Government of West Bengal
Irrigation & Waterways Department
Jalasampad Bhavan, 3rd Floor, Salt Lake City, Kolkata 700091,
Ph & Fax-033-23215211, Email- ds-works@wbiwd.gov.in

**Memo No.** 145(8)-IB **Dated: 19.06.2017**
**IW/O/IB-Misc-14/2011(Pt-III)**

**From: Biplab Mukherjee**
Deputy Secretary to the
Government of West Bengal

**To:** **1.** Chief Engineer (South)
Irrigation & Waterways Directorate, 1st floor, Jalasampad Bhavan,
Salt Lake, Kolkata-91

**2.** Chief Engineer (West)
Irrigation & Waterways Directorate, P.O. Sadhanpur (Near Polytechnic)
District-Burdwan, Pin - 713101

**3.** Chief Engineer (South West)
Irrigation & Waterways Directorate
Khusjungle, P.O Abas, District Paschim Medinipur
Pin 721 102

**4.** Director of Personnel & Ex-officio Chief Engineer
Irrigation & Waterways Directorate, 1st floor, Jalasampad Bhavan,
Salt Lake, Kolkata-91

**5.** Chief Engineer (North)
Irrigation & Waterways Directorate,
3rd floor, Netaji More Market Complex, Saraju Prasad Road
Malda, Pin: 732 101.

**6.** Chief Engineer (Design & Research)
Irrigation & Waterways Directorate, 1st floor, Jalasampad Bhavan,
Salt Lake, Kolkata-91

**7.** Chief Engineer (North East)
Irrigation & Waterways Directorate,Club Road, P.O & District Jalpaiguri
Pin 735 101

**8.** Chief Engineer, Teesta Barrage Project
Irrigation & Waterways Directorate
Teesta Sech Bhavan,
2nd Mile, Sevoke Road, Siliguri, Dist : Darjeeling
Pin: 734 001

**Sub:** ***Quality Control manual of Irrigation & Waterways Department***



*Filepath: Quality Control>Quality Control Manual of I&WD*

**Ref:** **1.** Memorandum No. 454-IB/ IW/O/IB-Misc-14/2011(Pt-III) dated 24.03.2017 of Irrigation & Waterways Department.

**2.** Memo No-1Q-1/833 dated 13.06.2017 of THE Director, Central design Office.

With a view to adequately cover the quality check up of all ongoing works as per BIS standards and other established norms, seven independent Quality control units have been set up by the department in march 2017 vide Memorandum under reference -1. The Central Design Office had been entrusted with the assignment of preparation of a Quality control manual for reference by all the 7 Quality control units, who initially submitted a draft vide their memo No- 1M-10/507 dated 06.04.17.

Subsequently the draft has been finalised by the Central Design Office, incorporating suggestions received from different ends and modified manual has been submitted to this department vide Memo under reference-2.

In view of above the undersigned is directed to state that the aforesaid Quality Control Manual is to be followed by the Quality Control units, working divisions to carry out the Quality check-up of the ongoing works in the manner stated in the said manual. Suggestions for modification of this manual, if any, may be communicated to the Director, Central Design Office by 31.07.2017. The Director, River Research Institute will arrange training for staff of Quality Control units. A copy of the Quality Control Manual is enclosed. Soft copy of the same would be made available in the departmental website.

Enclo: as stated

**Biplab Mukherjee**
Deputy Secretary to the
Govt. of West Bengal

**Memo No. 145(8)/1(1)-IB**
**IW/O/IB-Misc-14/2011(Pt-III)** **Dated: 19.06.2017**

Copy forwarded for information to:

1. P.S to Hon'ble Minister-in-Charge, Irrigation & Waterways Department 1st floor, Jalasampad Bhavan, Salt lake, Kolkata- 91

**Biplab Mukherjee**
Deputy Secretary to the
Govt. of West Bengal



*Filepath: Quality Control>Quality Control Manual of I&WD*

**Memo No.** 145(8)/2(2)-IB **Dated: 19.06.2017**
IW/O/IB-Misc-14/2011(Pt-III)

Copy forwarded for information and necessary action to:

1. The Director, River Research Institute,Irrigation & Waterways Department, Haringhata Central Laboratory, P.O – Mohanpur, District – Nadia, Pin code – 741246.

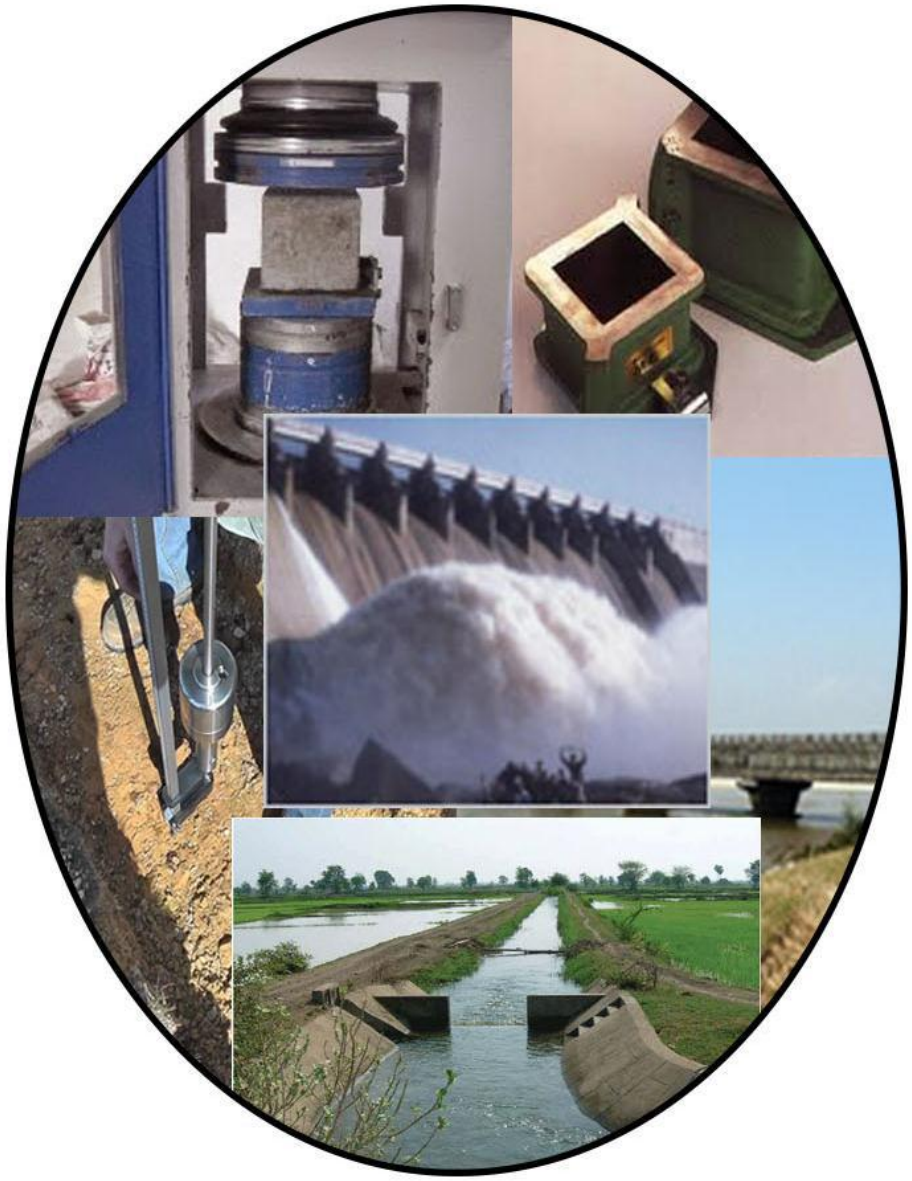
2. Director, Central Design Office, Irrigation & Waterways Directorate, 1st floor, Jalasampad Bhavan, Salt Lake, Kolkata-91.

**Biplab Mukherjee**
Deputy Secretary to the
Govt. of West Bengal

O/C

FOR OFFICIAL USE ONLY

# QUALITY CONTROL MANUAL



**IRRIGATION AND WATERWAYS DIRECTORATE**
**GOVERNMENT OF WEST BENGAL**

# PREFACE

The necessity of manual covering all aspects of Quality Control to be exercised on the construction work for civil Engineers was felt since last many years. Such manual was prepared in the past but were mainly meant to cater the needs of particular projects. To maintain a uniformity regarding quality control of work in the whole state, a quality control manual, to include the instruction, contained in the various technical circulars issued from time to time, material available in IS Code and also in the individual quality control manual of different major projects / river basin has been prepared. This manual has been prepared to provide a uniform guideline for quality control on all projects of Irrigation & Waterways Department of the state.

I am sure that it will serve a practical guide to the construction Engineers and also to the officers/officials entrusted with the quality control work for assisting and ensuring a uniform application of quality control procedure in Irrigation & Waterways Department in West Bengal.

This quality control manual is the outcome of the combined effort of officer and staff of the Irrigation & Waterways Directorate, Government of West Bengal.

Suggestions for improving the utility of the publication will be greatly welcome and appreciated.

Mahendra Pratap Ghosh
(Director of Designs)
Central Design Office
Irrigation & Waterways Directorate
Govt. of West Bengal

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# LIST OF INDIAN STANDARDS

| SL. NO. | SHORT TITLE | IS to various Standards |
|---|---|---|
| (A) | **Cement** | |
| 1 | Specification for 33 grade ordinary Portland cement | IS:269 -1989 |
| 2 | Specification for Rapid-hardening Portland cement | IS:8041 -1990 |
| 3 | Specification for Portland pozzolona cement | IS:1489 (Part 1&2) 1991 |
| 4 | Methods of physical test for hydraulic cement | IS:4031 -1988 |
| 5 | Method of chemical analysis of hydraulic cement | IS:4032 -1985 |
| 6 | Method of sampling for hydraulic cement | IS:3535 -1986 |
| 7 | Standard sand for testing of cement | IS:650 -1991 |
| 8 | Specification for 43 grade ordinary Portland cement | IS:8112 -1989 |
| 9 | Specification for 53 grade ordinary Portland cement | IS:12269-1987 |
| **(B)** | **Coarse / Fine Aggregate** | |
| 1 | Specification for coarse & fine aggregates | IS:383-1970 |
| 2 | Methods of test for aggregates for concrete particle size and shape. | IS:2386 (Part I)-1963 |
| 3 | Methods of test for aggregates for concrete estimation of deleterious materials and organic impurities. | IS:2386 (Part II)-1963 |
| 4 | Methods of test for aggregates for concrete specific gravity, density, voids, absorption & bulking. | IS:2386 (Part III)-1963 |
| 5 | Methods of test for aggregates for concrete Mechanical properties. | IS:2386 (Part IV)-1963 |
| 6 | Methods of test for aggregate for concrete Soundness. | IS:2386 (Part V)- 1963 |
| 7 | Methods of test for aggregate for concrete measuring mortar making properties of fine aggregates. | IS:2386 (Part VI)-1963 |
| 8 | Methods of test for aggregates for concrete alkali aggregate reactivity. | IS:2386 (Part VII)-1963 |
| 9 | Methods of test for aggregates for concrete petrographic examination. | IS:2386 (Part VIII)-1963 |
| **(C)** | **Bricks** | |
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| 2 | Method of tests of burnt-clay building bricks | IS:3495 (Parts 1 to 4)-1992 |
| 3 | Common burnt clay building bricks | IS:1077 -1992 |
| **(D)** | **Masonry Mortar** | |
| 1 | Specification for sand for masonry mortars | IS:2116 -1980 |
| 2 | Code of practice for preparation and use of masonry | IS:2250 -1981 |

| SL. NO. | SHORT TITLE | IS to various Standards |
|---|---|---|
| **(E)** | **Cement Concrete** | |
| 1. | Specification for coarse and fine aggregate | IS:383 - 1970 |
| 2 | Specification for compressive strength, flexural | IS:516 -1959 |
| 3 | Code of practice for plain & reinforced concrete | IS:456 -2000 |
| 4 | Methods of sampling and analysis of concrete | IS:1199 - 1959 |
| 5 | Recommended guide lines for concrete mix design | IS:10262 - 1982 |
| **(F)** | **PVC Water Stops** | |
| 1 | Code of practice for provision of water stops | IS:12200 - 1987 |
| 2 | Procedure for Testing | Parts of IS:8543 |
| 3 | Standard Test methods for Tensile properties of | ASTM: D 638-1991 |
| 4 | Standard Test methods for Thermoplastic | ASTM: D 412-1992 |
| **(G)** | **HYSD Bars** | |
| 1 | Specifications for HYSD bars. | IS:1786 – 1985 |
| 2 | Specification for Mild Steel and Medium Tensile | IS:432 (Part I) -1982 |
| 3 | Method for Tensile testing of steel wires | IS:1521 – 1972 |
| 4 | Hard drawn steel wire for concrete reinforcement | IS:432 (Part II) -1982 |
| 5 | Method for Tensile testing of Steel | IS:1608 – 1995 |
| 6 | Code of practice for bending & fixing of bars for | IS:2502 – 1963 |
| **(H)** | **Precast R.C.C. Pipes** | |
| 1 | Specifications for precast concrete pipes | IS:458 – 1988 |
| 2 | Methods of test for concrete pipes | IS:3597 – 1985 |

# CHAPTER – I

## QUALITY ASSURANCE AND CONTROL

### 1. INTRODUCTION

Evaluation of water resources projects involves enormous expenditure. They are time bound programme and require assistance from various technical bodies for investigation, design, planning and execution. To have a safe durable structure, it is necessary that the materials and standard of execution fully satisfy the specifications. It is to be recognized that the ultimate efficiency of the performance of a project will depend upon proper layout and designs, the ultimate health of the project during life scale of its operational phase will depend largely on the quality achieved during its construction.

Each and every job whether big or howsoever small shall require to be executed to acceptable construction quality duly confirming to sound design principles, specifications and deployment of good methodology or modern technique and procedures. To achieve the requisite objectives, it is essential to introduce a result oriented quality management system.

This system is planned to orient the whole range of quality effort on a continuous basis covering quality assurance and quality control, broadly out lined below including steps initiated for its meticulous implementation.

### 1.1 **Orientation and training of construction supervision/quality control Staff**

A capable and functional construction supervision (CS) and quality control / quality assurance team is needed to ensure implementation of contract specifications. To achieve this objective intensive training will be given to all related staff of construction / quality control in suitable batches covering specifications for the works to be executed and also the procedure to conduct various tests in the field and laboratories. Recommendation of I.S. codes will be explained in the training so as to cover key construction and QC / QA aspects.

### 1.2 **Laboratory system for testing of Input and Outputs**

Looking to the overall quantum of work and the scattered area in different zones, establishment of laboratories at different levels and places forms an important link of project organisation for quality control. The system is required to provide reliable and accurate testing support to fulfil the objectives. Accuracy and reliability in testing will depend upon the competence of testing personal, accuracy of apparatus, quality of reagents used, and maintenance of requisite environmental conditions. Introduction of "Zonal testing laboratory system" will prove to be highly result-oriented. This can be supplemented by adequate nos. of site labs, field laboratories.

## 2. OBJECTIVES AND SCOPE OF QUALITY CONTROL

The objective of quality control management is to collect, process and then communicate the data related to the quality of inputs and outputs as well as finished item of work to those who are responsible for the quality. Any programme of quality control seeks to ensure adequacy and uniformity of quality through the following operations.

1. To ensure that the works are being executed in conformity with the prescribed specification.

2. Inspection of storage, handling and processing facilities for all materials in conformity with accepted or specified practice.

3. Monitoring the variation in specification of the materials and quantities used in the operation of production and in the final product by suitable observation, measurements or tests.

4. In order to achieve the common goal – Construction quality in the execution of project, the roles and responsibility matrix, as depicted in **Annexure-I** shall be broadly followed by:

    i. Government of West Bengal
    ii. Executing Agency
    iii. Project Construction Team
    iv. Project QC/QA Team
    v. Project Design Team

5. Analysis of the observed variations by statistical or other techniques.

6. Feed-back of the results of analysis for exercise of control at each stage and to take corrective steps for maintaining the variations within specified limits.

7. Indicating expeditiously the possible remedial measures, wherever warranted to ensure execution of works as per drawings / specifications.

8. Rejecting, where warranted, the material or the product at any intermediate or final stage in case acceptance criteria is not satisfied. The rejected material should be removed from work site immediately.

## 3. QUALITY CONTROL MANUAL

It is very important constituent of the quality management system. It is a document encompassing specific requirement, which if fulfilled, shall help in effectively implementing the quality control system to achieve the objective of good construction quality. It covers broadly, the objectives, functions and operations of the Q.C. organisation; duties and responsibilities of Q.C. personnel; Q.C. Laboratory System; Monitoring through Control Charts; Control on workmanship; Tests on materials; Important specifications; Standards to be adopted for materials and works; Frequency of testing and reporting; Compilation of Q.C. Data and Statistical Analysis etc.; Documentation and Feed-back; Inspection etc.

## 4. CONFIGURATION OF QUALITY MANAGEMENT SYSTEM
## QUALITY MANAGEMENT SYSTEM

**Quality planning, ---------- Quality Control---------- Quality Assurance**
**Q.C. Manual;**
**Training of Q.C./Q.A.**
**Staff, Infrastructure**
**etc.**

### 5.1 QUALITY CONTROL: (Q.C.)

The operational techniques and activities that are used to fulfil the requirements for quality.

### 5.2 QUALITY ASSURANCE: (Q.A.)

All the planned and systematic activities implemented within the quality system and demonstrated as needed to provide adequate confidence that an entity will fulfil requirements for quality; and making sure that the quality of a product is what it should be. Purpose of Quality Assurance is to prevent problems before they occur, to identify and correct them swiftly if they occur and to uncover the root cause.

### 5.3 QUALITY MANAGEMENT

All activities of the overall management function that determine the quality policy, objectives and responsibilities, and implement them by means such as
Quality Planning, Quality Control, Quality Assurance, and Quality Improvement are within the quality system.

The **QUALITY CONTROL MANUAL** being adopted for Irrigation & Waterways Department (the salient requirements of which are being outline in the various chapters) aims at a "**System Approach**" to ensure that upon implementation, the quality levels as set and defined in the specifications and contract documents and relevant Indian Standards would be met in the execution of project works.

# CHAPTER – II

## ORGANISATIONAL SET-UP

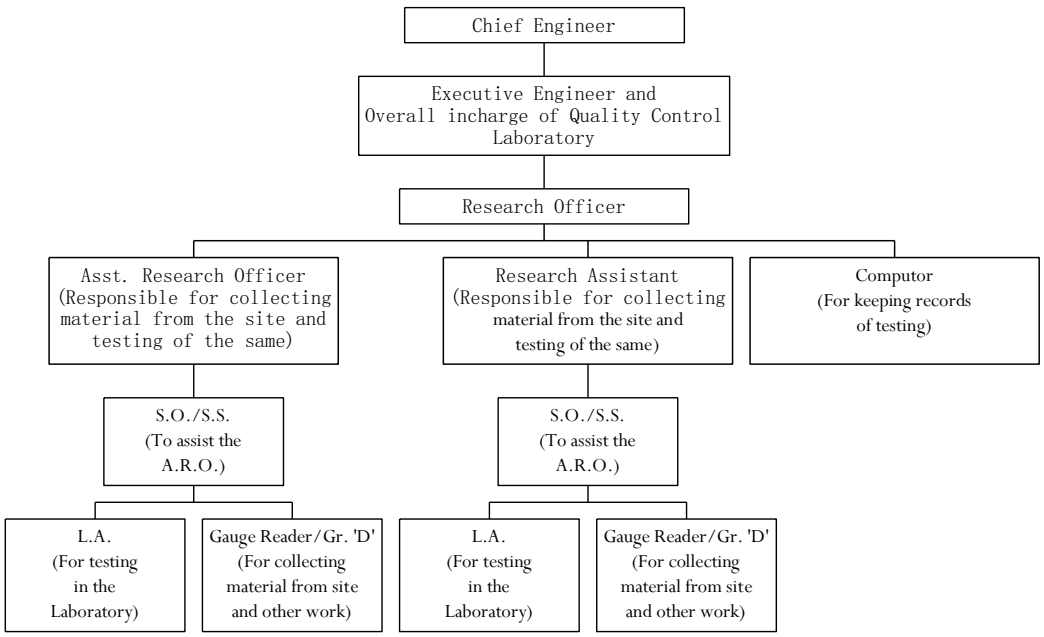
**GENERAL**

I. Anyone connected with quality control work, should possess adequate knowledge and experience of quality control works and be well conversant with testing of construction materials. The object of quality control should be clearly understood by them in letter and spirit so as to help in construction and achieve high order of quality as laid down in specifications for works by controlling various factors responsible for deterioration in quality, investigating reasons therefore and suggesting ways and means for improvement.

**II. ESTABLISHMENT OF LABORATORY.**

A separate quality control unit shall be established at a convenient location to ensure the quality of works for a specified zone under the control of an Executive Engineer / Deputy Director.

## ORGANISATIONAL SET-UP SHALL BE AS UNDER: -




- Each Quality Control unit would be set up under the administrative control of an Executive Engineer. He would report directly to the Chief Engineer of respective jurisdiction. He will also act as liaison officer with the working divisions under his area of activity of the Quality Control Unit.

- One Research Officer (R.O) would be placed under the control of the Executive Engineer. He will plan and manage, according to the work plan as fixed by the working divisions, the resources and manpower to collect the materials from site, test the same in the laboratory or site, generate the report of testing and be responsible for quality control of work. He will report to the Executive Engineer.
- One Assistant Research Officer (A.R.O.) and one Research Assistant (R.A.) would be placed under the Research Officer to assist him to maintain the quality at site. They will be responsible for collecting materials from site, testing of the same at the laboratory or in situ and report to the Research Officer. One Computor would be placed under the R.O. to maintain the records of testing and other records.
- One Silt Observer / Silt Surveyor would be placed under the A.R.O. / R.A. to assist him for collecting and testing the material in the laboratory or in situ. They will report to the A.R.O. / R.A.
- One Laboratory Assistant (L.A.) would be placed under A.R.O. / R.A. for testing in the Laboratory.
- Group D would be kept in the Laboratory for collecting materials from site and other works in the Laboratory.

Though most tests will be performed at the Zonal Quality Control Laboratory located in his office, the Chief Engineer may in his discretion sent some samples in Reputed testing laboratory for testing. if the Zonal Quality Control Laboratory is not functioning due to some unforeseen reasons.

# CHAPTER - III

## FUNCTIONS OF QUALITY CONTROL UNITS

The main function of Q.C. units is to have independent checking and control of works. Since the works in the zones are of scattered nature, the quality control units cannot exercise concurrent quality control, but it has been planned that these units should act in such a manner that necessary quality control requirements are fulfilled jointly with the executing staff. It will be the responsibility of quality control staff to ensure that all-requisite test as per IS / relevant standards and specifications are carried out in site / field or zonal laboratories. The quality control units will carry out periodic inspections of works and conduct field tests with consultation with the Engineer-in-Charge of the working division. The frequency of testing should be as per codal provisions as mentioned in Chapter VIII. The Engineer-in-Charge will be responsible for any deficiencies in the execution of works and taking corrective measures. The following broad indications of functions of quality control units are given which may be supplemented by issue of any further instructions by the Chief Engineer, of his respective jurisdiction.

(1) They should monitor that all required tests are carried out before start of work as well as during execution.

(2) They should ensure that all arrangements for carrying out routine field tests in the temporary site laboratories and zonal laboratories are duly made including provisions and up-keeping of equipment, personnel etc. and record of these field tests in prescribed formats are maintained. They should check this record and also sign in the relevant registers in token of their inspection. They should conduct field tests whenever they visit site of construction work and record results of such tests in the registers maintained for the purpose.

(3) They shall bring to the notice of the respective Chief Engineer if deficiencies or defects are noticed during execution. Order for suspension of work can only be passed by the respective Chief Engineer under his jurisdiction.

(4) Inspection Book should be maintained at site wherein remarks should be recorded by quality control staff whenever they visit site which should be noted for compliance by the construction unit. They should specifically record any deficiency noted to bring the same to the notice of appropriate authority through remarks in the inspection book or inspection note. The execution staff shall ensure the compliance of such deficiency and intimate to the concerned officer of Quality Control Unit.

# DUTIES OF FIELD STAFF IN RELATION TO QUALITY OF WORKS

## DUTIES OF R.O. INCHARGE OF LABORATORY

i) To ensure proper up-keep and maintenance of laboratory equipment in laboratory.

ii) To ensure proper up-keep of records of all samples being tested in the laboratory as per prescribed norms and communication of the results to the concerned.

iii) To supervise the testing works of Assistant Research Officer, Research Officer and personally to check the tests to the extent of 25%.

iv) To prepare fortnightly review of all the tests results and submit to the Executive Engineer, Quality Control.

v) The Zonal Laboratories have to conduct tests for the suitability of materials proposed from various quarries, well in advance of the actual execution of work, for which the construction staff shall send the material to the lab well in advance.

vii) Steel rods as proposed to be used shall be tested for ultimate tensile strength elongation and bond etc. as per standards.

## DUTIES OF A.R.O.

Shall perform important tests as mentioned below:

**A) CEMENT:**

1. Fineness Modulus as per IS: 4031 (Part-I)-1996
2. Soundness as per IS: 4031 (Part-III)-1988
3. Initial and Final Setting time as per IS: 4031 (Part-V)-1988
4. Compressive strength as per IS: 4031 (Part-VI)-1988

**B) SAND:**

1. Sieve Analysis & Fineness Modulus as per IS: 2386 (Part-I)-1963
2. Test for organic impurities silt & clay as per IS: 2386 (Part-II)-1963 reaffirmed 2002
3. Decantation test for silt as per IS: 2386 (Part-II)-1963 reaffirmed 2002

4. Specific gravity as per IS: 2386 (Part-III)-1963
5. Unit weight and bulkage factor as per IS: 2386 (Part-III)-1963

**C) COARSE AGGREGATE:**

1. Sieve Analysis and gradation as per IS: 2386 (Part-I)-1963
2. Specific gravity as per IS: 2386 (Part-III)-1963
3. Water absorption
4. Examination of deleterious materials as per IS: 2386 (Part-II)-1963 reaffirmed 2002
5. Crushing strength as per IS: 2386 (Part-IV)-1963
6. Impact as per IS: 2386 (Part-IV)-1963
7. Abrasion as per IS: 2386 (Part-IV)-1963
8. Flakiness index as per IS: 2386 (Part-I)-1963
9. Alkali – Silicate reactivity as per IS: 2386 (Part-II)-1963 reaffirmed 2002

**D) CONCRETE:**

1. Workability of Concrete as per IS: 1199-1959 Reaffirmed 1999
2. Compressive strength as per IS:456-2000
3. Water Cement Ratio as per IS:456-2000
4. Mix proportion as per IS:456-2000
6. Cement content as per IS:456-2000

**E) MORTAR:**

1. Consistency
2. Compressive Strength
3. Cement Content

**F) SOILS :**

1. Consistency limits as per IS:2720 (Part-V)-1985 Reaffirmed 1995
2. Porosity & Voids ratio
3. Specific gravity as per IS:2720 (Part-III/ Section-1 & Section-2)-1980 Reaffirmed 1997
4. Swell pressure as per IS:2720 (Part-XLI)-1997 Reaffirmed 1997
5. Grain size as per IS:2720 (Part-IV)-1985

## DUTIES OF SILT OBSERVER / SILT SURVEYOR / LABORATORY ASSISTANTS

i) To assist A.R.O/ R.O/ Executive Engineers r e q u i r e d in laboratory and field work.

ii) To perform tests in laboratory such as:

a) Compaction tests

b) Limit tests

c) Analysis of fine & coarse aggregates

d) Silt in fine aggregate

e) Slump test

f) Collection of samples of concrete and mortars for filling moulds for compaction test.

**DUTIES OF GROUP 'D' / GAUGE READER**

a) To keep instruments clean.

b) To prepare samples for test.

d) To arrange samples systematically.

**CONTROL OF INSPECTION, TESTING AND MEASURING EQUIPMENT** The identification, calibration, and adjustment of all inspection, measuring and test equipment and devices will be done at prescribed intervals as stated below against certified equipment having a known valid relationship to nationally recognised standards. Periodical test will be made at least once in a month in case of equipment for measuring water, cement, admixtures, sand and coarse aggregate. Other measuring equipment will be tested once in a year unless some defects are noticed earlier, in which case these will be attended immediately.

Documents will be established and calibration procedures will be maintained including details of the following:

1. Equipment type
2. Identification number
3. Location
4. Frequency of Checks
5. Check method
6. Acceptance criteria
7. Action to be taken for unsatisfactory results, to ensure that the inspection, measuring, and test equipment are capable of the required accuracy and precision.

## DUTIES OF ASSISTANT ENGINEER

| ASSISTANT ENGINEER CONSTRUCTION | RESEARCH OFFICER QUALITY CONTROL |
|---|---|
| 1. Shall see that sufficient quantities of input materials as per agreement specifications are made available at site of work and to arrange testing equipment, men and material required for conducting field tests, sending samples of input materials for testing to central lab, field laboratories as per norms. | 1. Shall conduct / get conducted by different laboratories the field tests on input materials and record the results and to inform the Assistant Engineer construction to rectify the defects if any. |
| 2. Shall inform the Research Officer Quality Control before starting any work. | 4. Shall check the adequacy of the construction equipment and curing/ watering arrangements before start of work and during excavation. |
| 3. Shall supervise and ensure that correct quantities of input materials as per mix design communicated by the quality control laboratory are fed into the mixers/batching plants etc., and shall ensure specified mixing time. | 3. Shall make regular checks of the feeding of input materials mixing time and suggest the quantity of water depending on the moisture content of sand as and when required. |
| 4. Shall ensure proper vibration, rolling etc., during course of day to day work. Shall conduct test of earth work, gradation of material, slump test and to extract field samples of material and finished products to be sent to different laboratories also provide men and material required for extracting samples of finished product for quality control staff. | 4. Shall ensure slump test, core tests, proctor density etc., conducted as per norms by the construction and quality control staff and to extract field samples of finished product to be sent to laboratory later. He shall personally check tests to the extent of 25%. |
| 5 Shall ensure timely green cutting of concrete with proper air – water gun; nicking & chipping (wherever so warranted) so as to prepare the surface for next concrete lift for effective bond at the lift / construction joints | 5. Shall check and see that the preparation of the surface is adequately done for starting the next lift. |

| ASSISTANT ENGINEER CONSTRUCTION | ASSISTANT ENGINEER QUALITY CONTROL |
|---|---|
| 9. Shall ensure proper curing / watering and allow removal of shuttering only after the time limit prescribed in the specifications and to see that the surface is finished to the plumb/straight lines etc., after removal shuttering. | 9. Shall check the adequacy of curing/watering and see that the final surfaces are finished neatly plumb/straight lines etc. |
| 10. Shall maintain site inspection book. | 10. Shall maintain registers of field tests conducted. |

## DUTIES OF EXECUTIVE ENGINEER

| EXECUTIVE ENGINEER CONSTRUCTION | EXECUTIVE ENGINEER QUALITY CONTROL |
|---|---|
| 1. Shall supervise, check, advice, and instruct the JE /AE. construction regarding discharge of their functions properly. | 1. Shall supervise, check, advice and instruct the R.O. Quality Control regarding discharge of their functions properly. |
| 2. Shall intimate the Executive Engineer quality control before starting of any new work, duly endorsing a copy of work order. Shall supply copies of contract documents, drawings construction programme etc., to Executive Engineer Quality Control. | 2. Shall maintain copies contract document, drawings, construction programme, extracts of inspection notes etc., and shall see that his subordinates go through the above documents. |
| 3. Shall get all ingredients of concrete, masonry got tested before use. Shall see that the soils are tested for various properties like OMC, MDD, etc., before starting of Embankment work. | 3. Shall remind and verify whether test results are available or not before starting up of any new work and during execution of work. |
| 4. Shall see that all the Machinery/ Equipment being used by the contractor is in good condition. | 4. Shall assist in upkeep and calibration of equipment. |
| 5. Shall see that relevant Test Certificates are OK before starting of any work. Also, will ensure rectification of work before releasing payments. | 5. Shall inspect during execution of work. Defects of construction will be pointed out and remedies suggested for achieving good quality construction. |

| EXECUTIVE ENGINEER CONSTRUCTION | EXECUTIVE ENGINEER QUALITY CONTROL |
|---|---|
| 6. Foundations and reinforcement, shuttering, centering where heavy reinforcement is involved is to be checked by Executive Engineer invariably before starting the work. | 6. Foundations and reinforcement, shuttering, centering where heavy reinforcement is involved is to be tallied by Executive Engineer invariably before starting the work, during his field visits. |
| 7. Shall personally see that the samples to the laboratories are sent regularly, obtain the results and communicate the same to Executive Engineer quality control. | 7. Shall pursue and keep track of sending of samples various laboratories and to keep record of results received. |
| 8. Shall jointly inspect the site with quality control Executive Engineer in case variation in classification is less than 10% (+/-) and finalize the classification. | 8. Shall jointly inspect the site with Construction Executive Engineer in case variation in classification is less than 10% (+/-) and finalize the classification. |

## CO-ORDINATIONS

The construction staff and quality control staff must act in tandem to achieve good quality of the finished product and construction as per the contract specifications.

