GOVERNMENT OF ANDHRA PRADESH
IRIGATION & C.A.D. DEPARTMENT

Andhra Pradesh Water Sector Improvement Project (APWSIP)

QUALITY CONTROL MANUAL

Chief Engineer, Nagarjunasagar Project

October – 2007.

FORWORD

This Manual on Quality Control shall provide adequate exposure on Quality Control and Quality Assurance aspects to both the construction supervision and quality control engineers engaged on the execution of the Andhra Pradesh Water Sector Improvement Project (APWSIP) relating to the rehabilitation and modernization of the gigantic Nagarjunasagar multipurpose Project.

The project envisages optimum rehabilitation of the Irrigation System by addressing the existing deficiencies through meticulous implementation of rehabilitation works in accordance with relevant design standards and technical specifications duly conforming to sound construction procedures. Besides the rehabilitation and modernization of the vast network of canal and distribution system, the project also envisages execution of dam safety works on the Nagarjunasagar Dam.

The project of such a magnitude involves a very wide range of construction activities, techniques, and construction materials. This Manual provides comprehensive guidelines on the needed quality control & quality assurance aspects on the various inputs / outputs, as specified in the contract documents and relevant Indian Standards, to ensure that the works are executed to acceptable quality control standards.

Chief Engineer,
Nagarjunasagar Project.

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LIST OF INDIAN STANDARDS

S. No	Short Title	Ref. to various Standards
1	Preparation of dry sample (soil)	IS:2720 (Part .I) 1983
2	Determination of water content (moisture content)	IS:2720 (Part .III) 1980 Sect/1
3	Determination of specific gravity of fine grained soil	IS: 2720 (Part. III) 1980 Sect/2
4	Determination of specific gravity of fine, medium & coarse grained soil.	IS: 2720 (Part. III) 1980 Sect/2
5	Grain size analysis	IS:2720 (Part.4) 1985
6	Determination of Liquid and plastic limit	IS:2720 (Part.5) 1985
7	Determination of shrinkage factors	IS: 2720 (Part. VI) 19872
8	Determination of water content - dry density relation using light compaction.	IS: 2720 (Part. VII) 1980
9	Determination of water content - dry density relation using heavy compaction.	IS:2720 (Part.8) 1983
10	Determination of water content - dry density relation using constant wt. soil method.	IS:2720 (Part IX) 1971
11	Determination of Unconfined compressive strength	IS: 2720 (Part. X) 1991
12	Determination of shear strength parameters (tri-axial) with out measurement of pore pressure parameters (Tri-axial compaction)	IS: 2720 (Part. XI) 1971
13	Determination of shear strength parameters (Tri-axial compaction)	IS: 2720 (Part. XII) 1981
14	Direct shear test	IS: 2720 (Part. XIII) 1986
15	Determination of Density Index (R.D) of cohesion less soil.	IS:2720 (Part.14) 1983
16	Determination of consolidation properties	IS:2720 (Part.15) 1986
17	Determination of permeability	IS:2720 (Part.17) 1986
18	Determination of dry density of soils, in place by the sand replacement method.	IS:2720 (Part.28) 1974
19	Determination of dry density of soils, in place by core-cutter method.	IS:2720 (Part.29) 1975
20	Laboratory vane shear test.	IS:2720 (Part.30) 1980
21	Determination of the density in place by the ring and water replacement method.	IS:2720 (Part.33) 1971
22	Determination of free swell index of soils	IS: 2720 (Part. XI) 1977
23	Measurement of swelling pressure of soils.	IS: 2720 (Part. XII) 1978
24	Classification and identification of soils for General Engineering purposes.	IS:1498 1970

MATERIALS

S. No	Short Title	IS. to various Standards
(A)	**Cement**	
1	Specification for 33 Grade ordinary portland cement	IS 268 - 1989
2	Specification for Rapid hardening portland cement	IS 8041 - 1990
3	Specification for portland Pozzolona cement	IS 1489 (part 1&2) 1991
4	Methods of physical test for hydraulic cement	IS 14032 - 1988
5	Method of chemical analysis of hydraulic cement	IS 4032 - 1985
6	Method of sampling for hydraulic cement	IS 3535 - 1986
7	standard sand testing of cement	IS 650 - 1991
8	Specification for 43 Grade OPC…	IS 8182 - 1989
9	Specification for 53 Grade OPC…	IS 12269-1987
(B)	**Coarse / Fine Aggregate**	
1	Specification for coarse & fine aggregate	IS 383-1970
2	Methods of test for aggregate for concrete particle size and shape	IS 2386 (Part I) 1963
3	Methods of test for aggregate for concrete estimation of deleterious materials and organic impurities.	IS 2386 (Part II) 1963
4	Methods of test for aggregate for specific gravity, density, voids, absorption & bulking	IS 2386 (Part III) 1963
5	Methods of test for aggregate for Mechanical properties.	IS 2386 (Part IV) 1963
6	Methods of test for aggregate Soundness	IS 2386 (Part V) 1963
7	Methods of test for aggregate measuring mortar making properties of fine aggregates.	IS 2386 (Part VI) 1963
8	Methods of test for aggregate for alkali aggregate reactivity	IS 2386 (Part VII) 1963
9	Methods of test for aggregate for petrographic examination	IS 2386 (Part VIII) 1963
(C)	**Bricks**	
1	Method of sampling of clay building bricks	IS 5454 - 1978
2	Method of test for burnt-clay building bricks.	IS 3495 (Parts I TO iv) 1976
3	Common burnt clay building bricks.	IS 1077 - 1992
(D)	**Masonry Mortar**	
1	Specification for sand for masonry mortars.	IS 2116 - 1980
2	Code of practice for preparation and use of masonry mortar	IS 2250 - 1981

S. No	Short Title	IS. to various Standards
(E)	**Cement Concrete**	
1	Specification for coarse and fine aggregate.	IS 383 - 1970
2	Specification for compressive strength, Flexural strength	IS 516 - 1959
3	Code of Practices for Plain & reinforced concrete etc.	IS 456 – 2000
4	Methods of sampling and analysis of concrete	IS 1199 – 1959
5	Recommended Guide Lines for Concrete Mix Design	IS 10262 – 1982
(F)	**Curing Compound**	
1	Standard test method for water retention & day light reflection test on concrete.	ASTM-C-156809
2	Standard method of test for effect of organic materials in fine aggregate on strength of mortar.	ASTM-C. 87-69
3	Standard specification for liquid membranes forming compounds.	ASTM C. 309-89
(G)	**PVC Water Stops**	
1	Code of practice for provision of water stops.	IS 12200 – 1987
2	Procedure for Testing	Parts of IS 8543-19
3	Standard Test methods for Tensile properties of Plastics.	ASTM : D 638-1991
4	Standard Test methods for Thermoplastic Elastomers - Tension.	ASTM D 412-1992
(H)	**HYSD BARS**	
1	Specifications for HYSD bars.	IS 1786 – 1985
2	Specification for Mild Steel and Medium Tensile steel bars.	IS 432 (P II) 1966
3	Method for Tensile testing of steel wires.	IS 5121 – 1972
4	Hard drawn steel wire for concrete reinforcement.	IS 1566 – 1982
5	Method for Tensile testing of Steel products	IS 1608 – 1972
6	Code of practice for bending & fixing of bars for concrete reinforcement	IS 2502 - 1963
(I)	**Pre cast R.C.C. Pipes**	
1	Specifications for pre cast concrete pipes.	IS 458 – 1988
2	Methods of Tests for concrete pipes.	IS 3597 - 1985

CHAPTER – 1

QUALITY ASSURANCE AND CONTROL

1. INTRODUCTION:

Execution of multipurpose river projects involves enormous expenditure. They are time bound programmes and require assistance from various technical bodies for investigation, design, planning and execution. To have a safe durable structure, it is necessary that the materials and Standard of execution fully satisfy the specifications.

It is to be recognized that while the ultimate efficiency of the performance of a project will depend upon proper layout and designs, the ultimate health of the project during life scale of its operational phase will depend largely on the quality achieved during its construction.

This can be realized through stringent quality control measures jointly by the team members comprising of G.O.A.P., Contractor, Project Construction Team, Project Q.C /Q.A Team and Project Design Team. The pursuit of quality shall be the cement holding these members together in a stable pattern where each supports the other in producing a successful project executed to acceptable quality control standards.

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 adequacy and uniformity of quality through the following operations.

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

2. 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.

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

    i. G.O.A.P.
    ii. Contractor
    iii. Project Construction Team
    iv. Project QC / QA Team and
    v. Project Design Team

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

5. 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.

6. Indicating expeditiously the possible remedial measures, if specifications are not likely to be met.

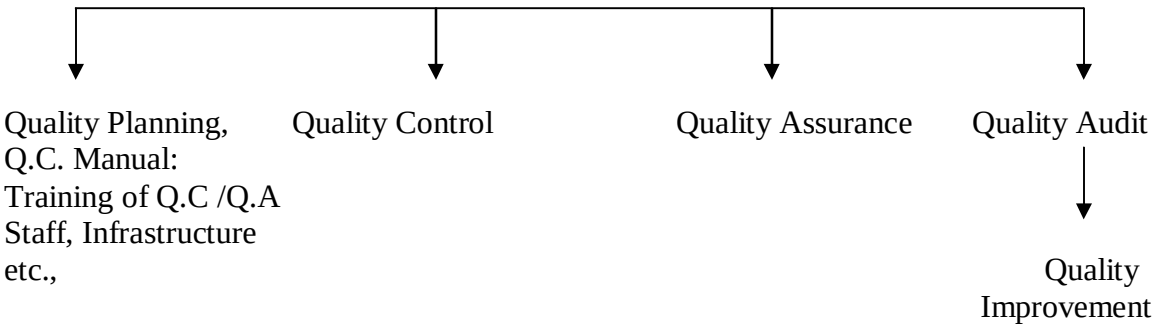
7. Rejecting, where warranted, the material or the product at any intermediate or final stage in case acceptance criteria is not satisfied.

3. QUALITY CONTROL MANUAL:

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

4. Configuration of Quality Management System

QUALITY MANAGEMENT SYSTEM



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.

5.3 QUALITY MANAGEMENT:

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

THE QUALITY CONTROL MANUAL being adopted for APWSIP (the salient requirements of which are being outlined in the various Chapters) aims at a "Systems Approach" to ensure that upon implementation, the quality levels as set and defined in the specifications and contract documents and relevant Indian Standards would be met in the execution of project works.

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CHAPTER – II

ORGANISATIONAL SETUP

GENERAL:

Any one connected with quality control work, should possess adequate knowledge and experience of quality control works and be conversant with general 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 and not to hinder the progress.

Quality Control Organization

Presently, one QC Division with 5 Sub-Divisions is working under the construction Circle, Nuzvid under Chief Engineer, Nagarjunasagar Project. Else where, there are 2 QC Sub-Divisions under Lingamguntla Circle and one QC Division with 3 Sub-Divisions at Vinukonda under Ongole Circle under Chief Engineer, Nagarjunasagar Project. The existing set-up envisages quality control -related inspection of works costing upto Rs.1.0 million. There is a separate QC Circle under Chief Engineer, Central Designs Organization for State-wide quality inspection of works costing more than Rs.1.0 million. Testing of inputs/outputs is being got done through APERL, Hyderabad and near-by Engineering Colleges etc. The QC Laboratory located at Lingamguntla (near Guntur), is reported to be non-functional due to very poor condition of Laboratory equipment.

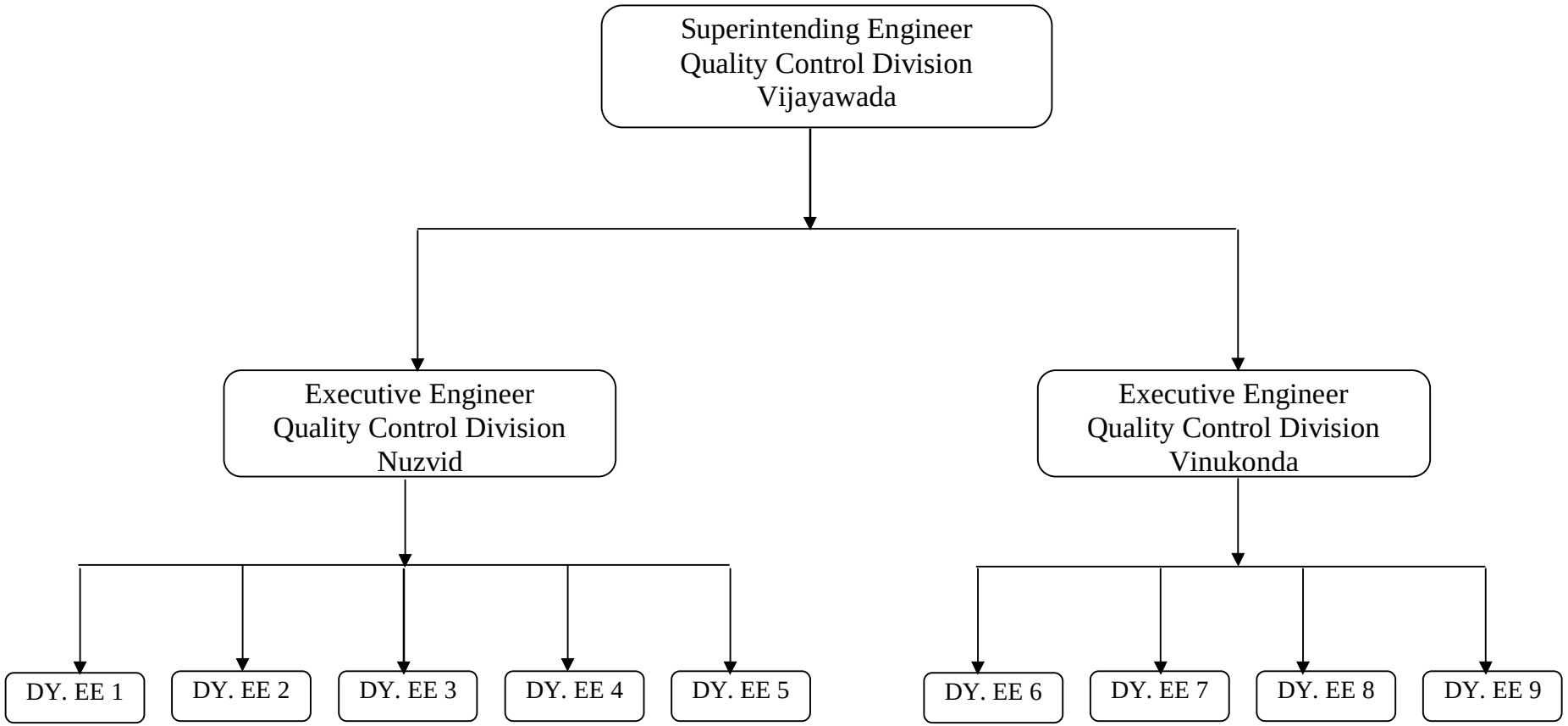
a) It is proposed to set up one Quality Control circle at Vijayawada headed by a Superintending Engineer, 2 QC Divisions along with 9 Sub Divisions to look after the Quality Control aspects during the execution of rehabilitation works. organization chart is enclosed

b) The existing QC laboratory at Lingamguntla would be properly equipped and towards this end, the old and non functional lab equipment be replaced with new equipment. Also, one new QC laboratory would be established at Mylavaram.

c) In addition 4 “Mobile Quality Control testing Laboratories” would be deployed during peak construction period for proper quality control and for complying with the Indian Standard frequency of testing.

Attachment - I

Quality Control Organisation Chart



CHAPTER – III

GENERAL FUNCTIONS OF LABORATORIES

The Laboratory system in addition to evaluate and monitor the inputs and outputs would also evaluate and monitor the workmanship as well as construction plant, machinery and equipment. This would, thus, be accompanied by testing as well as inspection.

FUNCTIONS OF CENTRAL LABORATORY SYSTEM

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.

III For masonry and concrete, the strength of mortar and concrete has to be as specified in agreement. Laboratory has to design the proportions of different ingredients through tests for the specified strength. The proportioning shall be done by weight.

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 to the field and also it entails adding or reducing cement content based on the strength of the cement.

VII The strength of concrete is specified for 28 days. It will be difficult to wait for 28 days to get the strength of concrete and assess its quality. Hence accelerated curing test be undertaken as per the relevant I.S. using boiling water method. From this method, a relationship between strength attained with accelerated curing versus normal curing at 28 days may be arrived at.

VIII Results of tests performed in the central laboratory should be reported in the prescribed proforma pertaining to the following tests.

A. 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.
Shear test (remoulded at OMC, MDD Drained/undrained) 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 NMC or saturation.
Swell pressure

B. SAND

Grading I.S. 2386 (Part 1) 1963. F.M. Bulkage I.S. 2386 (Part IV) Organic and silt content. Deleterious material and mica content.

C. CNS:

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

D. CEMENT:

Consistency, Specific gravity, Compressive strength, setting time, soundness by Le Chillier test.

E. COARSE AGGREGATE:

Grading I. S. 2386 (Part 1) 1963.
Soundness. Crushing value. Impact test.
Abrasion. Absorption. I.S. 2386 (III) 1963. Specific gravity I.S. 2386 (Part III) 1963 lakiness.

F. BOULDERS:

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

G. FILTER MATERIALS:

Grading, uniformity Co-efficient, weathering conditions (visual) and test for fine and coarse aggregate.

H. WATER:

pH value, silt content, soluble salts.

I. HARDENED CONCRETE AND MORTARS:

Proportions by chemical analysis and compressive strength.

J. BRICKS:

Dimensions and physical properties including compressive strength.

K. TESTS FOR FOUNDATION INVESTIGATION AND INSITU PERMEABILITY:

Other properties, if tested shall be reported in the remarks column or foot note.

L. IMPROVED DEVICES FOR QUALITY CONTROL:

It is planned to introduce improved devices for achieving speedy and efficient quality control.
The canal rehabilitation works involve huge compaction of earth fill placement, and it is planned to introduce "portable electronic density testers" for rapid on – site determination of compaction parameters like, moisture content, wet density, dry density, and percentage of compaction in forms of Proctor density.
On embankment construction, it is planned to produce an engineering device of the type "Nuclear Gauge" to enable much more rapid and economic compaction and quality control on the construction of dams in the Owk complex 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.

Scope and inspection activities are illustrated in ANNEXURE - II

FUNCTIONS OF FIELD LABORATORY SYSTEM:

I To carry out routine daily tests of soils and filter material, such as sieve analysis moisture content, needle density tests, compaction efficiency, field density test etc., and to take samples from compacted fill from different zones of the embankment.

II To carry out routine daily test, like silt test of fine aggregates, F.M. sieve analysis, bulkage of fine aggregates. Absorption, specific gravity and grade analysis, surface moisture content tests on coarse aggregates. Slumps test of concrete and mortar and collect samples of concrete and mortar in moulds as per approved frequency.

III To report results of tests performed in the field laboratories in the prescribed proformae pertaining to the following tests.

A. SOILS:

1. Moisture content.
2. Density and compaction efficiency.
3. Needle penetration.
4. Proctors compaction.
5. Sleeve analysis.

B. CNS:

1. Gradation analysis.
2. Shear Parameters.
3. Index properties.

C. SAND:

1. Presence of deleterious materials.
2. Grade Analysis and Fineness Modi
3. Bulkage.

D. COARSE AGGREGATES:

1. Grading.

E. FRESH CONCRETE AND MORTAR:

1. Water cement ratio.
2. Workability by slump test/flow table test.

F. BOULDER SAMPLE:

1. Absorption
2. Dimensions
3. Visual observation as regards weathering etc.

G. CEMENT:

1. Setting time by vacate needle test.

H. BRICKS:

All tests for physical properties except strength which will be conducted at central laboratory .

All other tests will be conducted in central Laboratory for which samples shall be sent by the field laboratory to central laboratory.

The field laboratories will report the testing data in the prescribed forms meant for soil, concrete masonry, filler and boulder pitching work, lining etc.

FUNCTIONS OF MOBILE LABORATORY (FIELD TESTS)

i. To carry out daily routine tests on compaction efficiency. Field density and field moisture content determination test.

ii. To carryout daily routine tests like silt content, fineness modulus and gradation of line Aggregates and coarse aggregates.

iii. To carry out slump test, unit weight and Temperatures of concrete by using fresh concrete insitu testing equipment, and to take fresh concrete as per the required frequency.

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CHAPTER – IV

DUTIES OF DEPUTY EXECUTIVE ENGINEER INCHARGE OF LABORATORY

i. To ensure proper up-keep and maintenance of laboratory equipment in laboratory.
ii. To ensure proper up-keep of records of all samples being tested in the laboratory as per prescribed forms and communication to the concerned.
iii. To supervise the testing works of Assistant Engineer / Assistant Executive Engineers, laboratory Assistants and personally to check the tests to the extent of 25 %.
iv. To prepare fortnightly review of all the tests results and submit to the Executive Engineer, Quality Control.
v. To conduct any research work as may be assigned by the Executive Engineer.
vi. Steel rods as proposed to be used shall be tested for ultimate tensile strength elongation and bond etc., as per standards.
vii. Samples of welded rods, welded at site shall be collected and tested to the quality of welding.
viii. The Central laboratory has to conduct the test on the suitability of materials proposed from various quarries of work, well in advanced of the actual execution of work, for which the construction staff shall send material to the lab well in advance.

DUTIES OF ASSISTANT ENGINEERS / ASSISTANT EXECUTIVE ENGINEER (LABORATORY)

Shall perform important tests as mentioned below:

A. CEMENT:

1. Fineness by Blains.
2. Normal Consistency.
3. Setting time.
4. Soundness.
5. Specific gravity.
6. Compressive strength.
7. Adulteration test.

B. SAND:

1. Sieve Analysis & Fineness modulus.
2. Test for organic impurities, silt & clay.
3. Decantation test for silt.
4. Specific gravity.
5. Unit weight and bulkage factor.

C. COARSE AGGREGATE:

1. Sieve Analysis and gradation.

2. Specific gravity.
3. Water absorption.
4. Examination of deleterious materials.
5. Crushing strength.
6. Impact.
7. Abrasion.
8. Flakiness index.
9. Alkali Silicate reactivity.

D. CONCRETE:

1. Consistency – slump or compaction factor.
2. Compressive strength.
3. Air content.
4. Yield per unit quantity of cement.
5. Mix design test.
6. Cement content.

E. MORTAR:

1. Consistency.
2. Compressive Strength.
3. Yield per unit quantity of cement.
4. Cement Content.

F. SOILS:

1. Gradation (Grain size analysis).
2 Consistency limits.
3. Porosity & Void ratio.
4. Specific gravity.
5. Swell pressure.

DUTIES OF LABORATORY TECHNICIANS / WORK INSPECTORS

i) To assist Assistant Engineers / Assistant 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.

DUTIES OF LABORATORY ATTENDANTS

a) To keep instruments clean.
b) To assist Assistant Engineers / Assistant Executive Engineers and Laboratory Technicians in conducting tests.
c) To prepare samples for test.
d) To arrange samples systematically.

Control of Inspection, Testing, and Measuring Equipment:

The identification 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 recognized standards. The equipment will be capable of controlling the delivery of material for weighing so that inaccuracies 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 2 weeks in case of equipment for measuring water, cement and admixtures and at least once in every month in case of equipment measuring 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.

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CHAPTER – V

DUTIES OF FIELD STAFF IN RELATION TO QUALITY OF WORKS

ASSISTANT EXECUTIVE ENGINEER / ASSISTANT ENGINEER CONSTRUCTION		ASSISTANT EXECUTIVE ENGINEER / ASSISTANT ENGINEER QUALITY CONTROL
Shall see that the mark out of the area to be tackled is properly given, shuttering, centering, reinforcement are done as per drawings 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 and got verified by Quality Control Assistant Engineers / Assistant Executive Engineer.	1	Shall check the mark out foundation/pre levels and centering/shuttering reinforcement arrangements and inform the Assistant Executive Engineer/Assistant Engineer construction to rectify the defects if any. Shall certify the mark out of canal excavation as per drawings. Pre levels, classification levels and final levels of canal shall be checked.
Shall see that the construction equipment like mixers, vibrators, rollers, 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.
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 on input materials or for sending samples of input materials to central lab.	3	Shall conduct the field tests on input materials and record the results and to inform the Assistant Executive Engineer/Assistant Engineer construction to rectify the defects if any. To send the samples of input materials to central lab as and when required. To conduct core tests and other field test as per I.S.I. incase of Embankment works.
Shall write O.K. Cards after area is ready to start the work and to inform the Assistant Executive Engineer / Assistant Executive Engineer Quality Control and Deputy Executive Engineer construction and take permission to start the work O.K. Card.	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 he Deputy Executive Engineer / Executive Engineer quality control and to permit to start the work.
Shall supervise and ensure that correct quantities of input materials as per mix design communicated by the central laboratory are fed into the mixers/batching plants etc., and shall ensure adequate mixing time.	5	Shall make constant 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.

Shall ensure proper vibration, rolling etc., during course of day to day work and to provide men and material required for quality control staff.	6	Shall conduct slump test, record temperature of concrete, bore tests, proctor of concrete, proctor density etc., and to extract field samples of finished product to be sent to central laboratory later.
Shall ensure proper curing of samples extracted till the curing time is over and to make arrangements to send the samples to central lab.	7	Shall assist the Assistant Engineer / Assistant Executive Engineer Construction in Proper handling / transport of samples to central lab.
Shall ensure timely green cutting of concrete with proper air: water gun: nicking & chipping (wherever so warranted) so as to prepare the surface for concrete lift for effective bond at the lift / construction joints.	8	Shall check and see that the preparation of the surface is adequately done for starting the next lift.
Shall ensure proper curing/watering and allow removal of centering only after the time limit prescribed in the specifications and to see that the surfaces 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.
Shall maintain (1) mark-out register (2) OK Card files (3) Load Register.	10	Shall maintain registers of field test conducted.

The AEE.s / A.E.s working at Owk tunnel both in construction and Q.C. shall pay special attention on

Marking / checking the centre line after every head blasting & mucking.

Monitoring oxygen and carbon Monoxide levels in the tunnel as well as visibility.

Checking the alignment of concrete placement Gantry.

Monitoring Safety measures.

DEPUTY EXECUTIVE ENGINEER (CONSTRUCTION)		**DEPUTY EXECUTIVE ENGINEER (QUALITY CONTROL)**
Shall exercise proper check over all the activities of Assistant Engineer/Assistant Executive Engineer, Construction.	1	Shall exercise proper check over all the activities of Assistant Engineer/Assistant Executive Engineer / Quality Control.
Shall verify the foundation / pre-levels check the mark-out, reinforcement / centering etc., invariably for all works.	2	He shall invariably check foundation of all components of works. Final OK is to be recorded before the work is started. Where heavy reinforcement is involved the same also should be checked invariably and final OK is to be recorded.
Shall check feeding of input materials, mixing, placing, vibration rolling etc.	3	Shall check at random feeding of input materials, mixing, placing, vibration rolling etc.
To ensure that the cement used at site of work is tested in the central laboratory.	4	Shall check the test reports of cement, date of manufacture etc., and satisfy before starting of the work.

