PREFACE

Kerala Water Resources Department is one of the main organisations taking part in the infrastructural development activities utilising the funds of the State Government as well as the Central Government – the plan fund and the non plan funds under commercial or non commercial heads. The plan Schemes are either centrally sponsored or externally aided schemes. It is the agency that constructs, operate and maintain Minor Irrigation including Lift Irrigation, Major irrigation including major and medium projects, Costal & River Protection works, Flood control works, and Inland Navigation works and rendering assistance to the works taken up by the Local Self Governments. There are 6 Chief Engineers, 15 Superintending Engineers, 58 Executive Engineers, 197 Asst. Executive Engineers, 778 Assistant Engineers and supporting technical and ministerial staff in the department whom are mainly for the execution of new projects and their maintenance and a few for the investigation & planning, designing, hydraulic data collection, monitoring and quality control. Projects to the tune of about 500.00 Cores are under taken every year under this department. Though Assistance is being rendered by the Central Government and other external agencies to take up new projects, the maintenance are to be done by the state fund only. Due to the lack of sufficient fund, maintenance is not carried out in time and hence the anticipated benefits are not achieved for the years considered for the projects and some times most of the components or the project as a whole is to be abandoned prematurely. Producing quality structures, which will, not only survive with the strength characteristics, but also durable till the anticipated life time is the remedy of the above situation and a strict quality control is the only way to ensure and achieve this goal. Probably, realization of this would have resulted in the formation of the Quality Control Wing in the Irrigation Department of Kerala in 1995 vide GO (MS) No. 87/95/Irrn. Dated Tvpm 13.06.95.

There are two Divisions at Kottarakkara and Thrissur, 9 Subdivisions and 17 Sections with supporting staff spread over Kerala under the control of the Superintending Engineer, Investigation & Planning, Thrissur. Though while forming the wing, the objectives were mentioned, no clear cut directions, specifications, duties and responsibilities of the personnel for the quality control operations were issued. Being new and different from other technical personnel of the department, the performance of the wing was not come to the expected level.

The execution staff is supposed to adhere to the provisions of the MDSS, the relevant Indian Standard Specifications or the Kerala PWD Manual, but very often they could not strictly adhere the exact provisions in all aspects of investigation, design, material procurement or execution, may be due to their work load and non availability of the above specifications at the right place and time. There are so many instances of failure of structures or deterioration before the anticipated life time because of the poor quality of construction. Also in the tender documents or agreements of works, the detailed specification or the minimum standards to be adhered to are not included in detail with quality standards and quality assurance methods, which have resulted not only failure to structures, but also litigation with contractors disciplinary action against the Engineer. Even after the formation of the Quality Control Wing, the situation is not different. This is only because of the absence of mandatory Quality Control Manual specifying the duties and responsibilities of officers, Methodology of inspection and testing and implementation of quality assurance programme. As per the request of the Superintending Engineer, Investigation Planning, Trissur, during 8/1998, the Kerala Engineering Research Institute, Peechi had prepared certain guidelines mentioning the relevant Indian Standards for the investigations and design but detailed manual was not prepared. The Accountant General has commented about the poor functioning of the Quality Control Wing and the officers are of the opinion that the poor functioning is due the absence of a Quality Control Manual which is mandatory for the contractor, execution and quality control staff.

Hence a manual 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.

I had the opportunity to work in almost all types of works undertaken by the Department and have personally given interest to assure quality works. Now I am happy to be in charge of the Quality assurance for the works under taken by Water Resource Department all over Kerala.

I am of the opinion that the overall control of Quality Assurance should be entrusted with the Director, Kerala Engineering Research Institute, Peechi and the Chief Engineer, Irrigation Design and Research Board, Thiruvananthapuram as they are independent body and are equipped in all sense for the purpose.

INDEX

CHAPTER-I

QUALITY CONTROL AND ASSURANCE

1. Introduction

Kerala Water Resources Department is one of the main organisations taking part in the infrastructural development activities utilising the funds of the State Government as well as the Central Government – the plan fund and the non plan funds under commercial or non commercial heads. The plan Schemes are either centrally sponsored or externally aided schemes. It is the agency that constructs, operate and maintain Minor Irrigation including Lift Irrigation, Major irrigation including major and medium projects, Costal & River Protection works, Flood control works, and Inland Navigation works and rendering assistance to the works taken up by the Local Self Governments. There are 6 Chief Engineers, 15 Superintending Engineers, 58 Executive Engineers, 197 Asst. Executive Engineers, 778 Assistant Engineers and supporting technical and ministerial staff in the department whom are mainly for the execution of new projects and their maintenance and a few for the investigation & planning, designing, hydraulic data collection, monitoring and quality control. Projects to the tune of about 500.00 Cores are under taken every year under this department. Though Assistance is being rendered by the Central Government and other external agencies to take up new projects, the maintenance are to be done by the state fund only. Due to the lack of sufficient fund, maintenance is not carried out in time and hence the anticipated benefits are not achieved for the years considered for the projects and some times most of the components or the project as a whole is to be abandoned prematurely. Producing quality structures, which will, not only survive with the strength characteristics, but also durable till the anticipated life time is the remedy of the above situation and a strict quality control is the only way to ensure and achieve this goal. Probably, realization of this would have resulted in the formation of the Quality Control Wing in the Irrigation Department of Kerala in 1995 vide GO (MS) No. 87/95/Irrn. Dated Tvpm 13.06.95.

Presently there are two Divisions at Kottarakkara and Thrissur, 9 Subdivisions and 17 Sections with supporting staff spread over Kerala under the control of the Superintending Engineer, Investigation & Planning, Thrissur. Though while forming the wing, the objectives were mentioned, no clear cut directions, specifications, duties and responsibilities of the personnel for the quality control operations were issued. Being new and different from other technical personnel of the department, the performance of the wing was not come to the expected level. The execution staff is supposed to adhere to the provisions of the MDSS, the relevant Indian Standard Specifications or the Kerala PWD Manual, but very often they could not strictly adhere to the exact provisions in all aspects of investigation, design, material procurement or execution, may be due to their work load and non availability of the above specifications at the right place and time. There are so many instances of failure of structures or deterioration before the anticipated life time because of the poor quality of construction. Also in the tender documents or agreements of works, the detailed specification or the minimum standards to be adhered to are not included in detail with quality standards and quality assurance methods, which have resulted not only failure to structures, but also litigation with contractors disciplinary action against the Engineer. Even after the formation of the Quality Control Wing, the situation is not different. This is only because of the absence of mandatory Quality Control Manual specifying the duties and responsibilities of officers, Methodology of inspection and testing and implementation of quality assurance programme. As per the request of the Superintending Engineer, Investigation Planning, Trissur, during 8/1998, the Kerala Engineering Research Institute, Peechi had prepared certain guidelines mentioning the relevant Indian Standards for the investigations and design but detailed manual was not prepared. The Accountant General has commented about the poor functioning of the Quality Control Wing and the officers are of the opinion that the poor functioning is due the absence of a Quality Control Manual which is mandatory for the contractor, execution and quality control staff. Hence a manual 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.

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 materials supplied at site and works are being executed in conformity with the prescribed standards and 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, as illustrated in this manual shall be followed by:

    a. Government
    b. Project Design Team
    c. Project Construction Team
    d. Project QC/QA Team and
    e. Contractor

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 Management System

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 within the quality system.

4. Quality Control Manual

Quality Control Manual is a document encircling 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 Quality Control Organisation, Duties and Responsibilities of Q.C. personnel, Q.C. laboratory system, O.K. Cards, monitoring through control charts, control on workmanship, tests on materials, important specifications, quality audit & quality improvement, standards to be adopted for materials and works, frequency of testing and reporting; compilation of Q.C. data and statistical analysis, documentation and feed-back, inspection etc.

5.1 Quality Control (Q.C.)

The operational techniques and activities that are used to fulfill 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 fulfill 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.

CHAPTER-II

ORGANISATIONAL SETUP

General

One of the fundamental principles to be understood and kept in mind is that the overall responsibility for achieving construction quality in each work rests with the execution wing and construction staff shall be fully responsible for quality of work. The responsibility of the Quality control wing shall be checking the quality of the materials and the product in accordance with the standards, specifications at random and ensure that the execution staff are maintaining the quality so as to achieve the anticipated strength and durability.

Quality control wing shall act as a correcting mechanism or assisting mechanism to the execution staff to ensure the quality.

1. Any one 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.

2. To have proper and independent quality, Quality Control Wing shall be an independent unit. It shall be headed by Superintending Engineer, Quality Control Circle, Trissur and the Chief Engineer, IDRB, Thiruvanathapuram shall be the appeal authority for final decision in case of any dispute. There shall have at least three Executive Engineers to look after the Q.C work of different regions – Viz. Kottarakkra, Thrissur and Kozhikode. There shall be one Assistant Executive Engineer and three Assistant Engineers for each district exclusively for quality control with necessary supporting staff for technical and non – technical assistance.

Functions of Quality Control Wing

The main function of Quality Control wing is to have independent checking and control of works. Since the works in different regions are of scattered nature, the Quality Control Wing can not exercise concurrent quality control, but it is to be planned that these units should act in such a manner that necessary quality control requirements are fulfilled jointly with the execution 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 the laboratories. The quality control units will carry out periodic inspections of works and conduct field tests so that any deficiencies in the execution of works are properly brought to the notice of concerned authorities and execution staff for 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, IDRB, Thiruvananthapuram or the Superintending Engineer, Quality Control Circle, Trissur from time to time.

(1) They should monitor that all required tests are carried out before start of work as well as during execution. At least 10% tests are to be conducted by the quality control units for reliability of the results and counter checking.

(2) They should ensure that all arrangements for carrying out routine field tests in the field laboratories and site laboratories are duly made including provisions and up-keeping of equipments, 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 be empowered to order the suspension of work if deficiencies or defects are noticed during execution and not rectified in time. Order for stoppage of work if given by the officer below the rank of Executive Engineer/Q.C should be got examined and confirmed by Executive Engineer/Q.C. very promptly, preferably within 24 hours and

reported to the Executive Engineer in charge of execution and the Superintending Engineer, Q.C. However final order for suspension of work can only be passed by the Superintending Engineer Quality Control after examining and confirming the cause of suspension by the Executive Engineer with in three days and reported to the Chief Engineer, IDRB, the agreement executing authority and the Chief Engineer in charge of execution.

(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 execution 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 Wing.

(5) The Executive Engineer, Quality Control shall ensure at least one test check of all the works costing more than Rs. 15.00 lacks in a year. This does not preclude him for conducting more than one test check of any work for important works; frequent checking is to be carried out.

(6) The Superintending Engineer, Quality Control shall ensure at least one test check of all the works costing more than Rs. 25.00 lacks in a year. This does not preclude him for conducting more than one test check of any work for important works; frequent checking is to be carried out.

The test check shall be thorough to ensure the quality of work and shall include

a. Observation of moisture contents of earthwork in filling reaches.
b. Fineness modulus of sand, grading of sand and coarse aggregate.
c. Water Cement ratio for concrete
d. Checking of lining work/masonry work/concrete work.
e. Any other requisite tests as per case.

CHAPTER-III

LABORATORIES

Laboratories are to be established as Regional Level, District Level and at site. Regional Laboratories shall be equipped with major tests while District Laboratories shall have equipments for minor tests. Apart from this testing facilities established at the respective work site by the contractors for works costing more than the TS power of the Superintending Engineer vide GO(P) 87/94/PW&T dt. 19.08.1997 shall be made use of by the Quality control wing also for those works. If no such laboratories are established by the contractor at site, the fact shall be brought to the notice of the Superintending Engineer, Q.C and Agreement Executing Superintending Engineer. Mobile laboratories are also established to conduct minor tests of small works. The Regional Laboratories shall be under the control of the Executive Engineer, The District Laboratories shall be under the control of the Asst. Executive Engineer and the Site/ Mobile Laboratories shall be under the control of the Assistant Engineers.

The cost of consumables and other incidental charges for testing shall be charged to the respective works which shall be paid to the quality control wing by the payment authority of the concerned work which shall be recovered from the bill of the contractor as the contractor is bound to bear the testing charges as per agreement conditions.

Any test that can not be carried out in the above mentioned laboratories shall be carried out an any of the approved laboratories by the Quality Control wing and the charges towards such tests shall be collected from the payment authority of that work, which shall finally be recovered from the contractor.

In addition to evaluate and monitor the inputs and outputs utilising the laboratories, the Quality Control Wing shall also evaluate and monitor the workmanship as well as construction plant, machinery and equipment accompanied by testing as well as inspection.

