERL, Hyderabad should impart on-job training to Work Inspectors, Assistant Engineers Assistant Executive Engineers, and Deputy Executive Engineers in each district headquarters and at other suitable places:

l) **Workshops & Discussion Sessions:** The respective superintending Engineer of each region should hold workshops and convene discussion sessions: to make WI's, AE's, AEE's, DEE's and EE's fully conversant with the technical specifications guidelines on design and construction and, the OK Card System.
SURPLUS WEIR

TYPICAL REMEDIAL MEASURES FOR HEAVILY LEAKING BODY WALL OF MASONRY WEIR

Existing Weir (Masonry)

Surface to be thoroughly washed as per specifications & is raked to 25 mm depth

Body wall of Concrete M16

18 mm dia. bars - (200 mm spacing both ways)

30 cm (20 cm for small height) + up to 1.5 m

Bed Level

0.6 m

20 cm (16 cm for small height) + up to 1.5 m

Shape to be as original (Shape net to be changed)

Removing top one layer of seating stone and anchoring it (with concrete skin)

Anchors 16 mm dia

Any modifications needed as per site situations and condition of weir be done after due consultation with C.D.O.
CHAPTER - 5
GUIDELINES OF WORLD BANK MISSION ON TECHNICAL SPECIFICATIONS, CONSTRUCTION PROCEDURES AND CRITICAL EQUIPMENT FOR PREPARATION OF COST ESTIMATES FOR REHABILITATION OF MI TANKS.

5.1. INTRODUCTION:

Andhra Pradesh has about 74000 Tanks that together have the capacity to irrigate some 1.5 million hectares of land. 11,277 of M.I scheme tanks, having a command area of 40 hectares or more, have the capacity to irrigate 1.15 million hectares. However, mainly because of deficient maintenance, most of the tanks are functioning at a low efficiency level and, consequently the irrigated area has declined from about 1 million hectares in 1990 to about 0.50 million hectares in 2004. Faced with this grim situation, GOAP has initiated a comprehensive community based tank project with the assistance of World Bank in Minor Irrigation Sector with an objective to improve tank systems and strengthen community management of these selected systems. Comprehensive rehabilitation of about 3,000 Minor Irrigation Schemes throughout the State, based on sound technical and economic principles.

5.1.1. Selection of sample Minor Irrigation Schemes.

Twelve samples schemes have been selected covering the three principal regions of the state spread over in 6 districts. The details of these schemes are appended in Annexure – 1 at Page No. Rehabilitation and modernizing of these sample schemes on a comprehensive basis will help in evolving requisite principles and guidelines for the cost criteria and technical parameters for adoption in the execution of rehabilitation / restoration / modernization works in all the Minor Irrigation Schemes.

5.1.2. Field visits to selected M.I Schemes

The mission made field visits to 11 schemes during the 6 - day period, July 25 to 30, 2006. The project team headed by the Chief Engineer, Minor Irrigation, and two Consultants accompanied the mission. The mission during visit to various works in each scheme interacted with WUAs. The respective field engineers also participated in field visits and discussions. These visits enabled the mission to have a fairly broad assessment of the existing physical condition of the various civil works components including the shutters installed in the irrigation – Sluice structures, and the Regulation Division Dams.

5.2. Broadly, an M.I Scheme comprises of the following components:

a) Tank bund, Sluice structures, waste / surplussing Weir;

b) Irrigation canals and Distribution system; and

c) Feeder Channel.

An Anicut is also a part of an M.I Scheme.

Presently, all these components, by and large, are in a poor state of health and need systematic rehabilitation to the respective designs standards in order to make these fully functional.

5.3. Process involved in Rehabilitation:

The following process is involved to be completed before the rehabilitation works can be undertaken.

5.3.1 (a) Tank Bund Complex:

• In respect of Tank Bund, detailed surveys should be conducted through L – Sections and Cross – Sections to work out the earth fill requirement to bring the respective bund to the specified design sections.
Walk – through survey should be conducted on each tank, to identify the various distress features requiring rehabilitation measures, such as: settlement of revetment, seepage reaches, vulnerable sections, water logged areas downstream of the embankment toe, phenomenon of any retrogression occurring at the waste weir, adequacy of out flow channel D/S of weir and behaviour of out flow channel including evidence of slippages in the channel etc. Inputs from CDO / Dam Safety Panels should form the basis of estimating the various quantities.

5.3.1.(b) Irrigation Canals and Distribution System.

1). Detailed surveys should be done to determine the quantum of re-sectioning and strengthening involved in various channels to bring these to the design standards and the quantities of earth work estimated.

2). In respect of the unlined channels which are proposed to be lined, hydraulic designs should be prepared to fix the requisite parameters. Based there-on, the quantities of earthwork and lining be estimated.

3). Type Designs of New Structures proposed to be constructed should be ready for estimation of various quantities involved.

5.3.1.(c) Feeder Channels

Detailed survey be carried out through L – Sections and X – Sections, based on which the estimation of re-sectioning / strengthening of these channels can be made. Any vulnerable locations needing protection through construction of side guide walls be also identified.

