MANUAL FOR QUALITY CONTROL
IN
ROAD & BRIDGE WORKS

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

NOVEMBER, 2017

Price : ₹ 1500/-
(Plus Packing & Postage)

IRC:SP:112-2017

First Published : November, 2017

Printed by India Offset Press, Delhi-110 064
500 Copies

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MANUAL FOR QUALITY CONTROL IN ROAD & BRIDGE WORKS

SECTION 1

INTRODUCTION

1.1 Three special publications were published by IRC in different years regarding quality control on road and bridge works as mentioned below:

IRC:SP:11-1984	Handbook for Quality Control for Construction of Roads and Runways;
IRC:SP:57-2000	Guidelines for Quality Systems for Road Construction;
IRC:SP:47-1998	Guidelines for Quality Systems for Road & Bridges.

The above publications were formulated in pre NHDP environment when bridges were mostly constructed on stand-alone basis. Need was felt to merge the three publications to suit the manner of implementation of highway projects post NHDP and also upgrade the content to capture all aspects of quality assurance and control in line with best international practices.

1.2 Accordingly, it was decided in the 1st meeting of Project Preparation, Contract Management, Quality Assurance and Public Private Partnership Committee (G-1) held on 06.06.2015 to merge the 3 special publications as above and upgrade the same. A sub-group was formed under the chairmanship of Co-Convenor with other members to prepare the draft of the **"Manual for Quality Control in Road & Bridge Works".** The sub-group prepared different sections of the special publication, which was discussed in different meetings of G-1 Committee between 25.07.2015 and 19.11.2016 and lastly on 29.04.2017 under the chairmanship of Convenor Shri B.N. Singh where Shri D. Sarangi; Shri Kishore Kumar; Shri A.V. Sinha; Shri Ashok Kumar; Shri Ashok Bhasin and Shri S.K. Nirmal attended. The sub-group gratefully acknowledges peer review of the draft by Shri D P Gupta. Finally the draft of the entire publication was considered and approved by G-1 Committee (personnel given below) in its 9th meeting held on 19.11.2016.

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1.3 The document was approved by the General Standards and Specifications Committee (GSS) in its meeting held on 24th June 2017 for placing before the IRC Council. The draft was finally approved by the IRC Council in its 212th meeting held at Udaipur(Rajasthan) from 14th to 15th July, 2017.

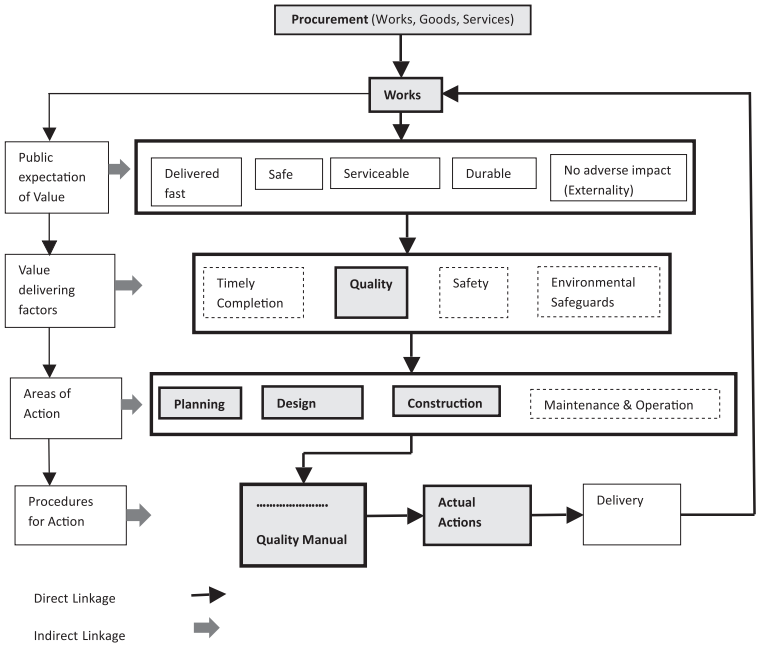
SECTION 2

GENERAL APPROACH

2.1 Concept

2.1.1 Beginning in the year 1998, when implementation of 4-laning of Golden Quadrilateral was announced, there have been huge strides in development of roads in India. The road development programme is also very wide and vast starting from expressways to rural roads. Road infrastructure has seen a quantum jump in investments during the past two decades. The agencies involved in road construction are quite disparate. The contracting modes are also different. But what is demanding from and common to all road projects is total quality starting from Project Planning to Construction to Operation and Maintenance. Quality of the projects/works should be such that the road performs according to the specified standards during the design life. Quality is essential so that i) users enjoy safe and comfortable riding quality throughout the design life and ii) vehicle operating costs are minimised and iii) resources of the nation are otherwise efficiently utilised. It also simultaneously ensures enrichment of knowledge in the industry, lower bid prices and faster completion of projects. This Manual endeavours to describe different components and aspects of Total Quality Management in Road Projects. It covers various steps/procedures required to be followed to ensure quality matching with international standards. This Manual does not embody extracts from other IRC Codes, Manuals and MORT&H Specifications for Road & Bridge Works. Therefore, this Manual needs to be used in conjunction with MORT&H Specifications for Road & Bridge Works and other applicable codes, manuals and guidelines.

2.1.2 The role of Quality Manual in overall procurement of works is best described by the following pictorial chart:



Place of Quality Manual in overall Procurement of Works

2.1.3 At the outset, it is necessary to recall the definition of Total Quality Management as stipulated in various international codes of practice along with other terminology associated with it for proper appreciation of quality requirements.

ISO 8402: 1994

(i) Quality: The totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs.

(ii) Total Quality Management: A management approach of an organisation centred on quality, based on the participation of all its members and aiming at long term success through customer satisfaction and benefits to all members of the organisation and society.

(iii) Quality Policy: The overall quality intentions and direction of an organisation as regards quality as formally expressed by top management.

(iv) Quality Management: The aspect of the overall management function that determines and implements the quality policy.

(v) Quality Planning: Activities that establish the objectives and requirements for quality and for application of quality policy.

(vi) Quality Assurance: All the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for Quality.

(vii) Quality Control: The operational techniques and activities that are used to fulfil requirements for quality.

(viii) Requirements of Quality: Expression of the needs or their translation into a set of quantitatively/qualitatively stated characteristics of an entity.

(ix) Quality Systems: The organisation structure, responsibilities, procedures, processes and resources for implementing Quality Management.

(x) Quality Plan: A document setting out the specific quality practices, resources and sequence of activities relevant to a particular product.

(xi) Quality Audit: A systematic and an independent examination to determine whether quality activities and related result comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

BS 7850-1:1992

(i) Total Quality Management: A management philosophy and company practices that aim to harness the human and material resources of an organization in the most effective way to achieve the objectives of the organization.

Transport Reasearch Board

(i) Quality: The degree of excellence of a product or service; (2) the degree to which a product or service satisfies the needs of a specific customer; or (3) the degree to which a product or service conforms with a given requirement.

(ii) Quality assurance: All those planned and systematic actions are necessary to provide confidence that a product or facility will perform satisfactorily in service.

(iii) Quality control: Those QA actions and considerations necessary to assess and adjust production and construction processes so as to control the level of quality being produced in the end product.

(iv) Acceptance: Sampling and testing, or inspection, to determine the degree of compliance with contract requirements.

(v) Quality characteristic: That characteristic of a unit or product that is actually measured to determine conformance with a given requirement. When the quality characteristic is measured for acceptance purposes, it is an acceptance quality characteristic (AQC).

(vi) Quality measure: Any one of several means that have been established to quantify quality. Some examples of quality measures are the mean, the standard deviation, the percent within limits, the average absolute deviation, and the quality index.

American Society for Quality Control

(i) Quality: The totality of features and characteristics of a product or service that bear on its ability to satisfy given needs.

(ii) Quality assurance: All those planned or systematic actions necessary to provide adequate confidence that a product or service will satisfy given needs.

American Society for Testing and Materials (ASTM-E699)

(i) Quality assurance: A planned system of activities whose purpose is to provide assurance that the overall quality control program (see quality control) is in fact being effectively implemented. This system involves a continuing evaluation of the adequacy and effectiveness of the overall quality control program with a view to having corrective action initiated where necessary. For a specific material, product, service, etc., this involves verification, audits, and evaluations of the quality factors that affect the specification, production, inspection, and use of the material product, service, system, or environment.

(ii) Quality control: A planned system of activities whose purpose is to provide a level of quality that meets the needs of users: also, the use of such a system. The objective of quality control is to provide an overall system integrating the quality factors of several related steps including: the proper specification for what is wanted: production to meet the full intent of the specification: inspection to determine whether the resulting material, product, service, etc., is in accord with the specification: and review of usage to determine necessary revisions of the specification.

BS 4778-Quality Vocabulary

(i) Quality: The totality of features and characteristics of a product or service that bear upon its ability to satisfy stated or implied needs.

(ii) Quality Policy: The overall quality intentions and directions of an organisation as regards quality as fully expressed by top management.

(iii) Quality Management: The aspect of the overall management function that determines and implements the quality policy.

(iv) Quality System: The organisational structure, responsibilities, procedures, processes and resources for implementing quality management.

(v) Quality Assurance: All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.

(vi) Quality Control: The operational techniques and activities that are used to fulfill requirements for quality.

The above definitions are universal in nature and apply to all fields. In the context of road projects, the definitions are used with suitable interpretation as considered applicable to road projects.

2.1.4 There are three focal points of Total Quality Management. These are Quality Assurance, Quality Control and Acceptance. All the activities related to Quality spin around these focal points. Notwithstanding the contracting format used for a particular project, quality control vests with the Contractor/Concessionaire, whereas acceptance vests with the Employer/Authority, who is normally assisted by Consultants in medium and large size projects. Quality Assurance applies to all the entities involved in the project. Quality Assurance Plan of all the entities involved in the project must be compatible following the broad parameters specified in this Manual. Acceptance criteria should be built into the contract in clear and unambiguous terms, which makes it obligatory on the part of the Contractor/Concessionaire to plan, build and follow its Quality Assurance and Quality Control programme so as to fulfill the acceptance criteria. Whereas the Contractor/ Concessionaire and Engineer/Consultant are required to have a project specific Quality Assurance Plan, the Employer/Authority may have a generic Quality Assurance Plan/Quality Policy. This Manual attempts to specify various aspects of the focal points mentioned above for road projects in general, without any reference to particular contracting format. The contract should take care to adapt to the provisions of this Manual with modifications, if any, as applicable to a particular contracting format. The approach to quality requirements as applicable to four broad stages of a road project i.e. (i) project preparation, (ii) procurement, (iii) construction and (iv) operation and maintenance are discussed below.

2.2 Step wise procedure in Total Quality Management

The following paragraphs of this section give an overview of different steps to be followed in Total Quality Management of a road project in a sequential order, whereas details are brought out in the succeeding sections.

2.2.1 *Selection of the class of Quality Assurance*

Depending upon the rigors of control and cross verification, four classes of Quality Assurance (QA) are prescribed:

Classes of Quality Assurance	Class Nomenclature
Nominal QA	Q-1
Normal QA	Q-2
High QA	Q-3
Extra high QA	Q-4

Quality Assurance class needs to be decided prior to start of the Project Preparation. However, during the course of project implementation, Quality Assurance class of some of the items/ attributes may be upgraded to next class based on specific requirements. Provision for such up-gradation needs to be built into a Contract. This Manual is basically meant for Q-3 class of quality assurance which is applicable to projects in following situations:

i) National Highways and State Highways
ii) Coastal roads
iii) Roads in high altitudes
iv) Roads in high rainfall areas (average over 2000 mm)
v) Large size projects on Major District Roads

Q-2 class QA is recommended for rural roads and average size projects/works on Major District Roads. Q-1 class QA may be restricted to rural roads in remote areas subject to specific approval of the concerned road agency. Q-4 class QA is applicable to expressways. Q-4 class QA is also applicable to following specialised components of projects following lower class of QA.:

i) Tunnels
ii) Elevated highways

For quality management in rural roads, reference may be made to Quality Assurance Handbook for Rural Roads of the National Rural Roads Development Agency of the Ministry of Rural Development.

2.2.2 *Personnel*

Both the Contractor/Concessionaire and Engineer/Consultant are required to engage adequate number of personnel with required knowledge, experience and expertise to control quality. The knowledge and experience of lab technicians who actually carry out the tests is also very critical. The size and complexity of a project determines the range of personnel, their knowledge, experience and expertise. The quality personnel of the Contractor may be independent of production and laying unit or part of it. This Manual suggests the list of quality personnel required with Contractor / Concessionaire and Engineer / Consultant for projects of different size and complexity in **Section 3**. The organizational structure of the quality control personnel along with qualification and experience requirements of the said personnel are also specified so that each of the personnel is capable of meeting the requirements of the chosen field and the team has the right mix of personnel to attend to all the quality requirements of a project.