General functions of laboratories

1. Site/ Field/ Mobile/ Laboratories

To carryout daily routine tests of soils, filter material, ingredients of concrete and mortar for the on going works and material supplied at site before use. Results will be recorded by the supervisor in charge of execution in registers kept at site for inspection purposes and will be reported to the Assistant Engineer, Execution and Assistant Engineer Q.C. in the prescribed Performa pertaining to the following. Assistant Engineer shall conduct surprise inspection at least once in a month or at least once in the case of small works and verify the records and conduct test for materials at site, work in progress and the completed portion of the work as he desires to suit to be fit for the circumstance, compile with the records and report the details with specific remarks to the Assistant Executive Engineer. For small works the construction staff shall be allowed to use any of the nearest laboratories at the request of the Assistant Engineer to the Assistant Engineer in charge of the laboratories with out charging any cost if they are conducting the test themselves or at nominal charge (to be fixed) which is to be recovered from the contractors bill, if got done by others.

Soils & earth work

- Moisture content, thickness and Consolidation layer wise.

Sand

- Gradation analysis & Fineness Modulus.
- Bulkage

Coarse aggregate

- Gradation analysis.
- Physical properties

Cement

- Casting of cubes for strength

Fresh concrete & mortar

- Slump test
- Physical properties of Ingredients;
- Proportion of cement and sand in Concrete and mortar.
- Casting of concrete / mortar cubes.

Boulder sample

- Dimensions & physical properties including weathering etc.
- Water absorption

Bricks

- Dimension & physical properties
- Sampling of bricks for testing.

Record of daily activities / tests will be maintained at site in the registers such as :-

a. Inspection Register
b. Cement Consumption Register
c. Slump Test Register

Daily progress register- progress to be compared with consumption of various ingredients including cement.

2. District Laboratories

To carry out tests of soils, filter materials, ingredients of concrete, tests of cement and mortar etc. of the samples collected by the quality control staff and also such samples collected by construction staff whose facility of testing is not available at site/ field laboratories. The samples shall be taken at least by an officer not below rank of an Assistant Engineer and brought to the District laboratory by him and assist the Assistant Executive Engineer for testing. Frequency of testing shall be as indicated elsewhere in the manual as per the Indian Standard Specifications. Results of tests performed will be reported to Executive Engineer construction and Quality Control unit in the prescribed Performa by the Asst. Executive Engineer pertaining to the following tests.

Soils:

- Density, moisture content and compaction efficiency.
- Sieve analysis.
- Proctor density & O.M.C.
- Atterberg's limits.
- Specific gravity.

Sand:

- Gradation analysis & silt content
- Presence of deleterious materials including organic impurities.
- Bulkage.

Coarse aggregate

- Grading
- Specific gravity
- Impact Value, Soundness, Crushing Value, Flakiness.

Fresh concrete & mortar

- Water cement ratio, slump test
- Compressive strength of Concrete & Mortar
- Mix Proportions specifically Cement and Water content.

Boulder sample

- Absorption
- Dimensions
- Visual observation as regards weathering etc.
- Specific gravity, impact value, soundness, specific gravity.

Cement

- Setting time by vicat needle test
- Strength of cement

Bricks

- Dimensions and physical properties including compressive strength.

Water

- Chemical - CL, SO4, Organics & Inorganic Solids, Ph., Alkalinity, Acidity
- Setting time of mortar

3, Regional 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. If requested by the Executive Engineer, Construction, Regional 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 3). 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 Regional laboratory should be documented in prescribed Performa pertaining to following tests.

Soils:

- Disturbed grain size analysis I.S. 2720 part (IV) 1965.
- Proctors compaction I.S. 2720 (Part VII & VIII) 1965.
- Atterberg's limit I.S. 2720 (Part V) 1970.
- Permeability I.S. 2720 (XVII). 1966
- Shear test I.S. 2720 (Part XIII) 1972.
- Specific gravity I.S. 2720 (Part III) 1964.
- Undisturbed density and natural moisture content, permeability, consolidation, shear test (drained/undrained) at OMC or saturation.
- Free swell index; Swelling pressure of soil sample.
- Dispersibility of soils.
- Total Soluble salts.
- Chemical test for carbonates & sulphates (Chlorides Gypsum test).

Sand:

- For I.S. 383 (1970) Grading I.S. 2386 (Part I) Fineness Modulus Bulkage I.S. (Part IV) Organic and silt content.
- Deleterious material and mica content, and presence of organic impurities, if any.

Cohesive - Non - Swelling Soils

- Requirement should broadly conform to I.S. 9451-1994

Cement:

- Fineness, Consistency, specific gravity, compressive strength, setting time,
- Soundness by Le-Chetlier test.

Coarse aggregate:

- Grading I.S. 2386 (Part I)
- Soundness, crushing value, impact test.
- Abrasion, Absorption, I.S. (III) Specific gravity I.S. (Part III). Flakiness.

Boulders:

- Soundness, weight and size, absorption, specific gravity, weathering conditions (visual) abrasion after breaking to proper sizes.

Filter materials:

- Grading, uniformity co-efficient, weathering conditions (visual) and tests for fine and coarse aggregate fulfillment of filter criteria as per I.S . Code.

Water:

- P.H. Value, silt content, soluble salts and any other impurities.

Concrete :

- Air Content, Mix Proportions; Test on admixture (if used); Test on Super-plasticiser (if used)

Hardened concrete and mortars:

- Proportion by chemical analysis and compressive strength.

Bricks:

- Dimensions and physical properties including water absorption and compressive strength.

Improved Devices for Quality Control

It shall be planned to introduce improved devices for achieving speedy and efficient quality control. Monitoring the characteristics of fresh concrete is important from the point of view of quality control. The 28 - day strength of concrete is the criteria for acceptance and is the basis of quality evaluation. However, one has to wait for 28 days to get the results of compressive strength of concrete cubes/cylinders. Even the accelerated compressive strength tests take considerable time.

The portable electronic devices, commercially available now, have made it possible for rapid on-site measurements of slump, temperature, water-cement ratio (the most important factor influencing the strength of concrete) and the likely 28-day strength of fresh concrete mixes. Software supplied with the electronic unit also produces `quality control certificates' based on the measurements taken by this unit. This evidence of the properties of concrete gives the site Q.C./Q.A. Engineer, the confidence to accept or, if necessary, to reject the concrete mix before it is placed.

On embankment construction and compacted earth fill placement it shall be planned to procure an engineering device of the type "Nuclear Guage" to enable much more rapid and economic compaction and quality control than the conventional methods, without any loss in accuracy. Such a device is capable of quickly computing and displaying wet density, moisture content, dry density, and percentage of compaction in terms of Proctor density.

CHAPTER-IV

DUTIES AND RESPONSIBILITIES OF QUALITY CONTROL STAFF

General

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. The equipment will be capable of controlling the delivery of material for weighing so that in accuracies in feeding and measuring during normal operation will not exceed 1% for water and 3% for all aggregates. 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 equipments 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.

Laboratory Attendants/ Lascars

a) To keep instruments clean.

b) To assist Assistant Engineer / Executive Engineer and Laboratory Technicians in conducting tests.

c) To prepare samples for test.

d) To arrange samples systematically.

Laboratory Technicians/ Overseers

i) To assist Assistant Engineer / Executive Engineers whenever required 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.

Assistant Engineer

- To ensure proper up-keep and maintenance of laboratory equipment in laboratory.
- 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.
- To supervise the testing works of his Subordinate staff, Laboratory Assistants and personally to check the tests to the extent of 50 %
- To prepare fortnightly review of all the test results and submits to the Asst. Executive Engineer and copies to the Executive Engineer, Quality Control & Construction.
- To conduct any research work as may be assigned by the Executive Engineer.
- The Regional laboratories & District 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.

Assistant Executive Engineer

- To ensure proper up-keep and maintenance of laboratory equipment in laboratory.
- 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.
- To supervise the testing works of his Subordinate staff, Laboratory Assistants and personally to check the tests to the extent of 25 %
- To prepare fortnightly review of all the test results and submits to the Executive Engineer and copies to the Superintending Engineer, Quality Control & Construction.
- To conduct any research work as may be assigned by the Executive Engineer.
- The Regional laboratories & District 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.

Shall perform important tests as mentioned below:

Cement:

- Fineness by Blains
- Normal Consistency
- Setting time
- Soundness
- Specific gravity
- Compressive strength
- Adulteration test

Sand:

- Sieve Analysis & Fineness modulus
- Test for organic impurities silt & clay
- Decantation test for silt
- Specific gravity
- Unit weight and bulkage factor

Course aggregate:

- Sieve Analysis and gradation
- Specific gravity
- Water absorption
- Examination of deleterious materials
- Crushing strength
- Impact
- Abrasion
- Flakiness index
- Alkali - Silicate reactivity

Concrete:

- Consistency - slump or compaction factor
- Compressive strength
- Air content
- Yield per unit quantity of cement
- Mix design test
- Cement content

Mortar:

- Consistency
- Compressive Strength
- Yield per unit quantity of cement
- Cement Content

Soils:

- Gradation (Grain size analysis)
- Consistency limits
- Porosity & Void ratio
- Specific gravity
- Swell pressure

Executive Engineer

- To ensure proper up-keep and maintenance of laboratory equipment in laboratory.
- 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.
- To supervise the testing works of his Subordinate staff, Laboratory Assistants and personally to check the tests to the extent of 10 %
- To prepare fortnightly review of all the test results and submits to the Superintending Engineer, Quality Control & Construction.
- To conduct any research work as may be assigned by the Superintending Engineer.
- The Regional laboratories & District 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.

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- Consistency
- Compressive Strength
- Yield per unit quantity of cement
- Cement Content

Soils:

- Gradation (Grain size analysis)
- Consistency limits
- Porosity & Void ratio
- Specific gravity
- Swell pressure

Superintending Engineer

- He shall be in charge of the over all control of the quality control operations.
- Carry out surprise inspections, verify the records maintained by the subordinate officers, assessing the overall quality and workmanship towards strength and durability for the ongoing and completed works before making payment or with in the defect liability period.
- Collect the details of ongoing works in the state and distribute the works among his subordinates for effective operation and monitor the progress.
- He shall analyse the results reported by the Executive Engineer and take immediate action for unsatisfactory or defective constructions including suspension of works for further analysis or order for rejection or abandoning.
- Arrange research works and prepare chart for the properties of the natural construction materials specifying its source which shall be a guideline for the Executive Engineer or Superintending Engineer to fix the approved quarries/Source of arranging the works.
- Any other works as directed by the Chief Engineer, IDRB or the Government.

Chief Engineer

- He shall interfere and take appropriate decision in the case of any dispute regarding the action taken by quality control officers which shall be final and legally binding to both the parties.
- Arrange Internal Quality Auditing and submit recommendation to Government.

CHAPTER-V

DUTIES OF FIELD STAFF IN RELATION TO QUALITY OF WORKS

CONSTRUCTION TEAM	QUALITY CONTROL TEAM
1. Shall see that the mark out of the area to be tackled is properly given, shuttering, centering, reinforcement are done as per drawing and technical specifications, to record the Pre levels/ foundation levels, and to see that mark-out for canal excavation is perfectly given as per drawings. Pre-levels, classification levels and final levels of canal shall be taken as per specification.	1. Shall check the mark-out of foundation and centering/ shuttering reinforcement arrangement and inform the Assistant Engineer construction to rectify the defects if any.
2. Shall see that the construction equipment like mixers, vibrators, compaction equipment, pumping arrangements for curing/watering are arranged before starting of any work.	2. Shall check the adequacy of the construction equipment and curing/ watering arrangements before start of work and during execution.
3. 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.	3. 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.
4. Shall write O.K. Cards after area is ready to start the work and to inform the Assistant Engineer Quality Control and Executive Engineer construction and take permission to start the work	4. Shall check and write the O.K. card and record the deviations, defects if any or otherwise to record the final OK and to inform Executive Engineer quality control and to permit to start the work.

CONSTRUCTION TEAM	QUALITY CONTROL TEAM
5. Shall supervise and ensure that correct quantities of input materials as per mix design are fed into the mixers/batching plants etc., and shall ensure specified mixing time. (minimum 2 ½ minutes)	5. 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.
6. Shall ensure proper vibration, rolling etc., during course of day to day work. Shall conduct test of earth work, gradation of materiel, slump test, core drill 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.	6. 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.
7. Shall ensure proper curing of samples extracted till the curing time is over and to make arrangements to send the samples to the laboratories	7. Shall assist the in Proper handling/transport of samples to laboratory
8. 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 bend at the lift/construction joints.	8. Shall check and see that the preparation of the surface is adequately done for starting the next lift.
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 are finished to the plumb/ straight lines etc., after removal of 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 (1) mark-out register (2) OK Card files (3) Load Register.	10. Shall maintain registers of field tests conducted.