Shall write the OK cards after satisfying about the arrangements made for starting of the work and report to the Executive Engineer / Construction, Executive Engineer / quality control accordingly.		5	Shall write O.K. cards as and when required and inform the Executive Engineer / Quality Control accordingly.
Shall see that samples of finished products are transported to the central laboratory.		6	Shall conduct the field tests like slump, temperature of concrete at random.
Shall personally supervise the rectifications pointed out by Executive Engineer Construction / Executive Engineer Quality Control.		7	Shall intimate the defects if any to the Executive Engineer Construction and Executive Engineer Quality Control. Check and verify whether rectifications are done as per the norms laid down in the contract specifications.
Should arrange to get the foundations of soil tested incase of weak soil over which heavy Embankments are proposed.		8	Shall assist the Deputy Executive Engineer Construction in conducting these tests.
He should send disturbed soil samples in various reaches well in advance to central laboratory and get the soil tested for various properties and obtain OMC and MDD values.		9	Shall assist the Deputy Executive Engineer Construction in sending the samples to central laboratory.
Shall order temporary suspension of work if any serious defects are noticed and shall intimate immediately to Executive Engineer Construction and Executive Engineer Quality Control.		10	Shall order temporary suspension of work if any serious, defects are noticed and shall intimate immediately to Executive Engineer Construction and Executive Engineer Quality Control.

DUTIES OF EXECUTIVE ENGINEER

	EXECUTIVE ENGINEER CONSTRUCTION		EXECUTIVE ENGINEER QUALITY CONTROL
1	Shall supervise, check, advise, and instruct the A.E./A.E.E./D.E.E. Construction regarding discharge of their functions properly.	1	Shall supervise, check, advise and instruct the A.E./A.E.E./D.E.E. Quality control regarding discharge of their functions properly.
2	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 program etc., to Executive Engineer Quality Control, and Superintending Engineer Designs and Inspection Circle.	2	Shall maintain copies of approved Designs, reports, contract document, drawings, construction program, extracts of inspection notes etc., and shall see that his subordinates go through the above documents.
3	Shall see that all ingredients of concrete, masonry are got tested before use. Shall see that the soils are tested for various properties like OMC, MDD, etc., before starting of Embankment work.	3	Shall remind, ensure and verify whether test results are available or not before starting up of any new work.

4	Shall see that all the Machinery / equipment being used by the contractor is got periodically calibrated.	4	Shall assist in upkeep and calibration of equipment.
5	Shall see that OK Cards are written and kept at site of work before starting of any work.	5	Shall inspect and sign on O.K. Cards during field visits.
6	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	6	Shall order the suspension of work if any defects are noticed or reported by quality control staff and intimate his counter part to see that defects are rectified. If not rectified the matter is to be reported to the Superintending Engineer Quality Control.
7	Foundations and reinforcement, shuttering, centering where heavy reinforcement is involved is to be checked by Executive Engineer invariably before starting the work.	7	Foundations and reinforcement, shuttering, centering where heavy reinforcement is involved is to be checked by Executive Engineer invariably before starting the work.
8	Shall jointly inspect the site with quality control Executive Engineer in case variation in classification is less than 10% (+/-) and finalize the classification.	8	Shall jointly inspect the site with Construction Executive Engineer in case variation in classification is less than 10% (+/-) and finalize the classification.
9	Shall personally see that the samples to the laboratories like A.P.E.R.L. / N.C.C.B. are sent regularly, obtain the results and communicate the same to Executive Engineer quality control.	9	Shall peruse and keep track of sending of samples to A.P.E.R.L. / N.C.C.B. and to keep record of results received.
10	Shall take the help of quality control Executive Engineer whenever a dispute is referred to Technical Expert.	10	Shall co-ordinate with the Executive Engineer/Construction division render assistance in resolving the issues referred to technical expert.

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CHAPTER – VI

CO-ORDINATIONS

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

Construction staff should make it a point to inform the quality control staff, the date of starting of any 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 that particular date.

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

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

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 shall to draw the attention of the construction staff, whenever they notice defective work during their course of inspection. It is the 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 organization.

The Assistant Engineer / Assistant Executive Engineer (Quality Control) can address Assistant Engineer / Assistant Executive Engineer or Deputy Executive Engineer construction regarding defects, rectification testing etc.

As far as possible the defects are to be rectified in the presence of the Quality Control staff and the payment shall be effected only after the Quality Control Staff are fully satisfied with the rectification and quality of work. Any rectification done subsequently without any intimation and presence of Quality Control staff shall be at the sole responsibility of the construction staff.

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.

The Operations of the Quality Control Staff shall not interfere in any way, with the executive powers vested with the officers in charge of execution. They will also in no

way diminish the responsibility of the officers in charge of execution. The field officers in charge of works are primarily responsible for the quality of all works and to carry out the work as per the technical specifications.

In case of difference of opinion between quality control staff and construction staff, 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.

Where the objection raised by the Assistant Engineer / Assistant Executive Engineers of quality control is not acceptable to his counter part by the construction unit, the Deputy Executive Engineer of construction shall discuss with his counter part of quality control to settle the objection. If they fail to arrive at a solution, the matter may be reported to the 'Executive Engineer/Construction who would discuss the issue with the Executive Engineer, Quality Control. In case Executive Engineer, Quality Control is not readily available at site, the Executive Engineer, Construction may take suitable decision and intimate the Executive Engineer, Quality Control and Superintending Engineer, Construction of the decision taken with reasons.

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.

In case there is a difference of opinion between Superintending Engineer, Construction and Quality control the matter would be referred to Chief Engineer 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. Disciplinary action shall be taken against the construction staff concerned who fragmentally violate this rule and appropriate measures taken against the contractor to rectify unacceptable work at contractor's cost.

The construction and quality control staff shall keep a regular liaison with the Geologist in respect of all Geotechnical problems and enlist his input on foundations of structures & dams, Cut off Trenches, tunneling; contact/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.

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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 out put product will satisfy given requirements of quality and all the components of works perform satisfactorily during life period of service, adequate quality checks as analyzed during construction is a record which speaks 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 a 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. Control charts are one such presentation. Visual displays on these charts greatly enhance the communication of information. Accordingly, Control charts for all critical tests including the following should be prepared and presented to the quality Audit Team:

- Test strength of cement.
- Test strength of concrete.
- Slump Test.
- Concrete Temperature.
- Air Content.
- Aggregate gradation.
- Field moisture and density test results.

Quality Audit: The Scope of Quality Audit is limited to post construction and verification in the following manner.

1. Evaluation.
2. Compliance.

1. Evaluation:

It shall broadly cover the following aspects.

i) Evaluation of testing inspection efficiency from the standpoint of such matter as:

a. Effectiveness of procedures.
b. Operational efficiency of plant and equipment.
c. Adequacy of personnel.
d. Program records.

ii) Evaluation of internal control from the stand point of Quality Control / Quality Audit System provides for.

a. Information that is Adequate Accurate.
b. Effectiveness of Communication and feed back of quality control decisions to the operational level.
c. Control over all phases of operation.

iii) Evaluation of overall performance of various project laboratories from the Standpoint of:

a. Procedures being followed.
b. Performance of individual laboratories.
c. Inter laboratory testing.

2. Compliance:

Procedures and controls are of no significance unless those are meticulously followed in practice. Quality Audit shall endeavor to ascertain whether or not the planned program is actually being carried out in practice. The technique of ascertaining this shall be through.

a. Inspection and visual observation of work to Audit the quality of output.
b. Examination of O.K. Cards.
c. Examination of test records and reports of various inputs.
d. Perusal of control charts for cement and concrete.

The quality Audit shall also make a broad review of the activities of each laboratory and the associated quality control group in order to determine whether the functions and responsibilities assigned to them are being performed in a satisfactory manner to determine.

a. Whether the testing and inspection personnel have adequate understanding of testing procedure.

b. Whether the testing and inspection carried out are adequate.

c. Whether adequate corrective actions are being taken to prevent the use of defective materials or workmanship.

d. Whether the records and repots of testing and inspection maintained are adequate and complete.

e. Whether these records are checked by the senior officers at regular intervals.

List of Documents:

Each laboratory should hold the following documents:

- Quality control manual.
- Technical Records: Specification, Contract documents, inspection and Test Procedures, relevant standards/codes of practice.
- Mill Certificates.
- Corrective action records.
- Material test reports, test reports of cores.
- Inspection Reports.
- Photographic/Video film records of construction which may not remain accessible after commissioning of the project.
- Non-conformance reports.
- Statistical evaluation reports.
- Technical Literature.
- Standardization of records.

Quality Control Personnel should Document:

- Data of test.
- Area where material is used.
- Test method with reference to Standards.
- Testing results, including those of cores of concrete.
- Acceptance criteria.
- Statement of compliance / non-compliance.
- Remarks.
- Test personnel signature.

Presentation to **QUALITY AUDIT** Team.

To have uniformity in presentation, it will be good to standardize:

- Forms for testing of material.
- Inspection “Check items”
- O.K. Cards.

Focus of Internal Quality Audit and Report:-

Broadly the Internal Quality Audit Group (constituted by GOAP) shall focus on the following to afford a reasonable basis for an opinion on the adequacy of Q.C./Q.A. system and the acceptance of Quality in construction:

- Visual inspection of works completed and / or under progress:
- Perusal of Quality Control & Quality Assurance (Q.C./Q.A.) documentation; and all test records including O.K. Cards and Control Charts;
- Inspection of Testing laboratories (level II Labs, Field Labs Level III), adequacy of testing facilities, and reliability there-of and general competence of laboratory staff;
- Contractor's workforce and construction equipment deployed at works and assessing the adequacy there-of in respect of quality-related aspects;
- Whether any corrective actions are being implemented in the shortest possible time period.

The internal Quality Audit shall be planned on a regular annual basis, It would culminate in a comprehensive Report for G.O.A.P. which shall bear the data of audit and the signature of audit group. The Report should contain an abstract of findings, observations, including opinions and recommendations. It should be duly substantiated by the supporting documents and explanations.

TEST OF DRILL CORES:

A good canal lining should be strong, durable and of optimum water tightness. A well graded concrete mix, composed of sound aggregates with a close control on its workability as well as placement on a dense sub-grade, followed by good finishing and adequate curing shall ensure a sound lining capable of a long service life.

As the lining work progress, testing of the output should be taken up on a regular basis accordingly, to evaluate the quality of concrete lining completed and cured (for 28 days) in respective reaches, cores should be taken of lining concrete. Frequency of drill cores could be say one core each from bed, side lining per 2.000 square meter of insitu-lining. The frequency shall be decided by the engineer in consultation with the project Chief Engineer.

The cores should be inspected for

Segregation
Honey combing and
Thickness of lining

The cores should be tested for

Density (gm/cc)
Compressive strength and Water absorption.

A standard test cylinder has a diameter one-half of its height viz., the (L) Length/ Diameter (D) ratio is 2. However, the cores taken from in-situ-lining shall not have these relative dimensions and consequently L/D ratio will not be 2. Accordingly, the test strengths of these cores should need to be corrected. The curve in Attachment be used to correct the indicated strengths so that they will be comparable with those obtained from standard specimens. The equivalent cube strength of the concrete shall be determined buy multiplying the corrected cylinder strength by 5/4. The correction factor can also be determined from the curve on page 13 of I.S.: 516 – 1959. (curve enclosed as **Annexure-III).** The cores should be properly stacked in sheds.

Complete data and test results of cores should be meticulously recorded. It should include.

- Location of test core (chainage: bed and side slope lining panel).
- Grade of concrete mix, maximum size aggregate of in-situ lining, slump, W/C ratio.
- Density of standard specimen, prepared and cured in laboratory.
- Density of test core (gm/cc).
- Thickness of lining exhibited by the test core.
- Compressive strength of test core.
- Connected compressive strength (as per curve of Attachment A) in kg/cm
- Water absorption in percentage.
- Remarks-visual observations on any honey combing/segregation viz. lack of consolidation be recorded.

Separate quality audit team shall review the results of tests performed on materials by the Quality control staff and for some tests got conducted through APERL, Hyderabad / NCB / CSMRS laboratories, New Delhi. In addition, the Audit shall also review.

Data on aggregate grading (daily, month wise) preferably computer printouts.

Grading curves for aggregates, preferably computer printouts, slump data of various grade of concrete mixes at the batching and mixing plants and corresponding placement sites (daily data, month-wise) preferably computer print outs.

Data on quality characteristics of cement being procured from various cement plants.

Test report of water samples.

The above review will facilitate the Quality Audit Team in making correct assessment of the quality of inputs.

Acceptance Criteria:-

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

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CHAPTER – VIII

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 1 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 work 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 IV.

Preparation of quality Control Reports and Control Charts is considered to be a vital step towards the process of achieving good construction quality. The Control 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 – 1982)

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

$$S = \text{sqrt}\left(\sum \Delta^2/(n-1)\right)$$

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

n = number of sample test results.

If 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/mm^2 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	5.6	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; weight – batching of all materials, controlled water; graded aggregate; occasional grading and moisture tests; periodic check of workability and strength; intermittent supervision, and experience workers.
Fair	Proper storage of cement, volume batching of all aggregate, allowing for bulking of sand, weigh-batching of cement, water content controlled by inspection of mix, and occasional supervision and tests.

Acceptance Criteria for Concrete: As per IS: 10262 – 1982

The concrete shall be deemed to comply with strength requirement if:

a) Every sample has a test strength not less than the characteristic value, or

b) The strength of one or more samples though less than the characteristic value, is in each case not less than the greater of:

1. The characteristic strength minus 1.35 times the standard deviation; and

2. 0.80 times the characteristic strength:
   and the average strength of all the samples is not less than the characteristic strength plus.

$$\left| 1.65 - \frac{1.65}{\sqrt{\text{Number of samples}}} \right|$$ times the standard deviation.

The concrete shall be deemed not to comply with the strength requirements if:

a) The strength of any samples is less than the greater of:

1. The characteristic strength minus 1.35 times the standard deviation : and
2. 0.80 times the characteristic strength : or

b) The average strength of all the samples is less than the characteristic strength plus

$$\left| 1.65 - \frac{3}{\sqrt{\text{Number of samples}}} \right|$$ times the standard deviation.

Note: As per latest Indian Standard I.S. 456 = 2000, the Acceptance criteria is given below:

ACCEPTANCE CRITERIA:

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 compiles with the appropriate limits in col2 of Table 11.

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

Table 11 Characteristic Compressive Strength Compliance Requirement

Specified Grade Test	Mean of the Group of 4 Non-overlapping Consecutive Test results in N/mm^2	Individual Results in N/mm^2
(1)	(2)	(3)
M15	$\geq f_{ck}$ + 0.825 X established Standard deviation (rounded off to nearest 0.5 N/ mm^2 or f_{ck} + 3 N/ mm^2 , whichever is greater	$\geq f_{ck}^{-3}$ N/ mm^2
M 20 Or above	$\geq f_{ck}$ + 0.825 X established Standard deviation (rounded off to nearest 0.5 N/ mm^2 or f_{ck} + 4 N/ mm^2 , whichever is greater	$\geq f_{ck}^{-4}$ N/ mm^2

NOTE: In the absence of established value of standard deviation, the values given in table 8 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.

Concrete which does not meet the strength requirements as specified in (1) but has strength greater than that required by (2) may at the discretion of the designer be accepted as being structurally adequate without further testing.

If the concrete is deemed not to comply pursuant to the structural adequacy, the parts so affected shall be investigated and any consequential action as needed shall be taken.

Concrete of each grade shall be assessed separately.

Concrete shall be assessed daily for compliance.

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

Coefficient of variation

The Co-efficient of variation (COV) and Standard Deviation are the two statistical tools which are utilized to indicate the level of quality control. A high COV indicates poor control and a low COV indicates good control. The following Table gives the ratings that are commonly assigned to various COVs for deciding the level of control of concrete strengths. These standards represent the average of 28 days compressive strength tests:-

Coefficient of variation (COV) for different control standards (%)

	Excellent	Good	Fair	Poor
General construction	Below 10	10 to 15	15 to 20	Above 20
Lab. Control	Below 5	5 to 7	7 to 10	Above 10

Standard Deviation and Co-efficient of Variation (COV) will be worked out for different Grades of concrete in addition to the 28 day compressive strength. This will be done on a continuing basis and updated regularly and documented in the following format :-

S.No.	Grade of concrete	Period	No. Of Samples	Ave.28 day compressive strength	Standard Deviation	Co-efficient of variation (COV)	Degree of field control	Re-marks

The COV ratings for concrete for different control standards are indicated in the table.

Assumed Standard Deviation:

When sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in Table 8 may be assumed for design of mix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly.

However, when adequate past records for a similar grade exist and justify to the desiner a value of standard deviation different from that shown in Table 8, it shall be permissible to use that value.

Table 8: Assumed Standard Deviation
(Clause 9.2.4.2 and Table 11)

Grade of concrete	Assumed Standard Deviation N/mm^2
M10	3.5
M15	
M20	4.0
M25	
M30	
M35	
M40	5.0
M45	
M50	

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

INSPECTION AND TESTING OF STRUCTURES

Inspection – Immediately after striping the formwork, all concrete shall be carefully inspected and any defective work of 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 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 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, M 15 (F_{ck}=15 N/MM^2 is to be used. The assumed standard deviation for this grade of concrete from table is 3.5 N/MM^2. 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/MM^2.

22.6, 22.7, 20.7, 19.7, 13.2, 11.8, N/MM^2
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 characteristic strength, these can be acceptable if their values are not less than the greater of:

1) F_{ck}. 1.35 = 15.1.35 X 3.5 = 10.275 N/MM^2

2) 0.8 X F_{ck} = 0.8 X 15 = 12 N/MM^2

The average strength $= \dfrac{22.6+21.7+20.7+20.6+19.7+13.2+11.8}{7} = 18.61$

The average strength should not be less than

$$F_{ck} + \left| 1.65 - \frac{1.65}{\sqrt{n}} \right| X \; S$$

$$= 15 + \left| 1.65 - \frac{1.65}{\sqrt{n}} \right| X \; 3.5 = 18.59 \text{ N/MM}^2 = \text{O.K.}$$

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 – IX

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 round shaped tin box and placed right at the construction site. The exterior of the tin box shall be painted red. After the particular work has been completed (say concrete placement has been completed in a particular lifts likewise say fill placement has been completed in a particular layer etc.,) the two O.K. Cards shall be removed from the tin box and filed in the permanent record files of the construction and Q.C./Q.A. divisions respectively. Senior Officers shall also check the O.K. Cards during their field inspections to ensure that those are being maintained and properly/genuinely filed.

An O.K. Cards 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. Card System shall be followed. The O.K. Cards should be made available on the site in a regular manner.

The O.K. Card consists of 3 columns. Besides, the location and type of work, the first column 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 Okays through his signature and then puts up the Q.C/Q.A engineer for his final O.K.

The Assistant Executive Engineer (Construction) will prepare two copies of O.K Cards by filling in the first set of columns meant for the construction staff and hand over to the Assistant Executive Engineer (Quality Control) in charge of the Quality Control Unit. The Quality Control staff at actual work site shall check the requirement or shall perform necessary tests under the guidance of Assistant Executive Engineer, Quality Control. The Assistant Executive Engineer, Quality Control will scrutinize the O.K. Card and finally Okay the work if anything other wise is not observed. Should anything otherwise be found, the O.K. Card shall not be signed by him and ask the Assistant Executive Engineer (Construction) for necessary rectification.

Subsequently, O.K. Card should refer to the defect removed, if pointed out previously in O.K. Cards and counter reference to the previous Check and should be signed if Okayed.

It must be borne in mind that work cannot be held up unduly for disposal of O.K Card. The Executive Engineer, Deputy Executive Engineer (Quality Control) will be the okaying authority for concerned work like dam, spillway and barrage and important structures and the Assistant Engineer / Assistant Executive Engineer Quality Control will be the okaying authority for scattered works like canals and small structure. Random checks by Superior officers should be recorded on O.K. Cards at site.

After processing through various levels and entering observations one copy of the O.K. Card (Red Colour Card) shall be retained with the Assistant Executive Engineer (Construction) for record and reference and the other copy shall be forwarded to the Executive Engineer Quality Control for record.

Specimen of O.K. Cards for various work such as embankment. Concrete, masonry, Grouting and Tunneling etc., are as follows:

O.K. CARD FOR EARTH WORK EMBANKMENT

S. No.	Description	Contractor	GOAP (CS)	GOAP (qcs)	Remarks.
1.	Date				
2.	Location of work from Km---------- to Km ----------				
3.	Elevation (R.L.)				
4.	Surface preparation, whether as per specification.				
5.	Type of Compaction equipment used				
6.	Location of test at Km.				
7.	Thickness of loose layer.				
8.	Initial moisture content.				
9.	Removal of over size.				
10.	Top level after compaction of layer.				
11.	Wet density.				

12. Moisture content in rolled fill

13. Dry density

14. Laboratory OMC and MDD

15. Compaction efficiency

16. Embankment of instruments devices (in case of earth dam)

17. Methodology of addition of Moisture (whether through spray from sprinkler tanker)

18. Manual compaction, if any

19. Layer passed

20. Any other remarks.

Sign of Contractor With date	Sign of GOAP (CS) With date	Sign of GOAP (QCS) with date

O.K. CARD FOR SUB GRADE PREPARATION

S.No.	Description	Contractor	GOAP (CS)	GOAP (QCS)	REMARKS
1.	Date				
2.	Location				
3.	Whether sub-grade is prepared as per specification in case of c) ROCK-(Over excavation) d) Swelling soils (Treatment With CNS soils) e) Over excavation in soils				
4.	Whether the profile of canal section is prepared to model section.				
1.	Whether porous plugs cast as per specification.				
6.	Whether the work of laying the filter media is carried out as per approved drawing in case of a) Porous Plugs b) Longitudinal and transverse drains.				
7.	Flap valves placed as per drawing				
8.	Whether sub-grade is wetted to 150 mm depth as per specification.				
9.	Compaction of Sub-grade to specified density.				
10.	Methodology of compaction.				
11.	Methodology of moistening, wetting of sub-grade.				
12.	Any other remarks.				
		Sign of Contractor With date	Sign of GOAP (CS) with date		Sign of GOAP (QCS) with date

O.K. CARD FOR CAST – INSITU CONCRETE LINING

S.No.	Description	Signatures of Contractor	GOAP (CS)	GOAP (QCS)	REMARKS
1.	Date				
2.	Location from Km ------ to --------- Km ---------- bed side slope L/R.				
3.	Proportion of the mix / Grade of concrete				
4.	Materials a) Coarse aggregate nominal maximum size 40 mm. 20mm & 10 mm b) Fine aggregate, F.M. of sand c) Cement make / Date of Manufacturer d) Admixtures make / date of mfr. and % used.				
5.	Method of concrete mix a) Mix vol./weight b) Batching plant by vol / weight				
6.	Transport a) By transit mixer b) By mobile self loading / weigh-batching & mixing and transporting (viz moving B & M Planet)				
7.	Temperature of concrete specified.				
8.	Temperature of concrete as placed.				
9.	Slumps a)Design slump i. At the batching plant ii. At the site of placement.				
10.	Water Cement Ratio.				
11.	Method of consolidation Mechanical vibrators / screened vibrator / Plate vibrator				
12.	Whether contraction / Joints are provided as per approved drawings.				
13.	Treatment of cold joint/joints				
14.	Curing: Water curing/curing compound.				
15.	Quality / Workman ship of concrete laid.				
16.	No. of C.C. cubes casted.				
17.	Any other remarks.				

Sign of Contractor With date	Sign of GOAP (CS) With date	Sign of GOAP (QCS) with date

O.K. CARD FOR MASONARY WORK

S. No.	Description	Signatures of Contractor	GOAP (CS)	GOAP (QCS)	REMARKS
1.	Date				
2.	Location of work				
a)	Component of work (with Elevation)				
3.	Specification of work.				
4.	Cleaning of Old Layer				
5.	Curing of Old Layer				
6.	Batching of Cement Mortar				
7.	Materials whether available as per specifications a) R.R. Stones b) C.R. Stones c) Bond Stones d) Dressing of Stones e) Sand F.M.				
8.	Placing of Stone, hearting and thickness of joints.				
9.	No. of C.M. Samples collected.				
10.	Any other remarks.				
		Sign of Contractor With date	Sign of GOAP (CS) With date		Sign of GOAP (QCS) with date

O.K. CARD FOR STRUCTURAL CONCRETE WORKS

S.No.	Description	Signatures of Contractor	GOAP (CS)	GOAP (QCS)	REMARKS
1.	Date				
2.	Grade of Mix				
3.	Location of work				
	a. Foundation (with elevation) b. Super structure (with elevation)				
4.	Methodology of preparation of surface joints				
	a) Green cutting b) Sand Blasting c) High pressure water blasting.				
5.	Materials				
	a) Coarse aggregate of maximum nominal size / Grade analysis. b) F.M. of sand c) Cement make/date d) Water quality				
6.	Tools and plants				
	a) Form work details of shuttering Should be checked with dimensions. b) Mixer c) Vibrators				
7.	Batching				
8.	Temperature of concrete specified in technical specifications.				
9.	Temperature of concrete as placed				
10.	SLUMP				
	a) Design slump b) At the batching and mixing plant c) At the site of placement				
11.	Method of placing.				

S.No.	Description	Signatures of Contractor	GOAP (CS)	GOAP (QCS)	REMARKS
12.	Method of consolidation				
13.	Water cement ratio				
14.	Treatment of construction joints				
15.	Embedments				
16.	Water stopper				
17.	Concrete finish (Wood float steel trowel)				
18.	Quantity of concrete laid.				
19.	No. of CC Cubes cast				
20.	Checking of reinforcement				
21.	Curing arrangements				
22.	Any other remarks.				

Sign of Contractor With date	Sign of GOAP (CS) With date	Sign of GOAP (QCS) with date

O.K. CARD FOR GROUTING

CONTRACT NO. ---------- CHAINAGE OF STRUCTURES ----------

NAME OF CONTRACTOR ----------

S.No.	Description	Dated Signature of Contractor	GOAP (CS)	GOAP (QCS)	Remarks
GENERAL					
1.	R.L. and area surface to be grouted.				
2.	Classification of the rock strata				
3.	Salient feature of the strata such as a fault zone cavities, fissures etc.				
4.	Permeability value of the strata before grout.				
GROUP					
5.	Pattern of Grout adopted				
6.	Depth and dia of the hole				
7.	Pressure adopted for grout				
8.	Proportion of grouting mix				
9.	Intake of slurry mortar per unit area per unit time				
10.	Total Quality of intake				
11.	Final permeability value of the strata after gout.				
12.	Whether the grout strata is OK.				

Signature of
Contractor GOAP/C/S/ D.E.E. / E.E. (GOAP/Q/CS) AE/AEE D.E.E. /E.E.