2.2.3 *Quality Assurance Plan*

Quality Assurance has already been defined as "All the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for Quality." In a way Quality Assurance is sum of Quality Control and Acceptance. Quality Assurance Plan (QAP) is, therefore, a document chronicling the actions to be taken and steps to be followed by each party to the project for successful implementation of the project duly fulfilling the Quality Requirements.

The project cycle involves three broad stages i.e. Project Preparation, Project Development and Construction. Therefore, for a single project, different quality assurance plan needs to be prepared by different parties in different stages. The requirement of QAP during different stages of a project is summarized below:

Project stage	Requirements of QAP by different parties to project
Project Preparation	DPR consultant will prepare QAP for Project Preparation.
	Client will have a general protocol for association with DPR consultant and scrutiny/verification of data, design and drawings.
	Independent Engineer/Authority's Engineer will have a protocol to review drawings in BOT/EPC Contract.
Development	Employer/Authority will have a general protocol for bid document preparation, bid evaluation and award.
Construction	Contractor/Concessionaire will prepare QAP.
	Supervision manual prepared by Engineer/ Consultant will contain Quality Assurance mechanism to be followed by the Engineer/Consultant.
	Employer/Authority will have a general protocol for Quality Control.

Model structure of QAPs as above and protocol for Employer/Authority/Engineer are given in Section 4.

2.2.4 *Quality Requirements for Factory Manufactured Materials, Products and Specialized Items*

Supplier's quality policy indicates commitment of the management of the supplier to achieve and sustain quality of the product to meet purchaser's stated or implied needs, whether contractually required or not. In case of road projects, supplier's Quality Policy in respect of factory manufactured materials, products and specialized items such as steel, bitumen, bearings, expansion joints, road signages, crash barriers etc. is very important. **Section 5** gives a broad contour of the minimum elements of quality policy of suppliers of such products. Notwithstanding whether a supplier is empanelled or not, the Quality Policy of the supplier shall be furnished by the Contractor/Concessionaire to the Engineer / Consultant, who will ascertain that the Quality Policy of such supplier shall be commensurate with the details given in **Section 5**. In large and complex projects, the Engineer / Consultant may further

exercise independent check as to whether the Quality Policy of the supplier is being duly complied with.

Section 5 stipulates testing requirements of most of the factory manufactured materials, products and specialised items and whether site testing facility available for them. For all such materials and products, the supplier/manufacturer is required to submit detailed documents as specified in **Section 5**. **Section 5** also delineates responsibilities of Supplier / Manufacturer / Concessionaire / Contractor / Engineer / Consultant / Employer/Authority in further confirming quality of such materials either by witnessing tests in manufacturer's laboratory or conducting third party testing.

2.2.5 *Laboratory set up*

Section 6 gives a broad outline of the Contractor's site laboratory. General infrastructure requirement of the laboratory, layout and suggestive list of equipments and consumables for main/plant laboratory, routine and special upkeep of equipments are covered in **Section 6**. Suggested codes of practice for various tests to be conducted on naturally occurring materials in original/crushed form and various types of mixes is also given in **Section 6**. Any third party laboratory, where testing of materials is proposed to be carried out by any entity involved with road project, must satisfy the requirements of **Section 6** as a minimum. The requirements of **Section 6** also apply to the laboratory for testing of different materials related to Project Preparation as well as Operation and Maintenance.

2.2.6 *Calibration of Inspection, Measuring and Testing Equipments*

Calibration is defined as specific type of measurement performed on measurement standards, material measures and measuring instruments to establish the relationship between the indicated values and known values of a measured quantity. The term covers calibrations carried out using appropriate reference equipment at any location. The requirements for equipment calibration, measurement and traceability are given in ISO/IEC 17025. The laboratory's programme for the maintenance and calibration of equipment will typically comprise of periodic cleaning, servicing, calibration and safety checks (where applicable). While establishing a calibration programme, aspects of measurement traceability, procedures, intervals and records for both calibration and checks, need to be considered for each item of IMT equipment in relation to the particular test method for which it may be used. Calibration of equipment is a must for certainty/reliability of the test results. Calibration requirement ranges from sieves to nuclear density meter. Calibration of plant and equipments such as Hot Mix Plant, Concrete Batching Plant etc. are also very important. Calibration requirements, types of calibration, interval of calibration, and method of calibration of different IMT equipments typically used in a road project, recall procedure etc. are given in **Section 7**. Wherever time interval for calibration specified by the manufacturer is smaller than the time interval indicated in Section 7, the manufacturer's recommendation shall be followed. External laboratory used for calibration must be accredited by NABL. Calibration Certificate as well as documentary evidence of the accreditation of the calibrating laboratory should be made available in the laboratory. Recall procedures of the IMT equipments are given in **Section 7**. The requirements of **Section 7** also apply to calibration of testing equipments related to Project Preparation and Operation and Maintenance.

2.2.7 *Inspection and Testing*

Inspection and Testing generally covers the following:

(i) Alignment and surface regularity
(ii) Reinforcement detailing
(iii) Positioning of furniture/accessories
(iv) Testing of constituent materials and finished products
(v) Field/in situ testing

Whereas the requirements of tests for different materials/products/works are given in MoRT&H Specifications for Road & Bridge Works/**Section 5** of this Manual, details of testing procedure are given in applicable code of practice. Test frequency is given in MoRT&H Specifications for Road & Bridge Works/**Section 5** of this Manual/ applicable codes of practice. **Section 8** of this Manual deals with general overview of testing procedures. It includes both in-process and final inspection and testing. The activities include surveys, measurements and tests in laboratory as well as site. General principles/guidelines about inspection and testing including source approval, receiving inspection, in process inspection, final inspection, sampling of materials from quarries, borrow pits, stock piles, trucks/pavers etc., maintaining integrity of samples, testing method for each of the tests, handling procedures, recording of observations, formats for recording observations in various tests etc. are covered in **Section 8**.

2.2.8 *Documentation and Communication*

Documentation of Quality Assurance and Quality Control processes with proper authenticity are critical for arriving at acceptance or otherwise of a finished product. The Contractor/ Concessionaire and Engineer/Consultant shall establish mechanism for documentation well in advance. Documentation shall be in both soft and hard format. Proper arrangement for security/authenticity of documentation shall be made by both Contractor/Concessionaire and Engineer/Consultant. General principles and guidelines for establishing mechanism for documentation are explained in **Section 9**. Communication between different parties to the Contract is an important aspect. Though it is not limited to only Quality Control aspects, communication related to Quality Control occupies a larger share of the total communication. Communication should be fast, reliable and well documented both in soft and hard format. E-tools may be followed for faster communication and contract management. General aspects of such e-tools are discussed in **Section 9**. Besides, sample formats for RFI, Notices etc. are given in **Section 9**.

2.2.9 *Statistical Analysis*

Variability of materials, workmanship and construction process is a reality in road construction like any other manufacturing process. Adding to the variability of materials and processes, there is also considerable variation in the testing process resulting in measurement errors. Acceptance procedure is therefore, required to factor in variability of test results or in other words statistical analysis of test results. **Section 10** gives an idea about various methods of statistical analysis practiced internationally. **Section 10** outlines the salient aspects of sampling, criteria for selection of Lot (Population in statistical terms). **Section 10** gives

fundamental principles of statistical analysis and indicates relationship between mean value of the test results carried out on the sample in respect of particular Quality Characteristic of a material/item of work vis-à-vis specification limit for that particular Quality Characteristic.

2.2.10 *Acceptance/non conformance/rectification*

Acceptance criteria for different materials/finished products/items of work are given in different Sections of MoRT&H Specifications for Road & Bridge Works whereas acceptance criteria of some additional Quality Characteristics of factory manufactured materials, products and specialized items as detailed in **Section 5** of this Manual are mentioned in applicable codes of practice as mentioned therein. **Section 11** prescribes Quality Characteristics of materials/ works where statistical analysis is to be carried out for final acceptance and also specifies the procedure for statistical check of such Quality Characteristics. **Section 11** details the procedure/protocol for acceptance/rejection of raw/factory manufactured materials/mixes/ finished products/works based on quality control test results and supplemented by statistical analysis where ever applicable. **Section 11** prescribes various options available in case of failure of a sample to meet acceptance criteria and also gives a detailed protocol to deal with non-conformance works.

2.2.11 *Third party Quality Audit*

ISO 19011 specifies third party audits as audits performed by external agencies primarily for the purpose of certification. In the context of road projects, Third Party Quality Audit is a review by an independent entity (a separate firm/group of experts) of how well the key areas of a project quality plan is being followed and whether it's effective in getting the quality results originally envisaged. **Section 12** gives a general overview of third party quality audit. **Section 12** specifies criteria for selection of road projects for third party quality audit. It outlines scope of third party quality audit and general requirements of audit team. A sample terms of reference for third party quality audit is also given in **Section 12**.

2.2.12 *Safety, Health and Environment*

Although safety, health and environmental issues are not precisely part of this Manual, quality in such issues at work places has huge importance to the nearby communities, road users and construction workers during construction stage as well as nearby communities and road users post construction. It is further established that better care for Safety, Health and Environment at work places automatically enhances quality in road construction.

Section 13 makes a modest approach to identify and list those aspects of safety, health and environment during road construction.

SECTION 3

PERSONNEL

3.1 Introduction

Both the Contractor and Engineer are required to engage adequate number of personnel with required knowledge, experience and expertise to control quality. Right type of quality control personnel with Contractor and Engineer is a must to achieve desired quality of the project. This section gives an outline of the type of personnel and their qualification and experience for different size of projects.

3.2 Integral/Outsourced Quality Assurance/Control Unit of Contractor and its Hierarchical Position in Organisation

The Quality Assurance/Control Unit of Contractor may be a unit of inhouse personnel of the Contractor or a unit outsourced from a consulting firm exclusively for the project. Both the practices have inherent advantages and disadvantages. Contractor should choose a system convenient to its internal capacity and demand of delivery. But in either case, the head of the unit shall report to Project Manager or head of the project team of the Contractor and will have say on all raw and mixed materials, plants and equipments brought to site for use in the work. The Contractor shall furnish details of its Quality Assurance/Control Unit in the Quality Assurance Plan.

3.3 QA/QC personnel of Contractor

The Contractor shall have dedicated key and sub-professional for Quality Assurance/Control. Their numbers and position depend on size and complexity of a particular project. Tentative details of key and subprofessional persons in the organization of the Contractor vis-à-vis size of projects is given below:

Size of the Project	Details of Key & Sub-Professional
< Rs. 300 crore	Material Engineer-1, QC/Asst. QC Engineer-2, Lab Technician-4
≥ Rs. 300 crore	Material Engineer-1, QC/Asst. QC Engineer-3, Lab Technician-6

Additional/specialized personnel may be required to be engaged by the Contractor for complex projects such as tunnel/innovative structures or projects involving new materials etc. which may be decided on case to case basis.

3.3.1 The typical organizational charts of quality control personnel of Contractor for different size of projects are given at **Annexure 3.1**.

3.3.2 *Role and Responsibility of Contractor's QA/QC Personnel*

The role and responsibility of Contractor's QA/QC personnel are broadly described below:

Material Engineer

Material Engineer shall remain responsible for all Quality Assurance, Quality Control and Acceptance requirements of the project and will directly report to the Project Manager or project head. He will regularly supervise the activities of QC/Asst. QC Engineer. Material Engineer will provide all necessary assistance to the construction team with reference to acceptance of all raw, manufactured, mixed materials used in the project. His responsibilities include the following:

- Preparation of Quality Assurance Plan;
- Providing inputs to Project Manager for preparation of work methodology;
- Setting up of field laboratories;
- Calibration of equipments;
- Preparation of JMF for flexible pavement & concrete mix design;
- To maintain an effective documentation system for QA/QC throughout the project;
- To monitor and coordinate quality control activities on site;
- Ensure that tests are carried out as per relevant IS/applicable international code of practice;
- Maintain the test records for all the construction material used in the project and submit them to Project Manager before forwarding them to the Consultant.
- To verify the system for reporting and disposing non-conformance and corrective action requests;
- Have final say about acceptance of a material/work;
- To perform internal quality audits on site in accordance with applicable procedures;
- Advising on, planning and organizing inspections, maintenance and repairs;
- Liaising with suppliers, customers and manufacturing/development staff.

QC/Asst. QC Engineer

QC/Asst. QC Engineer will be directly responsible for quality control. He will report to the Material Engineer. He will supervise the activities of the Lab Technician. Besides he will carry out the following activities himself.

- Assisting Material Engineer in setting up the field laboratories;
- Day to day supervision of works of Lab Technicians;
- Ensuring proper calibration of all laboratory equipments;
- Preparation of JMF for flexible pavement & concrete mix design;
- Conducting laboratory and field tests on random basis;
- Calculation of test results from test observations carried out by Lab Technician, analysis and interpretation of the test results;
- Maintaining respective records;
- Selection of borrow areas;

- Periodical checking of calibration of WMM Plant, Hot mix plant, Batching plants;
- Preparation of summary test results for monthly progress report.