Construction staff should make it a point to inform the quality control staff, the date of starting of any activities or component of the work well in advance so as to enable the quality control staff to schedule their work plan and attend the particular work on the particular date.

In turn quality control staff should schedule their programme, so as to attend to the work on the dates required by the construction staff and ensure that, the progress of work is not hampered.

The quality control staff shall be responsible for exercising the various field checks with reference to drawing and specifications laid down in respective I.S. code during construction and carrying out all the laboratory and field tests on materials used for construction and reporting through their higher officer, to the field staff for ensuring quality.

As far as possible the defects are to be rectified in the presence of the Quality Control staff and the payment shall be effected only after the Quality Control Staff are fully satisfied with the rectification and quality of work. Any rectification done subsequently any intimation and presence of Quality Control Staff shall be at the

sole responsibility of the construction staff.

The defects, if any, noticed by the quality control staff during their course of inspection shall be brought to the notice of the construction staff then and there. It is the primary responsibility of the Quality Control & Inspections staff to draw the attention of the construction staff, whenever they notice defective work during their course of inspection. It is duty of the construction staff to attend to the rectification and maintain proper specifications as pointed out by their counter part of the Quality Control organisation.

All observations regarding substandard or below specification work will be dully recorded in the inspection / visit books kept at site by inspecting officer. The defects pointed out by Quality Control Unit will be communicated to the execution unit for compliance immediately. The compliance report should be sent by execution unit within ten days.

The quality control staff cannot supervise the placement of concrete on a mix to mix basis continuously. They can only conduct random check of input materials, mixing time, placement of concrete, vibration etc. It's the primary responsibility of the construction staff to ensure adequate supervision of mix to mix placement of concrete.

The Operations of the Quality Control Staff shall not interfere in any way, with the executive powers vested with the officers in-charge of execution. They will also in no way diminish the responsibility of the officers in-charge of execution. The field officers in-charge of works are primarily responsible for the quality of all works and to carry out the work as per the technical specifications.

In case of difference of opinion between quality control staff and construction staff, the Chief Engineer of the respective jurisdiction will act as an arbitrator between the two.

The construction and quality control staff shall keep a regular liaison with the Geologist in respect of all Geo-technical problems and enlist his input on foundations of structures & dams; Cut Off Trenches, consolidation/curtain grouting; Rock / Excavation Slopes (stability of slopes); protection measures; permeability / Water loss tests etc., as well as any geological problem. The advice rendered by the Geologist should be discussed with the Designers and duly respected and implemented.

# CHAPTER – IV

## SETTING UP OF LABORATORIES

The laboratory system, should evaluate the inputs and outputs, would also evaluate and monitor the workmanship. This should be accompanied by testing as well as inspection.

### FUNCTIONS OF ZONAL LABORATORY

I. To conduct laboratory tests on samples of sand, coarse aggregate, stone, cement and steel for use in masonry and concrete works.

II. To conduct laboratory tests for foundation soil, and for selection of soils from proposed borrow areas, for use in the various zones of embankment as per specifications, proctor density & optimum moisture content of soils before start of earth work.

III. For masonry and concrete, the strength of mortar and concrete has to be as specified in agreement. Laboratory has to design the proportions of different ingredients through tests for the specified strength. The proportioning shall be done by weight. It should be co-related with volume for volumetric batching of concrete where quantity of concrete to be placed is of small magnitude. Volume batching may be allowed by the Engineer-in-charge where weight batching is not practical and provided accurate bulk densities of materials to be actually used in concrete have been established. Allowance for bulking shall be made in accordance with IS: 2386 (Part III)-1963. The mass volume relationship shall be checked at periodical frequency to ensure that specified grading is maintained.

IV. For concrete and mortars where strength is not given and only proportions have been specified, the strength should be treated as standard for execution.

V. When controlled concrete is specified, it is essential that mix design is to be done.

VI. Since the strength of cement varies from batch to batch in a cement factory itself, it is essential that a relation between strength of cement versus strength of concrete

may be worked out in the lab, well in advance of the starting of the work. This would facilitate in furnishing the proper proportion of the mix for adopting in the field and also it entails adding or reducing cement content based on the strength of the cement.

VII. Results of tests performed in zonal laboratory should be documented in prescribed Performa as per Chapter-VII pertaining to following tests.

# CHAPTER-V

## VARIOUS TESTS TO BE CARRIED OUT BY QUALITY CONTROL WING

### EARTH DAM & EMBANKMENTS:

### SOIL IDENTIFICATION AND DESCRIPTION

### VISUAL SOIL CLASSIFICATION

Before testing a soil, the sample has to be examined and data obtained from visual inspection is to be noted. This includes noting of the colour, odour presence of minerals, presence of organic and foreign matter and geological history as may be often evident from visual inspection. The visual inspection aids the development of a feel, soil behaviour and it helps in interpretation of the results, obtained. A possible error in sample numbering will also' be detected in case the visual inspection does not tally with actual results in the laboratories. An experienced technician can even predict the behaviour of a soil with sufficient accuracy by working it in his hand and inspecting it carefully. At the conclusion of a test, the laboratory technician should check to see that the results are in agreement with what' was expected from his visual classification.

### STORE OF SAMPLES

The soil samples have to be inspected and tested soon after their arrival at the laboratory. If testing is likely to be delayed, proper storing has to be ensured by providing adequate space and proper containers. The samples have to be labelled properly as per standard form.

### VARIOUS TESTS ON SOILS.

Following tests are conducted on soils to be used in dam construction.

### VISUAL TESTS

### DRY STRENGTH

Dry strength is measured by the effort required to break thumb and forefinger an intact fragment of dry soil about 3mm (1/8 in.)

### THREAD TESTS

Thread test performed by rolling a sample of moist soil on a plain surface using the palm of the hand and fingers. If the thread can be rolled to a diameter of about 1/8 in. (3mm) it is picked up, remoulded, and rolled out again. The process is repeated until the soil dries below the plastic range and begins to crack or crumble. Just before the crumbling state is reached highly plastic clay can be rolled into a thread of about 1/8 in. (3mm) diameter, which is able to support its own weight when about 3 in. (75 mm) long. Silt can seldom be rolled into threads as small as 3 mm diameter without severe cracking unless some clay is present. In has no tensile strength at all.

**DISPERSION TEST**.

A small quantity of soil is dispersed with water in a glass cylinder or test tube and then allowed to settle. The coarser particles will settle first and the finest particles remain in the suspension longest. Normally, sand settles in 30-60 seconds, silt in 15 to 60 minutes while clay remains in suspension for hours.

**DILATENCY TEST**

Diligence or reaction to the shaking is measured by shaking a wet pat of soil in the palm of the hand. If the soil reacts to the test, free water will rise to the surface giving it a glittering appearance. This will disappear when the soil is squeezed between the fingers. The reaction may be rapid, sluggish or non-existent depending upon the grain size. This is of little value for sands and is used to distinguish between silt and clay.

**ENGINEERING CLASSIFICATION OF SOIL**.

**GENERAL.**

Since all civil engineering works are founded on soils and many employ excavated soil as a material of construction, it is necessary to investigate the properties of soil so that an economical and safe design can be made. These materials have been systematically studied and methods of testing for classification are now well established and their practical value recognized.

It is advantageous to have a standard method of identifying soils and classifying them into categories or groups which have distinct engineering properties. This enables Engineers in the design office and those engaged on the field work to speak in the same language.

Soils in nature seldom exist separately as gravel, sand, silt, clay or organic matter but are usually found admixtures with varying proportions of these components. Representative soil samples from project sites are sent to the soil testing laboratory with requisite details in standard pro-forma in respect of the soil samples.

The Engineering classification of soils for use on earthen dams / embankment, is to be done as per I.S. code No. 1498 of 1987.

**Test for Suitability of soils**

All tests are to be carried out as per the relevant/prescribed I.S Codes.

**Grain Size Analysis Test**

Grain size analysis gives the distribution of various particle sizes in soil. It comprises of two parts, sieve analysis and sedimentation analysis. Percentage of various sizes above 75 microns is determined by standard sieves whereas percentage of various size below 75 microns is determined by sedimentation analysis. Sedimentation Analysis is based on Stoke's law of falling bodies, with the assumption that solid particles are spherical in shape have the same specific gravity and settle independent of other particles. This test indicates whether the soil is fine grained or coarse grained and gives the percent of clay, silt, sand and gravels present in the soil and helps in obtaining the engineering classification for deciding its suitability in construction of earth dams. The grain size analysis curve which is plotted between the particle size in mm and the cumulative percent final than the corresponding size indicates whether the soil is well or poorly graded which is necessary to find out the engineering classification of course grained soils, graded.

**CONSISTENCY LIMITS (ATTERBERG'S LIMITS)**

Consistency denotes the degree of firmness of the soil which may be termed as soft, firm, stiff or hard. Atterberg divided the entire range from liquid to solid state into four stages -

The liquid state
The plastic state
The semi-solid state
The solid state

These arbitrary limits are known as consistency limits or Atterberg's limits in terms of water content.

The Atterberg's limits are (1) Liquid limit, (2) Plastic limit, (3) Shrinkage limit.

**UTILITY OF DETERMINATION OF ATTERBERG'S LIMITS**

They help in the classification of soil which determines its placement in various zones of dam.

They give an approximate assessment of cohesion of inter molecular attraction.

They give an assessment of Shrinkage of the soil on drying.

**LIQUID LIMIT**

The liquid limit of a Soil is the water content expressed as percentage of the weight of the oven dry soil, at the boundary between liquid and plastic states of consistency of soil. It is the minimum water content at which a grooved portion of soil cut by a specially designed grooving tool of standard dimension will flow together for a distance of 12 mm under the impact of 25 blows in a standard liquid limit device.

**PLASTIC LIMIT**

The plastic limit of a soil is the water content expressed as a percentage of the weight of the oven dry soil at the boundary between the plastic and semi-solid states of consistency of the soil. It is the minimum. Water content at which the soil will just began to crumble when rolled into a thread of approximately 3 mm in diameter.

**SHRINKAGE LIMIT**

This is a water content below which a reduction in moisture will not cause a decrease in the volume of the mass. Below the Shrinkage limit values together with other index values are useful in identifying expansive soils.

**ENGINEERING TESTS FOR EARTH DAM DESIGN**

**COMPACTION OF SOILS (MOISTURE DENSITY RELATION)**

In the stability analysis of all earthen embankments, the density of the soil and its shear strength play an important role. The unit weight or density of the soil varies with the degree of compaction of the soil in the embankment. Stability of the

embankment largely depends upon the compaction achieved because compaction also improves its shear strength, bearing capacity and bring about a lower permeability of the soil and decreases the tendency of the soil to settle under repeated loads.

Compaction tests or Moisture density relation-ship is useful in designing the dam section in quality control of each work where results of density achieved in the fill is compared with maximum dry density for assessing compaction efficiency and determining the quantity of water to be added to the soil brought on the embankment before rolling begins.

**SHEAR STRENGTH**

Once of the important parameters to know properties of a soil is its shear strength. Shear strength of the soil is the limiting resistance offered by the soil to shearing forces. It is customary to measure it in two components viz. "Cohesion" and "Angle of internal friction" and then evaluate it on the basis of Coulombs equation given by French Engineer, Coulombs.

$S = C + N \tan\emptyset$

Where S is the shear strength of soil, C - is cohesion, N is normal load and Ø is the angle of internal friction.

**SHEAR TEST RESULTS HELPS IN: -**

- Designing the dam section
- Assessing the bearing capacity foundation
- Assessing the pore pressures likely to develop in the dam under different conditions.
- Assessing stability of an existing dam when undisturbed soil samples from the dam are tested for shear.

## TRI-AXIAL SHEAR TEST COMPRISES FOLLOWING TYPE OF TESTS

## UNCONSOLIDATED UNDRAINED TEST WITHOUT PORE PRESSURE CORRECTION (Q-TEST).

**Purpose:**

For determination of shear strength parameters of soil from consolidated undrained Tri-axial compression test with measurement of pore water pressure-knowledge of shear strength parameters that is cohesion intercept and the angle of internal friction both in terms of total stress and effective stress obtained from the Tri-axial compression shear tests conducted under consolidated undrained condition with measurement of pore water pressure. The test is essential for solving problems involving stability of earth embankment.

## DRAINED TEST/SLOW TEST (S-TEST)

Like R-Test saturated and drained testing conditions are developed in this test and saturated specimen is consolidated in the same way as in the above mentioned consolidated undrained test. Drainage is allowed during shearing of the specimen and also sheared at very slow rate of strain so that consolidation is complete at stage allowing sufficient time for the full dissipation of pore pressure developed during the application of shear test and drainage is allowed during shearing of the specimen and also the valve connecting the cell to the pore pressure apparatus is kept closed.

## PERMEABILITY OF SOILS

Permeability is the ease of facility with which water percolates through soil. Darcy is first to study flow of water through soil and demonstrated that the rate of flow of discharge per unit time is proportionate to the unit hydraulic gradient Q = KIA where,
Q= discharge/unit.
I = units Hyd. Gradient
A = c/s area of media
K = constant of proportionality

## SWELL PRESSURE TEST

Expansive soils are those which swell considerably on absorption of water from outside and shrink on removal of water. Although, the phenomenon of swelling and shrinkage is not uncommon with most of the soils (except sand and gravel) it is exhibited to a very marked degree only by certain clayey soils and hence the term expansive soil is used only for such soils.
The capacity to swelling of a soil depends upon the type amount of clay minerals and the exchangeable bases. Out of the three major mineral groups; Montmorillonite, Illite and Kaolinite the Montmorillionite clay minerals swell on coming in contact with water, whereas the clay minerals of the other two groups do not swell or swell to very less extent.

The volume changes associated with expansive soils are liable to cause considerable distress to structures involving this use or coming in contact with them. Hence call for detailed investigation and testing.

## DETERMINATION OF TOTAL SOLUBLE SOLIDS

The presence of soluble solids in soil is one of the important aspects requiring examination as these soluble solids greatly influence the Engineering properties of the soil. 31

## GRADATION TEST FOR FILL/FILTER MATERIAL

The proportion of the fine and coarse aggregate and gradation characteristic will be given after gradation test are carried out in the laboratory as per specifications.

## DETERMINATION OF SPECIFIC GRAVITY

Specific gravity of soil finds application in finding out the degree of saturation and moist weight of soils.

## TESTING OF BRICKS

The brick is the oldest and the most extensively used building material. It is essentially a local building material. Hence there is considerable variation in the quality and size of the material.

To maintain some standard of their common building brick material with regard to its quality and dimensions I.S.I. has recommended certain methods test and requirements of the properties. Some of these the tests are given below.

## TEST OF BURNT CLAY BUILDING BRICKS

.

This test conforms to the quality of bricks for the recognition of the standard of the material.

## FIRST CLASS TABLE MOULDED BRICKS

Water absorption test is done to see any signs of efflorescence are there on drying.

## SECOND CLASS BRICKS

Water absorption test is done.

## DETERMINATION OF COMPRESSION STRENGTH OF BRICKS

To assess the quality by comparing with the specified strength

## TESTING OF HYDRAULIC LIME

Lime has been used as a material of construction from very ancient days. It is 90% carbonate of lime. I.S.I. has specified specification and testing in view of quality of which lime varies from place to place.

## FINENESS

To determine the quality of lime and to compare the fineness with standard specification.

## WORKABILITY OF HYDRATED LIME

The test is conducted to assess the qualitative requirement of suitable lime.

## DETERMINATION OF SETTING TIME FOR HYDRATED LIME

To assess the quality and period of manufacture of hydrated lime for the use in the construction work.

## DETERMINATION OF SOUNDNESS OF HYDRATED LIME

This test is performed to assess the qualitative measurement of the hydrated lime and the results are compared with the standard specifications.

## DETERMINATION OF COMPRESSIVE STRENGTH OF HYDRATED LIME

.

For the assessment of the quality of hydrated lime and comparing the results with the specifications

## TESTING OF POZZOLANA

In order to effect economy in the construction, a part of cement is replaced by pozzolana material viz, fly-ash, surkhi etc. without impairing the ultimate strength and at the same time improving the durability. Various tests are therefore need to be conducted as described below:

## DETERMINATION OF FINENESS BY SIEVING:

This test is conducted to determine the suitability of pozzolanas. Fineness is an important property as finer the material the greater is the reactivity.

## DETERMINATION OF SPECIFIC SURFACE OF POZZOLANA:

This test is conducted to know the fineness for checking with the standard specification.

**DETERMINATION OF LIME REACTIVITY:**

This test is Per-formed for determining the reactivity of the pozzolanic material with hydrated lime, as represented by compressive strength of standard mortar test cubes prepared and tested wider specific conditions.

**DETERMINATION OF COMPRESSIVE STRENGTH OF POZZOLANIC CEMENT MORTAR**

This test is conduct for the determination of the quality of the material and is to be compared with the compressive strength of the cement.

**TESTING OF CONCRETE:**

Concrete is made with cement, sand, coarse aggregate and water but admixtures can also be used for modifying and improving the properties of concrete. The science of proportioning of concrete is mainly concentrated on the principle obtaining a durable and strong concrete at the most economical rate possessing a good workability.

**COMPRESSION STRENGTH OF CONCRETE:**

Concrete is a variable material. The quality of concrete is usually assessed from the results of crushing strength test on concrete cubes or cylinders.

**SLUMP TEST OF CONCRETE:**

This test is conducted to determine the consistency of concrete and hence workability. Workability means the ease with which concrete can be handled transported and placed

.

**PERMEABILITY TEST OF CEMENT MORTAR & CONCRETE:**

This test is of particular significance in structures which are intended to retain water or which come into contact with water. It is intimately related with durability of concrete. Hence it is of considerable importance. \

**RAPID ESTIMATION OF CEMENT IN MORTAR AND CONCRETE:**

This test is conducted to analyze the mortar/concrete with respect to their proportions of the mixed ingredients in the mortar/concrete. This test is based the calcium content in the mortar, Cement and sand.

**DETERMINATION OF COMPRESSIVE STRENGTH OF NATURAL BUILDING STONE:**

For assessing the suitability of stone, this test is conducted for the selection of the material to be utilized for its satisfactory performance.

**DETERMINATION OF SPECIFIC GRAVITY, APPARENT SPECIFIC GRAVITY, WATER**

**ABSORPTION AND POROSITY OF NATURAL BUILDING STONES**

These test conform to the properties of the natural building stones. The suitability of the natural building stone is known and hence the quality is assessed.

**DESIGN OF CONCRETE MIX**

The proportion of cement, fine and coarse aggregate will be given after tests are carried out in the Laboratories in accordance with the specifications laid down.

**DESIGN OF MORTAR MIX**

The proportion of cement and fine aggregate will be given after the tests are carried out in the Laboratory in accordance with the specification laid down.

TEST PROCEDURES FOR CHEMICAL TESTING

**WATER**

Generally any potable water can be used for construction purpose.

Following tests should be conducted.

i) PH Value

ii) Silt content

iii) Soluble Salts

iv) Hardness.

**CEMENT:**

Cement should be tested for following test

i) Calcium Oxide Content

ii) Adulteration of Cement

# CHAPTER-VI

## LIST OF EQUIPMENT FOR CEMENT, STEEL, CONCRETE AND SOIL TESTING

### CONCRETE TESTING APPARATUS

| Sl. No | Items Description | Unit | Quantity |
|---|---|---|---|
| 1 | Universal Testing Machine Computerised, Capacity, 1000 kN, 6 pillar type with Hydraulic Jaws | No. | 1 |
| 2 | Digital Compression Testing Machine, Capacity 2000kN | No. | 1 |
| 3 | Concrete Mixer, Pan Type, Capacity 40L | No. | 1 |
| 4 | Vibrating Table, 50 x 50cm for 4 moulds of 150mm cube | No. | 1 |
| 5 | Mould, Cast Iron, for 150mm Cube with ISI Certification Mark | No. | 10 |
| 6 | Sieve G.I. Frame 45cm dia | No. | 1 |
| 7 | Sieve G.I. Frame 30cm dia | No. | 1 |
| 8 | Sieve Brass Frame 20cm dia | No. | 1 |
| 9 | Compaction Factor Apparatus | No. | 1 |
| 10 | Slump Test Apparatus with testing rod and base plate | No. | 2 |
| 11 | Vicat Apparatus with ISI Certification Mark, IS:5513, fitted in Aluminium Box | No. | 2 |
| 12 | Mould, Steel, for 70.6mm cube | No. | 6 |
| 13 | Le-Chatelier Mould, with ISI Certification MarkIS:5514, each | No. | 5 |
| 14 | Le-Chatelier Water Bath with Controller size 12"x9"x12". | No. | 1 |
| 15 | Le-Chatelier Flask | No. | 5 |
| 16 | Mortar Mixer Capacity 4.75litre (New Design) | No. | 1 |
| 17 | Vibration Machine, with built-in Digital Timer, NABL Calibrated | No. | 1 |
| 18 | Los Angeles Abrasion testing machine with Counter | No. | 1 |
| 19 | Crushing Value Apparatus | No. | 1 |
| 20 | Aggregate Impact Tester | No. | 1 |
| 21 | Thickness Gauge with ISI Certification Mark IS:2386 (Part I) | No. | 1 |
| 22 | Length Gauge with ISI Certification Mark IS:2386 (Part I) | No. | 1 |
| 23 | Density Basket | No. | 1 |
| 24 | Buoyancy Balance | No. | 1 |
| 25 | Laboratory Electric Oven, Thermostatically Controlled, range 50° to 250°C +/-3°C with Air Circulating Fan, S.S. Inside Size 600 x 600 x 600mm | No. | 1 |
| 26 | Electronic Balance, Capacity 3200g x 0.01g | No. | 1 |
| 27 | Electronic Balance, Capacity 10kg x 0.5g | No. | 1 |
| 28 | Electronic Balance, Capacity 15kg x 01g | No. | 1 |
| 29 | Electronic Balance, Capacity 20kg x 2g | No. | 1 |

| Sl. No | Items Description | Unit | Quantity |
|---|---|---|---|
| 30 | Concrete test Hammer with NCCBM calibrated with Anvil | No. | 1 |
| **SOIL TESTING APPARATUS** | | | |
| | **IS SIEVE FOR GRAIN SIZE** | | |
| 1 | Sieve Brass Frame 20cm dia x 4.75mm | No. | 1 |
| 2 | Sieve Brass Frame 20cm dia x 2.80mm | No. | 1 |
| 3 | Sieve Brass Frame 20cm dia x 2.36mm | No. | 1 |
| 4 | Sieve Brass Frame 20cm dia x 2.00mm | No. | 1 |
| 5 | Sieve Brass Frame 20cm dia x 1.18mm | No. | 1 |
| 6 | Sieve Brass Frame 20cm dia x 425 microns | No. | 1 |
| 7 | Sieve Brass Frame 20cm dia x 212 microns | No. | 1 |
| 8 | Sieve Brass Frame 20cm dia x 75 microns | No. | 1 |
| 9 | Sieve Brass Frame 75mm dia x 75 microns | No. | 5 |
| 10 | Sieve Shaker, Motorised, with Built-in Digital Timer | No. | 1 |
| 11 | Adapter for 30cm dia sieves | No. | 1 |
| **INSTRUMENTS TO DETERMINE PROPERTIES OF SOIL** | | | |
| 1 | Hydrometer, Range : 0.995 to 1 | No. | 2 |
| 2 | Measuring Cylinder, Graduated , Polycarbonate, Capacity 1000ml | No. | 15 |
| 3 | Measuring Cylinder, Glass, Graduated,Capacity 2000ml | No. | 1 |
| 4 | High Speed Stirrer New Model | No. | 1 |
| 5 | Liquid Limit Device, motorised, with Casagrande grooving tools and gauge block (suitable for operation on 50 Hz, single phase AC Supply) | No. | 1 |
| 6 | Plastic Limit set comprising of glass plate, Brass rod, Spatula, Moisture Tin & Porcelain Dish. | No. | 1 |
| 7 | Glass Plate with Rounded edges 600mm x 600mm x10mm | No. | 1 |
| 8 | Pycnometer | No. | 5 |
| 9 | Measuring Cylinder, Glass,Graduated,Capacity 100ml | No. | 1 |
| 10 | Measuring Cylinder,Graduated,Polycarbonate,Capacity 100ml | No. | 1 |
| 11 | Electronic Balance, Capacity 600g x 0.01g | No. | 1 |
| 12 | Compaction Test Apparatus, Manual -Light Compaction made of Mild Steel | No. | 1 |
| 13 | Compaction Test Apparatus, Manual-Heavy Compaction made of Mild Steel | No. | 1 |
| 14 | Laboratory Electric Oven, Thermostatically Controlled, range 50° to 250°C ± 3°C with Air Circulating Fan, S.S. Inside Size 600 x 600 x 600mm | No. | 1 |
| 15 | Moisture Content Tin, Size 65mm dia x 20mm deep | No. | 10 |
| 16 | Moisture Content Tin, Size 90mm dia x 20mm deep | No. | 10 |

| Sl. No | Items Description | Unit | Quantity |
|---|---|---|---|
| 17 | Laboratory Permeability Apparatus | No. | 1 |
| 18 | Overhead Tank, made of steel, approx, 37.5cm dia x 1m high | No. | 1 |
| 19 | Laboratory California Bearing Ratio Test Apparatus, Prooving Ring Type Motorised with Load Frame four Speed | No. | 1 |
| 20 | Mild Steel, Zinc Plated Mould, 150mm ID x 175mm | No. | 5 |
| 21 | Mild Steel, Zinc Plated Perforated Base Plate for MS Mould | No. | 5 |
| 22 | Mild Steel Zinc Plated Extension Collar 150mm ID x 50mm high | No. | 5 |
| 23 | Electronic Balance, Capacity 10kg x 0.5g | No. | 1 |
| 24 | Core Cutter | No. | 1 |
| 25 | Sand Pouring Cylinder Apparatus, 100mm Dia | No. | 1 |
| 26 | Speedy Moisture Meter, Range 0-25% (Gauge Div :0.5%) with digital weighing balance | No. | 1 |
| 27 | Tri-axial Test Apparatus, Analog, with all accessories | No. | 1 |
| 28 | Consolidation Apparatus,with all accessories | No. | 1 |
| 29 | Hand Operated Extractor for 38mm & 50 mm dia specimen | No. | 1 |
| | | | |

# CHAPTER-VII

## TEST CERIFICATES FOR VARIOUS MATERIALS

### TEST CERTIFICATE FOR CEMENT

1. Format No.: IW-1 Lab Ref. No._____

Date _____

| | | |
|---|---|---|
| Name of Work: | | |
| Name of Agency: | | Work Order No. |
| Brand & Type of Cement: | | Quantity: _____T, Bags ____ |
| Consignment No.: _____<br>Stores Entry No.: _____ | No. of sample tested:<br>Tested as per IS: | Sample collected on:<br>Tested on: |

1. *COSISTENCY*

| Trial No. | Wt. Of cement (gms) | Wt. Of Water added (gms) | Percentage indicator (%) | Reading of indicator (mm) | Consistency (p) | Remarks |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |

2. *SETING TIME*

| Setting Time | Time records when water added | Time Record at set | Setting Time | Remarks |
|---|---|---|---|---|
| | | | | |
| | | | | |

3. *FINENESS (BY DRY SIEVING)*

| Wt. Of cement used | Retained on 90 micron IS sieve | Percentage retained | Remarks |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

4. *COMPRESSIVE STRENGTH (Check for 72,168 & 672 hrs.)*

| Room temp | Date of | | Age of specimen | Crushing load (T) | Crushing strength kg/cm$^2$ |
|---|---|---|---|---|---|
| | Casting | Testing | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(cube size = 7.06 cm, Wt. Of cement = 200gms, of Standard Sand =600 gms)

Tested in presence of: ..... ..... .....