CHAPTER – X

TESTS TO BE PERFORMED ON MATERIALS

MATERIAL		TEST	METHOD
Cement	a)	Chemical	IS: 4032-1985
		i) Sio_2, Al_2O_3, Fe_2O_3, CaO MgO, SO_2, Insol residue & Loss On ignition	
		ii) Alkalies & Chlorides	
		iii) Free Lime	
	b)	Physical	
		i. Specific gravity	
		ii. Fineness	
		iii. Soundness	
		iv. Compressive Strength	
		v. Drying shrinkage	
Coarse Aggregates		i) Sieve Analysis	IS: 2386-1963
		ii) Flakiness index	
		iii) Elongation index	PART – I
		iv) Deleterious materials	
		v) Specific gravity	PART – II
		vi) Bulk Density	
		vii) Moisture content	PART – III
		viii) Absorption value	
		Mechanical tests	PART - IV
		ix) Aggregate crushing value	
		x) Impact value	PART – V
		xi) Abrasion value	
		xii) Potential reactivity of aggregate	PART – VI
		xiii) Petro-graphic examination	
		xiv) Alluli Aggregate reactivity test	PART – VII
Water		Chemical	
		i) CL, SO_4, Organic & Inorganic Solids, pH, Alkalinity / Acidity	IS: 3025-1968
		ii) Setting time of mortar	IS: 516 – 1959
		iii) Relative strength of concrete	IS: 1199-1959
Admixtures		i) Relative water content	IS: 9103-1959
		ii) Bleeding	IS: 9103-1959
		iii) Relative strength	IS: 516-1959
		iv) Setting time	IS: 8142-1959
		v) Relative length change	IS: 1199-1959

MATERIAL	TEST	METHOD
Concrete	a) Fresh Concrete	IS : 516 - 1959
	i) Air content	
	ii) Vibration	
	iii) Yield	
	iv) Temperature measurement	
	v) Mix proportions	
	vi) Water cement ratio	
	b) Workability test	IS: 516-1959
	i) Slump test	Usual procedure
	ii) Compaction Factor test	IS:CED2(CESS) ASTM C 597-83
	c) Hardened Concrete	BS 4408
	i) Compressive strength	PART 5:1974
	ii) MDT Tests	IS:CED 2(3890)
	iii) Ultrasonic pulse velocity	ASTM C805-85
	iv) Rebound Hammer	BS 4408 PART – 1971
	d) Special Test	
	i) Microscopy	
	ii) Non-destructive	
	iii) Core Testing	
Embankment	i) disturbed grain size analysis	IS 2720 Part (iv) 1965
	ii) Proctors compaction	IS 2720 Part (vii & viii) 1965
	iii) Atterbergs Limits	IS 2720 Part (v) 1970
	iv) Permeability	IS 2720 Part (xvii) 1966
	v) Shear test	IS 2720 Part (xiii) 1972
	vi) Specific gravity	IS 2720 Part (iii) 1964

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CHAPTER – XI

LIST OF EQUIPMENT FOR CEMENT AND CONCRETE TESTING

TEST			EQUIPMENT
1	A.	CEMENT	Flame Photometer
	a)	Chemical	Spectrophotometer
	i)	Alkalies	Potentiometer, Silver Electrode, Calomel
	ii)	Minor, major oxides by Calorinetry	Reference Electrode, Salt bridge.
	iii)	Chloride	Water Distillation still, even, Hot plate, Balance (Acc.0.0002 g) Muffle furnace (upto 1200 c).
	iv)	General	Platinum Crucibles, conductivity Bridge, pH Meter, Sample Divider for powers, physical balance (Cap. 150 g)
	b)	Physical	
	i) ii) iii) iv) v) vi) vii)	Fineness Soundness LeChatelier Consistency and setting time. compressive strength Heat of Hydration Drying shrinkage General	Blaines Apparatus, stop watch. Lachatelier Moulds, hot water batch Autoclave, length comparator moulds 25 x 25 x 250 mm.
B	AGGREGATES & CONCRETE		
a) i) ii) iii) iv) v)		General Crushing value Impact value Abrasion value Alkali Aggregate Reactivity Flakiness & Elongation indices.	Vicat Apparatus, moulds setting time needles and plunger compression testing machine (50 tonnes). Vibrating machine, moulds 50 sq.cm. Area, calorimeter, beckmann thermometer length comparator. flow table, stop watch, timer, temperature controlled oven, humidity chamber, incubator, physical balance (ACC 0.001 g) balance (cap. 5 kg. ACC 1g), control room (Temp. controlled curing tanks), set of standard sieves lid and receiver.
			Electric Drier, hot plates, set of standard sieves lid and receiver, balance 10 kg ACC 1g), 100 KG (ACC 0.001kg), 200 Kg. (ACC 0.5 kg) scop. Enamel trays, balance, showel, compression testing machine (200 tonnes), crusher and ball mill prevailing rings 2, 25, 50, 100 tonne. Crushing apparatus Aggregate impact test machine Angles machine Reaction Containers Apparatus for measuring flakiness and elongation indices

TEST			EQUIPMENT	
	vi)	Unit Weight containers	Minimum Capacity of Measures	
	vii)	Sampling (Sand)	Max.C.A.	Size of mm Capacity of measure dm^3
	viii	Specific Gravity and Absorption	2.50	6
			37.50	11
	C	CONCRETE	50.00	14
	a)	Fresh Concrete	75.00	28
	i)	Air content	114.00	71
	ii)	Vibration	152.00	99
	iii)	Temperature measurement		
	iv)	Mix proportions		
	b)	Workability Tests:		
	i)	Slump Test		
	ii)	Compaction factor test.	Reffler sample Divider	
	c)	Hardened concrete	Pycnometer	
	i)	Compression, Flexural, tension bending & Brinnel" hardness tests.		
	ii)	Capping of cylinders	air meter	
	iii)	Mixing of concrete	Internal Vibrator, table vibrator	
	iv)	Testing of curing compounds	metallic Thermometer	
			Equipment as in IS: 1199 for Determination of constituents, slump cone Apparatus,	
	d)	Special Tests	Compaction Factor apparatus, Universal Testing	
	i)	Microscopy	Machines with accessories (Cap. 100 tonnes).	
	ii)	Non-Destructive	Concrete workability meter.	
	iii)	Core Testing		
			Capping moulds	
			Laboratory concrete mixer	
			Reluctance meter	
			Optical microscope, grinding and polishing equipment, ultrasonic pulse velocity, rebound hammer core drilling machine, RCC cutting machine, thermal conductivity apparatus permeability apparatus.	

CHAPTER – XII

NAME OF WORK:-

Determination of field moisture and dry density of compacted earth fill

1. Date

2. Sample No.

3. Wt. Of Core Cutter = W_C
   Wt. of core cutter + wet soil = W_s

4. Wt. Of Wet Soil in gms (Ws-Wc) = W

5. Wet Density gms / c.c. = W / V

6. Moisture container No.

7. Wt. Of container + Wet Soil in gms.

8. Wt. Of container + dry soil in gms.

9. Wt. Of moisture in gms (m)

10. Wt. Of dry soil in gms (d)

11. % moisture content (m.c) = m x 100/d

12. Dry density in gms /cc.

SIGNATURE OF A.E. / A.E.E. / D.E.E.

Name of Work:-

REGISTER FOR COMPACTION EFFICIENCY DETERMINATION

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 Denalty	M.C.%	% OMC	MDD	Gms/C.C.	%
6	7	8	9	10	11	12

Signature of A.E. / A.E.E. / D.E.E.

Name of Work:-

Testing results of post checking of rolled fill of Dam/Canal Embankment

(Central Lab test)

S.No.	Date of sampling	Lab Sample No.	Location		Rolled Fill Dry Density Gms/CC
			CH.	Off-L/R	
1	2	3	4	5	6

M.C. of the Fill	Permeability of U/D Sample Mt. / Yr	Performed as per frequency (Dam every alternate day and Canal weekly).	REMARKS
7	8	9	10

Signature of A.E. / A.E.E. / D.E.E.

Name of Work:-

Testing results of soil samples of borrow area (Central Laboratory)

S.No.	Date of Sampling	Lab Sample No.	Location			Natural M.C. %	Natural Dry Density gms/C.C.
			Borrow	Offset	R.L.		
1	2	3	4	5	6	7	8

Specific Gravity	Grain size Analysis (I.S.No. 480)				Proctor's Compaction	
	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
9	**10**	**11**	**12**	**13**	**14**	**15**

Permeability mt/yr.U/D	At OMC MDD	Atterberges Limits			Shear Test at O.M.C.&M .D.D.	REMARKS
		L.L.	P.L.	P.I.	Drained/Undrained/ Saturated/Gms/C.C.	
16	17	18	19	20	21	22

A.E./A.E.E.
CENTRAL LABORATORY

D.E.E.
CENTRAL LABORATORY

Name of Work:-

Test results of sand samples conducted at central lab/field

LAB ……

Location Quarry/stock Ref: _____

PERCENTAGE OF PASSING FOR

L.S. Description	Sample	Grading Zone-1	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		15-35	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 _____

Signature of A.E./ A.E.E./D.E.E.

Name of Work:-

Testing results of Coarse samples of borrow area (Central Laboratory)

Field Lab :

Location Quarry stock Ref :

I.S.SIEVE Description	**Percentage Passing for Graded aggregate or Normal Size**			
	Sample	40 mm	20 mm	12.5 mm
80 mm		100		
40 mm		95-100	100	
20 mm		30-70	95-100	100
12.5 mm		---	---	90-100
10 mm		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 $Na_2 So_4$
> 15% for Mg $S0_4$

Signature of
A.E./A.E.E./D.E.E.

Name of Work:-

Testing results of Cement samples (Central Laboratory)

Name of godown _____ for use in structure _____

Manufactured at _____ factory _____ Ref. _____

S.No.	Sample No.	Lab. No.	Size of Cube	Physical, Tests setting times		Specific Surface	Compressive strength test Cube Kg/Cm^2		LE Chat Test	Remarks
1	2	3	4	5	6	7	8	9	10	11

A.E./A.E.E.
CENTRAL LAB.

D.E.E.
CENTRAL LAB.

Name of Work:-

Test Results of Stone samples conducted at Central Laboratory _____

Location Quarry Stock _____ Ref. _____

S.No.	Lab Sample	Wt. Of Individual Piece Kg	Size LxBxH	Absorption	Density Gm/CC
1	2	3	4	5	6

Soundness with Na_2So_4	Abrasion Acid Reaction with HCL conc.	Abrasion	Visual	Curing	General Remarks including Suitability
7	8	9	10	11	12

A.E./A.E.E.
CENTRAL LAB.

D.E.E.
CENTRAL LAB.

Name of Work:-

Test Results of water samples conducted at Central Laboratory

Location River

Reservoir_____ Ref. _____

Storage

For use in concreting/mortar/curing/other_____purpose in

Structure at_____

S.No.	Sample	Qualitative Tests Percentage of						Quantitative Tests		Remarks
		SO_4	CO_3	CL	NO	PO	pH	Silt & Suspended Impurity	Total Soluble Salt	
1	2	3	4	5	6	7	8	9	10	11

A.E./A.E.E.
CENTRAL LAB.

D.E.E.
CENTRAL LAB.

Name of Work:-

Test Results of HYSD bars samples conducted at Central Lab

Location Godown _____for use Structure_____
Work site

Manufacture at_____ Factory _____

Ref: _____

MACHANICAL PROPERTIES OF HIGH STRENGTH DEFORMED BARS

S.No.	Properties	Sample Grade		
		Fe 415	Fe 510	Fe 550
1	0.2 percent proof stress/yield stress Min. N/mm^2	415	500	550
2	Elongation percent Min. on gauge length @5.65 A. where A is cross sectional area of test piece.	14.5	12	8
3	Tensile strength Min.	10% more than the actual 10.2% proof stress but not less than the 485 N/mm^2	8% more than the actual 10.2% proof stress but not less 545 N/mm^2	6% more than the actual 0.2 proof stress but not less than 585 N/mm^2

A.E. / A.E.E. D.E.E.

Name of Work:-

Test Results of hardened samples conducted at Central Laboratory _____

Location of Sample		Concrete cube No.	Designed concrete mix properties		Test Results	
Block	CH. Off R. Set		W/C Proportion	Comp. Stren. 28 days Kg/Cm^2	7 days Comp. Stren. Kg/Cm^2	28 days Comp. Stren. Kg/Cm^2
1	2	3	4	5	6	7

Designed Mortar Mix Properties		Test Results		Remarks
W/C Prop.	Comp. Strength of 28 days Kg/Cm^2	Comp. Strength 7 days Kg/Cm^2	Com. Strength 28 days Kg/Cm^2	
8	9	10	11	12

A.E./A.E.E.
CENTRAL LAB.

D.E.E.
CENTRAL LAB.

Name of Work :-

Test results of common brick samples conducted at Laboratory Location

For use in _____at_____

Samples mark of Ref. _____ Lab No. _____

Properties of bricks I.S. 3102-1965 & I.S. 3367 - 75	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 % on dimension		
9. Compressive strength Kg/Cm^2		
10. Water Absorption		

Checked & Supervised
A.E.E./ A.E.
Laboratory

Signature of
Deputy E.E.
Laboratory

Test Results of concrete / mortar cubes casted by Quality Control Staff @ Site

R.D. ——————To ——————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.Cm.		Designed 28 days Strengths of Cube Mortar Kg/Sq.cm	Remarks
			7 days	28 days		
7	8	9	10	11	12	13

A.E./A.E.E.
CENTRAL LAB.

D.E.E.
CENTRAL LAB.

CHAPTER – XIII
IMPORTANT SPECIFICATIONS
EARTH WORK
(IS CODES 2720, 4701, 8237, 9451, 4081, 1200)

DO'S	DO NOTS
A) EXCAVATION OF CANALS	
1 Fix up the centre line and set the curves correctly. 2 Take working levels, real variation in ground levels and classification of soils as per Govt. Memo No. 1970 – 12/72 – 11, dated 4-7-1994 3 Get top soil vegetation etc. removed. 4 Provide treatment with C.N.S. soils in B.C. reaches (Expensive soils) 5 Form spoil bank as per drawing and away from side drain with suitable gaps for drainage into the valley. 6 Form Dowel Bank, as per drawing. 7 Form Inspection path to a uniform longitudinal gradient and with gentle transverse slope towards drains. 8 Compact over excavation/breakage portion with suitable soils, gravel, spalls.	1 Do not avoid approval of the deviation statement. 2 Avoid over break and loosening of canal. 3 Do not mix up useful soils with other soils of cutting.
B) FORMATION OF EMBANKMENTS	
1 Get the top spoil, vegetation and sand patches removed to complete depth. 2 Scarify the ground and wet properly. 3 Obtain P.D. OMC for the useful soils and borrow soils. 4 Provide C.O.T.s according to height of bank. 5 Raise embankment to full width with uniform horizontal layer ± 25 cm thickness. 6 Break clods, remove roots, big boulders other materials etc., larger than 80mm from the soils used in embankment 7 Supplement deficit moisture whenever required. 8 Provide 0.45 mt. Extra offset on both sides of bank, as warranted. 9 Compaction with 8 to 10 tonnes power roller/vibratory power roller to specified density 10 Conduct field compaction tests and determine compaction efficiency. 11 Check embankment profiles periodically. 12 Provide 10% allowance in setting profile of the embankment	1 Do not raise the bank in piecemeal. 2 Do not allow new layer without scarification and wetting of old layer. 3 Do not allow new layer unless required degree of compaction is achieved. 4 Don't leave any loose layer un-rolled at the end of the day in rainy season. 5 Don't allow compacted layer to be more than about 150 mm 6 No new layer to be laid unless the over moistured layer is either completely removed or allowed to dry. 7 Don't dump soils in heaps. 8 Don't dump the soils in water and slush 9 Do not forget to provide settlement allowance of 2 cm/mt Height of bank 10 Don't use expansive soils in banking.

CONCRETE

(IS CODES 383, 269, 2116, 2386, 456, 516, 1199, 3878, 9103)

CONSRUCTION JOINTS& TECHNIQUE OF GREEN CUTTING:

CONSTRUCTION JOINTS:

Concrete shall be placed in massive structure 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-V.

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 required 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/cm^2 (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 (70cfm) 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 kilogram 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 millimeter)	26
16 mesh per inch (25.40 millimeter)	30
30 mesh per inch (25.40 millimeter)	23
50 mesh per inch (25.40 millimeter)	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 ineffective. If sand having large percentage of lines 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.

DO'S		DO NOTS	
A) FOR FOUNDATION:			
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 150mm or to impermeable material	2	Don't lay the foundation concrete without wetting the surface.
3	Ensure the rock surface free from oil, objectionable coating unsound fragments.	3	Do not lay the concrete under water and over slush.
4	Check-up correct batching of ingredients.	4	The minimum missing time should not be less than 2 min.
5	Check the batch of cements and its make.	5	Do not forget to keep stand by vibrator and needles.
6	Check-up water cement ratio and slump test	6	Do not place concrete in raw in sufficiently heavy to wash mortar from concrete.
7	Ensure uniform mixing	7	Do not forget to cast the cubes.
8	Ensure proper compaction with vibrators and keep stand-by vibrator and needles.	8	Do not allow segregation of concrete.
9	Operate immersion type vibrators nearly in vertical position to vertical drain.	9	Do not use unsatisfactory mix.
10	Cure with water for 28 days	10	Don't allow admixture which will harm the strength of concrete.
11	Compact with suitable bedding materials in case of over excavations and with M.5 grade concrete in case of rock.		
12	Allow admixtures as per I.S: 9103 - 1979.		
B) SUPER STRUCTURE			
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 cross section from 6mm to +12 mm.
3	Clean and cover with a layer of 10 to 15mm thick mortar of the same proportion of concrete mix for horizontal joints.	3	Do not allow concreting all form work installation of items t0o be embedded and preparation of surface involved are approved.
4	Place the concrete at temperature between 15 C to 30 C.		
5	The concrete shall be discharged with in half hour after introduction of the mix water and cement.		

MASONRY

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 stones other than granite of crushing strength less than 1000 kgs / sq. cm
2	Dress C.R.S. stone to a depth of 75 mm on all four sides.	2	Do not allow bushing 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 3/4 of thickness of wall
5	Provide weep holes at 2m interval staggered as per drawing.	5	Do not allow breaking of vertical joints less than 75 mm.
6	Chisel dress the corner stones.	6	Headers shall not project not less than, 10cm 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 2m. Interval in each layer and mark.	8	Do not allow skin stones weathered stones.
9	Place the hearting stones on its broadset face.	9	Do not place stone in position without wetting.
10	Ensure perfect hearting to make the masonry water tight	10	Smaller stones shall not be placed in lower cores.
11	Mortar shall be used within 30 min. after discharge from miser.	11	Joints stones shall not be more than 12 mm.
12	Sieve analysis for sand shall be done periodically which confirm to I.S. Seive Designation 'X' of passing. 4.75mm 100 2.36mm 90 to 100 1.18 mm 70 to 100 600 micron 40 to 100 300 micron 5 to 70 150 micron 0 to 15	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 130mm.
14	Joints shall be raked out to minimum depth of 12mm when the mortar is green.	14	Avoid spreading of mortar over the surfaces of the masonry.
15	Cure the masonry with water for 2 weeks.	15	No pointing to be commenced without washing and wetting the joints thorough.
16	Cure the plastered surface with water for 14 days.		
17	Cure the pointing surface with water for 7 days.		

REINFORCED CEMENT CONCRETE SLABS

(I.S. CODES 2502.1786)

DO'S	DO NOTS
1 Check the reinforcement as per drawing.	Do not pass without proper cover.
2 Provide asphaltic pad and water stopper as per drawing.	Do not allow less lengths in over laps

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.

TESTS TO BE CONDUCTED
1 Sieve analysis for fine aggregate (Field test)
2 Sieve analysis for coarse aggregate (Field test)
3 Slump test (Field test)
4 Compressive strength of concrete (Lab test).

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

PREPARATION OF SUB- GRADE

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 in some measure to poor preparation of sub-grade, Due stress is therefore to be laid on control and proper preparation of sub-grade for lining. Sub-grade in different soil reaches shall be prepared based on IS: 3873-1966, 2720 (Part-VII), 4701.

Preparation of Sub-grade consisting of Earth:

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.

The consolidation of the bed in predominantly sandy reaches should be done by over saturating the bed by flooding it with water before lining is laid. The consolidation of sides in such reaches should be done by over cutting the sub-grade by 15cm and re-filling it with sand concrete with adequate quantities of cement or by vibro-compactors. The relative density of the compacted sub-grade shall be at least 70%.

All compaction in other than predominantly sandy reaches should be done at optimum moisture content in layers preferably not more than 15cm thick to obtain a dry bulk density of not less than 98 percent of the density at optimum moisture content in main canals and branch canals and 95% in distributaries/minors etc. Compaction of sub-grade depending upon the position of sub-soil water level shall be carried out in accordance with I.S : 3873-1966 and by employing portable electronic density testers (insitu cement concrete lining in canals)

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 15cm and 20 to 22cm in case of sand or else the concrete would extract moisture from the sub-grade. Compliance of these requirements must be recorded by the 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.

Preparation of Sub-grade consisting of Rock:

The Sub-grade should be prepared and dressed true to level and according to the required cross-section of the canal. All excavation including over-breakage below lines of under side of lining should be filled completely up to the lines of the under side of lining with suitable material. viz., spalls, lean concrete or sand compacted to density equivalent to sub-grade. Care should be exercised in selecting refill material for use over fractured rock of rubbles because of the danger of washing of fines into the sub-grade voids and thus loosing support.

Preparation of sub-grade consisting of Expansive Soils (IS. 9451: 1994)

In respect of the provision of CNS layer, the thickness is worked out from the consideration of swelling pressure. However the thickness of CNS layer to be provided on slopes shall in addition, be governed by the construction considerations viz., from rollable width consideration for achieving effective compaction.

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 India Standard, IS: 9451 – 1994, out lined below. CNS material shall be non-swelling with a maximum swelling pressure of $10KN/m^2$ 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 soils are all adequately compacted clayey soils, silty clays, sandy clays, gravelly sandy clays, etc. Exhibiting cohesive properties and containing predominantly non-expanding type clay minerals with liquid limit not exceeding 50 percent.

Expansive soils are inorganic or 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 is given in the following tables corresponding to various discharge ranges given in the following tables corresponding to various discharge ranges in canals. Side slopes shall not be steeper than 1.5:1, though slopes of 2:1 shall be preferable.

TABLE -13.1

Thickness of CNS layer in channels of carrying capacity less than 3 cumecs

Discharge in cumecs (m^3 / sec)	Thickness of CNS layer in cm (minimum)	
	Swell pressure 50-150 KN/m^2	Swell pressure more than 150 KN/m^2
1.4 – 2.0 (50 to 70 cusecs)	60 cm	75 cm
0.7 – 1.4 (25 to 50 cusecs)	50 cm	60 cm
0.3 – 0.7 (10 to 25 cusecs)	40 cm	50 cm
0.03 0 0.3 (1 to 10 cusecs)	30 cm	40 cm

TABLE – 13.2

Thickness of CNS layer in channels of carrying capacity of 2 cumecs and more

Swelling pressure of soil KN/m^2	Thickness of CNS material (minimum)
50 to 150	75 cm
150 to 300	85 cm
300 to 500	100 cm

Note:- CNS soil is to be laid in layers and compacted, to specified density.

Specification of CNS Soils

(i) General Gradation of CNS soil

Clay (less than 0.002 mm)	15 to 20 %
Silt (0.06 mm – 0.002 mm)	30 to 40 %
Sand (2mm – 0.06 mm)	30 to 40 %
Gravel (greater than 2 mm)	0 to 10 %

(ii) The CNS material shall be non-swelling, with a maximum swelling pressure of 10 KN/m^2 when tested in accordance with IS: 2720 (part-41) 1977 at optimum moisture content and minimum cohesion.

(iii) Index properties

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 satisfy the condition of swelling pressure mentioned in the sub para (ii) above. In respect of the provision of CNS layer in the bed, it shall be as worked out from consideration of selling 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 the specified proctor density.

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 (± 20 cm thickness0 and compacted to at least 95%/98% Proctor Density as specified in the Bid documents, preferably, by Power Rollers viz. Mechanized compaction.

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 and mechanized compaction of sub grade for side lining on slopes and bed is very important in cutting or embankments. In addition to the designed thickness of CNS, 15cm or more (perpendicular to side slope 0 of extra thickness (called pride) shall be provided and compacted. This pride 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 95%/98% proctor density as specified in the Bid document), 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. However this is included in the item rate of providing CNS & will not be paid separately.

vii. Under drainage arrangement, as per drawing, shall be provided.

C.C LINING
(I.S. CODES 353, 269, 2116, 456, 516)

CONCRETE CORES FROM CANAL LINING AND OTHER STRUCTURES

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 coarse 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: 457-1957)

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 atleast 10 cm. A core specimen for the determination of compressive strength shall have a diameter of atleast three times the maximum nominal size of the course aggregate used in concrete and in no case shall the final diameter of the specimens 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 the 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 specimen 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:
End Preparation: 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 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 atleast 85% of t6he cube strength of the grade of concrete specified for the corresponding age and no individual core has strength less than 75 percent.

	DO'S		DO NOTS
1	Check the canal prism and verify the bed levels.	1	Do not allow the concrete over loose sub-grade.
2	Check the graduation analysis of fine and coarse aggregate to the requirement of mix at batching plant	2	Do not allow lining manually 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 by plate vibrators.
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 sub-grade from transit mixer.
6	Check the batch of cement, its discharge.	6	Do not form contraction joints over longitudinal drains.
7	Check the batch of cement, its make and test results.	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 over the surfaces of the lining.
9	Maintain load register.	9	Do not remove the channels immediately before setting of C.C.
10	Record the No. CC cubes case and its compressive strength.	10	Do not use untested cement.
11	Cure CC lining with water for 28 days (bed lining curing by water and the slope lining curing either by water or by application of curing compound.)	11	Do not allow to sink the porous plugs in the drains.
12	Ensure smooth surface with paver roller passes.	12	Do not allow lining without making proper arrangement for curing with water curing compound.
13	Form the contraction and construction joints as per approved drawing.	13	The co-efficient of variation in the compressive strength of cement should preferably not be more that8%
14	Check the thickness of C.C lining for each canal.		
15	Checking placing of mastic pad at structures of construction joints.		
16	Allow concrete lining at temperature between 15^0 C and 32^0 C.		
17	Check periodically the coefficient of variation in the compressive strength of cement.		
18	The batching plant to be used shall confirm to the required of IS: 4925-1968.		

DRILLING AND GROUTING

1.0 SCOPE:

The pressure grouting of rock, masonry, concrete dams with cement and with or without suitable admixtures and fillers applicable to general grouting, consolidation grouting, and curtain grouting shall broadly conform to Indian Standard, IS 6066: 1994. The Indian Standards listed in the Table 13.3 are necessary adjuncts to these specifications.

2.0 GENERAL

(a) The design requirements for adopting a grouting programme are as under. The parameters will depend on the type of structure.

A) Curtain Grouting:

(i) To safeguard the foundation against erodibility hazard, and / or
(ii) To reduce quantity of seepage.

B) Consolidating grouting.

(iii) To reduce the deformability of jointed or shattered rock.
(iv) Grouting the masonry dams to minimize seepage.

(b) To Reduce Quantity of Seepage:

(i) For dams exceeding 30 m height, curtain grouting should be carried out when the water absorption exceeds one lugeon.
(ii) For dams under 30 m, height, curtain grouting is to be carried out where the water absorption exceeds 3 lugeon.

