GOVERNMENT OF MADHYA PRADESH
WATER RESOURCES DEPARTMENT

QUALITY CONTROL MANUAL
VOLUME-1

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CHAPTER - 1

INTRODUCTION

1.1 GENERAL

The importance of quality control for construction work of Irrigation projects needs no emphasis. Irrigation projects involve heavy expenditure and contribute to the prosperity of the State. If the projects are not executed with desired quality, then the constructed structure may get damaged, leading to loss of human lives too. As such construction should proceed with diligence as per prescribed specification. To ensure execution of work as per specified standards, effective control on quality is essential. By “Control” we mean guidance or direction. As such “Control of Quality” is an activity to achieve a particular standard of work, which would produce such a structure that serve its purpose and attain the required standard fixed up by the designer, at minimum overall cost.

The basic elements of the “Control” procedure in case of Civil Engineering works are very simple.

1.1.1 In case of works for Earthen dam, these are:-

1. Adoption of proper zones of soil.
2. Use of right soils in proper zones.
3. Insistence upon proper compaction.
4. Control over moisture.
5. Proper drainage system inside the dam as well as outside.

1.1.2 In case of works of Concrete, such basic elements are:-

1. Designing of proper mix.
2. Use of Weigh batching.
3. Use of Controlled grading.
4. Production of constant workability.
5. Insistence upon full compaction of the concrete.

1.1.3 Where the work consists of Masonry (Cement, lime or surkhi) these elements would be:-

1. Use of proper stones of required crushing strength and absorption.
2. Correction for bulkage of sand and grading.

3. Designing of mortar mix.
4. Achieving proper calcination, grinding and sieving in case of surkhi.
5. Checking use of surkhi as pozzolana or inert material.

1.1.4 Where steel be used:-

1. It should be as per I.S.S., if tested; or
2. If non-tested, the same should be got tested.

1.2 OBJECTIVES

The objective of quality control is to help the construction staff for achieving high order of quality as laid down in the specifications, by diagnosing and controlling various factors responsible for deterioration in quality. Investigating reasons and suggesting ways and means for improvements without putting hindrance in the progress of construction work.

The person connected with the quality control of works should possess adequate knowledge and experience of quality control methods and be conversant with testing procedures of construction materials. The objective should be clearly understood by him in letter and spirit.

The suitability of foundation materials on which the irrigation and other hydraulic structures are erected, the suitability of materials used for their construction, the care with which the construction is carried out as per specifications and proper & optimum design, the degree of post construction maintenance, all these affects the safety, reliability, durability, economy of construction and optimum use of scarce building materials and efficient use of the precious natural resources. Evolving better testing procedures, equipping the testing centre with better, and modern testing facilities and using modern technological innovations in updating them should be continuous endeavor to maintain and if possible to improve the quality standard of the work.

For fulfilling the objectives, following points should be kept in mind-

1.2.1 The significant parameters of design methods are to be formulated, specifications regarding the acceptability and regulations on the allowable variations are laid down. These should be continuously reviewed and should incorporate the latest innovations in science and technology from time to time.

1.2.2 The use of accurate and even elaborate, methods of testing in the research laboratory requires no justification. The extent to which these methods should be adopted in routine testing depends largely upon whether they reduce the margin of uncertainty in design sufficiently to justify their cost.

1.2.3 The quality control in particular, aims at reducing the discrepancies in the quality of different items of same finished product with a view to decrease scrap, rejection, repair, spillage, over-sizing, under-sizing etc. Thus ensuring construction so as to match with the assumptions made in design, to the maximum possible extent.

1.3 TECHNOLOGIES INVOLVED IN QUALITY CONTROL

Successful implementation of modern quality control involved various technologies listed below and their right mix-up in any given situation.

(i) Management of personnel’s;
(ii) Engineering Knowledge i.e. specifications and testing procedures;
(iii) Statistical knowledge for interpretation of results and
(iv) Documentations and evaluation.

1.4 NECESSITY OF TRAINED PERSONNELS

For carrying out various tests on suitability of materials to be used in the construction and ensure good and acceptable quality of work, experienced and trained persons are essentially required in view of following facts:-

1.4.1 Various types of structures have to be built using different kinds of materials. The quality of the structure depends upon the quality of the material used. The testing of the materials of construction is therefore, an important activity to be taken up much before the construction starts. Even during the process of construction, the concrete and mortar made up of tested ingredients have to be tested for their quality to ascertain correctness of the procedures of mixing, curing and the net results. Thus testing of materials and quality control go now hand in hand. They are of great importance to check and ensure the expected results of all the efforts and money spent in building the structure.

1.4.2 The role of soil as foundation material and as a construction material is of great importance in engineering, because most of the structures rest on soil and majority of dams constructed are earthen dams. Owing to the variable and complicated behavior of soil, its properties have to be tested to ensure construction of a safe and sound structure. Generally the soil has to be used are as available at site and the choice of soils is limited. In addition to its variable nature from place to place, soil is difficult to deal with because of its complex physical properties. Soil mechanics is not an exact science and for rational decisions in soil engineering, routine procedures should be given importance only to develop sound judgment. The field engineer has to use his knowledge and experience in applying results of the laboratory tests to an actual soil problem because there are many conditions such as soil disturbance during sampling and unknown boundary conditions in nature. For such problems, the laboratory test will serve only as a guide to the designer where as field test will often be required. A proper perspective on the role of laboratory testing in soil mechanics has to be developed. The properties of the soil in question are determined by suitably designed laboratory tests and field tests for employing the results to work out a solution to a problem in soil engineering. Since every site will have soils of different properties, testing of the soil is required for practically every situation.

1.4.3 Concrete is made with cement, sand, coarse aggregate and water but additives and admixtures can also be used for modifying and improving the properties of concrete. The mixture of the four main ingredients is converted to a hard mass, due to the chemical reactions between cement and water, each of the ingredients has its separate function. Coarse aggregate acts as a main filler, sand (fine aggregate) fills in the voids in the coarse aggregate, cement and water form the binder.

1.4.4 The science of proportioning of concrete is therefore mainly concentrated on the principle of obtaining a durable and strong concrete at the most economical rate possessing a good workability.

1.5 STAGES OF CONTROL

1.5.1 The quality control shall be exercised at three stages i.e,

(i) Selection of materials
(ii) Processing of materials and
(iii) Execution of works.

1.5.1.1 **SELECTION OF MATERIALS**: - Selected raw materials shall only be used in construction. In the case of manufactured articles such as steel, cement etc. certain guarantee of the properties is already available, but some check is still needed to ensure the quality. In the case of materials like stone, sand, soils etc. the properties vary from place to place and selection of right type of material depends upon proper determination of properties of materials by conducting test in the laboratory.

Major compounds in Portland Cement:

In all the Portland cements, there are four major compounds. the variation in percentage composition of compounds influences the properties of cement. These compound are given in table below:

Sl. No.	Name of Compound	Oxide composition	Abbreviations	Approximate percentage	Function
1	Tricalcium Silicate	$3CaO.SiO_2$	C_3S	45-55 %	Mainly responsible for early strength (1 to 7 days)
2	Dicalcium Silicate	$2CaO.SiO_2$	C_2S	20-30 %	Mainly responsible for later date strength (7 days and beyond)
3	Tricalcium Aluminate	$3CaO.Al_2O_3$	C_3A	6-10 %	C_3A increases rate of hydration of C_3S . C_3A gives flash set in absence of gypsum. its contribution to strength is low.
4	Tetracalcium Aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	15-20 %	it hydrates rapidly but its contribution to strength is uncertain and generally very low.

Cement Types and Adoptability : As per the Bureau of Indian Standards , no cement can be marketed to the retail consumers without IS certification mark. The Bureau of Indian Standards has issued the codes shown below:

Sl.No.	IS Codes	Cement Type	Applicability for
1	IS 269:2013	Specification for 33 Grade OPC (First Revision)	For general civil engineering works especially for mass concrete under normal environmental conditions. Normally not used where high grade of concrete viz. M-20 & above is required.
2	IS 455: 1989	Specification for Portland Slag Cement (4th Revision)	All civil engineering works but has more advantage for Marine and coastal structures, Sewage disposal and treatments works, Underground Structures, Water treatment plants & the structures which are expected to be attacked by dissolved chlorides and sulphate ions either in soil, water or environment.
3	IS 1489 (Part 1):1991	Specification for Portland Pozzolana Cement Part 1- Fly ash based(Third Revision)	All types of civil engineering works & ideally suited for Hydraulic Structures , Mass concreting works, Marine structures, Masonry mortars and plastering, Under aggressive Conditions.
4	IS 1489 (Part 2):1991	Specification for Portland Pozzolana Cement Part 2- Calcined clay based (Third Revision)	
5	IS 3466 :1988	Specification for Masonry Cement (Second Revision)	Used for Masonry mortars, stones and concrete block masonry and for rendering and plastering works.
6	IS 6909 :1990	Specification for Super Sulphated Cement (First Revision)	Marine and coastal works , Mass concrete jobs, Aggressive conditions, RCC pipes in ground water, Chemical works where concrete is exposed to high

			concentrations of sulphates, Concrete sewers carrying industrial and sulphatic effluents.
7	IS 8041 : 1990	Specification for Rapid hardening Portland Cement (Second Revision)	Used for repair and rehabilitation works and where speed of construction and early completion is required due to limitations of time, space or other reasons.
8	IS 8042 : 1989	Specification for white Portland Cement (Second Revision)	Used for architectural purposes such as mosaic tiles, wall paintings and special effects. Very good quality white cement equivalent to that of 43/53 grade OPC can be used for structural concrete also.
9	IS 8112 : 2013	Specifications for 43 Grade Ordinary Portland Cement (First Revision)	General Civil Engineering construction works, RCC works(Preferably where grade of concrete is up to M-30), Precast items such as blocks, tiles, pipes etc, Asbestos products such as sheets and pipes & non structural works such as masonry mortars, plastering , flooring etc.
10	IS 12269:2013	Specification for 53 Grade Ordinary Portland Cement (First Revision)	RCC works(Preferably where grade of concrete is M-25 and above), Precast concrete items such as paving blocks, tiles, building blocks etc, Pre-stressed concrete components, Runways, concrete roads, bridges etc. Multi- storey buildings and tall structures,
11	IS 12600 : 1989	Specification for low heat Portland Cement	it is particularly suited for making concrete for dams and many other types of water retaining structure, bridge abutments, massive retaining walls. piers and flat slabs etc

1.5.1.2 **PROCESSING OF MATERIALS: -** The raw materials required for construction shall be processed before execution of works. For certain process there are no tests to check that processing is being done properly. It is only the properties of final product that reveal the inadequacies of processing.

1.5.1.3 **EXECUTION OF WORKS**:- Checking the properties of final product helps in different ways i.e.

(i) In determining whether quality control has been exercised fully, properly and according to the specifications.
(ii) In rejecting the defective product in time and replacing it, by a proper one and
(iii)In knowing whether design assumptions are being fulfilled or any modifications are required in design itself.

1.6 MEANS OF QUALITY CONTROL

1.6.1 The quality control shall be done by (i) Testing of Materials, (ii) Supervision during execution and (iii) Analysis and interpretation of the test results.

1.6.1.1 **TESTING:** Testing shall be done for determining the properties of materials which helps in their selection as well as in ascertaining the quality of the product. The standard type of equipments or apparatus shall be used for conducting tests.

1.6.1.2 **SUPERVISION:** - The officers responsible for construction shall supervise the work during construction for ensuring the quality of works by frequent inspections and shall issue inspection notes for follow up action.

1.6.1.3 **COMPILATION, ANALYSIS AND INTERPRETATION OF TEST RESULTS:** Compilation, analysis and interpretations of test results shall be done systematically considering the specifications and design, every month. The analysis and interpretation shall be based on sufficient data of test results.

1.7 STATISTICAL QUALITY CONTROL

1.7.1 Despite all efforts to execute a work in strict accordance with specifications, variations do occur. If a number of cubes or cylinders be made from a single mix of concrete with all possible precautions, the observed strength of these cubes or cylinders will by no means be identical but might well vary over a range of 30 Kg. per sq.cm. if a second mix be made and tested, a similar spread will be found and in addition the results may be on the average somewhat higher or lower than those from the first mix. Similarly, in case of compacted earth-fill, its properties such as water content or density are bound to vary. These variations cannot be attributed to faulty workmanship as the same are invariably inherent in the process.

1.7.2 The aim of QUALITY CONTROL is to reduce such variations and achieved homogeneity. This is best ascertained by an application of statistical Mathematics and is referred to as "Statistical Quality Control" (S.Q.C.).

1.7.3 Statistical method is a method for dealing with data that have been obtained by repetitive operations. Experience indicates that many repetitive operations behave as though occurred under essentially stable conditions, that is there is only one variable to be measured by the operations. The field density tests, the standard laboratory compaction tests of Earth work, crushing strengths of cubes or cylinders of cement concrete or cement/lime mortars are considered to be repetitive operations fitting this condition. In other words variations of test results due to testing or sampling techniques are ignored and the property under test of the material like soil, mortar, concrete etc. is assumed to be the only variable to be measured.

1.7.4 The main differences between the usual methods of Quality Control and statistical Quality Control, is that ordinarily a product is first manufactured and then inspected so that remedial actions on defects if any, have to be taken afterwards, though the defective products continue. In contrast, Statistical Quality Control produces technique which help to feed back data very quickly in production process and thereby helps in taking corrective action as soon as a defect develops in the process, many a time even giving warning before hand. In this manner defective work can either be eliminated or minimized with this help of statistical Quality Control technique. This will be further clarified in the coming paras when application of this technique to works in progress at present will be described.

1.7.5 The concept of S.Q.C. was introduced in 1924 in a systematic way by Dr W.A. Shewart, Japan, notorious for inferior quality goods prior to world war – II-took advantage in 1950 of S.Q.C. technique and brought about a spectacular improvement in Quality along with reduction in cost of production. Attempts to introduce S.Q.C. in India were started in 1944 earlier than in Japan, but the progress in our country has been very slow in this field. Dr Shewart was invited in India in 1947 to deliver lectures on this subject.

1.7.6 Variations in any process are results of two factors namely uncontrollable factors, and controllable factors. Problems of Quality Control is just to find out the presence of these controllable factors, so as to be able to preserve the quality at the optimum level with the minimum of non-uniformity.

1.7.7 Statistical concepts embody the theory that in any controlled process there is a degree of uncontrolled (Random) variation and that commonly this uncontrolled variation can be well represented by a "Normal- Distribution Curve".

1.7.8 The law of normal distribution is a law of nature and its effect is visible in all measurable characteristics. As an example if we consider heights of people, it can be seen that there are more people of average or near average height and less of extreme heights. Thus, if any measurable characteristic is plotted against frequency, a bell-shaped curved is obtained, provided of course that there are enough samples.

1.7.9 Such a frequency distribution curve helps us in knowing-

a) Distribution around a certain maximum (called average) and

b) Variation.

1.7.10 It also informs us at once whether data has been properly collected by random sampling, as only such data will approximate to the bell curve. No matter how many examples, the natural range of variation is constant provided the set of conditions remain the same.

1.7.11 Thus normal distribution curve can usually be considered to present any random variation and permits characterization of the random variation in terms of only two quantities namely "the average" X called ex-bar and "the standard deviation" called sigma.

1.7.12 while the average value of test data is easily understood and readily computed, it has certain disadvantages as a reliable measure of Quality Control.

1.7.13 The statistical Quality Control technique assists the Quality Control officer by pointing out when exactly the construction engineers special attention is to be called in to tighten up the control measures and the location in the work where such measures are necessarily and that if it is essential to revise the design suitable to suit the actual degree or control in the work

1.8 VARIOUS PHASES OF OVERALL QUALITY CONTROL

The various phases of overall quality control can be presented as in this flow diagram.

Preliminary Surveys to assess

I. Suitability of foundation Materials.
II. Cost of construction including materials, men, machinery and maintenance.
III. Availability of materials required for construction.

Quality control of Design

I. Reliability
II. Environmental affects.
III. Value engineering
IV. Producibility

Quality Control of Construction

I. Input material control
II. Process control
III. Cost control
IV. Tools control

Quality Control of performance of end product

I. Meeting functional requirements
II. Usability
III. Ease of maintenance
IV. Durability
V. Safety

CHAPTER - 2

ORGANIZATIONAL SET-UP

A separate quality control Unit shall be established for all dams and for structures costing more than Rs 45 Crores. For other works quality control unit sufficient to carry out the tests as specified in Annexure no. 1of Vol II shall be established.

2.1 ORGANIZATIONAL SET-UP

Organizational set up shall be as under:-

i) For each major project, one quality control circle headed by Superintending Engineer, with Quality Control Division and Sub Divisions as per actual requirement.

ii) For each medium project CCA more than 5000 hectare. One Quality Control Division headed by an Executive Engineer / Research Officer, with Sub- Divisions as per actual requirement. In case of non irrigation projects norms will be worked out assuming 200 hec.per MCM consumption of water.

iii) For each medium project costing less than Rs 45 Crores, One Quality Control Sub Division headed by an Assistant Engineer/ Assistant Research Officer.

No separate quality control staffs need to be posted on individual minor irrigation Project but the Executive Staff posted shall be trained in taking samples, carrying-out field tests themselves and interpret the results. 10 percent of the samples, taken shall be got tested at Circle level laboratories. The Superintending Engineer shall be responsible to ensure that adequate training is given in circle laboratory to the executive staff posted on such project.