Lab Technician

Lab Technician will work under the guidance of QC/Assistant QC Engineer. He will carry out the following activities:

- Sampling of construction materials and preparation for testing as per IS Code;
- Conducting laboratory test of aggregate, cement, soil, bitumen and other materials;
- Recording of test observations;
- Inspection of batching plant, hot mix plant and WMM plant at the time of production;
- Conducting field tests at site and recording test observations.

3.4 QC personnel of Engineer

The number and position of QC personnel of the Engineer depend on mode of contract apart from size and complexity of the project. Tentative list of key and sub-professional for different types of projects is given below:

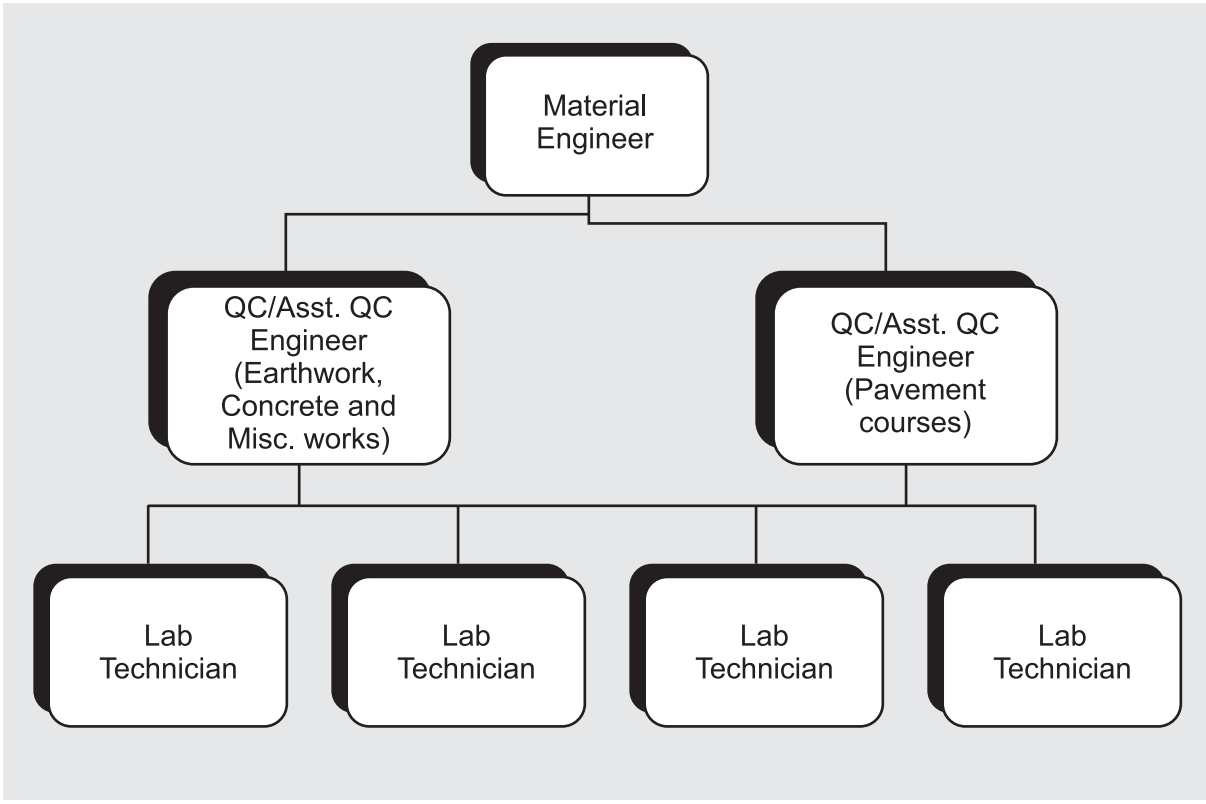
Size of the Project	Details of Key & Sub-Professional
< Rs. 300 crore	Material Engineer-1, QC/Asst. QC Engineer-1, Lab Technician-2
≥ Rs. 300 crore	Material Engineer-1, QC/Asst. QC Engineer-2, Lab Technician-4

3.5 Qualification and experience of key and sub-professional to be engaged by the Contractor/Consultant is given at **Annexure 3.2**.

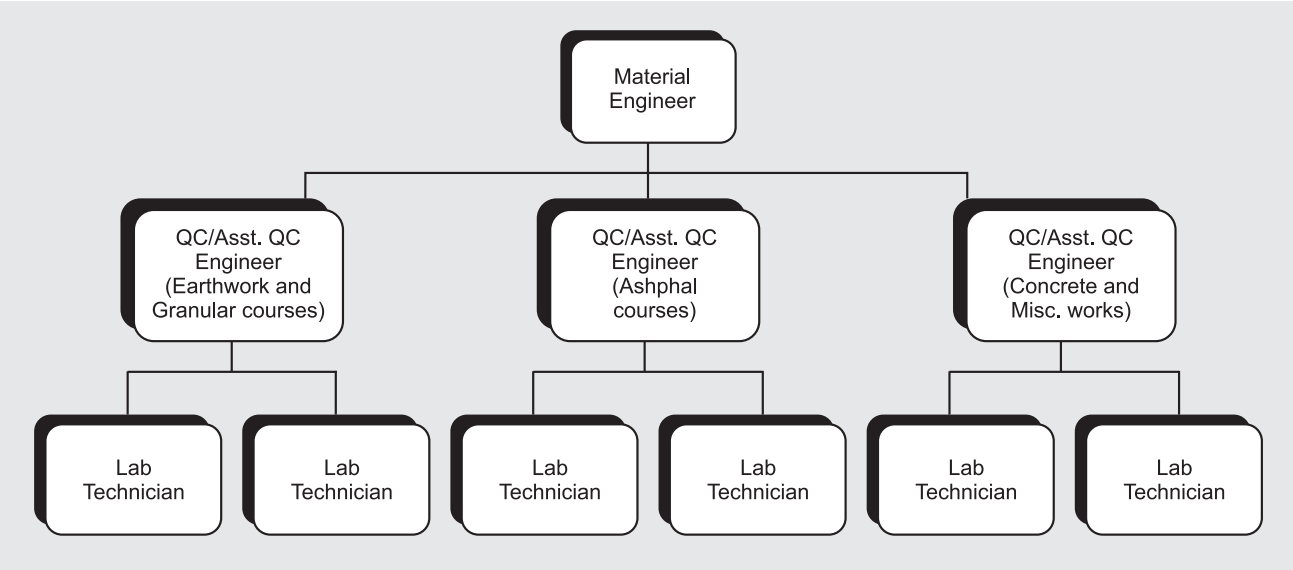
Annexure 3.1

TYPICAL ORGANISATION CHARTS OF QUALITY CONTROL PERSONNEL OF CONTRACTOR

I Size of Project < Rs. 300 crores



II Size of Project ≥ Rs. 300 crores



Annexure 3.2

QUALIFICATION AND EXPERIENCE OF QUALITY CONTROL PERSONNEL OF CONTRACTOR/ENGINEER

I Material Engineer

The Material Engineer shall be graduate in civil engineering from a recognized university. He shall have professional experience of 12 years in construction of highways / roads / airfield runways. He shall have experience of 5 years in similar capacity in construction / construction supervision of highway projects. He shall have experience as Material / Geotechnical Engineer in construction / construction supervision of at least 2 highway projects. He must be familiar with material property of road construction material, technical specifications and procedures of material tests and testing equipments. He shall not be more than 65 years of age. The Material Engineer should preferably have post graduate degree in Geo-Technical Engineering/Soil Mechanics and Foundation Engineering. He should also preferably have experience as Material Engineer in highway construction projects outside the country.

II Quality Control Engineer

Quality Control / Assistant Quality Control Engineer shall be at least Graduate / Diploma in Civil Engineering having minimum 2/5 years of work experience (2 year in case of Graduate and 5 year in case of Diploma) in the field of quality control in road/bridge construction projects. He should be conversant with testing of different materials/finished products, testing apparatus, calibration, sampling, testing, recording test observations in proper formats and determination of test results.

III Lab Technician

Lab Technician shall be at least Diploma in Civil Engineering /Science Graduate /ITI having minimum 2/5 years of work experience (2 year in case of Diploma and 5 year in case of Science Graduate /ITI) in the field of testing of materials.

SECTION 4

QUALITY ASSURANCE PLAN

4.1 Introduction

Definition of the following terms as stipulated in ISO 8402 of 1994 is reproduced below for proper appreciation of the subject:

Quality Policy: The overall quality intentions and directions of an organisation as regards quality as formally expresssed by top management;

Quality Assurance: All the planned and systematic activities implemented within the quality system and demonstrated as needed to provide adequate confidence that an entity will fulfill requirements for quality;

Quality Plan: A document setting out the specific quality practices, resources and sequence of activities relevant to a particular product, project or contract.

A road project goes through several stages and involves several stakeholders from inception to implementation. Quality of final product is possible only if quality is ensured in each stage. Quality Assurance Plan of each of the major stakeholders consistent with its own Quality Policy is crucial to ensure quality of a particular stage.

4.2 Objective

The objectives of preparing a Quality Assurance Plan (QAP) are as follows:

- Understanding the project requirements/features in totality;
- Assessing the impact of environment on quality;
- Developing quality systems to ensure that the process and product fulfil quality requirements consistently;
- Assignment of responsibilities with absolute clarity;
- Establishing methods for meaningful evaluation;
- Establishing documentation processes and systems to minute details.

4.3 General Principles

The different stages of a project cycle such as project preparation, procurement and implementation have different concerns with respect to quality. The following general principles are intended to address those concerns of quality:

(i) Preparation of Quality Assurance Plan starts with review of contract documents and all project related information. This will help in identifying thrust areas of the project from quality perspective. This will also help in exercising control over works programme and methodology;

(ii) Next step is evolving organisational structure of the particular stakeholder clearly delineating therein the personnel responsible for quality. The organisational structure shall be followed by establishment of interpersonal

relationship within the organisation and entity(ies)/individual(s) outside the organisation for implementation and overseeing;

(iii) Data collection, validation, storage and retrieval are essential requirements of project preparation. Accuracy and reliability of data is key to success of a project. Assignment of responsibilities among the personnel for all the activities starting from planning of survey and investigation to storage of data is essential for good project preparation;

(iv) It is necessary to establish quality requirements of the material sources keeping specifications, terrain, climate, project completion schedule, Govt. regulations etc. in view so that the same are satisfied before identification of a particular quarry;

(v) It is necessary to establish quality requirements of the machinery to be deployed for a particular project keeping project completion schedule, packaging, specifications/capacities envisaged etc. in view;

(vi) Documentation of project related information and communication between the parties to the contract are very important requirements to achieve quality apart from project implementation itself. QAP shall establish these two aspects in detail considering all the aspects of project implementation;

(vii) Site laboratory is the real bastion of quality control. Infrastructure and other requirements of site laboratory are given in MORT&H Specifications and also **Section 6** of this Manual. QAP shall customise it to meet the specific needs of a particular project;

(viii) Calibration is defined by the International Bureau of Weights and Measures as: “Operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties (of the calibrated instrument or secondary standard) and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.”Procedure for calibration of instruments and frequency thereof as recommended by the manufacturers and standardised by NABL shall be elaborated in QAP keeping in view the specific needs of the project and planning for field laboratory;

(ix) Verification process (raw materials, mix, finished state) is the domain of quality control. It covers inspection, sampling of materials and testing. The details of tests to be conducted, frequency of tests etc. are given in MORT&H Specifications and **Section 5** of this Manual and tests have to be conducted as per relevant BIS or other applicable code of practice/standards but protocol for such activities with laid down procedure in detail keeping the specific needs of a particular project in view shall be established in the QAP;

(x) Three aspects are of relevance in accepting or rejecting an item of a work i.e. result of verification process, statistical analysis and correction, corrective/ preventive actions when a Non Conformance Report (NCR) is generated. QAP shall establish the procedure for handling NCRs for different category of works.

4.4 Quality Assurance Plan for different stages of Project Implementation

4.4.1 *Project Preparation*

Project preparation is traditionally carried out by a consulting firm engaged by the Client. Project preparation is also carried out by DBFOT Concessionaire/EPC Contractor though a consulting firm engaged by it although the scope of project preparation in such case is confined within the boundaries set out by the Schedule-B & C of Concession/Contract agreement and following relevant Manual of IRC i.e. IRC:SP:73/84/86. Accordingly the activities and outputs of project preparation by DBFOT Concessionaire/EPC Contractor is limited compared to the one prepared by Client. However, the quality concerns and responsibility assignment of personnel remain the same.

4.4.1.1 Output Desirability

Project preparation should be such that the project is technically sound, assures optimal cost utilisation, adequately provides for safety requirements and social & environmental safeguards, is easy to implement and ensures intended performance over design life. QAP is a tool that guards the project preparation process in achieving its stated desirable outputs.

4.4.1.2 QAP for Project Preparation Consultant

Model Structure is given at **Annexure 4.1**.

4.4.1.3 General Protocol for Client to Supervise Project Preparation

Client has to play a crucial role in preparation of good project report. Client's participation should spread over entire duration of project preparation. A critical requirement is that Client's views on different reports submitted by the Consultant should be communicated to the Consultant within the prescribed time period so that project can be prepared within the scheduled time and services of the key personnel are truly utilised.