(c) The depth, spacing and orientation of grout holes are to be related to the geological features; for example, inclined holes should be preferred when the rock permeability is primarily due to closely spaced vertical/sub-vertical system of joints. It is sometimes necessary to evolve a pattern of holes consisting of different sets of holes appropriate to each type of discontinuity, such as bedding planes, system of joints and lava contacts.

3.0 GROUTING METHODS:

Rock grouting consists essentially of drilling a series of grout holes in rock and injecting grout under pressure, which eventually sets in the openings and voids in the rock. The drilling and grouting operations can be carried out either to the full depth in one operation or in successive depths either by stage grouting or by packer grouting.

3.1 FULL DEPTH GROUTING

In the full depth method each hole shall be drilled to the full desired depth, washed, pressure tested and grouted in one operation. This method shall be usually limited to short holes, 5 m or less in depth, or holes up to 10 m that have only small cracks and joints with no risk of surface leakage. In deep bore holes high grouting pressures shall be used to achieve proper penetration of the grout at a spacing of holes shown in the drawing or directed by the engineer-in-charge. As full depth grouting involves the risk of disturbance in the upper elevations, it is not generally considered suitable for grouting deep holes. For grouting in heterogeneous strata, where the nature of rock discontinuities is subjects to large variations in relation to the depth, full depth grouting shall not be used and stage grouting shall be preferred to packer grouting in such cases.

3.2 STAGE GROUTING

Stage grouting shall be conducted to permit treatment of various zones individually, by grouting successively increasing depths, after sealing the upper zones. Stage grouting, in descending stages, shall be carried out by adopting the procedure given below.

Grouting shall be done by drilling the holes to a predetermined depth and grouting this initial depth at an appropriate pressure. Grout shall be then washed from the hole prior to its final set (within 2-4 hours) and the hole deepened for the next stage. Alternatively the grout shall be allowed to harden and re-drilling shall be carried out through the hardened grout and the holes extended to the next stage. In another procedure called the one stage re-drilled method, which may be sometimes used, grout is washed out within a small depth of the top of the stage being routed and only one stage shall be re-drilled for proceeding to the next stage. In each of the above procedures the cycle of drilling-grouting-washing or re-drilling shall be repeated until the required depth of the hole is reached.

For stage grouting, the connection at the top of the hole can be made directly to the header or by sealing a packer at the top of the hole in the casing pipe. Alternatively, it is sometimes advantageous to install a packer immediately above the stage that is being routed in order to isolate the upper portion of the hole. Higher pressures can then be permitted for grouting of the lower stage without causing upheaval in the higher stages.

Grouting with double packer shall be adopted where a few well defined seams or zones exist and the packers can be seated above and below such zones. Rotary drilling method is preferred when double packers are used.

When packers can be seated and there is no risk of upheaval, grouting shall be carried out with single packer in ascending stages.
However, in many cases packers may function yet grout may over travel and cause upheaval in the zones above the section being grouted. At such places stage grouting in descending order shall be adopted in case of badly jointed and fissured strata vulnerable to upheaval.

In relatively compact rocks it may be more convenient to seal the packer at the top of the stage being grouted. The hole shall then be washed, as soon as the period of initial set of cement is over, to the entire depth of the hole up to the bottom of the stage in progress.
In strata vulnerable to upheaval, it may be necessary to allow the grout to set and form a sheath around the hole in order to enable high pressures to be used in the lower portions of the hole. In such cases, the washing and single stage re-drilling procedure shall be adopted.

4.0 PATTERN AND DEPTH OF HOLES AND SEQUENCE OF GROUTING

The pattern and depth holes shall be governed primarily by the design requirements and the nature of the rock. When the purpose will be consolidation, the holes shall be arranged in a regular pattern over the entire surface area required to be strengthened and the depth shall be determined by the extent of broken rock as well as the structural requirements regarding the deformability and strength of the foundation. When the purpose will be impermeabilization, the grout holes shall be arranged in a series of lines to form a curtain approximately perpendicular to the direction of seepage. The depth of holes shall dependent on design considerations as also on depth of pervious rock and the configuration of zones of relatively impervious strata. For grouting with cement, 38 mm dia holes may be used. In long holes, the diameter at the top of holes may have to be larger than the final diameter at the bottom of the hole to facilitate telescoping or to allow the wear of the bit.

5.0 PATTERNS OF HOLES FOR CURTAIN GROUTING.

SINGLE LINE GROUT CURTAINS.

Single line grout curtains are effective only in rocks / masonry / concrete having a fairly regular network of discontinuities with reasonably uniform size of openings. In such cases a curtain of adequate width can be achieved by grouting a single line of holes. In massive rocks/masonry/concrete with fine fissures, uplift control shall be primarily achieved by drainage and the grout curtain shall be used only as a supplementary measure to avoid concentrations of seepage which may exceed the capacity of the drainage system. Single line curtain may serve this limited objective in comparatively tight rock formations. In Single line curtains a widely spaced system of primary holes, subsequently followed by secondary and tertiary holes at progressively smaller spacing shall be drilled and grouted at spacing as shown on the drawing or as directed by the engineer-in-charge. The usual practice of splitting the spacing from primary to the secondary and secondary to tertiary phase shall be adopted. At every phase of the grouting operation, the results of percolation tests and grout absorption data shall be compared with the previous set of holes in order to decide whether a further splitting of the spacing of holes is worthwhile. When no significant improvement shall be noticed either in terms of decrease of the grout absorption or water percolation, careful review shall be made of the rock / masonry features, the nature of the rock / masonry and its relations to the patterns of holes. Sometimes it may be required to drill another line of holes at a different angle and orientation than to split the spacing further. If the area is too limited, the setting time of the grout becomes important since it is not desirable to

drill too close to a freshly grouted hole. Before pressure grouting is started, drilling of all the holes shall be completed within a distance of 20 m of the hole to be grouted.

Depending upon initial investigation and strata conditions the spacing of primary hole shall be decided. If the primary holes were spaced more than 6 m apart secondary holes should be drilled and grouted. On completion of primary holes spaced closer than 6 m or secondary holes (when the primary holes are spaced more than 6 m), should the percolation tests carried out in a few test holes indicate that further grouting of the area is necessary, secondary or tertiary treatment, as the case may be, shall be carried out systematically thereafter in the whole are or in the particular section where the rock conditions are bad. Similarly tertiary holes shall be taken over the whole area or the full length of the section which requires the treatment. (Please refer Drawing at the end of the chapter).

6.0 PATTERN OF HOLES FOR CONSOLIDATION GROUTING

The choice of pattern of holes, for consolidation grouting shall depend on whether it is necessary to wash and jet the hole systematically. When washing has to be carried out, a hexagonal pattern shall be preferred as this admits for flow reversal. When systematic washing and jetting is carried out to remove all soft material in seams it may not be necessary to use a primary and secondary system of holes.
When it will be desirable to test the efficacy of consolidation grouting by comparing the grout absorption in primary and secondary holes a rectangular or square pattern of holes shall be preferred. This shall be the case when the joints are irregular and relatively free from in filling or it is not necessary to remove the materials filling the joints.

7.0 SEQUENCE OF GROUTING.

While carrying out grouting operations it is necessary to ensure that no hole is drilled so close to a hole being grouted that inter connections develop. Spacing between primary holes is generally so selected that the drilling could be carried out without interference from grouting due to inter-connections from adjoining holes. Sometimes a situation arises when drilling of upper stages of secondary holes may be in progress concurrently with the grouting of the deeper stages of primary holes. In such cases, inter-connections would not be prevented if a sufficient cover of rock is not available between the portion which is being grouted and the zone in which the drilling of secondary holes in any zone of the foundation shall not be taken up until sufficient cushion of already grouted stages of primary holes in the same area is not available.

In multiple line curtains relative sequence of outer and inner rows shall also be strictly followed.

When grouting in rock overlain by pervious soil it is necessary to complete grouting of the contact zones of the rock and soil before commencing the grouting of the rock otherwise the grout would escape into the soil and it may be possible to control or detect excessive leakage.

8.0 GROUT MIXTURE

Rock? Masonry/Concrete grouting is usually performed with a mixture of cement and water with or without additives.

The cement generally used shall be any of the following.

(i)	Ordinary Portland	-	IS 269 : 1989 or
		-	IS 8112 : 1989 or
		-	IS 12269: 1987
(ii)	Portland Pozzolana	-	IS 1489 (Part 1) : 1991 (Part 2) : 1991
(iii)	Portland Slag	-	IS 455 : 1989
(iii)	Super sulphated Cement	-	IS 6909 : 1990
(iv)	Sulphate Resisting Portland	-	IS 12330 ; 1988.

9.0 DRILLING AND GROUTING EQUIPMENT

DRILLING EQUIPMENT

The equipment shall be capable of drilling holes of size 38 mm to 75 mm dia to the required depths. The equipment shall be capable of providing a continuous water or air flush of adequate capacity.
The various types of drilling equipment can be grouted as under.

(a) Percussive drilling equipment:

  (i) Standard drifter or wagon drill;
  (ii) Down the hole drilling equipment; and
  (iii) Overburden drilling equipment.

(b) Rotary drilling equipment with suitable drive, that is, hydraulic, electric, diesel or compressed air.

Percussive drilling methods are generally more economical in all types of rocks. For deep holes it may be advantageous to use overburden drilling equipment. By virtue of the separate rotation drive, greater speed and economy can be achieved, also by virtue of the greater rigidity of casing tube combined with the drill rods, better control on inclination of holes can generally achieved in the overburden drilling equipment. Down the hole hammer is also capable of maintaining a better control on the inclination. However, the hammer may get clogged when the drill cuttings form slush soft saturated strata cannot be removed by air flushing.

During percussive drilling in stratified rocks where the resistance of the rocks is prone to variation the holes may get curved and control on inclination may be lost. In such cases guide tubes may be used for ensuring verticality of the holes of alternatively rotary drilling may be used.

10.0 GROUT EQUIPMENT

The equipment for mixing and grouting shall be capable of effectively mixing in correct and specified proportions, agitation the grout and pumping it into the holes, in an uninterrupted flow at the designated pressure it into the holes, in an uninterrupted flow at the designated pressure upto atleast of 5 kg/cm^2) (75 psi) –7 kg/ cm^2) (100 psi). There should be satisfactory arrangements for accurately measuring the quantity of water, cement and other ingredients to be used. The agitator shall have paddles of suitable design and shape to keep the mix in proper consistency till it is pumped into the holes. Standard equipments of approved quality shall be used.

The mixing and conveying system shall be laid to provide sufficient capacity for a heavy flow of grout. The mixer shall be in two compartments or parts so that grout could be mixed one when that from the other is being pumped. In general an uninterrupted flow of grout shall be maintained and the grout conveyed from the pump to the hole through a pipe.

The mixer shall be placed as near the hole as possible and long pipe lines avoided. The flow of grout into the holes shall be controlled by the pressure relief valve by passing and returning to the mixer all grout not accepted by the hole at the desired pressure.

Proper pressure gauges shall be provided to measure the pressure of the grout pumped into the hole. They shall be provided with diaphragms to prevent grout from getting into the gauges and clogging them.

11.0 CIRCULATION SYSTEM

The circulation system required two pipe lines, a supply line from the grout pump to the grout hole and a return line from the grout hole to the agitator/pump. By opening the supply and grout hole valves, grout is forced into the hole as required. Pressure is maintained by adjusting either the supply valve or the return valve, or both, so that complete control of pressure is maintained at the hole. There should be a pressure gauge at the delivery end of the pump. No grout is wasted when washing out the grout lines and close control of the grouting operations is maintained. When directed electric or diesel drive pumps shall be employed, use of a return line is necessary. Long supply lines shall be avoided to reduce the chances of change is consistency of the grout and clogging. Field telephones are useful for communication between the pump operator and the grout man at the collar.

The circulating system shall be so provided that the grout shall be kept circulating continuously at sufficient velocity to prevent settlement of cement or clogging of pipe line and fittings. The pump and the pipe line shall be flushed with clear water at frequent

intervals, to keep them clear. Deposits of grout in the pump, mixer etc not removed by flushing shall be removed, scraping, clipping etc. A fine screen capable of being readily removed, cleaned and replaced would be desirable between the mixer and the pump. Proper arrangement shall also be provided with equipment to stock adequate quantity of cement, stone dust etc. likely to be required for the grouting.

After the grouting operations are completed for shift on the day, the remaining unused grout mix shall be thrown away. Also a mix not used up completely within one hour after mixing or that which in the opinion of the Engineer has set or clogged shall be thrown away. At no extra cost to the development. No payment shall be made on account of such wasted labour, material etc.

12.0 DRILLING THE GROUT HOLES

In such area as may be designated, holes shall be drilled size 38 mm 50 mm in dia. These will be spaced in rows spaced 3 meters apart or as specified in the drawings. The holes specified for coring and exploratory drilling / test holes shall be of 75 mm dia or as directed by the engineer-in-charge.

Drilling in masonry, concrete or combination of these for local drainage or shallow grouting shall also be done by percussion tube drilling method and paid for under the same item as for the above. Grout holes both in the masonry or concrete shall be of varying depth. The drilling in masonry or concrete above will be paid for at the same rate as for as drilling in rock.

All holes will be drilled with the equipment of the type specified most suitable for the particular job as approved by the Engineer-in-charge.

The depth and requirements of the drilled holes indicated are approximate and may be altered as per actual needs, as found necessary.

The grout holes shall be drilled normal to the surface of masonry, or if so directed inclined to the normal upto any inclination, in the direction as may be indicated without any extra cost.

At locations, where the leakages are excessive, masonry might require additional drilling and grouting of any area which may have earlier been drilled, grouted and even covered by concrete or masonry. The contractor shall comply with directions in this behalf. The unit rate for all such holes also be the same as quoted in the bill of quantities and shall be paid separately.

Re-drilling required, if any, in case of incomplete holes because of the contractors failure to clean the hole before the grout has set or for any other reason shall be performed at the contractors expense. Where the grout has been allowed to set as per specific directions or approval of the Engineer-in-charge the required re-drilling shall be paid for at 25% of the tendered rate of drilling grout holes.

After the drilling of the grout hole has been completed it shall be temporarily capped or plugged until it is grouted. Any hole that gets checked before it is grouted shall be opened to the satisfaction of the Engineer-in-charge by and at the expense of the contractor.

13.0 CLEANING OF HOLES

Before grouting and when a suitable small group of holes has been drilled, all but three holes (consecutive or as otherwise considered suitable for the purpose of cleaning) shall be closed temporarily at the surface. Water and air shall be pumped under pressure as determined by the Engineer-in-charge into two holes and allowed to escape from the third until all possible loose materials and mud etc., has been washed out of communicating seams or other passage ways, if any. Combinations of three holes at a time shall thus be cleaned before applying any grout into the holes. Suitable valves shall be used to permit alternate or continuous injection of air and water and for quickly switching the flow from one hole to other so as to produce turbulent action necessary to dislodge the softer materials if any. Water will be connected to one hole and air to the other adjoining hole. The water and air connections shall be interchanged at frequent intervals, to cause water to flow in every possible direction. The operation should be continued till reasonably clean water emerges out of the holes. In general the pressure of water and of air shall be such as to maintain the minimum possible velocity but sufficiently low to prevent heaving and movement of masonry. The normal maximum pressure should be about 5 kg/ cm^2 , higher pressure shall be used where so directed by the Engineer-in-charge. The connected holes shall be blown clear of any detritus that might have settled in the seams therein, washing shall be so timed as to immediately precedes the grouting. Before the grouting of a hole under grouting in case they are found connected to the hole under grouting. The cost of testing and preparing the holes and cleaning them shall be deemed to be covered in the item of drilling.

14.0 PRESSURE GROUNTING

The proportion of cement and water will be as determined by the Engineer-in-charge.

Cement and water shall be of the same quality as specified under section IC- sub-section A & D. Payment shall be made for the quantities of material actually used as assessed by the Engineer which shall be final and binding. The grout shall be applied at a low pressure (as may be specified by the Engineer) initially and gradually but within the time as may be specified by the Engineer, increased upto the maximum pressure. It shall be maintained for minimum period of about 10 minutes thereafter. Care shall, however, be taken to release the pressure immediately should there be signs of any movement of any part or heaving of rock/concrete/masonry, which might amongst other observations, be indicated by sudden and erratic fall in pressure.

When grouting has just been commenced in any hole, if it is found that the grout has been freely flowing too far to fast from the hole at low pressure, fine stone dust, or other suitable material as may be approved by the Engineer shall be immediately be added in order to block the leakage at sufficient distance from the hole and thus localize the area to be grouted for any particular hole or set of holes. As a hole approaches refusal the grout

shall be progressively thinned and grouting operation continued to refusal at the specified maximum pressure maintained for period of minimum 10 minutes as stated in above para. The consolidation grouting of the foundations shall be done at pressure upto 5 Kg/cm^2 or as directed by Engineer-in-charge.

Utmost care and precautions shall be taken to ensure that the dam masonry or concrete is not damaged during the grouting. Any damage caused to the concrete or masonry or any other element, material or structure in the dam or adjacent to it shall be made good by the contractor at his own expenses and to the satisfaction of the Engineer-in-charge.

15.0 METHOD OF APPLYING GROUT

It is always advisable to begin with a low initial pressure say 0.10 to 0.25 kg/cm^2/m of overburden, and build-up the pressure gradually. Initially the rate of intake may be 20 to 30 lit/min. In order to avoid the premature build-up of high pressure a general guideline should be followed that the pressure should be raised only when the intake rate falls below 5 lit/min. When surface leaks develop, pressure should be immediately reduced. Sub-surface cracking may sometimes be indicated by an abrupt rise in the rate of intake after grouting at a constant value of pressure for a considerable period.

Grout mixture (ratio by weight of water and cement ranging from 5:1 to 0.8:1 are recommended. It is only in exceptional circumstances that mixtures leaner that 10:1 need be used. The choice of grout mixtures may be based on results of percolation tests conducted prior to grouting.

The grouting of hole shall be continued till the hole or a combination of holes takes grout mix at a rate less than –

Rate of grout intake	**Time in Min**	**Pressure**
0.03 Cum (1 cft)	20	3.5 kg/cm^2 (50 psi or less)
0.03 Cum (1 cft)	15	3.5 kg/cm^2 to 7 kg/cm^2 (50 to 100 psi)

The grouting shall, however be stopped when the pressure gauge registers sudden rise or when other indications are seen of extension or upheaval or rock/masonry/concrete, under the pressure being applied. After the hole has been grouted it should be closed by means of a valve to maintain the grout under pressure in the seams or crevices into which it has been forced.

After any hole is grouted, it should be examined if cement has settled, unduly with water coming up, the amount of settlement depending on the proportion of mix used. Holes, where such settlement has taken place, are to be cleaned of all soft sediment and grouted again under pressure.

Shallow grouting (i.e. grouting not exceeding 15m in depth) operations shall always be started on the side of pattern so that the trapped air may be more easily forced out.

Grouting shall be continued until at the specified pressure the hole refuses to take grout more than specified above. If for any reasons grouting operations must be stopped before a hole has been grouted to refusal, clear water shall be kept running into the hole until grouting is resumed.

16.0 TEST FOR GROUTING WORK

To test the efficiency and penetration of grouting, fresh holes shall be drilled as directed by the Engineer-in-charge, after the grouting operations are completed to determine post grouting permeability values. These holes shall be tested by water under pressure actual to the maximum grout pressure adopted at the particular location and the amount and the rate of leakage if any measured in each such hole. If the Engineer-in-charge so directs, such holes shall be grouted at pressure specified by the Engineer. If not they shall be left open. No extra payment will be made for testing the holes by water. If such holes are grouted under direction Engineer, such grouting will be paid for as ordinary grouting on the basis of the quantity of cement and stone dust (where used) actually forced in. Cost of drilling of such holes shall be paid under the appropriate item of drilling.

17.0 RECORDS

The information to be recorded daily is as follows:

1) Result of the pressure test;
2) Grouting feature, for example, curtain and consolidation;
3) Date;
4) Shift;
5) Name of foreman;
6) Grouting method, packer grouting or full depth grouting and stage whether first, second or third;
7) Hole station number or co-ordinates;
8) Time grouting begun;
9) Time of each change in mix, pressure, or pumping rate;
10) Name of Inspector;
11) Time of hole completion;
12) Total quantity of cement used for each pressure or mix charge;
13) Water-cement ratio at the start and each change thereafter;
14) Air pressure;
15) Grout consumption and time required for consumption of each batch;
16) Pressure recorded at 3 min to 15 min intervals and on completion;
17) Rate of injection;
18) Cement washed;
19) Total quantity of cement injected into the hole;
20) Reason for abandoned holes(if any);
21) Number and depth of holes left for re-drilling; and

22) In addition, the inspector should record under 'Remarks' any change or incident affecting the grouting operation; such as 'tight hole', 'no leakage', 'had leakage', 'leaks caulked' 'grout pump down', 'hole completed' and so forth.

18.0 REPORTS

In order to facilitate control and planning of grouting operations, reports should be prepared at regular intervals to summarize important observations and data. It serves no useful purpose to maintain elaborate records unless they can be complied in such a form that significant trends can be determined regarding the efficacy or otherwise of the grouting operations. In the absence of such reports timely action would not be possible and procedures which may be ineffective or unsuitable may be continued indefinitely. These reports may consist of:

a) a hole-wise register of drilling, water tests, routing and inter connections
b) for consolidation grouting ------ a plan showing grout hole stages and grout intake.
c) for curtain grouting----- a 'L' section showing driving stages and grout intake.

19.0 GROUTING MUST BE DONE IN THE PRESENCE OF THE ENGINEER-IN-CHARGE OR HIS REPRESENTATIVE

Whenever pressure grouting is to be done, the contractor will give due notice thereof to the Engineer-in-charge to enable him or his authorized representative to be present during the grouting operations which will always be done in his presence.

20.0 FINISHING

The grout mix that might flow out or otherwise get spilt on the concrete or masonry or other surface shall be removed expeditiously without allowing any time for the grout to set on any of the aforesaid surface. After the grout has set the grout holes shall be plugged with cement mortar in the proportion of one to two by volume and the surface finished smooth in line with floor at that location.

21.0 CALIBRATION OF PRESSURE GAUGES & WATER METERS ETC.

The pressure gauges and water meters shall be got calibrated by the contractor at his cost, for their accuracy from time to time as may be directed by the Engineer-in-charge. The contractor shall produce necessary test certificate for such calibration. The pressure gauges and water meters which have been duly tested and calibrated shall only be used for grouting and testing holes.

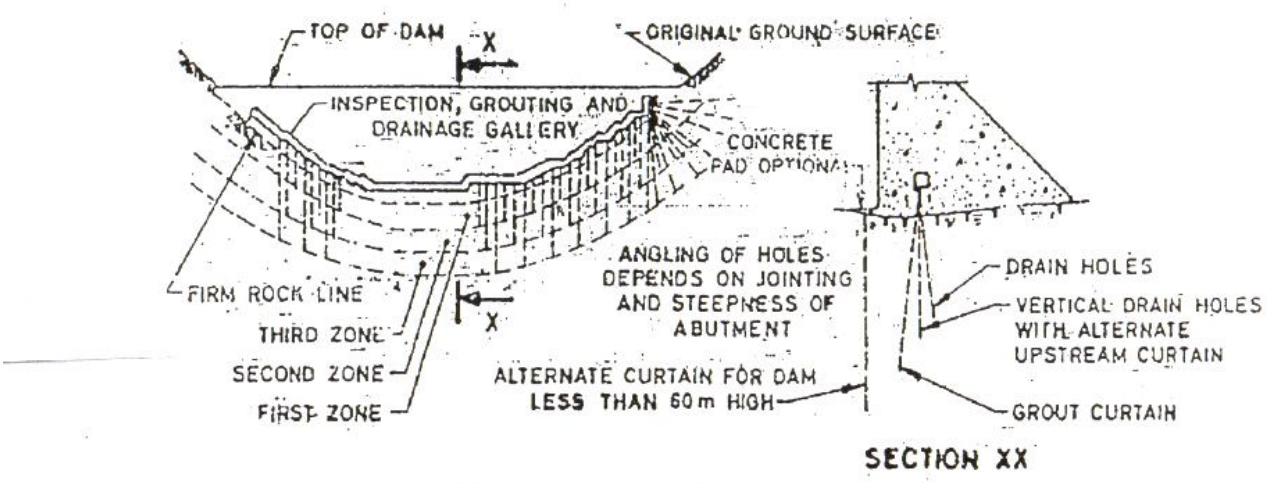
22.0 MEASUREMENT AND PAYMENT

The exploratory holes shall be measured and paid, for in actual linear meter of depth drilled or as directed by the Engineer-in charge which ever is less and shall include drilling taking water intake test in stages under pressure wherever specified.

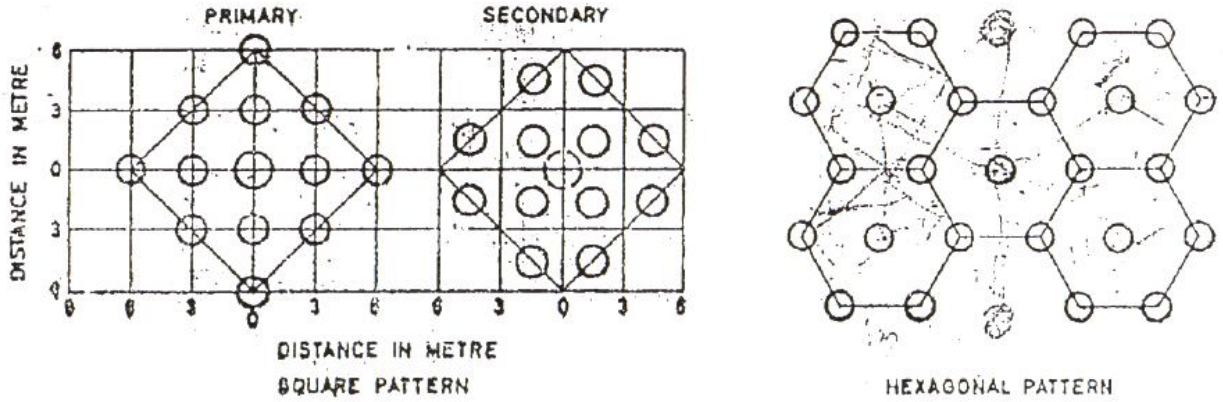
Drilling shall be measured for actual depth of drilling and paid to for at the unit price tendered for the relevant item in the bill of quantities. These unit prices shall include drilling of holes and maintaining the hole free from choking until grouted, washing and preparing the holes for grouting, and all works incidental thereto.

Measurement and payment for pressure grouting shall be made on the basis of cement actually forced into the grout holes. All wastage due to any cause shall not be paid for.

Payment for grouting shall be made at the unit price per metric tonne of cement tendered in the bill of quantities and shall include all material, plant and labour required for the grouting operation.