ALTERNATIVE PROPOSAL FOR MINOR IRRGATION WORKS:
For Medium Irrigation Projects generally, the quality control is required for each work. For which it is proposed that a Q.C. unit be established directly under the Executive Engineer In-Charge of the division. The head of the unit being A.O. attached in the Division and Sub-Engineer/Embankment

Inspector will be attached to A.O. to look after the work of whole division. The Sub Engineer will be attached to A.O. from the existing sanctioned strength of the division. This unit will not get any additional staff to be posted to Division. The work will be got done by the existing staff of the division

2.2 FUNCTIONS OF LABORATORIES: -

Each major / medium project will have a main laboratory under Research Officer / Assistant Research Officer / Assistant Engineer for carrying out the test specified in Annexure No. 1 in Vol. II. In addition, field laboratories shall be established at work sites which will be part of the main laboratory to conduct daily routine tests.

2.2.1 FUNCTIONS OF MAIN LABORATORY:-

2.2.1.1 To conduct laboratory tests on samples of Cement, Sand, Aggregates, Stones etc., for use in masonry and concrete works.

2.2.1.2 To conduct laboratory tests for selection of Soils from proposed borrow areas for use in the various zones of embankment.

2.2.1.3 To fix proportions of mortar for masonry work and proportions of ingredients for concrete work as per prescribed specifications.

2.2.1.4 To evolve various mix designs of concrete and mortars to be used in works and to make modifications, if necessary.

2.2.1.5 To organize test procedures and to submit daily reports on the quality of works to the concerned authorities.

2.2.2 FUNCTIONS OF FIELD LABORATORIES / MOBILE LAB:-

2.2.2.1 To carry out routine daily tests of soils and filter materials such as moisture content, needle density tests, field density tests etc and to take samples from compacted fill from different zones of the embankment.

2.2.2.2 To carry routine daily test like silt test of fine aggregates, surface moisture content tests of fine & coarse aggregates, bulking of fine aggregates, slump test of concrete, consistency tests of mortar and to collect samples of concrete and mortar to fill in moulds as per approved frequency.

2.2.2.3 To transport concrete/ mortar test specimens to main laboratory for curing and testing.

2.2.2.4 To prepare daily reports of test in prescribed proforma for compilation in main laboratory and communicating to the officer- in charge of execution.

2.3 STAFF PATTERN

2.3.1 The Technical and Ministerial staff required for one Quality Control circle, Division and Sub Division is given below. The requirement of Division and Sub Division is as per Sanction accorded by G.O.M.P. letter no. 2/40/82/p/31/Date 16/12/82. In Addition some more staff is also proposed looking to the present system. For circle the normal required staff, is shown below:

2.3.2 STAFF REQUIRED FOR QUALITY CONTROL CIRCLE

Table :1

S.No	Post	No.	Duty Entrusted
1	Superintending Engineer/R.O. (Quality Control)	1	Overall incharge of Quality Control work of Major Project
2	A. R. O.	1	To work in S.E.'s Office
3	Drafts man	1	To work in S.E.'s Office
4	Assistant Draftsman	2	To work in S.E.'s Office
5	Tracer	2	To work in S.E.'s Office
6	Head Assistant	1	To work in S.E.'s Office
7	Asstt. Grade II	2	To work in S.E.'s Office
8	Asstt. Grade III	2	For office work
9	Computer Operator/ Data Entry Operator	1	For entry of Data and Computer work
10	Steno Typist	1	To Assist Director and office work
11	Poen/ Daftari / Dak Runner	3	Work as a post
12	Driver	1	For Driving of Vehicle
13	Watch Man	2	To work as a security guard

2.3.3 STAFF REQUIRED FOR QUALITY CONTROL DIVISION

Table :2

S.No	Post	No.	Duty Entrusted
1	Executive. Engineer / /Research Officer(Quality Control)	1	Overall Incharge of Quality control work
2	A. R. O.	1	To Assist the E.E. / R.O.
3	Research Assistant	1	To Assist the E.E. / R.O.

4	Draftsman	1	To work under E.E. / R/O. in office
5	Assistant Draftsman	2	To work under E.E. / R/O. in office
6	Tracer	1	To work under E.E. / R/O. in office
7	Head Assistant/ Assistant Grade II	1	To work under E.E. / R/O. in office
8	Assistant Grade III	1	To work under E.E. / R/O. in office
9	Computer Operator/ Data Entry Operator	1	To work under E.E. / R/O. in office
10	Steno	1	To work under E.E. / R/O. in office
11	Peon	2	Work according to Post
12	Watch Man	2	For Security of Office
13	Dak Runner	1	To Distribute Dak
14	Driver	1	For Driving of Vehicle

2.3.4 STAFF REQUIRED FOR QUALITY CONTROL SUB-DIVISION /UNIT/MOBILE LAB

Table: 3

S.No	Post	No.	Duty Entrusted
1	Assistant. Engineer / Assistant Research Officer Quality Control	1	Over all in charge of Quality Control Work
2	Research Assistant/ Embankment Inspector	5	For Testing Work of Soil, materials, Concrete and mortar mixes, submission of results
3	Laboratory Technician	1	To Assist RA , EI
4	Laboratory Assistant	1	To Assist L T
5	Laboratory Attendant	5	To Assist RA / EI / LT
6	Head Assistant/ Assistant Grade II	2	For office work
7	Assistant Grade III	1	For office work
8	Computer Operator	1	For office work
9	Driver	1	For Driving of Vehicle
10	Peon	2	Work according to Post
11	Watch Man(Chaukidar)	2	For Security of office
12	Dak Runner	1	To distribute dak

2.4 TRAINING OF STAFF

2.4.1 All the supervisory staff right from the Time Keeper/ Work Mistry up to Executive Engineer in charge of Project / work should be given proper adequate training. The importance of the quality of the execution should be brought to them by imparting minimum training as specified below:-

2.4.2 **Time Keeper / Work Mistry**: Time Keeper is last but not the least and a very important person who gets all the work done but without any responsibility fixed. Therefore he should be taught as to how the quality and workmanship should be maintained.

2.4.3 **Sub Engineer:** Sub Engineer is the person who directly holds the charge of the Job Work. Therefore, he should possess the thorough knowledge of specifications conforming to which the construction is to be got done.

2.4.4 **Assistant Engineer (Works):** The Assistant Engineer in charge of work is the first supervisory officer under whom the construction work progresses. Therefore, he should have thorough knowledge of specifications, technical circulars, I.S. codes, Contractual Provisions, provisions in schedule of rates and related references books etc. He should also possess basic training on construction of works by attending regular courses being arranged by the Department. He should visit and see such project under construction in the state or other states also. The Assistant Engineer who does not acquire above knowledge should not be posted on the construction of the project.

2.4.5 **Assistant Engineer / Assistant Research Officer (Quality Control):** The Assistant Engineer, Quality Control is incharge officer for ensuring that proper quality and workmanship is exercised in the construction. He should have undergone training in the quality control subject arranged by the Department. He should have thorough knowledge of specifications, Technical circulars, I.S. Codes & relevant reference books and testing of all construction materials and finished products. He should have experience of construction also. He should visit Soil & Material Testing Laboratory of W.R.D. at Bhopal and Research laboratories of other sites also. The Assistant Engineer who is having all these qualities should be posted as Assistant Engineer / Assistant Research Officer quality control on the project under construction.

2.4.6 **Executive Engineer (Works):** In addition to be training mentioned in the para 2.4 & 2.5, training related to holding the responsibility of division and proper controlling of the staff should also be given.

2.4.7 **Executive Engineer / Research Officer (Quality Control):** In addition to the training mentioned in the para 2.4.4 & 2.4.5, training related to holding the responsibility of division and proper controlling of the staff should also be given.

2.5 SEMINARS AND TECHNICAL SYMPOSIUM

2.5.1 At regular intervals, the seminars and technical symposium should be arranged by the Executive Engineer/ Superintending Engineer incharge of works and Executive Engineer / Research officer / Superintending Engineer Quality control amongst the supervisory staff [(Time keeper, Sub Engineer Assistant Engineers (Works), Assistant Engineer /Assistant Research Officer Quality Control] and Technical personnel of the contractor also and various technical problems should be discussed at length. These discussions would also help in sorting-out many problems confronted during the construction and progress of works

2.5.2 The Assistant Engineer / Executive Engineer (works), Assistant Engineer / Assistant Research Officer &, Executive Engineer / Research Officer Quality Control and Superintending Engineer (works) / Superintending Engineer Quality Control should also attend similar seminars being arranged at state level and National level. They can also discuss with the Director in charge of Research and Chief Engineer BODHI about such problems needing special attentions etc.

2.6 FACILITIES TO ASSISTANT ENGINEER / ASSISTANT RESEARCH OFFICER, QUALITY CONTROL

2.6.1 Superintending Engineer works should ensure that the Assistant Engineer / Assistant Research Officer Quality Control is provided with all the facilities required for doing his job expeditiously and smoothly as shown below:

2.6.1.1 To arrange an office for Assistant Engineer / Assistant Research Officer.

2.6.1.2 To arrange requisite staff for his office.

2.6.1.3 To arrange all the equipments needed for carrying out various tests in the laboratory and field laboratory with Assistant Engineer / Assistant Research Officer (Quality Control).

2.6.1.4 To arrange a vehicle for Assistant Engineer / Assistant Research Officer (Quality Control) to collect samples of materials, concrete & mortar and to conduct different necessary tests at field.

2.6.1.5 To arrange the various necessary literatures, IS Codes, reference books etc for Assistant Engineer / Assistant Research Officer Quality Control.

2.6.1.6 To supply technical circulars, specifications, agreement etc to him.

CHAPTER – 3

DUTIES & RESPONSIBILITIES

3.1 ROLE OF QUALITY CONTROL

3.1.1 IMPORTANCE:-

3.1.1.1 Quality Control is an important aspect in construction work and negligence in exercising quality control at any level may lead to a disasters and may further lead to reduction in life of structures, or may result in curtailed benefits or may even lead to complete failure. Good quality control can therefore ensure the safety and life of the structure.

3.1.1.2 Quality of work as a whole would depend upon the quality of material used in the construction and strict adherence to the specifications. Therefore, laboratory and field tests should ensure this.

3.1.1.3 Thus laboratory tests conducted would ensure good quality of materials to be used in the constructions of structure, while field tests conducted would ensure adherence to specifications and confirm to standards laid-down, as the construction advances.

3.1.2 LABORATORY TESTING AND FIELD TESTING:-

3.1.2.1 Various tests on materials, mixes of concrete and mortar etc. are carried out in the laboratory for obtaining good quality of materials and to decide the design of mixes to be used in the construction work.

3.1.2.2 Field testing, as the construction work progresses, is carried out to ensure the good quality of the finished product so as to conform to the specifications and standards as laid down.

3.2 JOBS TO BE CARRIED OUT BY QUALITY CONTROL STAFF

3.2.1 To Demarcate borrow area of all the construction materials.

3.2.2 Collection of samples, Testing and reporting will be carried out as described below:-

3.2.2.1 After the field engineers have supplied information about the quantum of various materials involved in the construction along with the borrow area plan duly demarcated (approximately), the Assistant Engineer / Assistant Research Officer Quality Control will obtain samples in adequate number through the field engineers and get them tested in the Laboratory so as to know the qualitative nature of all the construction materials

3.2.2.2 The samples required to be tested at Soil and Material Testing Laboratory, W.R.D. Hathaikheda, Bhopal/ Divisional Laboratory Jabalpur will be got collected by Assistant Engineers / Assistant Research Officer, Quality Control as per procedure laid down in the various Technical circulars issued by the Department/ Indian Standards . The Results will be intimated by him to Superintending Engineer (works) for design and execution purpose.

3.2.2.3 All the Qualitative assessment will be done by the Assistant Engineer / Assistant Research Officer, Quality Control. The Quantitative assessment will also be done by him which ultimately will be checked by the Executive Engineer (works), since all constructional operations are to be handled by Executive Engineers (works).

3.2.2.4 Assistant Engineer / Assistant Research Officer Quality Control, shall prescribe the various proportions of Plain Cement Concrete, Reinforced Cement Concrete, Mortar, admixture etc. after designing in his laboratory and intimate to Executive Engineer (works).

3.2.2.5 The Design of Filter will be done by the Assistant Engineer / Assistant Research Officer (Quality Control), on the basis of gradation and intimated to Executive Engineer (works).

3.2.2.6 Suitability of stone, coarse aggregate, fine aggregate & CNS material will be tested in the laboratory and will be intimated to Executive Engineer (works) by Assistant Engineer / Assistant Research Officer Quality Control,

3.2.2.7 Assistant Engineer / Assistant Research Officer Quality Control will be responsible for his work relating to testing done in his laboratory and in Field laboratory by his personnel's for carrying-out the prescribed tests on the samples collected for as per the para 3.2.2.1 to 3.2.2.6 above and furnish test reports to Superintending Engineer (works).

3.2.2.8 Embankment test section shall be got constructed before embankment construction to determine the optimum practicable moisture content and number of roller passes required to compact the material to the required density.

3.2.2.9 Assistant Engineer / Assistant Research Officer Quality Control will be authorized to reject any material not conforming to the specifications if brought to the site.

3.2.2.10 Assistant Engineer / Assistant Research Officer Quality Control, Will have to maintain the following records:-

3.2.2.10.1 Various testing done by him in his laboratory and field laboratory of all the materials.

3.2.2.10.2 To keep all the O.K. cards in cut file neatly and properly.

3.2.2.10.3 To preserve all the testing reports received from Soil & Material Testing Laboratory W.R.D., Bhopal / Laboratory Jabalpur / Circle Level Lab / Project Level Lab.

3.2.2.11 Assistant Engineer / Assistant Research Officer Quality Control, is authorized to write comments on the site order book.

3.3 DUTIES OF QUALITY CONTROL STAFF

3.3.1 The primary duty of quality control staff engaged on construction work is to carry out various tests of input materials, extract samples of finished product, carry out test on such samples, supply the test results to construction staff and convey the interpretations of test results suggesting methods of rectifying the defects if any, for achieving the requirement of specifications. Therefore quality control is necessary for safety, reliability, durability / economy of all structures and also optimum use of materials.

3.3.2 The duties of quality control staff up-to the rank of Superintending Engineer are as shown below:-

3.3.2.1 Duties of Superintending Engineer (Quality Control):-

3.3.2.1.1 To supervise the work of Executive engineer/ Research Officer Quality control Division.

3.3.2.1.2 To organize and monitor working of all subordinate staff under him.

3.3.2.1.3 To supervise the work in the field.

3.3.2.1.4 To organize Proper co- ordination between Quality Control staff and field staff.

3.3.2.1.5 To monitor the use of funds for Quality Control Divisions

3.3.2.1.6 To ensure that all the jobs as described in para 3.2 above to be got done through Executive Engineer / Assistant Engineer / Assistant Research Officer (Quality Control).

3.3.2.2 Duties of Research Officer /Executive Engineer (Quality Control):-

3.3.2.2.1 To remain in constant touch with the execution of works of the projects.

3.3.2.2.2 To suggest ways and means to improve the standard of work in case the test results indicate sub- standard quality of work.

3.3.2.2.3 To organize proper up keep and calibration of the equipments in the main and field laboratory at proper intervals.

3.3.2.2.4 To organize monitoring of test procedures and to submit daily reports on the quality of works to authorities specified.

3.3.2.2.5 To maintain copies of approved design, reports, plans and estimates, specifications, extracts of inspection notes and data of machinery used on works.

3.3.2.2.6 To carry out at least 5% of important tests in a month personally so that deficiencies, if any are brought to light.

3.3.2.2.7 As per para 4.2 & 4.3 all the jobs related for testing.

3.3.2.2.8 To organize and monitor working of all subordinate staff under him.

3.3.2.3 Duties of Assistant Research officer / Assistant Engineer (Quality Control):-

3.3.2.3.1 To ensure proper up-keep and maintenance of Laboratory equipments.

3.3.2.3.2 To supervise the work of Research Assistants and Laboratory Technicians etc

3.3.2.3.3 To ensure that the correct methods of sampling and testing are being followed.

3.3.2.3.4 To check whether the work is proceeding in accordance with the specifications and to bring sub- standard work to the notice of Research Officer and other specified authorities for action.

3.3.2.3.5 To compile daily reports of tests in prescribed forms and to submit to Research Officer for onward transmission.

3.3.2.3.6 To check proper placements of concrete and mortar at project site.

3.3.2.3.7 To organize and monitor working of all subordinates staff under him.

3.3.2.4 Duties of Research Assistant/ Embankment Inspector:-

3.3.2.4.1 To perform important tests like consolidation test, specific gravity test, permeability test, shear test and grain size analysis test for the samples of soils.

3.3.2.4.2 To perform tests like adulteration of cement, specific gravity test, water absorption and compressive strength tests.

3.3.2.4.3 To perform necessary test for fixing the proportions for mix design of concrete and mortar, being used in construction works.

3.3.2.4.4 To maintain records of test results.

3.3.2.4.5 To perform needle density test, field density test etc. in the field.

3.3.2.4.6 To check mixing time, water cement ratio and correct quantities of ingredients in concrete and mortar at project Site.