11. Shall intimate the Executive Engineer quality control regarding signing of agreement for 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, and Superintending Engineer.	11. Shall maintain copies of approved Designs, reports, contract document, drawings, construction programme, extracts of inspection notes etc., and shall see that his subordinates go through the above documents.
12. 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.	12. Shall remind and verify whether test results are available or not before starting up of any new work and during execution of work.
13. Shall see that all the Machinery / Equipment being used by the contractor is got periodically calibrated.	13. Shall assist in upkeep and calibration of equipment.
14. Shall see that OK Cards are written and kept at site of work before starting of any work. Also will ensure rectification of work before releasing payments.	14. Shall inspect and sign on O.K. Cards during field visits. Defects of construction will be pointed out and remedies suggested for achieving good quality construction.
15. Shall order the suspension of work if any defects are noticed or reported by quality control staff and resume the work only after rectification of defects in the presence of quality control staff.	15. Shall order the stopping of work if major defects are noticed or reported by quality control staff and intimate his counter part to see that defects are rectified. Also defects noted during construction are to be reported to the S.E./Quality Control & construction.

16. Foundations and reinforcement, shuttering, centering where heavy reinforcement is involved is to be checked by Executive Engineer invariably before starting the work.	16. 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.
17. Shall personally see that the samples to the laboratories are sent regularly, obtain the results and communicate the same to Executive Engineer quality control	17. Shall pursue and keep track of sending of samples various laboratories and to keep record of results received.
18. Shall take the help of quality control Ex. Engineer whenever a dispute is referred.	18. Shall co-ordinate with the EE/ Construction division render assistance in resolving the issues referred to him.

CHAPTER-VI

CO-ORDINATIONS

1. 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.

2. 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 the enable the quality control staff to schedule their work plan and attend the particular work on the particular date.

3. 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.

4. 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.

5. Quality Control staff will monitor that all tests required as per agreement and I.S. Codes are carried out in different laboratories by the field staff they will also test check to the extent of minimum 10% (or as decided by Superintending Engineer / QC) of the required tests and co-relate with the other tests conducted in different laboratories.

6. All observations regarding substandard or below specification work will be dully recorded in the inspection/visit books kept at site by inspecting officer. Such substandard or below specification works should be got stopped/ dismantled immediately by execution unit. 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 with in ten day.

7. The quality control staff can not 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 is the primary responsibility of the construction staff to ensure adequate supervision of mix to mix placement of concrete.

8. 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.

9. In case of difference of opinion between quality control staff and construction staff, it should be sorted out by way of discussions in cordial atmosphere and mutual trust as per the guide lines indicated below. In case it involves any design feature/problem/aspect, the design office should be duly consulted and the advice given by the designer should be accepted.

10. In case of difference of opinion between Executive Engineer, Construction and Executive Engineer, Quality Control it would be referred to Superintending Engineer, Construction, who would discuss the matter with Superintending Engineer, Quality Control and settle the issue. Similarly, when the Superintending Engineer, Quality Control is not readily available, the Superintending Engineer Construction can over rule after recording the reasons in writing. In such cases the Superintending Engineer, Construction has to discuss with Superintending Engineer, Quality Control at the earliest opportunity and modify his earlier orders, if necessary. Similar action will be taken incase of difference of opinion on the comments of Superintending Engineer quality control.

11. In case there is a difference of opinion between both the Superintending Engineer, Construction and Quality Control the matter would be referred to Chief Engineer, IDRB, whose decision shall be final and binding on all. Work should immediately be suspended

and not allowed to resume until the defects pointed out by Quality Control and Inspection staff are rectified.

12. 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, tunneling; contract/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 – VII

QUALITY ASSURANCE AND INTERNAL QUALITY AUDIT

QUALITY ASSURANCE:

All planned and systematic strategies and actions necessary to generate adequate confidence that Input and Output product will satisfy given requirements of quality and all the components of works perform satisfactory during life period of service, adequate quality checks as analysed during construction is a record of "Quality Assurance". It comprises planning and policies, education and training standards and specifications, contracts and agreements, and quality control. Quality assurance is to assume that the materials as per standard and as per the requirements have gone into the production of concrete, earth, masonry work etc. This is achieved by evaluating the quality checks during construction and post construction tests made and compared.

QUALITY AUDIT:

It is systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve the objectives. It is considered to be an effective management tool to promote good quality construction and workmanship.

It will be expedient and useful to present the requisite of Quality Assurance to the Quality Audit team in as concise format as possible.

Internal Quality Audit shall be conducted periodically, preferably once a year at least, to assess whether the construction procedures, Quality Control procedures, and Quality assurance. aspects including workmanship are being implemented properly during the execution of works.

Chief Engineer, IDRB shall constitute the audit team for undertaking the internal quality audit of selective works. The team shall, preferably be headed by the Chief Engineer, IDRB or his

Superintending Engineer (Designs). Other members could be: an Engineer having good academic qualification and experience in the construction field from any of the institutions other than the Water Resources Department and one nominee of Chief Engineer General & Administration.

Broadly, the Internal Quality Audit team shall focus:-

i) Visual Inspection of works completed and/or under progress; perusal of photographic record, if any.

ii) Perusal of Quality Control & Quality Assurance (Q.C./Q.A.) documentation; and all test records including O.K. Cards and registers.

iii) Inspection of Testing Laboratories, adequacy of testing facilities, and reliability there of and general competence of laboratory staff;

iv) Contractor's workforce and construction equipment deployed at works and assessing the adequacy thereof in respect of the quality related aspects; whether the contractor is deploying the key/critical equipments, as listed in contract document

v) Whether any corrective actions are being implemented in the shortest possible time period.

The Internal Quality Audit would culminate in a comprehensive report for Chief Engineer, IDRB, which shall bear the date of audit and the signature of audit team. The Report should contain an abstract of findings, observations, including opinions and recommendations. It should be duly substantiated by the supporting documents and explanations. Major findings if noticed in the report are to be brought to the notice of the Government with his recommendation by the Chief Engineer, IDRB.

CHAPTER – VIII

O.K. CARDS

General

Since O.K. Cards contain important entries/information on execution of works at all stages and are liable to be referred/perused at a later stage also, particularly during the Internal Quality Audit of works, the O.K. Cards shall be maintained in duplicate in two colours. The green coloured card shall form a part of the record of Q.C. /Q.A. Wing and the red coloured card remains in the custody of construction wing. The O.K. Cards, relating to any particular work, shall be put in a tin box and placed right at the construction site. The exterior of the tin box shall be painted red. Senior officers shall also check the O.K. Cards during their field inspections to ensure that those are being maintained and properly/genuinely filled.

An O.K. Card is a condensed form of specifications and essential requirements for achieving specified workmanship and quality level of output. Each work is sub-divided into various construction activities in proper sequence / order of construction. Such activities are listed in chronological order on the O.K. Cards

For various stages of construction activities where laboratory tests or checks with reference to drawing and specification are required from quality control unit, O.K. Cards System shall be followed. The O.K. Cards should be made available on the site in regular manner. Approval of the component of work in progress at the times of inspection should be recorded by the inspecting officer.

The O.K. Card consists of two parts for each work. Part first covers the initial preparedness for the work and indicates pre-requisites where as the second part covers the daily performance of activities based on pre-requisites and also giving permission to perform the job by the construction as well as Quality Control staff. Besides the location and type of work, the first column of O.K. Card is to be filled by the construction agency (contractor) by preparing each feature and making it ready for inspection by the project construction engineer who Okay

through his signatures and then puts up to the Q.C./Q.A. engineer for his final O.K. If Q.C./Q.A. engineer is not available at site then O.K. given by construction engineer will be treated as final, if any thing otherwise is not observed. Should anything otherwise be found, the O.K. card shall not be signed by him and ask the construction engineer/agency for necessary rectification.

Subsequently, O.K. card should refer to the defects removed, if pointed out previously in OK card and counter reference to the previous check and should be signed of Okayed.

It must be borne in mind that work can not be held up unduly for disposal of OK Card. The Assistant Engineer (Quality Control)/Construction will be okaying authority for concentrated work like dam, spillway, head regulator etc. and Assistant Engineer/Overseer in charge of construction will be okaying authority for scattered works like canals and small structures. Random checks by supervising officers should be recorded on OK Cards at site. Fortnightly report of OK Cards maintained by construction unit should be submitted to E.E/Q.C. of the area who has to monitor and ensure that adequate check is being maintained by field staff. Confirmation regarding rectification of defects be obtained from E.E/Q.C. before making payment once in three bills and final bill of the contractor by the payment authority.

After processing through various levels and entering observations and rectification, OK Card will be closed at the time of taking measurements for releasing payments to the contractor. Photocopy of the OK Cards will be kept at site and original copy will be attached with the bill and will be kept on record by the division/Subdivision office while making payments to the contractor. Photo copy of OK Card of Quality Control will also be enclosed with the bill & kept on record with the bill by the division/subdivision office. However OK Card of quality control will not be closed till the work is finalized and will be kept on record by the Executive Engineer Quality Control after the rectification is completed by the construction wing and final comments are recorded by both the Assistant Engineer.

Specimen of OK Cards for various works such as embankment, concrete, masonry etc. has been enclosed below.

Raising/Strengthening of Earthen Embankments/ Fill Placement & Compaction (Part-I)

Name of Project……

Name of Work				
Agency		Contract No.		
Location		Date		
Description of Activities		Remarks & Dated Signatures of Agency	Remarks and Date Sign. Of Construction Staff	Remarks & Dated Sign. Of AE/QC
			Overseer / AE	
Layout/Demarcation/Fixing & checking T.B.M.				
Removal of Vegetation, debris & Site clearance				
Benching, stripping of base (±20 cm)				
PRE-REQUISTES				
(1) Proctor's density of borrow area				
(2) Designation of borrow area & checking of required moisture				
(3) Excavation and shaping of rain cuts and its refilling				
(4) Weather key- trench made and/or plowing of old embankments done if required.				
(5) Watering of base				
OK FOR FILL PLACEMENT				
Thickness of loose layer (cm)				

Removal of oversize (more than 7.5 cm size) layer				
Moisture content (%) –initial				
Moisture content (%) final (OMC =%)				
Weather soil laid as per profile				
OK FOR COMMENCING COMPACTION				
Checking of Type of Compaction Equipment/Roller				
Checking of In place density (D.B.D.)				
Compaction Efficiency (%)				
Specified Compaction (%) of Proctor				
Re-Rolling/Re-compaction if required				
D.B.D. after Re-Rolling				
OK FOR NEXT LAYER				
Removal of extra /loose earth from –U/S & D/S faces				

Supplementary O.K. Card for subsequent layers (Part II)

Name of Project……

Name of Work			
Agency		Contract No.	
Location		Date	

Date	Description of Activities (Chainage layer)	Weather Pre-Requisites fulfilled	Weather satisfactory consolidation achieved	Weather permitted for next layer	Dated Signature of Agency/ Contractor	Dated Signature of construction		Remarks & dated signature of QC Engineer
						Overseer	AE	
1	2	3	4	5	6	7	8	9

O.K Card No. 3

Sub grade preparation for placement of lining (Part-I)

Name of Project……

Name of Work			
Agency		Contract No.	
Location		Date	

Description of Activities	Dated Signature of Agency	Remarks & Sig. of Date Sign. of Construction		Remarks & Dated Sign. Of QC Engineer
		Overseer	AE	
Chainage				
Removal of Vegetation, debris				
Completion of dewatering				
Filling of over excavation, depressions /Pockets in soil/rocky strata as per specification				
Watering of sub-grade				
Compaction of sub-grade (bottom & sides) through slope compaction /Pneumatic rammer /power roller to specific density (……%)				
Final Lip cutting & checking sub-grade surface to ensure within permissible tolerances (up to 6.5 mm on sides, up to 12.5 mm on Bed)				
Laying of under-drainage arrangement (a) Porous Plugs (b) Longitudinal & Transverse Drains (c) Porous Panels				
Final wetting of sub-grade to 15 cm depth				
Checking of quantity and quality of material stacked at site Cement, Aggregate, Sand, Water				
Checking of mixer, vibratos & power				

Checking of form work/ Shuttering true to line and grade				
O.K. for lining placement				

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Placement of cast-in-Situ Concrete lining (Part II)

Name of Project……

Name of Work										
Agency					Contract No.					
Location					Date					
Date	Description of Activities & location	Weather Pre-Requisites of Sub-grade preparation done.	Satisfactory Quality & Quantity of material stacked at site	Signature of Contractor/ Engineer	Whether slump checked & cubes casted	Whether concrete vibrated	Whether specified contraction joints provided	Dated Signature of construction staff		Remarks & dated signature of QC Engineer
								Overseer	AE	

O.K. Card No. 5

Random Rubble Stone Masonry

Name of Project……

Name of Work				
Agency		Contract No.		
Location		Date		
Description of Activities	Dated Signatures of Agency	Remarks & Dated Signature of Construction Staff		Remarks & Dated Sign. of QC Engineer
		Overseer	AE	
Stone – Quality & Size				
Suitability of a) Cement b) Sand c) Water				
Mortar i) Mix, measurement ii) Mixing, Consistency				
Pointing, thickness of joints, staggering of joints, laying of stones, hearting stones, bond stones spacing..				
Whether samples of mortar collected in cubes for testing				
Green cutting with proper air water gun/sand blasting				
Adequacy of curing for masonry work.				
Verticality of structure check by using plumb bob				

Embedded Materials.				
Final OK for masonry work				

O.K. Card No. 6

Plain & Reinforced Cement Concrete

Name of Project……

Name of Work				
Agency		Contract No.		
Location		Date		
Description of Activities	Dated Signatures of Agency	Remarks & Dated Signature of Construction Staff		Remarks & Dated Sign. of QC Engineer
		Overseer	AE	
Material Suitability 1 Cement 2. Steel, Reinforcement placing & tying 3. Aggregate 40mm, 20 mm 4. Sand 5. Water 6. Admixture				
O.K. for materials				
Form Work & Centering i) Tightness, Stability, Smoothness. ii) Cleaning, oiling, perfect ness of form work. iii) R.L. of Centering iv) Checking of reinforcement.				
O.K. for reinforcement				
Tools & Plants i) Mixers & Vibrator				

ii) Adequacy of concrete production/transportation, placement, consolidation.				
O.K. for Placement				
1. Mixing/Consistency 2. Slump 3. Compaction of Concrete 4. Joints 5. Finishing 6. Casting of Cubes 7. Curing 8. Compressive strength 28 days 9. Cement content per M^3 10. Water content per M^3				
Final O.K.				