5.3.2 Cost Estimation of Rehabilitation of MIS Schemes

The execution of rehabilitation works should be in accordance with technical specifications conforming to acceptable standards / relevant Indian Standards and sound construction procedures as well as deployment of proper construction equipment. Broad guidelines on these aspects are outlined below.


5.3.3.1. Strengthening of Tanks Bunds

Cost Estimates should be based on the following provisions:-

(a) Complete removal of Jungle growth, bushes, roots, and vegetation growth from the upstream and downstream slopes.

(b) Proper benching of the existing slope and stripping of the bank proposed to be strengthened for effective bonding of the fresh soil placement with old embankment and mechanized compaction there – of. Dimensioning of benches (30 cm x 30 cm or 45 cm x 45 cm or more) will be governed by the type of compaction equipment to be deployed.

(c) During earth fill placement in layers, extra width of 30 cm or more is to be laid to ensure full compaction of designed section. Provision of this extra earth fill, and its later trimming to the designed slope, and its re – use is to be made in the cost estimate.

(d) Compaction of earth fill placement in layers to 95 % Proctor density.

Compaction of earth fill is of paramount importance and is the key requirement. No compromise is to be made on this requirement.

5.3.3.2 Compaction Equipment:

It may be 8 – 10 standard Power Roller or 1 meter wide vibratory power roller or any short drum width vibratory power roller or fuel – operated vibratory plate compactor,
depending upon the width available for compaction. (Photo copies of compaction equipment are enclosed for illustration) (Pages 73-79)

5.3.4. Designs of Upstream and Downstream Slopes and Top Width of Bund.
These should conform to Indian Standard, IS: 12169 – 1987 (General Guidelines for Embankment Sections). Copy of Table 1 of this Standard is enclosed (Page No. 67). A minimum 3.0 m top width of bund is envisaged.

5.3.5. Borrow Areas:
The earth 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 tank bunds. Cost of “Classification tests” and any other tests be included in the estimates, as warranted.

Note:- In case, determination of Maximum Dry Bulk Density (MDBD) and Optimum Moisture Content (OMC) is not sometimes easily feasible, these values may be assumed as outlined in Table 2 of Indian standard, IS : 12169 – 1987 (copy enclosed) (Page No. 68) for assessing the compaction efficiency of the compacted earth fill layers.

Raising and strengthening of Tank Bund to the Designed Section is illustrated in the enclosed Sketch 1 for proper understanding of the field engineers. (Page No. 69)

5.3.6. Stone Revetment Rip – Rap on upstream slope of Tank Bund.

In order that the stone revetment remains stable, durable, and functional the following guidelines / requirements are to be implemented and provided for in the cost estimates.

1) The sub-grade / slope on which stones are to be laid is to be well consolidated. Under no circumstances, the stones are to be placed on a loose sub-grade, as else, the revetment would settle and slip.
2) The quality and size of stones should conform to the specifications. Thickness of stone revetment is to be preferably 300 mm.
3) Filter of 150 mm to 300 mm thickness is to be provided on the consolidated sub-grade prior to the placement of stones by hand. For Bunds of height up to 5.0 m, the filter to comprise of 75 mm sand and 75 mm stone jelly (natural / crushed aggregate of 10 mm to 20 mm size). For Bunds of height from 5.0 m to 10.0 m, the filter thickness of 200 mm to comprise of 100 mm sand and 100 mm stone jelly. For Bunds of height more than 10.0 m, 300 mm thick filter (150 mm sand layer and 150 mm stone jelly layer) be used.
4) Purpose of provision of filter is to prevent the possible loss of soil particles from the sub-grade. If soil loss occurs, it would cause slippage of stones. Moistening and consolidation of filter, prior to placement of stone revetment, is an essential requirement.
5) Provision should be made in the cost estimate for adequately moistening and consolidating the filter prior to the placement of stones. Consolidation can be accomplished through the deployment of vibratory plate earth rammer. Alternatively, a very convenient and effective method of compaction is to use the thick stems of the coconut tree. Three or four persons can go on consolidating the filter layers (duly moistened with water) on slope with the thick stems. The process of hand placement of stones, commencing from the bottom, should then be taken up.

Photo copy of a thick stem to be used for consolidation of filter is enclosed for illustration. (Page No. 76)

6) A toe protection is to be invariably provided in the form of a key trench / toe wall to prevent the sliding of the revetment. The key trench be excavated to a depth of at least
1.5 times the thickness of revetment. Width of this trench is to be 2 times the thickness of revetment. The stones are to be placed in the key trench and firmly bedded into the slope and adjoining stones.

7) Provision should also be made for proper anchorage of revetment into the sub-grade both at the commencement of revetment and at the location, where it ends, by providing “keys” (60 cm x 60 cm) into the slope and embedding stones there in.

8) Masonry Model Sections (say, ± 30 cm x 60 cm or of any other dimension) be provided at specified intervals. 50 m interval may be quite adequate.

9) Provision for placement of stone revetment up to the TBL should be made.