(i) Client's participation can be meaningful if availability of minimum counterpart personnel of the Client exclusively assigned to project preparation is ensured. The following table gives desirable workload with different rank of officers for handling average size DPR:

Designation of officer	Maximum number of DPRs to be assigned
Asst. Executive Engineer/Deputy Manager	2 with no other responsibility/1 with other responsibilities
Executive Engineer/ Manager/ Deputy General Manager	4 with no other responsibility/2 with other responsibilities
Superintending Engineer/General Manager	4 with other responsibilities

(ii) Client's counterpart personnel must frequently interact with Key Personnel of the Consultant. The interaction should be both at site and office. For this purpose Client's personnel shall visit the site often. Client's personnel shall

interact with material engineer, survey engineer, bridge engineer and traffic engineer at site during survey and investigation and team leader, highway engineer and bridge engineer during alignment finalisation and project scope finalisation as a minimum.

(iii) Client's personnel shall verify/witness 1% of total field/laboratory tests and various surveys including traffic surveys as a minimum.

(iv) Client's personnel not below the rank of Superintending Engineer/General Manager shall verify the alignment of the entire length of a project at site including widening scheme, bypasses and realignments. Based on the inspection report of the Superintending Engineer/General Manager, the alignment shall be approved by Client's personnel not below the rank of Chief Engineer/Chief General Manager.

(v) Client's personnel shall scrutinise following parts of reports and drawings as a minimum:

- Reasonableness of traffic data;
- Analysis of growth rates;
- Capacity augmentation plan such as addition of lanes, paved shoulders, service road etc;
- Widening scheme;
- Alignment plan, junction lay out etc;
- Design life of pavement;
- Approach/scheme for overlay, partial/full reconstruction of existing carriageway;
- Typical cross sections;
- Approach/scheme for reconstruction, widening and/or rehabilitation of existing bridges based on 100% site verification;
- Departure from standards;
- BOQ;
- Basic rate of materials;
- Comparison of average cost;
- Supplementary Specifications;
- Schedules of bid documents;
- Traffic diversion plans.

(vi) After scrutiny of final drawings, Client's personnel not below the rank of Superintending Engineer/General Manager shall verify the following at site as a minimum before final approval of DPR:

- Alignment plan;
- Lay out plan for grade separated and major at-grade intersections;
- Provisions such as service road, underpass, bus bay, truck terminal etc.;

- Accident black spot rectification proposal;
- Bridge rehabilitation proposal;
- Drain outfall.

The above requirements should be inbuilt into Quality Policy/Manual of the Client.

4.4.1.4 General Protocol for Independent Engineer/Authority's Engineer to Review Drawings in BOT/EPC Contract

Independent Engineer (IE)/Authority's Engineer (AE) shall follow the procedures mentioned below but not limited to it while reviewing the drawings prepared by Concessionaire/Contractor of a BOT/EPC contract:

- Site visit and verification of correctness of data as given in Schedule A of contract;
- Study of DPR prepared by Client;
- Review of Schedule B, C & D of contract agreement and identification of ambiguity/discrepancy/lack of clarity, if any;
- Action under the provision of contract agreement to resolve the discrepancies and establish clarity;
- Comparative study of various survey and investigation data/results as per DPR and that prepared by Concessionaire/Contractor. In case of major differences, IE/AE shall reconfirm accuracy of survey and investigation data/ results prepared by Concessionaire/Contractor;
- Scrutiny of the design reports and drawings as per requirement of Schedule B, C & D of contract agreement and site validation of the drawings from technical, social, environmental, health and safety considerations.

The above requirements shall be inbuilt into Quality Assurance Mechanism of Construction Supervision Consultant / Independent Engineer / Authority's Engineer.

4.4.2 *Procurement*

Procurement is another key activity in the project development cycle. The principles of procurement as set out by World Bank in their draft Procurement Policy 2014 for Procurement in World Bank Investment Project Finance is summarised below:

- Value for money;
- Economy;
- Integrity;
- Fit for purpose;
- Efficiency;
- Transparency;
- Fairness.

These policies are nonetheless equally applicable to procurement of projects with domestic funding irrespective of whether contract is EPC, BOT or Item Rate. Pursuance of the above mentioned policies require a stringent protocol to be meticulously followed by the Employer/

Authority. A sample but not exhaustive protocol is given below:

- Employer/Authority shall ensure that there is absolute clarity and consistency in bidding documents and qualification criteria is objective and quantifiable.
- Employer/Authority shall ensure that bid notice is given adequate publicity.
- Bid evaluation shall be strictly an inhouse exercise of Employer/Authority without any outsourcing.
- Evaluation process shall have undeniable transparency and accountability.
- There should be strong deterrent to conflict of interest.
- Employer/Authority shall ensure that evaluation process is fully documented.
- There should be a credible complaint and grievance redressal mechanism.

The above requirements should be inbuilt into Quality Policy/Manual of the Employer/ Authority.

4.4.3 *Construction*

The objective of Quality Assurance Plan for the construction stage is clearly spelt out in Clause No. 4.2 of this Section. QAP is a tool that ensures that construction of the project is done in a manner such that quality standards of the project are duly achieved as evidenced in outcome of quality control tests. It covers both process and end control and acts as a precussor to cost and time control such that value for money is achieved.

A Quality Assurance Plan for the Contractor shall typically cover but not limited to the following aspects:

- Organisation structure of contractor's project implementation team including assignment of duties and responsibilities and internal chain of command;
- Operational skills and training of workforce;
- Performance standards of machinery;
- Laboratory infrastructure, equipment and personnel;
- Calibration of equipments;
- Document control;
- Methodology of working, test and inspection plan;
- Control of materials including source selection;
- Control of workmanship;
- Plan for acceptance, non conformities, correction and rejection;
- Plan for adherance to safety, health and environmental considerations.

4.4.3.1 QAP for Contractor

Model Structure is given at **Annexure 4.2.**

4.4.3.2 Quality Assurance Mechanism for Construction Supervision Consultant/ Independent Engineer/Authority's Engineer

The Construction Supervision Consultant/Independent Engineer/Authority's Engineer shall work out a mechanism to be followed within its organisation and team so as to exercise

effective supervision of the project within the provision of contract document and carry out documentation of the process in an efficient manner.

Model Structure is given at **Annexure 4.3.**

4.4.3.3 General Protocol for Employer/Authority during Construction Stage

Notwithstanding the role and responsibility of Construction Supervision Consultant/ Independent Engineer/Authority's Engineer, Employer/Authority has to play a crucial role in ensuring quality of construction. The broad requirements are discussed below:

(i) Employer/Authority shall ensure availability of minimum staffing both at PIU and HO level so that decisions are fast and just. While it may not be appropriate to exactly specify the details of personnel considering variability of size and complexity of project, additional and miscelleneous responsibilities etc. an idea is given below for desirable strength at PIU level for handling average size projects:

Designation of officer at PIU level	**Maximum number of projects to be assigned**
Asst. Executive Engineer/Deputy Manager	1 with no other responsibility
Executive Engineer/ Manager/ Deputy General Manager	2 with no other responsibility/1 with other responsibilities
Superintending Engineer/General Manager	3 with other responsibilities

(ii) Employer/Authority shall have an independent evaluation and monitoring system to ascertain quality control of project. It may be through a dedicated cell at HO level, third party auditing or any other appropriate method but the extent and contour of independent evaluation and monitoring system shall be decided well in advance of commencement/appointed date.

(iii) Employer/Authority shall install a robust mechanism for dissemination of project information. Dissemination shall be multi modal to cater to the reach of the stakeholders and shall be continued on sustained basis upto completion of the project

(iv) Employer/Authority shall put in place a credible complaint and grievance redressal mechanism through which complaints/grievances of stakeholders can be genuinely and timely addressed.

The above requirements should be inbuilt into Quality Policy/Manual of the Employer/ Authority.

4.4.3.4 Interaction between QA & QC Personnel of Contractor and Engineer

Proper and timely interaction between QA and QC personnel of Contractor including its project management contractor, if engaged, and Engineer is very critical for achieving quality as well as progress of work. Interaction involves both physical interaction as well as communication

in hard copy and digital format. Contractor will evolve a mechanism for interaction as above and include the same in its QAP.

4.4.3.5 Pre-audit of QAP

QAP prepared by the Contractor is subject to review of Construction Supervision Consultant/ Independent Engineer/Authority's Engineer. Contractor may also engage a separate entity for pre-audit of the QAP before it is submitted to the Engineer for approval. The general points for pre-audit/review of QAP is given below:

- QAP is prepared in sync with the Quality Policy of the Contractor.
- All the works, materials and finished products are covered.
- There is clear task delineation.
- Material/finished product procurement method established.
- Machinery selection established in conformity with methodology and quality control.
- Laboratory infrastructure and testing processes established.

Annexure 4.1

MODEL QUALITY ASSURANCE PLAN FOR PROJECT PREPARATION

1. Brief particulars of assignment

- Name of Client including all units/offices associated with project preparation
- Scope of assignment;
- Brief description of location, terrain, topography, climate, socio-economic characteristics of the project area;
- Stages of project preparation including allocated timeline for each stage;
- Reference and applicable documents;
- Any other important point(s).

2. Quality policy

- Quality policy of the Consultant as per its own charter and reference to such document

3. Consultant's organization and responsibility matrix

A pictorial chart of the organization of the Consultant responsible for project preparation alongwith unit(s)/individual(s) of Consultant's HO who may check/vet the reports/designs/ drawings shall be provided in QAP.

Responsibility matrix for main tasks/group of tasks showing clearly the primary, secondary and tertiary responsibility shall be provided in QAP. The primary responsibility shall mean actual performance of tasks such as survey, field data collection, design, drawing etc. Secondary responsibility includes guidance, supervision and checking with or without approval in respect of the tasks being performed by personnel directly reporting to a particular personnel. It also includes opinion/vetting about a particular output by another personnel/expert which may have a bearing on such output. Tertiary responsibility includes final approval of major tasks involving final outputs. Tertiary responsibility may lie with Team Leader or senior expert(s) in Consultant's HO. Preparation of responsibility matrix hinges on understanding of the interfaces of major tasks e.g. geometrics design depends on topographical survey, siting and FRL of bridges, traffic forecast, social and environmental impact assessment etc. QAP shall classify interfaces of all major tasks in the form of a flow chart before finalising responsibility matrix.

4. Control of surveys

Quality of data is key to preparation of a sound and accurate project report. QAP shall contain the following details as regards to survey activities:

- List of the details of surveys to be conducted as per ToR;
- List of additional surveys, if any, required to be conducted for overall requirement of project preparation;
- List of relevant IRC/IS/other Codes of Practice/Guidelines/Manuals for each survey to be conducted;

- List of the equipments to be used for each survey;
- Formats for recording of data for each of the survey in accordance with the respective Codes of Practice/Guidelines/Manuals. All the formats shall be enclosed to QAP;
- Responsibility Matrix of survey and supervision thereof among key and sub professional,each survey wise, pursuant to para 3 of this Annexure;
- Percentage of checking of data to be carried out by the key professional during survey and post survey, each survey wise;
- Any other point(s) considered relevant.

5. Control of laboratory and field testing

QAP shall contain the following details as regards testing:

- List of the details of laboratory and field testing to be conducted as per ToR;
- List of additional testing, if any, required to be conducted for overall requirement of project preparation;
- List of relevant BIS/other Codes of Practice/Guidelines/Manuals for each test to be conducted;
- List of the equipments and consumables to be used for each test;
- List of the calibration requirements of the testing equipments;
- Formats for recording of test data in accordance with the respective Codes of Practice/Guidelines/Manuals. All the formats shall be enclosed to QAP;
- Responsibility Matrix for testing and supervision thereof among key and sub professional, each test wise, pursuant to para 3 of this Annexure;
- Percentage of testing to be witnessed by the key professional, each test wise;
- Any other point(s) considered relevant.

6. Control of alignment fixation including siting of bridges

Alignment fixation is a key requirement and involves of technical, economic, environmental and social considerations and particularly expanse and depth of social considerations. Alignment needs to be finalised after careful evaluation of all these considerations and in due consultation with all stakeholders. QAP shall contain following details specific to the project in this regard:

- Guidelines for widening scheme;
- Guidelines for deciding the requirement of a bypass and actual alignment of the bypass;
- Guidelines for realignment;
- Procedure for consultation with stakeholders and dissemination of information about alignment and other project related features;
- Any other point(s) considered relevant.

7. Control of data analysis and detailed design

The following shall be provided in QAP regarding data analysis and detailed design.