O.K Card No. 7

PCC Slab Canal Lining

Name of Work				
Agency		Contract No.		
Location		Date		
Description of Activities	Remarks & Dated Signatures of Agency	Remarks and Date Sign. Of Construction Staff		Remarks & Dated Sign. Of QC Engineer
		Overseer	AE	
A. Materials Suitability: i) Cement ii) Aggregate 40 mm, 20 mm iii) Sand iv) Water v) Treatment of soil if any				
OK for Materials				
B. Formation of Canal Banks: i) Stripping/Removal of vegetation ii) Cutting canal bed & sides to the geometric section/shape iii) Consolidation iv) Trimming				
C. Casting of PCC Slabs: i) Mix, Measurement by weight ii) Mixing, consistency iii) Slump				

iv) Water Cement Ratio v) Casting of PCC Slabs vi) Casting of cubes of concrete mix vii) Providing sub base if necessary viii) Laying/Placing in position PCC Slabs ix) Construction joints x) Contraction Joints xi) Pointing with CM xii) Curing xiii) Pressure Relief Hole xiv) Flexural Strength of PCC Slabs				
Final OK				

CHAPTER – IX

TESTS TO BE PERFORMED ON MATERIALS

MATERIAL	TEST	METHOD
Cement	**a) Chemical** i) Sio2, A1203, Fe203,Cao MgO, SO2, Insoluble residue & Loss On ignition ii) Alkalies & Chlorides	IS:4032-1985
	b) Physical i) Specific gravity ii) Fineness iii) Soundness iv) Compressive strength	
Water	**Chemical** i) CL, S04, Organic & Inorganic-Solids, pH, Alkalinity / Acidity ii) Setting time of mortar iii) Relative strength of concrete	IS : 3025-1968 IS : 516-1959 IS : 1199-1959
Fine Aggregate	i) Sieve Analysis & Fineness Modulus ii) Test for organic impurities silt & clay iii) Decantation test for silt iv) Specific gravity v) Unit weight and bulkage	IS: 383, IS 2386 (Part I & IV) IS 2386 (Part II) IS 2386 (Part III) IS 2386 (Part III) IS 2386 (Part III)

MATERIAL	TEST	METHOD
Coarse Aggregates	i) Sieve Analysis ii) Flakiness index iii) Elongation Index iv) Deleterious materials v) Specific gravity vi) Bulk Density vii) Moisture content viii) Absorption value	IS: 2386-1963 PART - I PART - II PART - II
	Mechanical tests ix) Aggregate crushing value x) Impact Value xi) Abrasion Value xii) Alkali Aggregate reactivity test.	 PART - IV PART - V PART - VII
Embankment	i) Proctors compaction	IS 2720 Part (vii & viii) 1965
	ii) Atterbergs Limits	IS 2720 Part (v) 1970
	iii) Permeability	IS ; 2720 Part (xvii) 1966
	iv) Shear Test	IS : 2720 Part (xiii)1972
	v) Specific gravity	IS : 2720 part (iii) 1964
Concrete	**a) Fresh Concrete** i) Air Contents	IS : 516-1959
	ii) Vibration iii) Temperature measurement iv) Mix proportions mainly cement v) Water cement ratio	

MATERIAL	TEST	METHOD
	b) Workability test i) Slump Test ii) Compaction Factor test	IS: 516-1959 Usual procedure IS:CED2(CESS) ASTM C 597-83
	c) Hardened Concrete	BS 4408
	i) Compressive strength	PART - 5:1974
	d) Special Test if Admixtures	
	i) Bleeding ii) Relative Strength iii) Setting Time	IS : 9103-1959 IS : 516-1959 IS : 8142-1959
Masonry	i) Gradation of Sand	
	ii) Slump Test	
	iii) Compressive strength of mortar	I.S. 1121
	iv) Tests for stone -	I.S. 1124
	- Water absorption	
	- Specific gravity	
	- Porosity	
	- Weathering of natural building Stone	I.S. 1125

CHAPTER – X

LIST OF EQUIPMENT FOR CEMENT AND CONCRETE TESTING

TEST	EQUIPMENT
A. CEMENT **a) Chemical** i) Alkalies ii) Minor, major oxides by Calorimetry iii) Chloride	Flame Photometer

TEST	EQUIPMENT
iv) General **b) Physical** i) Fineness ii) Soundness LeChatelier iii) Consistency and setting time. iv) Heat of Hydration v) General	Hot plate, Balance (Acc. 0.0002 g) Muffle Furnace (up to 1200 c). Platinum Crucibles, conductivity Bridge, pH Meter, physical balance (Cap. 150 gm) Blaines Apparatus, stop watch. Le Chatelier Moulds, hot water bath Autoclave
B. AGGREGATES & CONCRETE **a) General** i) Crushing value ii) Impact value iii) Abrasion value iv) Alkali Aggregate Reactivity. v) Flakiness & Elongation indices. vi) Unit Weight Containers vii) Sampling (Sand) viii) Specific Gravity and Absorption	Vicat Apparatus, moulds setting time needles and plunger compression testing machine (50 tonnes). vibrating machine, moulds 50 sq. cm. Area, calorimeter thermometer, flow table, stop watch, timer temperature controlled oven, humidity chamber incubator, physical balance (ACC 0.001 g), balance (cap. 5 kg. ACC 1g), set of standard sieves lid and receiver. Electric Driver, hot plates, set of standard sieves lid and receiver, balance 10 Kg. ACC 1g), 100 KG (ACC 0.001 Kg), 200 Kg. (ACC 0.5 Kg.) scop, Enamel trays, balance, shovels, compression testing machine (200 tones), crusher and ball mill prevailing rigs 2,25,50,100 tone. Crushing apparatus Aggregate impact test machine Apparatus for measuring flakiness Minimum Capacity of Measures

TEST	EQUIPMENT
C. CONCRETE **a) Fresh Concrete** i) Vibration ii) Temperature measurement iii) Mix proportions **b) Workability Tests:** i) Slump Test ii) Compaction factor test **c) Hardened concrete** i) Compression, tension bending & Brinnel: hardness tests.	Pyhcnometer Internal Vibrator, table vibrator constituents, Slump cone Apparatus, Compaction Factor apparatus, Universal Testing Machines with accessories (Cap. 100 tones), Concrete workability meter. Laboratory concrete mixer.

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CHAPTER – XI

FORMATS OF TEST RESULTS

DRY BULK DENSITY (DBD) SHEET

1. NAME OF WORK_____
2. REACH_____
2. MAX. LAB DENSITY OF SOIL PROFILE_____
3. OPTIMUM MOISTURE CONTENT_____
4. D.B.D. TO BE ATTAINED IN THE FIELD (GMS/C.C.)_____
   (..... OF THE LAB DENSITY)

Date	Sub reach	Number of layer with location	Thickness of the layer with R.L.	Wt. of soil in l grams		Volume of soil in c.c.	Dry bulk density (DBD)	Moisture content %	Signature of		Remarks & dated signature QC Engineer
				WET	DRY				Overseer	AE	
1	2	3	4	5	6	7	8	9	10	11	12

…… …… …… ……

Dated Signature of Overseer Assistant Engineer Asst.Ex. Engineer Ex. Engineer

Prepared by Er. K.A. Muhamed Kunju, (B.Sc. (Engg), F.I.E, C(Eng), FIV), Superintending Engineer (Rtd)

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REGISTER FOR COMPACTION EFFICIENCY DETERMINATION

Name of Work _____

Reach _____

Date	Sample No.	Location of Sample R.D. Off R.L. Set	Field Classification	Earth Fill zone
1	2	3	4	5

Embankment Data			Laboratory Data			Compaction
W.D.	Dry Density	M.C. %	% OMC	MDD	Gms/C.C.	
6	7	8	9	10	11	12

TEST RESULT OF SOIL FOR FILLING

Name of Work_____

Location_____

S. No.	Date of Sampling	Lab Sample No.	Location			Specific Gravity
			Borrow	Offset	R.L.	
1	2	3	4	5	6	7

Grain size Analysis (I.S. No. 480)				Proctor's Compaction		Permeability mt/yr. U/D
Gravel 4.75 mm%	Sand 4.75 To 0.075	Silt 0.75 to 0.002 mm%	Clay 0.002 mm	% OMC	M.D.D. Gms/cc	
8	9	10	11	12	13	14

At OMC MDD	Atterberges Limits			Shear Test at O.M.C. & M.D.D.	Dispensability	REMARKS
	L.L.	P.L.	P.I.	Drained/Undrained/ Saturated./Gms/C.C.		
15	16	17	18	19	20	21

TEST RESULT OF COURSE AGGREGATE

Field Lab. : _____

Location of Quarry/Stock_____

Ref. : _____

I.S. SIEVE Description	Percentage Passing for Graded aggregate or Normal Size			
	Sample	40mm	20mm	12.5mm
80mm		100		
40mm		95-100	100	
20mm		30-70	95-100	100
12.5mm		-	-	90-100
10mm		10 to 35	25-55	40-85
4.75 mm		0 to 5	0-10	0-10
2.36 mm		-	-	-

Crushing Value (>45)_____ Impact Value (> 45)_____

Abrasion (>50)_____ Absorption _____

Soundness Loss > 12% for Na2 So4_____

> 15% for Mg So4_____

TEST RESULT OF FINE AGGREGATE/SAND

LAB _____

Location Quarry/stock _____ Ref_____

Percentage Of Passing For

L.S. Description	Sample	Grading Zone-I	Grading Zone-II	Grading Zone-III	Grading Zone-IV
1	2	3	4	5	6
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

F.M._____ SILT_____

BULKAGE_____

REMARKS_____

NOTE :

1. For crushed stone sand, the permissible limit on 150-micron IS Sieve is increased to 20 percent. This does not affect the 5 percent allowance permitted in 4.3 applying to other sieve sizes.

2. Fine aggregate complying with the requirements of any grading zone in this table is suitable for concrete but the quality of concrete produced will depend upon a number of factors including proportions.

3. Where concrete of high strength and good durability is required, fine aggregate conforming to any one of the four grading zones may be used, but the concrete mix should be properly designed. As the fine aggregate grading becomes progressively finer, that is, from Grading Zones I to IV, the ratio of fine aggregate to coarse aggregate should be progressively reduced. The most suitable fine to coarse ratio to be used for any particular mix will, however, depend upon the actual grading, particle shape and surface texture of both fine and coarse aggregates.