Provision of key trench, toe-wall, and anchorage are depicted in the enclosed Sketch 2 for illustration. (Page No. 70)

5.3.7. Re-Sectioning & Strengthening of Canal Sections.

Presently, almost all irrigation channels are in bad shape. The channels have lost their design profiles, banks have eroded, beds are silted, and channel sections have widened in several reaches. Following Action Points are to be implemented and requisite provisions made in the cost estimates:

1) Jungle growth in the channel prism be removed. Detailed surveys be carried out; L – sections and Cross – Sections be plotted; and the quantum of earth work needed for re-sectioning & strengthening of channel sections to bring these to the designed profiles determined. This is an essential step. Detailed Surveys have still to be undertaken by the field engineers.

2) For re-sectioning / raising / strengthening of existing earthen channel sections, provision is to be made for benching the slopes in suitable steps, earth fill placement in layers, watering, and mechanized compaction with appropriate compaction equipment (Viz 8 – 10 T Power Roller, 1 m wide Power Roller, or Fuel – Operated Vibratory Plate Compactors) depending upon the site situation and availability of space.

3) In case of non-cohesive soils, the layers are to be compacted to 65 % Relative Density. Compaction of earthwork is of paramount importance

4) Provision for regarding the channel banks be made and a cross slope, say 1: 80, provided towards the rear side.

5) In Small Section Channels, provision for “cut & fill method” may be made in order to achieve effective compaction, as is outlined below. “The channel section is excavated, say, in 500 m long reach; earth fill is placed in layers in the full section, watered (as required), and each layer compacted to 95 % Proctor Density through deployment of 8 – 10 ton Power Roller, vibratory Power Roller / 1 m wide drum Vibratory Power Roller. This process of compaction is continued right up to the top of designed section. There – after, the compacted section is scooped out to the proposed designed section and the scooped earth re-handled for use in the next reach taking into account some wastage during re-handling.

6) Where CC lining is to be laid in the channels passing through the swelling black cotton soils, provision for CNS treatment of the sub-grade is to be made prior to placement of lining as per Indian Standard IS 9451: 1994. Thickness of CNS material is to be in accordance with the following tables.

5.3.7.1 Table 1A: Thickness of CNS layer in canals carrying less than 2 Cumecs (70 Cusecs)

<table>
<thead>
<tr>
<th>Discharge Cumecs (Cusecs)</th>
<th>Thickness of CNS layer in Centimeters (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Swelling pressure of BC Soils (50 – 150) KN/m²</td>
</tr>
<tr>
<td>1.4 – 2.0 (50 – 70)</td>
<td>60 cm</td>
</tr>
</tbody>
</table>
5.3.7.2 Table 1B: Thickness of CNS layer in canals carrying more than 2 Cumecs (70 Cusecs)

<table>
<thead>
<tr>
<th>Swelling pressure of BC Soils $\frac{KN}{m^2}$</th>
<th>Thickness of CNS layer in Centimeters (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7 – 1.4 (25 – 50)</td>
<td>60 cm</td>
</tr>
<tr>
<td>0.3 – 0.7 (10 – 25)</td>
<td>50 cm</td>
</tr>
<tr>
<td>0.03 – 0.3 (1 – 10)</td>
<td>40 cm</td>
</tr>
</tbody>
</table>

The CNS soils have to be non-swelling with a maximum allowable swelling pressure of $10 \frac{KN}{m^2} \ (0.10 \frac{Kg}{CM^2})$ when tested in accordance with Indian Standard, IS : 2720 (Part 41) – 1977.

**CNS soils are to broadly conform to the following range:**

- Clay = 15 – 20 %
- Silt = 30 – 40 %
- Sand = 30 - 40 %
- Gravel (of size greater than 2mm) = 0 – 10 %
- Liquid Limit = More than 30 % but less than 50 %
- Plasticity Index = More than 15 % but less than 30 %

**Note:** In order to assess the extent of provision of CNS in the cost estimates for the treatment of sub-grade in swelling BC soils, it is essential to determine the swelling pressure. Accordingly, a “crash program” needs to be launched for getting the representative soil samples tested for their swelling pressure from the soil testing laboratories.

*Cost estimates can be firmed up only if the “Swelling Pressures” are got determined and borrow areas for obtaining CNS soil are identified.*

(i) Provision for mechanized compaction of CNS soil layers to at least 95 % proctor Density, though 98 % would be preferable is to be made in the cost estimates.

5.3.8. Model Sections in Unlined channels:

In the irrigation channels proposed to be left Un-lined, “model sections” of either stone masonry or concrete (± 30 cm x 30 cm) should be provided at intervals of say, 50 m, and at closer spacing in curved reaches. (The spacing be decided in consultation with the Chief Engineer).

5.3.9 Excavation of Tank Bund for Reconstruction of Irrigation Sluices:

When any irrigation sluice is to be re-constructed, portion of earthen embankment on either side of the sluice is required to be removed right up to the bottom of the sluice / sluice barrel. Provision should be made in the cost estimate for excavating the existing embankment to a slope of at least 3 (H): 1 (V) on either side of the sluice, benching of the excavated slope; and finally compaction of earth fill placed in layers to specified density after the new sluice is constructed. Effective bonding of new earth fill with the previous one is of paramount importance.
5.3.10. Canal Lining.