- List of the details of analysis and designs to be carried out as per ToR;
- List of relevant IRC/BIS/other Codes of Practice/Manuals/Guidelines for each analysis/design;
- List of the software/programming to be used for different analysis and designs;
- Responsibility Matrix for analysis and design and supervision thereof among key and sub professional each case wise pursuant to para 3 of this Annexure;
- Procedure for numbering and storage of manuscripts;
- Procedure for maintaining records of correction and final clearance/approval by designated personnel of Consultant. Suitable formats shall be devised for the purpose;
- Control of revisions- The first formal issue of analysis/design sheet and also drawings referred to in para 7 of this Annexure shall be marked as R0 and subsequent revisions, if any, shall be marked R1, R2 etc. A sample format for keeping a watch on the amendments is given below:

Rev	Section	Page	Revision Description	Appd.	Date

- List the procedure for identification and traceability of documents;
- Any other point(s) considered relevant.

8. Control of safety, health and environment

Safety, health and environment are growing concerns in a road project during both construction and operation. Project preparation must address concerns of safety, health and environment during project cycle. A set of action points to the effect must be included in QAP keeping specific project features in view in line with **Section 13** of the Manual.

9. Control of drawings

- List the rules for deciding sizes of drawings. The drawings shall be of standard size as mentioned below:

Sl. No	Conventional Size	Dimension
1.	A0	(840mm x 1188mm)
2.	A1	(594mm x 840mm)
3.	A2	(420mm x 594mm)
4.	A3	(420mm x 297mm)
5.	A4	(297mm x 210mm)

- Devise standard title block for drawings.
- List the rules for incorporating notes on the body of drawings such as design basis/philosophy, design parameters, characteristics of selected materials,

loading details, description of implementation scheme of design if any, etc.

- Devise procedure for preparation, checking and approval of drawings with assignment of responsibility among sub professional, key professional and senior expert from HO of the Consultant pursuant to para 3 of this Annexure. A sample checklist for preparation, correction and approval of junction drawing is given below. Similar checklist for other drawings shall be devised.

Sl. No.	Particulars	Yes	No	NA	Compliance to Item marked "No"
A	***GENERAL***				
1.	Drawing title corrected				
2.	Drawing number/date corrected				
3.	Revision status given				
4.	Signature of all concerned				
5.	Legend abbreviation and notes				
B	***JUNCTION ELEMENTS***				
1.	Scale of the drawings as per TOR				
2.	Grids and station points on the drawing with value				
3.	Check the centre line at the junction, whether it matches with related plan drawing				
4.	Check acceleration, deceleration and storage lane provided as per requirement				
5.	Tapering and additional lane is as per design requirements				
6.	Turning radius is as per design requirement				
7.	Stop line, lane, edge, chevron markings and over head gantry location are correct				
8.	Cross drainage structures and side drain is tied up properly for smooth flow of water and shown properly				
9.	For existing situation, the plan of existing junction to be super imposed and shown in up graded drawings				
10.	Traffic flow markings are shown on all the arms at appropriate locations				

11.	Dimensions of all the lanes, curve radii mentioned and across section cut and shown separately				
12.	From (Place Name) To (Place Name) mentioned on all the arms				
13.	Traffic island at appropriate location with complete dimensions of all elements (radius etc.)				
14.	Sufficient clearance and storage lane at junction available for right turning movements				
15.	All types of traffic signs boards at appropriate places on all the arms of the intersection drawings shown				
16.	All features to be named (e.g. existing road, main carriage way, service road, existing culvert and other details)				
C.	***OTHER***				
1.	Text and line styles should be same for all the similar drawings				
D.	***CLIENT COMMENTS***				

- List the procedure for identification and traceability of drawings

Annexure 4.2

MODEL QUALITY ASSURANCE PLAN FOR CONSTRUCTION

1. Brief particulars of project

- Name of Employer/Authority including all units/offices associated with project implementation;
- Name of the Independent Engineer/Authority's Engineer/Construction Supervision Consultant;
- Name of Concessionaire and/or Contractor;
- Brief description of location, terrain, topography, climate, socio-economic characteristics of the project area;
- Any other important point(s).

2. Scope of civil works

List the scope of civil works such as earthwork, pavement courses, structures, drainage and protection works, safety measures etc. Scope of works should indicate use of site and factory manufactured materials in particular items.

3. Applicable documents and references

List all the applicable documents such as contract agreement, applicable manual, MoRT&H Specifications, relevant IRC/BIS/other codes of practice.

4. Quality policy

Contractor's own quality policy as per its own charter and reference to such document.

5. Contractor's organisation and structure

- Indicate organisational chart of the project implementation team of the contractor.
- Chart shall show the QA and QC section of the contractor/ project management consultants as applicable in more detail.
- Chart shall show interface with top management of the contractor and Independent Engineer/Authority's Engineer/Construction Supervision Consultant as applicable.

6. Responsibility matrix among the contractor's key personnel

- All the major tasks in project implementation including pre-construction/ preparatory works shall be identified.
- The role of QA&QC personnel of contractor/ project management consultants as applicable during performance of different tasks shall be established.

7. Control of sub-contracting

Sub contracting is a reality in almost all contracts though varying in nature and extent. Sometimes sub contracting of a specialised nature of work is a genuine necessity. While finalising a sub contractor, qualification criteria as stipulated in contract agreement shall be followed. QAP shall provide the following details as regards sub contracting:

- Works/items to be sub contracted in the project as a whole;
- Plan as to how the works/items to be sub contracted will match the works programme of the contractor for the whole project;
- Plan as to how the role of QA&QC personnel of contractor/ project management consultants shall be enforceable to the works/items to be sub contracted.

8. Control of documentation and communication

- Procedure for filing, indexing and maintainence of records in a manner that provides for ready access to documents and prevents loss, damage, or deterioration;
- RFD (Result Framework Document) by contractor (A results framework is an explicit articulation (graphic display, matrix or summary) of the different levels or chains of results expected from a particular intervention).

9. Control of methodology

Contractor is required to submit methodology as per provision of agreement. QAP shall indicate a plan of approach as to how approved methodology shall be followed diligently during execution.

10. Human resources and training

Skill, knowledge and expertise of contractor's personnel responsible for various activities such as plant/machinery operation and maintenance, laboratory/field testing etc. are extremely important to ensure quality of the project. QAP shall deal with contractor's plan and programme to train its own personnel.

11. Control of materials including traceability and product identification

QAP will contain two different protocols to be followed by the Contractor to procure naturally occuring minerals and manufactured materials. There will be a separate protocol to control mix materials at Contractor's plant site. The protocol will list the responsibility of Contractor's key personnel and sub professional pursuant to para 6 of this Annexure as regards control of materials. The protocols will contain a faultless system for maintaning product identification. A sample protocol is given below:

- Estimate material quantities with reference to drawings and specifications;
- Prepare requirement plan;
- Float enquiries' enclosing specifications;
- Assign the responsibility of testing and obtaining approval among Contrctor's personnel;
- Collect samples, test independently;
- Seek/obtain approval of the source, if necessary;
- Place order, receive materials, test samples;
- Assign suitable identification number to each lot/stack and maintain record of the same;
- Allow for usage if test reports are satisfactory;

- Untested materials to be stacked at locations designated for the purpose;
- Where routine tests are not conforming to requirements, materials to be segregated at locations designated for rejected materials and quickly removed from site;
- If materials from a particular source continue to fail in the tests, discard the source.

12. Control of machinery

- Plan for selection of machinery (number, type and capacity) keeping in view production rate;
- Plan for training of operators as per manufacturer's requirement;
- Plan for calibration, routine checking and upkeep of machinery including all relevant parts responsible for different controls.

13. Control of laboratory and field testing facility

- Plan for laboratory infrastructure such as location, space size, personnel, equipments, accessories, consumables, general facilities commensurate with work requirements;
- Plan for calibration of equipments;
- Plan for upkeep of equipments;
- Plan for identification of samples and documentation of test results;
- Sample formats for collection of samples, recording of test (field and laboratory) observations and analysis/calculation of test results;
- Sample formats for statistical analysis;
- Sample formats for checking of levels and profiles.

All the sample formats mentioned above shall be included in QAP.

14. Control of corrective action

List the protocol for retesting and acceptance mechanism.

15. Control of traffic management, work zone safety, health and environment

Enforcement of traffic management, work zone safety, health and environment management plans are often neglected. QAP shall provide a protocol for enforcement of these plans.

16. Interaction between QA & QC Personnel of Contractor and Engineer

QAP will detail the mechanism for interaction between QA & QC Personnel of Contractor including its project management consultant, if engaged, and Engineer to achieve quality of works together with timely completion.

Annexure 4.3

MODEL QUALITY ASSURANCE MECHANISM FOR CONSTRUCTION SUPERVISION CONSULTANT/INDEPENDENT ENGINEER/AUTHORITY'S ENGINEER

1. Brief particulars of assignment:

- Name of Employer/Authority including all units/offices associated with project implementation;
- Name of the Independent Engineer/Authority's Engineer/Construction Supervision Consultant;
- Name of Concessionaire and/or Contractor;
- Brief description of the scope of work of consultancy services;
- Any other important point(s).

2. Applicable documents and references

List all the applicable documents such as contract agreement, applicable manual, MoRT&H Specifications, relevant IRC/BIS/other Codes of Practice/Guidelines/Manuals.

3. Quality policy

State the Consultant's own quality policy as per its own charter and reference to such document.

4. Consultant's organization and structure

Indicate organizational chart of the consultant's team with clear emphasis on QA and QC team

5. Responsibility matrix among consultant's personnel

List out the tasks of the consultancy services related to quality assurance and control. Prepare responsibility matrix among key personnel, sub professionals and HO support for quality assurance and control clearly showing primary, secondary and tertiary responsibility.

6. Control of documentation and communication

7. Protocol for acceptance, non conformance and rejection

SECTION 5

QUALITY REQUIREMENTS FOR FACTORY MANUFACTURED MATERIALS, PRODUCTS AND SPECIALIZED ITEMS

5.1 Introduction

The materials used in road construction can be broadly classified into three categories i.e. natural materials such as soil, sand, gravel, stone etc., factory manufactured materials such as steel, cement, bitumen etc. products and specialized items such as bridge bearing, expansion joint, tolling equipment, crash barrier etc. Field laboratory is required to be equipped for carrying out most of the tests specified for natural materials and factory manufactured materials. However, the finished items are usually tested in manufacturer's own laboratory or in a specialized laboratory.

5.1.1 Tentative list of factory manufactured materials used in road construction and testing requirements for the same are indicated in **Annexure 5.1**. The tests, which are normally carried out in field laboratory in respect of such materials, are also indicated therein.

5.1.2 Tentative list of factory manufactured finished items used in road construction and operation are indicated in **Annexure 5.2** along with testing requirements for the same. Normally, there is no facility in field laboratory to carry out such tests.

5.1.3 Reliability of factory manufactured materials and finished items specified in **Annexure 5.1** & **5.2** in the absence of regular site testing has a lot of concerns which need to be duly addressed through a combination of testing in manufacturer's/third party laboratory and rigorous protocol to ensure adoption of correct practices by the manufacturers.

5.2 General Principles

5.2.1 Quality of factory manufactured materials and finished items specified in **Annexure 5.1** & **5.2** hinges upon the manufacturer's commitment and implementation of a rigorous protocol in a sustained manner in pursuance to ISO 9001-2015 or similar standard. Three aspects are critical in this regard:

- Process approach
- Plan-Do-Check-Act (PDCA) cycle
- Evidence based decision making

5.2.1.1 Process Approach

A process is defined as a set of interrelated or interacting activities that use inputs to deliver an intended result. The process approach is a management strategy. When a firm/company uses a *process approach*, it means that it manages and controls the processes that make up its organization, the interactions between these processes, and the inputs and outputs that tie these processes together.

When this approach is applied to quality management, it means that the processes and process interactions are managed by the firm/company as a coherent *process-based quality*

management system. A process-based quality management system (QMS) uses a process approach to manage and control how its quality policy is implemented and how its quality objectives are achieved. In a nutshell, a firm/company is required to identify the processes that its QMS needs, to identify their sequence and interaction, to identify required inputs and expected outputs for each process, to identify process risks and opportunities, and to assign responsibilities and authorities for each process. It also expects the firm/company to identify the methods needed to manage, monitor, measure, evaluate, and control each process and to provide the resources that each process needs.

5.2.1.2 Plan-Do-Check-Act (PDCA) Cycle

A firm/company is required to (i) plan its process based QMS, (ii) operate its process based QMS, (iii) evaluate its process based QMS and (iv) finally improve its process based QMS. A firm/company is required to consistently follow the steps (iii) and (iv) during its operation/ manufacturing.

5.2.1.3 Evidence based Decision Making

Making decisions involves a degree of uncertainty, but ensuring that decisions are based on the analysis and evaluation of data is more likely to produce the desired result. This principle is directly applied to step 1,3 and 4 of PDCA cycle in managing and ensuring quality.

5.2.2 When reliance is made on the quality of a factory manufactured material or finished item, it must be certified that the manufacturer is reasonably complying with the requirements stated in 5.2.1 above.