4. It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

5. For sand to be used for masonry work and plastering work, please see back side

ACCEPTANCE CRITERIA
OF
FINE AGGREGATE FOR MASONARY

(AS PER IS : 2116 - 1980)

IS Sieve Size	Percentage Passing by Weight
4.75 mm	100
2.36 mm	90-100
1.18 mm	70-100
600 micron	40-100
300 micron	5-70
150 micron	0-15

ACCEPTANCE CRITERIA
OF
FINE AGGREGATE FOR PLASTERING WORK

(AS PER IS : 1542 - 1977)

IS Sieve Size	Percentage Passing by Weight
10.00 mm	100
4.75 mm	95-100
2.36 mm	95-100
1.18 mm	90-100
600 micron	80-100
300 micron	20-65
150 micron	0-50

TEST RESULT OF CEMENT

Name of Godown _____ for use in structure _____

Manufactured at _____factory _____ Ref. _____

S. No.	Samples No.	Lab. No.	Size of Cube	Physical Testing Setting times		Specific Surface	Compressive strength test Cube Kg/Cm2		LF Chart Test	Remarks
1	2	3	4	5	6	7	8	9	10	11

TEST RESULT OF WATER SAMPLES

Location_____ River_____

Reservoir _____ Ref. : _____

Storage _____

For use in concreting / mortar / curing / other _____purpose in

Structure at _____

S. No.	Sample	Quantity Tests Percentage of						Quantitative Tests		Remarks
		SO4	CO3	CI	NO	PO	pH	Silt & Suspended Impurity	Total Soluble Salt	
1	2	3	4	5	6	7	8	9	10	11

TEST RESULT OF STONE FOR MASONRY/ SEA WALL ETC.

Location Quarry _____ Ref. _____

Approximate Quantity Supplied _____

S.No.	Lab Samples	Wt. of Individual Piece Kg.	Size L x B x H	Absorption (%)	Density Gm/CC
1	2	3	4	5	6

Soundness With Na2So4	Abrasion Acid Reaction with HCL Conc.	Abrasion	Visual	Curing	General Remarks including suitability
1	2	3	4	5	6

……. …… …… ……

Signature of with date | Overseer | Assistant Engineer | Asst.Ex. Engineer | Ex. Engineer

TEST RESULTS OF BRICK SAMPLES

Name of work _____Location_____

Sample mark of Ref._____ Lab No. _____

Properties of bricks	Observation	Remarks
1	2	3
1. Colour		
2. Burnt Character		
3. Shape		
4. Edges		
5. Texture after breaking		
6. Sound when struck		
7. Effloresence		
8. Tolerance (as per Agreement / I.S. Code)		
9. Compressive strength Kg/Cm2		
10. Water Absorption		
11. Flexural strength for tile.		

Note : Properties of bricks with dimensions / tolerances and compressive strength etc. shall be covered by the specifications as per Agreement / relevant I.S. Codes.

……. …… …… ……

Signature of Overseer Assistant Engineer Asst.Ex. Engineer Ex. Engineer with date

TEST RESULTS OF CONCRETE / MORTAR CUBES CASTED SITE

Name of Work:- _____

Location of structure _____

Sample No.	Date of Casting	Location of Sample			Mark on the Cube
		Block R.D.	Offset	R.L.	
1	2	3	4	5	6

Proportion	W/C Ratio	Slump	Compressive Strength of Concrete / Mortar Cube in Kg/Sq.cm2.		Designed 28 days Strengths of Cube Mortar Kg/Sq.cm2.	Remarks
7	8	9	10	11	12	13

……. …… …… ……

Signature of with date Overseer Assistant Engineer Asst.Ex. Engineer Ex. Engineer

CHAPTER – XII

IMPORTANT SPECIFICATIONS

EARTH WORK (IS CODES : 2720, 4701, 8237, 9481, 4081, 1200 and 9451)

The procedures to be adopted while doing earth work excavation for various jobs and the precautions to be taken are prescribed in the IS specified above. The important Do's and Don'ts are given below for ready reference.

A. General	
DO'S	**DO NOTS**
1. Fix up the centre line and set the curves correctly.	1. Do not avoid approval of the deviation statement.
2. Take working leves, real variation in ground levels and classification of soils.	2. Avoid over break and loosening of canal
3. Get top soil vegetation etc., removed	3. Do not mix up usefull soils with other soil of cutting.
4. Form spoil bank as per drawing and away from the side drain with suitable gaps for drainage into the valley.	
5. Form Dowel Bank, as per drawing.	
6. Form Inspection path to a uniform longitudinal gradient and with gentle transvrse slope towards drains.	
7. Compact over excavation/ breakage portion with suitable soils. gravel, spalls.	
8. Provide CNS treatment in expansive black cotton soils.	

B) Formation Of Embankments	
1. Get the top spoil, vegetation and sand patches removed to complete depth.	1. Soil required for embankment to be obtained from borrow area should be got tested for proctor density & O.M.C. before start of work.
2. Scarify the ground and wet properly.	2. Do not raise the bank in piecemeal.
3. Obtain Proctor density OMC for the useful soils and borrow soils.	3. Do not allow new layer without scarification and wetting of old layer.
4. Raise embankment to full width with uniform horizontal layer of 15 cm to 22.5 cm thickness.	4. Do not allow new layer unless the old layer compacted up to required density.
5. Break clods, remove roots, big boulders other materials etc. larger than 75mm form the soils used in embankment.	5. Don't leave any loose layer un-rolled at the end of the day in rainy season.
6. Supplement deficit moisture whenever required.	6. Don't allow compacted layer to be more than 150mm.
7. Compaction with 8 to 10 tones power roller or Fuel - operated vibratory plate compactors.	7. No new layer to be laid unless the over moistured layer is either completely removed or allowed to dry.
8. Conduct field compaction tests and determine compaction efficiency.	8. Don't dump soils in heaps
9. Check embankment profiles periodically.	9. Don't dump the soils in water and slush. Do not forget to provide settlement allowance of 2 cm/mtr. Height of bank.

PLAIN AND REINFORCED CONCRETE (IS CODES 383, 269, 2116, 2386, 456, 516, 1199, 3878, 9103) & C.C. LINING (I.S. CODES, 353, 269, 2116, 456, 516)

1. Proportioning & batching

Design mix concrete (controlled concrete) shall be used for concrete of grade M10 and higher. Nominal mix concrete (as per table) may be used for lean concrete mix (viz. concrete mix of grade lower than M10 viz. M5, M7.5). In proportioning concrete, the quantity of both cement and aggregate shall be determined by mass. Water shall be either measured by volume in calibrated tanks or weighed. Concrete shall be manufactured in mechanical mixers either in batching mixing plants or mechanical mixers of various capacities (14/10 or 10/7). Alternatively, mobile self-loading weight batching-mixing and transporting mixers of suitable drum capacity, can be used, both for mixing and transporting concrete. The mix proportions shall be such as to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability, and surface finish.

Proportions for Nominal Mix Concrete

Grade of concrete	Total quantity of dry aggregates by mass per 50 kg. of cement to be taken as the sum of the individual masses of fine and coarse aggregate (kg.)	Proportion of fine aggregate to coarse aggregate (by mass)
1	2	3
M5	800	Generally 1:2 but subject to an upper limit of 1:1.5 and a lower limit of 1:2.5
M7.5	625	
M10	480	

Notes:

i) Graded aggregates shall be used.

ii) Water cement ratio should be as per mix design.

Design Mix concrete

The mix shall be designed to produce the grade of concrete having the required workability and characteristics strength not less than appropriate values given below:

Grade of Designation of concrete	Specified characteristic compressive Strength of 150mm cube at 28 days in N/mm2
M10	10
M15	15
M20	20
M25	25

The concrete mix shall be designed for the `target mean strength'. The target mean strength of concrete mix should be equal to characteristic strength plus 1.65 times the standard deviation.

Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given below shall be assumed for design mix of concrete in the first instance. As soon as the results of samples are available, actual standard deviation shall be used and the mix designed accordingly.

Assumed standard deviation (as per IS : 456 - 2000)

Grade of concrete	Assumed standard deviation
M10	3.5
M15	3.5
M20	4.0
M25	4.0

Water cement ratio (W/C):

Water cement ratio is one of the key elements for a durable and sound concrete of adequate strength. Accordingly, Water cement ratio shall be maintained at correct value. The water contents in both fine and coarse aggregate shall be determined regularly. The amount of added water shall be adjusted to compensate for any observed variation in moisture content. The amount of surface water may be estimated from the following table in the absence of exact data:

S.No.	Aggregate	Approx. quantity of surface water	
		% by mass	Litre/m3
1.	Very wet sand	7.5	120
2.	Moderately wet sand	5.0	80
3.	Moist sand	2.5	40
4.	Moist sand/crushed rock	1.25 to 2.5	20 to 40

Durability of concrete:

It is essential that the concrete be durable viz., it should perform satisfactory in the working environment during its anticipated exposure conditions during service. The materials and mix proportions are to be such as to maintain its integrity, and (where ever applicable), to protect embedded metal/reinforcement from corrosion.

Environmental exposure conditions(as per Table 3 of IS 456 : 2000)

S. No.	Environment	Exposure condition
1.	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.
2.	Moderate	☐ Concrete surfaces sheltered from severe rain or freezing whilst wet.

		☐ Concrete exposed to condensation and rain. ☐ Concrete continuously under water. ☐ Concrete in contact or buried under non-aggressive soil/ground water. ☐ Concrete surfaces sheltered from saturated salt air in coastal area.
3.	Severe	☐ Concrete surfaces exposed to severe rain, alternate wetting and drying, or occasional freezing whilst wet or severe condensation. ☐ Concrete completely immersed in sea water. ☐ Concrete exposed to coastal environment.
4.	Very Severe	☐ Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. ☐ Concrete in contact with or buried under aggressive subsoil/ground water; concrete exposed to alternate wetting & drying.
5.	Extreme	☐ Surface of members in tidal zone. ☐ Members in direct contact with liquid/solid aggressive chemicals.

The severity level in the works in Kerala may be assumed moderate to severe only, except in such environment which is associated with corrosive fumes or where the concrete work is to be in contact with or buried under aggressive sub-soil/ground water.

Workability of concrete:

The concrete mix proportions chosen shall be such that the concrete is of adequate workability for the placing conditions of the concrete and can be properly compacted. Slump for good workability of concrete shall be as per mix design / as per IS code 456 - 2000

Mixing :

Concrete ingredients shall be mixed thoroughly in the mechanical mixer and the mixing shall be continued until there is a uniform distribution of the ingredients and the mass is uniform in colour and consistency. Minimum mixing time shall be 2 minutes or as determined by the Engineer-incharge. 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 and water being measured.

Transporting :

Concrete shall be transported from the mixer to the form work/site of placement as quickly as possible by methods, which shall prevent the segregation and maintain the requisite workability. Transportation of concrete in ordinary open tippers or trucks shall not be allowed as it causes segregation. Transit concrete mixers can be used for transportation. Self loading, batching, mixing & transporting mixers can also be used both for mixing and transporting concrete.

Placing:

The concrete shall be placed and compacted with vibrators (Immersion/needle) and plate vibrators in case of lining before initial setting of concrete commences and shall not be subsequently disturbed. Methods of placing shall be such as to avoid segregation. Strict and meticulous care shall be taken to avoid displacement of reinforcement or movement of form work and concrete. Concrete shall be fully worked around reinforcement and in the corners of form work. Over vibration resulting into bleeding of concrete shall be strictly avoided. Spare vibrator shall be kept by the contractors as stand by. Temperature of concrete, as placed, shall preferably be restricted to about 32 Degree C (90DegreeF)

Curing :

Curing shall commence as soon as possible after concrete is placed and initial set has occurred but before it has hardened. Curing with water shall be continued for at least 14 days. Exposed surfaces of concrete shall be kept continuously in a damp/wet condition by pounding or by covering with a layer of sacking, canvas, hessian, or similar materials and kept continuously wet for 14 days.

Sampling of concrete:

A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested, viz. the sampling should be spread over the entire period of concreting and cover all mixing units (concrete production units).

Frequency of sampling:

The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

Quantity of concrete in the work, m3	Number of samples	Remarks
Upto 50 cum.	One set of 3 samples	
51 and above	One additional set of 3 sample for each additional 50 m3 or part thereof.	

At least one sample shall be taken from each shift.

Test specimen:

Three test specimens shall be made for each sample for testing at 28 days. Additional specimens may be taken to determine the strength of concrete at 7 days. Test results of the

sample shall be the average of the strength of 3 specimens. The individual variation should not be more than + 15% of the average strength of 3 specimens. If more, the test results of the sample are considered invalid.

Acceptance criteria of compressive strength:

The concrete shall be deemed to comply with the strength requirement when both the following conditions are met, as per IS: 456-2000:

(a) The mean strength determined from any group of 4 non-overlapping consecutive test results complied with the appropriate limits in columns 2 of the following table.

(b) Any individual test results complied with the appropriate limits in column 3 of the following table.