1A Typical Profile of Curtain Grout Holes



1B Consolidation Grouting

TABLE 13.3

LIST OF INDIAN STANDARDS

IS No.	Title	IS No.	Title
269 : 1989	Specifications for 33 grade ordinary Portland cement *(fourth revision)*	3812 : 1981	Specification for fly ash for use as pozzolana and admixture *(first revision)*
383 : 1970	Specification for coarse and fine aggregate from natural sources for concrete *(second revision)*	5313 : 1980	Guide for core drilling observations *(fist revision)*
		5529 (part 2):1985	Code of practice for in-situ permeability test: Part 2 Test in bedrock *(first revision)*
455 : 1989	Specification for Portland slag cement *(fourth revision)*	6909 : 1990	Specification for Supersulphated cement.
1344 : 1981	Specification for calcined clay pozzolana *(second revision)*	8112 : 1989	Specification for 43 grade ordinary Portland cement *(first revision)*
		9103 : 1979	Specification for admixtures for concrete
1489 (Part 1):1991	Specification for Portland pozzolana cement : Part 1 Fly ash based *(third revision)*	12269:1987	Specification for 53 grade ordinary Portland cement.
		12330:1988	Specification for sulphate resisting Portland cement
1489 (Part 2):1991	Specification for Portland pozzolana cement : Part 2 Calcined clay based *(third revision)*	12584:1989	Specification for bentonite for grouting in civil engineering works.

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CHAPTER – XIV

FREQUENCY OF TESTING

S. No	Test	Frequency of Test	Purpose	Test Designation
1	Grain size analysis For classification	One test per day for every 3000 m^3	To know the classifications of soil actually put in the embankment	As per IS: 2720 - IV - 1975
2	Atterberg Limit test	One test per day	-do-	IS: 2770.V-1970
3	Specific Gravity	One test per day	-do-	IS: 2720.III-1964
4	Field Density and Moisture content	One test for every 1500 m^3 of earth work and atleast one test for 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
5	In-situ Permeability test	One test in one weak or every 3m^3 of embankment height or for 20,000m^3	To determine permeability characteristics of fill materials	IS: 2720 - XVII - 1966
6	Tri axial Shear test	One test in one week or every 3m^3 of embankment or for 30,000 m^3	To know the shear characteristics of filler materials	IS: 2720 - XII - 1975
7	Consolidation test	Test of 3 samples in every 6m height of embankment or for 30,000m^3 or once in ten days	To know the settlement and its magnitude	IS: 2720 - XV - 1965
8	Standard Proctor test	One test per day for individual borrow Area	To determine MDD and OMC of the soils and compare the results with laboratory value.	IS: 2720 - VII - 1970
9	Moisture content	One test in each sample	To know the moisture content of the sample	IS: 2720 - II - 1975

10	Shrinkage Factor	One test in one week or 6m of embankment height	To determine shrinkage limited	IS: 2720 - II -1972
FILTERS				
11	Grain size Analysis	One test for every 200$m^3$of filler (sand) one test for every 200 m^3 of	To find % of the D10,D15,D30,D50,D60 grain sizes of materials	IS: 2385 Part-I
12	Clay are organs	One test for every 200 m^3 (sand) one test for every 200 m^3 (Aggregate)	To find out clay lumps & Organic imparities level	IS: 2386 - Part-II

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

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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:

1. Brief report of the project for which the data is compiled.
2. Index plan.
3. Geologists report depending upon the nature of the project.
4. Note of foundation treatment grouting pattern if suggested.
5. Nature of input materials like soil cement, aggregates, steel and their source of supply.
6. Test reports on input materials and acceptance criteria as laid on in I.S.: codes.
7. Designs of concrete mixes.
8. Summary of records and reports on grouting as specified in I.S.: 6066-1984 and IS:
9. Test reports on concrete like slum, compressive strength etc.
10. Control charts for cement and cement concrete i.e. Master charts, moving average strength and range chart etc.
11. Statement showing the deployment of machinery.
12. Statement showing the quality of concrete and earth work executed and number of cube tests conducted.

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CHAPTER XVI

PROCEDURE FOR EXECUTING EARTH WORK

(A) General:

(i) Sufficient number of reference Bench marks for facilitating setting out works and taking levels shall be established.

(ii) Permanent reference lines and check profiles at suitable intervals for checking the execution of all slopes, steps and elevation of the profiles of the approved drawings, shall be established.

(iii) The entire area required for setting out, shall be cleared of all tree stumps, roots, bush wood, rubbish of all kinds, loose and all objectionable materials.

(B) Stripping:

(i) The work area shall be stripped of the surface soil, including vegetation, overlying grass, organic matter, bushes, roots and other perishable or unsuitable material before commencing of the excavation. It shall be done as per the requirement or to a depth of 0.30 m or as specified or as directed by the Engineer-in-charge.

(ii) Prior to starting the stripping, initial cross-sections shall be taken at suitable interval of 10 m to 30 m, or as specified or as directed by Engineer-in-charge and shall be recorded in ink directly in the field books.

(iii) After the work of stripping in the canal width is completed, detailed cross-sections shall be taken as specified or as directed by Engineer-in-charge to form the base for computing the quantities of excavation or embankments.

(C) Borrow Area:

(i) In case when the materials required for construction of different zones of embankment and backfill around the structures are not available from canal excavation foundation excavation, the same are to be obtained from the approved borrow area, designated within the reasonable lead or as directed by the Engineer in charge.

(ii) Borrow pits, along the canal shall be operated in special case only after due approval of the competent authority keeping in view the hydraulic gradient line. This should no impair the usefulness of soil, the appearance of any part of work or any other property.

(iii) The stripping of borrow areas shall be done as per “B (i)” above.

(iv) Necessary grid lines with base line at suitable intervals shall be marked prior to and after stripping to take the levels of the cross-sections to compute the quantity of stripping and the materials borrowed from the borrow area.

(v) Necessary sample from the different depth shall be collected and got tested for their suitability in different zones of embankment / backfill prior to commencing the borrow area.

(vi) The required moisture as determined by the laboratory test shall be introduced in to the borrow area itself, by watering well in advance of the excavation to ensure uniformity of moisture content.

(vii) Moisture control register shall be maintained looking to the day to day initial moisture content of borrow area's material and the optimum moisture content of the respective material obtained from proctor tests.

(viii) The depth of cut in all borrow areas and borrow pits shall be designated by the Engineer-in-charge. Each borrow area shall be fully exploited to avoid haphazard exploitation. The borrow area excavation shall be carried out in such a way so as to produce the required uniformity mixture of materials for the embankment with the available excavation machinery.

(D) Embankment :

(i) This may be in the reaches of canals in partial cutting and partial banking or in full banking with or without bed banking.

(ii) Before commencement of the work, it shall be ensured that the materials of different zones for a particular section based on laboratory tests, are available.

(iii) Stripped ground shall be scarified and loosened by using plough or ripper.

(iv) The base-seat for embankment to receive earth shall be watered to the required moisture content and shall be compacted with suitable type of compactor so as to attain 95% of MDD or as specified.

(v) The layers for the embankment portion shall be placed continuously and approximately in horizontal layers of thickness varying from 15 to 23 cm is depth, in the respective zone, to the full width of the embankments, including slopes at the respective level.

(vi) Construction of embankment shall begin at toe of the fill and in no case material shall be dumped from the top, to widen the embankment.

(vii) Adequate Proud Section not less than 20 cm in thickness measured perpendicular to the slope or as specified shall be provided on canal lining side and outer side.

(viii) Each layer shall be tested for FDD and FMC as per the frequency stipulated in the tender specifications.

(ix) No fresh layer shall be laid until the previous layer is properly watered &compacted as per requirement.

(x) For proper bond of the embankment done in the previous season with new embankment, care shall be taken as under:

(a) In case of the bank to be extended horizontally, it shall be cut to a slope not steeper than I in 3 and the surface so prepared shall be scarified and made loose at least for a depth of 15 cm. Necessary watering shall be done. Earlier surface shall be thus prepared to receive new embankments. The bank material shall be laid in layers of 15 cm to 23 cm thickness or as specified and compacted to the required degree of compaction to have proper bond with the old one.

(b) If the old bank is to be raised vertically, vegetation shall be cleared followed by scarifying, watering and placing of new earth layer as specified above.

(c) The rain cuts, if any, shall be made good with due care by filling with proper / selected soil duly watered and compacted with suitable compactors or tempers.

(E) Important Features

(i) Laboratory testing of soil to be used shall be done well in advance.

(ii) Borrow areas to be identified looking to the suitability of soil available for different zones of the embankment.

(iii) Water content control to be exercised rigorously either by borrow area watering or spreading it uniformly over loose layer before rolling.

(iv) Proper roller should be selected for compaction looking to the type of soil e.g. pad foot/sheep foot roller for cohesive solid vibrator/ random roller for cohesion less soil.

(v) Thickness **of layer shall** be controlled

(a) Initial, layer shall be of 15 cms to 20 cms thick.

(b) Thickness of subsequent layers can be increased depending on the equipment used after trail runs / results and on approval of the Engineer in charge.

(vi) Regular tests for field density and Moisture control shall be taken as per provisions.

(vii) No fresh layer shall be laid until the previous layer is properly watered and Compacted as per requirement and tests are taken and recorded.

(viii) In case of cohesion less soil, where compaction test for MDD/OMC is not feasible, it shall be compacted to at least 65% of RD or as directed by the Engineer in charge.

(ix) When the filters are to be provided filter material to be used shall be checked for gradation curves and filter criteria's provided in tender. Compaction shall be done as specified.

(F) Records to be Maintained

(i) Date of Earth work as indicated in Design note and Drawing of embankment section.

(ii) Record of properties of soil available from canal excavation and Borrow area.

(iii) Confirmatory tests of soil being used for embankment (during construction)

(iv) Compaction test results of each layer and base seat of embankment.

(v) Data for proctor test for each type of material used.

(vi) Moisture control (before spreading @ NMC comparison with OMC)

(vii) Layer wise R.L. Location etc.

(viii) Daily & Monthly Progress report.

(ix) Record for filter material used shall be maintained such as Filter Criteria, Gradation Curve, Compaction / Watering etc.

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CHAPTER XVII

PROCEDURES FOR EXECUTING CONCRETE LINING

(I) General:

(i) The area shall be cleared of the objectionable material, before taking up lining work.

(ii) Center line, bed-width, inner & outer slopes etc. With the due provision for proud cutting shall be marked before start of trimming or bed excavation.

(iii) The excavation for trimming for preparing base for lining, i.e. sub grade shall be carried out / - (trimmed prior to lining) and to the profile. Trimming should not be exposed much before the actual starting of the lining of the work so as to preserve the O.M.C. in soil which comes in contract with cement mortar layer of the lining. Over cutting shall be avoided. However, over excavated portion shall be filled up with suitable material, moistured and compacted to the required density by tamping, roiling or slope compactor so as to form properly compacted sub-grade to receive the concrete for lining.

(iv) Check the profile of sub-grade so prepared and also check and record the density and the moisture content of sub grade. All loose materials on sub grade shall be removed and compacted suitably if required, by slope compacters.

(v) In case where rocky strata is met with over excavation shall have to be carried out as specified and shall be filled up with the selected material and compacted as per requirement.

(vi) Necessary under drainage arrangements shall be provided.

(II) Mechanized Lining:

(i) The thickness of un-reinforced in situ cement concrete lining (M 15 grade) to be provided in the main canals, branch canals, majors, and minors is indicated in the drawings.

(ii) Paver machine (Cylinder forming type) used for lining consists of conveyer belt, paver and foot bridge.

(iii) Temporary rails on wooden sleepers are laid of movement of conveyor belt and paver assembly. It is therefore very important to maintain the line and levels of the rails to achieve the required uniform thickness of concrete, proper placement, compaction, finishing and maintaining profile. As such, wooden sleepers shall be provided at closer interval of nearly 0.50 m for ensuring firm fixation of rails. Leval shall be marked on jacks of the paver to achieve the desired uniform thickness of concrete.

(iv) Behind the roller, an attachment for inserting PVC strip Joint/chatter for cutting groves are provided. Similar attachment for providing transverse joints at 4 m c/c are also attached. In case of PVC strips the position of transverse joints at maximum @ 4 m c/c shall be marked and the fin of longitudinal joints shall be cut to accommodate the transverse joint at the crossings.

(v) A work bridge is also provided to follow the movement of paver for attending to the finishing of concrete and working of labourers during lining, operation and subsequently for application of curing compound.

(III) Materials:

(i) Cement either OPC or PPC to be used shall be got tested in advance. Cement older then 90 days shall not be used without retesting and prior approval of E.I.C. Daily consumption record for cement shall be maintained in cement Account books.

(ii) **Fine Aggregate :** Sand shall conform to the requirement of IS 383-1970 and other relevant specifications. Sand shall be tested for gradation, specific gravity water absorption, fineness modulus, petrographic analysis etc. It should be brought from approved quarry / Source with requisite F.M. of 2.4 to 3.0 or as specified.

(iii) **Coarse Aggregate :**

(a) Coarse aggregate for concrete shall be clean, hard, dense, free from vegetation it shall be confirming to IS: 383 – 1970 or the Specification Concerned with the work. Predominately flaky and elongated aggregate shall not be used. Gravel / metal shall be brought from the approved source / quarry only and shall be tested for their gradation, specific gravity, water absorption, impact and abrasion values, soundness, petrographic analysis, flakiness and elongation.

(b) Each grade of material ranging from 40 mm to 4.75 mm shall be stacked separately.

(iv) **Water:** Potable water free from any other deleterious material shall be used. Water shall be got tested as per relevant standards.

(v) **Admixture:** Air entraining agent (AEA) as an admixture shall be added to the concrete batch as per the dose prescribed in the mix-design. (Normally 200 ml / cu. mt. of concrete)

(IV) Manufacturing of cement concrete:

(i) The concrete shall be manufactured of the controlled grade as specified with suitable admixture, using well graded aggregate with msa 40/20 mm, OPC or PPC cement, coarse aggregate, sand etc. in accordance with the mix design.

(ii) Concrete should be properly mixed in mixing plant or tilting type mixer. The weighting and measuring equipment, i.e., Batching plant or weight batcher shall operate within the limits of accuracy specified. They shall be calibrated regularly to ensure accurate performance.

(iii) The Proportion of different types of aggregate, sand, cement and water, and w/c ratio shall be in accordance with design mix and necessary correction for variation for over size and undersize and water absorption shall be made. Time of mixing shall be in accordance with specification to obtain dense, plastic, with uniform distribution of material and the concrete of uniform colour and consistency.

(iv) Mixer efficiency test shall be conducted from time to time.

(V) Transporting, Placing & compaction of Concrete:

(i) Concrete manufactured shall be handled from the place of mixing to the place of deposit as rapidly as practicable by use of transit mixers in agitating conditions or suitable placers and placed in final position within the specified time. Alternatively, mobile "Self Loading, weight-batching & mixing and transporting concrete mixture (of ± 2.5 m^3 drum capacity)" viz visibly moving B &M plant can be deployed.

(ii) During placement segregation of concrete should be avoided.

(iii) Before placing of concrete, sub-grade shall be moistened adequately.

(iv) Concrete shall be placed directly to the final position and shall not be allowed to flow.

(v) Manual placing of the concrete shall not be permitted. Suitable means to convey the concrete shall be provided to avoid free fall of concrete from the unacceptable height or angle.

(vi) Cutting grooves or inserting PVC strip, for longitudinal and transverse joints shall be attended as per the requirement.

(vii) The surface of the concrete finished and vibrated shall be even, smooth and free from pockets, projections honey combing and other objectionable defects.

(VI) Curing of Concrete:

(i) The concrete lining on slopes including curvature portion shall be cured with liquid membrane forming curing compound. The concrete lining in bed shall be cured with water.

(ii) Curing compound to be used shall be conforming to the relevant ASTM standards. It should be got tested for water retention and reflectance. Curing compound as per relevant ASTM-C-309 and ASTM-C-156 and other ASTM standard well in advance before use.

(iii) Curing compound shall be sprayed only by mechanical sprayer to ensure uniform and continuous application on concrete surface. The coverage achieved shall be kept on record and maintained regularly. The curing compound shall be sprayed / applied as soon as water seen is disappeared & curing compound sprayed shall not mix with the concrete. Record of test results of curing compound its coverage and consumption shall be maintained.

(iv) Record for curing period in case of water curing as per specification shall be maintained. Vehicles shall not be allowed on lining work.

(VII) Testing of Concrete …….

(i) Concrete shall be tested for workability (slump and air content), at B.M. Plant & / or site, cubes shall be cast at site / B.M. Plant specified.

(ii) Concrete shall be tested at site and in Laboratory on representative sample collected at site during laying in accordance with relevant specifications. Sampling procedure, frequency and preparation of test specimens etc. shall be followed as per the relevant specification.

(iii) Test strength of samples shall be compared and evaluated as per the provisions contained in the specifications.

(iv) Concrete shall be accepted as per the acceptance criteria laid down in the relevant specification.

(v) Cores from the hardened concrete shall be taken to check the thickness, density, water absorption compressive strength etc.

(vi) Necessary insitu density test of green concrete shall be taken & recorded.

(vii) Records to be maintained.

****

CHAPTER XVIII

PROCURES FOR EXECUTING R.C.C. WORK & CONCRETE FOR STRUCTURES

(I) General:

(i) Necessary TBM, Reference line etc. Shall be maintained and kept undisturbed till completion of the structure.

(ii) The foundation or the concrete surface of the structures shall have to cleared of the objectionable matter before putting the concrete and shall be got approved from competent authority.

(iii) O.K. Card for placement of concrete shall be maintained.

(iv) Incase of earth foundation, all soft, loose mud and surface debris shall be scrapped and removed. The surface shall be moistened to a depth of about 15 cm to prevent absorption of water from the fresh concrete.

(v) In case of old concrete surface, the surface shall be clean, rough and damp when receiveding the next lift by scrapping, chipping or by other suitable means.

(II) Materials:

(A) **Cement:**

(i) Ordinary Portland cement (OPC) conforming to relevant IS according to different grades shall be used, In case foundation concrete or mass concrete, PPC may be used if permitted.

(ii) Samples from the stock of cement shall be collected in accordance with IS procedures and shall be got tested well in advance as per the frequency specified.

(iii) Cement older than 90 days shall not be used without retesting & prior approval of EIC.

(iv) Daily Receipt and consumption record shall be maintained in Cement Account Book.

(B) **Fine Aggregates:**

(i) Sand to be used shall be brought from the approved river shoal only. It shall conform to the requirement of IS 383-1970 and other relevant specifications.

(ii) Sand should be tested for fineness modulus (F.M) gradation, specific gravity.

(C) **Coarse Aggregeres:**

(i) Coarse aggregate for concrete shall be clean, hard, dense, free from vegetation. It shall be conforming to IS: 389-1970 or the Specifications concreted with the work. Predominantly flaky and elongated aggregate shall not be used. Gravel/metal shall be brought from only approved quarry and shall be tested for their gradation, specific gravity, water absorption, impact and abrasion values, soundness, petrographic analysis, flakiness and elongation.

(ii) Each grade of material ranging from 40 mm to 4.75 mm shall be stacked separately.

(D) **Water:**

Potable water free from any other deleterious or organic material shall be used.

(E) **Reinforcing Steel:**

H.Y.S.D. bars, M.S. Bars or other structural steel conforming to relevant IS shall be used as reinforcement. However, samples of such bars shall be collected and got tested prior to their use as per the frequency specified in the relevant specifications.

(III) Manufacturing of Cement Concrete:

(i) The concrete mix shall be got designed in laboratory for various grades i.e. M-10, M-15, M-20 & other grade as specified, used proposed construction materials to achieve the required workability & strength at optimum cement level for RCC works, minimum grade of concrete shall be M 2O.

(ii) The prescribed amount of different materials such as coarse aggregate, fine aggregate, water, cement and AEA as per the mix-design, incorporation correction for over/under size and water absorption shall be measured at the Batching plant or weigh batcher. Batching plant or weigh batcher shall operate within the limits of accuracy specified. They shall be calibrated regularly to keep the combined inaccuracies in feeding and measuring the material, water and cement within the specified limit.

(iii) The concrete ingredients thus measured and fed shall be mixed thoroughly in batch mixers for the prescribed time of mixing so as to uniform distribution of all the constituent material resulting in dense, plastic, stiff concrete of uniform colour and consistency.

(IV) Transporting, Placing & Compaction of concrete

(i) Concrete shall be transported from the mixing plant to the placement position as rapidly as possible, by use of transit mixer or suitable placers, conveyors etc.

(ii) In case when chutes are used for concrete conveying, they shall be of such size and shape as to ensure a steady uniform flow of concrete without segregation.

(iii) Before placing of concrete, foundation surface or surface of old, concrete shall be cleaned, roughened and damped.

(iv) Concrete, as far as practicable, shall be placed directly in final position, and shall not be caused to flow to avoid segregation.

(v) In case of old concrete surface, it should be cleaned and chipping / cutting shall be attempted as per requirement. Clearing with wire brush / roughening of surface shall be done invariably.

(vi) Hand placing of concrete shall not be permitted and it should always be insisted for providing suitable means to convey the concrete to avoid free fall from unacceptable height or angle.

(vii) Cold joints shall be avoided. However, in unavoidable circumstances, if Cold joints is formed then necessary remedial measures and contraction joint treatment shall be done prior to resuming the placement of concrete.

(viii) Concrete placed shall be concreted in final position within specified time. Retamping of concrete shall not be permitted.

(ix) Concrete shall be compacted with the help of suitable type of vibrators, (Normally it shall be immersion type having vibrating head of 100 mm, operated at speed of at least 6000 vibrations per minutes when immersed in the concrete). It shall be compacted to achieve the desired density.

(x) Necessary in-situ density test of green concrete shall be taken and records for it shall be maintained.

(xi) The surfaces of the concrete vibrated and finished shall be even, smooth and free from pockets, projections, honey-combing and other objectionable defects.

(V) Form Work:

(i) Formwork to be used to confine the concrete for bringing shape and required lines shall preferably be of steel and got approved from the Engineer-in-charge Effective and Sufficient number of props and bracing shall be provided to prevent deformation due to placing, vibrating and compacting concrete.

(ii) The surface of formwork shall be such as to produce surface finishes as specified and form work joints tight enough i.e. grout tight.

(iii) Before fixing the formwork in line and level it shall be properly cleaned and oiled.

(iv) Formwork fixed in position duly lines and leveled shall be inspected prior to commencing of concrete and O.K. card shall be maintained.

a) Embedded parts shall be fixed in position with desired standard of Geometry.
b) PVC water stops shall be fixed in position so as to have its bulb in the centre of joint.

(v) Formwork shall be removed as soon as the concrete has hardened sufficiently or looking to the requirement of design. Due care shall be taken at the time of removal, so as to avoid damage to concrete.

(vi) Formed surfaces shall have finish F1, F2, F3, or F4 as specified in the relevant specification. Similarly unformed surfaces, i.e., U1, U2, U3 and finish U4 shall be in conformity with relevant specifications.

If concrete is to be repaired then the repair of concrete shall be attended immediately as per the provisions contained in the relevant specifications.

(VII) Curing of Concrete:

(i) Top surfaces of concrete shall be kept moistened by covering with wet jute bags : or by sprinkling water or by any other effective means.

(ii) Steeply sloping or vertical surfaces shall be kept completely and continuously moist by water.

(iii) Concrete cured with water shall be kept wet at least for 14 days when ordinary Portland Cement (OPC) is used.

(B) Membrane Curing:

(i) Membrane curing shall be done by application of suitable approved white pigmented type curing compound.

(ii) When curing compound is to be used, application shall commence immediately after the finishing operations are completed. It shall be applied with mechanical spray pump of insecticide or Jumbo mounted on Work Bridge.

(iii) Curing compound to be used shall be of approved quality and shall be got tested for water retention and reluctance test, well in advance.

(iv) Record for test results consumption and coverage of curing compound shall be maintained.

****

ANNEXURE – I
SKETCH SHOWING ROLES AND RESPONSIBILITY MATRIX

OWNER GOAP	PROJECT CONSTRUCT TEAM	PROJECT Q.C/Q.A. TEAM	CONTRACTOR HAS RESPONSIBILITY FOR
Set the tone for Quality Construction	Organize for construction supervision	Organize for QC/QA supervision	Means and methods of construction to ensure progress with quality.
Issue directive on firm commitment to quality & strict implementation of QC/QA programs on projects.	Convene preconstruction meeting with Contractor after award on Contract. Introduce OK Card System	Implement OK Card System meticulously.	Construction sequencing and scheduling.
Establish project requirement and arrange project financing.	Job-specific specifications be made available to all, right to the lowest supervising level.	Acquaint fully with technical specifications in the contract documents and implement strictly.	Quality control related to construction activities.
Set organization of field construction team	monitor regularly the adequacy of contractor's equipment and plant for progress and quality	Conduct sampling and testing of inputs and outputs as per specified frequency.	Site safety first aid, ambulance, house keeping.
Set organization of quality control team.	Administer contract strictly.	Calibrate the lab testing equipment regularly	Strict compliance of technical specifications.
	Enforce house keeping and site safety by the contractor.		
Approve training programme for construction supervision and quality control personnel on QC/QA aspects through a specialist organization (Like NCB)	Conduct regular progress & quality review meetings with contractor	Acquaint fully with testing procedures and standards.	Filling of OK Cards and presenting to construction staff.

Get QC labs recognized for their reliability, and competence through a specialist organisation (Like NCB)	Involve Geologist on geo technical problems Ensure regular payment to the contractor for works done.	Communication and feed back of deficient quality work be very prompt work be stopped, if necessary and construction team informed for violation of specified procedures by contractor.	Planning and deployment of construction plant and equipment consistent with progress & quality.
Constitute high level co-ordination committee to coordinate Quality management system for QC/QA and oversee implementation	Ensure preparation of "as built drawing" as work proceeds		Fulfilling contract commitments completely and faithfully: performing on schedule.
Conduct internal Quality Audit of Project works yearly through CE(CDO)	Encourage Contractor to get his nucleus personnel trained in NCB /any reputed organization on QC/QA aspects.	Compile statistical Quality Control Data on continuing basis This be preferably computerised.	Implementation contract changes orders.
		Use Control Charts as dynamic tools to monitor QC of cement/ concrete/mortar.	Constructing project facilities as specified by contract document.
		Maintain all relevant Indian Standards booklets.	Avoiding conflicts.
		Have close liason with construction team and contractor on QC/QA aspects.	Inducting experienced supervisory personnel on construction.
		Keep abreast with improved quality control procedures/equipment and deploy the same.	Maintaining photographic record of work.