5.3 Responsibility of Supplier/Manufacturer

The supplier/manufacturer has the responsibility of formulating a sound quality management plan (QMP) in accordance with the principles set out in clause 5.2 above that meets the specification requirements through systematic program of sampling, testing, and inspection. QMP shall be consistent with quality policy of the manufacturer. The quality management plan shall cover aspects such as particulars of certification of company by ISO or any other organization, testing facilities, accreditation of manufacturer's laboratory by NABL/equivalent international organisation, calibration process, QC personnel, acceptance mechanism, documentation, third party testing and evaluation method. The supplier shall follow its QMP diligently. The supplier/manufacturer shall furnish its quality management plan and accurate reports of its in house testing and third party laboratory test reports to the purchaser (employer/authority/contractor). **Annexure 5.3** gives list of documents to be furnished by supplier/manufacturer. **Annexure 5.3** is a minimum requirement only. If any Code of Practice/ Guidelines specifies the details of documents to be provided by supplier/manufacturer for a particular material/item, the same shall also be provided additionally. Requirements given in **Annexure 5.3** may be further improved by concessionaire/contractor in its QAP for any specific factory manufactured material/finished item.

5.4 Responsibility of Concessionaire/Contractor

The concessionaire/contractor will remain responsible for the ultimate quality of an item produced using factory manufactured material or a finished item itself. The contractor shall therefore, exercise its checks pursuant to its own QAP for such materials.

5.5 Responsibility of Engineer/Consultant/Employer/Authority

The responsibility of Engineer/Consultant is basically threefold. First, the Quality Management Plan and other documents submitted by the supplier/ manufacturer shall be scrutinized at length to find consistency of documents in accordance with quality policy of the manufacturer. Second, the Engineer/Consultant is required to witness a certain percentage of in house tests conducted by the supplier/manufacturer. The Employer/Authority shall carry out witnessing of tests, wherever Engineer/Consultant is not engaged for a particular project. Engineer/ Consultant/Employer/Authority shall get third party testing of certain manufactured materials/ finished items in a laboratory of repute depending upon the volume of work, importance/ unique nature of a particular finished item, inconsistency of manufacturer's test reports, fragile results of the tests. Random sampling along with traceability of sample is a pre-requisite for third party testing. Quality Assurance Mechanism of Engineer/Consultant shall firm up the details of tests to be witnessed by Engineer/Consultant and third party testing of certain manufactured materials/ finished items to be carried out.

5.6 New Materials

Several new materials are being developed from time to time which are not incorporated in MoRT&H Specifications for Road & Bridge Works. Such new materials are meant for use in pavement courses, concrete and various miscellaneous works to bring in economy in construction/enhancement of performance/protection of environment etc. . Whereas decision as to use of such materials shall be taken as per provisions of Contract Agreement or based on judgement of Employer/Authority, following guidelines shall be followed to ensure that stated objectives are duly realized.

- All new materials proposed to be used should be fit for the intended purpose of the material or the work in which these are incorporated (e.g. strength, durability, volume stability, permeability, separation or filtration, visibility, reflectivity, impact resistance, etc. as relevant), tested in reputed laboratories and in the field.
- The material should have a technology and production base that is capable of producing the required quantity with consistent and reproducible quality.
- Full responsibility of the manufacturer shall be guaranteed towards performance of the material.
- The manufacturer's Quality Policy shall be submitted.
- The specification limits of the material shall be informed for different quality characteristics.
- Undertaking of the manufacturer about no adverse environmental impact shall be furnished supported with test reports.

Annexure 5.1

*LIST OF FACTORY MANUFACTURED MATERIALS USED IN ROAD CONSTRUCTION

***(This is not an exhaustive list)**

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
1	Fly Ash	Requirement of IRC SP:58	IS:2720-Part-2 IS:2720-Part-4 IS:2720-Part-5 IS:2720-Part-8 IS:2720-Part-13 IS:2720-Part-15 IS:2720-Part-16 IS:2720-Part-17	Yes
		Grain Size Analysis Atterberg Limits MDD/OMC CBR Moisture Content Cohesion (C) Angle of Shearing Resistance (φ) Coefficient of Consolidation Compression index Permeability Coefficient of Uniformity		
		Requirement of IS:3812 (Part 1)	IS:1727 IS:4032 IS:12423 IS: 2720	No
		pH Silicon Dioxide Magnesium Oxide Sulphur Trioxide Loss on Ignition Sodium Oxide Silicon Dioxide, plus Aluminium Oxide plus Iron Oxide Total Chloride Reactive Silica Fineness Wet Sieving Lime Reactivity Compressive Strength Soundness		
2	Lime	Requirement of MoRT&H Specifications	IS:1514	No
		Sieve Analysis Calcium Carbonate Calcium Oxide		

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
3	Ordinary Portland Cement	Requirement of IS:269	IS:4031-Part-1 IS:4031-Part-2 IS:4031-Part-3 IS:4031-Part-4 IS:4031-Part-5 IS:4031-Part-6 IS:4031-Part-11	Yes
		Physical Tests Consistency Setting Time Fineness(Blaine's air, dry seiving) Soundness Density Compressive Strength		
		Chemical Tests Lime Soluble Silica Alumina Iron Oxide Total Sulpher Content Tricalcium Aluminate Magnesia Loss on Ignition Chloride Content Insoluble Residue Alkali	IS:4032, IS:12423-1988	No
4	PPC	Requirement of IS:1489	IS:4031-Part-1 IS:4031-Part-2 IS:4031-Part-3 IS:4031-Part-4 IS:4031-Part-5 IS:4031-Part-6 IS:4031-Part-10 IS:4031-Part-11	Yes
		Physical Consistency Setting Time Fineness (Blaine's air, Dry Seiving) Soundness Density Compressive Strength Drying Shrinkage		
		Chemical Sulpheric Anhydride Magnesia Loss on Ignition Insoluble Residue	IS:4032, IS:12423	No
5	PSC	Requirement of IS:455	IS:4031-Part-1 IS:4031-Part-2 IS:4031-Part-3 IS:4031-Part-4 IS:4031-Part-5 IS:4031-Part-6 IS:4031-Part-11	Yes
		Physical Consistency Setting Time Fineness(Blaine's air, dry seiving) Soundness Density Compressive Strength		

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	**Applicable Code of Practice**	
		Chemical Sulpher Trioxide Sulphide Sulphur Magnesium Oxide Loss on Ignition Total Chloride content Insoluble Residue	IS:4032, IS:12423	No
6	Rapid Hardening Portland Cement	Requirement of IS:8041	IS:4031-Part-1 IS:4031-Part-2 IS:4031-Part-3 IS:4031-Part-4 IS:4031-Part-5 IS:4031-Part-6 IS:4031-Part-11	Yes
		Physical Consistency Setting Time Fineness(Blaine's air, dry seiving) Soundness Density Compressive Strength		
		Chemical Lime Silica Alumina Iron Oxide Total Sulpher Content Tricalcium Aluminate Magnesia Total loss on Ignition Total Chloride Content Insoluble Residue	IS:4032, IS:12423	No
7	Viscous Grade Bitumen	Requirement of IS:73	IS:1203 IS:1206-Part-2 IS:1206-Part-3 IS:1448-Part-69 IS:1216 IS:1205 IS:1208	Yes
		Penetration at 25°C, 100 g, 5 s, 0.1 mm Absolute Viscosity at 60°C, Poises Kinematic Viscosity at 135°C, cSt, Flash Point (Cleveland open cup), °C Solubility in Trichloroethylene, per cent, Softening Point (R&B), °C Tests on Residue from rolling thin film Oven Test: a) Viscosity Ratio at 60°C b) Ductility at 25°C, cm		

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
8	Modified Bitumen	Requirement of IRC:SP:53		
		Penetration at 25°C 0.1 mm 100 gm, 5 sec Softening point (R&B)°C Ductility at 27°C Fraass Breaking Point °C Flash Point CoC °C Elastic recovery of half thread in Ductilometer at 15°C per cent Separation difference in softening point, R&B Method in °C Viscosity at 150°C Flash Point, COC Thin film oven test on residue a) Loss in Mass b) Increase in Softening Point c) Reduction in penetration of Residue at 25°C , percent(IS 1203) d) Elastic recovery of half thread in ductilometer at 25°C	IS:1203 IS:1205 IS:1208 IS:9381 IS:1209 IS:1206-Part 2 IS:15462-A Annex-1,2,3 & 4 of IRC:SP:53 IS:9382	Yes
9	Cationic Bitumen Emulsion	Requirement of IS:8887, ASTM:D-2397		
		Viscosity by Saybolt Furol Viscometer, seconds Storage Stability Particle Charge Test Cement Mixing Stability Distillation Residue on 600 micron IS Sieve, percentage by mass Penetration Ductility Solublity in Trichloroethylene Miscibility with water Residue by evaporation	ASTM: D-244 ASTM: D-6933 ASTM: D-6935 ASTM: D-6997 Annex-B, D, E, G, H and J of IS: 8887	No
10	Cut back	Requirement of IS:217		
		Kinematic viscosity at 60°C Flash point Pensky Mortens Closed Type °C Distillate volume per cent of total distillate upto 360°C	IS:1206-Part-3 IS:1209 IS:1213	No

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
11	Modified Bitumen Emulsion for Micro Surfacing	Requirement of MORTH Specification		
		Residue on 600 micron IS sieve Viscosity by Say Bolt Furol Viscometer Coagulation of Emulsion Storage Stability Particle Charge Test on Residue Residue by evaporation Penetration at 25°C/100 gm/5 secs Ductility at 27°C cm Softening point °C Elastic recovery Solubility in trichloroethylene	IS:8887 IS:1203 IS:1208 IS:1205 IS:15462 IS:1216	No
12	Anti Stripping Agent	Requirement of MoRT&H Specifications		
		Appearance Odour Specific Gravity 27°C Pour Point °C Flash Point °(COC) Water Content per cent Vol. Solubility in diesel oil (HDO or LDO) in the ratio of 2:98 at 50°C Total base value mg KOH/g Nitrogen Content per cent Wt. Stripping value with bitumen containing 1 per cent Wt. anti stripping compound at 40°C 24 hours Under water coating test Thermal stability at 163°C 5 hours Boiling Water Test per cent coating Retained Marshall Stability per cent	IS:1202 IS:1448 ASTM: D-664 IS:6241 ASTM: D-3625	No
13	Stabilizer additive for stone matrix asphalt	Requirements of MORTH Specifications		
		Maximum fibre length Ash Content Oil Absorption Moisture Content	ASTM:D-6390 MORTH Specifications IRC:SP:79 AASHTO:T-283	No

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
14	Silica Fume	Requirement of IS:15388		
		Physical Specific Surface Pozz Activity Index 45 Micron Retained Bulk Density **Chemical** Silicon Dioxide Moisture Content Loss in Ignition Alkalis as Na_2O	ASTM C:1240	No
15	Cement Admixture	Requirement of IS:9103		
		Dry Material Content Ash Content pH Water Soluble Chloride Relative density	IS:6925 IS:9103 (Annex E)	No
16	Joint Ceiling Compound	Penetration Flow Bond Resilience	ASTM:D-5329-Sec.6 ASTM:D-5329-Sec.8 ASTM:D-5329-Sec.9 ASTM:D-5329-Sec.12	
17	Reinforcing Steel	Requirement of IS:1786 & IS:2062		
		Physical Unit Weight (kg/m) Yield Strength (0.2% proof stress) (N/mm^2) Ultimate Tensile Strength (N/mm^2) % Elongation Bend & Re- bend test **Chemical** Carbon (%) Sulphur (%) Phosphorus (%) Sulphur (%) + Phosphorus(%)	IS:1608	No

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
18	Structural Steel	Requirement of IS:11587, IS:1977, IS:8500 & IS:2062		No
		PHYSICAL Tensile Strength (N/mm^2) Bend Test Impact Test Flattening Test	IS:1608 IS:1599 IS:1757 IS:2328	
		CHEMICAL Carbon (%) Sulphur (%) Phosphorus (%) Sulphur (%) Phosphorus (%)	IS:11587	
19	Pre-Stressing Steel Stands	Requirements of IS:14268		No
		Nominal Diametre Nominal Area Nominal Mass Proof Load Breaking Strength of Strand % Elongation	IS:14268 IS:1608	
20	Fusion Bonded Epoxy Coated Steel	Requirements of IS:13620		No
		Coating Thickness Chemical Resistance Corrosion Test Adhesion Bond Strength to Concrete Abrasion Resistance Impact Test Hardness Test	IS:1786 IS:6885	
21	Stainless Steel	Requirements of IS:6603, IS:6911		No
		Chemical composition Titanium Niobium Molybdenum Copper	IS:228 IS:1608 IS:1599 IS:1500 IS:1501 (Pt.-1) IS:1586 IS:1499 IS:6603	
		Mechanical property Tensile test Bend test Hardness Charpy impact test Dimensional tolerances		