5.3.11. Design of Cement Concrete Lining:

The lining is to be cast – in situ un-reinforced cement concrete lining. Thickness of lining may conform to either the Indian Standard, IS 3873 – 1993 or as per the US Bureau of Reclamation practice, tabulated below.

5.3.12. Thickness of Un-reinforced concrete lining

a) As per US Bureau of Reclamation Standard / Practice.

<table>
<thead>
<tr>
<th>Discharge in cusecs</th>
<th>Thickness of lining (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 500 Cusecs</td>
<td>2 ½ inches</td>
</tr>
<tr>
<td>500 – 1500 Cusecs</td>
<td>3 inches</td>
</tr>
<tr>
<td>1500 – 3500 Cusecs</td>
<td>3 ½ inches</td>
</tr>
<tr>
<td>3500 – 7500 Cusecs</td>
<td>4 inches</td>
</tr>
<tr>
<td>7500 – 20,000 Cusecs</td>
<td>4 ½ inches</td>
</tr>
</tbody>
</table>

b) As per Indian Standard IS 3873: 1993.

<table>
<thead>
<tr>
<th>Discharge capacity Cumeecs (Cusecs)</th>
<th>Depth of water (m)</th>
<th>Thickness of lining (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 5 (0 – 175)</td>
<td>0 – 1 m</td>
<td>50 – 60 mm</td>
</tr>
<tr>
<td>5 – 50 (175 – 1750)</td>
<td>1 – 2.5 m</td>
<td>60 – 75 mm</td>
</tr>
<tr>
<td>50 – 200 (1750 – 7000)</td>
<td>2.5 – 4.5 m</td>
<td>75 – 100 mm</td>
</tr>
<tr>
<td>200 – 300 (700 – 1050)</td>
<td>4.5 – 6.5 m</td>
<td>90 – 100 mm</td>
</tr>
<tr>
<td>300 – 700 (10500 – 24500)</td>
<td>6.5 – 9.0 m</td>
<td>120 – 150 mm</td>
</tr>
</tbody>
</table>

Taking into consideration the various factors including economy and ease / practicality of placement, it may be appropriate to adopt a lining thickness of 70 mm for channels of discharging capacity up to 175 cusecs and 75 mm for discharge beyond 175 cusecs to 1500 cusecs.

5.3.13 (i) Cement:

43 Grade or 53 Grade Ordinary Portland Cement conforming respectively to Indian Standard, IS 8112 and IS 12269 is to be used.

(ii) 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, provisions of a minimum cement level of 250 kg / m3 of concrete mix be made in the cost estimate of CC lining from “durability consideration”. Water Cement ratio is to be restricted to not exceed the range, 0.55 – 0.60.

(iii) Maximum size of Coarse Aggregate:

Graded coarse aggregate with maximum nominal size (MSA) of 20 mm, down graded to IS grading is to be used in the concrete mix for 70 mm – 75 mm thick CC lining.

(iv) Air Entraining Agent (AEA)

Provision for using AEA in the concrete mix for CC lining, be made in the cost estimate. Concrete mix with AEA affords more “durability”, as well as better “workability (viz. fluidity)” and better “finish”.

60
Graded fine and coarse aggregate 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 adding AEA.

v) **Contraction Joints**:

As a thumb rule, the spacing of both the longitudinal and transverse contraction joints should not normally exceed 36 times thickness of lining to avoid cracking of the lining surface in between the joints.

<table>
<thead>
<tr>
<th>Lining thickness (t)</th>
<th>Spacing of joints (36 x t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 mm</td>
<td>2520 mm, say 2.5 m</td>
</tr>
<tr>
<td>75 mm</td>
<td>2700 mm, or 2.7 m</td>
</tr>
<tr>
<td>100 mm</td>
<td>3.60 m, better to keep 3.0 m spacing</td>
</tr>
</tbody>
</table>

If the perimeter of canal section is less than 6.0 m, no longitudinal contraction joints are to be provided. However, transverse contraction joints across the canal section are to be provided irrespective of the extent of perimeter.

vii) **Consolidation of concrete**:

Proper consolidation of concrete mix for CC lining, as being placed, is of paramount importance. One of the most effective methods comprises of deploying a “vibratory plate device”, operated by a fuel – operated motor. This mechanism is depicted in the enclosed photocopies for comprehensive understanding and broad guidance of the field engineers. Such a device can also be used for compaction of the sub-grade of small section channels. In clause 4.5 B(a) Section 1 of the Bid Document, incorporation of such an equipment in the list of key / critical equipment would be needed.

viii) **Cutting Grooves for Contraction Joints**.

Grooves should be cut to the specified size when the concrete is still plastic. At the time of filling of the grooves with the sealing compound, these should be thoroughly cleaned of all dirt, mortar, or any set grout.

ix) **Curing of lining**.