Comments of laboratory In- Charge _____

Signed & Sealed by laboratory in- charge

## TEST CERTIFICATE FOR SAND

FORMAT No.: IW-2

Lab Ref. No._____
Date _____

| | | |
|---|---|---|
| Name of Work: | | |
| Name of Agency: | | Work Order No. |
| Source of Supply: | | |
| Consignment No.: _____ | No. of Sample tested:<br>Tested as per IS: | Sample collected on:<br>Tested on: |

Whether Bulking Test Carried out for this source: Yes /No,
If yes, give Lab Ref. No._____ Date _____

Dry bulk Density (Loose) _____

1. *SIEVE ANALYSIS (IS -2386)*

| Sieve No. | Sieve size (mm) | Retained Each Sieve (% Wt) | Cumulative percentage Retained | Passing Through (%Wt) | Grading Limits/ Remarks |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

2. *FINENESS MODULUS:* _____
3. *DELITERIOUS METIRIALS:* *Type of material* _____

*% by Weight* _____
Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## WATER ABSORPTION TEST

Format No.: IW-3 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Source of Supply | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |
| Material Name: | |

| Sl. No. | Wt. Of Oven dried Material(gms) | Wt. Of Wet Material (gms) | Wt. Of water Absorbed (gms) | % of Water Absorbed | Remarks |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Water absorption of Material _____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## MOISTURE CONTENT TEST (FIELD)

Format No.: IW-4 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Source of Supply | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

| Test No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Container No. | | | | | |
| Wt. of Wet soil taken ($S_w$) | | | | | |
| Wt. of dry soil in pan ($S_d$) | | | | | |
| Wt. Of Water ($W=S_w-S_d$) | | | | | |
| Moisture Content $=100*W/S_d$ | | | | | |

Water absorption of Material _____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## LIQUID LIMIT AND PLASTICITY INDEX (Atterberg limits)

Format No.: IW-5 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Source of Supply | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

| Sr. No. | Particular | Unit | Liquid Limit | | | | | Plastic limit | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | No. of Blows | No | 1 | 2 | 3 | 4 | 5 | | |
| 2. | Cup No. | | | | | | | | |
| 3. | Wt. of cup+ wet soil(W1) | | | | | | | | |
| 4. | Wt. of cup+ wet soil(W2) | | | | | | | | |
| 5. | Wt. of water =W3=(W1-W2) | | | | | | | | |
| 6. | Wt. of cup =W4 | | | | | | | | |
| 7. | Wt. Of dry soil W5 = W2-W4 | | | | | | | | |
| 8. | Moisture content W=W3/W5x100 | | | | | | | | |

Liquid limit $W_L$: %

Plastic limit, $W_p$ : %

Plasticity index, $Ip=W_l - w_p$= %

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## OMC & MDD TEST

Format No.: IW-6 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Source of Supply | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

a) Bulk density

| Sr. No. | Particular | Unit | Test no. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | Wt. of mould +compacted soil (W1) | | | | | | | | | |
| 2. | Wt. Of mould (W2) | g | | | | | | | | |
| 3. | Wt. of mould compacted soil (W1-W2)) | g | | | | | | | | |
| 4. | Volume of mould (V) | cc | | | | | | | | |
| 5. | Wet density (ρb) W1 –W2)/V | | | | | | | | | |

b) Dry density

| Sr. No. | Particular | Unit | Test no. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | Wt. of cup + wet soil (W3) | g | | | | | | | | |
| 2. | Wt. of cup +dry soil (W4) | g | | | | | | | | |
| 3. | Wt. of water = W5=(W3-(W4) | g | | | | | | | | |
| 4. | Wt. of cup (W6) | cc | | | | | | | | |
| 5. | Wt. of dry soil, W7=W4-W6 | | | | | | | | | |
| 6. | Moisture content =W= (W5/W7)x100 | % | | | | | | | | |
| 7. | Dry density = ρd=ρb (1+W/100) | g/cc | | | | | | | | |

Maximum dry density _____, Mean MDD: g/cc_____

Mean OMC: %_____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## GRAIN SIZE DISTRIBUTION GRAPH

Format No.: IW-7 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Source of Supply | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

1. Description of soil:
2. Type of sieve analysis : dry/ wet
3. Total wt. of soil sample : W (g) =

| IS Sieve opening | Wt. of Sieve dish (g) | Wt. Of Sieve + dry soil (g) | Wt. Of soil Retained (g) | Cumulative Wt. Retained (g) | Cumulative percent Retained | ..... |
|---|---|---|---|---|---|---|
| 100 mm | | | | | | |
| 63 mm | | | | | | |
| 22 mm | | | | | | |
| 6.3 mm | | | | | | |
| 4.75 mm | | | | | | |
| 2.0 mm | | | | | | |
| 600 micron | | | | | | |
| 212 micron | | | | | | |
| 75 micron | | | | | | |
| 63 micron | | | | | | |
| Passing 63 micron | | | | | | |

Report on gradation of curve:

Uniformity coefficient = $C_u = D_{60}/D_{10}$

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

**APPROVAL OF BORROW MATERIAL SOURCE FOR SOIL TO BE USED IN EMBANKMENT**

Format No.: IW-8 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location of Borrow Material Source : | |
| Inspected by: | Inspection Date: |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

| Sample No. | Sand content % | Wet. sieve analysis | | | | | Plasticity index % | Proctor density g/cc | CBR % | Compaction test | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4.75 | 0.60 | 0.30 | 0.15 | 0.075 | | | | MMD | OMC % |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

Comments of the Engineer: _____

☐ **APPROVED** ☐ **NOT APPROVED**

Give source Reference No. _____

(This ref. No. Is to be quoted by the contractor whenever material from this source is used)

Signature of contractor

## CONCRETE COMPRESSIVE STRENGTH TEST

Format No.: IW-9 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location of Borrow Material Source : | |
| Inspected by: | Inspection Date: |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

| Sr. No | Particulars | Unit | Test No | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. | Identification mark/Sample No. | | | | |
| 2. | Wt. Of specimen | Kg | | | |
| 3. | Length of specimen | Cm | | | |
| 4. | Breadth of specimen | Cm | | | |
| 5. | Height of specimen | Cm | | | |
| 6. | Cross section area of the specimen | $Cm^2$ | | | |
| 7. | Crushing load | kg | | | |
| 8. | Compressive strength | $Kg/cm^2$ | | | |

Average compressive strength of concrete = _____ $kg/cm^2$

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## CONCRETE SLUMP TEST

Format No.: IW-10 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location of Concreting : | |
| Inspected by: | Inspection Date: |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

| Sr. No | Particulars | Unit | Test No. | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. | Wt. of cement | Kg | | | |
| 2. | Wt. of fine aggregate | Kg | | | |
| 3. | Wt. of coarse aggregate | kg | | | |
| 4. | Water cement ratio | | | | |
| 5. | Wt. of water | kg | | | |
| 6. | slump | mm | | | |

Average Slump of concrete = _____mm

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## CONSISTENCY OF MORTAR TEST

Format No.: IW-11 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location: | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

| **Sr. No.** | **Particulars** | **Unit** | **Test No.** | |
|---|---|---|---|---|
| | | | 1 | 2 |
| 1. | Wt. Of Cement | Kg | | |
| 2. | Wt. Of Sand | Kg | | |
| 3. | Water7 cement /Ratio | | | |
| 4. | Wt. Of water | Kg | | |
| 5. | Dial gauge reading before penetration | mm | | |
| 6. | Dial gauge reading after penetration | Mm | | |
| 7. | Consistency of mortar | mm | | |

Average consistency of mortar = _____mm

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## FIELD DENSITY TEST BY SAND REPLACEMENT METHOD

Format No.: IW-12 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location: | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

### I. Determination of Bulk Density of sand

| Sl. No. | Particulars | Unit | Trail No. | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. | Inside dia. of calibrating container | Cm | | | |
| 2. | Inside height of calibrating container | Cm | | | |
| 3. | Volume of calibrating container | CC | | | |
| 4. | Wt. of sand +cylinder before pouring | Gm | | | |
| 5. | Wt. of sand in the cone | Gm | | | |
| 6. | Wt. of sand +cylinder after pouring in calibrating container | Gm | | | |
| 7. | Wt. of sand filling with calibrating container | Gm | | | |
| 8. | Bulk density of sand | Gm/cc | | | |

### II. Determination of Bulk Density of Soil In-situ

| Sl. No. | Particulars | Unit | Trail No. | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. | Wt. Of Wet soil from hole | Gm | | | |
| 2. | Wt. Of sand +cylinder after pouring into the hole | Gm | | | |
| 3. | Wt.of sand of soil | Gm | | | |
| 4. | Volume of the hole | CC | | | |
| 5. | Bulk density of soil in-situGm/cc | | | | |

### III.Determination of dry Density of Soil In-situ

| Sl. No. | Particulars | Unit | Trail No. | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| 1. | Container No. | | | | |
| 2. | Wt. of Container | Gm | | | |
| 3. | Wt. of Container +wet soil | Gm | | | |
| 4. | Wt. of Container +Dryt soil | Gm | | | |
| 5. | Wt. Of dry soil | Gm | | | |
| 6. | Wt. Of water | Gm | | | |
| 7. | Water content % | % | | | |
| 8. | Dry density | Gm/cc | | | |

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## TEST CERTIFICATE FOR BRICKS

Format No.: IW-13 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location: | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |

### 1. PHYSICAL PROPERTIES

| | |
|---|---|
| Dimensional Conformance | |
| Sounding | |
| Color | |
| Foreign particle | |
| Obliqueness | |

### 2. COMPRESSIVE STRENGTH

| **SL. No.** | **Forg Mark** | **Size of Bricks LxBxH mm** | **Crusing Surface area ($cm^2$)** | **Crushing Load (T)** | **Crushing Strength ($kg/cm^2$)** | **Remarks** |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

### 3. WATER ABSORPTION

| **Sl.No.** | **Gorg Mark** | **Wt.of oven dried Brik (gms)** | **Wt.of wet Brik (gms)** | **Wt. of water absorbed (gsm)** | **% of water absorbed** | **Remarks** |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## FREE SWELL INDEX TEST FOR SOILS

Format No.: IW-14 Lab Ref. No. _____

Date _____

| | | |
|---|---|---|
| Name of work: | | |
| Name of Agency: | Work order No. | |
| Location: | | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: | |
| *Oven Dry Soil Passing Through 425-micron IS Sieve* | *Weight of Each Sample* ____ *gms* | *Glass Graduated Cylinders* _____ *ml size* |

1. Volume of Soil Specimen read from the Graduated Cylinder Containing Distilled Water ($V_d$) _____ ml
2. Volume of Soil Specimen read from the Graduated Cylinder Containing Kerosene ($V_k$) _____ ml
3. Free Swell Index .. 100 x $(V_d-V_k)/V_k$ _____ %

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## AGGREGATE IMPACT VALUE TEST

Format No.: IW-15 Lab Ref. No. _____

Date _____

| | | |
|---|---|---|
| Name of work: | | |
| Name of Agency: | Work order No. | |
| Location: | | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: | |
| **Material Name :** | **No. of Std. Blows : 15** | **Height of Fall : 380 mm** |

| No. | Detail | Unit | Trial | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| 1 | Wt. of dry aggregate passing 12.5 mm and retained on 10 mm sieve + cylinder measure | Gms | | | | | |
| 2 | Wt. of cylindrical measure | Gms | | | | | |
| 3 | Wt. of dry aggregate taken (1)-(2) | Gms | | | | | |
| 4 | Wt. of crushed aggregate passing 2.36 mm sieve after subjecting the test specimen to 15 blows | Gms | | | | | |
| 5 | Aggregate Impact Value 100*(4)/(3) | % | | | | | |

Average Value: _____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## LOS ANGELES ABRASION TEST

Format No.: IW-16 Lab Ref. No. _____

Date _____

| | | |
|---|---|---|
| Name of work: | | |
| Name of Agency: | Work order No. | |
| Location: | | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: | |
| **Material Name:** | **No. Of Revolutions**<br>**500/100 rpm** | **No. Of Abrasive Changes** |

| No. | Detail | Unit | Trial | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| 1 | Weight of aggregate of specified gradation | Kg | | | | | |
| 2 | Weight of passing IS 1.7 mm sieve after specified revolution | Kg | | | | | |
| 3 | Los Angeles Abrasion Value =100*(2)/(1) | % | | | | | |

Average Value : _____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## SOUNDNESS TEST

Format No.: IW-17 Lab Ref. No. _____

Date _____

| | | |
|---|---|---|
| Name of work: | | |
| Name of Agency: | Work order No. | |
| Location: | | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: | |
| **Material Name:** | **Immersion Time** | **Type of Solution** |

| No. | Detail | Unit | Number of Cycle | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | Wt. Of clean dry aggregate of specified size range | Gms | | | | | | | | | | |
| 2 | Wt. of dry aggregate dried in oven after each cycle | Gms | | | | | | | | | | |
| 3 | Loss of aggregate after 10 number of cycles subject to immersion and oven drying after each cycle =(1)-(2) | Gms | | | | | | | | | | |
| 4 | Soundness Value =100*(3) / (1) | | | | | | | | | | | |

Average Value: _____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## FLAKINESS AND ELONGATION INDEX TEST

Format No.: IW-18 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location: | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |
| **Material Name:** | |

| Sieve Range (mm) | Total Wt. of Aggregate (gms) | Wt. Of Aggregate Passing Thickness Gauge | Flakiness Index | Wt. Of Non-flaky Sample | Wt. Of Aggregate Passing Elongation Gauge | Elongation Index | |
|---|---|---|---|---|---|---|---|
| 63-50 | | | | | | | |
| 50-40 | | | | | | | |
| 40-31.5 | | | | | | | |
| 31.5-25 | | | | | | | |
| 25-20 | | | | | | | |
| 20-16 | | | | | | | |
| 16-12.5 | | | | | | | |
| 12.5-10 | | | | | | | |
| 10-6.3 | | | | | | | |

Flakiness Index _____

Elongation Index _____

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

## GRADATION/SIEVE ANALYSIS

Format No.: IW-19 Lab Ref. No. _____

Date _____

| | |
|---|---|
| Name of work: | |
| Name of Agency: | Work order No. |
| Location: | |
| No: of Samples Tested: _____<br>Tested as per IS_____ | Sample collected on:<br>Tested on: |
| **Material Name:** | |

| Sieve No. | Sieve Size (mm) | Wt. Of material retained (g) | Retained on Each Sieve (% Wt) | Cumulative Percentage Retained | Passing Through (%Wt) | Grading Limits/Remarks |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Tested in presence of: ..... ..... .....

Comments of Laboratory in- Charge: _____

Signed & sealed by Laboratory-in- charge

# CHAPTER-VIII

## IMPORTANT SPECIFICATION AND PROCEDURES FOR TESTING

**STRUCTURAL WORKS**

**1. METHODS OF SITE EXPLORATION (IS: 1892-1979, Reaffirmed 1997): -**

**1.1.** Subsurface explorations should generally be carried out in two stages, that is, preliminary and detailed.

**1.1.1.** ***Preliminary Exploration:*** **-**The scope of preliminary exploration is restricted to the determination of depths, thickness, extent and composition of each soil stratum, location of rock and ground water and also to obtain approximate information regarding strength in compressibility of the various strata. When reconnaissance is not possible it is essential to carry out preliminary investigation to decide the method of approach of investigation. During preliminary investigation, geophysical methods and tests with cone penetrometers and sounding rods are useful guides.

**1.1.2.** ***Detailed Exploration:*** **-** Detailed investigations follow preliminary investigation and should be planned on the basis of data obtained during reconnaissance and preliminary investigations. This plan may require review as the investigations progress. The scope of detailed exploration is ordinarily restricted to the determination of engineering properties of strata which are shown by preliminary exploration to be critical. The object of detailed exploration is to determine shear strength and compressibility of all types of soils, density, density index, natural moisture content, and permeability. It may also be necessary to determine the pre-consolidation pressure of the strata from oedometer tests and to determine the consolidation characteristics beyond pre-consolidation pressure. Appropriate shear tests should also be conducted on samples subjected to ambient pressures beyond the pre-consolidation range also. The detailed investigation includes boring programme and detailed sampling to determine these properties. Field tests which may be performed are in-situ vane shear tests and plate load tests. The field permeability test and the test for the determination of dynamic properties of soils may also be conducted where necessary. All in-situ tests are to be supplemented by laboratory investigations.

**1.2. Tests for deep foundation: -**

**1.2.1.** Sections of trial boring, supplemented, wherever appropriate, by penetration tests, should incorporate data/information down to depth sufficiently below the anticipated level of founding of piles but this should generally be not less than 10 m beyond the pile founding level. The nature of the soil both around and beneath the proposed pile should be indicated on the basis of appropriate tests of strength, compressibility, etc. Ground water level and artesian conditions, if any, should also be recorded. Results of chemical tests to ascertain the sulphate, chloride and any other deleterious chemical content of soil and water should be indicated.

**1.2.2.** For piling work in water, as in the case of bridge foundation, data on high flood levels, water level during the working season, maximum depth of scour, etc., and in the case of marine construction, data on high and low tide level, corrosive action of chemicals present and data regarding flow of water should be provided.

**1.2.3.** Disturbed samples of soils may be obtained in the course of excavation and boring. The taking of disturbed samples of clay may result in the remoulding of the material and may render it unsuitable for shear strength measurements unless it is required for fill. Such samples are suitable for mechanical analysis and tests for index properties. These samples may not be truly representative, especially when taken from below the ground-water level. This is more so in the case of gravels containing a portion of fine sand, since the finer fractions tend to be washed off the sampler by the water.

**1.2.4.** Undisturbed Samples shall be obtained in such a manner that moisture content and structure do not get altered. That may be attained by careful protection and packing and by the use of a correctly designed sampler.

**1.2.5.** Routine load test should be done at foundations of bridges to reconfirm or modify the allowable loads.

## 2. CEMENT AND CONCRETE (IS:456 2000 AND OTHER CODES)

### 2.1. MATERIAL

**2.1.1.** **Cement: -**The Chemical and physical requirement of OPC should be as per **Table 2 and Table 3 of IS:269 2015** respectively.

**2.1.1.1.** ***Physical Properties: -***

***2.1.1.1.1.*** **Fineness Modulus (IS:4031 (Pt. 1) 1996): -**The fineness of cement is measured by sieving it on standard sieve. The proportion of cement of which the grain sizes are larger than the specified mesh size is thus determined. A reference sample having a known proportion of material coarser than the specified mesh size is used for checking the specified sieve.

***2.1.1.1.2.*** **Soundness of Cement (IS:4031 (Pt. 3) 1988): -**Soundness of cement may be determined by two methods, namely Le-Chatelier method and autoclave method.

***2.1.1.1.3.*** **Initial and Final Setting Time (IS:4031 (Pt. 5) 1988): -**The initial and final setting time for OPC of any grade except the sleeper variety should be 30 minutes and 600 minutes respectively. If cement exhibits false set, the ratio of the final penetration measured after 5 minutes of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall be not less than 50. In the cement of exhibiting false set, the initial and final setting time of cement when tested after breaking the false set, shall conform to the value as above.

***2.1.1.1.4.*** **Compressive Strength (IS:4031 (Pt. 6) 1988): -**

| Compressive Strength (MPa.) | OPC 33 | OPC43 | OPC 43S | OPC 53 | OPC 53S |
|---|---|---|---|---|---|
| 72 ± 1h. Min. | 16 | 23 | 23 | 27 | 27 |
| 168±2h. Min. | 22 | 33 | 37.5 | 37 | 37.5 |
| 672±4h. Min. | 33 | 43 | 43 | 53 | 53 |

| | | | | | |
|---|---|---|---|---|---|
| Max. | 48 | 58 | - | - | - |

Notwithstanding the compressive strength requirements specified above the cement shall show a progressive increase in strength from the strength at 72 h.

**2.1.2. <u>Fine and Coarse Aggregates (IS: 383 1970, Reaffirmed 2002): -</u>**Aggregates most of which (95% to 100%) pass through 4.75 mm IS Sieve are called Fine Aggregates. Aggregate most of which is retained on 4.75-mm IS Sieve are called Coarse Aggregates. The quality of aggregates should be as per IS:383.

**2.1.2.1.** ***General:*** **-**Aggregates shall consist of naturally occurring (crushed or uncrushed) stones, gravel and sand or combination thereof. They shall be hard, strong, dense, durable, clear and free from veins and adherent coating; and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible flaky, scoriaceous and elongated pieces should be avoided.

**2.1.2.2.** ***Deleterious Materials:*** **-**Aggregates shall not contain any harmful material, such as pyrites, coal, lignite, mica, shale or similar laminated material, clay, alkali, soft fragments, sea shells and organic impurities in such quantity as to affect the strength or durability of the concrete. Aggregates to. be used for reinforced concrete shall not contain any material liable to attack the steel reinforcement. Aggregates which are chemically reactive with alkalis of cement are harmful as cracking of concrete may take place.

**2.1.2.3.** ***Aggregate Crushing Value:*** **-**The aggregate crushing value, when determined in accordance with IS: 2386 (Part IV)-1963 shall not exceed 45 percent for aggregate used for concrete other than for wearing surfaces, and 30 percent for concrete for wearing surfaces, such as runways, roads and pavements.

**2.1.2.4.** ***Aggregate Abrasion Value:*** **-**Unless otherwise agreed to between the purchaser and the supplier, the abrasion value of aggregates, when tested in accordance with the method specified in IS:2386 (Part IV)- 1963 using Los Angeles machine, shall not exceed 30 percent for aggregates to be used in wearing surfaces and 50 percent for aggregates to be used in other concrete.

**2.1.2.5.** ***Soundness of Aggregates:*** **-**For concrete liable to be exposed the action of frost, coarse and fine aggregates shall pass a sodium or magnesium sulphate accelerated soundness test specified in IS: 2386 (Part V)-1963, the limits being set by agreement between the purchaser and the supplier, except that aggregates failing in the accelerated soundness test may be used if they pass a specified freezing and thawing test satisfactory to the user. As a general guideline, it may be taken that the average loss of weight after 5 cycles shall not exceed the following: -

| | |
|---|---|
| a) For Fine Aggregate | 10 per cent when tested with Sodium Sulphate ($Na_2SO_4$), and |
| | 15 per cent when tested with Magnesium Sulphate ($MgSO_4$). |
| b) For Coarse Aggregate | 12 per cent when tested with Sodium Sulphate ($Na_2SO_4$), and |
| | 18 per cent when tested with Magnesium Sulphate ($MgSO_4$). |

**2.1.2.6.** ***Size and Grading of Aggregates: -*** Coarse aggregates shall be supplied in the nominal sizes given in Table below. For any one of the nominal sizes, the proportion of other sizes, as determined by the method described in IS :2386 (Part I)-1963 shall also be in accordance with the Table.

| IS Sieve Designation | Percentage passing for Single-Sized Aggregate of Nominal Size | | | | | | Percentage passing for Graded Aggregate of Nominal Size | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 63 mm | 40 mm | 20 mm | 16 mm | 12.5 mm | 10 mm | 40 mm | 20 mm | 16 mm | 12.5 mm |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 80 mm | 100 | - | - | - | - | - | 100 | - | - | - |
| 63 mm | 85 to 100 | 100 | - | - | - | - | - | - | - | - |
| 40 mm | 0 to 30 | 85 to 100 | 100 | - | - | - | 95 to 100 | 100 | - | - |
| 20 mm | 0 to 5 | 0 to 20 | 85 to 100 | 100 | - | - | 30 to 70 | 95 to 100 | 100 | 100 |
| 16 mm | - | - | - | 85 to 100 | 100 | - | - | - | 90 to 100 | - |
| 12.5 mm | - | - | - | - | 85 to 100 | 100 | - | - | - | 90 to 100 |
| 10 mm | 0 to 5 | 0 to 5 | 0 to 20 | 0 to 30 | 0 to 45 | 85 to 100 | 10 to 35 | 25 to 55 | 30 to 70 | 40 to 85 |
| 4.75 mm | - | - | 0 to 5 | 0 to 5 | 0 to 10 | 0 to 20 | 0 to 5 | 0 to 10 | 0 to 10 | 0 to 10 |
| 2.36 mm | - | - | - | - | - | 0 to 5 | - | - | - | - |

The grading of fine aggregates, when determined shall be within the limits given in Table below and shall be described as fine aggregates, Grading Zones I, II, III and IV: Where the grading falls outside the limits of any particular grading zone of sieves other than 600-micron IS Sieve by a total amount not exceeding 5 percent, it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the600-micron IS Sieve or to percentage passing any other sieve size on the coarse limit of Grading Zone I or the finer limit of Grading Zone IV.

| IS Sieve Designation | Percentage Passing for | | | |
|---|---|---|---|---|
| | Grading Zone I | Grading Zone II | Grading Zone III | Grading Zone IV |
| 10 mm | 100 | 100 | 100 | 100 |
| 4.75 mm | 90 – 100 | 90 – 100 | 90 – 100 | 95 - 100 |
| 2.36 mm | 60 – 95 | 75 – 100 | 85 – 100 | 95 - 100 |
| 1.18 mm | 30 – 70 | 55 – 90 | 75 – 100 | 90 - 100 |
| 600 micron | 15 – 34 | 35 – 59 | 60 – 79 | 80 - 100 |
| 300 micron | 5 – 20 | 8 – 30 | 12 – 40 | 15 - 50 |
| 150 micron | 0 -10 | 0 – 10 | 0 – 10 | 0 - 15 |

If combined aggregates (All-in-Aggregates) are available, they need not be separated into fine and coarse, but necessary adjustments may be made in the grading by the addition of single-sized aggregates. The grading of the all-in-aggregate, when analysed, shall be in accordance with Table below: -

| IS Sieve Designation | Percentage passing for All-in-Aggregate of | |
|---|---|---|
| | 40 mm Nominal size | 20 mm Nominal Size |
| 80 mm | 100 | |
| 40 mm | 95 to 100 | 100 |
| 20 mm | 45 to 75 | 95 to 100 |
| 4.75 mm | 25 to 45 | 30 to 50 |
| 600 micron | 8 to 30 | 10 to 35 |
| 150 micron | 0 to 6 | 0 to 6 |

**2.1.3.** **Reinforcement: -**All Reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances which may destroy or reduce bonds. Sand blasting or other treatment is recommended to clean reinforcement. Reinforcement shall be of HYSD Bars (Fe415, Fe500, Fe550) or Mild Steel (Fe250).

**2.1.3.1.** ***High Yield Strength Deformed (HYSD) Bars:*** **-** For high strength bars whose pattern of deformation is such that by visual inspection, the cross-sectional area is substantially uniform along the length of the bar/wire, the effective cross-sectional area shall be the gross sectional area determined as follows, using a bar/wire not less than 0.5 m in length:

Gross Cross Sectional Area in $mm^2$ $=\omega/0.00785L$

Where,

$\omega$ = mass in kg weighed to a precision of ± 0.5 percent, and

L = length measured to a precision of ± 0.5 percent.

Cross sectional area and mass shall be as per table below: -

| Nominal Size (mm) | Cross Sectional Area ($mm^2$) | Mass per Metre run (kg) |
|---|---|---|
| 8 | 50.3 | 0.395 |
| 10 | 78.6 | 0.617 |
| 12 | 113.1 | 0.888 |
| 16 | 201.2 | 1.58 |
| 20 | 314.3 | 2.47 |
| 25 | 491.1 | 3.85 |
| 28 | 616 | 4.83 |
| 32 | 804.6 | 6.31 |

Proof stress, percentage elongation and tensile strength for all sizes of deformed bars/wires determined on effective cross-sectional area shall be as specified in Table below: -

| Sl. No | Property | GRADE | | |
|---|---|---|---|---|
| | | Fe 415 | Fe 515 | Fe 550 |
| 1 | 2 | 3 | 4 | 5 |
| i) | 0.2 percent proof stress/yield stress, Min, $N/mm^2$ | 415.0 | 515.0 | 550.0 |
| ii) | Elongation, percent, Min, on gauge length 5.65 √A, where A is the cross-sectional area of the test piece | 14.5 | 12.0 | 8.0 |
| iii) | Tensile strength, Min | 10 percent more than the actual 0.2 percent proof stress but not less than 485.0 $N/mm^2$ | 8 percent more than the actual 0.2 percent proof stress but not less than 545.0 $N/mm^2$ | 6 percent more than the actual 0.2 percent proof stress but not less than 585.0 $N/mm^2$ |

The reinforcement shall withstand the Bend Stress and Rebend Stress as per Cl 8.3 and 8.4 of IS: 1786.

***2.1.3.1.1.*** All test pieces shall be selected by the purchaser or his authorized representative, either from the cuttings of bars/wires; or if, he so desires, from any bar/wire after it has been cut to the required or specified size and the test piece taken from any part of it. In neither case, the test piece shall be detached from the bar/wire except in the presence of the purchaser or his authorized representative.

***2.1.3.1.2.*** The test pieces obtained shall be full sections of the bars/wires and shall be subjected to physical tests without any further modifications. No reduction in size by machining or otherwise shall be permissible, except in case of bars of size .28 mm and above.

***2.1.3.1.3.*** No test piece shall be annealed or otherwise subjected to heat treatment except test pieces may be subjected to artificial ageing at a temperature not exceeding 100°C and for a period not exceeding 2 hours. Any straightening which a test piece may require shall be done cold.

***2.1.3.1.4.*** For the purpose of carrying out tests for tensile strength, proof stress and percentage elongation for bars 28 mm in diameter and above, deformations of the bars only may be machined. For such bars, the physical properties shall be calculated using the actual area obtained after machining.

***2.1.3.1.5.*** Before the test pieces are selected, the manufacturer or supplier shall furnish the purchaser or his authorized representative with copies of the mill records giving the mass of bars/wires in each bundle/cast with sizes as well as the identification marks, whereby the bars/wires from that cast can be identified.

***2.1.3.1.6.*** The bend test shall be performed in accordance with the requirements of IS: 1599-1974 and the mandrel diameter shall be as specified in Table below. The specimen shall be considered to have passed the test if there is no transverse crack in the bent portion.

| Nominal size (mm) | MANDREL DIAMETER FOR DIFFERENT GRADES | | |
|---|---|---|---|
| | Fe 415 | Fe 500 | Fe 550 |
| 1 | 2 | 3 | 4 |
| Up to and including 22 | 3ϕ | 4ϕ | 5ϕ |
| Over 22 | 4ϕ | 5ϕ | 6ϕ |

Where, ϕ is the nominal size in mm of the test piece.

***2.1.3.1.7.*** Rebend test piece shall be bent to an included angle of 135o using a mandrel of appropriate diameter (5 to 8 ϕ). The bent piece shall be aged by keeping in boiling water (100°C) for 30 minutes and then allowed to cool. The piece shall then be bent back to have an included angle of 157.5$^{o}$. The specimen shall be considered to have passed the test if there is no fracture in the bent portion.

**2.1.3.2.** ***Mild Steel Plain Bars:*** -The ultimate tensile stress, yield stress and elongation of bars shall be as per table below. The test pieces shall be cut from finished material and straightened where necessary. They shall not be annealed or otherwise subjected to heat treatment. Any slight straightening which may be required shall be done cold.

| SL NO | TYPE AND NOMINAL SIZE OF BAR | ULTIMATE TENSILE STRENGTH *MIN* | YIELD STRESS *MIN* | ELONGATION PERCENT *MIN* |
|---|---|---|---|---|
| 1 | *Mild Steel Grade I* | | | |
| | For bars up to and including 20 mm | 410 | 250 | 23 |
| | For bars over 20 mm and up to and including 50 mm | 410 | 240 | 23 |
| 2 | *Mild Steel Grade II* | | | |
| | For bars, up to and including 20 mm | 370 | 225 | 23 |
| | For bars over 20 mm and up to and including 50 mm | 370 | 215 | 23 |

**2.1.4.** **Admixtures: -**Admixtures, if used shall comply with IS: 9103. Previous experience with and data on such materials should be considered in relation to the likely standards of supervision and workmanship to the work being specified.

**2.1.4.1.** Admixtures should not impair durability of concrete nor combine with the constituent to form harmful compounds nor increase the risk of corrosion of reinforcement.

**2.1.4.2.** The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures.

**2.1.4.3.** The chloride content of Admixtures shall be independently tested for each batch before acceptance.

**2.1.4.4.** If two or more admixtures are used simultaneously in the same concrete, data should be obtained to assess their interaction and ensure their compatibility.

**2.1.5.** **Storage of Materials: -**For any site, there should be proper planning of the layout for stacking and storage of different materials, components and equipment with proper access and proper manoeuvrability of the vehicles carrying the material. While planning the layout, the requirements of various materials, components and equipment at different stages of construction shall be considered.

**2.1.5.1.** ***Cement:*** **-**Cement is generally received in bags.

***2.1.5.1.1.*** Cement shall be stored at the work site in a building or a shed which is dry, leakproof and as moisture-proof as possible. The building or shed for storage should have minimum number of windows and close fitting doors and these should be kept closed as far as possible.

***2.1.5.1.2.*** Cement shall be stored and stacked in bags and shall be kept free from the possibility of any dampness or moisture coming in contact with them. Cement bags shall be stacked off the floor on wooden planks in such a way as to keep about 150 mm to 200 mm clear above the floor. The floor may comprise of lean cement concrete or two layers of dry bricks laid on well consolidated earth. A space of 600 mm minimum shall be left all-round between the exterior walls and the stacks. In the stacks the cement bags shall be kept close together to reduce circulation of air as much as possible. Owing to pressure on the bottom layer of bags sometimes ‘warehouse pack’ is developed in these bags. This can be removed easily by rolling the bags when the cement is taken out for use. Lumped bags, if any should be removed and disposed of.

***2.1.5.1.3.*** The height of stack shall not be more than 10 bags to prevent the possibility of lumping up under pressure. The width of the stack shall be not more than four bags length or 3 metres.

***2.1.5.1.4.*** For extra safety during the monsoon, or when it is expected to store for an unusually long period, the stack shall be completely enclosed by a waterproofing membrane such as polyethylene, which shall close on the top of the stack. Care shall be taken to see that the waterproofing membrane is not damaged any time during use.