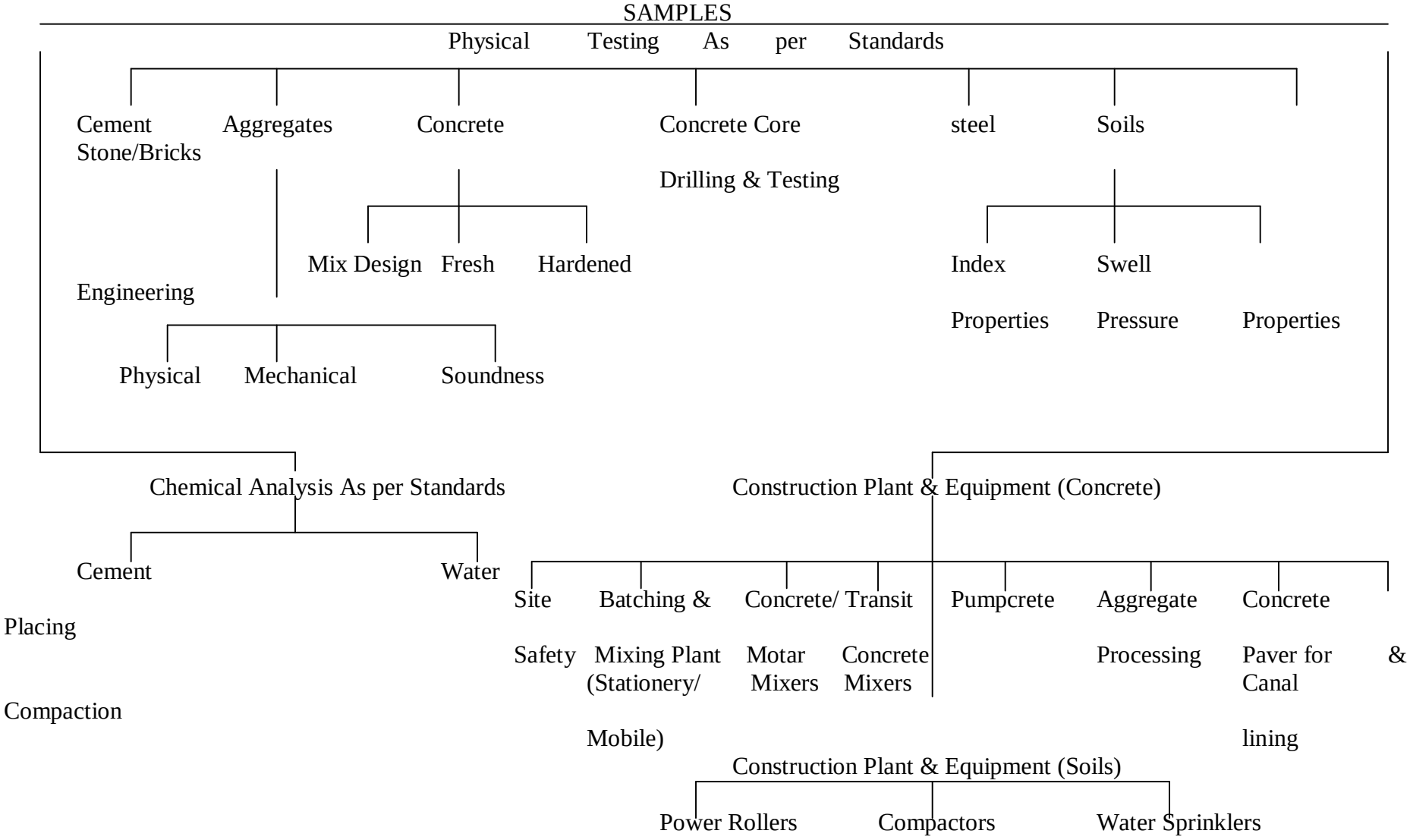
PROJECT DESIGN TEAM

To:

- Furnish construction drawings well in time.
- Provide prompt advice on design and design related quality aspects.
- Review and approve job-specific technical specification and acceptance criteria
- Inspect works regularly to ensure proper implementation of design, safety, and quality, related aspects in construction.
- Provide guidance to project teams on technical elements of contract change orders.
- Review adequacy of contractor's infrastructure. Job facilities and construction plant development to assist owner in achieving quality construction.
- Co-Ordinate with Dam Safety Review Panel/Panel of Experts and incorporate Panel Recommendations in designs/drawings.
- Maintain close liaison with Geologist.

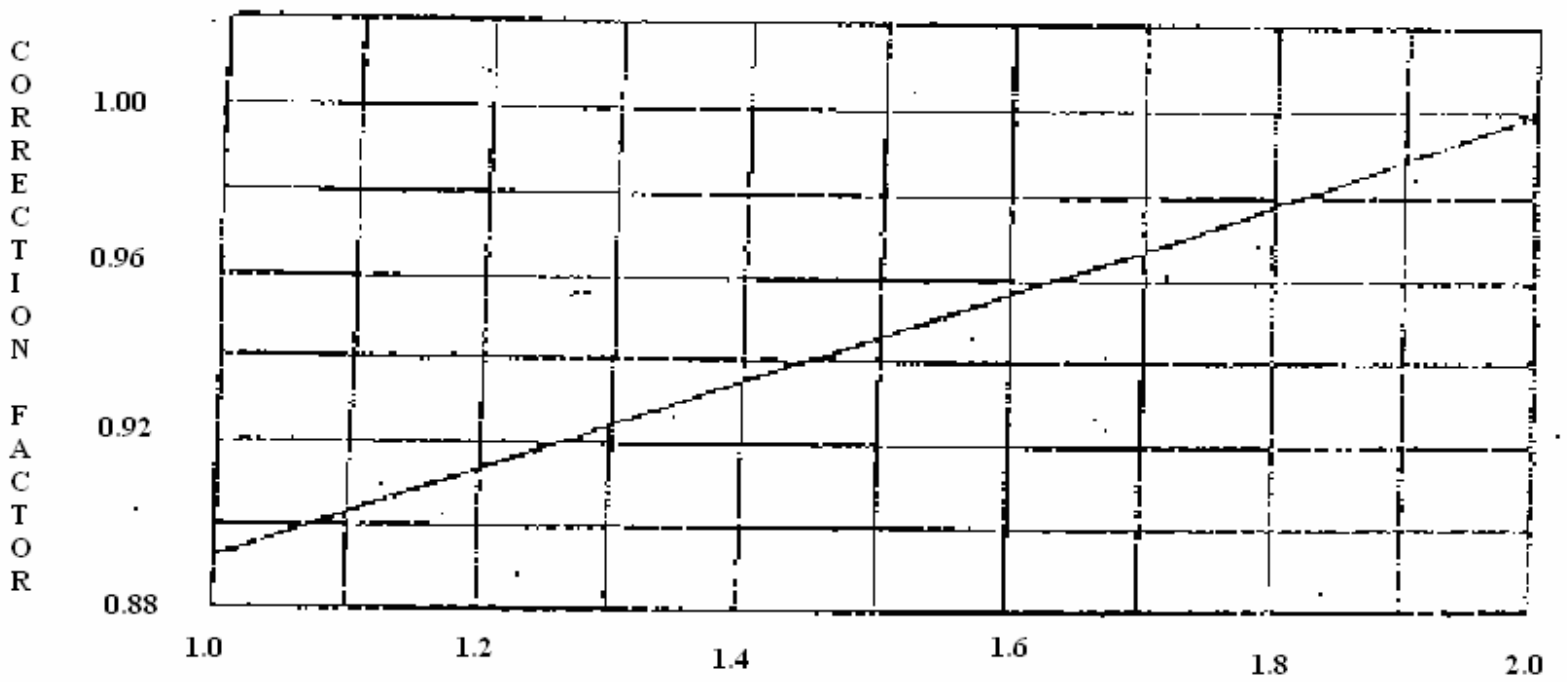
ANNEXURE - II

Scope and Inspection of Testing Activities



ANNEXURE – III

IS 516-1969



RATIO= HEIGHT / DIAMETER

CORRECTION FACTOR FOR HEIGHT/DIAMETER RATIO OF A CORE

ANNEXURE –IV

ILLUSTRATION OF PREPARATION OF CONTROL CHARTS FOR CEMENT AND CONCRETE

A. CONTROL CHARTS FOR CONCRETE STRENGTHS

1. An illustrative set of compressive strength data (hypothetical data) and its further analysis for incorporation in a typical set of control charts is shown in the enclosed Table A. It is assumed that 3 companion specimen samples are made from each homogeneous batch and constitute a 'test'. Thirty such tests are covered in this Table.

   Master Chart
   The axis indicates the chronological order of tests (col.1 of the Table). Strengths of the individual companion specimens constituting a given "test:" (Cols.2 to 4), are plotted one above the other along the ordinate and their mean values (col. 5) representing each "test" are joined to generate the Chart. Refer Plate IA.

   Moving – Average strength chart.
   Each test is averaged with 4 number of previous test, making a total of 5 and this "Moving average" viz average of 5 consecutive tests (col 6) is plotted. Refer Plate 2A.

   Range Chart
   The range between the maximum 5 consecutive tests, as shown in Col.7 is also plotted. This chart monitors the overall batch to batch variation of production. Refer Plate 2A.

2. The target average strength and control limits can be estimated depending on the percentage of test values permitted to fall below the specified or " Characteristic" strength fsp in terms of the standard deviation δ (or coefficient of variation Cv) corresponding to the degree of control aimed at. The target average strength (TAV) is worked out as.

   Fsp+0.84 δ for mass concretre

   And fsp + 1.65 for structural concrete conforming to IS: 456.

The standard deviation is what is assumed for mix design. For mass concrete, coefficient of variation Cv is assumed as 15% and the target average strength is 160+0.84 δ

Then $\frac{\delta}{160+0.846}$ = Cv =15%
Solving , δ = 27.5 kg/cm^2
So, target avg. Strength =160+0.84 δ

=160+0.84 x 27.5

=182 kg/ cm^2

Upper warning limit (UWL) =183 + 0.84 δ (TAV + 0.84 δ)

= 206 kg/ cm^2

Lower warning limit (LWL) = 160 kg/ cm^2 (viz fsp)

Upper action limit (UAL) =183 + 3 x 27.5

=265 kg /cm^2

Lower action limit (LAL) =183 - 3δ

= 101 kg/ cm^2

Lower warming limit = $183 + 0.84 \times \frac{27.5}{\sqrt{5}}$

The control charts incorporating these limits are exhibited in plates 1A and 2A.

The lower action limit (LAL) shall, in no case, be lower than the absolute minimum strength wherever specified. IS: 456 – 1978 specifies on over riding absolute minimum of 0.8 times the characteristic concrete strength.

4. Target average range = dx6=2.326x27.5 = 64
(Refer para B.5 below)

This is depicted in Control Chart 3A.

B) CONTROL CHARTS FOR CEMENT STRENGTHS

1. An illustrative set of strength data and its analysis for incorporation in a typical set of control charts is shown in the enclosed Table B. Thirty one "test" (each consisting of 3 companion specimens) are covered in the Table. The Master Chart Moving Average Strength Chart and the Range Chart (range between the maximum and minimum 5 consecutive test) are depicted in Plate IB, Plate 2B and Plate 3B respectively

Target Avg. Strength	= 45 kg/ cm^2
Coefficient of variation(Cv)	=8%
So, standard deviation (δ)	=450x 8% =36 kg/ cm^2
The upper and lower warming limits are set as	= 450± 1.65 x δ
Upper and warming limit (UWL)	= 450 + 1.65 x 36 =509 kg/ cm^2

Lower warning limit (LWL) =450 - 1.65 x 36
= 391 kg/ cm^2

The upper and lower limits are set as = 450 ± 3 δ
Upper action limit (UAL) =450 + 3 x 36
=558 kg/ cm^2

Lower action limit (LAL) =450 – 3 x 36
342 kg/ cm^2

The lower action limit (LAL) should in no case to lower than the minimum specified strength in IS specification IS: 269 or IS: 1469 (330 kg/ cm^2 at 28 days).

The control chart in corpora ting these limits are exhibited in plates 1B and 2B.

5. Target average range = d δ

d= coefficient depending upon the no. of the tests considered for obtaining the range and less consecutive tests, d=2.326.

So, target av. Range = 2.326 x 36 = 84 kg/ cm^2

The control chart of cement test result ranges (between maximum and minimum of 5 consecutive tests) depicting the mean sample range (84 kg/ cm^2) as well is shown in Plate 3B.

TABLE – A

ILLUSTRATIVE DATA AND ITS ANALYSIS FOR SETTING UP CONTROL CHARTS OF CONCRETE STRENGTHS (Mass Concrete)

Location on x-axis of Chart sr. No./Dated of sample	Strength of individual companion Specimens			Test value "T"(Mean of a b & c) X (kg/cm^2)	Moving avg. Of "T" (Five consecutive test)	Range Bet. Max. 5 consecutive tests	$(X-\bar{X})^2$
	a	b	c				
	comp. Strength at 28 days (Kg/Cm^2)						
1	2	3	4	5	6	7	8
1	191	193	195	193	.....	.....	1.96
2	181	185	186	184	.....	.....	57.76
3	183	188	187	186	.....	.....	81.36
4	198	195	192	195	.....	.....	11.56
5	166	173	171	170	185.6	25	466.56
6	177	176	172	175	182.0	25	275.56
7	150	146	148	148	174.8	47	1900.96
8	187	191	192	190	175.6	47	2.56
9	214	211	211	212	179.0	64	416.16
10	212	217	216	215	188.0	67	547.56
11	232	231	227	230	199.0	82	1474.56
12	218	218	224	220	213.4	40	806.56
13	192	194	190	192	213.8	38	1.60
14	181	182	177	180	207.4	50	134.56
15	190	192	194	192	202.8	50	1.6
16	198	199	194	197	196.2	40	29.16
17	197	197	200	198	191.8	18	40.96
18	180	183	183	182	189.8	18	92.16
19	190	191	195	192	192.2	16	1.60
20	197	198	190	195	192.8	16	11.56
21	187	189	194	190	191.4	16	2.56
22	197	188	191	192	190.2	13	1.60
23	240	244	236	240	201.8	50	2342.56

24	208	208	214	210	205.4	50	338.56
25	155	150	151	152	196.8	88	1568.16
26	152	147	145	148	183.4	92	1900.96
27	168	166	161	165	183.0	92	707.56
28	193	198	200	197	174.4	62	29.16
29	222	214	215	217	175.8	69	237.16
30	187	188	195	190	183.4	69	2.56

STATISTICAL ANALYSIS

n (No. of sample) =30

X (Av. Strength) = 191.6 {Av. of Column 5 viz 5747/30}

Sd (δ) $= 21.52\ kg/cm^2$ Total of column 8 =13437.16

Percentage of samples = 90% Sd(δ) = $\sqrt{13437.16/N-1}$

Passing (viz. Comp. Strength more than (sp of 160 x Kg/Cm^2) = 21.52 Kg/Cm^2

NOTE: The data listed are hypothetical and in arbitrary units and are meant only to illustrate their analysis for incorporation in control charts.

- Conc. Grade A 150 S 160
- Cement level 170 kg/cm^2
- Specified strength 160 kg/cm^2 (fsp)

TABLE – B

IILUSTRATIVE DATA AND ITS ANALYSIS FOR SETTING UP CONTROL CHARTS OF CEMENT STRENGTHS

Location on x-axis of chart S. no. / Date of sample	Comp. Strength @28 days three individual specimens			Average of 4,5 and 6	Moving Avg. of 5 consecutive Test Results	Range bet. Max & min. 0of 5 Consecutive Test Results
1	2	3	4	5	6	7
1	500	490	495	495	……..	……..
2	450	430	425	435	……..	……..
3	500	480	490	490	……..	……..
4	550	555	545	550	……..	……..
5	415	430	415	420		130
6	430	430	430	430		130
7	400	390	395	395		155
8	405	425	445	425		155
9	440	445	450	445		50
10	465	435	435	445		50
11	445	435	440	440		50
12	450	410	430	430		20
13	505	495	500	500		70
14	500	495	490	490		70
15	465	450	450	455		70
16	445	465	455	455		70
17	465	490	485	480		45
18	430	445	445	440		65
19	445	455	465	455		60
20	410	430	420	420		60
21	490	510	485	495		75
22	450	450	465	455		75
23	450	435	450	445		75
24	470	460	465	465		75
25	475	470	465	470		50
26	450	465	465	460		25
27	460	450	440	450		25
28	450	450	450	450		20
29	470	470	470	470		20
30	490	490	490	490		40
31	470	475	480	475		40