3.3.2.5 Duties of Laboratory Technician:-

3.3.2.5.1 To assist Research Assistant / Embankment Inspector whenever required in laboratory and field work.

3.3.2.5.2 To perform tests in laboratory such as:-

3.3.2.5.2.1 Compaction Test of Soil

3.3.2.5.2.2 Limit Test of Soil

3.3.2.5.2.3 Sieve analysis of fine and Coarse aggregate

3.3.2.5.2.4 Silt content in aggregate

3.3.2.5.2.5 Slump test

3.3.2.5.2.6 Collection of samples of concrete and mortar for casting specimens for compressive strength test.

3.3.2.5.2.7 Numbering and tagging of samples

3.3.2.5.2.8 Other works as directed by higher officers

3.3.2.6 Duties of Laboratory Assistant:-

3.3.2.6.1 To keep instruments clean

3.3.2.6.2 To assist R.A. / E. I. and Lab Technician for conducting tests

3.3.2.6.3 To prepare samples for tests

3.3.2.6.4 To keep samples systematically

3.3.2.6.5 Other works as directed by higher officers

3.4 DUTIES AND RESPONSIBILITIES OF DIFFERENT OFFICERS FOR QUALITY CONTROL OF WORKS

3.4.1 DUTIES AND RESPONSIBILITIES OF ENGINEER-INCHARGE OF WORK:-

3.4.1.1 To render full assistance to Assistant Engineer/ Assistant Research Officer (Quality Control) for sample collection from borrow area, dispatch of samples, various tests involved in fields.

3.4.1.2 Foundation should be got okayed by the Chief Engineer (works) for dam of major projects, by Superintending Engineer (works) for dams of medium project and for small structures by Executive Engineer (works).

3.4.1.3 To get the work executed strictly in accordance with the specification and as per approved drawing with respect to lines & levels.

3.4.2 DUTIES OF INSPECTING OFFICERS:-

3.4.2.1 EXECUTIVE ENGINEER (WORKS):-

3.4.2.1.1 Will strictly ensure that the work is being executed as per approved drawings and specifications followed as per contract agreement.

3.4.2.1.2 All foundation and lay out of other than main dam should be inspected and approved and in token of doing it the working drawing should be signed.

3.4.2.1.3 To ensure that the specification and agreement are supplied up to sub Engineer level.

3.4.2.2 SUPERINGTENDING ENGINEER (WORKS):-

3.4.2.2.1 Will strictly ensure passing of lay out and foundation of main dam after inspecting it and approving it and in token of doing it sign on the working drawing.

3.4.2.2.2 To ensure a good co-ordination between the Assistant Engineer / Assistant Research Officer (Quality Control) and field engineers.

3.4.2.2.3 To arrange for seminars study tours and technical discussions so as to train the officers incharge and Assistant Engineer/ Assistant Research Officer (Quality Control) in particular with a view to achieve good quality of workmanship.

3.4.3 RESPONSIBILITY OF DIFFERENT OFFICERS

3.4.3.1 As per appendix 7.02 of works Departments manual Volume II page no. 256-257, s. no. 16 responsibilities of different officers has been fixed for the quality control of various types of works which are reproduced below:-

Table: 4

	C.E.	S.E.	E.E.	A.E.	Sub.Eng.
Major Dams Hydraulics structures costing more than Rs 225 Crores	Full Responsibility	Full Responsibility	Full Responsibility	Full Responsibility	Full Responsibility
Medium Dams& structures costing more than Rs 45 Crores up to 225 Crores	-------	Full Responsibility	Full Responsibility	Full Responsibility	Full Responsibility
Minor Dams & Structures costing more than Rs 90 Lacs up to 45 Crores	-------	-------	Full Responsibility	Full Responsibility	Full Responsibility
Structures costing less than Rs 90 Lacs	-------	-------	-------	Full Responsibility	Full Responsibility

3.5 ROLE OF DIRECTOR (IRRIGATION RESEARCH)

3.5.1 When the field formation requires opinion of Director (Irrigation Research) regarding the quality of work/ materials, he shall visit the work site and inspect the work in progress and express his opinion.

3.5.2 The opinion expressed by Director (Irrigation Research) may be attended by the Field Officers.

3.5.3 If there is any disagreement between the field officers and Director (Irrigation Research), the Chief Engineer incharge of the works will give his last decision.

3.5.4 The Director (Irrigation Research) should ensure that all the Quality Control units viz. at Divisional level, Circle level are visited and inspected once in a year. He will advise to the Quality Control staff.

CHAPTER - 4

TESTS & REPORTS

4.1 GENERAL

4.1.1 Various types of materials are used in construction of different works. The quality of the works would depend upon the quality of the materials used. The testing of materials of construction is therefore, an important activity to be taken up much before the construction starts. Even during process of construction of earthen dam, mortar and concrete made of tested ingredients have to be tested for their quality to ascertain correctness of the procedures of batching, mixing, placing, compaction and the net results. Thus, testing of materials and quality control go hand in hand. They are of great importance to check and ensure the expected results of all the efforts and money spent in building the structure.

4.1.2 Apart from the Departmental Laboratories, consultation for testing and technical advice can be made in Government Engineering College Laboratories, Central Government authorized laboratory like N.C.B. Vallabhgarh (Faridabad)/ Hydrabad, C.S.M.R.S. laboratory Dehli etc. & BIS certified laboratories.

4.2 TESTS FOR CONCRETE & MASONRY WORK

4.2.1 CONCRETE & MASONRY WORK:-

4.2.1.1 **TESTING OF WATER:** Natural or treated water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete.

In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive strength and the initial setting time tests specified in para 5.4.1.2 & 5.4.1.3 of IS 456, 2000. Following tests are mainly conducted before the water is used for construction work.

4.2.1.1.1 pH (HYDROGEN ION CONCENTRATION): (IS: 3025: PART 11:1986)

Measurement of ph is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and waste water treatment e.g. acid base neutralization, water softening, precipitation, coagulation, disinfection and corrosion control is ph dependent. At a given temperature the intensity of the acidic or basic character of a solution is indicated by ph or hydrogen ion concentration. For concrete work, the pH value of water shall be not less than 6.

4.2.1.1.2 HARDNESS: (IS: 3025: 2009):

Total hardness of water is the sum of the concentration of all the metallic cat ions other then cat ions of the alkali metals, expressed as equivalent calcium carbonate concentration. In most waters, nearly all the hardness is due to calcium and Magnesium ions. It is determine by the reaction of calcium and magnesium salts with standard E.D.T.A (Ethylene Di amine Tetra acetic acid) solution.

4.2.1.1.3 TURBIDITY: (IS: 3025 Part : 1986)

Turbidity in water is caused by suspended matter, such as clay silt, finely dissolved organic and inorganic matter, soluble colored organic compounds and plankton and other microscopic organism. Turbidity is an expression of the optical property that causes lights to be scattered and absorbed rather than transmitted in straight line through the sample.

4.2.1.1.4 TOTAL SOLIDS: (IS: 3025 Part 15:1986)

A well mixed sample is evaporated in a weighted dish and dried to constant weight in oven at 103^{o} C to 105^{o} C. The increase in weight over that of empty dish represents the total solids.

4.2.1.1.5 Test Procedures for suitability of water for making concrete (see Para 5.4 of IS: 456)

4.2.1.2 TESTING OF AGGREGATES:-

4.2.1.2.1 Various tests are carried out on aggregate to assess their quality. I.S. Specifications have grouped the test in eight parts. It may not be always necessary to assess all the qualities of aggregates for particular work/ purpose. Therefore, it is necessary to know the purpose for which the aggregate is to be tested. Aggregates larger than 4.75 mm are termed coarse and those passing through 4.75 mm are termed fine (Sand).

4.2.1.2.2 Though a number of tests have been specified by I.S. codes the Sieve analysis, Water absorption, Specific gravity, Crushing value, Abrasion value, Impact value generally give fairly good idea about the quality of aggregates.

4.2.1.2.3 Aggregates to be used for concrete should conform to I.S. 383-1963. Which lays down the following tests on aggregates [(I.S. 2386-1963) Part- I to VIII]:-

4.2.1.2.3.1 DELETERIOUS MATERIALS: Aggregates (fine & coarse) shall not contain any harmful material such as pyrites, coal, lignite, mica, shale or similar laminated material, clay, alkali, soft fragments, sea shells and organic impurities in such quantity as to affect the strength or durability of concrete. Aggregate to be used for reinforced concrete shall not contain any material liable to attack the steel reinforcement. Limits of deleterious materials are given in table 1 of IS: 383.

4.2.1.2.3.2 UNIT WEIGHT OR BULK DENSITY: This test is conducted on coarse and fine aggregates for deciding whether, specified range of value are satisfied by the aggregates being tested. This laboratory test is useful for comparing properties of aggregates available from different locations. This is also useful for conversion of weight batching to volumetric batching of fine and coarse aggregates for production of concrete/mortar.

4.2.1.2.3.3 WATER ABSORPTION AND SPECIFIC GRAVITY OF AGGREGATES: The test is intended to assist in assessing the quality of aggregates. It is a quick indicator of suitability of an aggregate (fine & coarse). Low specific gravity frequently indicates porous, weak and absorbable material and high specific gravity indicates good quality of material. Accurate knowledge of specific gravity of the aggregate is important for use in initial air entrained mix designs computations and in the determination of air content and actual field quantity of each material in the batch. The values of these tests are needed for the proper proportioning of the concrete mixes. The value of absorption of moisture is necessary to adjust the water content during mixing.

4.2.1.2.3.4 SURFACE MOISTURE OF AGGREGATE (HOT PLATE METHOD) (Ref USBR MANUAL Designation 11): It is approximate method for determining the surface (free) moisture of sand and coarse aggregate. In field it is easily conducted and useful for applying correction in quantity of water in mix proportion of concrete/ mortar.

4.2.1.2.3.5 TESTING OF FINE AGGREGATES:-

4.2.1.2.3.5.1 SILT PERCENTAGE (USBR Concrete manual, Designation 15):- This is a quick method for finding the silt percentage in sand and easily conducted in laboratory as well as in field.

4.2.1.2.3.5.2 SIEVE ANALYSIS: The test is performed to determine the grading zone of sand which is an important factor contributing to the quality of concrete. The grading zone of sand or fineness modules must be known. Higher the grading zone, sand is coarser. (I.S. 2386-1963). This test is important for design of concrete mix by different methods.

4.2.1.2.3.5.3 NECESSARY ADJUSTMENT FOR BULKING (FIELD METHOD) [IS 2386 (PARTIII) 1963 Reaffirmed 2011]:- Presence of moisture below saturation increases the volume (bulkage) of sand. There is no bulkage when sand is dry or saturated. The purpose of this test is to determine the excess volume of the moisture in sand which can be accounted for volumetric batching of concrete or cement sand mortar and make correction in the moisture for maintaining water cement ratio. Finer the sand the more is the bulkage. Also correction in sand volume should be made equal to excess volume of moisture for maintaining the proper quantity of sand.

4.2.1.2.3.5.4 MORTAR MAKING PROPERTIES OF FINE AGGREGATE: This test is performed for comparing compressive strength of fine aggregates with that of standard sand, whether that is within the specified limits.

4.2.1.2.3.5.5 SURFACE MOISTURE FIELD METHOD: [IS 2386 (Part III) 1963 Reaffirmed 2011]:- It is approximate method for determining the surface (free) moisture of fine aggregate. In field it is easily conducted and useful for applying correction in quantity of water in mix proportion of concrete/ mortar.

4.2.1.2.3.6 TESTING OF COARSE AGGREGATE:-

4.2.1.2.3.6.1 SIEVE ANALYSIS: The test is performed to determine the grading of the aggregate, which is an important factor contributing to the quality of concrete. Grading limits of coarse aggregates for different maximum size of aggregates should be as per IS 383.

4.2.1.2.3.6.2 COMBINED FLAKINESS AND ELONGATION INDEX: Flakiness and elongation shall be determined in accordance with IS 2386 (Part 1) on the same sample. After carrying out the flakiness index test, the flaky material shall be removed from sample and the remaining portion shall be used for carrying out elongation index. Indices so worked out shall be added numerically to give combined flakiness and elongation index. The combined flakiness and elongation index so obtained shall not exceed 40 % for uncrushed or crushed aggregate. However, the engineer-in-charge at his discretion, may relax the limit keeping in view the requirement, and availability of aggregates and performance based on tests on concrete.

4.2.1.2.3.6.3 ABRASION VALUE: The test determines the loss due to abrasion of aggregates. This test is conducted to assess the quality of aggregates with respect to hardness and toughness of the aggregates against abrasion.

4.2.1.2.3.6.4 AGGREGATE IMPACT-VALUE: This test gives a relative measure of the resistance of aggregates against impact.

4.2.1.2.3.6.5 CRUSHING VALUE: This test gives a relative measure of the resistance of an aggregate to crushing under a gradually compressive load.

4.2.1.2.3.6.6 ALKALI AGGREGATE REACTIVITY [Ref: IS:2386 (Part VII)] Some aggregates containing particular varieties of silica may be susceptible to attack by alkalis (Na_2O & K_2O) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally only occurs when all the following are present together:

A) A high moisture level within the concrete;

B) A cement with high alkali content, or another sources of alkali; and

C) Aggregate containing an alkali reactive constituent.

4.2.1.2.3.6.7 PETROGRAPHIC EXAMINATION [Ref: IS:2386 (Part VIII)] Petrographic Examination is made for the following purposes:

A) To determine the physical and chemical properties of the material that may be observed by petro graphic methods and that have a bearing on the quality of the material for its intended use,
B) To describe and classify the constituents of the samples; and
C) To determine the relative amounts of the constituents of the sample, which is essential for proper evaluation of the sample when the constituents differ significantly in properties that have a bearing on the quality of the material for its intended use.

4.2.1.3 TESTING OF CEMENT:

4.2.1.3.1 The two main things must essentially follow at the time of use of cement are:-

(i) Cement older than 90 days should not be used at any place without testing.

(ii) Cement older than 180 days should not be used in any important structure.

4.2.1.3.2 For suitability of use of the cement standard methods of its various tests have been adopted to acquire the requisite specification as referred by I.S. codes 4031, certain methods of tests are as given below:

4.2.1.3.2.1 FINENESS BY SIEVING: [IS 4031 (Part I) 1996, Reaffirmed 2005]: To check the fineness with the standard specifications prescribed by I.S. code. This method describe in part I, covers the procedure for determining the fineness of cement by dry sieving as represented by the mass of residue left on a standard 90 micron IS Sieve.

4.2.1.3.2.2 SPECIFIC SURFACE BY BLAIN AIR PERMEABILITY METHOD: [IS 4031 (Part II)1999, Reaffirmed 2004]:- This method describe in IS 4031 (Part 2) covers the procedure for determining by Blaine air permeability apparatus, the fineness of cement as represented by specific surface expressed as total surface area in cm^2/g.

4.2.1.3.2.3 SPECIFIC GRAVITY: (IS 1727-1967 Reaffirmed 2004): This test is necessary for designing the concrete mixes of rarest types of structure.

4.2.1.3.2.4 CONSISTENCY: The object of conducting this test is to determine the quantity of water for the completion of various tests of cement such as initial setting time, final setting time as well as compression strength of cement.

4.2.1.3.2.5 SETTING TIME [IS 4031 (Part V) 1988, Reaffirmed 2005]: This test is performed to confirm the quality of cement. The term setting is used to describe the stiffening of the cement paste and the terms “Initial Set” and “Final Set” are used to describe arbitrary chosen stages of setting.

4.2.1.3.2.6 SOUNDNESS TEST BY LE- CHATELIER’S METHOD [IS 4031 (Part III) 1988, Reaffirmed 2005]:**-:** Due to presence of free lime in the cement, sometime expansion is caused and hence the cracks develop. This test is conducted to determine the expansion of the cement.

4.2.1.3.2.7 COMPRESSIVE STRENGTH [IS 4031 (Part VI) 1988, Reaffirmed 2005]:-: This test shall be conducted to confirm about the quality of cement. Compressive strength of cement is an important parameter for design of concrete mixes of various structures. Cement older than 90 days should be necessarily tested for compressive strength before use.

4.2.1.4 TESTING OF ADMIXTURES:

4.2.1.4.1 Mineral Admixtures (IS456: 2000):

4.2.1.4.1.1 Pozzolanas:-

Pozzolanic materials conforming to relevant Indian Standards may be used with the permission of the engineer- in- charge, provided uniform blending with cement is ensured. Some of them are:-

i. **Fly Ash** (Pulverized fuel ash): Fly ash conforming to IS:3812 (part I) used as part replacement of ordinary Portland cement provided uniform blending with cement is ensured and IS 3812 part 2 use as admixture in cement, mortar and concrete.

ii. **Silica Fume**: Silica fume conforming to IS : 15388 may be used as part replacement of cement provided uniform blending with the cement is ensured.

4.2.1.4.1.1.1 Various tests are therefore need to be conducted as described below:

i. **FINENESS (IS 1727)**: This test is conducted to determine the suitability of pozzolanas. Fineness is an important property as finer the material the greater is the reactivity.

   (a)SPECIFIC SURFACE: This test is conducted to know the fineness for checking with the standard specifications. By Blaine's permeability method.

   (b)BY SIEVING: This test is conducted using 45 micron IS sieve.

ii. **SOUNDNESS TEST (IS 1727):** This test is conducted by Autoclave test in which expansion of specimen is to be find out in percent.

iii. **COMPRESSIVE STRENGTH OF POZZOLANIC CEMENT MORTAR (IS 1727):** This test is conducted for determination of quality of the material and is to be compared with the compressive strength of the cement.

iv. **SPECIFIC GRAVITY:** This test is conducted by "LeChaterlier Flask" method given as for cement in IS 1727. Which is useful for designing of concrete/ mortar mixes.