**2.1.5.2.** ***Aggregates: -***

***2.1.5.2.1.*** Aggregates shall be stored at site on a hard dry and level patch of ground. If such a surface is not available, a platform of planks or old corrugated iron sheets, or a floor of bricks, or a thin layer of lean concrete shall be made so as to prevent contamination with clay, dust, vegetable and other foreign matter.

***2.1.5.2.2.*** Stacks of fine and coarse aggregates shall be kept in separate stock piles sufficiently removed from each other to prevent the material at the edges of the piles from getting intermixed. On a large job, it is desirable to construct dividing walls to give each type of aggregates its own compartment. Fine aggregates shall be stacked in a place where loss due to the effect of wind is minimum.

***2.1.5.2.3.*** Unless specified otherwise or necessitated by site conditions stacking of the aggregates should be carried out in regular stacks.

**2.1.5.3.** ***Steel: -***

***2.1.5.3.1.*** For each classification of steel, separate areas shall be earmarked. It is desirable that ends of bars and sections of each class be painted in distinct separate colours.

***2.1.5.3.2.*** Steel reinforcement shall ordinarily be stored in such a way as to avoid distortion and to prevent deterioration and corrosion. It is desirable to coat reinforcement with cement wash before stacking to prevent scaling and rusting.

***2.1.5.3.3.*** Bars of different classification, sizes and lengths shall be stored separately to facilitate issues in such sizes and lengths so as to minimize wastage in cutting from standard lengths.

***2.1.5.3.4.*** In case of long storage, reinforcement bars shall be stacked above ground level by at least 150 mm. Also in coastal areas or in case of long storage a coat of cement wash shall be given to prevent scaling and rusting.

***2.1.5.3.5.*** Structural steel of different classification, sizes and lengths shall be stored separately. It shall be stored above ground level by at least 150 mm upon platforms, skids or any other suitable supports to avoid distortion of sections. In coastal areas or in case of long storage suitable protective coating of primer paint shall be given to prevent scaling and rusting.

**2.1.5.4.** ***Bricks (IS: 1077 1992, Reaffirmed 2007): -***

***2.1.5.4.1.*** The common burnt clay bricks shall be classified on the basis of average compressive strength as given in Table.

| **Classes of common Burnt Clay Bricks** | |
|---|---|
| **Class Designation** | **Average Compressive Strength ($N/mm^2$)** |
| 35 | 35.0 |
| 30 | 30.0 |
| 25 | 25.0 |
| 20 | 20.0 |
| 17.5 | 17.5 |
| 15 | 15.0 |
| 12.5 | 12.5 |
| 10 | 10.0 |
| 7.5 | 7.5 |
| 5 | 5.0 |
| 3.5 | 3.5 |

***2.1.5.4.2. General Quality: -***

a) Bricks shall be hand-moulded or machine moulded and shall be made from suitable soils. They shall be free from cracks and flaws and nodules of free lime.

b) Hand-moulded bricks of 90 mm or 70 mm height shall be moulded with a frog 10 to 20 mm deep on one of its flat sides.

c) Bricks of 40 mm height as well as those made by extrusion process may not be provided with frogs.

d) The bricks shall have smooth rectangular faces with sharp corners and shall be uniform in colour.

***2.1.5.4.3. Dimensions and Tolerances: -***

a) The standard modular building bricks shall be as follows:

| *Length (L)* | *Width (W)* | *Height (H)* |
|---|---|---|
| mm | mm | mm |
| 190 | 90 | 90 |
| 190 | 90 | 40 |

b) The following non-modular sizes of the bricks may also be used:

| Length (L) | Width (W) | Height (H) |
|---|---|---|
| mm | mm | mm |
| 230 | 110 | 70 |
| 230 | 110 | 30 |

c) For obtaining proper bond arrangement and modular dimensions for the brick work, with the non-modular sizes, the following sizes of the bricks may also be used:

| Length (L) mm | Width (W) mm | Height (H) mm |
|---|---|---|
| 70 | 110 | 70 ⅓ length brick |

## 2.2. CONCRETE: -

**2.2.1. <u>Grade of Concrete: -</u>** The concrete shall be in grades designated as per Table below:

| Group | Grade Designation | Specified Characteristic Compressive Strength of 150 mm Cube at 28 days in N/mm$^2$ |
|---|---|---|
| 1 | 2 | 3 |
| Ordinary Concrete | M10 | 10 |
| | M15 | 15 |
| | M20 | 20 |
| Standard Concrete | M25 | 25 |
| | M30 | 30 |
| | M35 | 35 |
| | M40 | 40 |
| | M45 | 45 |
| | M50 | 50 |
| | M55 | 55 |
| High Strength Concrete | M60 | 60 |
| | M65 | 65 |
| | M70 | 70 |
| | M75 | 75 |
| | M80 | 80 |

The minimum grade for Plain and Reinforced concrete shall be as per table below. Concrete of grades lower than those given in Table may be used for plain concrete constructions, lean concrete, simple foundations, foundation for masonry walls and other simple or temporary reinforced concrete construction.

**Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size (Clauses 6.1.2, 8.2.4.1 and 9.1.2 of IS:456 2000)**

| Sl No. | Exposer | Plain Concrete | | | Reinforced Concrete | | |
|---|---|---|---|---|---|---|---|
| | | Minimum Cement Content kg/m$^3$ | Maximum Free Water-Cement Ratio | Minimum Grade of Concrete | Minimum Cement Content kg/m$^3$ | Maximum Free Water-Cement Ratio | Minimum Grade of Concrete |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| (i) | Mild | 220 | 0.60 | - | 300 | 0.55 | M20 |
| (ii) | Modera | 240 | 0.60 | M15 | 300 | 0.50 | M25 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | te | | | | | | |
| (iii) | Severe | 250 | 0.50 | M20 | 320 | 0.45 | M30 |
| (iv) | Very Severe | 260 | 0.45 | M20 | 340 | 0.45 | M35 |
| (v) | Extreme | 280 | 0.40 | M25 | 360 | 0.40 | M40 |

Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions of pozzolana, fly ash, Silica fume and rice husk ash, Metakaolin, Ground Granulated Blast furnace slag. The additions should be done with the approval with the deciding authority. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolana and slag specified in IS 1489 (Part I) and IS 455 respectively.

**Adjustments to Minimum Cement Contents for Aggregates Other Than 20 mm Nominal Maximum Size**

| **Sl No.** | **Nominal Maximum Aggregate size** (mm) | **Adjustment to minimum cement contents in the above table** $Kg/m^3$ |
|---|---|---|
| 1 | 2 | 3 |
| (i) | 10 | + 40 |
| (ii) | 20 | 0 |
| (iii) | 40 | - 30 |

**2.2.2. Workability of Concrete: -**The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below: -

| *Placing Condition* | *Degree of Workability* | *Slump (mm)* |
|---|---|---|
| 1 | 2 | 3 |
| Blinding Concrete | Very Low | In the 'very low' category of workability where strict control is necessary, for example pavement quality concrete, measurement of workability by determination of compacting factor will be more appropriate than slump and a value of compacting factor of 0.75 to 0.80 is suggested. |
| Shallow Sections | | |
| Pavement using pavers | | |
| Mass Concrete | Low | 25 - 75 |
| Lightly reinforced sections in slabs, beams, walls, | | |

| *Placing Condition* | *Degree of Workability* | *Slump (mm)* |
|---|---|---|
| columns | | |
| Floors | | |
| Hand placed pavements | | |
| Canal Lining | | |
| Strip Footings | | |
| Heavily reinforced sections in slabs, beams, walls, columns | Medium | 50 - 100 |
| Slipform work | | 75 - 100 |
| Pumped concrete | | |
| Trench Fill | High | 100 - 150 |
| *In-situ* piling | Very High | In the 'very high' category of workability, measurement of workability by determination of flow will be appropriate. |
| Tremie Concrete | | |

**2.2.3. Durability of Concrete: -**A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

**2.2.3.1. Factors Affecting Durability: -**One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship used in making the concrete. with normal-weight aggregates a suitably low permeability is achieved by having an adequate cement content, sufficiently low free water/cement ratio, by ensuring complete compaction of the concrete, and by adequate curing. The factors influencing durability include:

***2.2.3.1.1.*** The environment,

***2.2.3.1.2.*** The cover to embedded steel,

***2.2.3.1.3.*** The type and quality of constituent materials,

***2.2.3.1.4.*** The cement content and water/cement ratio of the concrete,

***2.2.3.1.5.*** Workmanship, to obtain full compaction and efficient curing, and

***2.2.3.1.6.*** The shape and size of the member.

**2.2.3.2. Requirement of Durability: -**

***2.2.3.2.1.*** Care should be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to avoid the harmful effects of early loss of moisture (**see 2.2.3.5**). Member profiles and their intersections with other members shall be designed and detailed in a way to ensure easy flow of concrete and proper compaction during concreting.

***2.2.3.2.2.*** Concrete is more vulnerable to deterioration due to chemical or climatic attack when it is in thin sections, in sections under hydrostatic pressure from one side only, in partially immersed sections and at corners and edges of elements.

**2.2.3.3. Exposer to Sulphate Attack: -**The table below gives recommendation for the type of cement maximum free water/cement ratio and minimum cement content, which are required at different sulphate concentrations in near-neutral ground water having *pH* of 6 to 9. For the very high sulphate concentrations in Class 5 conditions, some form of lining such as polyethylene or polychloroprene sheet; or surface coating based on asphalt, chlorinated rubber, epoxy; or polyurethane materials should also be used to prevent access by the sulphate solution.

| Sl No | Class | Concentration Sulphates Expressed as $SO_3$ | | | Type of Cement | Dense, Fully Compacted concrete. Made with 20 mm Nominal Maximum Size Aggregates Complying with IS 383 | |
|---|---|---|---|---|---|---|---|
| | | In Soils | | In Ground Water | | Minimum Cement Content $Kg/m^3$ | Maximum Free Water-Cement Ratio |
| | | percent | g/l | g/l | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| (i) | 1 | < 0.20 | < 1.0 | < 0.3 | OPC/PSC/PPC | 280 | 0.55 |
| (ii) | 2 | 0.2 - 0.5 | 1 - 1.9 | 0.3 - 1.2 | OPC/PSC/PPC | 330 | 0.50 |
| | | | | | Supersulphated Cement/Sulphate resisting Portland Cement | 310 | 0.50 |
| (iii) | 3 | 0.5 - 1.0 | 1.9 - 3.1 | 1.2 - 2.5 | PPC/PSC | 330 | 0.50 |
| | | | | | Supersulphated Cement/ Sulphate resisting Portland Cement | 350 | 0.45 |
| (iv) | 4 | 1.0 - 2.0 | 3.1 - 5 | 2.5 – 5 | Supersulphated Cement/Sulphate resisting Portland Cement | 370 | 0.45 |
| (v) | 5 | > 2.0 | > 5.0 | > 5.0 | Supersulphated Cement with coating/Sulphate resisting Portland Cement | 400 | 0.40 |

| Sl No | Class | Concentration Sulphates Expressed as $SO_3$ | | | Type of Cement | Dense, Fully Compacted concrete. Made with 20 mm Nominal Maximum Size Aggregates Complying with IS 383 | |
|---|---|---|---|---|---|---|---|
| | | In Soils | | In Ground Water | | Minimum Cement Content $Kg/m^3$ | Maximum Free Water-Cement Ratio |
| | | percent | g/l | g/l | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Cement content given in this Table is irrespective of Grade of Cement. | | | | | | | |

**2.2.3.4. Drainage: -**At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete. Additional protection may be obtained by the use of chemically resistant stone facing or a layer of plaster of Paris covered with suitable fabric, such as jute thoroughly impregnated with bituminous material.

**2.2.3.5. Compaction, Finishing and Curing: -** Adequate compaction without segregation should be ensured by providing suitable workability and by employing appropriate placing and compacting equipment and procedures. Full compaction is particularly important in the vicinity of construction and movement joints and of embedded water bars and reinforcement.

a) *Good finishing practices are essential for durable concrete.*

b) *Overworking the surface and the addition of water/ cement to aid in finishing should be avoided; the resulting laitance will have impaired strength and durability and will be particularly vulnerable to freezing and thawing under wet conditions.*

c) *It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete and enhance its durability by extending the hydration of the cement, particularly in its surface zone.*

**2.2.3.6. Concrete in Sea-water: -**Concrete in sea-water or exposed directly along the sea-coast shall be at least M 20 Grade in the case of plain concrete and M 30 in case of reinforced concrete. The use of slag or pozzolana cement is advantageous under such conditions.

a) *Special attention shall be given to the design of the mix to obtain the densest possible concrete; slag, broken brick, soft limestone, soft sandstone, or other porous or weak aggregates shall not be used.*

b) *As far as possible, preference shall be given to precast members unreinforced, well-cured and hardened, without sharp corners, and having trowel- smooth*

*finished surfaces free from crazing, cracks or other defects; plastering should be avoided.*

c) *No construction joints shall be allowed within 600 mm below low water-level or within 600 mm of the upper and lower planes of wave action. Where unusually severe conditions or abrasion are anticipated, such parts of the work shall be protected by bituminous or silico-fluoride coatings or stone facing bedded with bitumen.*

d) *In reinforced concrete structures, care shall be taken to protect the reinforcement from exposure to saline atmosphere during storage, fabrication and use. It may be achieved by treating the surface of reinforcement with cement wash or by suitable methods.*

**2.2.4. MIX PROPORTION: -**The proportions shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish. The determination of the proportion of cement, aggregates and water to attain required strengths shall be made as follows:

**2.2.4.1.** By designing the concrete mix; such concrete shall be called 'Design mix concrete', or

**2.2.4.2.** By adopting nominal concrete mix: such concrete shall be called 'Nominal mix concrete.

Design Mix concrete is preferred to nominal mix. If design mix concrete cannot be used for any reason on the work for grades of M 20 or lower, nominal mixes may be used with the permission of engineer-in-charge which, however, is likely to involve higher cement content.

**2.2.4.3.** ***Information Required:*** **-**In specifying a particular grade of concrete, the following information shall be included:

***2.2.4.3.1.*** Type of mix, that is, design mix concrete or nominal mix concrete;

***2.2.4.3.2.*** Grade designation;

***2.2.4.3.3.*** Type of cement;

***2.2.4.3.4.*** Maximum nominal size of aggregate;

***2.2.4.3.5.*** Minimum cement content (for design mix concrete);

***2.2.4.3.6.*** Maximum water-cement ratio;

***2.2.4.3.7.*** Workability;

***2.2.4.3.8.*** Mix proportion (for nominal mix concrete);

***2.2.4.3.9.*** Exposure conditions as per Tables above;

***2.2.4.3.10.*** Maximum temperature of concrete at the time of placing;

***2.2.4.3.11.*** Method of placing; and

***2.2.4.3.12.*** Degree of supervision.

**2.2.4.4.** In appropriate circumstances, the following additional information may be specified:

***2.2.4.4.1.*** Type of aggregate,

***2.2.4.4.2.*** Maximum cement content, and

***2.2.4.4.3.*** Whether an admixture shall or shall not be used and the type of admixture and the condition of use.

## 2.2.5. DESIGN MIX CONCRETE: -

**2.2.5.1.** As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer within the limitations of parameters and other stipulations laid down by this standard.

**2.2.5.2.** The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than appropriate value given in**2.2.1**. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

**2.2.5.3.** Mix design done earlier not prior to one year may be considered adequate for later work provided there is no change in source and the quality of the materials.

**2.2.5.4.** Standard Deviation: - The standard deviation for each grade of concrete shall be calculated, separately.

***2.2.5.4.1.*** Standard deviation based on test strength of sample

a) *Number of test results of samples—The total number of test strength of samples required to constitute an acceptable record for calculation of standard deviation shall be not less than 30. Attempts should be made to obtain the 30 samples, as early as possible, when a mix is used for the first time.*

b) *In case of significant changes in concrete— When significant changes are made in the production of concrete batches (for example changes in the materials used, mix design, equipment or technical control), the standard deviation value shall be separately calculated for such batches of concrete.*

c) *Standard deviation to be brought up to date— The calculation of the standard deviation shall be brought up to date after every change of mix design.*

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

| Grade of Concrete | Assumed Standard Deviation/$mm^2$ |
|---|---|
| M10 | 3.4 |
| M15 | |
| M20 | 4.0 |
| M25 | |
| M30 | 5.0 |
| M35 | |
| M40 | |
| M45 | |
| M50 | |

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

**2.2.6. NOMINAL MIX DESIGN: -**Nominal mix concrete may be used for concrete of M 20 or lower. The proportions of materials for nominal mix concrete shall be in accordance with Table below.

**2.2.6.1.** The cement content of the mix specified in Table for any nominal mix shall be proportionately increased if the quantity of water in a mix has to be increased to overcome the difficulties of placement and compaction, so that the water-cement ratio as specified is not exceeded.

| GRADE OF CONCRETE | TOTAL QUANTITY OF DRY AGGREGATES BY MASS PER 50 KG OF CEMENT, TO BE TAKEN AS SUM OF THE INDIVIDUAL MASSES OF FINE AND COARSE AGGREGATES, KG,*MAX* | PROPORTION OF FINE AGGREGATES TO COARSE AGGREGATES (by mass) | QUANTITY OF WATER PER 50 KG OF CEMENT, *MAX* l |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| M5 | 800 | Generally, 1:2 but subject to an upper limit of 1:1½ and a lower limit of 1:2½. | 60 |
| M7.5 | 625 | | 45 |
| M10 | 480 | | 34 |
| M15 | 330 | | 32 |
| M20 | 250 | | 30 |

NOTE: - The proportion of the fine to coarse aggregates should be adjusted from upper limit to lower limit progressively as the grading of fine aggregates becomes finer and the maximum size of coarse aggregates becomes larger, graded coarse aggregate shall be used.
EXAMPLE: - For an average grading of fine aggregate (that is. Zone II of Table 4 of IS: 383), the proportions shall be 1: 1½, 1:2 and 1:2½formaximum size of aggregates 10mm, 20 mm and40mm respectively.

**2.2.7. PRODUCTION OF CONCRETE: -**

**2.2.7.1.** ***Quality Assurance Measures: -***

***2.2.7.1.1.*** In order that the properties of the completed structure be consistent with the requirements and the assumptions made during the planning and the design, adequate quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long term durability so as to lower the overall life-cycle cost. Quality assurance in construction activity relates to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care during the use of structure including timely maintenance and repair by the owner.

***2.2.7.1.2.*** Quality assurance measures are both technical and organizational. Some common cases should be specified in a general Quality Assurance Plan which shall identify the key elements necessary to provide fitness of the structure and the means by which they are to be provided and measured with the overall purpose to provide confidence that the realized project will work satisfactorily in service fulfilling intended needs. The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of hatching, mixing, transportation, placing, compaction and curing; and the related plant, machinery and equipment; resulting in the output in the form of concrete in place. To ensure proper performance, it is necessary that each step-in concreting which will be covered by the next step is inspected as the work proceeds (**see also 2.2.14**). Each party involved in the realization of a project should establish and implement a Quality Assurance Plan, for its participation in the project. Supplier's and subcontractor's activities shall be covered in the plan. The individual Quality Assurance Plans shall fit into the general Quality Assurance Plan. A Quality Assurance Plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures, and the organization and maintaining adequate documentation of the building process and its results. Such documentation should generally include:

a) *Test reports and manufacturer's certificate for materials, concrete mix design details;*

b) *Record of site inspection of workmanship, field tests;*

c) *Non-conformance reports, change orders;*

d) *Quality control charts; and*

e) *Statistical analysis.*

NOTE—Quality control charts are recommended wherever the concrete is in continuous production over considerable period.

**2.2.7.2.** ***Batching:*** -To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (see also IS 4925).

Ready-mixed concrete supplied by ready-mixed concrete plant shall be preferred. For large and medium project sites the concrete shall be sourced from ready- mixed concrete plants or from on site or off site batching and mixing plants *(see* IS 4926).

***2.2.7.2.1.*** Except where it can be shown to the satisfaction of the engineer-in-charge that supply of properly graded aggregate of uniform quality can be maintained over a period of work, the grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions when required, the different sizes being stocked in separate stock-piles. The material should be stock-piled for several hours preferably a day before use. The grading of coarse and fine aggregate should be checked as

frequently as possible, the frequency for a given job being determined by the engineer-in--charge to ensure that the specified grading is maintained.

***2.2.7.2.2.*** The accuracy of the measuring equipment shall be within ± 2 percent of the quantity of cement being measured and within ± 3 percent of the quantity of aggregate, admixtures and water being measured.

***2.2.7.2.3.*** Proportion/Type and grading of aggregates shall be made by trial in such a way so as to obtain densest possible concrete. All ingredients of the concrete should be used by mass only.

***2.2.7.2.4.*** Volume batching may be allowed only where weigh-batching is not practical and provided accurate bulk densities of materials to be actually used in concrete have earlier been established. Allowance for bulking shall be made in accordance with IS 2386 (Part 3). The mass volume relationship should be checked as frequently as necessary, the frequency for the given job being determined by engineer-in-charge to ensure that the specified grading is maintained.

***2.2.7.2.5.*** It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the engineer-in-charge according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates, IS 2386 (Part 3) may be referred to. To allow for the variation in mass of aggregate due to variation in their moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of exact data, only in the case of nominal mixes, the amount of surface water may be estimated from the values given in Table below: -

| SL NO. | AGGREGATE | APPROXIMATE QUANTITY OF SURFACE WATER | |
|---|---|---|---|
| | | Percent by Mass | $l/m^3$ |
| (1) | (2) | (3) | (4) |
| 1 | Very wet sand | 7.5 | 120 |
| 2 | Moderately Wet Sand | 5.0 | 80 |
| 3 | Moist Sand | 2.5 | 40 |
| 4 | Moist Gravel or Crushed Rock | 1.25 - 2.5 | 20 - 40 |
| Coarser the aggregate, less the water it will carry. | | | |

***2.2.7.2.6.*** No substitutions in materials used on the work or alterations in the established proportions, except as permitted in **2.2.7.2.4**and **2.2.7.2.5**shall be made without additional tests to show that the quality and strength of concrete are satisfactory.

**2.2.7.3.** ***Mixing:*** -Concrete shall be mixed in a mechanical mixer. The mixer should comply with IS 1791 and IS 12119. The mixers shall be fitted with water measuring (metering) devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete should be remixed**.**

***2.2.7.3.1.*** For guidance, the mixing time shall be at least 2 min. for other types of more efficient mixers, manufacturers recommendations shall be followed; for hydrophobic cement, it may be decided by the engineer-in-charge.

***2.2.7.3.2.*** Workability should be checked at frequent intervals.

***2.2.7.3.3.*** Dosages of retarders, plasticisers and super plasticisers shall be restricted to 0.5 1.0 and 2.0 percent respectively by weight of cementitious materials and unless a higher value is agreed upon between the manufacturer and the constructor based on performance test.

## 2.2.8. FORMWORK: -

**2.2.8.1.** ***General:*** **-**The formwork shall be designed and constructed so as to remain sufficiently rigid during placing and compaction of concrete, and shall be such as to prevent loss of slurry from the concrete. For further details regarding design, detailing, etc., reference may be made to IS 14687.The tolerances on the shapes, lines and dimensions shown in the drawing shall be within the limits given below:

| | | | |
|---|---|---|---|
| a) | Deviation from specified dimension of cross-section of columns and beams | +12<br>-6 | mm |
| b) | Deviations from dimensions of footings | | |
| | 1) Dimension in plan | +50<br>-12 | mm |
| | 2) Eccentricity | 0.02 times the width of footing in the direction of deviation but not more than 50 mm. | |
| | 3) Thickness | ±05 times the specified thickness. | |

The tolerance applies to concrete dimensions only, and not to positioning of vertical reinforcing steel or dowels.

**2.2.8.2.** ***Cleaning and Treatment of Formwork:*** **-**All rubbish, particularly chippings, shavings and saw dust shall be removed from the interior of the forms before the concrete is placed. The face of formwork in contact with the concrete shall be cleaned and treated with form release agent. Release agents should be applied so as to provide a thin uniform coating to the forms without coating the reinforcement.

**2.2.8.3.** ***Stripping Time:*** **-** Forms shall not be released until the concrete has achieved strength of at least twice the stress to which the concrete may be subjected at the time of removal of formwork. The strength referred to shall be that of concrete using the same cement and aggregates and admixture, if any, with the same proportions and cured under conditions of temperature and moisture similar to those existing on the work.

***2.2.8.3.1.*** While the While the above criteria of strength shall be the guiding factor for removal of formwork, in normal circumstances where ambient temperature does not fall below 15°C and where ordinary Portland cement is used and adequate curing is done, following striking period may deem to satisfy the guideline given in **2.2.8.3**

| *TYPE OF FORMWORK* | | MINIMUM PERIOD BEFORE STRIKING FORMWORK |
|---|---|---|
| a) | Vertical Formwork to columns, walls and beams | 16 - 24 hours |
| b) | Soffit Formwork to slabs<br>(Props to be re-fixed immediately after removal of formwork) | 3 days |
| c) | Soffit Formwork to beams<br>(Props to be re-fixed immediately after removal of formwork) | 7 days |
| d) | Props to Slabs: | |
| | 1. Spanning up to 4.50 m | 7 days |
| | 2. Spanning over 4.50 m | 14 days |
| e) | Props to beams and arches: | |
| | 1. Spanning up to 6.0 m | 14 days |
| | 2. Spanning over 6.0 m | 21 days |

For other cements and lower temperature, the stripping time recommended above may be suitably modified.

***2.2.8.3.2.*** The number of props left under, their sizes and disposition shall be such as to be able to safely carry the full dead load of the slab, beam or arch as the case may be together with any live load likely to occur during curing or further construction.

***2.2.8.3.3.*** Where the shape of the element is such that the formwork has re-entrant angles, the formwork shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking occurring due to the restraint imposed.

### 2.2.9. ASSEMBLY OF REINFORCEMENT: -

**2.2.9.1.** Reinforcement shall be bent and fixed in accordance with procedure specified in IS 2502. The high strength deformed steel bars should not be re-bent or straightened without the approval of engineer-in-charge.

**2.2.9.2.** All reinforcement shall be placed and maintained in the position shown in the drawings by providing proper cover blocks, spacers, supporting bars, etc.

**2.2.9.3.** Crossing bars should not be tack-welded for assembly of reinforcement unless permitted by engineer-in-charge.

**2.2.9.4.** ***Placing of Reinforcement:*** -Rough handling, shock loading (prior to embedment) and the dropping of reinforcement from a height should be avoided. Reinforcement should be secured against displacement outside the specified limits.

***2.2.9.4.1.*** *Tolerances on Placing of Reinforcement:* -Unless otherwise specified by engineer-in-charge, the reinforcement shall he placed within the following tolerances:

a) *for effective depth 200 mm or less ±10 mm*

b) *for effective depth, more than 200 mm ±15 mm*

***2.2.9.4.2.*** *Tolerance for Cover:* - Unless specified otherwise, actual concrete cover should not deviate from required nominal cover by ± 10.0 mm.

***2.2.9.4.3.*** Where reinforcement bars upto 12 mm for high strength deformed steel bars and up to 16 mm for mild steel bars are bent aside at construction joints and afterwards bent back into their original positions, care should be taken to ensure that at no time is the radius of the bend less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Care shall also be taken when bending back bars, to ensure that the concrete around the bar is not damaged beyond the band.

***2.2.9.4.4.*** Reinforcement should be placed and tied in such a way that concrete placement be possible without segregation of the mix. Reinforcement placing should allow compaction by immersion vibrator. Within the concrete mass, different types of metal in contact should be avoided to ensure that bimetal corrosion does not take place.

## 2.2.10. TRANSPORTING, PLACING, COMPACTION AND CURING

**2.2.10.1.** ***Transporting and Handling:*** **-**After mixing, concrete shall be transported to the formwork as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients or ingress of foreign matter or water and maintaining the required workability.

***2.2.10.1.1.*** During hot or cold weather, concrete shall be transported in deep containers. Other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted.

**2.2.10.2.** ***Placing:*** **-**The concrete shall be deposited as nearly as practicable in its final position to avoid re-handling. The concrete shall be placed and compacted before initial setting of concrete commences and should not be subsequently disturbed. Methods of placing should be such as to preclude segregation. Care should be taken to avoid displacement of reinforcement or movement of formwork. As a general guidance, the maximum permissible free fall of concrete may be taken as 1.5 m.

**2.2.10.3.** ***Compaction:*** **-**Concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into corners of the formwork.

***2.2.10.3.1.*** Concrete shall be compacted using mechanical vibrators complying with IS 2505, IS 2506, IS 2514 and IS 4656. Over vibration and under vibration of concrete are harmful and should be avoided. Vibration of very wet mixes should also he avoided.

***2.2.10.3.2.*** Whenever vibration has to be applied externally, the design of formwork and the disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

**2.2.10.4.** ***Construction Joints and Cold Joints: -***

***2.2.10.4.1.*** Joints are a common source of weakness and, therefore, it is desirable to avoid them. If this is not possible, their number shall be minimized. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated by the designer. Construction joints should comply with IS 11817.

***2.2.10.4.2.*** Construction joints shall be placed at accessible locations to permit cleaning out of laitance, cement slurry and unsound concrete, in order to create rough/ uneven surface. It is recommended to clean out laitance and cement slurry by using wire brush on the surface of joint immediately after initial setting of concrete and to clean out the same immediately thereafter. The prepared surface should be in a clean saturated surface dry condition when fresh concrete is placed, against it.

***2.2.10.4.3.*** In the case of construction joints at locations where the previous pour has been cast against shuttering the recommended method of obtaining a rough surface for the previously poured concrete is to expose the aggregate with a high-pressure water jet or any other appropriate means.

***2.2.10.4.4.*** Fresh concrete should be thoroughly vibrated near construction joints so that mortar from the new concrete flows between large aggregates and develop proper bond with old concrete.

***2.2.10.4.5.*** Where high shear resistance is required at the construction joints, shear keys may be provided.

***2.2.10.4.6.*** Sprayed curing membranes and release agents should be thoroughly removed from joint surfaces.

**2.2.10.5.** ***Curing:*** -Curing is the process of preventing the loss of moisture from the concrete whilst maintaining a satisfactory temperature regime. The prevention of moisture loss from the concrete is particularly important if the water- cement ratio is low, if the cement has a high rate of strength development, if the concrete contains granulated blast furnace slag or pulverised fuel ash. The curing regime should also prevent the development of high temperature gradients within the concrete.

The rate of strength development at early ages of concrete made with supersulphated cement is significantly reduced at lower temperatures. Super sulphated cement concrete is seriously affected by inadequate curing and the surface has to be kept moist for at least seven days.

***2.2.10.5.1.*** *Moist Curing:* - Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Portland Cement and at least 10 days where mineral admixtures or blended cements are used. The period of curing shall not be less than 10 days for concrete exposed to dry and hot weather conditions. In the case of concrete where mineral admixtures or blended cements are used, it is recommended that above minimum periods may be extended to 14 days.

***2.2.10.5.2.*** *Membrane Curing:* - Approved curing compounds may be used in lieu of moist curing with the permission of the engineer-in- charge. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set. Impermeable membranes such as polyethylene sheeting covering closely the concrete surface may also be used to provide effective barrier against evaporation. For the concrete containing, Portland pozzolana cement, Portland slag cement or mineral admixture, period of curing may be increased.

**2.2.10.6.** ***Supervision:*** **-**It is exceedingly difficult and costly to alter concrete once placed. Hence, constant and strict supervision of all the items of the construction is necessary during the progress of the work, including the proportioning and mixing of the concrete. Supervision is also of extreme importance to check the reinforcement and its placing before being covered.

***2.2.10.6.1.*** Before any important operation, such as concreting or stripping of the formwork is started, adequate notice shall be given to the construction supervisor.