Curing is the most vital requirement in the cement concrete lining. Any slackness in curing or in adequate curing shall weaken the lining and cause its early deterioration / cracking. **Fool – Proof curing is a MUST.** In case adequate water – curing of both the bed and side lining is assured, it is ideal. Alternatively, provision should be made for curing of bed lining by water (though construction of small height earthen bunds and ponding water) and the curing of side CC lining by application of “membrane – forming curing compound” to ensure fool – proof curing.

The curing compound should be white pigmented of approved quality conforming to ASTM – C – 309 – 81 Type – 2. This should meet the requirement of water retention test as per ASTM designation C – 158 – 80. Loss of water in this test is to be restricted to not more than 0.55 Kg / M² of exposed surface in 72 hours.

5.3.14. **Application of Curing Compound**

Curing compound is to be applied as soon as the bleeding water or shine on the concrete surface disappears, leaving dull appearance. This is when there is no longer
free moisture on the surface. If applied too early, the free moisture will prevent the compound from forming a moisture-proof film. If applied too late, some of the moisture will have already been lost that should have been retained. The proper time range will vary from about 30 minutes to 2 hours after placement of lining depending upon humidity and temperature. Uniform coverage of curing compound is very important. A good skill is needed when it is to be hand sprayed with a nozzle. The dosage of curing compound, sprayed on the lining surface with a nozzle, is 1 litre for about 3.75 M² of surface area of lining.

**Note:** The sub-grade on which lining is to be placed must be well consolidated, hard, and smooth. Any surface irregularities should be within the tolerance limits (Viz. not more than 6.5 mm on slopes and 12.5 mm on bed).

### 5.3.15. Selective Protective Lining immediately U/S & D/S of Canal Structures:

Cement concrete lining or Stone masonry lining be provided in at least 2.5 m reach upstream and downstream of structures.

**Note:** Particular attention need to be paid to the canal system in such reaches / locations when drainage water falls into the canal. Detailed survey should be carried out and inputs be obtained from CDO as to the types (and designs there-of structure to be provided for the disposal of drainage. Allowing any haphazard flow of drainage into the canal / canals severely damages the canal system.

### 5.3.16. Treatment of Under Side RCC Slabs of Structures:

The mission during field visit to an RCC. Aqueduct at Km 6.2 of Valagalamanda Main Canal observed large scale spalling / cracking of under side concrete and consequently exposure of reinforcement. “Shot Creting” shall provide a convenient and effective method for addressing such deterioration on the undersides of all R.C.C structures.

### 5.3.17. The cost estimate of shot creting can be based on the following guidelines.

**Shot - Creting**

(i) **Specifications & Procedure of Application.**

**a) Materials for Shot creting :**

Cement, sand, coarse aggregate, water and admixtures are used in the shot – crete mix. Ordinary Portland Cement, 43 Grade or 53 Grade will be used.

**b) Sand:** Well graded sand as per either of the following grading can be used.

### SAND

<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Percentage by mass passing for Grading - I</th>
<th>Percentage by mass passing for Grading - II</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mm</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>90 – 100</td>
<td>90 – 100</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>75 – 100</td>
<td>85 – 100</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>55 – 90</td>
<td>75 – 100</td>
</tr>
<tr>
<td>600 micron</td>
<td>35 – 59</td>
<td>60 – 79</td>
</tr>
<tr>
<td>300 micron</td>
<td>8 – 30</td>
<td>12 – 40</td>
</tr>
<tr>
<td>150 micron</td>
<td>0 - 10</td>
<td>0 - 10</td>
</tr>
</tbody>
</table>

Sand should be free from deleterious substances and organic impurities.
c) **Coarse Aggregate:**

The maximum size of coarse aggregate should be restricted to 10 mm. It should be free from impurities, clay / shale particles, and conform to the requirements of impact, abrasion, and crushing criteria (viz less than 45 %) and the soundness acceptance criteria (less than 12 % with sodium sulphate method). It should have a specific gravity of not less than 2.6. The aggregate should be well graded and should broadly conform to the following grading.

<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Percentage by mass passing for aggregate of 10 mm maxm. Size.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 mm</td>
<td>100</td>
</tr>
<tr>
<td>10 mm</td>
<td>85 – 100</td>
</tr>
<tr>
<td>4.75 mm</td>
<td>10 – 30</td>
</tr>
<tr>
<td>2.36 mm</td>
<td>0 – 10</td>
</tr>
<tr>
<td>1.18 mm</td>
<td>0 – 5</td>
</tr>
</tbody>
</table>

d) **Water:** Ordinary potable water with pH value not less than 6 and not more than 8.5 will be used.

e) **Chemical Additives:**

The following additives be used in the concrete mix in the ‘Dry Mix Process’ of shot creting.