4.2.1.5 TESTING OF CONCRETE & MORTAR:

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

4.2.1.5.2 **SLUMP TEST OF CONCRETE (IS: 1199):** This test is conducted to determine the consistency of concrete and hence workability. Workability means the ease with which concrete can be handled, transported and placed.

4.2.1.5.3 **COMPRESSIVE STRENGTH OF CONCRETE/MORTAR (Ref IS:516-1959(for concrete),IS: 2250 (for mortar), IS:1199 & TC No.57 memo no. 3484002/BODHI/Specifications /TC Date 23.10.2013 and IS:2250 & TC No. 23 memo no. 123/BODHI/R & C/TC/11/88 Dated 31.08.1989):-** Concrete/ Mortar are a variable material. The quality of these are usually assessed from the results of crushing strength test on concrete/mortar cubes or cylinders.

4.2.1.5.4 **PERMEABILITY TEST OF CEMENT MORTAR/ CONCRETE (IS: 3085)** : This test is of particular significance in structures which are intended to retain water or which come in contact with water. It is intimately related with durability of structure. Hence it is of considerable importance.

4.2.1.5.5 **RAPID ESTIMATION OF CEMENT IN MORTAR AND CONCRETE (IS: 1199)**: This test is conducted to analyze the mortar/ concrete with respect to their proportions of the mixed ingredients in the mortar/ concrete. This test is based on the calcium content in the mortar, cement and sand.

4.2.1.5.6 DENSITY AND AIR CONTENT OF FRESH CONCRETE (IS: 1199): It is used to determine the entrapped air percentage in fresh concrete.

4.2.1.5.8 NON DESTRUCTIVE TEST ON HARDENED CONCRETE:

4.2.1.5.8.1 A number of techniques are available for conducting in situ tests on the hardened concrete laid in the structure, which causes either no damage at all or involve only insignificant invasion. These are very convenient for general monitoring of the quality and its uniformity or detecting local zones of weakness or inadequate workmanship. Although these are indirect and essentially qualitative test, they can provide quantitative assessment of the concrete strength if calibrated against works test specimens or cores from the concrete actually being used. The two main non destructive test are pulse velocity meter and rebound hammer test (Ref: IS :13311 Part 1 & 2, 1992).

4.2.1.5.8.1.1 ULTRASONIC PULSE VELOCITY METER:

The ultrasonic pulse velocity method could be used to establish:

(i) The homogeneity of the concrete
(ii) The presence of crakes, voids and other imperfections.
(iii) Changes in the structure of the concrete which may occur with time.
(iv) The quality of the concrete in relations to standards requirements.
(v) The quality of one element of concrete in relation to another, and
(vi) The values of dynamic elastic modulus of the concrete.

(Detailed procedure are given in IS: 13311, (Part 1), 1992

4.2.1.5.8.1.2 REBOUND HAMMER:

The Rebound Hammer could be used for:

(i) Assessing the likely compressive strength of concrete with the help of suitable co-relation between rebound index and compressive strength.
(ii) Assessing the uniformity of concrete.
(iii) Assessing the quality of the concrete in relation to standard requirements and
(iv) Assessing the quality of one element of concrete in relation to another.

(Detailed procedure are given in IS: 13311, (Part 2), 1992.

4.2.1.5.9 TESTING OF FLEXURAL STRENGTH OF TILES: (IS10646:1991):- When tested according to the method as per referred IS, minimum breaking load per cm weight of tile shall not less than41 kg for 60 mm, 29 kg for 50 mm and 18 kg for 40 mm tiles thickness for M-15 grade concrete tiles.

4.2.1.5.10 TESTING OF CORE SPECIMEN FROM HARDENED CONCRETE (IS:516, IS:457 & TC No. 57 Memo No. 3484002 /BODHI/Specifications/TC Date 23.10.2013): It includes criteria and requirement of test specimen and acceptance criteria for hardened concrete.

4.2.1.5.11 DESIGN OF CONCRETE MIX: The proportion of cement, fine and coarse aggregate & admixtures will be given after tests are carried out in the laboratories in accordance with the specifications laid down. It should be done as per the Guidelines given in IS: 456, IS:10262 and IS: 457 for different types of structures according to field conditions. Other methods of mix design can be used for designing concrete mixes.

4.2.1.5.12 DESIGN OF MORTAR MIX (IS: 2250):- The proportion of cement and fine aggregate will be given after the tests are carried out in the laboratory in accordance with the specifications laid down.

4.2.1.6 TESTING OF BOULDER OR RUBBLE (NATURAL BUILDING STONE):

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

4.2.1.6.2 WHEATHERING: A good building stone should possess better weathering qualities; it should be capable of withstanding adverse effects of various atmospheric and external agencies such as rain, frost, wind etc. This standard lays down the procedure for testing weathering of natural building stones used for constructional purposes.

4.2.1.6.3 TOUGHNESS: The property of toughness of stone is resistance to failure under impact, stones of low toughness are apt to fail when exposed to rough usage, as occurs on steps, flooring of factories, stories, warehouses, godown etc. for calculation of toughness impact test is to be carried out.

4.2.1.6.4 **DETERMINATION OF TRUE SPECIFIC GRAVITY, APPARENT SPECIFIC GRAVITY, WATER ABSORPTION AND POROSITY OF NATURAL BUILDING STONE:** these tests conform to the properties of the natural building stones. The suitability of the natural building stone is known and hence the quality is assessed

4.2.1.6.5 **DURABILITY:** A good building stone should be durable. Various factors contributing to durability of a stone are its chemical composition , texture, resistance to atmospheric and other influences, locations in structure etc. for making stones durable, their natural bed should be carefully noted. Stones should be arranged in a structure that natural bed is perpendicular or nearly so to the direction of pressure.

4.2.1.7 TESTING OF BRICKS:

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

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

4.2.1.7.3 **TEST OF BURNT CLAY BUILDING BRICKS:**

4.2.1.7.3.1 **WATER ABSORPTION (IS 3495 part 1):** This test conforms to the quality of bricks for the recognition of the standard of the material. A brick is taken and it is weighted dry. It is then immersed in water for a period of 16 hours. It is weighted again and the difference in weight indicates the amount of water absorbed by the brick. It should not, in any case, exceed 20 percent of weight of dry brick.

4.2.1.7.3.2 **COMPRESSIVE STRENGTH (IS 3495 part 1):** To assess the quality by comparing with the specified strength.

4.2.1.8 TESTING OF LDPE FILM **(TC No. 3 Memo No. 107/BODHI/R&C/TC/11/88 Date 31.12.88):** Introduction of plastic sheets in the form of LDPE film below the hard cover lining is effective in, reducing

seepage losses and improving water tightness of lining. The LDPE film may be used in canal lining with sub grade soils in one of the following ways;

I. Under hard lining such as concrete, tiles, stones slabs, bricks etc.
II. Buried under earth cover.

4.2.1.9 TESTING OF REINFORCEMENT BARS: Reinforcement used shall be confirmed to the requirements of IS 432 "Specification of mild steel and medium tensile steel bars" IS 1786 "Specification for high strength deformed steel bars" for concrete reinforcement characteristics strength ultimate tensile stress and elongation percentage test should be conducted. Hard drawn steel wire fabrics shall be manufactured and have the properties in accordance with the requirement of IS 1566-1982 and shall be used for floor slabs (hollow block, ribbed), for secondary reinforcement in developing fire resistance and in some precast concrete products like pipes.

4.3 TESTS FOR EARTHWORK & FILTERS

4.3.1 SOIL IDENTIFICATION AND DESCRIPTION

4.3.1.1 VISUAL SOIL CLASSIFICATION:-

4.3.1.1.1 Before testing a soil, the sample has to be examined and data obtained from visual inspection is to be noted in the proforma given in Annexure 40 of Vol. II, this includes noting of the color, odour, presence of minerals, presence of organic and foreign matter and geological history as may be often evident from visual inspection. The visual inspection aids the development of a feel soil behavior and it helps in interpretation of the results obtained. A possible error in samples numbering will also be detected in case the visual inspection does not tally with actual results in the laboratories. An experienced technician can predict the behavior of a soil with sufficient accuracy by working it in his hand and inspecting it carefully. At the conclusion of a test, the laboratory technician should check to see that the results are in agreement with what was expected from his visual classification.

4.3.1.1.2 The soil is fine-grained if it contains 50 percent or more fines and the soil is coarse grained if it contains less than 50 percent fines (Ref: (Ref: Bureau of Reclamation, USBR 5000[1] & 5005 [2] "Engineering Classification and Description of soil (Field Manual, Chapter 3)

4.3.1.1.3 PROCEDURES AND CRITERIA FOR VISUAL CLASSIFICATION OF FINE GRAINED SOILS: (Ref: Bureau of Reclamation, USBR 5000[1] & 5005 [2] “Engineering Classification and Description of soil (Field Manual, Chapter 3)

Select a representative sample of the material for examination and remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of representative material is available. Use this specimen for performing the identifications tests.

4.3.1.1.3.1 IDENTIFICATION CRITERIA FOR FINE GRAINED SOILS:

The tests for identifying properties of fines are:

i. Dry strength,
ii. Dilatency,
iii. Toughness
iv. Plasticity

4.3.1.1.3.1.1 Dry Strength (Crushing Characteristics**):** Select from the specimen enough material to mold into a ball about 1 inch (25 mm) in diameter. Mold or work the material until it has the consistency of putty, adding water if necessary. From them molded material, make at least three test specimens. Each test specimen should be a ball of material about ½ inch (12 mm) in diameter. Allow the test specimens to dry in air or sun, or dry by artificial means, as long as the temperature does not exceed 60 degrees centigrade (EC). In most cases, it will be necessary to prepared specimens and allows them to dry overnight. If the test specimen contains natural dry lumps, those that are about ½ inch (12 mm) in diameter may be used in place of molded balls. (The process of molding & drying usually produces higher strength than are found in natural dry lumps of soil). Test the strength of the dry balls or lumps by crushing them between the fingers and note the strength as none, low, medium , high, or very high according to the criteria in given table. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

Table:4 Criteria for describing dry strength

None	The dry specimen crumbles with mere pressure of handling
Low	The dry specimen crumbles with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure.
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface.
Very High	The dry specimen cannot be broken between thumb and a

	hard surface

4.3.1.1.3.1.2 Dilatancy (Reaction to Shaking): Select enough material from the specimen to mold into a ball about ½ inch (12 mm) in diameter. Mould the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or spatual. Shank horizontally (the soil ball), striking the side of the hand vigorously against the other hand several times. Note the reaction of the water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers and note reaction as none, slow, or rapid according to the criteria given in table. The reaction criteria are the speeds with which water appears while shaking and disappears while squeezing**.**

Table:5 Criteria for describing dilatancy

None	No visible change in the specimen.
Slow	Water slowly appears on the surface of the specimen during shaking and does not disappear or disappear slowly upon squeezing.
Rapid	Water quickly appears on the surface of the specimen during shaking and disappears upon squeezing.

4.3.1.1.3.1.3 Toughness (Consistency near Plastic Limit): Following completion of the dilatancy test, the specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about C in (3 mm) diameter. (if the sample is too wet to roll easily, spread the sample out into a thin layer and allow some water loss by evaporation). Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about C in (3 mm) when the soil is near the plastic limit . Note the time required to reroll the thread to reach the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also , note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.
Describe the toughness of the thread and lumps as low, medium, or high according to the criteria given in table below;

Table : 6 Criteria for describing toughness

Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the

	plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness.

4.3.1.1.3.1.4 Plasticity: On the basis of observations made during the toughness test, describe the plasticity of the material according to the criteria given in table below:

Table :7 Criteria for describing Plasticity

Non Plastic	A 3 mm thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll, and not much times is required to reach the plastic limit. The thread cannot be rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rolled several times after reaching the plastic limit. The lumps can be formed without crumbling when drier than the plastic limit.

After the dry strength, dilatancy, toughness and plasticity tests have been performed; decide on whether the soil is an organic or an inorganic fine grained soil.

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

4.3.1.1.4 PROCEDURES AND CRITERIA FOR VISUAL CLASSIFICATION OF COARSE GRAINED SOILS: (Ref: Bureau of Reclamation, USBR 5000[1] & 5005 [2] “Engineering Classification and Description of soil (Field Manual, Chapter 3):

4.3.1.1.4.1 A representative sample containing less than 50 percent fines is identified as a coarse-grained soil.

4.3.1.1.4.2 The soil is a gravel if the percentage by weight of gravel is estimated to be more than the percentage of sand.

4.3.1.1.4.3 The soil is a sand if the percentage by weight of sand is estimated to be more than the percentage of gravel.

4.3.1.1.4.4 The soil is a clean gravel or clean sand if the percentages of fines are visually estimated to be 5 percent or less. A clean gravel or sand is further classified by grain size distribution.

4.3.1.1.4.5 The soil is classified as a WELL GRADED GRAVEL (GW), or as a WELL GRADED SAND (SW), if a wide range of particles sizes are present. The soil is classified as a POORLY GRADED GRAVEL (GP) or as a POORLY GRADED SAND (SP) if the material is predominantly one size (uniformly graded) or the soil has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

4.3.1.1.4.6 The soil is identified as either gravel with fines or sand with fines if the percentage of fines is visually estimated to be 15 percent or more.

4.3.1.1.4.7 Classify the soil as a CLAYEY GRAVEL (GC) or a CLAYEY SAND (SC) if the fines are clayey as determined by the procedures for fine-grained soil identification.

4.3.1.1.4.8 Identify the soil SILTY GRAVEL (GM) or a SILTY SAND (SM) if the fines are silty as determined by the procedures for fine grained soil identification.

4.3.1.1.4.9 If the soil is visually estimated to contain 10 percent fines, give the soil a dual classification using two group symbols. The first group symbol should correspond to a clean gravel or sand (GW, GP, SW, SP), and the second symbol should correspond to a gravel or sand with fines (GC, GM, SC, SM). The typical name is the first group symbol plus “with clay” or “with silt” to indicate the plasticity characteristics of the fines. For example, WELL GRADED GRAVEL WITH CLAY (GW-GC); POORLY GRADED SAND WITH SILT (SP-SM).

4.3.1.1.4.10 If the specimen is predominantly sand or gravel but contains an estimated 15 percent or more of the other coarse-grained constituent, the words “with gravel” or “with sand” are added to the group name. for example POORLY GRADED GRAVEL WITH SAND (GP); CLAYEY SAND WITH GRAVEL(SC).

4.3.1.1.4.11 If the field sample contained any cobbles and / or boulders, the words “with cobbles” or “with cobbles and boulders” are added to the group name, for example, SILTY GRAVEL WITH COBBLES (GM).

4.3.1.1.5 VISUAL TEST PROCEDURES: Examine each unknown soil and records against their corresponding numbers on the data sheets the following information:-

4.3.1.1.5.1 Colour :if colour is dark brown, dark grey or black indicate if it has an organic odour.

4.3.1.1.5.2 Describe texture as:

i. Coarse- grained (mostly sand and gravel)
ii. Fine-grained (mostly sand and clay), or
iii. Mixed- grained

4.3.1.1.5.3 For coarse- grained soils, or coarse-grained fraction of mixed grained soils

Classify as: gravel, coarse sand, medium sand, fine sand or appropriate combination.

Describe grading as: well graded fairly well graded, fairly uniform, uniform or poorly graded.

Describe particle shape as: angular, sub- angular, sub rounded, or well rounded.

4.3.1.1.5.4 For fine grained soils or fine grained fraction of mixed grained soils:

Describe dry strength as: very low, low, medium, high or very high.

Describe reaction to shaking test (dilatency) as: rapid, sluggish or nonexistent.

Describe condition of plastic thread as: weak and soft medium, stiff, very stiff or tough.

Classify as: silt, clayey silt, silty clay, or clay.

4.3.1.1.5.5 If organic:

Indicated under texture what plant remains are visible and state of decomposition.

Classify as: peat, muck, organic sand, organic silt, or organic clay.

4.3.1.2 STORAGE OF SAMPLES: The Soil samples have to be inspected and tested soon after their arrival at the laboratory. If testing is likely to be delayed, proper storing has to be ensured by providing adequate space and proper containers. The samples have to be labeled properly as per standard form (Name of Projects, Date, Marked Locations, R.D., R.L. Off Set etc).

4.3.1.3 ENGINEERING CLASSIFICATION OF SOIL:

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

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

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

4.3.1.3.4 The engineering classification of soils for use on earthen dams, is to be done as per I.S. code no. 1498 of 1987.

4.3.1.4 TESTS FOR SUITABILITY OF SOIL: All tests are to be carried out as per the relevant/ prescribed I.S. codes.

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

4.3.1.4.2 CONSISTENCY LIMITS (ATTERBERG'S LIMITS):

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

The liquid state

The plastic state

The semi-solid state

The solid state

The arbitrary limits are known as consistency limits or Atterbergs limits in terms of water content. The Atterbergs limits are (i) Liquid limit (II) Plastic limit (III) Shrinkage limit.

4.3.1.4.3 UTILITY OF DETERMINATION OF ATTERBERGS LIMITS:

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

They give an approximate assessment of cohesion or inter molecular attraction. They give an assessment of shrinkage of the soil on drying.