**2.2.11. <u>CONCRETE UNDER SPECIAL CONDITION: -</u>**

**2.2.11.1.** ***Work in Extreme Weather Conditions:*** **-**During hot or cold weather, the concreting should be done as per the procedure set out in IS 7861 (Part 1) or IS 7861 (Part 2).

**2.2.11.2.** ***Under-Water Concreting: -***

***2.2.11.2.1.*** When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of the mix to be used shall be submitted to and approved by the engineer-in-charge before the work is started.

***2.2.11.2.2.*** Under-water concrete should have a slump recommended in 2.2.2. The water cement ratio shall not exceed 0 6 and may need to be smaller, depending on the grade of concrete or the type of chemical attack. For aggregates of 40 mm maximum particle size, the cement content shall be at least 350 kg/$m^3$ of concrete.

***2.2.11.2.3.*** Coffer-dams or forms shall be sufficiently tight to ensure still water if practicable, and in any case to reduce the flow of water to less than 3 m/min through the space into which concrete is to be deposited. Coffer-dams or forms in still water shall be sufficiently tight to prevent loss of mortar through the walls. De-watering by pumping shall not be done while concrete is being placed or until 24 h thereafter.

***2.2.11.2.4.*** Concrete cast under water should not fall freely through the water. Otherwise it may be leached and become segregated. Concrete shall be deposited continuously until it is brought to the required height. While depositing, the top surface shall be kept as nearly level as possible and the formation of seams avoided. The methods to be used for depositing concrete under water shall be one of the following:

a) *Tremie:* - The concrete is placed through vertical pipes the lower end of which is always inserted sufficiently deep into the concrete which has been placed previously but has not set. The concrete emerging from the pipe pushes the material that has already been placed to the side and upwards and thus does not come into direct contact with water.

b) When concrete is to be deposited under water by means of tremie, the top section of the tremie shall be a hopper large enough to hold one entire batch of the mix or the entire contents the transporting bucket, if any. The tremie pipe shall be not less than 200 mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum develops inside the pipe. Preferably, flanged steel pipe of adequate strength for the job should be used. A

separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end of the pipe shall be plugged with a wadding of the gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper, so that when the concrete is forced down from the hopper to the pipe, it will force the plug (and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to cause a uniform flow of the concrete, but the tremie shall not be emptied so that water enters the pipe. At all times after the placing of concrete is started and until all the concrete is placed, the lower end of the tremie pipe shall be below the top surface of the plastic concrete. This will cause the concrete to build up from below instead of flowing out over the surface, and thus avoid formation of laitance layers. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface, and unless sealed by a check valve, it shall be re-plugged at the top end, as at the beginning, before refilling for depositing concrete.

c) *Direct placement with pumps:* - As in the case of the tremie method, the vertical end piece of the pipe line is always inserted sufficiently deep into the previously cast concrete and should not move to the side during pumping.

d) *Drop bottom bucket:* -The top of the bucket shall be covered with a canvas flap. The bottom doors shall open freely downward and outward when tripped. The bucket shall be filled completely and lowered slowly to avoid backwash. The bottom doors shall not be opened until the bucket rests on the surface upon which the concrete is to be deposited and when discharged, shall be withdrawn slowly until well above the concrete.

e) *Bags* — Bags of at least 0.028 $m^3$ capacity of jute or other coarse cloth shall be filled about two-thirds full of concrete, the spare end turned under so that bag is square ended and securely tied. They shall be placed carefully in header and stretcher courses so that the whole mass is interlocked. Bags used for this purpose shall be free from deleterious materials.

f) *Grouting*—A series of round cages made from 50 mm mesh of 6 mm steel and extending over the full height to be concreted shall be prepared and laid vertically over the area to be concreted so that the distance between centres of the cages and also to the faces of the concrete shall not exceed one metre. Stone aggregate of not less than 50 mm nor more than 200 mm size shall be deposited outside the steel cages over the full area and height to be concreted with due care to prevent displacement of the cages.A stable 1:2 cement-sand grout with a water- cement ratio of not less than 0.6 and not more than 0.8 shall be prepared in a mechanical mixer and sent down under pressure (about 0.2 $N/mm^2$) through 38 to 50 mm diameter pipes terminating into steel cages, about 50 mm above the bottom of the concrete. As the grouting proceeds, the pipe shall be raised gradually up to a height of not more than 6 000 mm above its starting level after which it may be withdrawn and placed into the next cage for further grouting by the same

procedure. After grouting the whole area for a height of about 600 mm, the same operation shall be repeated, if necessary, for the next layer of 600 mm and so on. The amount of grout to be sent down shall be sufficient to fill all the voids which may be either ascertained or assumed as 55 percent of the volume to be concreted.

g) To minimize the formulation of laitance, great care shall be exercised not to disturb the concrete as far as possible while it is being deposited.

**2.2.12. SAMPLING AND STRENGTH OF DESIGNED CONCRETE MIX: -**

**2.2.12.1.** ***General:*** **-** Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516.

***2.2.12.1.1.*** In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72 ± 2 h or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days' compressive strength test. For this purpose, the values should be arrived at based on actual testing. In all cases, the 28 days' compressive strength specified in **2.2.1** shall alone be the criterion for acceptance or rejection of the concrete.

**2.2.12.2.** ***Frequency of Sampling: -***

***2.2.12.2.1.*** *Sampling Procedure:* - A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested that is, the sampling should be spread over the entire period of concreting and cover all mixing units.

***2.2.12.2.2.*** *Frequency:* - The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

| Quantity of Concrete in the work $m^3$ | Number of Samples |
|---|---|
| 1 - 5 | 1 |
| 6 - 15 | 2 |
| 16 - 30 | 3 |
| 31 - 50 | 4 |
| 51 and above | 4 plus one additional sample for each additional 50 $m^3$ or part thereof |
| NOTE—At least one sample shall be taken from each shift. Where concrete is produced at continuous production unit, such as ready-mixed concrete plant, frequency of sampling may be agreed upon mutually by suppliers and purchasers. | |

**2.2.12.3.** ***Test Specimen:*** **-**Three test specimens shall be made for each sample for testing at 28 days. Additional samples may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the formwork, or to determine the duration of curing, or to check the testing error. Additional samples may

also be required for testing samples cured by accelerated methods as described in IS 9103. The specimen shall be tested as described in IS 516.

**2.2.12.4.** ***Test Results of Sample:*** **-**The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15 percent of the average. If mote, the test results of the sample are invalid.

**2.2.13. ACCEPTANCE CRITERIA: -**

**2.2.13.1.** ***Compressive Strength:*** **-**The concrete shall be deemed to comply with the strength requirements when both the following condition are met:

***2.2.13.1.1.*** The mean strength determined from any group of four consecutive test results compiles with the appropriate limits in col 2 of **2.2.13.3**.

***2.2.13.1.2.*** Any individual test result complies with the appropriate limits in col 3 of **2.2.13.3**.

**2.2.13.2.** ***Flexural Strength:*** **-**When both the following conditions are met, the concrete complies with the specified flexural strength.

***2.2.13.2.1.*** The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 $N/mm^3$

***2.2.13.2.2.*** The strength determined from any test result is not less than the specified characteristic strength less 0.3 $N/mm^3$.

**2.2.13.3.** ***Quantity of Concrete Represented by Strength Test Results:*** **-** The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches. For the individual test result requirements given in col 2 of Table below or in **2.2.13.2.2**, only the particular batch from which the sample was taken shall be at risk. Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 $m^3$.

| **Characteristic Compressive Strength Compliance Requirement** | | |
|---|---|---|
| **Specified Grade** | **Mean of the Group of 4 Non-Overlapping Consecutive Test Results In $N/mm^2$** | **Individual Test Results In $N/mm^2$** |
| 1 | 2 | 3 |
| M15 | $\geq f_{ck}$ + 0.825 x established standard deviation (rounded off to nearest $0.50N/mm^2$) Or $f_{ck}$ + 3 $N/mm^2$ whichever is greater | $\geq f_{ck}$ $N/mm^2$ |
| M20 or above | $\geq f_{ck}$ + 0.825 x established standard deviation (rounded off to nearest $0.50N/mm^2$) Or $f_{ck}$ + 4 $N/mm^2$ whichever is greater | $\geq f_{ck}$ $N/mm^2$ |

**2.2.13.4.** If the concrete is deemed not to comply pursuant to 3.2.10, the structural adequacy of the parts affected shall be investigated (**see 2.2.14**) and any consequential action as needed shall be taken.

**2.2.13.5.** Concrete of each grade shall be assessed separately.

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

**2.2.14. INSPECTION AND TESTING OF STRUCTURES: -**

**2.2.14.1.** ***Inspection:*** **-**To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records, workmanship and construction.

***2.2.14.1.1.*** Tests should be made on reinforcement and the constituent materials of concrete in accordance with the relevant standards. Where applicable, use should be made of suitable quality assurance schemes.

***2.2.14.1.2.*** Care should be taken to see that: -

a) design and detail are capable of being executed to a suitable standard, with due allowance for dimensional tolerances;

b) there are clear instructions on inspection standards;

c) there are clear instructions on permissible deviations;

d) elements critical to workmanship, structural performance, durability and appearance are identified; and

e) there is a system to verify that the quality is satisfactory in individual parts of the structure, especially the critical ones.

**2.2.14.2.** Immediately after stripping the formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good before concrete has thoroughly hardened.

**2.2.14.3.** ***Testing:*** **-**In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete on the basis of **2.2.14.4**and/or load test (**see2.2.14.6**) may be carried out.

**2.2.14.4.*Core Test: -***

***2.2.14.4.1.*** The points from which cores are to be taken and the number of cores required shall be at the discretion of the engineer-in-charge and shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

***2.2.14.4.2.*** Cores shall be prepared and tested as described in IS 516.

***2.2.14.4.3.*** Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85

percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength less than 75 percent.

**2.2.14.5.** *In case the core test results do not satisfy the requirements of **2.2.14.4.3**or where such tests have not been done, load test as below may be resorted to.*

**2.2.14.6.** ***Load Tests for Flexural Member: -***

***2.2.14.6.1.*** Load tests should be carried out as soon as possible after expiry of 28 clays from the time of placing of concrete.

***2.2.14.6.2.*** The structure should be subjected to a load equal to full dead load of the structure plus 1.25 times the imposed load for a period of 24 h and then the imposed load shall be removed.

Note: Dead load includes self-weight of the structural members plus weight of finishes and walls or partitions if any as considered in the design.

***2.2.14.6.3.*** The deflection due to imposed load only shall be recorded. If within 24 h of removal of the imposed load, the structure does not recover at least 75 percent of the deflection under superimposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 80 percent, the structure shall be deemed to be unacceptable.

***2.2.14.6.4.*** If the maximum deflection in mm, shown during 24 h under load is less than $40/l^2/D$, where $l$ is the effective span in m; .and $D$, the overall depth of the section in mm, it is not necessary for the recovery to be measured and the recovery provisions of above shall not apply.

**2.2.14.7.** ***Members Other Than Flexural Members:*** **-** Members other than flexural members should be preferably investigated by analysis.

**2.2.14.8.** ***Non-destructive Tests:*** **-**Non-destructive tests are used to obtain estimation of the properties of concrete in the structure. The methods adopted include ultrasonic pulse velocity [see IS 13311 (Part l)] and rebound hammer [IS 13311 (Part 2)], probe penetration, pullout and maturity. Non- destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

***Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.***

## PROCEDURE FOR SHOT-CRETING AND GUNITING

### I. SHOT-CRETING

**Specifications & Procedure of Application**

**1. Materials for Shotcreting:**

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.

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

| Sieve Designation | Percentage by mass passing for | |
|---|---|---|
| | Grading -II | Grading -III |
| 10 mm | 100 | 100 |
| 4.75 mm | 90 – 100 | 90 – 100 |
| 2.36 mm | 75 – 100 | 85 – 100 |
| 1.18 mm | 55 – 90 | 75 – 100 |
| 600 micron | 35 – 59 | 60 – 79 |
| 300 micron | 8 – 30 | 12 – 40 |
| 150 micron | 0 – 10 | 0 – 10 |

Sand should be free from deleterious substances and organic impurities.

**1.2. Coarse Aggregate:**

The maximum size of coarse aggregate should be restricted to 10 mm. It should be free from impurities, clay / shale particles, and confirm 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 confirm to the following grading.

| Sieve Designation | Percentage by mass passing for aggregate of 10 mm maximum Size |
|---|---|
| 12.5 mm | 100 |
| 10 mm | 85 – 100 |
| 4.75 mm | 10 – 30 |
| 2.36 mm | 0 – 10 |
| 1.18 mm | 0 – 5 |

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

**1.4 Chemical Additives:**

The following additives be used in the concrete mix in the 'Dry Mix Process' of shotcreting.

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.

**1.5. 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 / $mm^2$ or more.

### 1.6 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 Shotcrete is a structurally adequate and durable material capable of excellent bond with concrete as well as masonry,

### 1.7 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 / $cm^2$ though strength of 250 kg / $cm^2$ would be preferable. Normally the following mix proportions would be adequate.

Cement = 450 kg / $m^3$

Sand = 1100 kg / $m^3$ (0.70 $m^3$)

Coarse aggregate (5 mm -10 mm size) = 500 kg / $m^3$ (0.30 $m^3$)

Proportioning of mix = 1:2.44:1.11

### 1.8 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 is provided if and as warranted.
3. Ensure sufficient clearance around the reinforcement to permit complete encasement with sound shot-crete. 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 shot-crete of about 38 mm thickness (hollow pockets) will consume more shot-crete.
5. Next "Welded wire mesh of size 100 mm x 100 mm x 5 mm" be nailed, butting with shot-crete. Binding wire of 20 gauge or 24 gauge be used for binding of wire mesh panels.
6. The second and final layer of shot-crete of thickness ± 38 mm be than pneumatically sprayed over the first layer. The finished shot-crete 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 rebounded material is not to be re-used in the shot -crete mix.

### 1.9 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 shot- crete, 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 shot -crete 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.

## II. GUNITING ON THE UPSTREAM FACE OF MASONRY DAM (50 mm thick gunite in 1:3 cement sand mortar)

### 2.1. Scope

These specifications cover, in general, all the materials, and the methods and workmanship for providing a 50mm thick guniting on the upstream face of masonry dam including preparation, providing and fixing reinforcement fabric, placing gunite finishing and curing.

### 2.2 Materials

The cement shall be ordinary Portland cement confirming to IS: 8112- 1989 or IS: 12269-1987, for use in massive structures. The sand shall consist of natural sand and shall be strong, hard, coarse, sharp, chemically inert, clean and free from any coatings, organic or any other impurities that may impair the strength or durability of the gunite mortar and shall confirm to IS: 1542-1960. It shall be well graded and particles shall range in size within the limits as specified in the latest relevant IS Specifications. The Fineness Modulus shall be between 2.4 to 2.8. The sand shall be screened and thoroughly washed so as to remove all earthy impurities and shall be dry before being used for the mix. The steel reinforcement where used, shall be of hard drawn

steel wire fabric of mesh size 150 mm x 150 mm formed of 3.15 mm dia. steel wires, confirming to IS: 1566-1982. The mild steel rod to be used as dowels or nails for anchoring the I.R.C. fabric shall confirm to IS: 432. The steel shall be free from loose mild scale, rust, oil, grease and other deleterious matter, before being placing in-situ. The water proofing compound shall be of approved quality confirming to IS: 2645-1975. The water for mixing the grout shall be clean and free from earth, organic matter, acids and alkaline substances in solution or in suspension, with the turbidity within permissible limits.

**2.3. Preparation of Surface for Guniting**

The masonry surface where guniting is required to be done shall be made rough by chipping and raking out mortar joint deep or as directed by the Engineer-in-charge. Chipping shall be done by using pneumatic chippers or manually by using chisels and hammers. After roughening the surface and raking of joints, the face shall be cleaned and washed by air and water jets under pressure. It shall be ascertained that no loose material, dirt, etc., is left on the face.

**2.4. Fixing Reinforcement**

10 mm dia. M.S. rods are to be securely fixed in masonry or concrete at 1m intervals both horizontally and vertically to a minimum depth of 225 mm. either by drilling holes or any other approved method. After the rods are fixed, the hard-drawn steel wire fabric reinforcement is to be securely tied to these rods by using binding wire of approved quality. The minimum space of 20 mm, is to be maintained between the surface of the Dam and the fabric reinforcement.

The adjacent sheets of wire fabric both horizontally and vertically shall be lapped at least 150 mm and firmly tied together with the binding wire of approved gauge. There should be at least 20 mm cover for the anchor rods.

Suitable additional anchor bars shall be provided at proper intervals, if necessary, for taking the thickness of guniting work to be done.

## 2.5. Composition and Mixing of Gunite

The average thickness of guniting shall be 50 mm. Gunite shall consist of an intimate mixture of ordinary port land cement, dry sand fly ash (Where used) and approved water proofing agent, by weight, 1½ kg of water proofing compound is to be added for 50 kg of cement.

All the ingredients shall be thoroughly mixed by machine mixing before feeding into the guniting machine. Hand mixing will not be generally permitted unless special approval is accorded. The mixing operation shall continue for not less than 1½ minutes, after all the ingredients have been placed in the mixer. Hand mixing, if permitted, shall be thorough and should be done on a clean and water tight floor. The water content shall be regulated so that the mix is elastic enough to give good compaction and a low percentage of rebound and stiff enough not to sag.

## 2.6. Placing of Gunite

The equipment used for guniting shall be capable of discharging the sand-cement mixture into the delivery hose under close control and it should deliver a continuous smooth stream of uniformly mixed materials at the proper velocity to the nozzle. The discharge nozzle shall be equipped with a manually operated water injection system for directing an even distribution of water through the sand-cement mixture. The water valve shall be capable of ready adjustment to vary the quantity of water and shall be located convenient to the nozzle operator. A nozzle velocity of about 150 m/sec is preferable.

The required layer of gunite is to be built up by making several passes of the nozzle over the working area. The gunite shall emerge from the nozzle in a steady stream. If the flow becomes intermittent, the nozzle shall be directed away from the face. The nozzle shall be held at a distance of about one meter and shall be perpendicular to the application surface, except when guniting through reinforcing bars, the nozzle shall be held close and at a slight angle

to permit better encasement and facilitate removal of rebound. Special care shall be taken to ensure that no loose material is left behind the reinforcement bars. Corners, re-entrant surfaces and pockets shall be filled first. The gunite shall be applied in thick layers normally 12 mm (½") thickness or as directed by the Engineer-in-charge under a pressure of 5 to 7 kg/cm$^2$. When the work is to be suspended at the end of the day or otherwise, the gunite shall be tapered, where practicable, to a thin edge over a width of 30 cm. Before work is resumed, the surface of the gunite upon or against which fresh gunite is to be placed shall be thoroughly cleaned and roughened and shall be wetted to ensure adequate bond between old and new gunites. The contractor shall take such preventive measures as the Engineer may consider to prevent injury to or the formation of objectionable coatings on completed gunite surfaces by particles, dust or rebound from subsequent guniting operation.

Materials which rebound and drop down, shall in no case be re-used and must be immediately removed and disposed off. The guniting shall be done in such a manner that waste of cement due to rebound is minimum. In any case, the consumption of cement shall not normally exceed 50 kg /cm$^2$ of gunited surface. The natural gun finish is preferable but when greater smoothness is desired, a fresh coat containing fine sand shall be applied.

During the period immediately followed by the placing of the gunite, the gunite shall be protected against injury from any cause which in the opinion of the Executive Engineer might result in weakening the bond between gunite and the surface to which it is applied or in otherwise injuring the gunite. As soon as the gunite is set, it shall be properly cured and protected.

After completing the guniting and after the mix is set, the surface should be thoroughly sounded by a hammer for drumming areas resulting from rebound pockets or lack of bond etc., which should be cut out and replaced to the entire satisfaction of the Engineer. Any guniting which is damaged or found to be defective any time before completion or acceptance of the work shall be replaced.

# EMBANKMENT FOR RIVERS AND CANALS

## 3. RIVERS: -

**3.1. Construction of Embankments: -**Construction of an embankment should envisage, for the sake of economy, maximum utilization of natural unprocessed materials available locally. Embankments may be homogeneous or zoned. They should generally be of compacted roll fill at controlled moisture content. Investigation of borrow areas, their location and depth of excavation, foundation preparation, earthwork, compaction, moisture control and slope protection are the important aspects to be carefully attended to during construction.

### 3.1.1. *Borrow Pits: -*

**3.1.1.1.** Borrow areas should preferably be located on the river side of the proposed embankment.

**3.1.1.2.** For low embankment, less than 6.0 m in height, borrow pit should not be selected within 25.0m from the toe/heel of the embankment. In case of higher embankments, the distance should not be less than 50.0m.

**3.1.1.3.** Preliminary soil investigation may be done from a few representative auger holes or borrow pits.

**3.1.1.4.** After selection of an area apparently suitable for borrow pits in accordance with **3.1.1.1**,**3.1.1.2**and **3.1.1.3**, detailed investigations should be undertaken for a systematic mapping and determination of engineering properties such as gradation, permeability, plastic limits, etc., of the soils in the borrow.

**3.1.1.5.** Plan showing borrow areas and the quantity of materials for different zones of the embankment section should be used for actual construction.

**3.1.1.6.** The recommended mean distance of the borrow pits from the toe of the embankments as well as the depth of borrow pits should generally be asunder:

| Distance of Borrow Pits (m) | Maximum depth of Borrow Pits (m) | |
|---|---|---|
| | River Side | Country Side |
| 25 to 50 | 1.0 | 0.60 |
| Over 50 up to 75 | 1.5 | 0.60 |
| Over 75 up to 100 | 2.0 | 0.60 |

**3.1.1.7.** In order to obviate development of flow parallel to embankment, cross bars of width eight times the depth of borrow pits spaced at 50 to 60 metres centre-to-centre should be left in the borrow pits.

**3.1.1.8.** All borrow areas/pits should be stripped of the top soil, sod, loam and other objectionable materials considered unsuitable for use in the embankment.

**3.1.2. *Laboratory Test:* -** For important and also for embankments higher than 6 m, representative samples obtained from the borrow areas should be tested in the laboratory to determine the engineering properties of soils, such as gradation, permeability, plastic limits, shear strength, dry density, compaction tests, etc. as given in design.

**3.1.3. *Preparation of Foundation:* -** The seat of the embankment should be properly prepared for fill placement. It should be ensured that all stumps, brush, large roots, top soil and other objectionable materials are completely removed before placement of the fill. Any ridges or

mounds, which are in line of embankment, should be loosened by ploughing or stepped or dug or provided with V-cut benching at intervals running parallel to the centre line. The prepared surface should enable proper bond with the fill material to be placed thereon.

### 3.1.4. *Earthwork: -*

**3.1.4.1.** *Embankment Profile:* -A complete profile of the embankment with its correct height, width and all slopes dressed to true form should be laid by pegs, bamboo posts and strings at 50 m intervals or by actual construction of the embankment of 3 m length at 150 m intervals. The actual construction should, however, be done by giving suitable settlement allowances which maybe about 1 to 2 percent of the embankment height.

**3.1.4.2.** *Embankment involving Mechanical Compaction:* -In case of embankment involving mechanical compaction, the materials free from all organic matter should be compacted in layers of 15 to 20 cm for the full width of the embankment and carried up regularly in accordance with embankment section. All clods should be broken up to a size having not more than 5 cm diameter. Each layer should be properly watered and compacted. The surface should be well graded and crowned in the centre so that during rain the surface water is carried rapidly to the slopes of the fill.

**3.1.4.3.** *Embankment involving Manual Compaction:* -In case of embankment involving manual compaction, the layers not exceeding 15 cm thickness should be placed slightly sloped towards the centre of the crest so that rainfall will naturally consolidate the embankment during the construction. The materials should be free from organic matter. The top layer forming the crest of embankment should be suitably graded so that the rainwater does not accumulate and create maintenance problems.

**3.1.4.4.** *Remodelling of Embankments:* -When adding new earthwork to existing embankment, the old bank should first be cut or benched into steps with the treads sloping slightly towards the centre of the embankment and the surface of the old work should be wetted so that new earth may adhere to the old. Similarly, junctions should be made by cutting grips or forks in the side slopes of the old embankment.

**3.1.4.5.** *Incomplete Embankments:* -In case the whole length is not taken up simultaneously, the incomplete embankment should have steps not steeper than overall longitudinal slope of 1 in 5 to permit satisfactory bond with the portion to be taken up later.

### 3.1.5. ***Compaction: -***

**3.1.5.1.** The basic criteria of the quality and suitability of the work done is the degree of compaction attained. For effective quality control, of compaction, data on optimum moisture content and maximum dry density obtained from laboratory compaction tests are required. For small embankments, in the absence of such laboratory data, values given in Table below may be used. The best result is obtained by spreading materials with a moisture content 1 to 2 percent less than the optimum moisture content in layers of limited thickness and rolling with properly designed rollers with sufficient number of passes. Smooth contact surface between successive layers should be avoided and uniform density throughout the fill should be achieved.

| *Approximate Values of Maximum Dry Density and Optimum Moisture Content for Different Type of Soils (Types of Soil as Per IS:1498)* | | |
|---|---|---|
| Soil Classification | Proctor Compaction | |
| | Maximum Dry Density ($g/m^3$) | Optimum Moisture Content Percent |
| (1) | (2) | (3) |
| GW | > 1.907 | < 13.3 |
| GP | > 1.762 | < 12.4 |
| GM | > 1.826 | < 14.5 |
| GC | > 1.843 | < 14.7 |
| SW | 1.907 ± 0.08 | 13.3 ± 2.5 |
| SP | 1.762 ± 0.032 | 12.40 ± 1.0 |
| SM | 1.826 ± 0.016 | 14.5 ± 0.4 |
| SM-SC | 1.907 ± 0.016 | 12.8 ± 0.5 |
| SC | 1.842 ± 0.016 | 14.7 ± 0.4 |
| ML | 1.650 ± 0.016 | 19.2 ± 0.7 |
| CL | 1.730 ± 0.016 | 16.8 ± 0.7 |
| MH | 1.314 ± 0.064 | 36.3 ± 3.2 |
| CH | 1.506 ± 0.032 | 25.5 ± 1.2 |

**3.1.5.2.** Compaction of each layer of fill materials should proceed in systematic, orderly and continuous manner so as to ensure the specified coverage by the compactors. Sheep-foot roller or tamping type roller is generally accepted as the best available means of ensuring proper compaction for average type embankment material. The acceptable limit of compaction as compared to the dry density at optimum moisture content would depend on the desired shear strength for the stability of side slopes. For mechanical compaction, the minimum compaction should be 90 percent and for manual compaction 85 percent. Adequate quality control and field tests are needed to ensure this.

**3.1.5.3.** If the soil is granular with practically no cohesion, road rollers are considered quite adequate for compaction.

**3.1.5.4.** Those parts of the fill which cannot be reached by rolling equipment should receive equivalent manual compaction or mechanical tampers. Particular care should be taken for suitable compaction and jointing of embankments with the structures.

### 3.1.6. *Moisture control for Mechanical Compaction: -*

**3.1.6.1.** Proper moisture control of the material is very important in order to ensure proper compaction. Materials may be conditioned to the desired moisture content either at the site of excavation, on the embankment or under same condition at both the borrow pit and during placement. It is necessary that some rapid and convenient methods be employed to determine whether or not the materials have the desired moisture content as they are placed on embankment.

**3.1.6.2.** The penetration resistance needle, which makes use of the penetration resistance-moisture relation for the material being placed, is very useful for the purpose. It is desirable to establish field laboratories to carry out tests in the field while compaction operation goes on.

**3.1.7.** ***Slope Protection:*** **-** The surface protection of embankment against action of rain and wind is usually achieved by turfing. In case of embankment using non-cohesive material, a cover of 0.3 to 0.6 m thick cohesive material can be given. Since velocities along river side slopes of embankment are expected to be low, no slope protection may ordinarily be required and turfing on both sides may suffice. If river action is more severe, suitably designed slope protection should be adopted.

**3.1.7.1.** The planting of trees on embankment should not be permitted because their roots tend to loosen the structure of the embankment when shaken by wind storm which, in turn, causes cracks and leaks. Shrubs, thorny bushes and short grass growing on the slopes of embankments provide good protection against erosions, wave wash and stray cattle. Generally, the side slopes and 0.6 metre width in top from the edges of the embankments should be turfed with grass sods and this turfing should extend beyond the toe to country-side and the river side by 6.0 metres and 3.0 metres respectively.

**3.2. Maintenance: -**

**3.2.1.** Proper maintenance of embankments is extremely important as breaches in them can be disastrous and may cause even greater damage than the inundation by the floods where no embankments are provided. The maintenance work can be divided into 2 parts:

(a) *Pre-monsoon maintenance and*

(b) *Post monsoon maintenance*

**3.2.2.** ***Pre-monsoon Maintenance: -***

**3.2.2.1.** Existing embankments have to be repaired or reconditioned to the original designed section in advance for their efficient performance during the ensuing monsoons. The free board may be checked up for any rise in the bed level of the river or other constrictions which may result in higher design flood level and provided/maintained accordingly.

**3.2.2.2.** All hollows and depressions in the embankment's section, wherever existing, should be made up with rammed earth after clearing the site of all loose and vegetal materials. Where the top material is sandy or silty, it is desirable to provide a cover of soil containing 10 to 15 percent of clay well rammed or rolled.

**3.2.2.3.** A register of leaks should be maintained indicating the location and action taken during the monsoon period. The leaks, which could not be fully treated during the monsoon period, should be attended to immediately afterwards. Such leakage sites should be opened in the full width of the embankment taking care to trace to its upstream ends, and then be refilled with good earth in 15 centimetre layers, watered and rammed, the old earth being stepped or benched back at the sides and new earthwork properly bonded and interlocked into the old.

**3.2.2.4.** Rodents and other animals make holes, cavities and tunnels through and under embankments. These are sources of danger causing leakage and excessive seepages which may give rise to serious breaches during flood period. Such holes should be carefully located, examined, provided with an inverted filter, filled with earth and rammed. Alternatively, such holes should be filled with well rammed stiff clay.

**3.2.2.5.** All the masonry works should be carefully inspected to detect if there is any danger of seepage of water along the planes of contact between the earth and masonry. The earth

adjacent to the masonry work should be laid in 15 cm layers, watered and compacted, and brought to the design section.

**3.2.2.6.** For embankments, which were severely threatened by erosion during the previous monsoon, revetment/rip rap or other river training works should be separately examined. Where stones or bricks, etc., are costly, cheaper means like brushwood matting, etc., may be used. In case of wave action, pitching should be taken at least 0.3 metre above the maximum height of wave expected.

**3.2.2.7.** Approach roads and also top of embankments, wherever they are designed to carry vehicular traffic, as well as ramps provided for inspection and maintenance should be kept in good condition so that they serve the purpose of transport of materials and inspections both during the pre-monsoon and monsoon periods. No habitation should be permitted on the embankments.

**3.2.2.8.** All departmental vehicles, boats and launches should be kept operational.

**3.2.2.9.** All sluice gates, regulation gates and valves should be properly greased, oiled and treated.

**3.2.2.10.** All tools and equipment including torch lights, hurricane lamps, spades, etc., and flood fighting articles as well as materials for erecting temporary sheds at the work sites for workers should be arranged and stored in suitable places.

**3.2.2.11.** Proper communication system should be installed for quick transmission of messages to the concerned authorities.

**3.2.3.** ***Maintenance during monsoon: -***

**3.2.3.1.** During monsoon, prompt maintenance of the embankment is required as the flood water of river threatens the safety of the embankment mostly during this period. This is all the more important in case of new embankments and also in case of those reaches of old embankments where breaches occurred in the past. The establishment required to be engaged for proper maintenance of an embankment will vary depending upon importance of the embankment and behaviour of the river. As soon as water touches the embankment and river shows rising trend of its water level, round the clock patrolling should start by the establishment engaged for this purpose and continue until water finally recedes from the embankment. During this period, inspection by senior officials should be carried out systematically and all the concerned officers and staff should remain alert to meet any emergent situation.