- Sodium Carbonate = ½ Kg per 50 Kg bag of cement
- Sodium Aluminate = ½ Kg per 50 Kg bag of cement
- Calcium Carbonate = 1 Kg per 50 Kg bag of cement

Total = 2 Kg per 50 Kg bag of cement viz 4% by weight of Cement

Alternatively, following additives can be used:

- Super plasticizer @ 1% by weight of cement viz 4.5 Kg of super plasticizer for 450 Kg cement to be used in the mix.
- Accelerator (say sodium Silicate) @ 5% by weight of cement Viz. 22.5 Kg for 450 Kg cement to be used in the mix.

f) **Air Supply:**

Properly operating air compressor is essential for a satisfactory shot creating operation. The compressor should be fitted with a moisture extractor to deliver clean and dry air. For hose length of up to 30 m, air pressure at the nozzle should be 0.3 N / mm² or more.

g) **Water supply:**

The water pressure at the discharge nozzle should be sufficiently greater than the operating air pressure to ensure that the water is intimately mixed with the other material.

Properly applied Shot Crete is a structurally adequate and durable material capable of excellent bond with concrete as well as masonry.

h) **Shot –Crete Mix:**

The water – cement ratio should be maintained within the range of 0.40 to 0.50 by mass. The mix should have a 28 day characteristic compressive strength of not less than 200 Kg / cm² though strength of 250 kg / cm² would be preferable. Normally the following mix proportions would be adequate.

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>450 kg / m³</td>
</tr>
<tr>
<td>Sand</td>
<td>1100 kg / m³ (0.70 m³)</td>
</tr>
</tbody>
</table>
Coarse aggregate (5 mm – 10 mm size) = 500 Kg/M³ (0.30 M³)
Proportioning of mix = 1:2.44:1.11

5.3.17. Application of Shot Crete: Following guidelines and sequence will be followed:

1) All unsound and deteriorated concrete be removed and chipping done, wherever necessary, or sand blasting done.
2) Exposed reinforcement bars be cleaned free of rust / scales. Additional reinforcement be provided if and as warranted.
3) Ensure sufficient clearance around the reinforcement to permit complete encasement with sound shotcrete. A clearance of at least 50 mm should be provided.
4) Air – water jet be applied for final clean – up of the surface. Spray pneumatically the first layer of shotcrete of about 38 mm thickness (hollow pockets) will consume more shotcrete).
5) Next “Welded wire mesh of size 100 mm x 100 mm x 5 mm” be nailed, butting with shotcrete. Binding wire of 20 guage or 24 guage be used for binding of wire mesh panels.
6) The second and final layer of shotcretes of thickness ± 38 mm be than pneumatically sprayed over the first layer. The finished shotcrete surface should be kept continuously wet (viz. cured) for at least 7 days. Alternately, ‘membrane –forming chemical curing compound’ be used for curing. A re-bound of 25 % to 30 % would occur and the re-bounded material is not to be re-used in the shotcrete mix.

5.3.18. Quality Control of Shot - Creting

The shot creting operation should be continuously inspected by the engineers who should check the materials, concrete mix, shot creting equipment, application of shotcrete, and curing. The finished surface should be sounded with a hammer for detection of any hollow pockets due to lack of bond. Such hollow pockets or other defects are required to be carefully cut out and replaced with the new shotcrete layer. The first layer is also to be sounded with a hammer and remedial action taken for any hollow pockets before commencing the application of the final layer.


Presently, there is no measuring structure on any of the canal distribution network. The existing sluice structures are not calibrated to indicate the quantum of flow in the off-taking channels. Neither there is any measuring device downstream of the Regulating Division Dams.

 Provision of CTF (Cut – Threat Flumes) in fibre glass reinforced plastic (FRP) material with “hold fasts” to be embedded in the concrete structures should be made in the cost estimates. Such a flume has engraved gauge marking in centimeters as well as in litres per second.

A large number of CTFs have been constructed in the SRBC distribution system of AP III project. Designs / Drawings and data on cost estimates be obtained from SRBC engineers.

A measuring structure be provided at off takes of distributaries from the main canal / branch canal and minors from the distributory.

b. Feeder Channels :

The mission observed one “Feeder Channel”, off – taking from the surplus weir of Sadasive kona project. This channel is in a poor shape. It is associated with extensive Jungle growth, silting, and widening of banks at several locations.
In all such types of feeder channels, re-sectioning and strengthening works be carried out, and masonry walls provided wherever necessary.

c. Reinforced concrete:

In all reinforced concrete structures, the minimum grade of concrete to be used should not be less than M 20. This is irrespective of the grade of cement used as per Indian Standard, IS 456: 2000.

d. Gabion Structures.

Construction of “gabion structure” proves very effective in earth control, and soil conservation. Gabions can be very usefully used in stream training works and for controlling erosion of earth. Where the outflow channel downstream of a weir poses a serous problem of slippages of earth, gabion retaining wall provides a practical solution to control such slippages.

Specifications:

**ASTM Designation:** A 975 – 97 outlines the standard specifications of “double twisted hexagonal mesh gabions”. Particulars about the mesh type and wire diameter of Zinc Coated gabions are given in Sketch 3. (Page 76).