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

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

4.3.1.4.3.3 SHRINKAGE LIMIT: This is a water content below which a reduction in moisture will not cause a decrease in the volume of the soil mass. Below the shrinkage limit, the soil is considered to be a solid. shrinkage limit values together with other index values are useful in identifying expansive soils.

4.3.1.5 ENGINEERING TESTS FOR EARTH DAM DESIGN:

4.3.1.5.1 Up to 40 feet height of dams, types designs of dams are to be followed. For greater heights stability analysis is necessary.

4.3.1.5.2 COMPACTION OF SOILS (MOISTURE DENSITY RELATIONS):

In the stability of all earthen embankments, the density of the soil and its shear strength play an important role. The unit weight or density of the soil varies with the degree of compaction of the soil in the embankment. Stability of the embankment largely depends upon the compaction achieved because compaction also improves its shear strength, bearing capacity and bring near lower permeability of the soil and decreases the tendency of the soil to settle under repeated loads.

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

4.3.1.5.3 SHEAR STRENGTH:

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

$$S= C+N \tan \varnothing$$

Where S is the Shear strength of soil, C- is Cohesion, N is Normal load and Ø is the angle of internal friction.

4.3.1.5.3.2 SHEAR TEST RESULTS HELPS IN:

I. Designing the dam section,
II. Assessing the bearing capacity of foundations;
III. Assessing the pore pressure likely to develop in the dam under different conditions; and
IV. Assessing stability of an existing dam when undisturbed soil samples from the dam are tested for shear.

4.3.1.5.3.3 TRIAXIAL SHEAR TEST COMPRISES FOLLOWING TYPES OF TESTS:

4.3.1.5.3.3.1 UNCONSOLIDATED UNDRAINED TEST WITHOUT PORE PRESSURE CORRECTION (Q-TEST):

PURPOSE

(I) For determination of the compressive strength of a specimen of the saturated cohesive soil in the Triaxial Shear machine under conditions in which the cell pressures is maintained constant and there is no change in total water content of the specimen. Thus this test is used for measuring the in-situ minimum strength of fully saturated or partially saturate cohesive soil in the field.

(II) This test is also used to measure the maximum shear strength developed in the compacted embankment when the samples are tested under the compaction moisture content and density conditions.

4.3.1.5.3.3.2 CONSOLIDATED UNDRAINED TEST WITH PORE PRESSURE MEASUREMENT (R-TEST):

PURPOSE-

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

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

4.3.1.5.3.4 PERMEABILITY OF SOILS:- Permeability is the ease or facility with which water percolates through soil. Darcy was first to study flow of water through soil and demonstrated that the rate of flow or discharge per unit time is proportional to the hydraulic gradient

$$Q = KiA$$

Where Q is discharge per unit Time
i= hydraulic gradient
A= Cross Sectional area of soil perpendicular to Flow
K= Darcy's Coefficient or Coefficient of Permeability

Coefficient of permeability "K" is defined as the superficial velocity of liquid under unit hydraulic gradient.
Description about Field Permeability Test is also given in Quality Control manual Vol II.

4.3.1.5.3.5 SWELLING PRESSURE TEST:

Expansive soils are those which swell considerably on absorption of water from outside and shrink on removal of water. Although, the phenomenon of swelling and shrinkage is not uncommon with most of the soils (excepts sand and gravel) it is exhibited to a very marked degree only by certain clayey soils and hence, the term expansive soil is used only for such soils.

The capacity to swell of a soil depends upon the type & amount of clay minerals and the exchangeable bases. Out of the three major mineral groups Montmorillionite, illite and Kaolinite, the montmorillionite clay minerals swell on coming in contact with water, where as the clay minerals of the other two groups do not swell or swell to very less extent.

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

4.3.1.5.3.6 TOTAL SOLUBLE SOLIDS: - The presence of soluble solids in soil is one of the important aspects requiring examination as these soluble solids greatly influence the Engineering properties of the soil.

4.3.1.5.3.7 SPECIFIC GRAVITY: Specific gravity of soil finds applications in finding out the degree of saturation and moist weight of soils.

4.3.1.5.3.8 FREE SWELL INDEX OF SOIL: Determination of free swell index of soil which helps to identify the potential of a soil to swell which might need further detailed investigation regarding swelling and swelling pressures under different field conditions

4.3.1.5.3.9 WATER CONTENT: The moisture (water content) of a soil sample can be determined by the calcium carbide method with the help of moisture tester. (Ref: Soil Mechanics and Foundation by Dr B.C. Punmia ,1982)

4.3.1.5.3.10 BEARING CAPACITY OF SOIL BY PLATE LOAD BEARING TEST: The load test on soils and the evaluation of bearing capacities & settlement can be determined by this method. This method assumes that down to the depth of influence of stresses the soil strata is reasonably uniform. This should be verified by boring or sounding (Ref. IS 1888-1992).

4.3.1.5.3.11 GRADATION TEST FOR FILL/FILTER MATERIAL:- The proportion of the fine and coarse aggregate and gradation characteristics will be given after gradation test are carried out in the laboratory as per specifications.

4.3.1.6 TEST PROCEDURES FOR DIFFERENT TESTS:

4.3.1.6.1 TEST PROCEDURES FOR TESTING OF MATERIALS USED IN CONCRETE AND MASONRY WORK:

4.3.1.6.1.1 TESTING OF WATER: Annexure (3)/1 Vol. II describes the water testing procedures for suitability of water used in construction work

4.3.1.6.1.2 TESTING OF FINE AGGREGATE: Annexure (3)/2 Vol. II describes the different testing procedures of fine aggregates.

4.3.1.6.1.3 TESTING OF COARSE AGGREGATE: Annexure (3)/3 Vol. II describes the different testing procedures of coarse aggregates.

4.3.1.6.1.4 TESTING OF CEMENT: Annexure (3)/4 Vol. II describes the testing of cement.

4.3.1.6.1.5 TESTING OF POZZOLANA: Annexure (3)/5 Vol. II describes the testing of pozzolana.

4.3.1.6.1.6 TESTING OF CONCRETE / MORTAR: Annexure (3)/6 Vol. II describes the testing of concrete.

4.3.1.6.1.7 TESTING OF NATURAL BUILDING STONE: Annexure (3)/7 Vol. II describes the testing of Natural building stone.

4.3.1.6.1.8 TESTING OF BRICKS: Annexure (3)/8 Vol. II describes the testing of bricks.

4.3.1.6.1.9 TESTING OF LDPE FILM: Annexure (3)/9 Vol. II describes the testing of LDPE film.

4.3.1.6.1.10 TESTING OF FLEXURAL STRENGTH OF TILES: Annexure (3)/10 Vol. II describes the testing of flexural strength.

4.3.1.6.1.11 TESTING OF REINFORCEMENT BARS: Annexure (3)/11 Vol. II describes the testing of reinforcement bars.

4.3.1.6.2 TEST PROCEDURES FOR DIFFERENT SOIL TESTS:

4.3.1.6.2.1 GRAIN SIZE ANALYSIS: Annexure (4)/1 describes the following:

I. Test
II. Theory
III. Purpose
IV. Equipment needed
V. Test procedures
VI. Observations
VII. Calculations
VIII. Results
IX. Precautions
X. Reference

4.3.1.6.2.2 LIQUID LIMIT AND PLASTIC LIMIT OF SOIL: Annexure (4)/2 Vol. II describes as above (i) to (X) as required.

4.3.1.6.2.3 SHRINKAGE LIMIT TEST: Annexure (4)/3 Vol. II describes as above (i) to (X) as required.

4.3.1.6.2.4 COMPACTION TEST: Annexure (4)/4 Vol. II describes as above (i) to (X) as required.

4.3.1.6.2.5 TRIAXIAL SHEAR TEST: Annexure (4)/5 Vol. II describes as above (i) to (X.) as required.

4.3.1.6.2.6 PERMEABILITY TEST: Annexure (4)/6 Vol. II describes as above (i) to (X) as required.

4.3.1.6.2.7 SWELLING PRESSURE TEST: Annexure (4)/7 Vol. II describes as above(i) to (X) as required.

4.3.1.6.2.8 **TOTAL SOLUBLE SOLID:** Annexure (4)/8 Vol. II describes as above (i) to (X.) as required.

4.3.1.6.2.9 **SPECIFIC GRAVITY:** Annexure (4)/9 Vol. II describes as above (i) to (X.) as required

4.3.1.6.2.10 **FREE SWELL OF SOIL**: Annexure (4)/10 Vol. II describes as above (i) to (X.) as required.

4.3.1.6.2.11 **WATER CONTENT OF SOIL:** Annexure (4)/11 Vol. II describes as above (i) to (X.) as required.

4.3.1.6.2.12 **BEARING CAPACITY OF SOIL BY PLATE LOAD BEARING TEST:** Annexure (4)/12 Vol. II describe as above (i) to (X) as required.

4.3.1.6.2.13 **GRADATION OF FILTER MATERIAL:** Appendix II Vol. II describes the gradation of filter material.

4.4 FREQUENCIES OF VARIOUS TESTS:

Frequency of various tests is as specified in Annexure no.2A and 2B in Quality Control Manual Vol II.

4.5 QUANTITY OF SAMPLES TO BE SENT FOR TESTING TO LABORATORIES:

Following table:8 show the quantity of samples to be sent for testing of various materials:

S.No.	Purpose	Quantity	IS Code No. Specifications for sampling	Special Information's if any	Remarks
1	Suitability of cement	20 Kg	3535-1966	To be sent in sealed tins	
2	Suitability of Aggregate	Max. size in substantial quantity 50 mm and above 150 kg. below 50 mm 100 kg	2426	To be sent in double gunny bages to avoid loss of fines	
3	Mix Design	Cement	3535-1961	Instructions	

	of Concrete	100 Kg sand 500 Kg		against each item to be followed	
		Coarse Aggregate 1000 kg	2430	---do---	
		Pozzolanas (if any) 200 kg	3535-1966	---do---	
4	Mix Design of mortar	Same as S. No. 4 except coarse Aggregate	3535-1966	---do---	
5	Suitability of Bricks	50 Bricks	2430	By random Selection	
6	Suitability of Pozzolanas	50 Kg	1727	To be Sent in sealed tins	
7	Natural Building Stone	50 mm, 75 mm and 100 MM cubes or cylindrical specimens so that height is double the diameter or samples to yield above size specimen	----	To be sent according to test requirement	
8	Tiles Suitability	50 Tiles	3367-1965	By Random Selection	
9	Soil Cement block Suitability	100 kg soil	4322- part-I-1967	To be sent in double gunny bags to avoid loss of fines	
10	Tiles (for lining) Suitability and flexural strength	10 tiles	4969- 1968	By Random Selection	
11	Shear Strength C and Ø	Soil samples 3 cores of	-	In core well sealed	

	Values of soil samples for various test with triaxial testing machine	each location			
12	Permeability test of soil samples	---do---	-	---do---	
13	Swell Pressure Test	Disturbed soil sample one gunny bag	-	Representative Sample in Gunny Bags	
14	Permeability test of concrete and mortar samples	As per S.No. 3 & 4 above (For mix Design)	-	---do---	
15	Classification limits & suitability of soils etc.	Disturbed soil samples in one gunny bags	-	---do---	
16	Compaction test of Soil	Undisturbed soil sample	-	---do---	
17	Permeability test of Soil	---do---	-	---do---	
18	Embankment test section	As per appendix No. 1 Enclosed	-	-	
19	Filter design and layers laid	As per Appendix No. II enclosed	-	-	
20	Compaction efficiency permeability of compacted earth fill	As per Appendix No. III and IV enclosed	-	-	
21	Field moisture and dry density of sites	As per appendix No. V enclosed	-	-	
22	Hydraulic	Estimate	-	Funds and	

	Model testing on 2 D and 3 D models	and models prepared by Laboratory		Data to be supplied by Field Formation	

4.6 METHODS OF SAMPLING OF DIFFERENT MATERIALS FOR TESTING PURPOSE

4.6.1 For proper designing and execution purpose, results of “True Representative Samples” are must. Methods for taking true representative samples are given in different IS codes/ Technical Circulars. Details of methods of various materials are given in volume II. Methods as per IS Codes/TCs should be followed strictly so that purpose of execution is fulfilled perfectly and no complication arise in future. Sampling of aggregates (IS 2430 :1986) and methods of sampling for identification of expansive soil in sub grade and Identification of CNS material also given in Volume II.

4.7 TEST TO BE CONDUCTED IN CENTRAL LAB /FIELD LABORATORY

4.7.1 Following test may be carried out in the field laboratory

I. Field moisture and natural dry density of soils.
II. Compaction efficiency of compacted earth fill.

4.7.2 Following Tests may be conducted in the Project site laboratory.

i. Suitability of cement, fine & coarse aggregates, bricks , pozzolanas, building stone, tiles for lining
ii. Shear strength and permeability of soils
iii. Mix Design of concrete and Mortar and permeability of the same.
iv. Classifications, limits and suitability of soils
v. Swelling pressure of soils
vi. Compaction test of soils
vii. Embankment test section.
viii. Filter design and layers of filter laid.
ix. Rolled fill of earth dam
x. Free swell Index of soil

4.7.3 IN CENTRAL SOIL AND MATERIAL TESTING LABORATORY AT BHOPAL / JABALPUR

Following test may be got done in Central Soil and Material testing laboratory at Hathaikheda, Bhopal and Jabalpur

Table:9

Test To be Conducted in Soil and Material Testing Lab Hathaikheda, Bhopal				
S.no	Item. No.	Name of Test	IS Codes	Remarks
Soil Testing				
1	4201	Grain Size Analysis	(IS: 2720PTIV) Reaffirmed in 2010	
2	4202	Apparent specific gravity test	IS: 2720-Pt-III and sec I and sec-ii	
3	4203	Liquid,Plastic Limit & Plasticity Index (Atterberg limit)	(IS: 2720/Pt.V&VI) Reaffirmed in 2010	
4	4203	Srinkage Limit	(IS: 2720/Pt.V&VI)	
5	4204	Standard (Light Compaction test/relative density test	(IS: 2720Pt.VII&VIII) Reaffirmed in 2011	
6	4205	Laboratory Permeability test	(IS: 2720PtXVII). Reaffirmed in 2011	
7	4206	Effective Shear parameters by consolidated undrained test byTriaxial Shear machine on 37.5 mm dia sample	(IS: 2720 Pt XII) Reaffirmed in 2011	
8	4207	Determination of In-Situ Moisture content and density of Undisturbed Sample	(IS: 2720 Pt- XXIX)	
9	4208	Shear parameters by quick saturated test(Q sat) by Triaxial machine on undisturbed samples	(IS: 2720Pt. XI)	
10	4209	Shear parameters by quick test on sample at OMC &MDD or NMC &NDD by Triaxial machine on 37.5 mm dia sample	(IS :2720 Pt.XI.).	

11	4211	Consolidation Test on Disturbed or undisturbed Samples	(IS: 2720 Pt XV)	
12	4217	Swelling Pressure Test- (a) Free Swell (b)Swelling Pressure	(a) (IS: 2720 Pt. XL). (b) (IS:2720 Pt.XLI).Reaffirmed in 2011	Depend up on nature of soil
13	4220	Field Permeability Test-(in- situ) (a) Pumping in Test (b) pumping out test	(a) IS: 5529 Pt I (b) IS: 2720 Pt II	
14	4214	Chemical Tests on Soils- (I) Soluble salts test	IS: 2720 Pt-xxi Reaffirmed in 2010	
Material Testing				
Test on Cement				
15	4234	Consistency Test	(IS: 4031)	Total Suitability of Cement required 10 working Days to Complete
16	4235	Test for Setting Time	(IS: 4031)	
17	4233	Fineness test (a)By Sieving method sample (b) By Specific Surface i.e. Permeability Apparatus	(IS: 4031)	
18	4236	Specific Gravity Test	(IS: 4031)	
19	4238	Soundness Test	(IS: 4031)	
20	4240	Compressive strength of cement	IS 4031	
Coarse Aggregate				
21	4242	Unit Weight of Bulk density	(IS: 2386 Pt- III)	Total Suitability of Coarse Aggregate required 10 working Days to Complete
22	4241	Seive Analysis	(IS: 2386 Pt- I)	
23	4244	Absorption and Specific Gravity Test	(IS:2386 Pt-III)	
24	4248	Aggregate Impact Test	(IS:2386 Pt-IV)	
25	4250	Aggregate Crusing Value	(IS:2386 Pt-IV)	