**3.2.3.2.** Special vigilance is necessary in the countryside of the embankment to detect any formation of boils due to seepage. This should be immediately attended to by providing loading berm to counter balance exit gradient. A suitable filter material may be placed around the boil below the loading berm to arrest fines in seepage water.

**3.2.3.3.** Water may seep through a sand stratum under the levee and emerge on the countryside in the form of bubbling springs. Under these conditions, a stream of water bursts through the ground, carrying with it sand which then settles around the edge of the hole. These sand-boils may be as large as 1 to 1.3 metres in diameter and may occur from 13 to 100 metres from the levee or even further away.

As a protective measure embankments of earth filled sacks may be built around them thus ponding the water and creating a head on the country side sufficient to stop the flow of silt

through minimising the effective head of water. If other boils take place outside this encircling embankment, it maybe necessary to construct sub-levees around the area containing such sand-boils.

**3.2.3.4.** To prevent the water from overtopping and washing out a portion of the levee, a dowel at the river side of the top of the embankment with sand/earth filled bags may be provided.

The bags should be filled half full only so that they will fit closely against each other. Sand should not be used for filling the sacks, if clay or loamy soil is available. In case of emergency, the material may be taken from the back slope of the levee much above the hydraulic gradient line with respect to maxi mum flood level.

**3.2.3.5.** Repair of rain cuts in the embankment, stacking of material and machinery required for repairing, putting the top of embankment in order, etc., should also be made. Scouring and eroding behaviour of the river should also be carefully watched for taking necessary precautionary measures. In this way, by means of proper vigilance and timely action for repair works, flood disaster can be reduced to a great extent.

**3.2.3.6.** All information connected with rising flood water level and flood situation should be passed on to concerned higher authorities to enable them to take safety measures in time.

## 4. CANALS (IS: 4701): -

### 4.1. GENERAL: -

**4.1.1.** ***Effect of Weather Conditions*** **-** An earthwork project may be affected weather conditions which may alter the conditions of the soil to some depth. The earthwork should be as far as possible, so planned that it is carried out during the most favourable season. Rainfall may so affect the exposed surface of cohesive soils as to result in interruption both in the use of excavating plant and in the transport of materials. In wet weather, work may have to be stopped entirely owing to excessive moisture near the surface of soil. In extremely dry weather, it may be necessary to add water to the soil in borrow area or at the fill to fulfil requirements of compaction. It is advisable to compact the soil in its final position in the fill or embankment immediately after it is placed.

**4.1.2.** ***Safety Precautions*** **-** Blasting, where required, shall be permitted only when proper precautions have been taken for the protection of persons and property in accordance with IS: 4081-1967t. Blasting shall be carried out only by persons thoroughly conversant with the working methods and precautions to be observed in using explosives. To avoid the danger of injury from flying debris all personnel in a blasting area shall retreat to an adequate distance and take adequate cover. While carrying out excavation adequate precautions in accordance with IS: 3764-1966: shall be taken for the safety of workers.

**4.1.2.1.** The location and design of magazines for explosives, method of their transport and general precautions to be taken to prevent accidents shall be in accordance with the provisions of Indian Explosives Rules, 1940 and local regulations and regular rules and regulations framed thereunder, if any.

**4.1.3.** ***Planning:*** **-** Prior to the commencement of a work all relevant data shall be collected and drawings prepared showing the location of the excavation, and embankment reaches separately. On these drawings both the excavation and filling reaches should be distinctively indicated separately and the quantity of material to be excavated and placed in fill stated in these reaches. This information would be useful to ensure economic hauls throughout the work. Where the material to be excavated consists of different types and if the various types have to be used separately in the fill or run to spoil tip, the quantities of each class of material in each area should be shown on drawings.

**4.1.3.1.** No earthwork on canals should be started unless proper acquisition and demarcation of land has been finalized and permission of concerned organization obtained. Such laud shall be demarcated by fixing permanent boundary stones at intervals of 200 m on both sides on straight reaches and at points where there is change in direction or change in land width. Similar precautions shall be taken for defining the borrow areas also. Such areas will be temporarily acquired and suitably demarcated.

### 4.2. SETTING OUT: -

**4.2.1.** Prior to the commencement of work the centre line of the proposed canal shall be marked by stones or pegs each at about 30 m interval: Curves shall be laid out; top and bottom edges of the excavation and toe of all embankments suitably peg marked. Reference pegs should also be driven into ground at a fixed distance outside peg markings. All levels shall be referred to an established bench mark not subject to subsidence or interference.

**4.2.2.** Profiles of designed canal section in fill and moderate cut reaches may be marked at intervals of 25 m at curves and 50 m in straight reaches.

### 4.3. CLEARING: -

**4.3.1.** The land over which embankments are to be formed and other excavation is to be carried out shall be cleared of all trees, bushes, rubbish, ant hills and other objectionable matter. The cleared materials shall be suitably disposed of.

**4.3.1.1.** All waste materials to be burned shall be piled neatly and when in suitable condition shall be burned completely. Piling for burning shall be done in such manner and in such locations as to cause the least fire risk. All burning shall be so thorough that the materials are reduced to ashes. Necessary precautions shall be taken to prevent fire from spreading to areas beyond the limits of cleared areas and suitable equipment, and supplied for use in preventing and suppressing fires shall be kept available at all times.

**4.3.2.** In filling reaches, all holes and hollows whether originally existing or produced by digging up roots shall be filled with suitable earth, well rammed and levelled off.

**4.3.2.1.** In filling reaches, the boulders in the top strata shall be removed and filled with suitable material.

**4.3.2.2.** Boulders which may interfere with the work should be generally removed after breaking them down, if necessary.

**4.3.3.** It is desirable to protect the trees outside the outer edge of the canal embankments. However, the presence of trees in the vicinity of a canal can accentuate variation of moisture content in the sub-stratum. In the case of expansive soils such excessive moisture variation can result in damage to the lining. Such influence is believed to extend to distances equal to twice the height of the tree.

### 4.4. EXCAVATION: -

**4.4.1.** ***Earthwork in Cutting: -*** Canal section shall be excavated as shown on the drawings or as directed by the engineer-in-charge. Both edges of the bank, specially the inner one shall be neatly aligned symmetrically to the centre line of the channel. They shall be absolutely straight in straight reaches and smoothly curved on bends. All gangways, roads and stoppings shall be such that they fall within the canal section so that final dressing of slope will consist of digging only and no filling will be required.

**4.4.1.1.** Suitable arrangements for drainage shall be provided to take surface water clear of the excavation during the progress of work. Sumps may be constructed at suitable places and water collected may be pumped out. When cutting on cross sloping ground, it is advisable to cut a catch water drain on the higher side to prevent water from flowing down the cutting slope.

**4.4.1.2.** Wherever ground water is met during excavation adequate measures shall be taken to dewater the cutting. The choice of method to be employed and type of equipment to be used would depend on the nature of ground and the volume of water to be dealt with.

***4.4.1.2.1.*** If there is a continuous flow of water a subdrain with sumps at intervals may be installed, Drainage will be helped by excavating from downstream side to upstream side so that water tends to drain away from the working face. Generally, area is drained by providing pilot cut to natural valley so as to drain the subsoil water.

***4.4.1.2.2.*** In case of lined canals subsoil water shall not be allowed to accumulate in the bottom of the canal and pumping arrangements shall be so organized as to deal with any temporary flood water which may occur. As described above (**4.4.1.2.1**) the subsoil water should be drained by providing drain or pumping the subsoil water so as to keep the area dry as far as possible.

**4.4.2.** Excavation may be carried out by manual labour or by excavating machines. The choice of type of excavating machine to be used will depend on the nature and quantity of materials to be excavated and also on the leads and lifts involved.

**4.4.2.1.** Side slopes for canals should be provided depending on type of soil through which the canal is laid. Generally, the following slopes are provided for unlined canals: -

| SL NO. | TYPE OF SOIL | SIDE SLOPES (H: V) |
|---|---|---|
| 1 | Very light loose sand to average sandy soil | 1.5:1to2:1 (in cutting)<br>2:1 to 3:1 (in embankment) |
| 2 | Sandy Loam | 1: 1 to 2: 1 (in cutting)<br>l.5:1 to 2:1 (in embankment) |
| 3 (a) | Sandy Soil or Gravel | 1: 1 to 1.5: 1 (in cutting)<br>l.5: 1 to 2: 1 (in filling) |
| 3 (b) | Muram Gravel mixed Soil | |
| 4 | Black Cotton | l.5: 1 to 2.5: 1 (in cutting)<br>2.5: 1 to 3.5: 1 (in embankment) |
| 5 | Clayey Soils | 1: 1 to 2.5: 1 (in cutting)<br>1.5: 1 to 3: 1 (in embankment) |
| 6 | Rock | 0.25: 1 to 0.5: 1 (in cutting) |
| Note 1: - The above slopes are for general guidance for height of embankment up to6 m. For heights in excess of the above special studies for the stability of slope are recommended. | | |
| Note 2: - In case of rocky areas above recommended side slopes may require change due to any adverse jointing pattern. | | |

**4.4.2.2.** Exploratory holes and type of soil shall be determined before excavation. The permeability characteristics of the soil encountered should be assessed by making use of in place permeability tests as required. Canal sub-grade soil on the slopes and bottom with respect to probable future seepage and erosion should be examined. In case of high seepage losses are anticipated, or if the soils are fine and lacking in cohesion and could erode badly under the proposed operating conditions, suitable measures such as lining, etc. should be planned.

**4.4.2.3.** Above the lining in case of lined sections and above the proposed water level in case of unlined sections the rock may be allowed to stand at its steepest safe angle and no finishing is required other than removal of rock masses which are loose and are liable to fall.

***4.4.2.3.1.*** Lined sections in areas of high ground water shall be protected against uplift by drainage system as per IS: 4558-1968*. If fine grain soils (sand) are to be placed as sub-grade below concrete or membrane lining, this should be without organic matter, gravel, pebbles, etc. Natural sub-grade should be inspected and organic material, gravels, pebbles, protruding should be removed from sub-grade. Filter blankets should be provided beneath lining as per IS: 4558-1968* to release uplift pressure. All washable materials and any soil which generally becomes unstable on saturation such as organic soil, loose, silts, expansive clays are generally removed or properly treated for embankment and canal linings so as to provide safe and stable sub-grade under operating conditions.

**4.4.3.** ***Rock Excavation:*** **-**Rock may be excavated by the following methods:

a) *Quarrying out by hand with suitable rock wedges and hammers, steel bars, picks, etc., and breakings with rock hammers;*

b) *Loosening by use of pneumatic paving breakers;*

c) *Drilling suitable holes by hand with jumpers or pneumatic drilling machines, and breaking up rock with plugs and features;*

d) *Drilling holes by hand jumpers or pneumatic drilling machines as above, but breaking the rock with suitable commercial explosives, or blasting devices; and*

e) *Ripping with suitable heavy duty tractors where the rock formation falls within the range of ripability of commercially available units.*

**4.4.3.2.** Classification of rock could be done as below:

a) *Disintegrated rock removable by crow bars and pick axes;*

b) *Fissured and fractured rocks jointed at less than 450 mm apart;*

c) *Hard rock boulders of size greater than 300 mm in any dimension up to 3 m3;*

d) *Solid and sheet rock boulders of size greater than 3 m3; and*

e) *Generally hard soil, hard muram, stoney earth and earth/sand mixed with stone and boulders not exceeding 300 mm in any direction.*

**4.4.3.3.** Excavation of rock is usually done by loosening and removing the rock by forming a slightly sloping open face across the cut and working towards this open face. The depth and width of this face will vary according to the nature of rock and method adopted. Several faces may be worked simultaneously, one behind the other, with benches between each face; the space between the faces and the length of each bench varying according to the conditions prevailing and the methods adopted for removing the rock. Provided that proper equipment and technique are adopted, drilling and blasting is the most speedy and economical method for excavating hard rock. For soft rocks ripping, may loosen the rock at greater speed and at much less cost.

**4.4.3.4.** Blasting in a manner as to produce over breakage which in the opinion of engineer-in-charge is excessive shall not be permitted. Special care shall be taken to prevent over-breakage or loosening of material on bottoms and side slope against which rigid lining is to be placed.

***4.4.3.4.1.*** Final cutting for 45-60 cm in hard rock shall be carried out by controlled blasting or trimming or with the help of pneumatic paving breakers.

**4.4.4.** ***Preparation of Subgrade*** **-** Where the canal is to be lined the excavation and preparation of subgrade shall be done in accordance with IS: 3837-1978*. Where the canal is not to be lined, excavation shall be done to full depth and width required and shall be finished to prescribed lines and grades. Where the original ground surface is below the grade of the canal the bottom of the canal shall be filled to the grade in a manner prescribed for the construction of canal embankments (**see 4.5.6.2**). In so far as practicable the finishing operation required on canal sections shall be performed simultaneously with canal excavation.

**4.4.4.1.** The sub-grade and embankment for a canal may comprise of rock or soil. Canal sections excavated in rock should be inspected to examine whether joints or fissures exist which will cause excessive seepage or piping. In case this is so, rock will require grouting or the section may require lining. Rock surfaces on which compacted earth is to be placed should be

moistened before placing the first layer of earth but standing water should not be allowed. The minimum soil cover over rock should be 225 mm.

## 4.5. EMBANKMENT CONSTRUCTION: -

**4.5.1.** Before commencing the work, the toe of the slope on each side of the banks shall be lock-spitted (Dag-Belled) and marked by pegs, firmly driven into the ground at intervals of about 20 III. Profiles made by bamboos, earth or other convenient materials and strings shall be set up for the guidance of the workmen at about 50 m apart over straight reaches and IS: 4701-1982 about 25 m apart at curves. In setting up the profile for an embankment a suitable allowance shall be made for settlement (**see 4.5.2.3**).

**4.5.1.1.** Masonry blocks shall be constructed at each profile to indicate the centre line as also the bed level of the canal before starting the entire earthwork.

**4.5.2.** ***General Requirements*** **-** Embankments shall be built to the height and slope as shown on the drawings. All the edges of the embankment shall be neatly aligned symmetrical to the centre line of the channel. They shall be absolutely straight in reaches and smoothly curved at bends.

**4.5.2.1.** The top of each embankment shall be levelled and finished so as to be suitable for roadway and given a cross outward slope to drain away rain waters. The bank carrying inspection road shall be given a suitable cross slope.

**4.5.2.2.** For embankment in which controlled compaction has not to be carried out (**see 4.5.6.1**), suitable allowance shall be made for settlement.

**4.5.2.3.** An allowance of about 10 percent for settlement is recommended for embankments in which controlled compaction has not been carried out (**see 4.5.6.1**).

**4.5.3.** ***Methods of Construction***-Embankments may be built by manual labour or by machinery depositing the materials directly from excavation. The choice of type of excavating plant will depend on many factors. Where boulders which may interfere with the work are encountered they shall be dealt with in accordance with **4.3.2.2**.

**4.5.3.1.** *General Drainage:* - Under ordinary circumstances no special drainage works are necessary in embankments but where required ditches may be dug at a distance not less than 3 m from the toe of the slope. The necessity for any drain so provided will depend on the topography of the ground on which the embankment is constructed, having regard to the desirability of preventing an accumulation of water at the base of the embankment.

**4.5.3.2.** In case any settlement takes place in the embankment after its completion it would also induce cracks in the embankment in addition to causing damage to lining. The following treatment is suggested to repair the settlement subject to site conditions.

A trench of minimum required width shall be dug along the crack in the embankment for a depth to which the crack has extended plus minimum 0.25 m or to a depth of 1 m whichever is more. The width of the trench shall, however, not be less than 0.5 m. This trench shall be filled back with a thorough mixture of clay and fine sand having plasticity index of 10 or less, and should be placed in 150 mm thick layers and thoroughly compacted.

**4.5.4.** ***Requirements for Material*** **-**Where the embankment is constructed by taking material from borrow pits care shall be exercised that all large clods are broken and no clod bigger than human fist, say 8 to 10 cm, roots, grass and other rubbish are buried in the banks. Before procuring materials from borrow pits all perishable materials shall be stripped off from the top

surface as specified in **4.5.5.1**.Unless otherwise directed by the engineer-in-charge all materials shall be deposited in embankments so that cobbles, gravel and boulders are well distributed through other material and not rested in any position within or under the embankment.

**4.5.4.1.** In areas where gravel and stone is mixed with earth, these should be removed as far as possible. But the areas where all gravel material cannot be economically removed, cobbles, stones of size greater than 40 mm should be removed to ensure proper compaction. This is very important for lined sections where plastic membrane is provided to reduce seepage. The existence of nest of cobbles may result in more seepage and piping. In view of this measure to remove cobbles of larger size should be taken at the excavation area itself.

**4.5.5.** ***Preparation of Ground Surface for Embankment*** **-** Before beginning the construction of embankments the surface area of ground to be occupied shall be cleared of all roots and vegetable matter of any kind and stripped to a suitable depth.

**4.5.5.1.** The depth to which top soil is removed shall be adequate to remove all perishable material and any soil which may become unstable on saturation or may interfere with development of proper bond between the foundation and embankment. It is not necessary to remove all the soil containing fine hair like roots but only the rather heavy mat. The Table below may serve as a guide for fixing the depth of stripping: -

| TABLE FOR DEPTH OF STRIPPING | |
|---|---|
| TYPE OF VEGETABLE COVER ON THE SOIL | DEPTH OF STRIPPING |
| Soil containing light grass cover | 5.0 to 7.5 cm |
| Agricultural Land | To the bottom of ploughed zone usually 15.0 to 22.50 cm |

**4.5.5.2.** The ground surface under all canal embankments (excepting rock surfaces) where it is below the maximum water level in the canal, shall be scarified making open furrows not less than 20 cm deep below natural ground surface at intervals of not more than 1.0 m. However, where the ground surface is below the bed level of the canal the entire surface of the foundations for embankments shall be stripped to a depth of not less than 20 cm.

**4.5.6.** ***Compaction Requirement*** **-** Embankments shall be compacted, as shown on the drawings, to achieve the requirements laid down in **4.5.6.1**and **4.5.6.2**. General methods of compaction of embankments are given in **4.6**.

**4.5.6.1.** *Embankments Without Controlled Compaction* - Where the natural ground surface is above the maximum water level in the canal but below the top of the embankment, the embankment shall be built in layers not exceeding 30 cm in thickness and to the full width of the embankment. Each layer shall be commenced from the edge farthest from the excavation. Top of each layer shall be kept slightly depressed in the centre. The excavating and hauling equipment shall travel over the embankment to evenly distribute the material and compacting effort over whole surface. If the embankment is to carry a highway it shall be constructed in accordance with **4.5.6.2**, **4.5.6.3.1**,**4.5.6.4**,**4.5.6.4.1**and**4.5.6.5**.

**4.5.6.2.** *Embankments with Controlled Compaction* - Where the natural ground is below the maximum water level in the canal the portion of the embankment up to the maximum water level or where rigid lining is to be laid, the portion of embankment up to the upper level of the lining, shall be built according to the requirements given in **4.5.6.3.1**, **4.5.6.4** and **4.5.6.5.**

***4.5.6.2.1.*** Embankment shall be built in layers generally not exceeding 25 cm in thickness (loose layer) and to full width of the embankment. Each layer shall be commenced from the edge farthest from excavation. Top of each layer shall be kept slightly depressed in the centre.

**4.5.6.3.** Generally blending of two or more materials are recommended to obtain suitable soil for earth lining. Fine soil from borrow areas is generally added to coarse soil to improve impermeability. But coarse soils are added to fine soils to improve erosion resistance. The proportions for blending should be ascertained by laboratory test.

***4.5.6.3.1.*** *Impervious zone*: -The impervious zone wherever shown on the drawings shall be built of material having sufficient percentage of clay so that it can be compacted at optimum moisture content by suitable compacting equipment to the maximum dry density. The material shall be compacted to a density as specified in **4.5.6.5**. The water tightness of material should be checked by carrying out permeability test. The coefficient of permeability of impervious material should not be greater than 30 cm per year. The impervious material should preferably be free from large size particles. If this is not possible the maximum size and percentage of gravels to be permitted is 40 mm and 20 percent respectively. When the above relaxation is allowed the engineer-in-charge should ensure that relative standards set for dry density and permeability are fulfilled.

***4.5.6.3.2.*** The rest of the compacted zone may consist of any suitable support for the impervious core under various conditions of saturation and draw down. If silty or sandy material is used for this portion, such a material will not be amenable to compaction by the usual compaction procedure using sheep foot rollers. For such. materials proper machinery utilising the principle of vibro-compaction should be used. The minimum relative density of the compacted material shall not be less than 70 percent. The distribution of material shall be such that the compacted material will be homogeneous and free from lenses, pockets or other imperfections. The maximum dimensions of stones placed in the embankment shall be not more than 10 cm. The excavating and placing operations shall be such that the materials when compacted will be blended sufficiently to secure the best practicable degree of compaction, impermeability and stability.

**4.5.6.4.** *Moisture Content* - Prior to and during compaction operations the embankment shall have optimum moisture content required for the purpose of compaction and this moisture content shall be fairly uniform throughout the layer. In so far as practicable the moistening of the material shall be performed at the site of excavation but such moistening shall be supplemented as required by sprinkling water at the site of compaction, if necessary.

***4.5.6.4.1.*** If the moisture content is greater than optimum for compaction, the compaction operation shall be delayed until such time as the material has dried to the optimum moisture content.

**4.5.6.5.** *Dry Bulk Density After Compaction* - The dry bulk density of the soil fraction in compacted embankment material shall be not less than 95 percent of the maximum dry bulk density at optimum moisture content obtained in accordance with IS: 2720 (Part VII)-1980, or as specified.

## 4.6. COMPACTION METHODS AND FIELD CONTROL: -

**4.6.1.** ***Methods of Compaction*** **-** To obtain the required amount of compaction by most economic means it is necessary to employ systematic field control. For a particular job the following items should be decided:

a) *Dry density of the soil required with regard to the soil type;*

b) *The most suitable moisture content at which to work and the effect of probable moisture content variation;*

c) *The type or types of compaction equipment most suitable for compacting the soil having due regard to relative costs: and*

d)*The thickness of loose layers.*

**4.6.1.1.** Average performances of compaction plant for various types of soils are given in Appendix A. Whilst exact details of the procedure for compacting every type of soil and materials are not given in Appendix A, the information contained in it may be used as a reasonable guide.

**4.6.1.2.** Where the magnitude of work justifies it, the procedure described in **4.6.1.2.1** to **4.6.1.2.3**is recommended to determine the required compaction method. In deciding the method to be employed, economic considerations should be kept in view. For example, it may have to be decided whether it is more economical to compact in layers of less thickness with a light roller or thick layers with heavy rollers; again, consideration may have to be given to the number of passes required with smooth and sheep-foot rollers to produce specified density. Often it may be found that a combination of two or more types of equipment would give best, results.

***4.6.1.2.1.*** Standard compaction tests shall be made on available materials. The tests will indicate broadly which are the most suitable and give a rough idea of the best type of equipment to be used and the moisture content at which compaction should be undertaken. This method would help in classifying a material according to its compaction characteristics.

***4.6.1.2.2.*** Having decided on the filling material to be used, field compaction trials should, where possible, be made with the compaction equipment expected to be used under conditions which are likely to obtain during construction to determine the effects of soil moisture content, thickness of layer, and number of passes.

***4.6.1.2.3.*** In deciding on the range of moisture contents, day-to-day variations in moisture content should be taken into consideration, particularly in the case of cohesive soils. Having decided on the thickness of layers and range of moisture contents, tests should be made with the different types of equipment available, and the required number of passes should also be determined. In all this work, the state of compaction should be measured in terms of dry bulk density.

**4.6.1.3.** During the actual construction of any earthwork, maximum use should be made of constructional plant and routing of the plant should be carefully controlled to obtain uniform compaction over as wide an area as possible. Care should also be taken during the compaction operation to shape the surface of the works to facilitate the shedding and to minimize the absorption of rainwater, particular attention being given to the prevention of ponding. It is advisable to do this at the end of each day's work.

**4.6.1.4.** Where, in the construction of an embankment, it is necessary to construct a culvert over which the filling has to be placed, it is essential that the filling and subsequent compaction should be carried out in such a manner as to avoid an unbalanced thrust on the culvert, which might displace or damage it.

**4.6.2.** ***Tests for Compaction of Earthworks*** **-** The following tests shall be carried out for determining compaction:

a) *Density moisture relationship of the soil;*

b) *Density of the soil in field; and*

c) *Moisture content.*

## 4.7. DISPOSAL OF MATERIALS: -

**4.7.1.** All excavated materials within economic lead, suitable for construction of canal embankment should be used in its construction. Where the canal is aligned on sloping ground excavated material not required for the construction of embankment on the higher side shall be deposited on the lower side. Where canal is on level or nearly level ground the material from excavation shall be deposited on embankments on both sides of the canal. If there is excess of material from the excavation than needed for construction of embankments of canals, it should be deposited outside the embankments on either side of the canal in the form of spoil banks leaving a suitable berm and cross drains as directed by the engineer-in-charge.

**4.7.2.** A gap 3 m wide at toe may be left in spoil banks at 150 m intervals for the purpose of drainage.

## 4.8. BORROW PITS: -

**4.8.1.** Where canal excavation does not furnish sufficient suitable material for embankments, additional material required may be procured from the borrow pits. The location of borrow pits will depend on the material that is being sought which in turn depends on the design consideration. It may be necessary to survey the soil by means of auger borings or trial pits to determine the extent and nature of the deposits in the borrow area.

**4.8.2.** No borrow pits shall be dug within 5 m of the toe of embankment, if their depth is less than 0.5 m, and 10 m, if their depth is more than 0.5 m; or within such a distance from the toe of the bank where a 4: 1 hydraulic gradient line cuts the ground surface, whichever is more. Borrow pits shall not be more than 1 m in depth and 25 m in length. A clear distance of 1 m shall be left between the pits. The bed of borrow pits shall be left reasonably smooth and even.

**4.8.3.** Borrow pits shall be drained to avoid stagnation of water. The bottom level of borrow pits should be fixed with reference to the prevailing ground slope towards the nearest natural drainage course. The pits shall be connected together by a drain about 0.5 m wide. The bottom level of connecting drain should suit the bed level of the pits it connects.

## 4.9. TURFING: -

**4.9.1.** ***Principles Underlying the Use of Grass on Earth Slopes*** **–** Surface stabilization of slopes and the prevention of soil erosion and weathering may be accomplished by the establishment of grass or other herbage. The living grass roots mechanically reinforce the soil, and the decaying organic matter improves soils structure. The grass leaves, living or dead, protect the surface against rain and wind. The combination of improved soil structure and protection gives stability against erosion.

Virgin clays and other subsoils are usually deficient in those bacterial organisms which promote healthy growth. The application of top soil to any new slope is usually a pre-requisite for the successful establishment of grass.

**4.9.2.** ***Top-soiling*** **-** The depth of topsoil required will vary according to the nature of the subsoil and a depth of about 15 cm of good quality soil overlying the subsoil is usually sufficient to sustain plant growth.

**4.9.3.** ***Sodding*** **-** The sods used shall be cut in rectangular shape 8 to 10 cm thick and laid so that their edges are in close contact and then welded by being gently rammed till they form a level and compact mat. When old surfaces are to be turfed, they shall be picked up to a depth of about 4 cm to give a hold to the sods. For sodding any grass which forms a thick short turf shall be used.

**4.9.4.** ***Turfing*** **-** It is difficult to generalize on the type of grass to be used since each particular soil type required a specific grass. To ensure a satisfactory result it is desirable to consult agriculture department, who would make any necessary analysis of the soil before specifying the type of grass. It would also be a help to study the grasses growing in the neighbourhood and to include the varieties that appear to be most suitable; this, of course, largely depends on the top soil being obtained from the same vicinity.

# LINING OF CANALS

## 5. PREPARATION OF SUBGRADE: -

**5.1. Preparation of Subgrade Consisting of Soil: -** The subgrade should be prepared, dressed and rolled true to level and according to the required cross-section of the canal to form a firm compacted subgrade for the lining.

**5.1.1.** In other than predominantly sandy reaches where the dry bulk density of the natural soil is not less than 1.8 g/cm$^3$, initial excavation should be done up to about 30 cm above the final section and the cutting to final shape should be done immediately before lining.

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

**5.1.3.** If at any point material of prepared subgrade has been excavated, beyond the neat lines required to receive lining, the excess excavation should be filled with graded filter material compatible with subgrade material and thoroughly compacted in accordance with **5.1.5**and **5.1.6.**

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

**5.1.4.** To cover up any lapses in the compaction of the inner core of the banks near the edges and to allow sufficient width for a labourer to work conveniently a lip cutting width of not less than 50 cm horizontally should be provided. Depending upon the nature of soil and the side slopes of the canal, the lip cutting width may be in the range of 50 to 100 cm. For canals in embankment it should be ensured that one monsoon is passed for proper consolidation before lining is done.

**5.1.5.** ***Compaction of Subgrade in Predominantly Sandy Reaches: -***

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

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

**5.1.6.** ***Compaction of Subgrade in other than Predominantly Sandy Reaches:*** **-** All compaction should be done at optimum moisture content in layers not more than 15 cm thick to obtain a dry bulk density of not less than 95 percent of the density at optimum moisture content obtained in accordance with **IS 2720 (Part 7): 1980.**

**5.1.6.1.** Where the dry bulk density of the natural soil is equal to or more than 1.8 g/cm$^3$, the procedure described in **5.1.1** should be followed.

**5.1.6.2.** *Bed:* - Where the dry bulk density of the natural soil is less than 1.8 g/cm$^3$ and the subsoil water is near the subgrade, the consolidation should be done by under cutting the bed by 7.5 cm and then ploughing up to 15 cm below the subgrade level. The loosened soil should then be recompacted with sheep foot rollers or other suitable devices.

Where the subsoil water is low, requiring no dewatering and the dry bulk density of the natural soil is less than 1.8 g/cm$^3$, the consolidation should be done by digging the canal up to subgrade level and after loosening the earth below subgrade up to 15 cm by disc harrows, or ploughing and compacting the same to a depth of 11 cm. After that, the second layer of 15 cm of earth should be laid over the compacted layer by taking earth from lip cutting and compacting this to a depth of 11 cm. The compacted layer of 7 cm above the subgrade level should be removed and the subgrade brought to design profile before laying the lining.

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

**5.2. Underdrainage: -** For a lined canal where the ground water level is higher or likely to be higher than water level inside the canal so as to cause damaging differential pressure on the linings; or where the subgrade is sufficiently impermeable to prevent free drainage of the underside of lining in case of rapid draw down, underdrainage should be provided in accordance with IS 4558: 1983.

**5.3. Anti-Salt Treatment: -** Soil in all reaches should be tested for salt content before the lining is started. Where the salt content is over 1.00 percent or sodium-sulphate is over 0.36 percent, the subgrade should be first covered with about 2 mm thick layer of bitumen obtained by evenly spraying bitumen at a rate of about 2.35 kg/m2. To get a good bond between bitumen and soil, crude oil at a rate of 60.5 lit/m2 should be sprayed over it in advance of spraying bitumen. In case such a situation is encountered only in small packets the replacement of subgrade up to a suitable depth by suitable earth from adjoining reaches should be considered, if economical.

**5.3.1.** Before spraying crude oil, subgrade should be perfectly dry, clean and free from dirt, and crude oil should be allowed to penetrate the subgrade surface. Bitumen should be heated to a temperature of 175°C and applied to the subgrade by a suitable sprayer. Immediately following the application of bitumen, dry sand should be uniformly spread. Lining should be started 6-12 hours after spraying.