Characteristics compressive strength compliance requirements

Specified grade	Mean of the group of 4 non-overlapping consecutive test results in N/mm2	Individual test results in N/mm2
M15	> fck + 0.825 x established standard deviation (rounded off to nearest 0.5N/mm2) Or fck + 3 N/mm2 whichever is greater	> fck - 3 N/mm2
M20 or above	> fck + 0.825 x established standard deviation (rounded off to nearest 0.5N/mm2) Or fck + 4 N/mm2 whichever is greater	> fck - 4 N/mm2

In the absence of established value of standard deviation the following value may be assumed in the first instance and there after established values based on the requisite number of test results.

Grade of concrete	Assumed standard devotion
M10 and M15	3.5N/mm2
M20 and M25	4.0N/mm2

fck = Characteristic compressive strength of 150mm cube at 28 days in N/mm2. For M15 & M20 grades, fck is 15N/mm2 and 20N/mm2 respectively. For M10 concrete, fck is 10N/mm2. In respect of CC lining with a minimum cement level of 250 Kg./m3, minimum fck envisaged is 13.5N/mm2. Based on the assumed standard of deviation values of 2N/mm2 and 2.5N/mm2 for M10 and M13.5 respectively their acceptance criteria of compressive strength can envisaged as;

Specified grade	Mean of the group of 4 non-overlaping consecutive test results in N/mm2	Individual test results in N/mm2
M10	> fck + 0.825 x established standard deviation	> fck - 2 N/mm2
M13.5 (CC lining with minimum cement level of 250 Kg/m3)	> fck + 0.825 x established standard deviation	> fck - 4 N/mm2

Note : The minimum cement level of 250kg/m3 for plain cement concrete lining is from the durability consideration and not on the 28 day characteristic strength basis alone.

Standard Deviation is calculated from the following equation:

$$Sd = \sqrt{\frac{(\bar{X} - X)2}{N-1}}$$

N	=	No. of samples (30 samples are generally considered)
`X	=	Sum of the mean value of 3 test specimens of each sample divided by the number of samples, viz. overall average strength.
X	=	Difference between overall average strength and the mean strength of 3 test specimen of each sample.

Construciton Joints:

Concrete shall be placed in massive structures in lifts, which are generally 1.5 m high. To develop proper bond between the lifts, the concrete surface shall be freed of all laitance, coating stains, defective concrete and all foreign material and the surface shall be roughened. This can be achieved by green-cutting. For lining work the construction joint where ever required is to be adopted as per the sketch in Annexure-III.

Green Cutting:

The surface of the joint shall be thoroughly green-cut with an air-water jet. Green cutting is usually done 8 to 12 hours after the top surface of a concrete lift has been completed and sufficiently hardened. The actual time for taking up the green cutting operation shall depend upon the following factors:

a) Concrete placement temperature:
b) Atmospheric temperature
c) Concrete mix; and
d) Slump

The air-water jet will remove the thin surface film of laitance and grout to expose clean surface.

Green cutting, if done at the proper time, shall yield very good results:

When started too early, it shall result in over-cutting and removing too much mortar. It is also liable to loosen the aggregate particle and leaving too poor a surface to bind the fresh concrete. On the other hand, if green-cutting is delayed too long, the cutting action of the air and water jet would be ineffective for proper removal of laitance. It, therefore requires much greater care and judgment for proper use at the proper time.

Skill Of Jet Operator

Besides determining the proper time for initiating green-cutting, the process will require constant attention on the part of the air-water jet operator. By correct manipulation of the high velocity air-water jet, a trained operator can ensure the removal of the thin surface film of laitance and grout effectively and at the same time leaving the aggregate stones, already embedded in the mortar, undisturbed.

Proper Air-Water Gun

In addition to the skill of the jet operator, a proper air-water gun is also a vital requirement for effective green - cutting. The issuing nozzle must be about 460 mm(18 inches) long to ensure the requisite cutting force close to the concrete surface. A dimensioned sketch of an air-water gun is enclosed as Annexure -VI.

Quantum Of Compressed Air And Water:

For effective green-cutting, it is essential that the air pressure should be around 6.33 to 7.03 kg/cm2 (90 to 100 lbs. Per square inch.) It should not be allowed to fall below 90 lbs. per square inch. The water pressure, of course, should be sufficient to bring the water into effective influence of the air pressure. As an approximate estimate, the quantity of compressed air required by the green-cutting gun is 2 cubic meters per minute (70 cfm) and the quantity of water 60 gallons (273 liters) per minute

Sand Blasting:

Sand blasting is the process of roughening and cleaning the surface of old and set concrete by means of coarse sand and air applied under pressure of 90 to 100 pounds per square inch (6.33 to 7.03 kilograms per square centimeter) through a nozzle, so as to erode the laitance and grout from the old and fresh concretes monolithic. Sand blasting of rock is also done so that concrete may be placed on or against a clean surface as required according to specifications.

There are two types of sand blasting, namely "wet sand blasting" and "dry sand blasting". In wet sand blasting water is also used along with sand and air under pressure, while in the latter, only sand and air under pressure are used. Normally the concrete and rock surface etc., are wet sand blasted to keep down the dust.

The percentage of different sizes of sand particles for efficient sand blasting shall be as follows:

Size	Percentage
8 mesh per inch (25.40 millimeters)...	26
16 mesh per inch (25.40 millimeters)...	30
30 mesh per inch (25.40 millimeters)...	23
50 mesh per inch (25.40 millimeters)...	21

For effective sand blasting it is essential that pressure of air should be between 90 to 100 pounds per square inch (6.33 to 7.03 kilograms per square centimeter). If pressure falls below 90 pounds per square inch (6.33 kilograms per square centimeter), sand blasting becomes in effective. If sand having large percentage of fines is used, it will not provide the requisite cutting power and the whole effort goes waste. A good quality well graded "sand -blast-sand" is needed for achieving the objective of sand blasting.

Registers To Be Maintained

1. Load Register
2. Cement Day book
3. Sieve analysis for sand and metal.
4. Slump for consistency.
5. Compressive strength of concrete.

The important Do's and Don'ts

Concrete Foundation Work

	DO'S		DO NOTS
1.	Verify dimensions and foundation levels as per drawing.	1.	Do not forget to compare bearing capacity of actual soils met with design strength.
2.	Wet the foundation surface to a depth of 150 mm or to impermeable material.	2.	Don't lay the foundation concrete without wetting the surface.
3.	Compact with suitable bedding materials in case of over excavations and with M-5 grade concrete in case of rock.	3.	Don't allow admixtures, which will harm the strength of concrete.
4.	Ensure the rock surface free from oil, objectionable coating unsound fragments.	4.	Do not lay the concrete under water and over slush.
5.	Check-up correct batching of ingredients.	5.	The minimum mixing time should not be less than 2 min.
6.	Check the batch of cements and its make.	6.	Do not forget to keep stand by vibrator and needles.

7.	Check-up water cement ratio and slump test.	7.	Do not place concrete in raw in sufficiently heavy to wash mortar from concrete.
8.	Ensure uniform mixing in a mixer for at least 2 ½ minutes	8.	Do not forget to cast the cubes
9.	Ensure proper compaction with vibrators and keep stand-by vibrator and needles.	9.	Do not allow segregation of concrete
10.	Operate immersion type vibrators nearly in vertical position to vertical drain.	10.	Do not use unsatisfactory mix.
11.	Cure with water for 28 days.		

Concrete Super Structure

	DO'S		DO NOTS
1.	Check the form work	1.	Avoid abrupt surface irregularities.
2.	Apply cement slurry after cleaning the surface at vertical joints.	2.	Do not deviate from specified dimensions of cross section from -6mm to +12 mm.
3.	Clean and cover with a layer of 10 to 15 mm thick mortar of the same proportion of concrete mix for horizontal joints.	3.	Do not allow concreting until all form work installation of items to be embedded and preparation of surface involved are approved.
4.	Place the concrete, preferable at temperature not exceeding about 90o F.		
5.	The concrete shall be discharged with in half an hour after introduction of the mix water and cement.		

Reinforced Cement Concrete Slabs (I.S. Codes 2502, 1786)

DO'S	DO NOTS
1. Check the reinforcement as per drawing and I.S. Code with particular reference to concrete cover.	1. Do not pass without specified cover.
2. Provide asphaltic pad and water stopper as per drawing.	2. Do not allow less lengths in over laps.
3. Ensure lightning arrangement if the work is to be carried out during night.	
4. Ensure stand by vibrator & mixer in working condition at site before start of work.	
5. Fill up the cubes of concrete samples for testing.	

Concrete Lining

DO'S	DO NOTS
1. Check the canal prism and verify the bed levels.	1. Do not allow concrete lining on loose sub-grade.
2. Check the gradation analysis of fine and coarse aggregate to the requirement of mix at batching plant.	2. Do not allow lining without wetting sub-grade
3. Allow the ingredients of fine and coarse aggregate as per required mix by weigh batching.	3. Do not allow C.C. lining manually without vibration.

4. Check the calibration of weighing machine at batching plant.	4. Do not allow segregation of concrete while laying through discharge conveyor.
5. Check the water meter and its discharge.	5. Do not allow concrete directly on subgrade from transit mixer.
6. Check the batch of cement, its make and test results.	6. Do not form contraction joints over longitudinal drains.
7. Check the water cement ratio and record the slump.	7. Do not fill up contraction joints with sealing compound without cleaning with air water jet or sand blast.
8. Check whether any retarders and air entraining agents are added.	8. Do not allow any projections or contraction joint over the surface of the lining.
9. Maintain load register.	9. Do not allow the C.C lining without applying suitable primer to sides.
10. Record the No. CC cubes cast and its compressive strength.	10. Do not remove the channels immediately before setting of C.C.
11. Cure CC Lining with water for 28 days.	11. Do not use untested cement.
12. Ensure smooth surface with paver roller passes.	12. Do not allow to sink the porous plugs in the drains.
13. Form the contraction and construction joints as per approved drawing.	13. Do not allow lining without making proper arrangements for curing with water.
14. Check the thickness of C.C. lining for each panels.	14. The Co-efficient of variation in the compressive strength of cement should not be more than 8%.
15. Checking placing of mastic pad at structures of construction joints.	
16. Allow concrete lining at temperature between 15o C and 32o C.	

17.	Check periodically the coefficient of variation in the compressive strength of cement.	
18.	The batching plant to be used shall confirmed to the required of IS 4925-1968.	

PREPARATION OF SUB-GRADE FOR C.C. LINING (I.S. CODES : 2720, 4701, 3873)

Preparation of Sub grade in hard soil

Preparation of sub-grade is a factor on which depends much of the successful performance of lining. Failure or cracking of lining in many cases can be attributed to poor preparation of sub-grade. Due emphasis is, therefore to be laid on control and proper preparation of sub-grade for lining. Sub-grade indifferent soil reaches shall be prepared based on IS : 3873-1978. Whereas the work of trimming the canal section up to underside of lining shall be carried out well in advance, the trimming of proud section equivalent to the thickness of lining (for base preparation of lining) should be carried out immediately prior to laying of lining but in no case the time interval shall exceed 3 days in normal weather and 2 days in adverse condition.
Preparation of Sub-grade consisting of Earth :

1. The sub-grade should be prepared, dressed and rolled true to level according to the required cross-section of the canal to form a firm compacted bed for the lining. Sample profiles true to the cross section of the canal should be made at suitable intervals to ensure correct formation of the sub-grade. If at any point material of sub-grade has been excavated beyond the neat lines required to receive lining, the excess excavation should be filled with material compatible with sub-grade material and thoroughly compacted.

2. When partial filling of existing canal sections is necessary to reduce the cross sectional area to that required for lined canal, the fill shall be paced and suitably

compacted by rolling / compactors/mechanical tampers to form firm foundation for placing the lining to avoid its settlement. Slope compactors shall also be used as required for effective compaction of sub grade to the specified density.

3. The consolidation of bed in sandy reaches shall be done by saturating the bed with water before lining is placed. The consolidation of side slopes in such reaches shall be done by over cutting the sub grade in slopes by 15 cm and refilling it with earth and compacting by vibro-compactors/ appropriate mechanical compactors.

4. The compaction of sub grade in other than predominantly sandy reaches shall be done at optimum moisture content in layers not more than 15 cm-20 cm thick to obtain a dry bulk density of 95% of the density at optimum moisture content obtained in accordance with IS:2720 (Part VII)-1965. Consolidation shall be done by power rollers/pneumatic or fuel-powered tampers/suitable compactors. In the sandy reaches, compaction shall be governed by `relative density test' and the relative density shall not be less than 70% Compaction by manual labour shall not be permitted.

5. Where placing and compacting bedding material is on sloping foundation, the layers shall be placed parallel to the surface of the foundation. If at any point the foundation material is disturbed or loosened, it shall be moistened if necessary and thoroughly compacted to form firm foundation for placing the lining.

6. All along the canal alignment, the rain cuts on the inner slopes of the banks shall be filled up with approved soil and shall be compacted thoroughly to required lines, dimensions, and levels.