26	4249	Abrasion Test by any of Following Method (a) Deval Abrasion Test (b) By Los Angelas Machine (C.) By Derry'es Abrasion Test	(IS:2386 pt-IV)	
27		Flakiness and Elongation Index		
28		Soundness Test	(IS:2386 Pt- V)	
Fine Aggregate				
29	4242	Unit Weight or Bulk density	(IS:2386 Pt- III)	Total Suitability of Fine Aggregate required 10 working Days to Complete
30	4241	Sieve Analysis	(IS:2386 Pt- I)	
31	4244	Absorption and Specific Gravity Test	(IS:2386 pt-III)	
32	4247	Soundness Test (a)10Cycles/Sample (b) 5Cycles/Sample	(IS:2386 Pt- V)	
33	4246	Test of Finding out Percentage of Clay, Silt and Fine Dust	(IS:2386 Pt-II)	
34		Determination of Moisture content	(IS:2386 Pt-III)	
Brick				
35	4264	Water Absorption of burnt Clay bricks (Five Specimen)	(IS:3495 Pt-2)	
36	4265	Compressive Strength of Bricks (a) Five No. (b) One No.	(IS:3495)	
37		Determination of Dimension		
Stone and Rock				
38	4275	Compressive Strength Test of Stone Specimen	(IS: 1121 Pt- I)	
39	4278	Water Absorbtion Test 24 Hours Immersion and 5		

		hours Boiling Test		
40	4277	Specific Gravity and Porosity Test	(IS: 1122)	
41		Slake Durability Test	IS; 10050	
Tiles				
42	4284	(a) Water Absorbtion Test		
		(b) Determination of Flexural Strength		
Beam				
43	4259	Determination of Flexural Strength of beam (a) Preparing Concrete beam of Size 10X10X50 cm		
Mix Design				
44		Mix Design	IS -10262 &456	
45	4255	Compressive strength of Cube Specimen of Size 15 Cm (a) Preparing Cube including Curing for Specified Time (minimum For 6 Specimen)	(IS: 516)	
46	4256	Compressive strength of Cube Specimen of Size 10 Cm (a) Preparing Cube including Curing for Specified Time (minimum For 6 Specimen)	(IS: 516)	
47	4263	Slump Test	(IS:1199)	
48	4262	Determination of permeability of Concrete	(IS:3085)	
Non Destructive Test of Concrete				

49	4260	(a) Pulse Velocity Meter minimum no. of Specimen Three		
		(b) Rebound Hammer minimum no. of Specimen Three		
Tensile Strength of LDPE				
50		Tensile strength of LDPE Film	IS :3395 1997	
Chemical Testing				
51	4214	Chemical Test on Soils- (a) Lime content test (b) Soluble Salt Test	(a) IS: 2720 Pt XXIII (b) IS: 2720 Pt XXI	
52	4215	Chemical test for water suitability for irrigation use		
53	4253	Alkali aggregate reactivity test As Per ASTM (Reduction of Alkali Silica release test)	IS: 2386 Pt VII	
54	4254	Potential alkali aggregate reactivity test	IS: 2386 Pt VII	
Water Testing For Drinking and irrigation Purpose				
55		Ph Value	IS: 10500	
56		Total Hardness	IS: 3025	
57		Calcium Hardness	IS: 3025	
58		magnesium Hardness	IS: 3025	
59		Alkalinity		
60		Total Dissolved Solids	IS: 10500	
61		Dissolved Solids And Suspended Solids	IS: 10501	
62		Turbidity	IS: 10502	
63		Conductivity	IS: 10503	
Water Testing by spectrophotometer				

64		Fluoride	IS : 3025 Pt-60	
65		Chlorine	IS : 3025 Pt-26	
66		Nitrate	IS : 3025 Pt-34	
67		Nitrite	IS ASTM D 3867-09	
68		Phosphate	ASTM F 1088-049	
69		Iron	IS : 3025 Pt-53	
70		Chloride	IS : 3025 Pt-32	
71		Sulphate	IS : 3025 F 1088-049	
72		Silica	ASTM D 859-10	
Determination of Mix proportion by Chemical Analysis				
73		Concrete	Publication E In C -25 year Nov-1981 page No. 95	
74		Mortar	Publication E In C -25 year Nov-1981 page No. 96	

Test & Study To be Conducted in Hydraulic Laboratory, Hathaikheda, Bhopal
Hydraulic Model Testing on 2D and 3 D models of major and medium projects spillways

4.8 TEST TO BE CONDUCTED ACCORDING TO THE COST OF STRUCTURE

4.8.1 Quality Control is necessary for safety, reliability, and durability of all structures and also for optimum use of building and scarce materials.

4.8.2 The degree of quality control to be exercised will depend on the importance, location, purpose and cost of the work. The Engineer in charge, responsible for the quality control of the work shall specify the type of the quality control to be exercised for the works under his control as follows:

I. For major , medium and minor dams and hydraulics structures costing more than Rs 2 crores quality control as specified in Annexure 2 (C) in Vol II shall be followed :

II. For other comparatively less important structures costing less than Rs 2.0 crores and more than Rs 20 lakhs following test as per list attached in Annexure 2 (C).in Vol II shall be exercised :
S.No. 2,3,4,5,6, 8(i),8(ii), 8(iii), 9, 11.

III. For Structure costing less than Rs 20 Lakhs following test as per list attached in Annexure 2 (C) in Vol II shall be exercised :

S.NO. 2 , 3 (4), 3 (5), 8(i)

4.9 REPORTING

4.9.1 The results of the test shall be communicated by the Officer –In Charge of quality control to the concerned Officer- In charge of Execution with a view to enable him to take corrective measures immediately.

4.9.2 The Weekly Progress Report of Dam/ Canal Work in proforma given in Appendix –XV, regarding quality control work, separately for earth fill work/ concrete/ masonry work shall be prepared and sent to Executive Engineer (Quality control) Executive Engineer (Constructions) by Assistant Engineer (Quality control).

4.9.3 The Weekly Progress Report on Borrow Areas operation Pass (Soil/Sand/Bricks) in proforma given in Appendix –XVII, regarding borrow areas operation pass (Soil / Sand / Bricks), shall be prepared and sent to Executive Engineer (Quality control) Executive Engineer (Constructions) by Assistant Engineer (Quality control).

4.9.4 For the whole working season, a seasonal report based on tests performed for various items of quality control work shall be prepared by the Executive Engineer (Quality Control) during monsoon period and submitted to Executive Engineer (Construction) , Superintending Engineer and Chief Engineer in September of Each Year. **(Ref: Kolar quality control manual 5.2)**

4.10 MAINTENANCE OF RECORDS

4.10.1 Okay is the approval given by either Quality Control Unit or field officers. On the basis of this okay or approval the construction of the work advances. Therefore all these Okays and approvals shall be properly kept in the record.

4.10.2 The okay cards should be prepared in 4 copies viz. one copy with Quality Control unit, Second copy A.E. Works, Third copy with Executive Engineer (works) and fourth copy with work site.

4.10.3 Okay card should be kept in file in the same order date wise as per progress of construction.

4.10.4 Okay cards should be maintained job-wise as per 4.10.3 above.

4.10.5 A register showing the Okays given by the Quality Control unit should be maintained in the proforma given in Annexure -40 and kept in the Quality Control Division.

4.10.6 Quality Control staff should not write in the site order book when the work of the contract as in progress.

4.10.7 Quality Control Staff should avoid unnecessary correspondence.

4.10.8 For each major project, the whole working season, a seasonal report based on tests performed for various items of quality control work shall be prepared by the Executive Engineer, Quality Control during monsoon period and submitted to Executive Engineer (construction), Superintending Engineer and Chief Engineer in September of each year & properly kept in the records.

4.10.9 Manufacturer tests certificate for each material duly tallying with Batch No., Site Inspection Report of Higher officers & Change orders for Design, materials etc. shall be kept in records.

4.11 TEST SPECIMEN, TEST RESULTS OF SAMPLES AND ACCEPTANCE CRITERIA FOR COMPRESSIVE STRENGTH OF CONCRETE:

4.11.1 Three test specimens shall be made for each sample for testing at 28 days. Additional specimen may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of stripping the formwork, or to determine the duration of curing, or to check the testing error. Additional specimen may also be required for testing specimens cured by accelerated methods as described in IS: 9013. The specimen shall be tested as described in IS: 516. The test results of the sample shall be average of the strength of three specimens. The individual variation should not be more than ± 15 % of the average. If more, the test results of the samples are invalid. In all cases the 28 days compressive strength specified shall alone be the criterion for acceptance or rejection of the concrete in accordance with the following:-

4.11.2 ACCEPTANCE CRITERIA: (IS 456: 2000):-

4.11.2.1 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 non-overlapping consecutive test results complies with the appropriate limits in Column 2 of Table 10 below.

b. Any individual test result complies with the appropriate limits in column 3 of Table 10 below .

4.11.2.2 **Flexural Strength**: When both the following conditions are met, the concrete complies with the specifies flexural strength.

The mean strength determined from any group of four consecutive test results exceeds the specified characteristics strength by at least 0.3 N/mm^2. The strength determined from any test results is not less than the specified characteristics strength less 0.3 N/mm^2.

4.11.3 Concrete of each grade shall be assessed separately.

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

Table:10: Characteristics Compressive Strength Compliance Requirement (Clauses 4.11.2.1 to 4.11.2.2)

Specified Grade	Mean of the Group of 4 Non-Overlapping Consecutive Test Results in N/ mm^2	Individual Test Results in N/mm^2
(1)	(2)	(3)
M 15 and above	≥ f_{ck} + 0.825X established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 3 N/mm^2 , whichever is greater	≥ f_{ck} -3 N/mm^2

NOTE: 1. In the absence of established value of standard deviation, the values given in Table 8 of IS:456 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.

2. For concrete of quantity up to 30 m^3 (where the number of samples to be taken is less than four as per the frequency of sampling, the mean of test results of all such samples shall be f_{ck} + 4 N/ mm^2, minimum and the requirement of minimum individual test results shall be f_{ck} - 2 N/ mm^2, minimum, however , when the number is only one as per frequency of sampling, the requirements shall be f_{ck} + 4 N/ mm^2, minimum.

4.12 GUIDELINES FOR ASSESSING THE QUALITY OF CONCRETE IN THE STRUCTURE: BY ADOPTING DIFFERENT TESTS MEHODS (CORE TEST, LOAD TESTS AND NON-DESTRUCTIVE TESTS):

4.12 GUIDELINES FOR ASSESSING THE QUALITY OF CONCRETE IN THE STRUCTURE: BY ADOPTING DIFFERENT TESTS MEHODS (CORE TEST, LOAD TESTS AND NON-DESTRUCTIVE TESTS): In case of doubt regarding the grade of concrete used, this procedure should adopted for assessing the quality of concrete.

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

4.12.2 The compression test on cubes /cylinders cast at the construction site from a batch of concrete indicates the potential strength of the concrete placed in the element of the structure since the strength of such specimens depends on many variables such as shape, proportion of the mix and size of the specimens. The strength also depends on the procedures followed while preparing the test specimens at site, such as compaction, curing, storage and handling before being subjected to the actual test. The conditions of placement of concrete also vary in respect of transportation, placing, compaction and curing compared to ideal conditions prescribed for making the test specimens.

4.12.3 All these factors contribute to variations in the compression test results of the specimens. If the test results are below the specified minimum then the actual concrete in the structure could be too weak, or else the specimens are not truly representative of the concrete in the structure. This can give rise to disputes on the acceptance or otherwise of a doubtful portion of a structure.

4.12.4 In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on the results of cube strength tests (do not satisfied the acceptance criteria), Compressive strength tests of concrete, core specimen and or load test may be carried out. Cores may also be taken to assess the actual potential strength of a structure at a later date to decide on its suitability for modifications such as the construction of additional floors, or changes in the loading pattern etc.

4.12.5 In case the core test results do not satisfy the acceptance criteria as per Para 17.4.3 of IS 456 or where such tests have not been done, load tests may be resorted to. Load test should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete.

4.12.6 There are occasions when the various performance characteristics i.e. overall quality / uniformity etc of concrete in structure, other than the compressive strength are required to be assessed. The various methods that can be adopted for in-situ assessment of strength properties of concrete in question. i.e., if the load carrying capacity of structural ensemble is to be assed, carrying out a full-scale load test, as per IS: 456 or IS: 1343, is the most direct way; On the other hand when the actual compressive strength of a concrete in the structure is to be measured, core testing as per IS: 516/457 is more reliable. However both these methods are relatively cumbersome and the later methods may leave the structure damaged locally in some cases. Use is, therefore, made of suitable non-destructive tests, which not only provide an estimate of the relative strength and overall quality of concrete in the structure, but also help in deciding whether more rigorous test like load testing or core drilling at selected locations are required.

4.12.7 The methods adopted include Ultrasonic Pulse Velocity (IS: 13311 part I) and rebound hammer (IS: 13311 Part II), Probe penetration, Pullout and maturity. These test methods can supplement the data obtained from a limited number of cores.

4.12.8 Non-destructive tests are at best indirect methods of monitoring the particular characteristics of concrete and the measurements are influenced by materials, mix and environmental factors proper interpretations of the results calls for certain degree of expertise. It is more so, when the data on the materials and mix proportions used in the constructions are not available as is often the case.

4.12.9 In view of the, limitations of the method for predicting the strength of concrete in the structure, it is preferable that both ultrasonic pulse velocity as per Part I of IS 13311 and rebound test hammer method as per Part 2 of IS 13311 are used in combination to alleviate the errors arising out of influence of material, mix and environmental parameters on the respective measurements. Relationship between pulse velocity, rebound number and compressive strength of concrete are obtained by multiple regressions of the measured values on laboratory test specimens. However, this approach has the limitation that the correlations are valid only for the materials and mix proportions used in the trials. The intrinsic differences between the laboratory test specimens and in-situ concrete for example surface texture, moisture condition, presence of reinforcement, etc, also affect the accuracy of results. The correlation is valid only within the range of values of pulse velocity, rebound number and compressive strength employed and any extrapolation beyond these is open to question. The rebound hammer test is not intended as a substitute for standard compression test, but as a method for determining the uniformity of concrete in the structure and comparing one concrete with another.

4.12.10 Because of the above Limitations, the combined use of these two methods is made in another way. In this , if the quality of concrete is assessed to be " excellent or good" by pulse velocity method, only then the compressive strength is assessed from the rebound hammer indices, and this is taken as indicative of strength of concrete in the entire cross –section of the concrete member . when the quality assessed is "medium" , the estimation of compressive strength by rebound indices is extended to the entire mass only on the basis of other colateral measurements, for example, strength of site concrete cubes , cement content in the concrete or core testing . When the quality of concrete is doubtful, no assessment of concrete strength is made from rebound indices.

4.12.11 In most of the situations, the records of the original materials or mix proportions used in the structure are not available. Therefore , considerable improvisations has to be done in evolving the testing scheme and use is made of comparative measurements made on adjoining portions of the structures or even other structures in the vicinity of the one in question. In doing so, an approach is taken that the same materials and similar mix proportions and level of workmanship were employed for the two situations, any significant differences in the Ultrasonic pulse velocity or rebound indices between them must be due to some inherent differences in the overall quality. If the nominal grades of concrete or mix proportions are known to be different in either case, suitable allowance is made for the same in interpretation of results.

4.12.12 The test results on ultrasonic pulse velocity and rebound indices are analyzed statistically and plotted as histograms and the lower fractiles or results are taken for assessing the quality or 'characteristics' strength of concrete , in line with the current limit state concepts of design.

4.12.13 These methods are based on measuring a concrete properly that bears some relationship to strength and the physical quality measured by the non destructive tests.

4.12.14 Any of these methods (Non destructive testing viz pulse velocity test, rebound hammer test) may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.

4.13 PHYSICAL /VISUAL/FIELD TESTS

4.13.1 FOR SAND:

4.13.1.1 Tests for Sand: Following test may be carried out to ascertain the properties of sand:

4.13.1.1.1 A glass of water is taken and some quantity of sand is placed in it. It is then vigorously shaken and allowed to settle. If clay is present in sand, its distinct layer is formed at top of sand.

4.13.1.1.2 For detecting the presence of organic impurities in sand, solution of sodium hydroxide or caustic soda is added to sand and it is stirred. If colour of solution changes to brown, it indicates the presence of organic matter.

4.13.1.1.3 Sand is actually tested and from its taste, presence of salts is known.

4.13.1.1.4 Sand is taken from a heap and it is rubbed against the fingers. If fingers are stained, it indicates that sand contains earthy matters.

4.13.2 FOR CEMENT:

4.13.2.1 Following field tests may be carried out to ascertain roughly the quality of cement.

4.13.2.1.1 **Colour:** The colour of cement should be uniform. It should be typical cement colour, i.e. grey colour with a light greenish shade.

4.13.2.1.2 **Physical Properties:** Cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand. If hand is inserted in a bag or heap of cement, it should feel cool. If a small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface.

4.13.2.1.3 **Presence of lumps:** Cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.

4.13.2.1.4 **Strength:** Strength of cement can roughly be ascertained by making briquettes with a lean or weak mortar. The size of briquette may be about 75 mm X 25 mm X 12 mm. Proportion of cement and sand may be 1:6. The briquettes are immersed in water for a period of 3 days. If cement is of sound quality, such briquettes will not be broken easily and it will be difficult to convert them into powder form.

4.13.3 PHYSICAL/ FIELD TEST OF STONE:

4.13.3.1 QUALITIES OF A GOOD BUILDING STONE: Following are the qualities or requirements of a good building stone:

4.13.3.1.1 **Appearance**: Stones which are to be used for face work should be decent in appearance and they should be capable of preserving their colour uniformly for a long time.

4.13.3.1.2 **Durability**: A good building stone should be durable. Various factors contributing to durability of a stone are its chemical composition, texture, resistance to atmospheric and other influences, location in structure etc. following are the important atmospheric agencies which affect durability of a stone

1. Alternate conditions of heat and cold due to differences in temperature;
2. Alternate conditions of wetness and dryness due to rain and sunshine;
3. Chemical agencies such as dissolved gases in rain;
4. Growth of trees and creepers in joints between stones;
5. Wind with high velocity; etc.

For making stones durable, their natural bed should be carefully noted. Stones should be so arranged in a structure that natural bed is perpendicular or nearly so to the direction of pressure.

4.13.3.1.3 **Facility of dressing**: Stones be such that they can be dressed easily and economically.

4.13.3.1.4 **Fractures**: For a good building stone, its fractures should be sharp even and clear.