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
22	Tubular Steel	Requirements of IS:1161		
		Mechanical Test Tensile Test Flattening Test Bend Test Retest	IS:1608 IS:2328 IS:2329 IS:228 IS:4376	No
		Chemical analysis test Hot-dip Zinc Coating Tolerance Sizes and Properties	IS:1161	
		Steel & Supply Manufacturing Process H F W H F S E R W/ H R I W	IS:10748	
23	GI Pipe	Requirement of IS:4736		No
		Quality of zinc Galvanizing Basic Metal for Tubes Mass of Zinc Coating Freedom from defect Free Bore Test Uniformity of Galvanized Coating Adhesion Test Sampling & Preparation of Test Specimen Re Test	IS:4736 IS:2629 IS:4736 IS:6745 IS:2629 IS:4736 IS:2633 IS:2629 IS:4736	
24	Cast Iron	Requirement of IS:1030		No
		Tensile Test Brindell Hardness Test Impact Test Bend Test Chemical Analysis Chemical Composition Non Destructive Test Hydraulic Test Radiographic Test Liquid Penetrant Flaw Detection Magentic particle flaw Detection	IS:1608 IS:1500 IS:1757 IS:1599 IS:228 IS:1030 IS:2595 IS:3658 IS:3703	

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
25	Steel Forgings	Requirement of IS:1875		
		Tensile Test Hardness Test Retest Bend Test Grain Size Macro structure Ultrasonic Test Magnetic Particle Test Blue Fracture Test Dimensional Tolerance Macro streak flaw test Chemical Analysis	IS:1608 IS:1500 IS:1599 IS:4748 IS:11371 IS:10138 IS:4075 IS:3739 IS:4075 IS:228	No
26	Steel Nut Bolt Washers	Requirements of IS:1364 and IS:1367	IS:1364 ISO:724 ISO:965-1 ISO:898-1 ISO:4759-1 ISO:4042 ISO:10683 IS:1367 (Pt.-17) ISO:3269	No
		Dimensions & Mechanical Properties Preferred Threads Non Preferred Thread Tolerance Property Class Product Grade **Finish and or Coating** For Electroplating For non electrolytically Applied Zinc Flake Coating **Plain washer** Hole Diameter Outside Diameter Hardness Test		
27	Aluminium Composite Material Substrate	Requirements of MORT&H Specifications		
		Mechanical properties of ACM Peel off strength with Retro-reflective Sheeting (Drum Peel Test) Tensile Strength 0.2% Proof Stress Elongation Flexural Strength Flexural Modulus Shear Strength with punch Shear Test	ASTM:D-903 ASTM:E-8 ASTM:393 ASTM:732	No
		Properties of Aluminium Skin Tensile Strength(Rm) Modulus of Elasticity Elongation 0.2% Proof Stress		

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
28	Retro-Reflective Sign Board & Sheeting	Tensile Strength % Elongation Aluminium Heat Stability Cracking Resistance Retro Sheeting	ASTM:B-209M	No
29	Ordinary Road Marking Paint	Requirement of IS:164		
		Durability Drying time on Bituminous Surface Surface Dry Hard Dry Consistency Finish Application Colour Wet Capacity Resistance to Bleeding Recoating Property Resistance to Wear Residue on Sieve Flash point Keeping properties	IS:164 IS:101	No
30	Thermo Plastic Road Marking Paint	Luminance Drying Time Skid Resistance Cracking Resistance at low Temperature Softening Point Flow Resistance Yellowness Index	AASHTO: M-249 MORTH Specifications BS:604 ASTM:D-36 AASHTO: M-249 AASHTO: M-249	No
31	Reflectorising Glass Beads	Gradation Roundness Refractive Index Free Flowing Properties	BS:6088 BS:6088 BS:3262 (Pt.-1) MORTH Specifications	No
32	Cold Applied Reflective Paint	Requirements of MORT&H Specifications		
		Binder Titanium Dioxide Calcium Carbonate & Interfiller Yellow Pigment Density Drying Time Sand Abrasion Test Elongation (Unbeated Dry Film) Water Resistance Skid Resistance Retro-Reflective Property	MORT&H Spec. ASTM:D-1475 ASTM:D-711 ASTM:D-968 ASTM:D-1737 ASTM:D-1647 BS:6044 BS:EN-1436-1998 ASTM:D-711 ASTM-D-4060 ASTM:D-968 BS:6088	No

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
		Luminous Coefficient No- Pick Up Time Resistance to Wear Gradation of Glass Beads		
33	Burnt Clay Bricks	Requirements of IS:1077	IS:3495 (Pt.-1) IS:3495 (Pt.-2) IS:3495 (Pt.-3)	Yes
		Compressive Strength Water Absorption Efflorescence		
34	Hume Pipe (NP-4)	Requirements of IS:458	IS:516 IS:5816 IS:3597 IS:3597 IS:3597 IS:458	No
		Compressive Strength Splitting tensile Strength Hydrostatic Test Three Edge Bearing Test Permeability Test Working Pressure Site Test Pressure Surge (Water Hammer) Pressure Design & Strength Test Spigot & Socket Dimension Test		
35	Sheathing Duct	Workability Transverse Load Rating Test Tension Load Test Water Loss Test Bond Test Compression Test for the Loss of Wall Thickness	IS:1343	No
36	Anchorage for Pre-Stressing	Requirements of IS:1343	IS:1343	No
		Static Load Test with Tendon Anchorage Assembly Dynamic Load Test with Tendon Anchorage Assembly Load Transport Test		
37	Chemical Resistant Anti corrosive Paint	Requirements of draft RDSO Specification No. M & C/PCN/123-II	IS:101	No
		Drying time Consistency Dry Thickness and Rate of Consumption		

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
38	Epoxy Based Paint	Requirements of IS:14589		
		Consistency Drying Time Finish Colour Volatile Matter Pigment Content Volume Solids Dry Film Thickness Flash Point Protection against corrosion Resistance to Salt Spray Effect of welding Keeping quality Pot life	IS:101	No
39	Grease	Requirements of IS:508		
		Kinematic Viscosity in CST Flash Point Penetration Test Graphite Content Drop Point Copper Strip Corrosion Water Content Free Acidity Free Alkalinity Heat Stability Low Temperature Pumping Properties Glycerine Content	IS:1448 (Pt.-25) IS:1448 (Pt.-69) IS:1448 (Pt.-60) IS:1448 (Pt.-58) IS:1448 (Pt.-52) IS:1448 (Pt.-51) IS:1448 (Pt.-40) IS:1448 (Pt.-53) IS:1448 (Pt.-62) IS:1448	No
40	Mild Steel	Requirements of IS:432 (Pt.-1)		
		Chemical Composition Mechanical Properties of Bars Tensile test Bend test	IS:226 IS:432 (Pt.-1) IS:1608 IS:1599	No
41	Epoxy	Requirements of MORTH Specifications		
		Viscosity Pot Life Test in Minute Bond Test Shear Test Core Test **Test for Injection Equipment** Pressure Test Ratio Test	MORT&H Specifications	No

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
42	Mechanically Woven Wire	**Mechanical properties** Tensile Strength of wire for double twisted **Physical properties** **Zinc Coating** Mass Zinc Coating Adhesion of Zinc Coating **PVC for coating** Specific Gravity Tensile Strength Hardness Test Resistance of PVC Coating to sodium Chloride Salt spray Exposure	 IS:280 IS:4826 IS:4826 IS:13360	No
43	Latex Acrylic Polymer	Appearance Melting point/ glass-transition Temperature Specific Gravity Water Solubility Flammability Limit Autoignition Temp. Explosive Properties Reactivity Particle size Distribution Purity of Chemical Maximum weight % of Residual Impurities	Acrylic Polymer Latex WB-111	No
44	Acrylic Elastomeric Coating	Requirements of MORT&H Specifications Specific Gravity Solid Content Ultra Violet Resistance IR-spectrum Adhesion with Concrete Dry Film Thickness Coverage Physical Properties Diffusion Resistance against Carbon Dioxide Diffusion Resistance against Water Vapour Water Proofing Characteristics Re-coat Ability	 IS:345 IS:345 ASTM:G-53/ DINEN-150-105 IR-spectrometer standard ASTM: D-4541-02/DIN 500014 MORT&H Specifications DIN: 53122-P-1 DIN: 52615	No

Sl. No.	Factory manufactured material	Testing requirements		Test facility at field laboratory
		Test	Applicable Code of Practice	
45	Soil Reinforcing	Requirements of MORT&H Specifications	ISO:10319 ASTM: D-6706 ASTM: D-5321 IS:13326 (Pt.-1) AASHTO: T-288 AASHTO: T-289 ASTM: D-4327 ASTM: D-4327	No
		Ultimate Tensile Strength Pull-out Resistance in Soil Coefficient of Interaction between Reinforced fill Soil and Geo grid Determining the Coefficient of soil and Geo Synthetic Friction by Direct Shear method **Electrochemical Properties for Reinforced Fills with Steel Reinforcement** Resistivity pH Chlorides Sulphates		
46	Soil Nailing	Requirements of MORTH Specifications	IS:1786 IS:9012 MORT&H Specifications	No
		Steel Grout Mix Field Pull Out Testing Verification Test Proof Test Creep Test		

Annexure 5.2

TENTATIVE LIST OF FACTORY MANUFACTURED FINISHED ITEMS USED IN ROAD CONSTRUCTION

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	Applicable Code of Practice	
1	Joint Filler Board	Requirements of IS:1838 (Pt.-1)		No
		Resistance to handling	IS:10566	
		Recovery	IS:10566	
		Compression	IS:10566	
		Extrusion	IS:10566	
		Water Absorption	IS:10566	
		Density	IS:10566	
		Bitumen Content	IS:10566	
		Weathering	IS:10566	
		Penetration of re-covered Bitumen	IS:10566	
2	Pre Formed Joint Seals	Requirements of ASTM:D-2628		No
		Tensile Strength	ASTM:D-412	
		Elongation at break	ASTM:D-2240	
		Hardness, Type A Durometer	ASTM:D-573	
		Oven aging, 70h at 100°C	ASTM:D-471	
		Tensile Strength Loss	ASTM:D-1149	
		Elongation Loss	ASTM:D-2240	
		Hardness Change Type A Durometer	ASTM:D-9.2D-2628	
		Oil swell, ASTM oil 3, 70h at 100° C	ASTM:D-9.3D-2628	
		Weight Change		
		Ozone Resistance 20 % strain, 300 pphm in air, 70h at 40° C		
		Low Temperature stiffening, 7 days at -10°C Hardness change Type A Durometer		
		Lower temperature recovery, 72h at -10°C , 50% deflection		
		Lower temperature recovery, 22h at -29°C, 50% deflection		
		High temperature recovery, 70h at 100°C, 50% deflection		
		Compression, Deflection, at 80% of normal width (min)		

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	**Applicable Code of Practice**	
3	Geo Synthetics Composite Drain	**General** Width Thickness Tensile strength Elongation at break Discharge Capacity i= 1.0 at. 300 kPa pressure **Filter Material** (Polyster/Polypropylene) Mass per unit area Tensile Strength Elongation at Break Trapezoid Tear Strength Permeability Apparent opening size	ASTM:D-5199 ASTM:D-4595 ASTM:D-4716 ASTM:D-5261 ASTM:D-4632 ASTM:D-4533 ASTM:D-4491 ASTM:D-4751	No
4	Perforated/ Imperforated Pipes (PVC)	**Tubings & Fittings** Corrugated Polyethylene (PE) tubing and fittings 3-6 in Corrugated Polyethylene (PE) tubing and fittings 8-24 in Corrugated Polyethylene (PE) drainage pipe 3-10 in Corrugated Polyethylene (PE) drainage pipe 12-60 in Dual wall High Density polyethylene (HDPE) pipe and fittings 3-6 in Dual wall High Density polyethylene (HDPE) pipe and fittings 8-24 in Corrugated Polyvinyl Chloride (PVC) pipe and fittings Polyvinyl Chloride (PVC) dual wall sewer pipe and fittings Polyvinyl Chloride (PVC) sewer pipe	ASTM:F-405 ASTM:F-667 AASHTO:M-252 ASSHTO:M-294 ASTM:D-3034 ASTM:F-949 ASTM:D-2729	No

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	Applicable Code of Practice	
5	Prefabricated Vertical Drain	Requirements of MORT&H Specifications		
		1. Composite drain Width Thickness Tensile Strength Elongation at break Discharge Capacity i= 1.0 at. 300 kPa pressure **2. Core** Material Configuration **3. Filter** Material Structure Mass per unit Area Tensile Strength Elongation at Break Trapezoid Tear Strength Permeability Apparent opening size	 ASTM:D-5199 ASTM:D-4595 ASTM:D-4716 ASTM D 5261 ASTM D 4632 ASTM D 4632 ASTM D 4533 ASTM D 4491 ASTM D 4751	 No
6	Tiles	Water Absorption & Bulk Density Moisture Expansion using Boiling water –Unglazed Tiles Linear Thermal Expansion Resistance to Thermal Shock Modulus of Rupture and Breaking Strength Chemical Resistance Unglazed Tiles Chemical Resistance Glazed Tiles Crazing Resistance Glazed Tile Frost Resistance Resistance of Surface Abrasion Glazed Tiles Resistance to Deep Abrasion Unglazed Tiles Scratch Hardness of surface according to MOHS Impact Resistance by Measurement of Coefficient of Restitution Sampling and basis for acceptance	IS:13630(Pt-2) IS:13630(Pt-3) IS:13630(Pt-4) IS:13630(Pt-5) IS:13630(Pt-6) IS:13630(Pt-7) IS:13630(Pt-8) IS:13630(Pt-9) IS:13630(Pt-10) IS:13630(Pt-11) IS:13630(Pt-12) IS:13630(Pt-13) IS:13630(Pt-14) IS:13630(Pt-15)	Yes No