**Definition of Gabion:**

It is a double twisted Zinc coated wire mesh container of variable sizes, uniformly partitioned into internal cells or diaphragms, inter – connected with other similar units, and filled with stones at the work site to form “flexible, permeable, monolithic structures such as retaining walls, revetments etc.,. The gabion shall be fabricated “Maccaferri” type or equivalent supplied by an approved / reputed manufacturer.

The stones used should have a minimum size of not less than the mesh width, as shown in Sketch 3. D is the distance between the axes of the twists.

**Important Points in Gabion Works**

a) Stones to be used shall be of good quality viz hard & free from soft seams or of any disintegration features.
b) Stone size shall range from about 200 mm to 300 mm. Stone size of 350 mm shall be preferable.
c) Use of small stones shall be restricted to the maximum feasible extent of fill the voids between bigger stones. Such small stones shall have a minimum size of not less than D, where D is the specified mesh width.
d) The Gabions and Mattresses shall be flexible galvanized gabions with the mesh panel wire of 3.0 mm dia, and shall be Maccaferri type or equivalent, and shall be procured from reputed agencies.
e) Foundation for each Gabion shall be free from depressions and protrusions. Any depressions are to be filled with suitable soil / gravel, moistened and consolidated. The protrusions are to be struck and leveled. Tolerance for surface irregularities shall not exceed ± 6.25 cm.
f) The Gabions shall be divided into cells by diaphragms, whose length shall not be more than the width of the gabions. Diaphragms shall be provided at not more than 1.0 m interval.
g) Where more than one layer of Gabions is to be laid, these be placed with a minimum step of 0.15 m between the faces of the lower and upper Gabions Boxes. In high walls, a step of 0.50 M shall be appropriate.

h) All Gabions shall be connected to each other along corners with – Lacing, the wire to be passed through each mesh making a double twist every other mesh.

i) Careful attention shall be given to the filling operation to ensure that the stones are placed evenly in the baskets with minimum voids in between. Smaller stones shall be hammer wedged into the voids. All external stones shall be of big size, preferably of 200 mm – 300 mm size range.

j) The stone to be used for the top layer of Gabion Boxes shall have a flat surface to ensure that the wire does not rest on sharp corners of stone if these are not flat.

k) Bracing wires shall be used as per Manufacturer’s instructions in the Brochure.

l) A Gabian shall not be completely filled until the adjacent basket has been half filled in order not to cause displacements / bulging during filling.

m) Before filling, adjacent baskets shall be secured together with steel lacing wire, duly galvanised.

n) Gabion walls shall have a vertical face, not exactly Vertical, but shall be given a slight angle to the vertical (Say 1.0 horizontal to 10.0 Vertical). This shall be achieved by sloping the foundation accordingly. This shall take care of the effect of back-fill pressure & also of the settlement / consolidation of the foundation.

(Construction of a Typical 8.0 m high Gabion Wall is illustrated in Sketch) (Page 77).

e. Dam Safety and Logistic Support from CDO & Dam Safety Panels.

The mission visited the earthen embankment of Tank bund of Vengalaraya Sagar M.I Scheme. It is of 11 m maximum height and suffers distress features including seepages emerging at downstream toe, causing water – logging in about 400 m reach. The toe – drain is full of jungle growth and provision of any rock – toe could not be ascertained. The top width is also short of the originally designed 2.4 m width. Both the slopes are covered with a thick jungle growth. Stone revetment is disturbed at some locations. The field engineer reported breaching of a portion of embankment on left flank in 1978 and another breaching on right flank, in 1983.

The mission strongly feels that technical inputs from CDO are needed for rehabilitation of this bund, based on which the cost estimate can be finalized. Like–wise, there may be large number of tank bunds of ± 10 m height and some tanks even higher than 10 m and in the range of 10 m – 15 m, which may be suffering from one sort of distress or the other. Logistic support from CDO will continue to be needed for such bunds for an effective rehabilitation in a systematic manner. Also, it shall be expedient and result – oriented if GOAP constitutes a “Dam Safety Panel” for each of the three regions to inspect such earthen bunds (also anicuts and weirs) and guide the project engineers on the specific measures to be taken for the implementation of rehabilitation measures of these dams and the appurtenant works.
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Description</th>
<th>Height Up To 5 m</th>
<th>Height Above 5 m And Up To 10 m</th>
<th>Height Above 10 m And Upto 15 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>Type of section</td>
<td>Homogeneous section/Modified homogeneous section</td>
<td>Zones section/Modified homogeneous section</td>
<td>Zoned section/Modified homogeneous section</td>
</tr>
<tr>
<td>ii)</td>
<td>Slopes</td>
<td>Up stream</td>
<td>Downstream</td>
<td>Up stream</td>
</tr>
<tr>
<td>a)</td>
<td>Coarse grained soil (GW, GP, SW, SP)</td>
<td>Not suitable</td>
<td>--</td>
<td>Not suitable</td>
</tr>
<tr>
<td>b)</td>
<td>Coarse grained soil (GC, GM, SC, SM)</td>
<td>(H) (V)</td>
<td>(H) (V)</td>
<td>(H) (V)</td>
</tr>
<tr>
<td>c)</td>
<td>Fine grained soil (CL, ML, CL, MI)</td>
<td>(H) (V)</td>
<td>(H) (V)</td>
<td>(H) (V)</td>
</tr>
<tr>
<td>d)</td>
<td>Fine grained soil (CH, MH)</td>
<td>(H) (V)</td>
<td>(H) (V)</td>
<td>(H) (V)</td>
</tr>
<tr>
<td>iii)</td>
<td>Heaving zone</td>
<td>Not required</td>
<td>--</td>
<td>May be provided</td>
</tr>
<tr>
<td>a)</td>
<td>Top width</td>
<td>--</td>
<td>--</td>
<td>3 m</td>
</tr>
<tr>
<td>b)</td>
<td>Top level</td>
<td>--</td>
<td>--</td>
<td>0.5 m above MWL</td>
</tr>
<tr>
<td>iv)</td>
<td>Rock toe height</td>
<td>Not necessary pto 3 m. Above 3 m height, 1 m height of rock toe may be provided</td>
<td>Necessary</td>
<td>H/5, where H is the height of embankment</td>
</tr>
<tr>
<td>v)</td>
<td>Berms</td>
<td>Not necessary</td>
<td>--</td>
<td>Not necessary</td>
</tr>
</tbody>
</table>