4.13.3.1.5 **Resistance of fire**: Minerals composing stone should be such that shape of stone is preserved when a fire occurs. Failure of stones in case of a fire is due to various reasons such as rapid rise in temperature, sudden cooling, different coefficients of liner expansions of minerals, etc. free quartz suddenly expands at a temperature lower than 600^{o} C. lime stone resists fire up to about 800^{o}C and it then splits into CaO and CO_2. Sand stone with silicates as binding material can resist a fire in a better way. Argillaceous stones are poor in strength. But they can resist fire quite well.

4.13.3.1.6 **Seasoning:** Stones should be well seasoned before putting into use. Stones obtained freshly from a quarry contain some moisture which is known as quarry sap. Presence of this moisture makes the stone soft. Hence, freshly quarried stones are easy to work. It is, therefore, desirable to do dressing, carving, etc when stones contain quarry sap. Stones should be dried or seasoned before they are used in structure work.

4.13.3.1.7 **Texture:** A good building stone should have crystalline structure stones with such texture are strong and durable.

4.13.3.1.8 **Weathering:** A good building stone should possess better weathering qualities. It should be capable of withstanding adverse effects of various atmospheric and external agencies such as rain, frost, wind, etc.

4.13.3.1.9 It should, however, be remembered that one kind of stone is not suitable in all types of constructions**.** For instance, soft stones are required for carving, light stones are required for arches and hard stones are necessary to stand high pressures. It is, therefore, necessary to study carefully the situation in which stones are to be used before any recommendation is made. Other factor which affects the selection of stone are easy availability, nearness of quarry, facility of transport, reasonable price, etc.

4.13.4 PHYSICAL/ FIELD TEST OF BRICKS:-

4.13.4.1 QUALITIES OF GOOD BRICKS: Good bricks which are to be used for the construction of important structures should possess the following qualities:

4.13.4.1.1 Bricks should be table-moulded, well-burnt in kilns, copper-coloured, free from cracks and with sharp and square edges.

4.13.4.1.2 Bricks should be uniform in shape and should be of standard size.

4.13.4.1.3 Bricks should give clear ringing sound when struck with each other.

4.13.4.1.4 Bricks when broken should show homogeneous and compact structure.

4.13.4.1.5 Bricks should not absorb water more than 20 percent by weight for first class bricks and 22 percent by weight for second class bricks, when soaked in cold water for a period of 24 hours.

4.13.4.1.6 Bricks should be sufficiently hard. No impression should be left on brick surface, when it is scratched with the finger nail.

4.13.4.1.7 Bricks should not break when dropped flat on hard ground from a height of about one meter.

4.13.4.1.8 Bricks should have low thermal conductivity and they should be sound-proof.

4.13.5 FOR IDENTIFICATIONS OF EXPANSIVE SOIL OF CANAL SUB GRADE FOR PROVISION OF CNS:

4.13.5.1 IDENTIFICATION OF EXPANSIVE SOIL: Following indications are generally observed in the case of expansive soil:

4.13.5.1.1 During summer wide deep and map type cracking is normally observed in expansive soils.

4.13.5.1.2 Walking over such soil is rendered difficult during heavy rain.

4.13.5.1.3 Thorny bushes, thorny trees (Babul) and cactus constitute the normal vegetation in such soil in India.

4.13.5.1.4 Building constructed using conventional methods exhibit heaving of floors, cracking of walls and jamming of doors during rainy season. Retaining structures get tilted and roads get rutted bed heaving and side slips and sloughing are noticed in canal.

4.13.5.1.5 The expansive soils can be identified by following visual properties.

Colour: - Black, Grey, Yellow and Yellowish Grey

Land Slope:- Normally to 2

Drainage:- Generally poor

4.13.6 IDENTIFICATION OF MATERIAL FOR PROVISION OF CNS IN CANAL:

The CNS material can be identified by using visual properties:

i. **Colour:** Red, Reddish, Yellow, Brown, White, Whitish, Grey, Whitish yellow, Green and Greenish grey.
ii. **Land Slope:** Normal land slopes are between 2 and 10, though on flatter slopes they are many times encountered with in 3 m below the overlaying expansive soil.
iii. **Drainage**: Generally good.

CHAPTER – 5

CHECK LISTS & O.K. CARDS

5.1 Construction activity can be broadly classified in following two categories

i. Activity not requiring Laboratory Test.
ii. Activity requiring Laboratory Test.

5.1.1 CHECK LISTS

Activities like stripping, foundation, preparation, laying chimney filler, rock toe, instrumentation, construction joints, contraction joint etc. are the activities where laboratory tests are not required and are okayed by visual inspection. For effective control on these important items of work, check lists are prescribed as per Annexure 6/1 to 6/8.

Check list consists of a questionnaire to be answered by construction staff only. After fulfilling the check list requirement, the subsequent activity should be permitted. These check lists duly filled and signed by construction staff, shall be kept in bound registers by Assistant Engineer (Construction).

In specific cases, however, the Executive Engineer (Construction) may direct the Assistant Engineer Quality Control to check any of these activities jointly with Sub Divisional Officer (Construction).

5.1.2 O.K.CARDS (For Major & Medium Projects)

For activities where laboratory tests are required for approval of the quality of work from quality control unit, O.K. card system shall be followed.

The O.K. card consists of two sets of columns One set to be filled by the construction staff and other by quality control personnel. The columns in first set relate to the location and type of work and the methods of its performance. The second set contains columns to be filled with field test results and laboratory data.

The Assistant 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 Embankment Inspector/ Assistant Engineer (Quality Control) in charge of the quality control unit. The quality control staff at actual work site will perform necessary test under guidance of Assistant Engineer (Quality Control). The Assistant Engineer (Quality Control) will scrutinize the O.K. cards and finally okay the work if anything otherwise is not observed, should anything otherwise be found, the O.K. cards shall be returned by him to the Assistant Engineer (Construction) for necessary rectification.

The Subsequent O.K. Cards should refer to the defects removed, if pointed out in the previous O.K. Cards, and counter reference to the previous O.K. Card returned with observation, shall be made.

It must be borne in mind that work cannot be held up for delay in disposal of O.K. Card. The Executive Engineer/ Assistant Engineer (Quality Control) will be the okaying authority for concentrated work like dam, spillway & Barrage & the Embankment Inspector (Quality Control) will be the okaying authority for scattered work like in canals.

In absence of Assistant Engineer (Construction) his concerned Sub-engineer-in-charge of works shall issue O.K. Cards while the Embankment Inspector will perform the duties of Executive Engineer/ Assistant Engineer (Quality Control) in his absence.

After processing through various levels and entering observation one copy of the O.K. Card shall be returned to the Assistant Engineer (Construction) for records & reference and the other copy shall be forwarded to the Executive Engineer (Quality Control) for record.

Specimen of O.K. Cards for various works such as Soil, Concrete, Masonry, Filter and boulder pitching have been appended as Annexure 6/9 to 6/12.

5.1.3 DECISION IN CASE OF DIFFERENCE OF OPINION

In case of difference of opinion over any matter concerning quality of material or work, the Assistant Engineer (Quality Control) should inform Assistant Engineer (Construction) who should generally accept the decision of Assistant Engineer (Quality Control) in this respect he should ensure that work is carried out as per specifications. If, however, the Assistant Engineer (Construction) differs from Assistant Engineer (Quality Control), then:-

(a) In Case of Dam: the matter should be reported by Assistant Engineer (Quality Control) to Executive Engineer (Construction) who should decide the issue with Executive Engineer (Quality Control) if required. In case of difference of opinion between the two Executive Engineer, the matter should be referred to Superintending Engineer (Construction) for final decision. Superintending Engineer Construction will decide the matter in consultation with Superintending Engineer Quality Control.

(b) In case Barrage & Canals, the matter should be reported by Assistant Engineer (Quality Control) to the Executive Engineer (Construction) who should decide the issue with Assistant Engineer (Quality Control). In case of difference of opinion between the Executive Engineer (Construction) &

Assistant Engineer (Quality Control) the matter should be referred to Superintending Engineer (Construction) for final decision. Superintending Engineer Construction will decide the matter in consultation with Superintending Engineer Quality Control.

5.1.4 DECISION REGARDING UNSUITABILITY OF MATERIAL:

The decision regarding un-suitability of material shall be taken not below the rank of Assistant Engineer (Quality Control). If the lower staff of quality control finds material unsuitable they should inform Assistant Engineer (Quality Control) immediately.

5.2 O.K. CARDS

5.2.1 LAY OUT:-

5.2.1.1 DAM AND APPURTENANT WORK

Proforma O.K. Cards as per Annexure -5 shall be followed.

5.2.1.2 CANAL AND STRUCTURES

Proforma O.K. Cards as per Annexure -6 shall be followed.

5.2.2 CONCRETE WORKS IN:-

5.2.2.1 FOUNDATION / PLINTH

Proforma O.K. Cards as per Annexure -7 shall be followed.

5.2.2.2 SUPER STRUCTURE

Proforma O.K. Cards as per Annexure -8 shall be followed.

5.2.3 MASONRY WORKS IN:-

5.2.3.1 FOUNDATION / PLINTH

Proforma O.K. Cards as per Annexure -9 shall be followed.

6.2.3.2 SUPER STRUCTURE:

Proforma O.K. Cards as per Annexure -10 shall be followed.

5.2.4 EARTH WORKS ON DAMS / CANALS- LAY OUT:-

5.2.4.1 DAMS FOR MAJOR PROJECT

Proforma O.K. Cards as per Annexure -11 shall be followed.

5.2.4.2 DAMS FOR MEDIUM PROJECTS

Proforma O.K. Cards as per Annexure -12 shall be followed.

5.2.4.3 DAMS FOR MINOR PROJECTS

Proforma O.K. Cards as per Annexure -13 shall be followed.

5.2.4.4 MAIN CANAL AND DISTRIBUTARY

Proforma O.K. Cards as per Annexure -14 shall be followed.

5.2.4.5 MINORS

Proforma O.K. Cards as per Annexure -15 shall be followed.

5.2.5 FILTERS:-

Proforma O.K. Cards as per Annexure -16 shall be followed.

5.2.6 BOULDER PITCHING ON:-

5.2.6.1 U/S SLOPE OF EARTH DAM

Proforma O.K. Cards as per Annexure -17 shall be followed.

5.2.6.2 IN BED OF RIVER OR CANAL

Proforma O.K. Cards as per Annexure -18 shall be followed.

5.2.6.3 AROUND THE ABUTMENT OR STRUCTURE

Proforma O.K. Cards as per Annexure -19 shall be followed.

5.2.7 ROCK TOE OR BOULDER TOE OR RIP RAP

Proforma O.K. Cards as per Annexure -20 shall be followed.

5.2.8 FOUNDATION OF:-

5.2.8.1 EARTH DAM

Proforma O.K. Cards as per Annexure -21 shall be followed.

5.2.8.2 MASONRY DAM

Proforma O.K. Cards as per Annexure -22 shall be followed.

5.2.8.3 STRUCTURE OF HEAD WORKS

Proforma O.K. Cards as per Annexure -23 shall be followed.

5.2.8.4 STRUCTURE OF CANALS
Proforma O.K. Cards as per Annexure -24 shall be followed.

5.2.8.5 GATES AND VALUES:
Proforma O.K. Cards as per Annexure -25 shall be followed.

5.2.9 INSTRUMENTATION OF:-

5.2.9.1 MASONRY DAM
Proforma O.K. Cards as per Annexure -26 shall be followed.

5.2.9.2 EARTH DAM
Proforma O.K. Cards as per Annexure -27 shall be followed.

5.2.10 TURFING ON:-

5.2.10.1 EARTH DAM ON U/S
Proforma O.K. Cards as per Annexure -28 shall be followed.

5.2.10.2 CANAL BANKS
Proforma O.K. Cards as per Annexure -29 shall be followed.

5.2.11 LINING IN CANALS:-

5.2.11.1 MAIN CANAL AND DISTRIBUTARY:
Proforma O.K. Cards as per Annexure -30 shall be followed.

5.2.11.2 MINORS
Proforma O.K. Cards as per Annexure -31 shall be followed.

5.2.11.3 FIELD CHANNELS AND WATER COURSES
Proforma O.K. Cards as per Annexure -32 shall be followed.

CHAPTER – 6

REFERENCE BOOKS AND CODES

6.1 REFERENCE BOOKS AND CODES

6.1.1 NEED:

It is needless to emphasize the necessity of proper and appropriate reference books, journals, I.S. codes, specifications, technical circulars etc. These should be readily available to the field and quality control staff. The A.E. works and Sub-Engineer works should have with them the contract agreement which contains the specifications of works and jobs to be executed invariably. The specifications and Technical circulars issued by BODHI from time to time should be made available at Assistant Engineer /Assistant Research Officer works / Quality Control Level. The specifications prepared by BODHI are quite exhaustive so also the technical circulars issued by BODHI are quite useful .The Assistant Engineer / Assistant Research Officer Works / Quality Control. should maintain a library in their office and all these reference books and relevant codes should be kept there.

6.1.2 I.S. CODES:

The I.S. Codes referred to in the manual are listed and enclosed as per Annexure 33 Vol.II.

6.1.3 REFERENCE BOOKS:

The books which are considered to be useful during execution of works and constructions progress are listed and enclosed as per Annexure -34 Vol.II.

6.1.4 SPECIFICATIONS ISSUED BY BODHI:

As list of specification issued by BODHI so far are as per list enclosed as per Annexure -35 Vol.II.

6.1.5 TECHNICAL CIRCULARS ISSUED BY BODHI:

As per Technical Circulars issued by BODHI related to quality control, so for are as per list enclosed vide Annexure -36 Vol.II**.**

6.1.6 SCHEDULE OF RATES IN FORCE FROM 2009

The Schedule of rates in force from 2009 should be followed. The provision in the schedule of rates will take precedence over the specification.

6.1.7 PRO FORMA FOR USE BY Q.C. STAFF/WORKS STAFF:

A list of Proforma to be used by Q.C. Staff is enclosed as per Annexure-37 Vol.II.

A list of Proforma to be used by works staff is enclosed vide Annexure -38 Vol.II.

CHAPTER – 7

DO’S & DO-NOT’S

7.1 DO’S AND DO-NOT’S

7.1.1 Do’s and Do-not’s for inspection and supervisory staff for following as per annexure -39 Vol.II may be followed.

i) Excavation
ii) Diversion of River
iii) Grouting
iv) Masonry
v) Concrete
vi) Laboratory

As a matter of fact S.No. (i) to (v) above should be kept before the eyes of Superintending Engineer to Executive Engineer level and daily it should be seen and S.No. vi should be kept in the Laboratory before the eyes of laboratory staff engaged in the quality control division / laboratory at Project site.

Note : Please see all Annexure and Appendix in Quality Control Manual Volume II.

CHAPTER - 8

DEFINITIONS

Various definitions of terms used are given below:

ABSORBED WATER:
Water held on surface of a material by electro chemical forces and having physical properties substantially different from those of absorbed water or chemically combined water at the same temperature and pressure.

ACCELERATOR:
A substances which when added to concrete, mortar or grout, increase the rate of hydration of the hydraulic cement, shortens the time of setting, or increase the rate of hardening or strength development.

ADDITION / ADDITIVE:
A material that is interground or blended in limited amounts into a hydraulic cement during manufacturer either as a “Processing addition” to aid in manufacturing and handling the cement or as a “ functional addition” to modify the use properties of the finished product.

ADMIXTURE:
A material other than water aggregates and hydraulics cement used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing to modify one or more of the properties of concrete in the plastic or hardened state.

AGGREGATE COARSE:
Aggregate most of which is retained on 4.75 mm, IS sieve and containing only so much of finer material, as is permitted by the specifications or alternatively (under differing circumstances), the portion of an aggregate retained on the 4.75 mm IS sieve.

AIR CONTENT:
The volume of air voids in cement paste, mortar, or concrete, exclusive of pore space in aggregate particles, usually expressed as a percentage of total volume of the paste, mortar or concrete.

AIR ENTRAINING ADMIXTURE:
An admixture for concrete or mortar which cause air to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase workability and resistance to freezing and thawing and disruptive action of de-icing salts.

ALKALI:
Salts of alkali metals, principally sodium and potassium specifically sodium and potassium occurring in constituents of concrete or mortar, usually expressed in chemical analysis as the oxides Na_2O and K_2O.

ALKALI AGGREGATE REACTION:
Chemical reaction in mortar or concrete between alkalis (Sodium and Potassium) from Portland cement or other sources and certain constituents of some aggregates; under certain conditions, deleterious expansion of the concrete or mortar may result.

ALKALI REACTIVITY (of aggregate):
Susceptibility of aggregate to alkali aggregate reaction.

BATCHING PLANT:
An operating installation of equipments including batchers and mixers as required for batching or for batching and mixing concrete materials; also called mixing plant when mixing equipment is included.

BLACK COTTON SOIL:
They are a type of expansive soil and form a major soil group in India. The colour of black cotton soil vary from black, yellowish to grey. They are characteristised by high shrinkage and swelling properties.

BULKING OF SAND:
Increase in the bulk volume of a quantity of sand in a moist condition over the volume of the same quantity, dry or completely inundated.

CLAY:
Clay constituents the finest and most active portion of the soil material and is generally characterized by high to very high dry strength. Lack of reaction to shaking test, and a plastic thread which is strong when wet and which becomes stiff or tough as it dries.