STATISTICAL ANALYSIS

N = 31

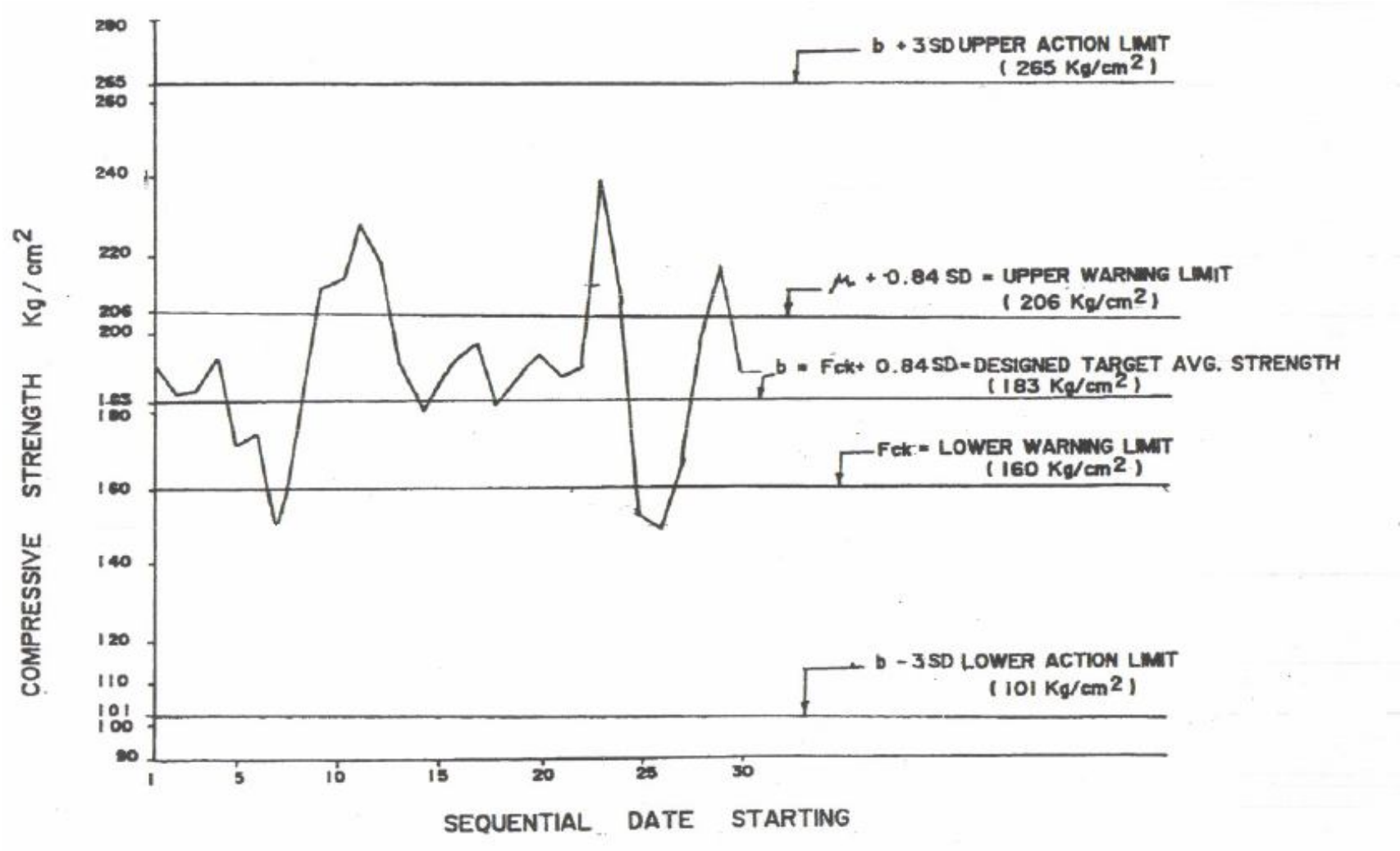
* = 459

Sd (δ) = 30.49

Cov (Cv) = 6.65

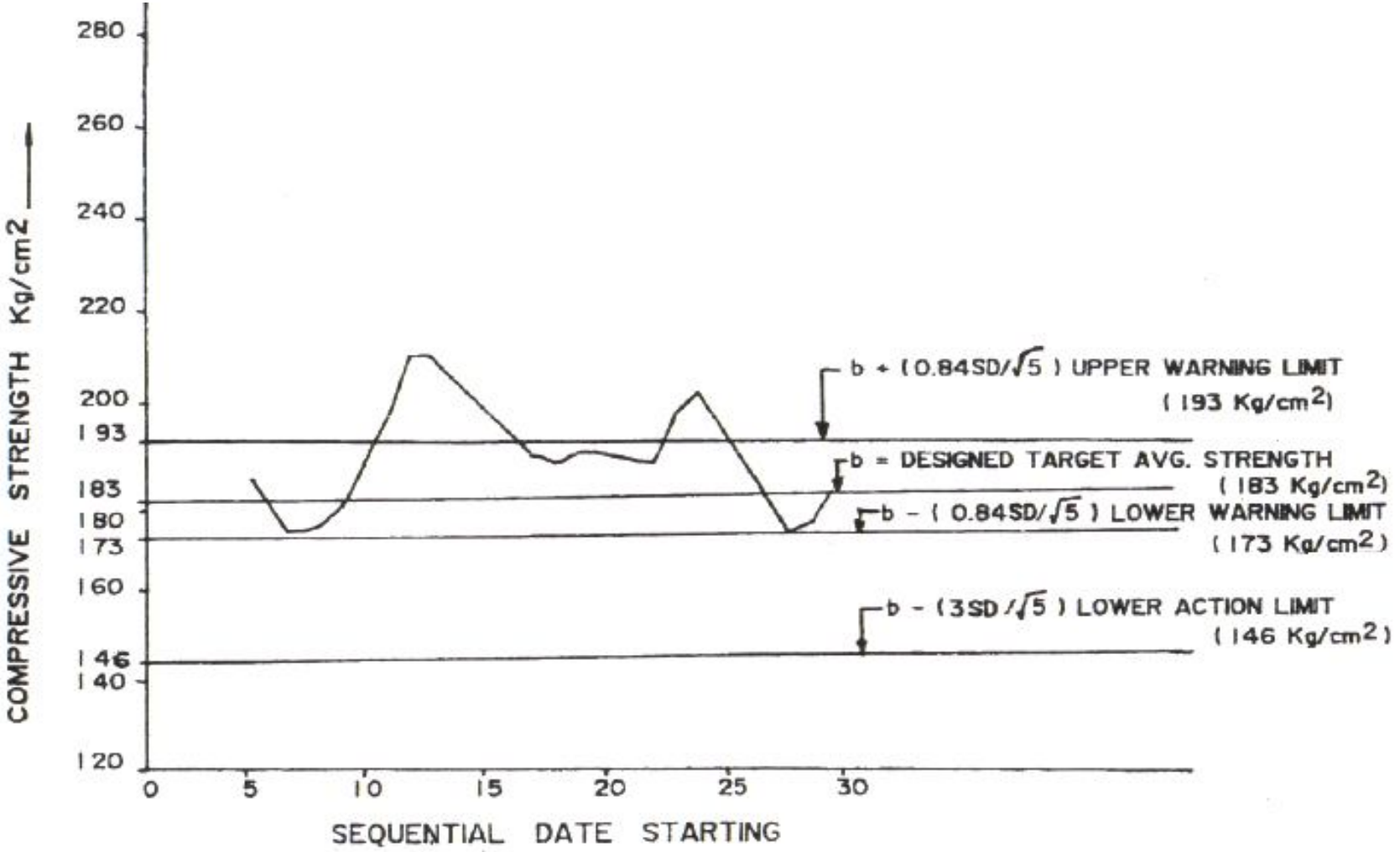
Target Av. Range : 84 Kg/Cm^2

PLATE – 1 A



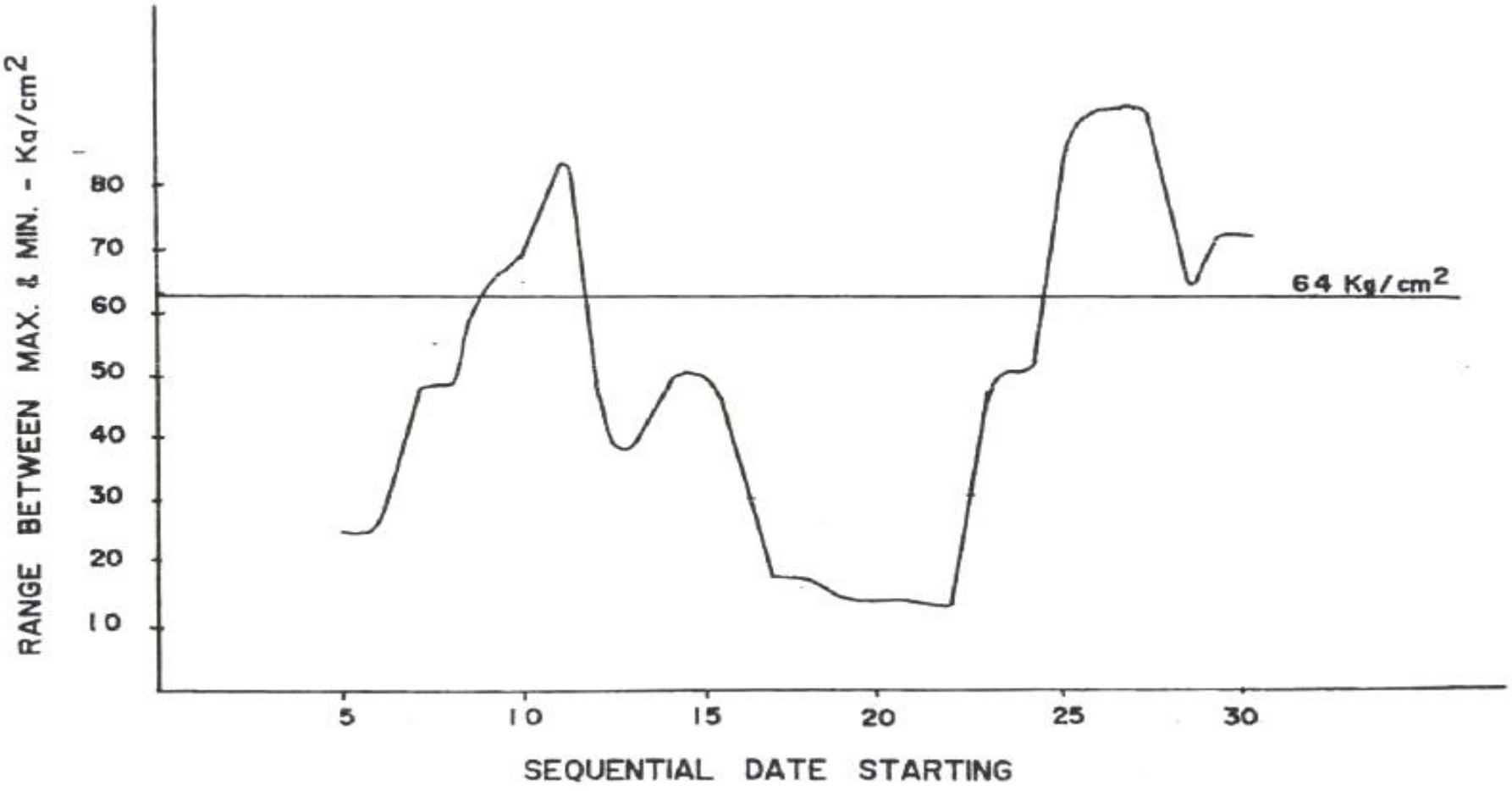
CONTROL CHART FOR 28 DAYS STRENGTH OF MASS CONCRETE INDIVIDUAL TESTS

PLATE – 2 A



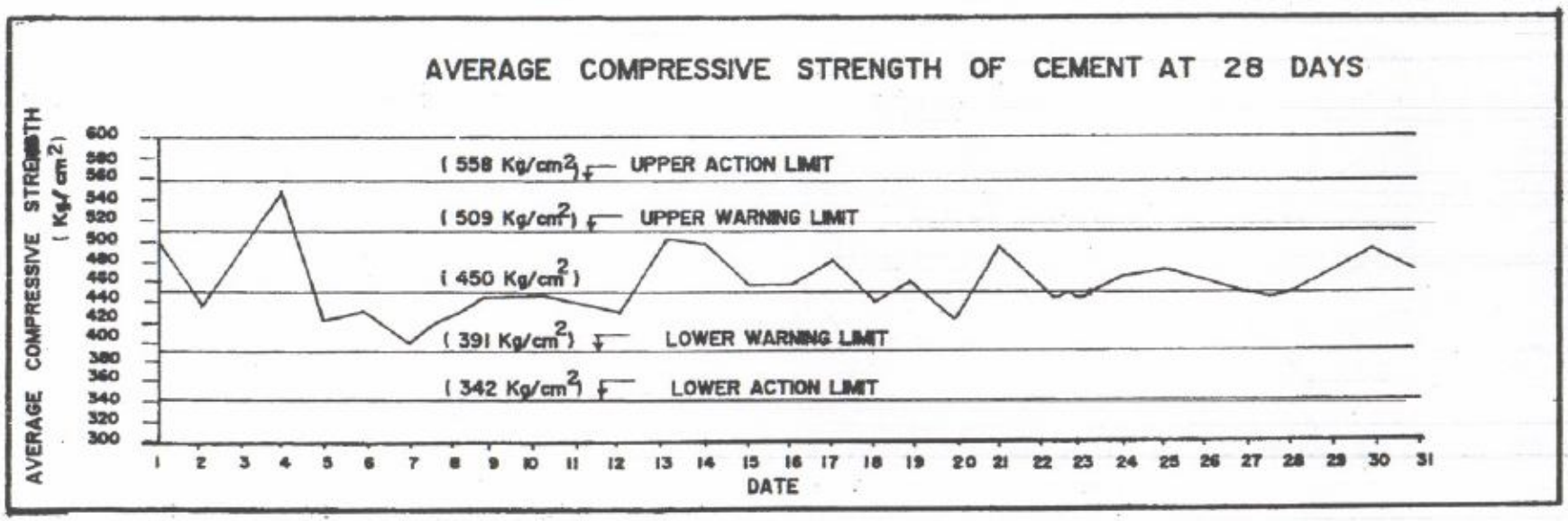
CONTROL CHART FOR 28 DAYS STRENGTH OF MASS CONCRETE INDIVIDUAL TESTS

PLATE – 3 A



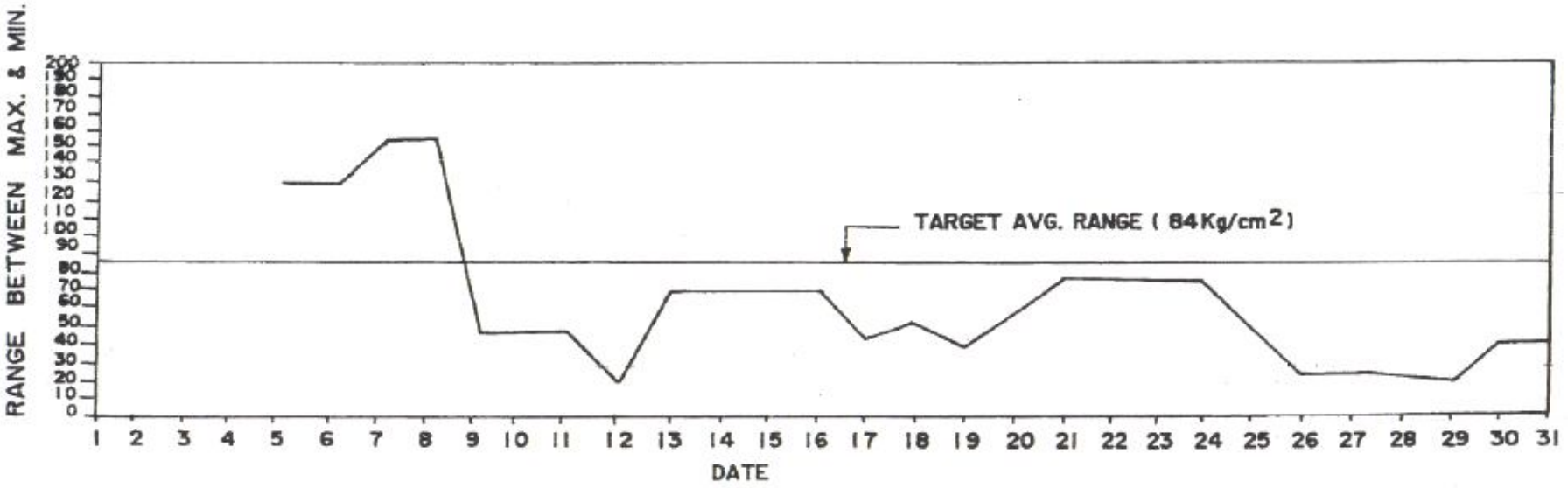
RANGE BETWEEN MAX & MIN OF 5 CONSECUTIVE TEST RESULTS

PLATE – 1 B



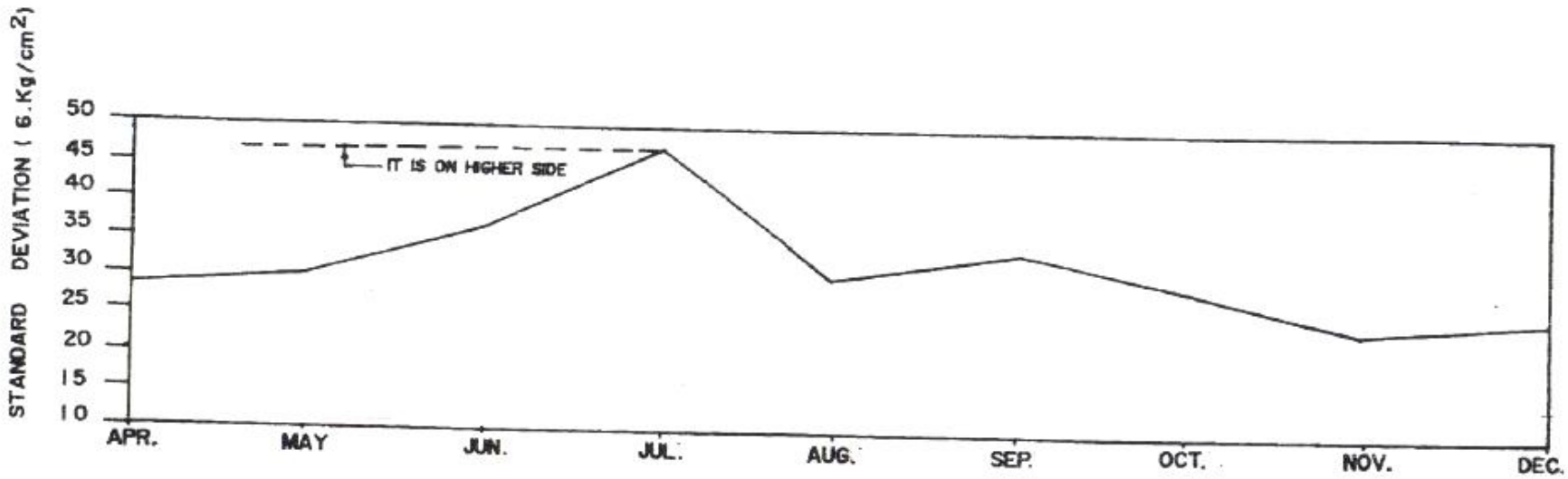
TARGET AVERAGE STRENGTH : 450Kg/cm2

PLATE – 3 B



RANGE BETWEEN MAX & MIN OF 5 CONSECUTIVE TEST RESULTS (CEMENT)

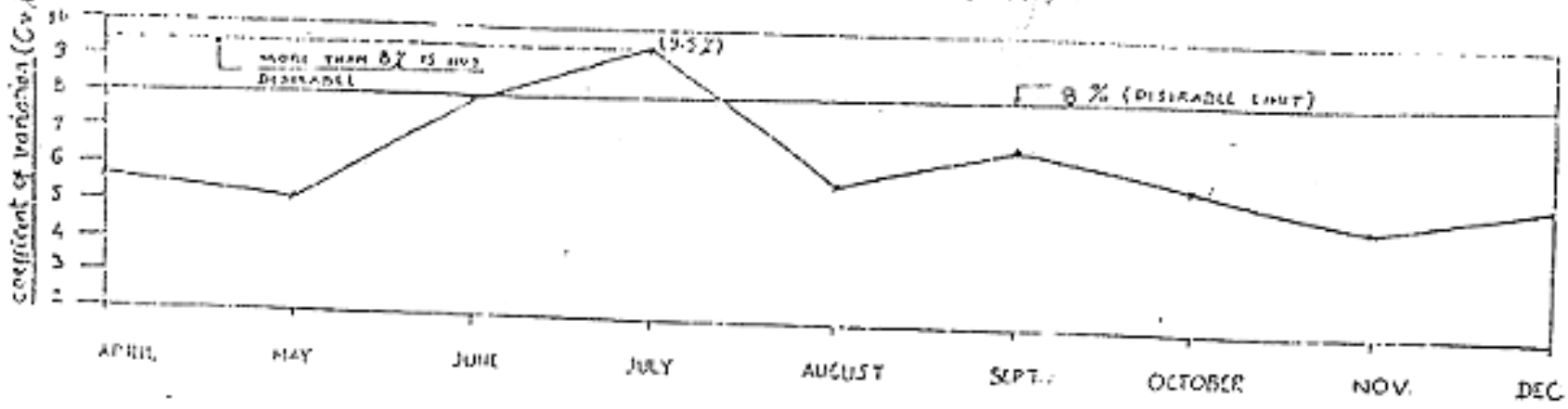
GRAPHICAL REPRESENTATION OF STANDARD DEVIATION



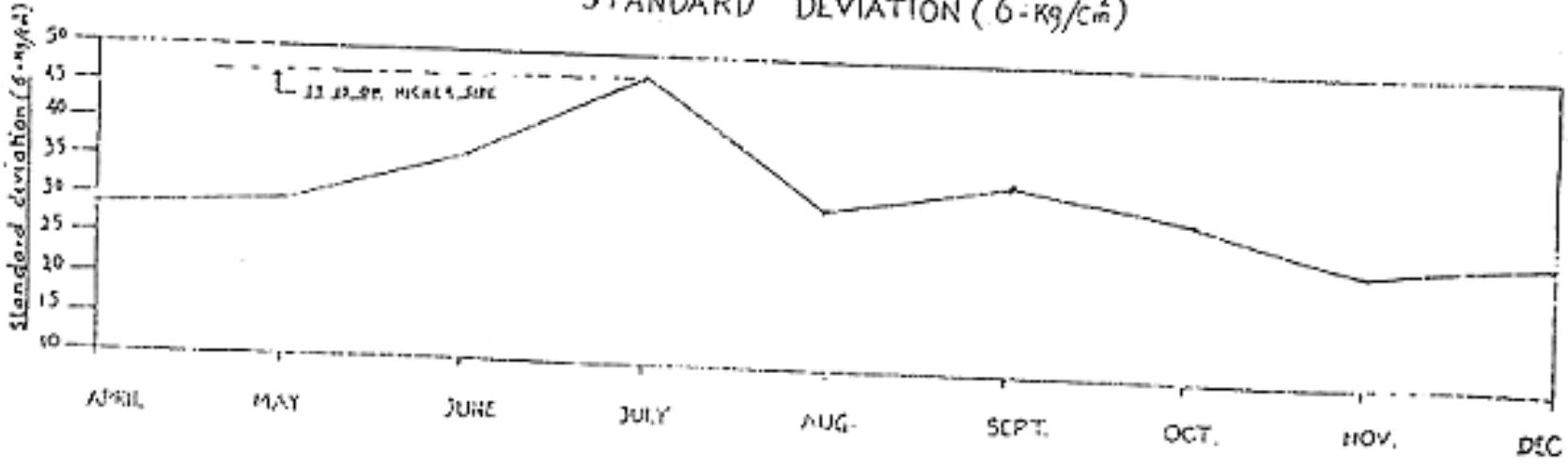
APPENDIX 3

CEMENT

CO-EFFICIENT OF VARIATION (Cv %)



STANDARD DEVIATION (6 - Kg/Cm²)



GRAPHICAL REPRESENTATION OF Cv & 6 (FOR ILLUSTRATION)

PROFORMA

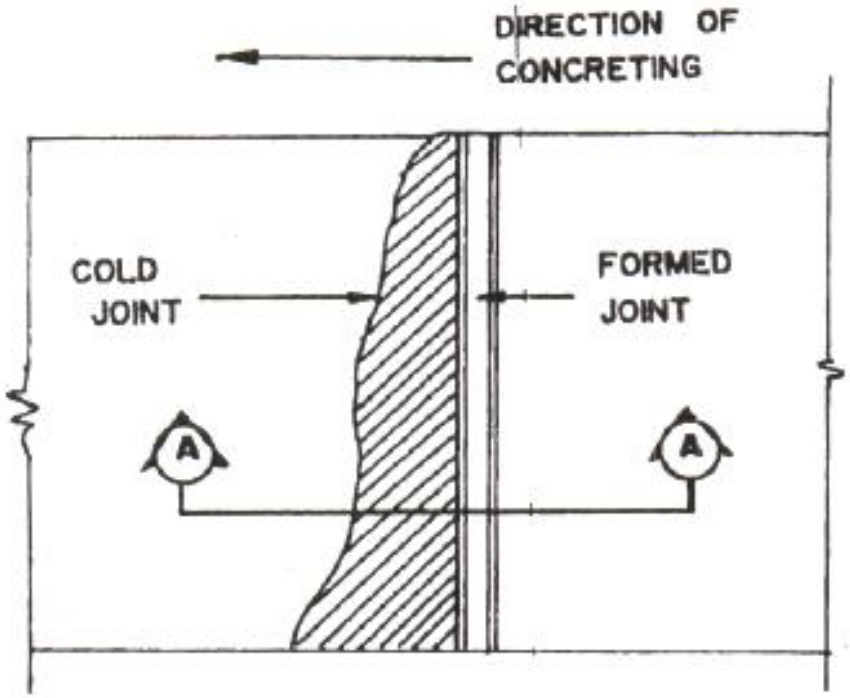
Test Results of Cement Samples

Name of Factory

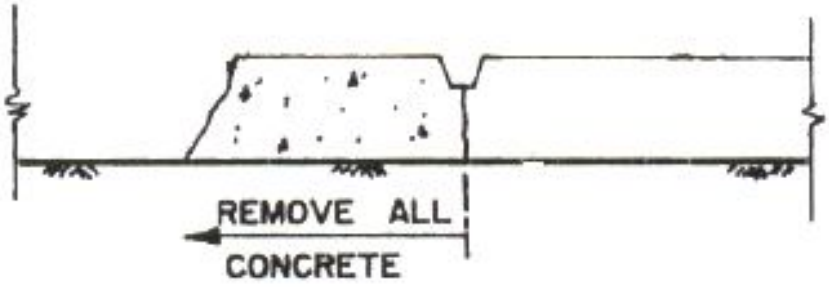
Tested at _____Laboratory

S.No	Particulars	Values for the Month of				Remarks
		Jan	Feb	Mar	May	
1	No. of test results(n)					
2	Av. Compressive strength at					
3	3 Days (Kg/Cm^2)					
4	Standard deviation (Sd) Co-efficient of variation (Cv)%					
5	Av. Compressive strength at					
6	7 days (Kg/Cm^2)					
7	Standard deviation (Sd) Co-efficient of variation (Cv)%					
8	Av. Compressive strength at					
9	28 days (Kg/Cm^2)					
10	Standard deviation (Sd) co-efficient of variation (Cv)%					

ANNEXURE – V



PLAN

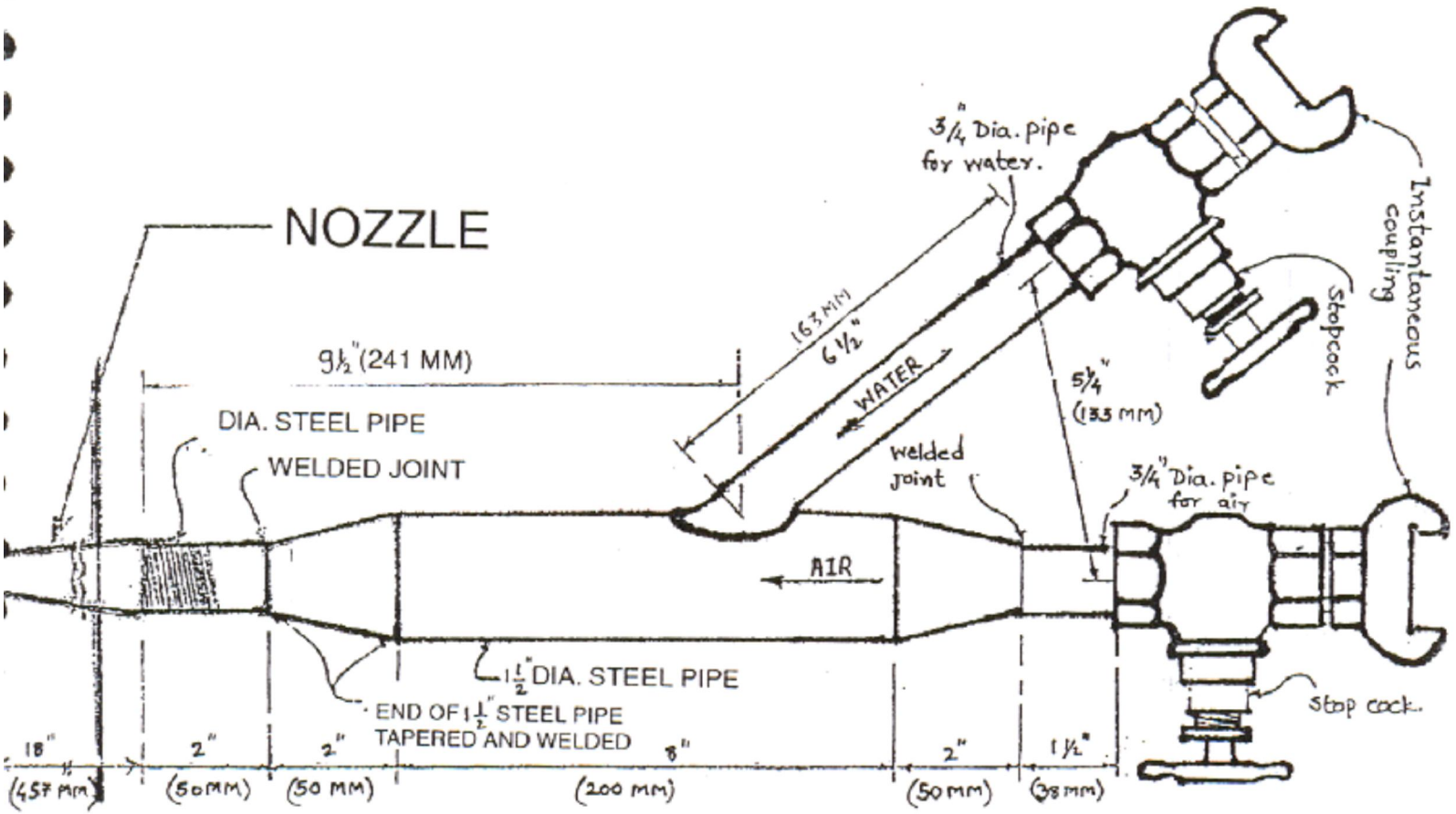


SECTION 'A - A'

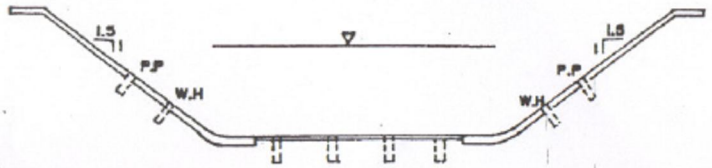
ELIMINATION OF COLD JOINTS

SKETCH SHOWING CONSTRUCTION JOINTS IN LINING

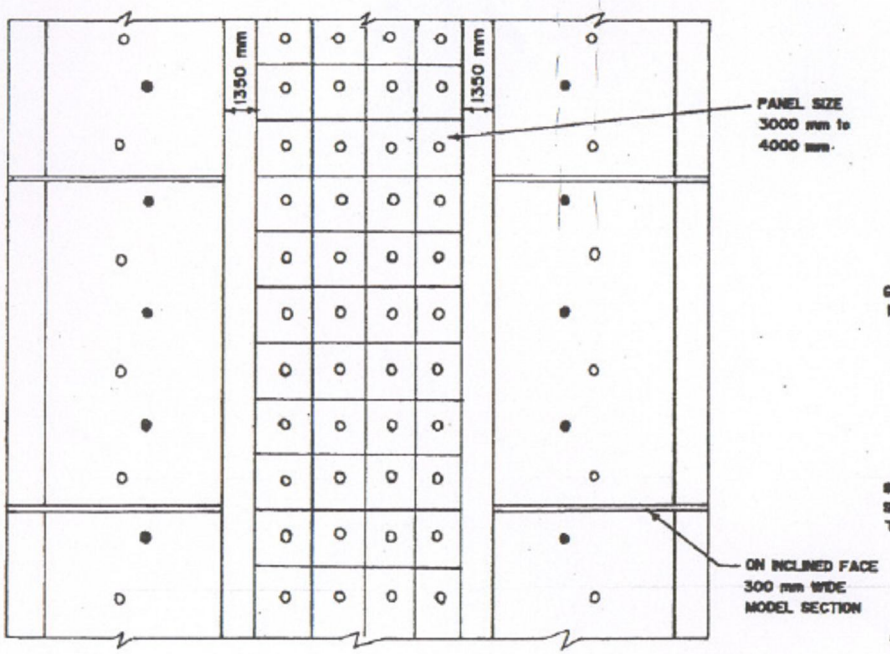
ANNEXURE – VI



PROPER AIR WATER GUN FOR GREEN CUTTING OF CONCRETE TO PREPARE GOOD CONSTRUCTION JOINTS



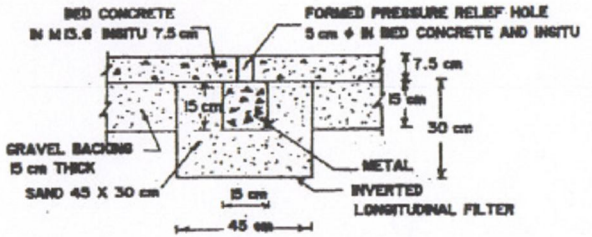
SECTION OF BED LINING



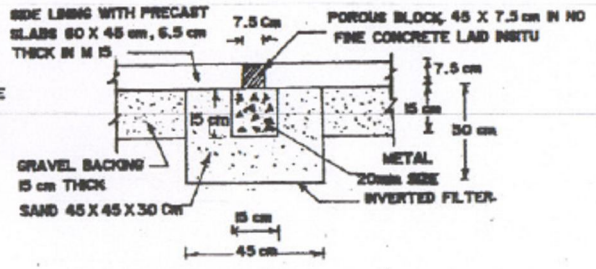
PLAN

O POROUS PLUG

● WEEP HOLES



PRESSURE RELIEF HOLE AT BED (SCALE 1 : 10)



WEEP HOLE AT SIDES (SCALE 1 : 10)

PRESSURE RELIEF HOLE AND LAYING CONCRETE IN PANELS

ANNEXURE – VII (A)

Extract of Para 7.1.3 on Specifications of Lining from C.B.I.P. Manual.

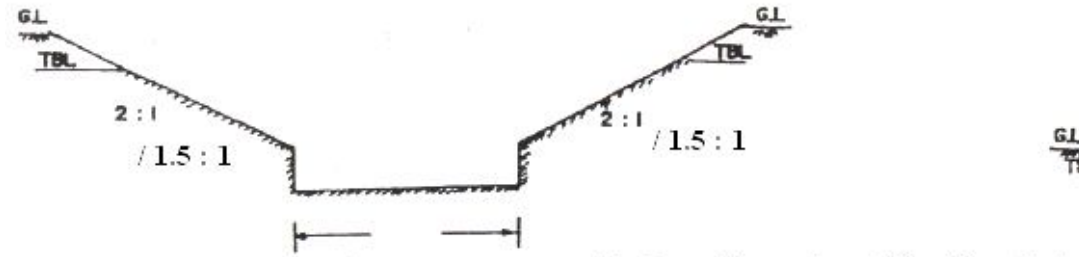
Lining should be avoided, as far as possible on expansive clays. However, if it is not possible and the canal proposed to be lined has to transverse a reach of expansive clays. Suitable Measures should be taken to prevent damage. These may comprise replacement of expansive soil by over-excavating the section and placing a layer of 15-30 cm thickness of suitable non-expansive soil duly compacted preferably good clean sand.

If the swelling of the clay encountered can be controlled by loading the surface with non-expansive compacted soil or gravel. The expansive clay bed should be over-excavated to depth of about 60 cm and filled to the grade of the underside of lining with good draining material leading away the seepage water to specially constructed points either to the outside of the canal or releasing it into the canal by provision of suitable pressure release valves. However, the excavated surface of expansive clay should be given a coat of asphalt before loading it to prevent the entry of water into clay.

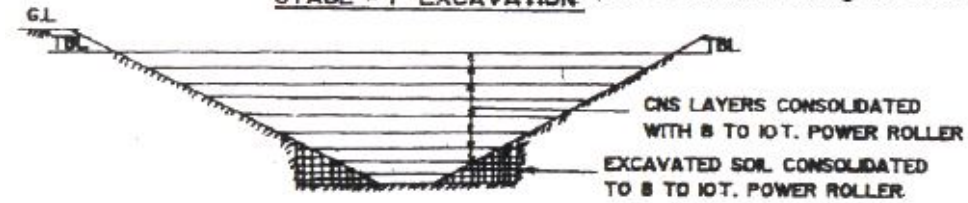
- Refer IS: 424-1965 specifications for Plastic Asphalt*.