**6. LAYING OF IN-SITU CONCRETE LINING: -**The concrete used for lining should be design mix concrete of grade M 10 or M 15 and should conform to requirement of IS 456: 1978.

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

**6.2. Thickness: -** The thickness of lining should be fixed depending upon the nature of the canal requirement, namely, hydel channel or irrigation channel, full supply depth and channel capacity. Hydel channel should have a greater thickness than channels meant for irrigation because of drawdown effects and where closure for repairs may not be usual. Deeper channels

should have greater thickness than shallow depth channels. Minimum thickness of canal lining based on canal capacities are given in the Table below.

| THICKNESS OF *IN-SITU* CONCRETE LINING | | |
|---|---|---|
| Capacity of canal (Cumec) | Depth of Water (m) | Thickness of lining (mm) |
| (1) | (2) | (3) |
| 0 - 5 | 0 - 1 | 50 - 60 |
| 5 – 50 | 1 – 2.5 | 60 - 75 |
| 50 – 200 | 2.5 – 4.5 | 75 - 100 |
| 200 – 300 | 4.5 – 6.5 | 90 - 100 |
| 300 – 700 | 6.5 – 9.0 | 120 - 150 |

**6.3. Mixing: -** Concrete should normally be mixed in a mechanical mixer.

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

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

**6.4.1. *Hand Placing:* -** Hand placing of concrete should normally be adopted where cheap labour is available.

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

**6.4.1.2.** The concreting of the sides and bed should be done in alternate panels. The panel width should vary from 2 to 3 m. In no case, should the panel width exceed more than 3 m as wider bays require unwieldy vibrators for compaction. The construction joints should be either parallel or perpendicular to the direction of flow. In case the full supply depth is high, construction joints along the direction of flow to divide the length of the panel should be provided. For this purpose, wooden rafters should be used.

The succeeding panels should be laid at an interval of one day. If the sloping length is less than 2.5 to 3 metres, concrete should be placed in one operation over the entire length. In case of deeper canals where the sloping length is more it should be suitably divided (say for a length of about 2 metres) in each alternate panel so as to prevent appreciable downward flow of concrete.

The bays/panels should be formed by proper form-work of M. S. channels laid all around the bay. The channels should be firmly spiked to the subgrade so that no movement takes place at the time of concreting and vibration. The depth of the M. S. channels should correspond to the required thickness of concrete lining. The concrete should be dumped in the bay from bottom to top and then spread all over the bay uniformly and to the required thickness guided by the channels. The spread concrete should then be compacted properly and thoroughly by means of mechanical or screed vibrators. An improvised plate vibrator operated by high horsepower engine and a winch for moving the vibrator up the inclined slope should be made use of for proper compaction. When width of panel is less i.e. up to 2 m manual operation of vibrators is possible and may be permitted. In no case the concrete should be compacted by tamping. The compacted surface should be true to the required side slope. Before re-using the channel forms, they should be thoroughly cleaned and well oiled. Care should be taken, while placing and vibrating the concrete that, the sub-grade in the adjacent bays does not get spoiled.

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

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

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

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

**6.4.2.** ***Mechanical Placing of Concrete:*** **-** Concrete for slip-form should be air entrained to provide a more workable and slippable mix.

**6.5. Finishing: -**The surface of concrete finished against forms should be smooth and should be free from projections, honeycombing and other objectionable defects. Immediately on the removal of forms, all unsightly ridges or lips should be removed and undesirable local bulging on exposed surfaces should be remedied by tooling and rubbing. Repairs to concrete surfaces

and additions, where required, should be made by cutting regular openings into the concrete and placing fresh concrete to the required lines. The chipped openings should be sharp and should not be less than 70 mm in depth. The fresh concrete should be reinforced with wire mesh extending to the full depth of the slab and chipped and trowelled to the surface of the openings. The mortar should be placed in layers not more than 20 mm in thickness after being compacted and each layer should be compacted thoroughly. All exposed concrete surface should be cleaned of impurities, lumps of mortar or grout and unsightly stains.

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

**6.6. Curing: -**Subsequent to laying of concrete lining and after a period of 12 hours, the lining should be cured for at least 28 days.

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

**6.6.2.** ***Side Lining: -***The panel in which concreting is done the previous day should be covered with burlap or empty cement gunny bags. For the purpose of curing, water tank of 5000litres capacity should be placed on a platform at the edge of service road at the rate of one for500 m length of lining, which should be kept filled with water, with arrangement of outlet and flexible hose of at least 300 m length. Water should be continuously sprinkled on the gunny bags or hessian cloth keeping them wet for 28 days. Sprinkling shall be done during night time also. The curing of side slopes maybe done by constructing masonry drains with weep holes or perforated pipes on the coping at the top of lining or by sprinklers.

**6.6.3.** ***Surface Drainage:*** **-** The top of the side lining concrete should be keyed into the subgrade both in cutting as well as banking by taking it horizontally for a width of about 300 mm. This key would prevent direct entry of surface rain water behind the lining. The top surface of the key should be finished with a downward slope of 1 in 10 or so towards the canal. A day after completion of concreting of all panels between two templates, concreting of key slab should be done.

Concurrently with the curing operation, surface drainage arrangement of the bank such as construction of keys, bank surface slope away from the lining and construction of longitudinal drain on the outer wedge shall be completed. This is necessary to prevent surface and subgrade erosion and consequent damage to lining.

**6.7. Joints: -**

**6.7.1.** ***Expansion Joints:*** **-** These should not be provided except where a structure intersect is the canal. The details are given in relevant Indian Standards covering such structures.

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

To cater for initial shrinkage and cracks, concreting should be done in alternate panels or bays. The panel size for the bed and slope of the canal should be adopted as given in **6.4**. 25 cm wide L.D.P.E film of 150-micron thickness should be placed on the top of sleepers, provided to support construction joints. The top of film and side of panel should be applied with primer conforming to IS 3384: 1985. This sheet acts as an interceptor for seepage through the joint. In case lining is laid by mechanical paver, PVC water stops are placed at joints along with the concreting. The water stops in such a case should be provided at a spacing not more than 4metres centre to centre.

**7. LAYING OF PRECAST CONCRETE TILES: -**

**7.1.** The lining should be started only when at least 35 m length of canals subgrade is properly dressed to receive lining. The arrangement for mortar and availability of sufficient number of tiles/stone slabs should be ensured before starting the work.

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

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

Tiles should be firmly embedded in mortar. Hollows, if any, should be rectified by relaying defective portion with fresh mortar. The tiles should be laid over a minimum of 12 mm thick cement mortar and having aggregate less than 6 mm to bring overall fineness modulus less than 2. Hollow joints should be raked and pointed with the same mortar. The thickness of joint should be 20 to 25 mm.

**7.4.** On completion of laying lining should be kept wet by sprinkling water over it to keep the mortar wetted. On the next day, the surface should be kept wet and joints should be carefully wetted. Hollow joints should be raked to a depth of 12 mm, loose mortar removed from sides and top of tiles/stone slabs and the joints properly refilled. Loose tiles/stone slab should be removed and re-laid.

**7.5.** The complete lining should be checked for level with wooden templates and spirit levels.

## 8. SAFETY LADDERS: -

**8.1.** Safety ladders should be constructed in canal lining as directed by the engineer-in-charge.

**8.1.1.** Safety ladders consisting of ladder rungs should be constructed in canal lining about 30.0 m upstream of the point where the canal enters some underground structure. In other reaches safety ladders, may be provided at a spacing of about 300 m; the ladders being provided alternatively on either side.

**8.1.2.** Ladder rungs should be smooth, round mild steel bars, galvanized or coated with coal-tar after installation.

**8.1.3.** As an alternative to safety ladders steps of rise 150 mm, tread 300 mm and 1500 mm wide may be provided in plain cement concrete of grade M-10 at a spacing of 300 m centre to centre (staggered) on either side of canal.

## MAINTENANCE OF CANALS

### 9. UNLINED CANALS:

**9.1. General: -** The chief requirements of uniform canal are as follows:

*a) A clean regular bed,*

*b) Straight clean slopes,*

*c) Uniform berm widths, and*

*d) Uniform regular top width.*

**9.1.1.** Closure on main canal and branches should be notified sufficiently in advance. Whenever a canal is closed it should be inspected as soon as possible. All pipes and openings in the crest of falls should be opened so as to drain off the water upstream of the fall. The canal should be cleaned before it is run again. All masonry work should be periodically cleared of rubbish, stones, brickbats, etc., as the opportunity offers, especially the siphons and the stilling basins.

**9.2. Bed and Berm: -** Bed and berm should be scraped, where necessary and especially in tail reaches. Berm and bed lines should be correctly aligned before scraping. Berm should not be scraped if it has not silted properly.

**9.2.1.** Before starting work on either the bed or berms, they should be aligned by flags and string. The former is necessary for the alignment in general and the latter to correct small irregularities in that. Every opportunity should be taken to straighten the canal and to get rid of kinks and irregularities in the alignment and also to ease off all curves where scouring or silting takes place.

**9.2.2.** Clearing operation should be started from downstream to upstream starting either from the tail or a fall.

**9.2.3. Bed: -** All grass should be scraped and weeds removed from the silted bed wherever they are found to exist since their presence induces silt deposit, reducing velocity and waterway.

**9.2.3.1.** All local accumulation or continuous deposits or mounds of silt should be removed to correct bed level (**see 9.4**).

**9.2.3.2.** Beds should be levelled and their gradients regularized by the removal of silt mounds higher than correct bed level. Bed levels should be fixed correctly at close intervals by means of boning rods. In case of main canals, branches, and distributaries, silt at the junction of bed and slopes should not be removed if the section of waterways is not unduly affected. Small minors and all tail reaches should, however, be cleared to the correct trapezoidal Section. The practice of cutting the silt deposited at the junction of side slope and bed and throwing it on the bed to level it should not be permitted.

**9.2.3.3.** Irrigation canals that carry silt-free water from reservoirs generally get infested with aquatic weed growth which reduces their capacity and thereby impairs their proper functioning. For maintaining these canals at designed efficiency, it is essential to keep them clear of aquatic weeds. In case of newly constructed canals regular inspections should be undertaken to locate any spots where the weed growth has set in. Weeds from such spots should be removed completely so that infestation does not spread. In the case of old canals where aquatic weed growth is profuse suitable mechanical or chemical methods may be employed at as early stage as

possible. Care should be taken that the chemical is used within reasonable limits so that it is not harmful for living beings and the corps. Biological methods such as fish culture of the type of grass-carp could also be tried.

**9.2.4. Inlets and Escapes: -** Inlets normally cause harm to the canals bed and side slopes and the drainage there from should be siphoned under the canals wherever economically feasible. If storm water is admitted to the canal at any place, the canal immediately, above and below the inlet, should be inspected after storms and any silt or sand that may have been brought down should be cleared away to maintain proper section. When inlets are provided with loose stone bunds or inlet walls or traps they should be cleared of silt and trash from time to time.

Escapes should be kept clear of silt and jungle growth. These should be run occasionally to test their discharging capacity and to maintain right of escaping excess water into natural drains in which such escapes join and to avoid tendency of cultivators to sow in low lying land in the bed and along the sides of such natural drains**.**

**9.2.5. Berm: -** Berm cutting should not be started until sample profiles have been cut and the lines carefully laid. Where earth is required for repair of banks, berm pockets may be made in the manner specified in **9.7.1.c)**

**9.2.5.1.** Wherever berms are fully formed up all grass and brush-wood should be removed from them since their presence induces abnormal and irregular growth resulting in constriction of canal section.

**9.2.5.2.** Irregular protruding and overhanging berms should be cut back to proper alignment and slope. If this is neglected berms fall in or protrude abnormally and the canals tends to adopt an irregular section or winding course.

**9.2.5.3.** Wherever berms have grown excessively thereby tightening the waterway they should be cut to proper section.

**9.2.5.4.** Berms should be kept straight by trimming projections after aligning them correctly. Heavy berm cutting may be avoided by regular trimming and scraping as the situation calls for every year.

**9.2.5.5.** Killa-bushing filled with brush-wood should be provided to induce formation of the berms.

**9.3. Silt Clearance: -** Silt ejectors/desilting basins wherever provided should be operated regularly to prevent accumulation of silt. If a canal is in regime and taking its full supply, it is not necessary to clear silt to the theoretical cross-section. If the canal is not functioning properly, it may be sufficient merely to clear a portion of silt to get it into efficient working order or it may be necessary to clear to full theoretical cross section (**see 9.2.3.2**). On run of the river canals and specially those which are also run for paddy irrigation silt is likely to deposit in distributaries and minors which may get picked up when clear water runs in the channel after monsoon. Longitudinal sections of silted bed of such channels should be taken during closure immediately after monsoons and the gradient at which silt should be removed and be approved by the Executive Engineer. Silt should not be cleared below falls but if outlets in such places are overdrawing water due to rise in water surface, they should be raised. Boning rods should be used to see whether the silt has been properly cleared.

**9.3.1.** As soon as a canal is closed for a fairly long period the bed bars should be uncovered and the depth of silt over them recorded.

**9.4. Silt Disposal: -** Disposal of silt form bed depends on its quality as given below:

a) *Coarse Silt* — Found in head reaches of distributaries. It contains a large percentage of sand which does not stabilize and is useless for any repairs. This should be disposed of in filling old borrow pits first and then on long outer slopes of banks; care being taken that the top of the heap is never allowed to come above the bank level. Silt thrown outer slopes of banks should be disposed of in a regular and uniform manner and not in irregular heaps;

b) *Medium Silt:* -Found in middle reaches of distributaries. It stabilizes after one monsoon passes over it if taken out before or during the monsoon. It may be utilized in: (1) closing leaks, (2) securing outward slopes, and (3) widening bank only as supplement to the berm earth if it proves insufficient; and

c) *Fine Silt:* - Found in tail reaches of canals. Contains a good proportion of clay and settles down to a very smooth surface and allows grass to grow freely on it, it is valuable for all repairs and should be used like berm earth.

**9.4.2.** Silt should not be heaped above bank level. It should not be used in raising and narrowing already high and narrow banks. It should never be thrown on the berm of inner slope of banks. Coarse and medium silt should not be spread on canal service road. If this has to be done for any reasons, the surface should be covered by a 15cm thick layer of good loamy soil or fine silt.

**9.4.3.** Material obtained from bed and berm cutting as specified in **9.4**and should be utilized in repairing the banks to make them up to the design section.

**9.4.3.1.** Bed silt should generally be thrown on outer slope of the weaker bank to strengthen it; if both banks are equally weak it should be thrown equally on each side.

**9.5. Miscellaneous: -** Where a canal is running brush-wood that collects at bridges, siphons and falls, it should be removed to some distance away from the banks, dried and burnt. When trees fall into a canal they should be removed at once. When general clearance is being done, it should be particularly seen that silt and rubbish are cleared from under the bridges.

**9.5.1.** Instances of excessive scouring at any point should be noted and adequate measures, such as driving in stakes along with brush-wood and construction of revetment should be taken to stop them.

**9.5.2.** It is not practically feasible to observe the discharge in the channels once a month. To have effective control in regulation, it will be desirable to observe discharge at conspicuous place near the flumes or free falls and to frame gauge discharge tables and such tables may be operated for a period of one year. In case where there is no other means of arriving at the discharge observations by way of meter flumes or free falls, discharge tables may be framed for operation for a period of six months.

**9.5.3.** Gauges at the head and tail of all the channels and at important points in between on long channels should be observed and recorded daily.

**9.6. Banks: -**

**9.6.1.** Regular cross-sections should be surveyed to see settlement pattern of banks. Banks shall be brought up and maintained to full section. The minimum width and free board of the bank should be in accordance with the relevant Indian Standard.

**9.6.2.** Before continuous bank repairs are started, profiles should be made, 30 m apart. These should be at the correct height and width of the bank repaired and should be checked before work is started.

**9.6.3.** All holes and rain cuts should be fully opened up to the bottom by digging steps not more than 0.5 m deep in the sides and removing all the fallen or loose lumps of earth, bushes, grass roots, etc. Filling and repairing should be done by placing level layers of earth (not more than 15 cm deep) obtained from source specified in **9.7.1**. The earth in each layer should be free from clods, roots, grass, brickbats and other debris and it should be compacted at adequate moisture content.

**9.6.4.** Leaks should be stopped from the upstream side by cutting off the penetrating water. If practicable cracks should have good earth worked into them by chisel pointed poles, but if the presence of water against the bank prevents, this, the leakage should be stopped by a cover of good earth thrown over it. Subsequently, in dry season the defective part should be opened up and properly remade.

**9.6.5.** Top of bank should be smooth and free from clods and silt mounds. They should be given a slight outward cross slope of about 1 in 80 in order to take the rain water away from the canal.

**9.6.6.** Both edges of banks especially the inner ones should be neatly aligned parallel to the canal. They should be absolutely straight in straight reaches and regular on curves.

**9.6.7.** Both inner and outer slopes and toes of banks should be free from irregularities. Only projections shall be cut down and earth thus obtained should be utilized in filling hollows.

**9.6.8.** The bank slopes should not be scraped or cut back as a general rule.

**9.6.9.** Loose earth should not be left lying on top of a bank. Wherever filling is necessary, it should be well compacted.

**9.6.10.** Grass or turfing should not be scrapped. It should only be cut as far as necessary to show the surface of the bank and to avoid the holes being hidden under long grass.

**9.6.11.** Scraping the top edges of banks for appearance should not be permitted.

**9.6.12.** Earth from any surface (**see 9.7**) for bank repairs should be placed where required and in such quantities only as needed, otherwise banks will become irregular by developing unwanted bulges and hollows.

**9.6.13.** The top of both banks should always be kept smooth and free from holes. One bank, at least, should be maintained as an inspection bank.

**9.6.14.** Banks that are too low should be raised to the proper design levels as early as possible.

**9.6.15.** Banks should generally be at least 30 cm above the country level to prevent drainage getting in the canal.

**9.6.16.** When banks show signs of slushing owing to saturation, they may be protected with an appropriately designed filter and/or drain.

**9.6.17.** In case of banks where there is trouble due to borrowing of animals, a sand core may be provided.

**9.6.17.1.** In pervious reaches where seepage is excessive puddled clay core, in place of sand core, may be provided.

**9.6.17.2.** Where water logging is observed seepage, drains should be provided on either bank.

**9.7. Sources of Earth for Repair: -**

**9.7.1.** Suitable earth for repairs may be obtained from the following sources:

a) *From Internal Clearances*—Material obtained from internal clearances should be utilized as given in **9.4.3.**

b) *By Removal of Irregularities* — High banks can be lowered and bumps or projections on top or sides cut down to fill in the hollows.

c) *By Making Pockets in Berms*—By making 1.5 m long pockets in the berm with a minimum distance of 1.0 m left in between them. Depth should be usually kept 30 cm. The silt should be removed leaving a layer of silt at least 15 cm thick next to the bank.

d) From Spoil Banks

e) From Prominent Mounds in the Fields Near the Site

f) From Beds of Drains Near the Site

g) *From Borrow Pits in the Bed of Distributaries and Minors* — These are usually not recommended but should not be used in any case at the tails of distributaries and minors which do not get silt. This is particularly important for canals fed from reservoirs.

h) *From Outside Borrow Pits* — Earth from outside borrow pits should be only obtained if it is not possible to procure earth from any of the other sources specified above.

**9.7.2.** The following precautions should be observed in taking earth from outside borrow pits:

a) No borrow pits should be dug within 6 m from the toe of banks or driving road or driving road or ramps of bridges.

b) Borrow pits should normally be not more than 30 cm deep; and

c) Earth should not be taken from the toe of banks, as the natural rounding of the corner should not be disturbed

**9.8. Roads and Ramps: -**

**9.8.1.** Roads and ramps should be kept smooth and shall have a regular longitudinal grade.

**9.8.2.** At outlet and bridge crossings the road should be specially attended to, for it is here that one generally gets very bad jolts while motoring due to bumps and hollows existing there. These defects should be removed by stretching a string across the top and shaving off the bumps and filling in the hollows till the string touches the surface all through.

**9.8.2.1.** Ramps and approaches to bridges should be maintained smooth and to the designed gradient.

**9.8.3.** Where there are spoil banks on the side of the roadway and higher than it, there should always be a continuous drain along the outer edge of the road as well as cross drains through the

spoil banks, the latter being at right angles to the former and leading with a gentle slope to the boundary ditch. Cross drains should not be allowed to get higher than side drains. Where there are no spoil banks outside then roadway no drain is required. Where the service road has a longitudinal gradient such as near bridges, side drain along dowel (earth in parapet) should be provided.

**9.8.4.** The roadway should be never allowed to remain blocked by fallen trees or in a dangerous condition by holes and hollows.

**9.8.5.** Spare construction material, if any, should be properly stacked along the outer edge of the road.

**9.8.6.** Kilometre stones should be adjusted to the correct position, whitewashed and lettering recoloured, when necessary. Guard stones and bumping stones should be adjusted and whitewashed.

**9.8.7.** While undertaking any repair work on service road suitable diversion should be provided to allow uninterrupted traffic during repairs.

**9.8.7.1.** All gaps, foundation pits, etc., should be fenced with spout railings their position being marked at night by lanterns or watch fires under the charge of a watchman.

**9.8.8.** A dowel should be made to the size and shape specified in the relevant Indian Standard. The bottom edge of the dowel should not be cut for repairing the banks.

**9.8.9.** If a portion of the dowel falls into the canal another dowel should be made a short distance behind and parallel to the old one. The new and old dowels should be joined with reverse curve. This should be considered only as a temporary measure pending further appropriate action for protecting the edge of the road.

**9.8.10.** Ordinary repairs to canal roadway should be taken in hand after first heavy rain falls and should never be postponed till the end of the monsoon.

**9.8.11.** The canal roadway should be inspected after heavy rain and holes where seen should be filled in accordance with **9.6.3**. Silt from canal berm may be used for closing these holes where there are no spoil banks. Holes generally result from defective drainage which should be looked into and remedied otherwise the holes will quickly re-open.

**9.8.12.** If the top of road over an outlet is higher than elsewhere a horizontal stretch of 15 m should be provided over the outlet with ramps having 1 in 30 slope.

**9.8.13. Main or Branch Canal Roads: -**A dry road surface disintegrates rapidly and it is, therefore, necessary that roads should be regularly watered. On main canals and branches where the strength of gangmen employed on maintenance works is sufficient, the road surface after watering should be worked with rings to give a good even surface. Where, however, the soil is too poor for this treatment, the road surface should be properly levelled by means of Kassi watering, and subsequently scraped with a scraper and then rolled over.

**9.8.14. Distributary Road and Boundary Roads: -** On distributary roads where the strength of gangmen is inadequate the watering of road surface should still be resorted to as frequently as possible. In the case of boundary roads, it is usual to construct a small dowel along the outer edge of the road and to arrange for watering the road from the adjoining water courses or by means of small pipes fixed in the distributary bank for this purpose. After such watering, the boundary road should be properly scraped by means of a scraper. In the case of boundary roads,

affected by Kallar an ordinary ‘Sohaga’ (Leveller) dragged over the road while water is still standing on the road is very effective in suppressing Kallar.

## 10. LINED CANALS:

**10.1. General: -** A lined canal should be maintained so that it continues to function efficiently and serves the purpose for which it has been constructed, throughout its effective span of life. In addition to maintaining its imperviousness, the lining should be maintained so that it also continues to have the same discharge capacity for which it has been designed and which it had when it started operating soon after the construction was over. The reduction in discharge may generally be due to accumulation of silt; cracking of lining; failure of the drainage; growth of weeds, algae and moss; seepage and evaporation etc.

**10.1.1.** Normally no silt deposition should be permitted to take place in a lined canal. Sometimes the canal may have to be run at less than the designed full supply discharge on account of fluctuating water demands, over the base periods of the crops to be irrigated. Also, even for a single crop discharge requirements vary from month to month. Such low discharge conditions include deposition of silt over the canal bed owing to low velocities of flow. Consequently, the discharge carrying capacity of the lined canal is adversely affected. Silt deposition in lined canals can be minimised by judicious operation of gates of cross regulators silt ejectors/desilting basins, wherever provided. These gates should be lowered for ponding on the upstream side only under the following conditions:

a) To limit the rate of drawdown in the lined canal to a maximum of 0.5 metre per day either during fluctuations of discharge or when the canal is being closed.

b) To enable channels taking off upstream of the regulator to be fed properly or to divert flow through escapes.

c) At all other times, the canal should be run with gates-full open.

**10.1.2.** Special design features like under-drainage arrangements, humps or regulators in canal bed, silt ejectors, surface drainage; etc. should continue to function efficiently so that the safety of the lining is not endangered.

**10.2. Canal Closure: -** Suitable rules should be framed and observed for each canal system to ensure that the closure does not create a rate of drawdown which is more than what is provided for in the design.

**10.3. Inspection of Lining: -**Whenever canal is closed for periodical inspection and repairs, the lining, its auxiliaries and special design features should be carefully inspected. The following points should be noted while carrying out the inspection:

a) Whether any cavities or pockets have been formed behind the lining;

b) Development of any cracks or displacement or damage to lining;

c) Whether the filler material in the joints of the lining is sound, intact and leak-proof and any weed growth in the joints has taken place;

d) Whether pressure release arrangements and humps or regulators (if any) function effectively;

e) Whether pipes and openings provided in the crest of falls are choked;

f) Silt deposits and weed growth; and

g) Bench marks/Boundary pillars, full supply water levels/gauge at suitable intervals be pointed/fixed to know about the hydraulic efficiency of the canal.

**10.4. Maintenance of Lining: -** There can be distress to the lining ranging from small settlement cracks to excessive heaving displacement and sinking of the lining in the following situations:

a) Cuts in soft fine grained soils, specially when the lining was laid directly on the soil without any special preparation of the subgrade;

b) High water table situated considerably above the canal bed, especially in fine grained soils, where weep holes or other simple drainage devices are not very effective;

c) Freshly laid embankments, especially if composed of clayey soils;

d) High continuous spoil banks, left too near the canal excavation without sufficiently wide berms and adequate arrangements for draining the rain water away from the canal and similar situations permitting surface drainage to enter behind the lining; and

e) Cavities behind lining caused due to sucking out action on subgrade material by oscillating waves or fluctuating supplies of water of the canal through cracks, open joints and holes in lining. Such action as may be necessary to avoid recurrence of any failure in the lining should be taken by investigating the causes of the failure and remedying them. The defects or damaged parts of the lining, joint filler, etc., should be immediately attended to and repaired so as to ensure a sound, stable and watertight lining.

**10.4.2.** Any activities or pockets detected behind the lining should be carefully packed with sand or other suitable material. Care should be taken to ensure that the lining does not get damaged or displaced during the operation.

**10.4.3.** Damaged or displaced portions of lining should be removed and replaced by fresh lining of quality comparable to the original lining. The sub-grade should be thoroughly compacted and prepared before laying the fresh lining. The cracks (other than hair cracks) should be filled with bitumen or other suitable filler so as to ensure water-tightness of the lining. A more effective sealing of cracks may be obtained by cutting a V-groove along the face of the cracks before filling with staling compound. Minor cracks on the lining may be sealed by dumping powdered clay upstream of the cracks.

**10.4.4.** The damaged or displaced portions of the joint filler should be carefully removed. The joint should be cleaned of dirt, weeds, etc., before filling in fresh filler material.

**10.4.5.** The chocked pressure release pipes should be cleaned by intermittent application of air and water or by rodding. Defective flap valves or other parts should be repaired or replaced. The humps or regulators should be well maintained and repaired, if necessary.

**10.4.6.** All drainage and pressure release pipes and openings should be cleaned of any dirt, debris, etc., and water accumulating upstream of the fall, if any, should be drained off.

**10.4.7.** In pervious linings, such as boulder lining, any portion in which excessive settlement has taken place, should be repaired by dismantling making up the sub-grade and relaying the lining.

**10.4.8.** The lining should be protected from ingress of rain water behind the lining. The free edge of the lining should be well tucked into the canal bank. Turfing of the slope above the lining level would greatly help in preventing scours and gully formation.

**10.4.9.** Discharge table be prepared once a year near the flumes or free falls or at other conspicuous points where such hydraulic structures are not available. Suitable measure be taken to bring the canal to carry its authorised discharge when it is noticed that the discharging

capacity is reduced. It should be done by maintaining the lined surface of the canal to its original shape and slopes.

**10.5. Reaches with High Subsoil Water Level: -** The subsoil water level should be observed in such reaches carefully and regularly during and after the rainy season besides routine observations from time to time. In case of rise, the adequacy of the pressure release system or other remedial measures like humps, regulators, etc., provided for the safety of the lining, should be reviewed and further measures adopted, if necessary.

**10.6. Seepage Through Embankments: -** Seepage through embankments, if any, should be observed at reasonable intervals, of time. Where necessary, particularly in high embankment reaches, observations of seepage flow should be made and any abnormal increase in the seepage rate and soil particles should be viewed with caution, its possible causes investigated and remedial measures taken.

**10.7. Weed Removal: -** Aquatic weed growth, if observed below the supply level should be removed. Land weed growing over the free board should also be controlled.

**10.8. Performance of Canal: -** An accurate and systematic record of the performance of a canal should be maintained by periodic observations of Manning's roughness coefficient evaporation and seepage losses, life and behaviour of the lining adopted, surge wave heights, and performance of any special design features like pressure release system, provision of humps or regulators, etc.

**10.9. Miscellaneous: -**Brushwood that collects at bridges, siphons and falls should be removed. When trees fall into canal they shall be removed at once.