COARSE GRAINED SOILS:

Coarse grained soils consists of mineral fragments visible with the naked eye and or having a gritty feel when rubbed between the fingers.

COHESIVE - NON-SWELLING SOIL (C.N.S.):

They are soils possessing the property of cohesion of varying degree and having non-expanding type clay minerals such as illite and kaolinite and their combination with low plasticity with liquid limit not exceeding 50.

COMPACTION:

The densification of a soil by means of Mechanical manipulation.

COMPACTION OF SOILS:

Compaction test of soils (Moisture density relationship) done in the laboratory is the dry density at particular moisture content at which the density of the soil is the maximum.

COMPACTING FACTOR:

The ratio obtained by dividing the observed weight of concrete which fills a container size and shape when allowed to fall into it under standard condition of test by the weight of fully compacted concrete which fills the same container.

CONSISTENCY:

The relative mobility or ability of freshly mixed concrete or mortar to flow, the usual measurement are slump for concrete and flow for mortar cement paste or grout.

CONSOLIDATION:

The gradual reduction in volume of a soil resulting from an increase in compressive stress.

CRUSHED STONE SAND:

Fine aggregates produced by crushing hard stone.

CRUSHED GRAVEL SAND:

Fine aggregates produced by crushing natural gravel.

CUBE STRENGTH:

The load per unit area at which a standard cube fails when tested in a specified manner.

CURING:

Maintenance of humidity and temperature of freshly placed concrete during some definite period following placing, casting or finishing to assure satisfactory hydration of the cementitious materials and proper hardening of the concrete.

DESIGNED MIX:

By designing the mix incorporating the various properties of ingredients to make the most economical use of available materials to produce the mix of required properties.

DURABILITY:

The ability of concrete to resist weathering action, chemical attack, abrasion and other conditions of service.

EARLY STRENGTH:

Strength of concrete or mortar developed soon after placement usually during the first 72 hours.

EXPANSIVE SOIL:

They are inorganic or organic clays of high plasticity with high compressibility and liquid limit more than 50 and are characterised by shrinkage and swelling properties.

FINE GRAINED SOILS:

Fine grained soils consists of mineral particles of microscopic or submicroscopic size which have a smooth or floury feel when moistened with water.

FIELD DENSITY TEST:

Compaction done in the field at the moisture content at which soil is placed.

FINE AGGREGATE:

Aggregate most of which passes 4.75 mm IS sieve & contains only so much coarser material as permitted in concern IS codes of specifications of sand for concrete/ mortar/ plaster.

FLY ASH:

A finely divided residue that results from the combustion of ground or pulverized coal & is transported from boilers by flue gases & collected by cyclone separation or electrostatic precipitation. It may be as part replacement of O.P.C provided uniform blending with cement is ensured.

FINAL SET:

A degree of stiffening of a mixture of cement and water greater than initial set, generally stated as an empirical value indicating the time in hours and minutes required for a cement paste to stiffen sufficiently to resist to an established degree, the penetration of a weighed test needle; also application to concrete and mortar mixtures with use of suitable test procedures.

FINAL SETTING TIME:

The time required for a freshly mixed cement paste, mortar or concrete to achieved final set.

FLAKINESS INDEX:

The flakiness index of an aggregate is the percentage of weight of particles in it whose least dimensions (thickness) is less than three fifth of their mean dimension.

FORM (SHUTTER):

a) That part of form work which consists of sheeting and its immediate supporting or stiffening members.

b) A temporary structure or mould for the support or concrete while it is setting and gaining sufficient strength to become self supporting,

FORM WORK:

Complete system of temporary structure built to contain fresh concrete so as to form it to the required shape and dimensions and to support it until it hardens sufficiently to become self supporting. Form work include the surface in contact with the concrete and all necessary supporting structures.

GRANULATED SLAG:

Slag in granulated form is used for the manufacture of hydraulic cement. Slag is a non-metallic product consisting, essentially of glass containing silicates and alumino silicates of lime and other bases, in the case of blast furnace slag which is developed simultaneously with iron and blast furnace or electric pig iron furnace. Granulated slag is obtained by further processing a molten slag by rapidly chilling or quenching it with water or steam and air.

GROUT:

Mixture of cementtitious material and aggregate to which sufficient water is added to produce pouring consistency without segregation of the constituents, or mixtures of other compositions, such as containing PVC or epoxy resin or sodium silicate, but of similar consistency.

GROUTING:

The process of filling with grout.

GRAVEL:

Gravel consists of coarse grained soil particles particularly larger than 2 mm (0.08 inch).

HARDENING:

The physio-chemical changes observed in a mortar due to the effect of the one or more of the following phenomena:

(a) Absorption of carbon, (b) Recrytallisation and (c) Chemical reaction

HONEYCOMB:

Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregates particles.

INITIAL SET:

A degree of stiffening of a mixture of cement and water less than final set, generally stated as an empirical value indicating the time in hours and minutes required for cement paste to stiffen sufficiently to resist to an established degree of penetration of a weighted test needle. Also applicable to concrete or mortar with use of suitable test procedures.

MASS CONCRETE:

Any volume of concrete cast in place (generally as a monolithic structure usually incorporating a high proportion of large coarse aggregate and a low cement content) and intended to resist applied load by virtue of its mass is distinct from other types of concrete because its dimensions are larger and requires measures for temperature control & placing to reduce volume changes.

Placing of reinforcement inside mass concrete for structural, temperature or other reasons, shall not change its classification from mass concrete to Reinforced cement concrete.

MIXING TIME:

The period during which the constituents of a batch of concrete are mixed by a mixer; for a stationary mixer, time is given in minutes from the completion of mixer charging until the beginning of surcharge; for a truck mixer; time is given in total minutes at a specified mixing speed or expressed in terms of total revolutions at a specified mixing speed.

MOULD:

a. A device containing a cavity into which neat cement mortar or concrete test specimens are cast; and

b. A form used in the fabrication of precast mortar or concrete units.

MUCK:

Muck is the name often given to well decomposed highly organic soils. It is usually black or very dark gray in colour and has very low dry strength and a plastic thread which is weak and soft.

NATURAL SAND:

Fine aggregates resulting from the natural disintegration of rock and which have been deposited by streams or glacial agencies.

NO-SLUMP CONCRETE:

Concrete with a slump of 25 mm or less.

NOMINAL MIX:

The nominal proportions of the constituents of a proposed concrete mix.

ORGANIC SOIL:

Organic soils are usually recognized by a dark brown or black colour and the typical odour of decaying vegetation.

ORGANIC SILT:

Organic silt is a combination of finely divided organic matter and silt size mineral soil. It is black or dark or dark gray colour and is generally characterized by low to medium dry strength, sluggish reaction to the shaking test and a plastic thread which is medium soft to the medium stiff.

ORGANIC CLAY:

Organic clay is a combination of finely divided organic matter with a significant amount of clay sized particles. it is black or dark gray in colour and is generally characterized by very high dry strength lack of reaction to the shaking test and a plastic thread which is very stiff or very tough.

PEAT:

Peat is the name often given to partially decomposed highly organic soil. It is usually brown to dark brown or black colour and the typical odour of decaying vegetation.

PITCHING:

A protective covering of properly packed or build in materials on the earthen surface slopes of irrigation canals, drainage channels, river banks etc. to protect them from the action of water.

PORTLAND SLAG CEMENT:

An intimately interground mixture of Portland cement clinker and granulated slag with addition of gypsum and permitted additives or an intimate and uniform blend of portland cement and finely ground granulated slag.

POZZOLANA:

An essentially silicious material which while in itself possessing no cementitious properties will, in finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. It may be used with the permission of the Engineer incharge, provided uniform blending with cement is ensured.

PLAIN CONCRETE:

Concrete containing no steel reinforcement or less amount of reinforcement than specified for reinforced concrete. The co-operation of such steel being ignored in resisting stress resultants.

Plain concrete cast in such massive dimensions as to require specific measures to be taken to cater for generation of heat and attendant volume change to minimize cracking is termed Mass Concrete.

PLUM:

A large random –shaped stone of 150 mm maximum size dropped into freshly placed mass concrete.

QUALITY:

Subjectively "Quality" refers to degree of goodness of a product/ structure. Objectively it consists of set of measurable characteristics for which standard dimensions together with small allowable departures (tolerances) up & down, may be prescribed moreover, this quality level should be allowable at satisfactory cost level.

QUALITY CONTROL:

Quality Control is systematic control by management of the variables in the constructions operations that affected the goodness of the end product. This is the administrative activities including inspection, setting of inspection standards and prescription of procedures for adherence to them.

ROCK:

Rock is a natural aggregate of mineral grains connected by strong and permanent cohesive forces.

RELATIVE COMPACTION:

The ratio of field density to the standard laboratory density of a soil is termed the "Relative compaction" .

RETARDER:

An admixture which delays the setting of cement pastes and hence of mixtures such as mortar or concrete containing cement.

RUBBLE MASONRY:

Masonry built of stones either irregular in shape as quarried or squared and only hammer dressed and having comparatively thick joints. Stones for rubble masonry are, as far as possible, angular.

REINFORCED CONCRETE:

Concrete containing steel reinforcement (non-prestressed) conforming to IS code and of no less than the minimum amount required by the code and is a composite material in which both materials act in co- operation to resist the stress resultants.

(Concrete containing prestressed steel reinforced for introducing pre compression of tensile flange of element is termed Prestressed Concrete). (Ref: Standard specifications & Code of Practice for Road Bridges Section III IRC).

SILT:

Silt (inorganic) constituents the coarse fraction of the fine grained soil materials and is generally characterized by low to very low dry strength, rapid reaction to the shaking test, and a plastic thread which is weak and soft when wet and which crumble easily as it dries

.

SOILS:

Soil is defined by the Civil Engineer as natural aggregate of mineral grains, with or without organic constituents; than can be separated by gentle mechanical means such as agitation in water.

STANDARD COMPACTION TEST:

The Standard compaction test of soil is the test in which compaction effort is applied by the specified compaction rammer in a specified manner which is considered equivalent to the compaction equipments used in the field.

SILICA FUME:

Very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a byproduct of the production of elemential silicon or ferro- silicon alloys. It may be used as part replacement of cement provided uniform blending with the cement is ensured.

SEGREGATION:

The differential concentration of the components of mixed concrete, aggregate, or the like, results in non-uniform proportions in the mass.

SIEVE ANALYSIS:

Determination of the proportions of particles lying within certain size ranges in a granular material by separation on sieves of different size openings.

SLIP-FORM (MOVING OR SLIDING FORM-WORK):

A form which moves, usually continuously during placing of the concrete. Movement may be either horizontal or vertical.

SLUMP:

A measure of consistency of freshly mixed concrete equal to the subsidence measured to the nearest in mm of the moulded truncated cone immediately after removal of the slump cone.

SLUMP CONE:

A mould in the form of a truncated cone with a base diameter of 20 cm, top diameter 10 cm and height 30 cm, used to fabricate a specimen of freshly mixed concrete for the slump test.

SLUMP TEST:
The procedure for measuring slump.

SOUNDNESS:
The freedom of a solid from cracks, flaws fissures, or variation from an accepted standard ; in the case of cement freedom from excessive volume change after, setting ; in the case of aggregate, the ability to withstand the aggressive action to which concrete containing it might be exposed particularly that due to weather.

SPALL:
A fragment, usually in the shape of a flake, detached from a large mass by a blow, by the action of weather, by pressure, or by expansion within the larger mass.

SPECIFIC GRAVITY:
The ratio of the mass of a unit volume of a materials at a stated temperature to the mass of the same volume of a gas free distilled water at a stated temperature.

STEAM CURING:
Curing of concrete or mortar in water vapour at atmospheric or high pressures and at temperatures between 30^o and 215^o Centigrade.

SUBGRADE:
The soil prepared and compacted to support a structure or a pavement system or lining of canal.

SWELLING:
Volume increase caused by wetting or chemical changes or both; a function of time but not of temperature or of stress due to external load.

TAMPING:
The operation of compacting freshly placed concrete by repeated blows.

TEMPERATURE CRACKING:

Cracking due to tensile failure, caused by temperature drop in members subjected to external restraints or temperature differential in members subjected to internal restraints.

TEST STRENGTH OF SAMPLE:
The test strength of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15 percent of the average.

TOE WALL:
A shallow wall constructed below the bed or floor level to provide footing for the sloped pitching or the face of an embankment.

UNIFORM OR POORLY GRADED SOILS:
Uniform or poorly graded soils are composed of particles all of which are approximately of the same size.

VIBRATOR:
An oscillating machine used to agitate fresh concrete so as to eliminate gross voids including entrapped air but not entrained air and produce intimate contact with form surfaces and embedded materials.

WELL GRADED SOILS:
Well graded soils contain a good representation of particles of several sizes ranging continuously from coarse to fine.

WATER RETENTIVITY:
The ability of mortars to retain water against suction and evaporation in general. It is indirectly a measure of the workability of mortars. It is measured by the flow of mortar when tested on a standard flow table before and after application of a specified suction.

WATER-CEMENT RATIO:
The ratio of the amount of water, exclusive only of that absorbed by the aggregates, to the amount of cement in a concrete or mortar mixture; preferably stated as a decimal by weight.

WEATHERING:

Change in colour, texture, strength, chemical composition or other properties of a natural or artificial material due to the action of the weather.

WORKABILITY:

That property of freshly mixed concrete or mortar which determines the ease and homogeneity, with which it can be mixed, placed compacted, and finished. It is the amount of energy to overcome friction and cause full consolidation.

YEILD:

The volume of freshly mixed concrete produced from a known quantity of ingredients; to total weight of ingredients divided by the unit weight of the freshly mixed concrete; also the number of product units, such as block, produced per bag of cement or per batch of concrete.

APPENDICES:

EMBANKMENT TEST SECTION:
Procedures for construction of an embankment test section is given vide Appendix -1 of Vol. II.

FILTER:
Details of filters are given in Appendix-II of Vol. II.

TEST RESULTS OF POST CHECKING OF ROLLED FILL COMPACTION
A Proforma for test results of post checking of rolled of Dam/ Canal embankment at a particular location also for compaction efficiency is given in Appendix III of Vol. II.

TEST RESULTS OF POST CHECKING OF ROLLED FILL PERMEABILITY
A Proforma for test results of checking of rolled fill of Dam at a particular location for permeability is given in Appendix-IV of Vol. II.

TEST RESULTS OF SOIL SAMPLES OF BORROW AREA/ EMBANKMENT:
A Proforma for test results of soil samples of borrow area embankment of grain size analysis (mechanical analysis) is given in Appendix –V of Vol. II.

TEST RESULTS OF SAND SAMPLES:
A proforma for test results of sand samples, to be conducted at project site laboratory are given in Appendix-VI of Vol. II.

TEST RESULTS OF COARSE AGGREGATE 75 MM AND BELOW;
A Proforma for above is given in Appendix –VII of Vol. II.

TEST RESULTS OF COARSE AGGREGATE 20 MM AND BELOW;
A Proforma for above is given in Appendix –VIII of Vol. II

TEST RESULTS OF COARSE AGGREGATE 12 MM AND BELOW;
A Proforma for above is given in Appendix –IX of Vol. II.

TEST RESULTS OF CEMENT SAMPLES:
A Proforma for above is given in Appendix –X of Vol. II.

TEST RESULTS OF BOULDER SAMPLES:
A Proforma for above is given in Appendix –XI of Vol. II.

TEST RESULTS OF WATER :
A Proforma for above is given in appendix –XII of Vol. II.

TEST RESULTS OF BRICK/ TILES:
A Proforma for above is given in Appendix –XIII of Vol. II.

TEST RESULTS OF CONCRETE/MORTAR:
A Proforma for above is given in Appendix –XIV of Vol. II.

WEEKLY PROGRESSS REPORT ON EARTH FILL OF DAM/CANAL WORK:
A Proforma for above is given in Appendix –XV of Vol. II.

WEEKLY PROGRESS REPORT DAM/CANAL CONCRETE AND WORK MASONRY
A Proforma for above is given in Appendix –XVI of Vol. II.

WEEKLY PROGRESS REPORT ON BORROW AREAS OPERATIONS PASS (SOIL /SAND/ BRICK)
A Proforma for above is given in Appendix –XVII of Vol. II.

DETERMINATION OF FIELD MOISTURE AND NATURAL DRY DENSITY OF COMPACTED EARTH FILL:
A Proforma for above is given in Appendix –XVIII of Vol. II.

DETERMINATION OF COMPACTION EFFICEINCY OF COMPACTED EARTH FILL
A Proforma for above is given in Appendix –XIX of Vol. II.

ABBREVIATIONS:

I.S. Code -	Indian Standards Code
O.M.C. -	Optimum Moisture Content
F A-	Fine Aggregates
C A-	Coarse Aggregates
D.I.R. -	Director Irrigation Research
M.D.D. -	Maximum Dry Density
S.E. -	Superintending Engineer
A.R.O. -	Assistant Research Officer
Q.C. -	Quality Control
E.E. -	Executive Engineer
A.O. -	Attached Officer
G.O.M.P. -	Government of Madhya Pradesh
Asstt. Gr.II. -	Assistant Grade II
Asstt. Gr. III. -	Assistant Grade III
C.C. -	Cement Concrete
R.C.C. -	Reinforced cement Concrete
O.K. -	Okay
M.B. -	Measurement Book
S.Q.C. -	Statistical Quality Control

O.P.C.	Ordinary Portland Cement
P.P.C	Pozzolana Portland Cement