Notation:
- More than
- Less than
### Table 2: Average Properties for Different Types of Soils

**(Clause 5.1.2.3)**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Engineering Classification of Soil (See IS: 1498 - 1970*)</th>
<th>Average Properties of Soil</th>
<th>Soil Constants for Recommended Slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MDD kg/m³</td>
<td>OMC percent</td>
</tr>
<tr>
<td>i)</td>
<td>GC</td>
<td>&gt; 1840</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>ii)</td>
<td>GM</td>
<td>&gt; 1830</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>iii)</td>
<td>SM</td>
<td>1830 ± 16</td>
<td>15 ± 0.4</td>
</tr>
<tr>
<td>iv)</td>
<td>SC</td>
<td>1840 ± 16</td>
<td>15 ± 0.4</td>
</tr>
<tr>
<td>v)</td>
<td>ML</td>
<td>1650 ± 16</td>
<td>19 ± 0.7</td>
</tr>
<tr>
<td>vi)</td>
<td>CL</td>
<td>1730 ± 16</td>
<td>17 ± 0.03</td>
</tr>
<tr>
<td>vii)</td>
<td>CH</td>
<td>1510 ± 32</td>
<td>25 ± 1.2</td>
</tr>
<tr>
<td>viii)</td>
<td>MH</td>
<td>1310 ± 64</td>
<td>36 ± 3.2</td>
</tr>
</tbody>
</table>

* Classification and identification of soils for general engineering purposes *(first revision).*
SKETCH - 1  Raising and Strengthening of Existing Earthen Embankment / Bund

Raised section of Embankment/ Bund to conform to Original designed TBL

Earthfill laid in layers and compacted to 95% density

Existing Embankment /Bund

Proposed strengthened section

Extra width (±10 cm) compacted and then trimmed to ensure full compaction of proposed section

Benching in steps 30 cm X 30 cm
### Zinc – Coated Gabions

<table>
<thead>
<tr>
<th>Mesh type</th>
<th>Wire diameter (mm)</th>
<th>Thickness (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 × 12</td>
<td>2.70</td>
<td>3.00</td>
</tr>
<tr>
<td>8 × 10</td>
<td>2.70</td>
<td>3.00</td>
</tr>
<tr>
<td>6 × 8</td>
<td>2.20</td>
<td>2.70</td>
</tr>
<tr>
<td>5 × 7</td>
<td>2.00</td>
<td>2.40</td>
</tr>
</tbody>
</table>

Lacing wire and selredge wire diameters will depend upon the mesh opening.
CONSTRUCTION OF GABION WALL

Slight angle, 10 V: 1 H

8.0M high Gabion wall

Earth Backfill (Well consolidated)

Stream

Stream Bed

0.5M thick Gabion mattress

Sloping the foundation slightly so that vertical face makes a slight angle.

Details of Gabion Wall (Placement of Gabion)

Slight angle 10 V: 1 H

Gabions

All off-sets of 0.5 m

0.5 m

Gabion Below foundation

wiz +/- 0.7 H
ONE METRE WIDE VIBRATORY ROLLER
BEING USED FOR EARTHFILL COMPACTION
Portable Fuel Operated Compactor for Subgrade Compaction
Thick Leaf of a Date Palm Tree
(for manual consolidation of slopes/filter layers on slopes)
1 H.P ENGINE (PETROL/KEROSENE DRIVEN)

FUEL-OPERATED PLATE VIBRATOR FOR
CONSOLIDATION OF CC LINING ON CANAL SLOPE
FUEL-OPERATED PLATE VIBRATOR FOR
CONSOLIDATION OF CC LINING ON CANAL SLOPE
U/S VIEW OF 8 CUSECS F.R.P. CUT THROAT FLUME FOR 2L MINOR OF
BLOCK NO.VII OF S.R.B.C