7. If at any place, placement of bedding material below the proposed lining is required, due care shall be taken to place the bedding material on scientifically approved surface adequately moistened (to be wet to a depth of 15 cm or to depth up to impermeable layer below, whichever is less) in layers not exceeding 15 cm in depth in a single operation and thoroughly compacted.

8. All loose materials likely to be present at the end panel of existing lining adjacent to which lining is to be placed shall be removed and all voids beneath the existing lining shall be refilled and compacted thoroughly.

Preparation of Sub grade consisting of Rock

1. The sub grade shall be prepared and dressed true to level and according to the required cross-section of the canal.

2. Final cutting for 300mm-450mm in hard rock shall be carried out by wedging, barring, controlled blasting or trimming with pavement breakers etc.

3. The bed and side slopes of the canal excavation profile over which the bedding material, under-drainage and pressure relief arrangements (where ever so required) are to be placed and over laid with lining shall be furnished accurately to true and even surfaces and to the dimensions shown on the drawings.

4. All excavation including over breakage below the lines of underside of lining shall be back-filled completely up to the lines of the underside of lining with suitable bedding material as under or as directed by the Engineer-incharge.

The bedding material shall be lean concrete (1:5:10) in bed and sides for thickness of filling less than 15 cm; and RR masonry in cement mortar (1:5) if thickness is more than 15 cm.

In Slopes : In slopes, the selected material shall be suitable semi-previous material/gravely soil and a layer of pea gravel as binding material duly moistened and compacted by appropriate compactors/tampers to form a firm backing for the lining.

In Bed: In bed, the selected bedding material shall be rock spalls and chips to form a firm backing.

Selected bedding material to be used over fractured rock or rubble shall be such as would resist piping and consequent washing of fines into the sub grade voids and thus losing support. The material shall be approved by the Engineer-incharge for its impermeability and care of placement.

Preparation of sub grade consisting of expansive soils (IS:9451-1994)

Field and laboratory tests shall be carried out to determine the physical, textural, engineering, and chemical properties of expansive soils and evaluate the swelling pressures of soils in various reaches to establish the thickness of CNS (Cohesive non-swelling soils) layer required so that the resulting deformation is within the permissible limit of 2 cm. The thickness of CNS layer to be provided normal to the sub grade shall be governed by the Indian Standard IS : 9451-1994, out lined below. CNS material shall be non-swelling with a maximum swelling pressure of 10KN/m2 when tested in accordance with IS 2720 (Part-41) : 1977 at optimum moisture content and minimum cohesion. Some of the soils which may be considered as cohesive non-swelling soils are all adequately compacted clayey soils, silty clays, sandy clays, gravelly sandy clays, etc. exhibiting cohesive properties and containing predominately non-expanding type clay minerals with liquid limit not exceeding 50 percent.
Expansive soils are inorganic or organic plastic clays characterized by shrinkage, high compressibility, and swelling properties. To counter act the swelling pressure and prevent deformation of lining, a CNS material of required thickness is sandwiched between the soil and lining. The thickness of CNS material is normal (perpendicular) to the sub grade. Guidelines for choosing the thickness of CNS materials (Cohesive Non-Swelling) required for balancing the different swelling pressures.

Specification of CNS Soils :

(i) Gradation of CNS Soil

Clay (less than 0.002 mm)	15 to 20%
Silt (0.06mm - 0.002mm)	30 to 40%
Sand (2mm-0.06mm)	30 to 40%

Gravel (grater than 2mm) 0 to 10%

ii) The CNS materiel shall be non-swelling, with a maximum swelling pressure of 10 KN/m2 when tested in accordance with IS: 2720 (part -41) 1977 at optimum moisture content and minimum cohesion.

Liquid limit Greater than 30, but less than 50%

Plasticity Index Greater than 15 but less than 30%

If given CNS material is not available, designed soils mix to produce artificial CNS may be used. The artificial CNS shall broadly satisfy all the requirements of CNS outlined above.

In respect of the provisions of CNS layer in the bed, it shall be as worked out from consideration of swelling pressure. However, the thickness of CNS layer to be provided on slopes shall, in addition, be governed by the construction consideration viz. from the Power Roller rollable width consideration for achieving effective compaction. CNS layers shall be compacted to 98% proctor density.

Note : During construction, it shall be ensured that :

(i) Serrations/steps/benches shall be provided in the side slopes of canal in cutting to provide a good bond between the CNS layers and expansive soil and to also prevent contact slides between CNS materials and expansive soil.

(ii) Proper moisture shall be added to CNS material and expansive soil.

(iii) CNS material shall be laid in layers (+ 20cm thickness) and compacted to requisite proctor density, preferably, by Power Roller.

(iv) To avoid slipping and rain cuts during the rainy season, it shall be advisable to provide CNS right up to the ground level.

(v) The sub grade on which CNS layer is to be laid shall, generally, be not kept exposed for more than 4 days prior to the placement of CNS layer.

(vi) Effective compaction of sub grade for side lining on slopes is very important in cutting or embankments. In addition to the designed thickness of CNS, 20 cm or more (perpendicular to side slope) of extra thickness (called proud) shall be provided and compacted. This proud shall be removed only just prior to the placement of lining (a time interval of, say, about one day), thus making a fresh and well-compacted surface available for bedding. IN small section channels, it shall be appropriate to over excavate the section, and fill the entire section with CNS material (laid in successive layers and compacted to 98% proctor density), and, thereafter, scoop this section to the designed section for placement of lining. This PAD method ensures effective compaction by 8-10 T power rollers or equivalent power vibratory rollers. The CNS material so scooped out is utilized in the next reach through re-handling.

(vii) To avoid slipping and rain cuts during the rainy seasons, the CNS shall be provided right up to ground level in cutting reaches.

(viii) Under drainage arrangement, as per provisions in the agreement.

Sub-grade Density and Moisture Control :

A sound dense earth foundation, carefully trimmed and pre-moistened before lining placement are critical steps, prerequisite to a good lining construction. Required foundation density of embankment and preparation coupled with moisture control are the key requirement. At the time, concrete is placed the sub-grade is required to be thoroughly moist (but not muddy) for a depth of about 12 to 15 cms and 20 to 22 cm in case of sand as else the concrete would extract moisture from the sub-grade. Compliance of these requirements must be recorded by the execution, QC staff in the OK card. Photographic record showing the actual use of very fine spray nozzles instead of hose (for moistening the compacted sub-grade) should also be kept.

Tolerance in Surface Irregularities in Preparation of Final Subgrade

Surface irregularities shall be tested by the use of a long template consisting of a straight edge or the equivalent there-of for curved surfaces and shall not exceed the following limits:

i) 6.25mm for sub grade in bed.

ii) 12.50 mm for sub grade in the side slopes.

Lining Preparation of Sub grade Do's & Do nots.

DO'S	DO NOTS
1. Check the model section to the canal profile i.e., bottom or lining viz side slopes, bed width, top width, slant length, smoothness of slant length.	1. Do not allow concrete lining on loose sub-grade.
2. Check the canal profile with reference to model section. Profile be prepared at 15 M intend in case of tile lining.	2. Do not allow any root or stumps to be on sub-grade.
3. Remove roots and stumps completely from the sub-grade	3. Do not allow lining in expansive soils without treatment with C.N.S. soils.
4. Compact over-excavation in soils with earth gravel duly wetted.	4. Do not place the porous plug below the surface of the lining.
5. Compact over-excavation in rocky area or fill up with not concrete as per specification.	5. Do not allow lining without wetting the sub-grade suitably.
6. Provide treatment with C.N.S. soils in expansive soils.	6. Do not allow movement of labourers after preparation of subgrade.

7. Provide porous plugs of specified size in each panel with specified local filters of graded metal and sand. 8. Check whether porous plugs are freely draining or not.	

CONCRETE CORES FROM CANAL LINING AND OTHER STRUCTURE

A specimen to be tested for strength shall not be removed from the structure until the concrete has become hard enough to permit its removal without disturbing the bond between the mortar and the course aggregate. In general the concrete shall be 28 days old before the specimens are removed. Specimens that show abnormal defects or that have been damaged in removal shall not be used. (IS: 457-1997).

Core Drill:

A core drill shall be used for securing cylindrical core specimens. For specimens taken perpendicular to a horizontal surface, a diamond drill shall be used.

Specimens: A core specimen for the determination of pavement thickness shall have a diameter of at least 10 cm. A core specimen for the determination of compressive strength shall have a diameter of at least three times the maximum nominal size of the course aggregate used in concrete and in no case shall the final diameter of the specimen be less than twice the maximum size of the course aggregate. The length of the specimen, when capped, shall be, as nearly as practicable, twice its diameter. The curve enclosed Annexure - VIII should be used to correct the indicated strengths so that they will be comparable with those obtained from standard specimens (having L/D ratio as 2).

Core Drilling:

A core specimens shall be taken perpendicular to a horizontal surface, so that its axis is perpendicular to the bed of the concrete as originally placed.

Frequency of drill cores could be one core each from bed and side lining per 2000 square meter of insitu lining. The cores should be inspected for

a) Segregation b) Honey-combing and c) Thickness of lining.

The cores should be tested for

a) Density b) Compressive strength and c) Water absorption.

Compressive Strength:

Core specimen to be tested in compression shall have ends that are essentially smooth. Perpendicular to the axis and of the same diameter, as the body of the specimen.

Moisture Conditioning:

Test specimens shall be completely submerged in water at room temperature for 40 to 48 hours immediately prior to the compression test. Specimens shall be tested promptly after removal from water storage. The testing shall be done in accordance with the guide lines laid down in I.S.: 516-1959 complete data and test results of cores should be meticulously recorded as per format enclosed (Annexure - IX).

Concrete in the member represented by a core test shall be considered accepted if the average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the grade of concrete specified for the corresponding age and no individual core has strength less than 75 percent.

MASONRY WORKS (I.S. CODES 1597, 1812, 1200 383, 269, 2116)

	DO'S		DO NOTS
1.	The stone shall be of uniform colour, texture, strong, hard durable.	1.	Do not use soft stones of crushing strength less than the specified strength.
2.	Dress C.R.S. stone to a depth of 75 mm on all four sides.	2.	Do not allow projections more than 40 mm on the face.
3.	Wet the stones before placing in position clean and cover with fresh mortar.	3.	Do not allow stones of length more than 3 times the height.
4.	Place stones in layers to the line and plumb.	4.	Do not allow stone of breadth less than height of ¾ of thickness of wall.
5.	Provide weep holes at 2 mtrs interval staggered as per drawing.	5.	Do not allow breaking of vertical joints less than 75 mm.
6.	Chisel dress the corner stones.	6.	Header shall not project not less than 10 cm beyond stretcher.
7.	Face stones shall be laid alternately in headers and stretchers.	7.	Do not place stones in position without cleaning and wetting.
8.	Provide bond stones at 2 mtrs. Interval in each layer and mark.	8.	Do not allow skin stones, weathered stones.
9.	Place the heating stones on its broadest face.	9.	Do not place stone in position without wetting.
10.	Ensure perfect heating to make the masonry water tight.	10.	Smaller stones shall not be placed in lower crores.
11.	Mortar shall be used within 30 min. after discharge from mixer.	11.	Joints thickness should not be more than 12 mm.
12.	Sieve analysis for sand shall be done periodically.	12.	Do not allow mixing less than 3 minutes for thorough mix.

13.	For flush pointing the mortar shall be finished off flush and level with edges of the stones.	13.	Do not add more water than required to have a consistency of 90 to 130 mm.
14.	Joint shall be raked out to minimum depth of 12 mm when the mortar is green.	14.	Avoid spreading of mortar over the surface of the masonry. Mortar should be spreaded over the stone just before laying the next layer.
15.	Cure the masonry with water for 14 days.	15.	No pointing to be commenced without washing and wetting the joints thoroughly.
16.	Cure the plastered surface with water for 14 days.		
17.	Cure the pointing surface with water for 7 days.		