ANNEXURE – VIIB

CUT & FILL METHOD FOR CNS TREAMENT IN SMALL SECTION CHANNEL

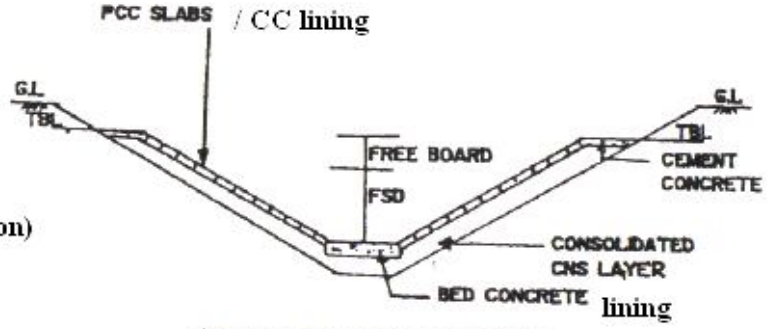


STAGE - I EXCAVATION (viz Over Excavating of Canal section)



STAGE - II - FILLING THE EXCAVATION
WITH CNS SOILS AND EXCAVATED SOILS

STAGE III - CUTTING THE FILLED SECTION TO THE REQUIRED THICKNSS OF
CONSOLIDATED CNS LAYER

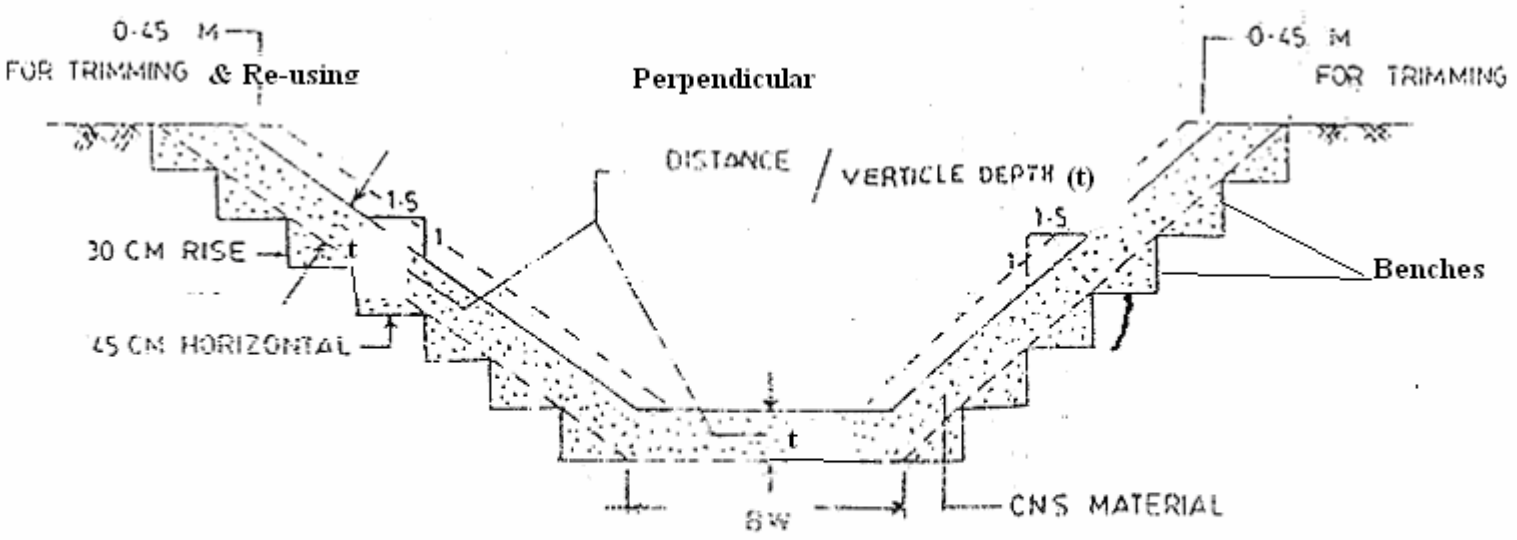


STAGE - IV - FINAL SECTION

ILLUSTRATIVE SKETCH SHOWING COMPACTION OF CNS SOIL IN DISTRIBUTORIES

ANNEXURE – VIIC

TREATMENT OF CANAL PRISM IN EXPANSIVE SOILS WITH CNS MATERIALS

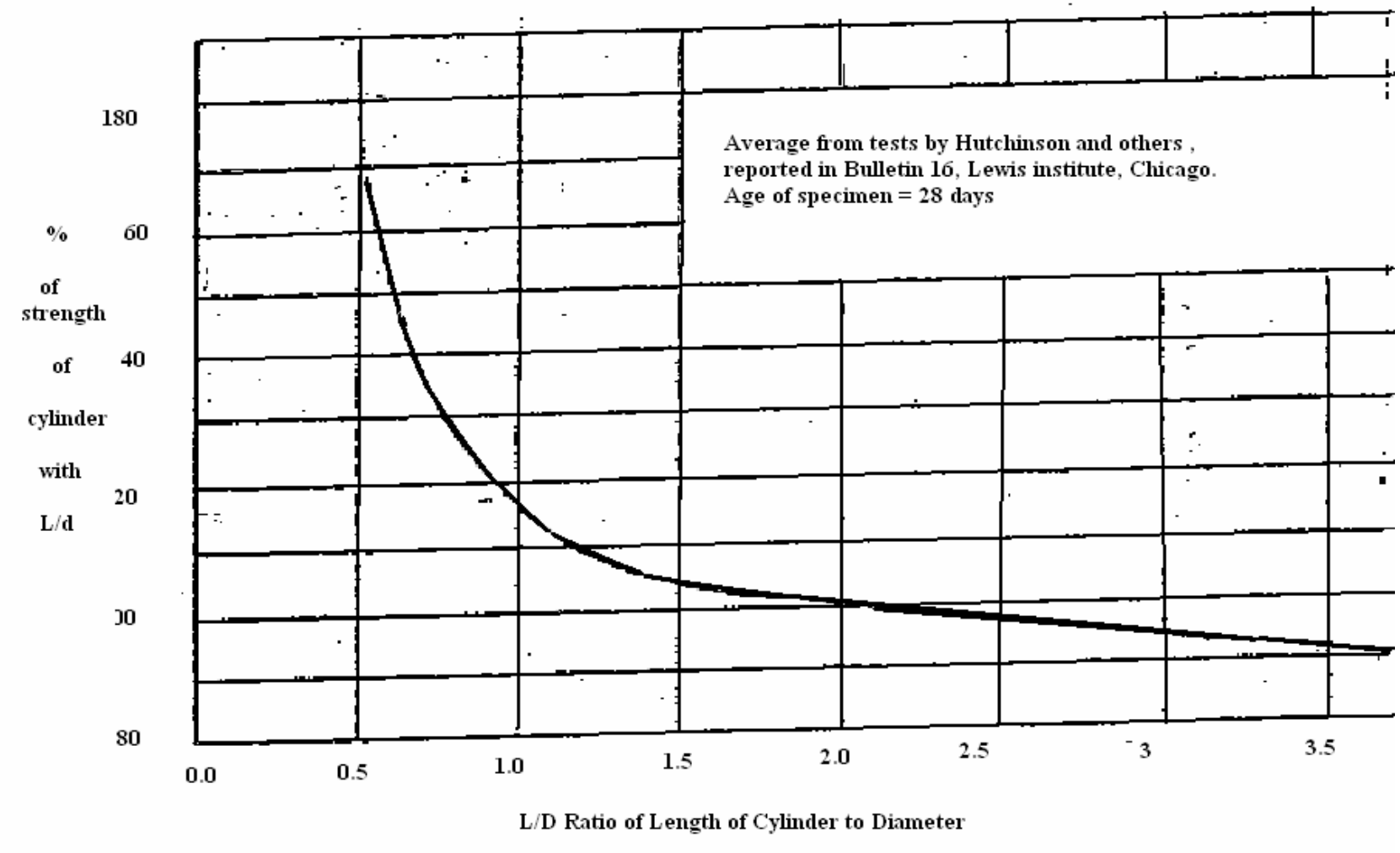


*** Thickness of CNS soil = t**
(governed by the swelling pressure of the soil as per IS 9451: 1994)

*** Extra width of 0.45m (for placement of CNS) is taken for deployment of power roller to ensure effective compaction to the specified density.**

ANNEXURE – VIII

CURVE SHOWING RELATION BETWEEN SPECIMEN SIZE AND STRENGTH OF CONCRETE CORE



Relation of length and diameter of specimen to compressive strength

ANNEXURE -IX

Data of the core taken from Instru Concrete canal lining

Name of Canal Grade of Concrete Mix

Reach Slump

Name of the Contractor W/C ratio

S.No	Chainage & Location of test core bedslopes	Thickness of lining exhibited by core (cm)	Density core gm/cc	Density of standard specimen prepared in Laboratory	Indicated compressive strength of core kg/cm^2	Compressive strength after correction kg/cm^2	Type of curing water or curing compound	Water absorption	Alkali reactivity test results of representative sample	Remarks
1	2	3	4	5	6	7	8	9	10	11

Paver

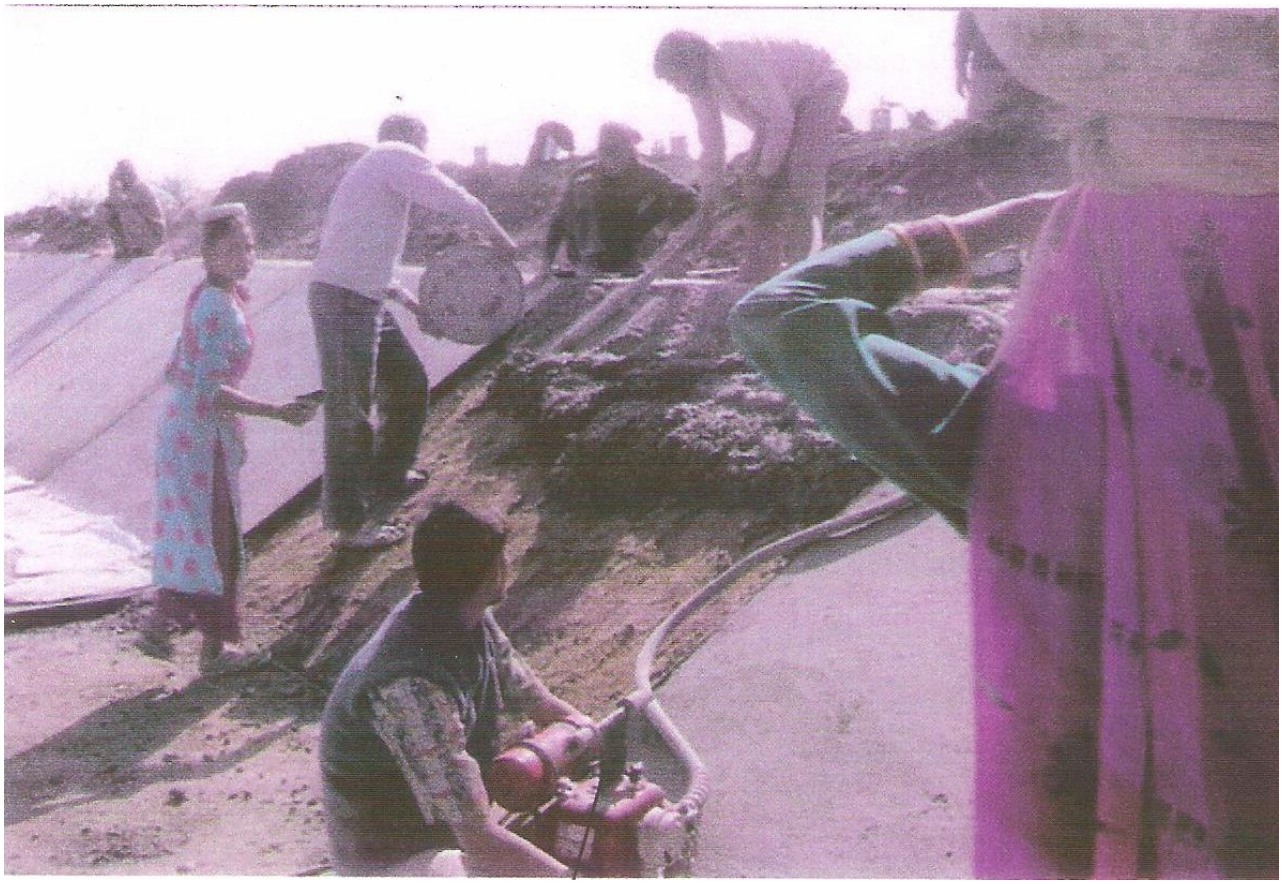
Paver Type	Rated Output On		Actual Average Output on	
	Bed Lining	Slope Lining	Bed Lining	Slope Lining
SL-450x (Gomaco) or of identical make	$15m^3$/hr (or $150m^2$/hr) for 10 cm thick lining	$10m^3$/hr (or$100m^2$/hr) for 10 cm thick lining	$10m^3$/hr (or$100m^2$/hr) for 10 cm thick lining or ($130m^2$/hr)	$10m^3$/hr (or$100m^2$/hr) for 10 cm thick lining
SL-750x (heavier version)	$40m^3$/hr (or $400m^2$/hr) for 10 cm thick lining	$30m^3$/hr (or $300m^2$/hr) for 10 cm thick lining	$22m^3$/hr (or $220m^2$/hr) for 10 cm thick lining	$15m^3$/hr (or $150m^2$/hr) for 10 cm thick lining

Mechanical Trimmer Type	Rated Capacity of Trimming	Average Actual Out put
Gomaco SL 450T	$200m^2$/hr (2.8cm to 4.0 cm cut in a single pass) or on depth of cut is about ±3 to 3.5 cum	$60m^2$/hr (depth of cut in a single pass was only 2.5 cum)
Gomaco SL-750 T (Heavy Duty Trimmer)	$400m^2$/hr (with a rated capacity to cut 10cum in a single pass)	$125m^2$/hr (depth of cut in a single pass was only 4.0 cum)

PHOTOS

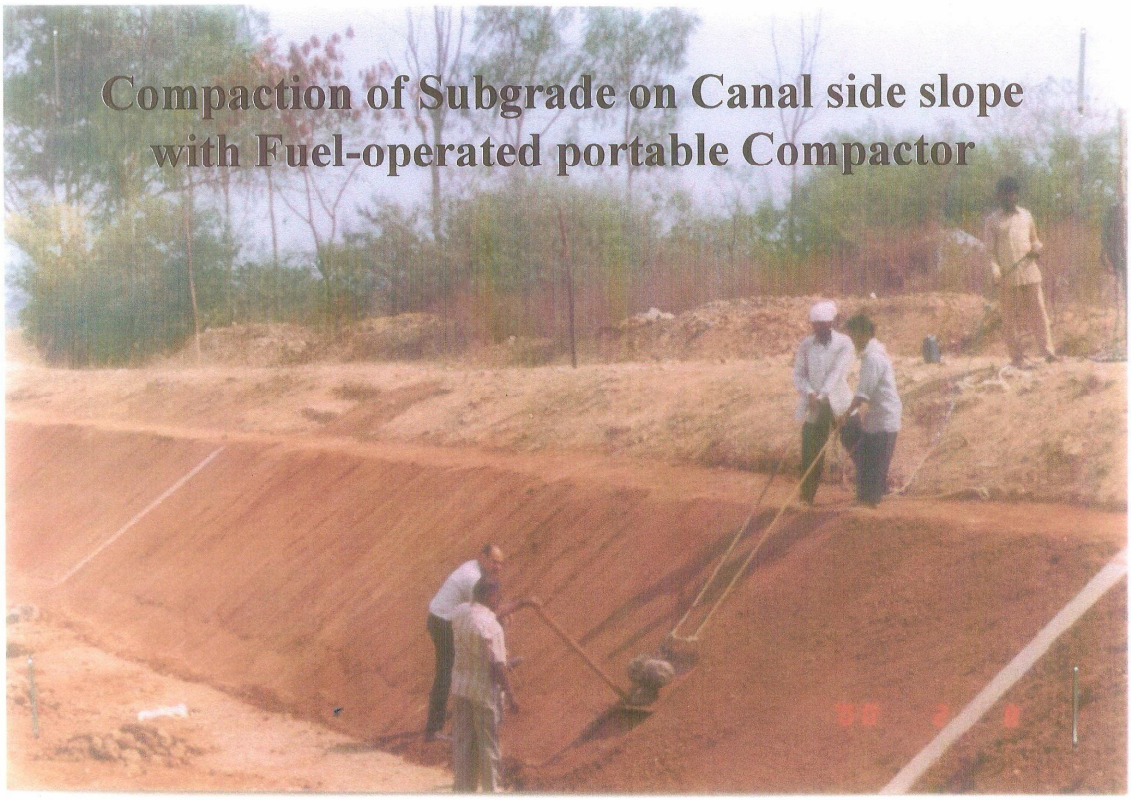
FUEL-OPERATED PLATE VIBRATOR FOR CONSOLIDATION OF CC LINING ON CANAL SLOPE

Portable Electronic Devices for Quick on-Site Measurement of Moisture content in place density & compaction efficiency during compaction of sub grade/embankment



1 HP ENGINE (PETROL/KEROSENE DRIVEN)

FUEL OPERATED PLATE VIBRATOR FOR CONSOLIDATION OF CC LINING ON CANAL SLOPE

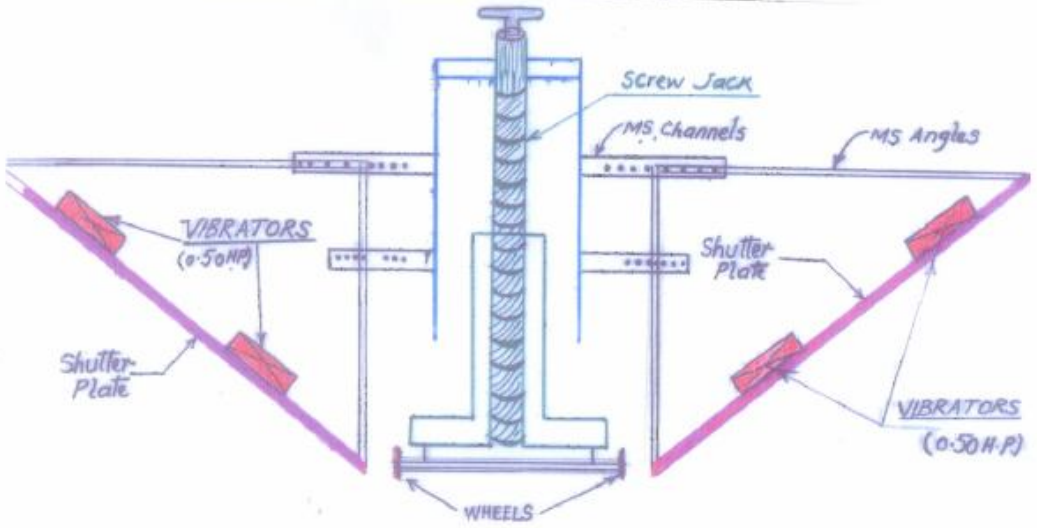


COMPACTION OF SUB GRADE ON CANAL SIDE SLOPE WITH FUEL-OPERATED PORTABLE COMPACTOR

ONE METER WIDE VIBRATORY ROLLER
BEING USED FOR EARTH FILL COMPACTION

ACROW GANTRY

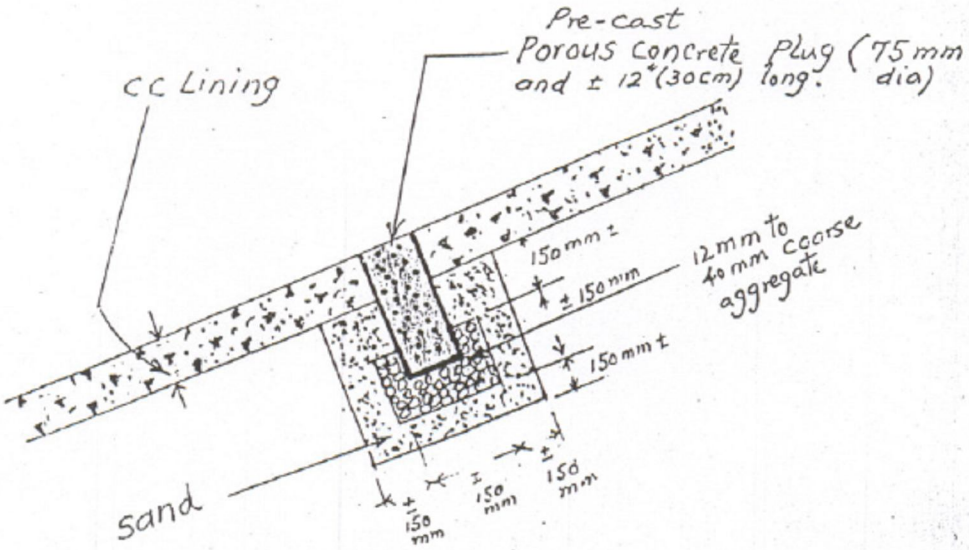
Mobile " Self-Loading, Weigh batching, and Mixing as well as transporting concrete mixer " (viz mobile B & M Plant)



STEEL SHUTTER GANTRY
for
PLACEMENT OF C.C LINING ON SIDES

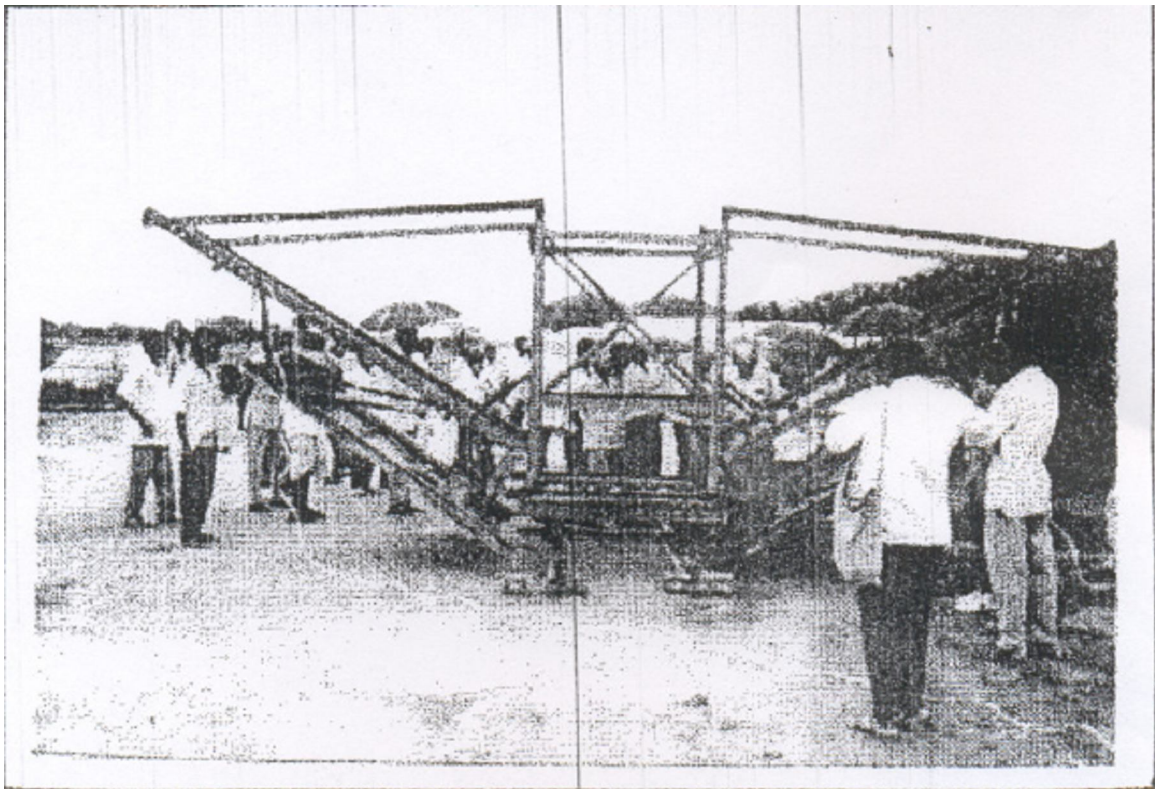
Under-Drainage Arrangement for Lining.

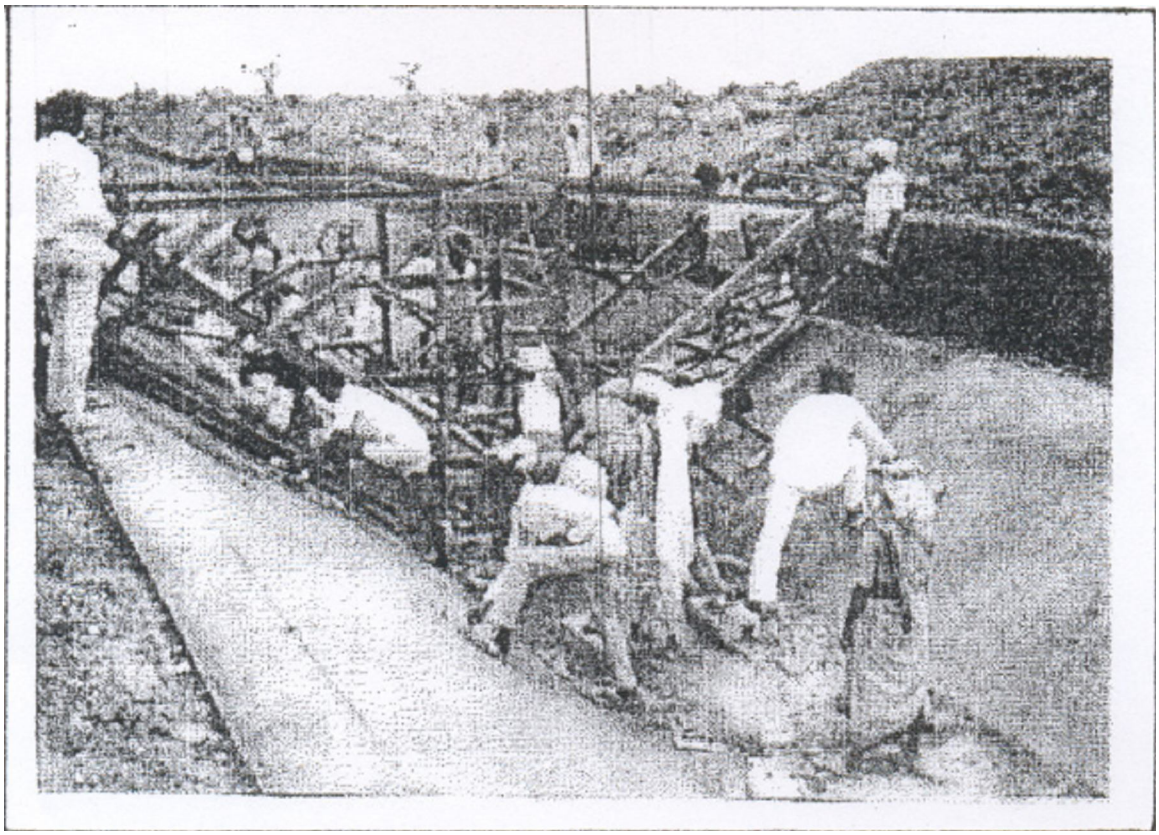
A Typical Porous Plug



- Precast Porous concrete Plug (Cement : 1 & Coarse aggregate : 4) of MSA 20 mm

NO SAND is to be used.





ACROW TYPE SHUTTERING FOR CANAL LINING