# CHAPTER-IX

## FREQUENCY OF TESTING

| S. No. | Test | Frequency | IS Codes | Allowable Limits | Name of Equipment |
|---|---|---|---|---|---|
| 1. | **CEMENT** | | | | |
| | i) Fineness | For each consignment | a) IS:269-2015 Table 3 | Min 225 $m^2$/kg | Brass Frame IS Sieve of 90μm. |
| | ii) Soundness by Le Chatelier Method | | b) IS:1489-1991<br>c) IS:4031(Pt-3)-1988 | Not > 10 mm | Le Chatelier Apparatus |
| | iii) Consistency | | b) IS:1489-1991<br>c) IS:4031(Pt-3)-1988 | Penetration upto 5 to 7 mm from base. | Vicat Apparatus |
| | iv) Setting Time (Initial Setting Time (IT) and Final Setting Time (FT)) | | b) IS:1489-1991<br>c) IS:4031(Pt-5)-1988 | IT – Not <30 min<br>FT – Not >600 min | Vicat Apparatus |
| | Compressive Strength | | b) IS:1489-1991<br>c) IS:4031(Pt-6)-1988 | At 72 ± 1h, 16 MPa, *Min*<br>At 168 ± 2h, 22 MPa, *Min*<br>At 672 ± 4h, 33 MPa, *Min* | Cube testing Machine |
| | Drying Shrinkage | | b) IS:1489-1991<br>c) IS:4031(Pt-10)-1988 | Shall not be more than 0.15% | Balance and Moulds |

| Sl. No. | Test | Frequency | Purpose | IS Codes | Allowable Limits | Name of Equipment |
|---|---|---|---|---|---|---|
| 2. | **FINE Aggregate** | | | | | |
| | i) Screen Analysis (Fineness Modulus) | One test for every 150 $m^3$ of sand used in concrete | To know grain size and the fineness modulus of sand | IS: 2386 Part I-1963 | Fineness Modulus of sand 2.2 to 3.2 | IS Sieve |
| | ii) Unit Weight and Bulkage of sand | - As above- (also once in a shift or for every consignment) | To utilize data for mix design computation | IS:2386 Part III-1963 | Bulkage of sand to be considered during design mix. | Cylindrical Measuring Glass |
| | iii) Organic impurities | - As above - | To assess the quality of sand | IS:2386 Part II-1963 | | Balance, Container and IS Sieve. |
| | iv) Soundness | One test for every 150 cum of sand used in concrete | To assess the quality of sand | IS :2386 Part V-1963 | Loss Not >10% after 5 cycles of immersion in $Na_2So_4$ | Balance, Container, IS Sieve and Drying Oven |
| | v) Silt Content | One test for every 150 cum of sand used in concrete | To assess the silt content present in the sand | IS:2386 Part II-1963 | Not greater than 3% for natural FA and Not greater than 5% for crushed FA. | Balance, Container and IS Sieve. |
| | vi) Specific Gravity, moisture content and absorption | One test for every 150 cum of sand used in concrete | To utilise the data for mix design computations | IS :2386 Part III-1963 | | Balance, Container, IS Sieve and Drying Oven |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3. | **COARSE AGGREGATE** | | | | | |
| | i) Sieve Analysis | One test for every 150 $m^3$ or less. | To know gradation and percent | IS :2386 Part I-1963 | | IS Sieve |
| | ii) Specific Gravity, Bulk Density, Moisture content, Absorption & Silt Continent | -do- | To utilize data for mix design computation. | IS :2386 Part III-1963 | Not >2.6<br>Not more than 5% by weight<br>Not >3% | Balance, Container, IS Sieve and Drying Oven |
| | iii) Soundness test (Sodium Sulphate method) | -do- | To assess the quality of course aggregate | IS :2386 Part V-1963 | Loss Not >12% after 5 cycles of immersion in $Na_2SO_4$ | Balance, Container, IS Sieve and Drying Oven |
| | iv) Abrasion, Impact & Crushing Value | -do- | -do- | IS :2386 Part IV 1963 | Wearing Surfaces: Loss Not > 30%<br>Non Wearing Surface Not > 4 | Los Angeles Abrasion Testing Machine |
| | v) Organic Impurities (Mica content) | -do- | -do- | IS :2386 Part II-1963 | Less than 1% | Balance, Container, Skimmer |
| | vi) Alkali reactivity (Alkali-Aggregate reactivity) | Twice in one working season | To know the 'innocuous' or 'deleterious' nature of aggregate | IS :2386 Part VII-1963 | Falling in left side of Sc/Re curve.. 'Innocuous'<br>Falling in right side of Sc/Re curve... 'Deleterious' | |

| | | | | | |
|---|---|---|---|---|---|
| | vii) Petrographic Examination | Twice in one working season | To know the deleteri o us constitu e nts and silt in aggrega t e | IS: 2386 Part VIII-1963 | Deleterious constituent plus silt shall not exceeds 5% |

| S. No | Test | Frequenc y | IS | Allowa ble | |
|---|---|---|---|---|---|
| 1. | **GRAVEL** | | | | |
| | i) Size of Gravel ii) Liquid limit iii) Plasticity Index | For each stack | IRC: 19-1977 | Not larger than ¾" < 20% < 6% | Cassagrande's Apparatus |
| 2. | **WATER** pH value, Organic ,In- organic | Two samples for each | IS:3025 Part II IS:3025 Part 18 | 6 to 8 Not greater than 200 | |
| | Sulphates ,Chlorides | | IS:3025 -Part 24 IS:3025 -Part 32 | Not greater than 400 mg/l Plain Concrete: Not greater than 2000 | |
| | Suspended Solids | | IS:3025-Part - | Not greater | |
| 3. | **RR STONE** | | | | |
| | i) Abrasion value | For each quarry | IS:1124-1974 | Not to | |
| | ii) Crushing Strength | | IS:1121-1974 | Granite – | |
| | | | | Basalt – | |
| | iii) Specific Gravity | | IS:1122-1974 | 2.60 | |
| | iv) Water Absorption | | IS:1124-1974 | Not to | |
| | v) Durability | | IS:1126-1974 | | |

| | | | | | |
|---|---|---|---|---|---|
| 4. | **REINFORCEMENT**<br>Weight<br><br>Diameter<br>Ultimate<br>Test<br>Strength<br>Yield Stress<br>Elongation | For each consignment | IS:1786-1985<br>IS:432-1982 | Dia ≤ 8mm ± 4%<br>Dia ≤ 8mm ± | |

# CHAPTER-X

## COMPILATION OF QUALITY CONTROL DATA

Quality control data shall be compiled on a continuing basis and reports prepared in a booklet form at regular intervals. These reports should include the following:

1. Brief report of the project for which the data is compiled.
2. Index Plan
3. Geologists report depending upon the nature of the project.
4. Note on foundation treatment, grouting pattern if suggested.
5. Nature of input materials like soil, cement, aggregates, steels and their source of supply.
6. Test reports on input materials and acceptance criteria as laid in I.S. codes.
7. Design of concrete mixes.
8. Summary of records and reports on grouting as specified in IS: 6066-1994.
9. Test reports on concrete like slump, compressive strength etc.
10. Control charts for cement concrete i.e. Master charts, moving average strength and range charts etc.
11. Statement showing the deployment of machinery.
12. Statement showing the quality of concrete and earthwork executed and number of cubes tests conducted.

# CHAPTER-XI

## CHECK LIST FOR QUALITY CONTROL UNIT

GOVERNMENT OF WEST BENGAL

IRRIGATION AND WATERWAYS DEPARTMENT

Name of work

Name of Division

Name of Sub division

Name & Designation of the Execution staff available at site

Date of Inspection

Brief description of work in progress during inspection

**Observation and comments of Inspection officer**

| S.No. | Check points | Observation |
|---|---|---|
| | **A. GENERAL** | |
| 1. | Whether the reference lines and Bench Marks have been established and marked at site, B.M. values written after double leveling. | |
| 2. | Whether set of approved drawings, specification, estimate & copy of agreement available at site or not. | |
| 3. | Whether construction material has been tested before its use and test result are available at site & areas per specification. | |
| 4. | Whether following record are available at site:- | |
| | I. Density Register | |
| | II. Cement receipt and Consumption Register | |
| | III. Slump Test Register | |
| | IV. Cube casting Register | |
| | V. Inspection Register | |
| | VI. FM & Gradation Register | |
| | VII. Test Result of Bricks, tiles / PCC Blocks | |

| | | |
|---|---|---|
| 5. | Field laboratory equipment available at site | |
| | I. DBD set | |
| | II. Sieve analysis | |
| | III. Slump cone | |
| | IV. Flexural tile testing machine | |
| | V. Cube moulds | |
| 6. | Any other point. | |
| | **GENERAL ITEMS FOR CONCRETE, MASONRY, LINING etc.** | |
| 1. | Specify the mode of mixing of ingredients in to the Mixer i.e. volumetric or by weight. | |
| 2. | Whether Concrete/ Mortar Mixer is as per specification and in proper working condition. | |
| 3. | Whether Sand being used has been screened and free from organic materials and confirms to specifications and gradations. | |
| 4. | Whether coarse aggregate used is confirming to the specification & washing is being done before feeding in Mixer. | |
| 5. | Whether Slump of the concrete is as per specification. Specify the Slump as per observation at the time of inspection (range 25mm to 75mm). | |
| 6. | Whether Cubes for compressive strength of Mortar/ concrete are being casted and tested, specify the variations in test results. | |
| 7. | Whether curing arrangement are adequate and curing is ensured up to specified time. | |
| **B. EARTHWORK FOR DAM & CANAL EMBANKMENT** | | |
| 1. | Whether approved borrow area plan with adequate test result is available at site. | |
| 2. | Whether the earth is being carted from the approved & designed borrow area. | |

| | | |
|---|---|---|
| 3. | Whether the Earth being used is free from organic material, plants, roots etc and does not contained kankar beyond permissible limit. | |
| 4. | Whether moisture contents of the earth in the borrow area / at the placement site is within permissible limit (OMC) (Specify the moisture contents after observation in the field). | |
| 5. | Whether the surface over which the earth layer is being laid is free from roots, vegetation and perishable material and pre-wetted and benched or not. | |
| 6. | Specify the layer thickness, whether the earth is being laid in horizontal layers or along slopes of existing bank. | |
| 7. | Specify the mode of compaction and frequency of density observations made by field staff at site and corrective measures taken in case required density has not been achieved. | |
| 8. | The density of surface over which earth layer is in progress on the day of inspection (either observed or as per density register). As far as possible density should be observed during inspection and also compared with Proctor density. | |
| **C.PREPARATION OF SUB GRADE FOR CANAL LINING** | | |
| | **I. Sub grade consisting of earth** | |
| 1. | Whether sub grade prepared dressed and rolled to the level and X-section to form firm compacted bed for lining or not. | |
| 2. | Whether the surface irregularities are within permissible limit. | |
| 3. | Whether the canal section is dewatered | |
| | **II. Sub grade consisting of Expansive Soil's** | |
| 1. | Whether CNS soil being laid /already laid confirm to gradation and other parameters | |
| 2. | Whether steps or benching is being | |

| | | |
|---|---|---|
| | provided. | |
| 3. | Whether pre-wetting of existing surface is being done. | |
| 4. | Whether CNS provided up to ground level, in Horizontal layers or along slopes. | |
| | **III. Sub grade consisting of Rock** | |
| 1. | Whether sub grade prepared and dressed true to level and according to require profile. | |
| 2. | Whether final cutting for 300 mm to 450 mm in hard rock carried out by wedging, barring or controlled blasting. | |
| 3. | Whether the over breakage below the lines under the side of lining back filled with suitable material. | |
| | **IV. Preparation of surface of existing masonry / concrete before raising / plastering** | |
| 1. | Whether the racking out of joints of existing masonry has been done to a depth of 12 mm. | |
| 2. | Whether all loose material has been removed or not? | |
| 3. | Whether the surface has been washed with air Water Jet or not? | |
| **D. CANAL LINING** | | |
| 1. | Whether section ready to receive lining is as per approved design & drawings. | |
| 2. | Whether model section / templates / concrete Sleepers provided at regular intervals. | |
| 3. | Whether under drainage arrangements provided. | |
| 4. | Whether sub grade is being moist to specified depth with water spray. | |
| 5. | Specify the mode of placement of concrete-paver or manual. | |
| 6. | Whether concrete for lining/mortar for brick lining is as per specification. | |

| | | |
|---|---|---|
| 7. | Whether Bricks are being soaked in soaking tank before using for lining. | |
| 8. | Whether green masonry/lining is being protected from movement of labour and material is not being stacked over it. | |
| 9. | Specify the lining thickness after actual observation at site during inspection. | |
| 10. | Whether base plaster and sandwich plaster (in case of PCC block lining) has been provided in required thickness and cured to specified period. | |
| 11. | Whether PCC block/bricks are being laid over 6 mm thick CM 1:3 and joints are upto 9 mm thick. Specify the average thickness of joints between two blocks. | |
| 12. | Whether dates of lining in each panel is marked or not. | |
| 13. | Whether proper curing is being done or proper curing compound is being used. | |
| 14. | Specify workmanship of lining. | |
| 15. | Whether construction joints are being provided as per specification. | |
| **E. CONCRETE** | | |
| 1. | Whether vibrator is being used for consolidation of concrete- specify the number and type of Vibrator being used at site. | |
| 2. | Whether surface of previous layer is green cut, roughened, cleaned, washed and moist before laying next layer of concrete to have good bond. | |
| 3. | Whether mix designed of concrete has been done. | |
| 4. | Whether contraction joints are being left as per specification. | |
| 5. | Whether shuttering confirms to the specifications and is in alignment as per drawing. | |
| 6. | Whether reinforcement is as per design & specifications. | |

| | | |
|---|---|---|
| | | |
| **F. MASONRY WORK** | | |
| 1. | Whether stones / bricks are as per specification. | |
| 2. | Whether bedding is being prepared before laying of stones. | |
| 3. | Whether thickness of joints is within permissible limit. | |
| 4. | Whether surface is cleaned, washed & moist before laying next layer. | |
| 5. | Whether stones / bricks are washed / submerged before using for masonry. | |
| 6. | Whether bond stones and headers are provided at 2 m intervals and are marked. | |
| **G. PITCHING / RIPRAP** | | |
| 1. | Whether stones being used for pitching are as per specification & proper size. | |
| 2. | Whether pitching is being done by constructing grids in specified pattern. | |
| 3. | Whether thickness of pitching is as per specification – specify the thickness of pitching with location after actual observations at site. | |
| 4. | Whether Quarry Spall and sand is as per specification & is in required thickness. | |
| **H. PCC BLOCK CASTING** | | |
| 1. | Whether forms being used for casting of blocks are as per specification rigid and without any distortion. | |
| 2. | Whether proper platform, vibration / consolidation and curing arrangements have been done. | |
| 3. | Whether block being casted are as per approved shape & size specify if there is any deformation or honey combing on the surface of the blocks. | |
| 4. | Whether flexural strength is being observed & whether required equipments are available for testing (One sample per 1000 blocks or as specified in the | |

| | | | |
|---|---|---|---|
| | agreement). | | |
| 5. | Whether curing is being done for 28 days. | | |
| **I. MATERIALS** | | | |
| 1. | Whether following field test are being conducted at site and sufficient equipments for testing are available at site. | | |
| | Sand | Silt contents, Gradation | |
| | Gravels | Gradation & Silt contents | |
| | Masonry Stones | Size, Water absorption | |
| | Coarse Aggregate | Gradation, Silt contents | |
| | Steel | Diameter of bars, corrosion. | |
| | Bricks | Size, Dimensions and water absorptions, compressive strength (strength for 10 bricks out of 35000 bricks) | |
| 2. | Whether laboratory test of the construction material is being done at regular interval as specified in manual and specification. | | |
| OTHER POINTS NOT COVERED UNDER ABOVE SUB-HEADS | | | |

Field Officer/Official Inspecting Officer

# ANNEXURE-I

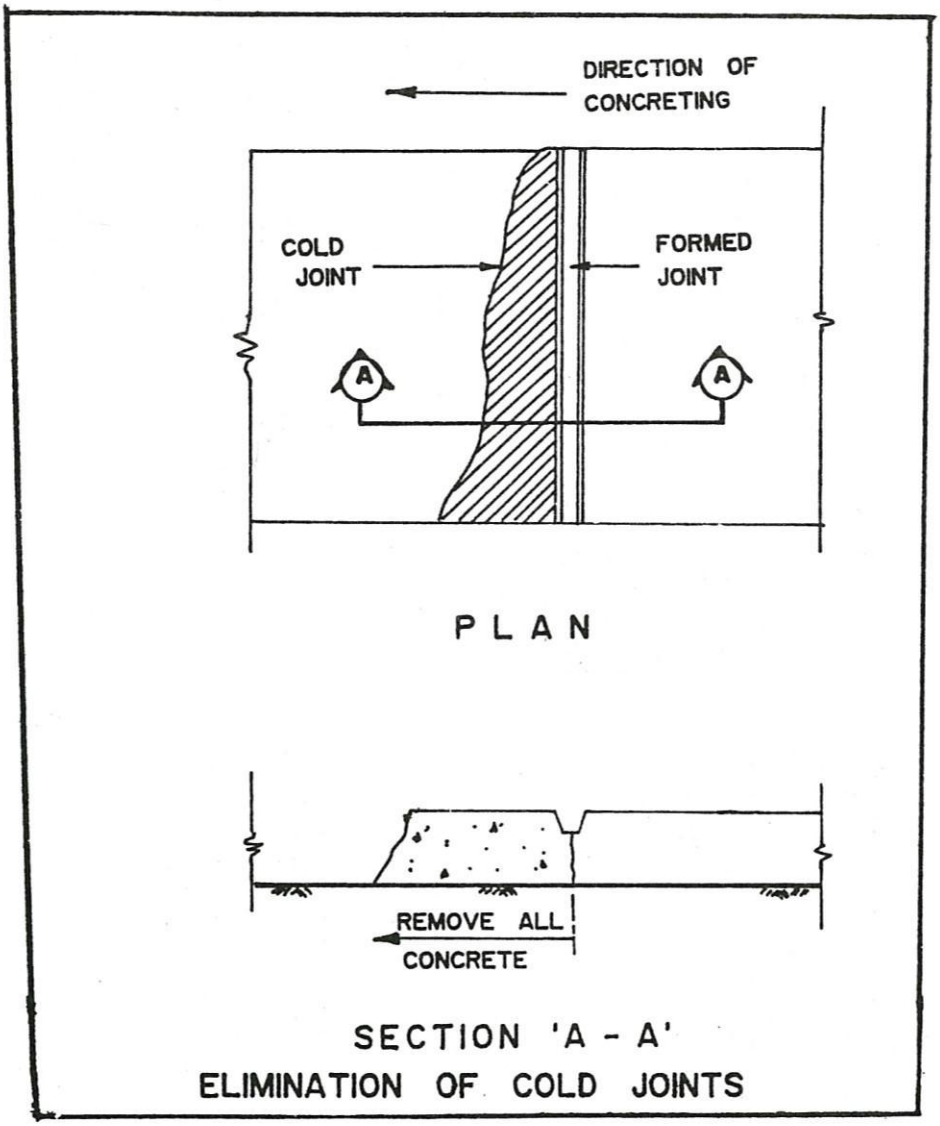
## TABLE SHOWING ROLES AND RESPONSIBILITY OF DIFFERENT WINGS FOR QUALITY ASSURANCE

| EXECUTING TEAM [1] | Q.C./ Q.A. TEAM [2] | AGENCY [3] |
|---|---|---|
| Set the tone for Quality Construction, Organise for construction supervision | Organise for QC / QA supervision | Adopt Means and methods of construction to ensure progress with quality. |
| Issue directives on firm commitment to quality & strict implementation of QC/QA programs on projects, Convene pre-construction meeting with Contractor after award of Contract. | Should attend the pre-construction meeting convened by the Executing Team. | Maintain proper Construction sequence and scheduling. Ensure proper quality of works during execution. |
| Set organization of field construction team, Monitor regularly the adequacy of contractor's equipment and plant for progress and quality. Conduct sampling of inputs and outputs and get them tested from laboratory as per specified frequency. Should inform the Quality Wing before starting any work. | Ensure conducting of sampling and testing of inputs and outputs as per IS-specified frequency. Should visit the site before starting of any work and ensure proper tools are kept at site for quality monitoring. | Maintain adequate number of equipment and plants for progress and quality, site safety, first aid, and housekeeping. Ensure house-keeping and site safety. |
| Set organization of quality control team., Administer contracts strictly. | Calibrate the lab testing equipment regularly | Strict compliance of technical specifications. |
| Conduct regular progress & quality review meetings with Quality Control Wing and Agency. | Approve training Programme for construction standards. Supervision and quality control personnel on QC/AC aspects, Acquaint fully with testing procedures and standards. | |
| Involve Geologist on geo technical problems (if any). Should know from the Quality Wing the type of samples to be collected during Geo-Technical Investigation. The respective Superintending Engineer should intervene in case of below-quality work. The respective Chief Engineer may at his discretion stop any work due to poor quality. | Ensure that QC labs are manned by competent personnel well versed in conducting tests on inputs/outputs and that tests are reliable., Communication and feedback of deficient quality work be very prompt, and construction team informed for violation of specified procedures by contractor. | Planning and deployment of construction plant and equipment consistent with progress & quality. |
| Ensure preparation of "as built drawing" as work proceeds. | Must maintain a Register for the test reports against a work. | Fulfilling contract commitments competently and faithfully; performing on schedule. |

[1] Executing Team comprising of Executing Division and Circle,
[2] Q. C./Q.A. Team comprising of Personnel from Quality Control Unit,
[3] Agency is the Contractor engaged by the Executing Team for implementing the work.

# ANNEXURE-II

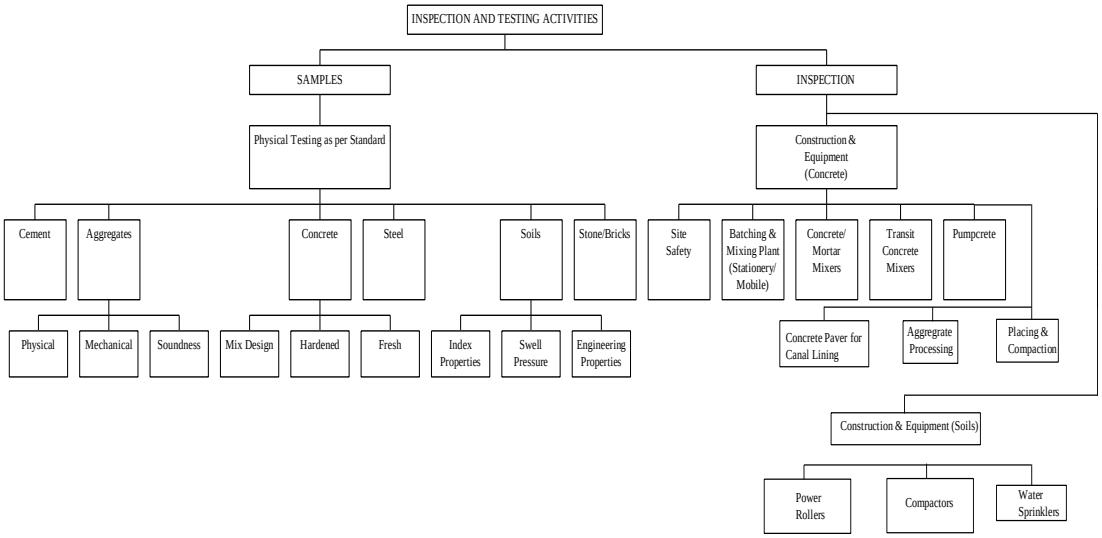
## SKETCH SHOWING CONSTRUCTION JOINTS IN LINING




SKETCH SHOWING CONSTRUCTION JOINTS IN LINING

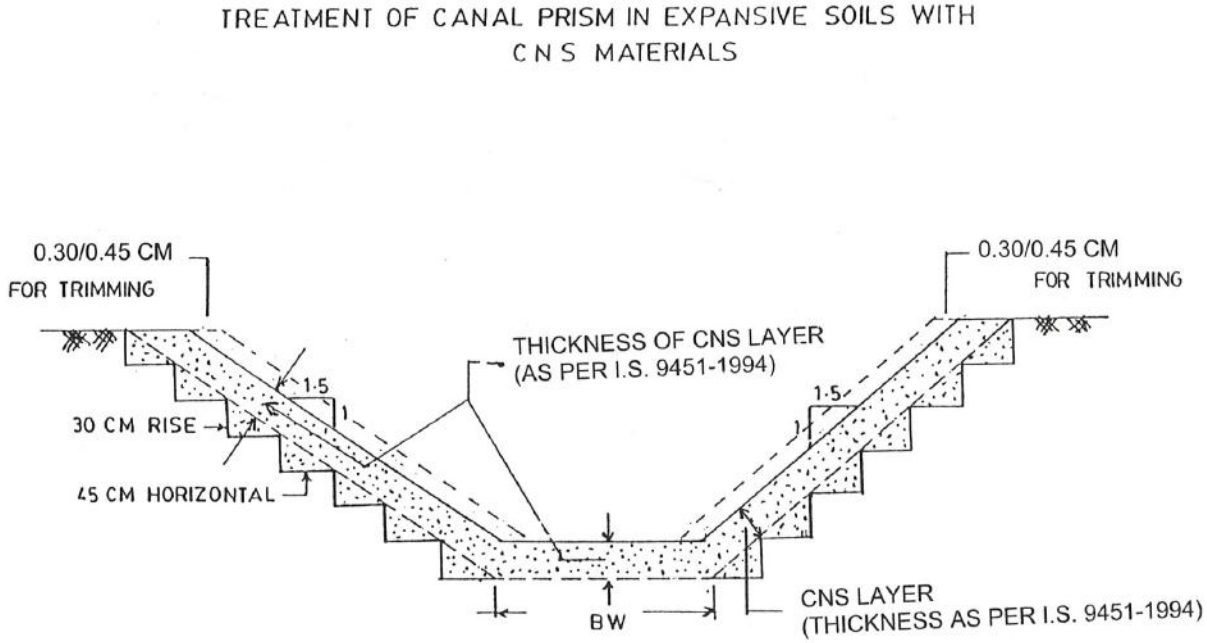
# ANNEXURE-III

## INSPECTION AND TESTING ACTIVITIES TO BE CARRIED OUT OF QUALITY CONTROL UNITS



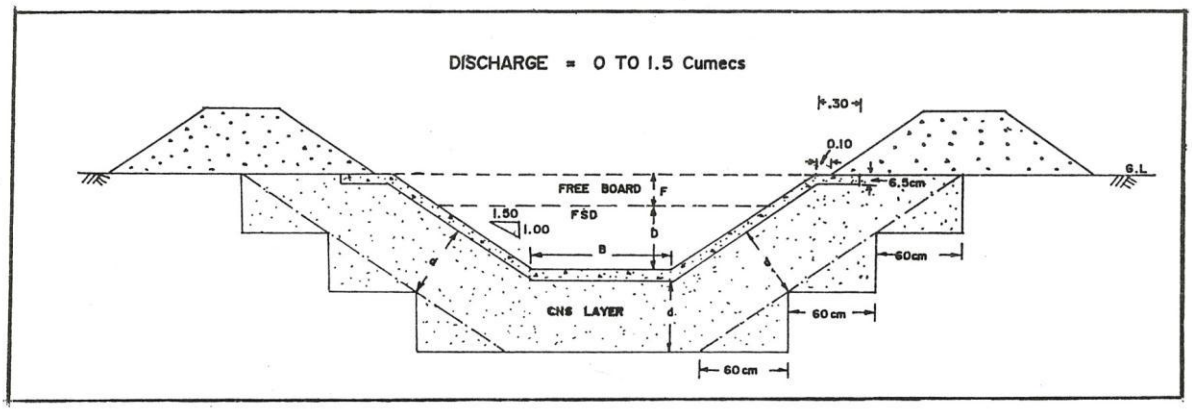

# ANNEXURE-IV

## TREATMENT OF CANAL PRISM IN EXPANSIVE SOILS WITH C N S MATERIALS



# ANNEXURE-V

## TYPICAL CROSS SECTION OF A DISTRIBUTORY WITH C N S SUB-GRADE




TYPICAL CROSS SECTION OF A DISTRIBUTORY WITH CNS SUB-GRADE

# APPENDIX A (IS: 4701-1982 Reaffirmed 2004)

## COMPACTION CHARACTERISTICS FOR SOIL AND OTHER MATERIALS USED IN EARTHWORK CONSTRUCTION

**(The information given should be taken only as an approximate guide)**

| MATERIAL | MAJOR DIVISIONS | SUB-GROUPS | SUITABLE TYPE OF COMPACTING EQUIPMENT | NO. OF PASSES FOR SATISFACTORY COMPACTION *Min* | THICKNESS OF LOOSE LAYER (ACTUAL THICKNESS DEPENDS ON PLANT USED) *Max*, cm | REMARKS |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Coarse grained soils and other materials | Boulders and Cobbles | Boulder Gravels | Heavy earth-moving equipment | | 30 | Minimum size of material will govern the minimum thickness of layer |
| | Other Materials | Hard: Hard Broken rock, hardcore, etc. (no soil binder)<br>Soft: Chalk, Soft rock, rubble | Heavy smooth-wheeled roller<br>Frog-rammer<br>Heavy vibrating plate<br>Track laying tractor and heavy smooth-wheeled roller<br>Frog-rammer | 8<br>4<br>2<br>4<br>4* | 30<br>37.5<br>30<br>20<br>37.5 | As for boulders and cobbles<br>Best compaction is obtained by spreading the material with a dozer and compacting with four passes of the roller. In wet weather a smooth-wheel roller may prove impracticable due to skidding. In this case adequate compaction can be obtained by using a heavy tractor and thinner layer. |
| | Gravel and gravelly soils | Well-graded gravel, gravels and mixtures, little or no fines | | | | A concrete vibrator may be used when these soils are used as subgrade materials. For effective use of a vibrator the soil should be in relatively dry condition |
| | | Well-graded gravel sand mixtures with excellent clay binders | | | | Close moisture content control is essential |
| | | Uniform gravel with little or no fine | | | | |
| | | Poorly-graded gravel and gravel sand mixtures, little or no fines | | | | As for well-graded gravel, gravel sand mixtures, little or no fines |
| | | Gravel with fines, silty gravel, clayey gravel, poorly graded gravel-sand clay mixtures | Smooth-wheel roller<br>Pneumatic-tyred roller<br>Vibrating smooth-wheel roller | 6<br>6<br>6 | 20<br>20<br>20 | Close moisture content control is essential |

| MATERIAL | MAJOR DIVISIONS | SUB-GROUPS | SUITABLE TYPE OF COMPACTING EQUIPMENT | NO. OF PASSES FOR SATISFACTORY COMPACTION *Min* | THICKNESS OF LOOSE LAYER (ACTUAL THICKNESS DEPENDS ON PLANT USED) *Max*, cm | REMARKS |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Coarse grained soils and other materials | Sands and sandy soils | Well graded sands and gravelly sands, little or no fines | Heavy vibrating plate<br>Frog-rammer<br>Power-rammer | <br>2*<br>3† | 37.5<br>37.5<br>20 | Vibrating rollers or vibrators will be very satisfactory if the moisture content of the soil is low, but may be uneconomical |
| | | Well-graded sand with excellent clay binder | | | | Close moisture content control is essential, when the moisture content is relatively high it is preferable to use a pneumatic-tyred roller |
| | | Uniform sands with little or no fines | | | | - |
| | | Poorly-graded sands little or no fines | | | | Vibrating rollers or vibrators will be very satisfactory if the moisture content of the soil is low, but may be uneconomical |
| | | Sands with fines, silty sands, clayey sands, poorly-graded sand. clay mixtures | | | | Close moisture content control is essential, when the moisture content is relatively high it is preferable to use a pneumatic-tyred roller |
| Fine grained soils | Soils having low compressibility | Silts (inorganic) and very fine sands, rock flour, silty or clayey fine sands with slight plasticity | | | | - |
| | | Clayey silts (inorganic) | | | | - |
| | Soils having medium compressibility | Organic silts of low plasticity | | | | These soils are difficult to compact and the effect of varying the contact pressure should be tried. Close moisture content control should be maintained |
| | | Silty and sandy clays (inorganic) of medium plasticity | Smooth-wheel roller<br>Pneumatic tyred roller<br>Track-laying tractor | 4<br>-<br>10 | 20<br>-<br>15 | - |
| | | Clays (inorganic) of medium plasticity | Sheep- foot roller ‡<br>Frog-rammer | 30<br>2* | 15<br>37.5 | - |
| | | Organic clays of medium plasticity | Power-rammer | 2† | 20 | - |

| MATERIAL | MAJOR DIVISIONS | SUB-GROUPS | SUITABLE TYPE OF COMPACTING EQUIPMENT | NO. OF PASSES FOR SATISFACTORY COMPACTION *Min* | THICKNESS OF LOOSE LAYER (ACTUAL THICKNESS DEPENDS ON PLANT USED) *Max*, cm | REMARKS |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Fine grained soils | Soils having high compressibility | Micaceous or diatomaceous fine sandy and silty soils, elastic silts | | | | These soils are considered very undesirable for use in earthwork and should not be employed if they are highly compressible_ |
| | | Clays (inorganic) of high plasticity, fat clays | | | | It is advisable to compact these soils at the moisture content at which no change will occur subsequently |
| | | Organic clays of high plasticity | | | | These soils are considered very undesirable for use in earthwork and should not be employed if they are highly compressible |
| Fibrous organic soils with very high compressibility | | Pest and other highly organic swamp soils | | | | These soils are entirely unsuitable for earthwork construction. |

* Where one pass is equivalent to 6 to 8 blows per unit area.
† Where one pass is equivalent to 2 to 3 blows per unit area
‡ For use in dry climates