CHAPTER – XIII

FREQUENCY OF TESTING

EMBANKMENT

Sl. No.	Test	Frequency of Test	Purpose	Test Designation
1.	Grain size analysis For classification and Alterberg limits	For every 3000 m3	To know the classifications of soil actually put in the embankment	As per IS-2720-IV-1975
2.	Field Density and Moisture content	One test for every 1500 m3 of earth work and at least one test in each layer laid on embankment.	To determine the placement density and moisture content.	IS-2720-XXVIII-1974 IS-2720-XXIX-1966 IS-2720-XXXIII-1971
3.	In-situ permeability Test	One test every 3m of embankment height or for 20,000 m3	To determine permeability characteristics of the fill material	IS-2720-XVII-1966
4.	Triaxial Shear Test	One test in every 3m of embankment or for 20,000 m3	To know the shear characteristics of fill material (in-situ)	IS-2720-XII-1975
5.	Consolidation Test	1 set of 3 samples in every 6m height of embankment or for 30,000 m3	To know the settlement rate and its magnitude	IS-2720-XV-1965

6.	Standard Proctor Test	For every 10,000 cum of compacted earth or where there is change in the borrow area or change of soil texture, limited to minimum three samples and maximum 10 samples.	To determine MDD and OMC of the soil and compare the results with Laboratory value	IS-2720-VII-1970
7.	Moisture content	One test in each sample	To know the moisture content of the sample	IS-2720-II-1975
8.	Shrinkage Factor	One test in 5 mtrs of embankment height.	To determine shrinkage limited	IS-2720-Part-VI-1972
FILTERS				
9.	Grain Size Analysis	One test for every 200m3 of filter (sand) One test for every 200 m3 of filter (Aggregate)	To find % of the D10, D15, D30, D50, D60 and D85 grain sizes of materials	IS-2385-Part -I
10.	Clay lumps and organic impurities	One test for every 200 m3 (sand) One test for every 200 m3 (Aggregate)	To find out clay lumps & Organic impurities level	IS-2386-Part II

CEMENT

Sl. No.	Test	Frequency	IS	Allowable Limited
1.	a) Chemical i) Alkalies	For each	a) 269-1989	OPC < 0.60%

	ii) Minor, major oxides by Calorimetry iii) Chloride	consignment	b) 1489-1976 c)IS-4032-1985	PPC < 0.70% PPC/OPC < 0.05%
	b) Physical i) Fineness ii) Soundness(Le Chatelier) iii) Consistency iv) Setting time (Initial & Final) v) Compressive Strength vi) Heat of Hydration vii) Drying shrinkage	For each consignment	a) 269-1989 b) 1489-1976 4031-1988	Not < 2250 cm2/gm Not > 10 mm Penetration upto 5 to 7 mm from base IT-Not < 30 min FT-Not > 600 min 3 days - 160 kg/cm2 7 days- 220 Kg/cm2 28 days-330 Kg./cm2 PPC 7 days - 65 Cal./gm OPC 28 days - 75 Cal/gm <0.15%

FINE AGGREGATE

Sl. No.	Test	Frequency	Purpose	IS	Allowable Limits
1.	i) Screen Analysis (Fineness modulus)	One test for every 150 m3 of sand used in concrete	To know grain size and the fineness modulus of sand	IS 2386 Part-I 1963	2.2 to 3.2
	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	Allowable limit of Bulkage of sand is 20%

	iii) Organic impurities	-As above-	To assess the quality of sand	IS-2386 Part II 1963	As explained in Sec. 4.2.2
	iv) Soundness	One test for every 150 cum of sand used in concrete	To assess the quality of sand	IS 2386 Part II 1963	Loss Not > 10% after 5 cycles of immersion in Na2 So4
	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 1963	Not greater than 3% for natural FA and Not grater than 5% for crushed FA.
	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	
COURSE AGGREGATE					
	i) Sieve Analysis	One test for every 150 m3 or less	To know gradation and percentage of various size	IS 2386 part I 1963	
	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 Not more than 5% by weight Not > 3%
	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 Na2 SO4

	iv) Abrasion, Impact & Crushing Value	-do-	-do-	IS 2386 part IV 1963	Wearing Surfaces: Loss Not > 30% Non Wearing Surface Not > 45%
	v) Organic Impurities (Mica content)	-do-	-do-	IS 2386 part II 1963	Less than 1%
	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' *Falling in right side of Sc/Re curve... `Deleterious'
	vii) Petrographic Examination	Twice in one working season	To know the deleterious constituents and silt in aggregate	IS 2386 part VIII 1963	Deleterious constituent plus silt shall not exceeds 5%

Sl. No.	Test	Frequency	IS	Allowable Limited
1.	GRAVEL i) Size of Gravel ii) Liquid limit iii) Plasticity Index	For each stack	IRC 19-1977	Not larger than ¾" < 20% <6%
2.	WATER PH value Organic In-organic Sulphate Chloride	Two samples for each source	3025 Part II Part XXIV Part XXXII	6 to 8 Not greater than 200mg/lit Not greater than 3000mg/lit Not greater than 500mg/lit Plain Concrete : Not greater than 2000mg/lit RCC Work : Not greater

Sl. No.	Test	Frequency	IS	Allowable Limited
	Suspended Solids		Part XVII	than 1000 mg/lit Not greater than 2000mg/lit
3.	RR STONE i) Abrasion value ii) Crushing strength iii) SP Gravity iv) Water Absorption v) Durability	For each quarry	1124-1974 1121-1974 1124-1974 1126-1974	Not to exceed 6% Granite -1000 Kg/cm2 Basalt-400 kg/cm2 2.60 Not to exceed 5%
4.	REINFORCEMENT Weight Diameter Ultimate Test Strength Yield Stress Elongation	For each consignment	1786-1985 432-1966	Dia < 8mm + 4% Dia < 8mm + 2.5% Dia < 25mm + 0.5% Refer the table below for allowable limits.

Allowable limits for Reinforcement Bars

Types of reinforcement	Characteristic strength (yield stress of 0.2% proof stress) N/mm2	Ultimate tensile stress, N/mm2	Minimum elongation on gauge length of 5.65x Sq.rt Cross - sectional area (%)
Mild steel of grades I II	 255 236 231 211	 412 373	 20-23 20-23
Medium tensile steel	353 348 323	538	17-20

Cold worked deformed bars	415	15% more than the actual 0.2% proof stress	14.5
	500	10% more than the actual 0.2% proof stress	12
Hot Rolled	412	15% higher than the yield stress	14.5
SAIL-MA of grades 300 HY 350 HY 410 HY	 300 350 410	 440-560 490-610 540-660	 20 20 19

Frequency of Testing Cement Mortar, Masonry and Concrete

Sl. No.	Test	Frequency	IS	Allowable Limited
1.	Cube Test for concrete	3 tests specimens per 50 m3 of concrete subject to a minimum of three samples per day for each grade of concrete.	456-2000	
2.	Cube test for cement mortar in masonry	3 tests per each grade of mortar per day	2250-1981 Appendix A	
3.	Permeability test on cement mortar	Once in a week	3085-1965	Not greater than 2.5x10-8 mm per sec. for rich mortar & 4.8x10-8 for lean mortar.
4.	Permeability test on masonry (applicable for	At least two holes in every block for every lift, one in upstream and	11216-1985	Not grater than 2.5 Lugeons in masonry in CM :1:3 and 5 Lugeons

	masonry dams)	one in downstream in staggered fashion.		in masonry in CM 1:4 for dams.
5.	Slump test	One test in each shift on at frequent intervals to checked workability	IS 1199	As per Mix design.

The actual frequencies shall be determined by the Engineer-in-charge to suit the nature and variability of material placed and the rate of fill placement with the objective of ensuring best quality control and quality construction.

CHAPTER – XIV

MONITORING THROUGH CONTROL CHARTS

Monitoring of quality control and assessment of the trend of quality control being exercised by the Project Management is best done through control charts. Indian Standards I.S.: 397 (Parts I to III) cover control charts for general and special application. These charts are based on compressive strengths of cement and concrete tests specimens. Control charts for cement strengths are for different test ages (i.e., 3,7 and 28 days) and both for strengths of individual test and moving average of five tests over periods of time control charts for concrete strengths are also constructed in more or less the same manner as per cement. In addition to the test data, the control charts also incorporate certain reference line constituting a frame within which the degree of control actually achieved is assessed and remedial measures initiated where called for. The reference lines are termed the "Warning" and "Action Limits". The warning and action lines provide feed-back for timely remedial measures.

The illustration of preparation of control charts of cement & concrete are appended in Annexure - X.

Preparation of quality control reports and control charts is considered to be a vital step towards the process of achieving good construction quality. The Central Charts should be used as a dynamic tool and accordingly these should be prepared as a concurrent exercise as the work proceeds. These should be constantly scanned to identify indication of any significant deviation in quality and initiate the remedial action promptly.

STANDARD DEVIATION (I.S. 10262 - 1962)

The estimated standard deviation of given grade of concrete can be calculated from the result of individual tests of concrete, using the formula:

$$S = \sqrt{\frac{\Sigma\Delta^2}{n-1}}$$

Where Δ = The deviation of the individual test strength from the average strength of `n' samples, and

n = number of samples test results.

It at least 30 test results for a particular grade of concrete at site with the same materials and equipment are not available, the standard deviation, S, for the corresponding degree of control, may be assumed from the following tabulation, given (IS: 10262 - 1982)

Degree of Control

Grade of Concrete	Assumed standard deviation, S, N/MM2 D.L.'s		
	Very good	Good	Fair
M 10	2.0	2.3	3.3
M 15	2.5	3.5	4.5
M 20	3.6	4.6	5.6
M 25	4.3	5.3	6.3
M 30	5.0	6.0	7.0
M 35	6.3	6.3	7.3
M 40	6.6	6.6	7.6

Degree of Field Control (as per I.S. 10262 - 1982)

Degree of Control	Condition of Production
Very Good	Fresh cement from single source and regular tests weight- batching of all materials; control of aggregate, grading and moisture content, control of water added; frequent supervision: regular workability and strength tests, and good field laboratory facilities.
Good	Carefully stored cement and periodic tests; weigh - batching of all materials; controlled water; graded aggregate; occasional grading and moisture tests; periodic check of workability and strength; intermittent supervision, and experienced workers.
Fair	Proper storage of cement; volume batching of all aggregates,

allowing for bulking of sand: weight-batching of cement; water content controlled by inspection of mix, and occasional supervision and tests.

Acceptance Criteria (As per IS : 456 - 2000)

Compressive Strength

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

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

b) Any individual test result complied with the appropriate limits in col 3 of Table 11.

Flexural Strength

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

a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristics strength by at least 0.3 N/mm2

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

Specified grade	Mean of the group of 4 non-overlaping consecutive test results in N/mm2	Individual test results in N/mm2
M15	> fck + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm2) or > fck + 3 N/mm2 whichever is greater	> fck - 3 N/mm2
M20 or above	> fck + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm2) or > fck + 4 N/mm2 whichever is greater	> fck - 4 N/mm2

NOTE- In the absence of established value of standard deviation; the values given in Table may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.

INSPECTION AND TESTING OF STRUCTURES

Inspection - 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.

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 and/or and load test may be carried out.

Core Test

The point 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.

Core shall be prepared and tested described in IS: 516 - 1959 :

Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal 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.

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

Ex. In a concrete work, M15(Fck =15 N/MM2) is to be used. The assumed standard deviation for this grade of concrete from table is 3.5 N/MM2. In the course of testing cubes, the following results are obtained from a week's production (average strength of 3 specimens) tested at 28 days in N/MM2.

22.6, 21.7, 20.7, 20.6, 19.7, 13.2, 11.8, N/MM2

Discuss the acceptance of the results

Sol:

a) First five results are accepted as being greater than the characteristic strength.

b) Sixth and Seventh samples are less than characteristics strength, these can be acceptable if their values are not less than the greater of:

i) Fck-1.35 s = 15-1.35x3.5 = 10.275 N/MM2

ii) 0.8xFck = 0.8x15 = 12 N/MM2

The average strength = $\frac{22.6+21.7+20.7+20.6+19.7+13.2+118}{7}$ =18.61

The average strength should not be less than

$$Fck + \left| 1.65 - \frac{1.65}{\sqrt{n}} \right| XS$$

$$\left| 1.65 - \frac{1.65}{\sqrt{n}} \right| X3.5 = 18.59 \text{ N/MM}^2 \text{ ..O.K.}$$

The Sixth sample is acceptable, the seventh sample is not acceptable according to code but the decision may be left to the engineer-in-charge.

CHAPTER XV

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:
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 I.S. 6066-1984

9. Test reports on concrete like slump, compressive strength etc.

10. Control charts for cement and 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.

under Minor Irrigation, 203.00 Crores under Costal protection, Flood/River protection, Inland Navigation, 5.00 Crores for Kallada Irrigation Project, 1.00 Crore for Pumba Irrigation Project, 45 lakhs for Kanjirapuzha Project, 90 Lakhs for Kuttiadi Irrigation Project, 72 lakhs for Periyar Valley Project, 5.00 Crores for Idamalayar Project, 7.80 Crores for Karappuzha Irrigatio Project, 8.00 Crores for Banasura Sagar Project, 38.30 Crores for MVIP, 50.00 Lakhs for Kuriarkutty Karappara Project, 1.20 Crores for Attapady Valley Irrigation Project, 5.50 Crores for Regulator cum Bridge at Trthala, 1.00 Crore for Chamravattom Irrigation project