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	Applicable Code of Practice	
7	Reflective Pavement Markers	Load Test Coefficient Luminance Lenses of Methyl Methecrylate	ASTM:D-4280 ASTM:E -809 BS:873 (Pt.-4) ASTM:D 788	No
	Solar Powered	Load Test	ASTM:D-4280	No
8	Road Markers	Water Resistance Dimensional tolerance	IS:12063	
9	Road Delineators	Requirements of IRC:79		
		Physical Dimension Test		No
10	Metal Beam Crash Barriers	Requirements of IS:5986, IS:4759		
		'W' Beam, Post, Spacer Thickness Yield strength, N/mm^2 Ultimate Strength N/mm^2 Elongation % Carbon % Sulphur % Phosphorus % Silicon % Manganese % Carbon Equivalent % Zinc Coating	IS:1367(Pt.-XIII)	No
11	Wire Rope Crash Barrier	Conformance with the requirements of Australian Standard Road Safety Barrier Systems. Satisfactory crash testing at least Test Level 4 including the 4-11 test designation, or other accepted equivalent procedures.	AS/NZS 3845 NCHRP Report 350	No
12	Traffic Cones	Crash Test	BS 873 BS EN-13422	No
13	Traffic Attenuator	Crash Test	NCHRP Report 350	No
14	Filler Joints	Requirements of IS:1838 (Pt.-3)		
		Resistance to Handling Recovery Compression Extrusion Water Absorption Density Weathering	IS:10566 IS:10566 IS:10566 IS:10566 IS:10566 IS:10566	No

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	Applicable Code of Practice	
15	Reinforced Elastomeric Joints	Requirements of MORT&H Specifications	IS:2062 IS:1030 IRC:83 (Pt.-II) IS:3400 (Pt.-I) IS:3400 (Pt.-II) IS:3400 (Pt.-IV) IS:3400 (Pt.-X) IS:3400 (Pt.-XIV) IS:3400 (Pt.-XX) IS:226	No
		Mild Steel for Reinforcing plates, Inserts and Anchorage Cast Steel for Reinforcing Plates Elastomer Laminates		
16	Single Strip/Modular Strip Seal Joints	Requirements of MORT&H Specifications	DIN:17100 ASTM:A-36 ASTM:A-588 IS:2062 ASTM:D-2240 ASTM:D-412 ASTM:D-624 DIN:53504 DIN:53505 DIN:53507 DIN:53512 DIN:53516 DIN:53517 ASTM:D-395 DIN:53508 DIN:53509 DIN:53521 ASTM:D-1043	No
		Edge Beam & Central Beam/Lamella **Anchorage** **Chloroprene Seal** Hardness Tensile Strength Elongation at Fracture Tear Propagation Strength Longitudinal transverse Shock Elasticity Abrasion Residual Compression Strain Ageing in Hot air Ageing in Ozone Swelling Behaviour in Oil Cold Hardening Point		
17	Asphaltic Plug Joint	Requirements of MORT&H Specifications	BS:2499 ASTM:D-1190 MORTH Specifications IS:2062	No
		Binder Softening point Cone Penetration at 25° C. 0.1 MM Flow Resistance at 70°C. 05 Hrs. Extension Test Safe heating Temperature, 210° **Aggregate** Grading Requirement Polished Stone Value Aggregate Abrasion Value Aggregate Impact Value Aggregate Crush value **Closure plate** **Foam caulking/Backer road**		

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	Applicable Code of Practice	
18	Compression Seal Joint	Requirements of MORT&H Specifications	IS:2062 ASTM:D-2240 ASTM:D-412 ASTM:D-624 DIN:53504 DIN:53505 DIN:53507 DIN:53512 DIN:53516 DIN:53517 ASTM:D-395 DIN:53508 DIN:53509 DIN:53521 ASTM:D-1043 ASTM:D-3575 IS:3400 (Pt.-XIV) ASTM:D-797 IS:3400 (Pt.-XXII) ASTM:D-3677	No
		Steel for Nosing and Anchorage **Chloroprene Seal** **Closed Cell Foam Seal**		
19	Steel Bearing	Requirements of IRC:83-2014 (Pt. I)		
		Raw Material a) Mild Steel b) Forged Steel c) High Tensile Steel d) Stainless Steel e) Cast Steel **Test on welding Dry penetration test** **Test on dimensions** **Ultrasonic Testing** **Load test** **Chemical Test**	IS:1030 IS:2062 IS:1875 IS:2004 IS:961 IS:6603 IS:7666 IS:1024 IS:814 IS:919 IS:3073 IS:9565 IRC:83 (Pt.-I)	No
20	Spherical/ Cylindrical Bearing	Requirements of IRC:83-2014 (Pt. IV)	IRC:83-2014 (Pt.-IV)	No
		Raw Material a) Cast Steel b) Rolled Steel c) Forged Steel d) Stainless Steel e) Duplex Steel f) PTFE g) UHMWPE h) CM 1 i) CM 2 j) Lubricant k) Anchoring Arrangement		

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	**Applicable Code of Practice**	
		Test on Corrosion Protection **Overall dimension** **Ferroxyl Test for Chromium Plating** **Test on welding e. g. Dye Penetration Test** **Ultrasonic inspection of the steel components** **Finished Bearing** a) Surface Finish b) Overall Dimension c) Vertical Load Test d) Coefficiient of Friction e) Permisisible Rotation		
21	Elastomeric Bearing	Requirements of IRC:83 (Pt.-II)		No
		Identification of Polymer Polymer Content Sp. Gravity Test Ash Content Hardness Tensile Strength Elongation at Break Compression Set Aceelerated Ageing Adhesion Strength Ozone Resistance of Elastomer Laminate	ASTM:D-3677 ASTM:D-297 IS:3400(P-I, II, IV, X, XIV, XX & XXII) IS:226 IRC:83 (Part-II)	
		Test on hole Bearing 1) Shear Modulus 2) Elastic Modulus 3) Visual test 4) Dimensional tolerance 5) Axial load on 15 Mpa Deflection under load 5 Mpa 15 Mpa (Ultimate Compressive Strength) 6) Adhesion Strength		

Sl. No.	Factory manufactured finished item	Testing requirements		Test facility at site laboratory
		Test	**Applicable Code of Practice**	
22	POT, PTFE, PIN & Mettalic Guide Bearings	Requirements of IRC 83 (Pt.-III)	IS:1030 IS:2062 IS:961 IS:1875 IS:6911 BS:3784 BS:5350:(Part C9) IRC:83 (Part III) IS:410 ISO:1183 ISO:1133 ISO:572-2 IS:1363 IS:1364 IS:1365 IS:2269 IS:3138 IS:6761 IS:6639 IS:1367 IS:4218 IS:2016 IS:6610 IS:9954 IS:816 IS:9595 IS:814 AISI 316L IS:2004	No
		Test on Raw Material a) Mild steel b) High Tensile Steel c) Cast Steel d) Forged Steel e) Stainless Steel f) PTFE g) Adhesive h) Elastomer i) Internal Seal j) Poly Oxy Methylene Sealing Chain k) Fasteners		
		Test on Corrosion protection **Test on Casting** **Test on welding** **Test on Bearing** **Overall dimension** **Surface Finish** **Load Test** **Friction Test** **Rotation Test**		

Annexure 5.3

LIST OF DOCUMENTS TO BE FURNISHED BY SUPPLIER/MANUFACTURER

1. Quality Policy of the Manufacturer

2. Quality Management Plan (QMP)

The QMP of the supplier/manufacturer is expected to give accurate information about the following aspects but not limited to it in so far as it relates to the particular manufactured material/finished item being sourced from it. However, in case some aspect is not covered, specific information may be called by Concessionaire/Contractor/Engineer/Consultant/ Employer/Authority from the supplier/manufacturer.

- Raw materials sourcing
- Manufacturing process of raw materials and finished product (The supplier/manufacturer shall furnish details of manufacturing process of the manufactured material/finished items along with manufacturing process of different raw materials by the respective raw material manufacturers. For example, bearing manufacturer shall furnish smelting/remelting and any subsequent process involved with steel manufacturing such as rolling, extruding, machining, bending, grinding, drilling and applying coatings.)
- Testing facilities
- Laboratory accreditation
- Calibration Process
- Personnel
- Details of sub contractors e.g. fabricators, galvanizers, and painters etc.
- Reference to applicable BIS/International Code of Practice
- Acceptance Mechanism
- Documentation system (internal as well as external) e.g. accurate communication of moulding, cutting, drilling, processing and testing operations in case of bearing to shop personnel
- Third party testing
- Traceability of materials, processes and testing
- Evaluation method

3. Copy of Certification by ISO or any other organization

4. Place and Period of manufacturing

5. Shipment/Lot Identification Number and Individual Product Identification Number wherever applicable

6. Manufacturer's Certificate about compliance to QMP Shipment/Lot wise

7. Certified Laboratory Test Reports Shipment/Lot wise

The test results shall include the following:

- Test reports from raw material manufacturers and sub contractors
- Test reports of material/finished item including destructive testing, acceptance testing etc.

8. As-built Shop Drawings and Installation Drawings (showing proper orientation) wherever applicable

SECTION 6

FIELD LABORATORY SET UP

6.1 Introduction

Quality Control requires testing of materials, processes and workmanship in various stages of road construction. Adequate number of field laboratories shall be set up by the Contractor at the project site by installing the equipments suggested in section 100 of the MORTH Specifications for Road and Bridge Works. The number and size of laboratories depend on the establishment and oraganisation structure at site. It also depends on the location of crushers, concrete batching plant, wet mix plant, hot mix plant and the camp office. If all are located in the same place, one single laboratory with the facilities to test all the construction materials shall be established in the camp site. If the plants are located in different locations, test facilities are required at the respective plant site for conducting corresponding tests and accordingly, it is a general practice to establish small plant laboratories to cater to the requirements of individual plants.

Generally, it is Contractor's obligation to establish the test laboratories but where a project includes different packages, the Employer/Authority may choose to establish a Central Labortaory at a convenient location, where the Engineer may also be able to conduct tests on all types of materials and mixes.

6.2 Objective

Field Laboratory is the real bastion of quality control. Infrastructure and equipments of Field Laboratory play critical role in quality control and, in fact, is a cornerstone in the process of quality assurance. The objectives of an ideal Field Laboratory can therefore, be summarized as:

i) Lay out plan is such that it accommodates the equipments in proper manner and provides good and efficient working environment.

ii) Intended equipments and accessories are available and properly maintained.

iii) Intended consumables are available and properly stored.

iv) Documentation management system is efficient.

6.3 General Features

6.3.1 *Type of Laboratory*

Depending on the size, packaging, field organization structure and geographical spread of the project site, there can be a central/main laboratory for each package. Further, plant laboratories can be established if they are located in different locations than the main camp site. Test equipments at each plant laboratory will be specific to the plant established at that location. The Authority / Employer may choose to establish a central laboratory, for conducting some important and critical tests.

6.3.2 *Lay out of Laboratory*

The layout of the laboratory depends on the test facilities required at that location. Test facilities can be divided in to three principal sections namely, soil and aggregate testing section, concrete section, asphalt section.

Plant laboratories will have a concrete section for concrete batching plant and aggregate and asphalt section for wet mix macadom and hot mix plants. However, the facilities required for mix designs need not be established at the plant laboratory. Depending on the Contractor's plans for establishing the plants and their relative positioning with the field laboratories, the placement of facilities may be optimized.

Considering that a field laboratory is established for each package and plant laboratory is established at the plant site, suggestive lay outs are furnished in **Annexure 6.1** of this Section.

6.3.3 *List of Equipment & Accessories*

The list of equipment and various accessories in each laboratory depends on the type of laboratory and the test facilities envisaged or planned by the Contractor at that location. With the same assumptions used for deciding the layout of various laboratories presented in para 6.3.1, a comprehensive list of equipment in each laboratory and the suggested inventory of consumables are furnished in **Annexure 6.2 and Annexure 6.3** of this Section, respectively. As such, this list shall be consistent with section 100 of MORTH Specifications for Road and Bridge Works. However, it may vary depending on the actual test facility envisaged at that location subject to approval of Engineer.

6.3.4 *Man Power*

Deployment of manpower depends on the size of the laboratory, the test facilities planned and the volume of work involved. The central/main laboratory shall be headed by Quality Control/Asst. Quality Control Engineer. The qualification and experience shall be as per the requirements of Section 3 of this Manual. Each plant laboratory shall be manned by atleast one lab technician.

6.3.5 *Codes of Practice*

All the tests shall be conducted as per relevant Indian Standard Codes of Practice, which have been mentioned in Section 900 and other sections of MORTH Specifications for Road and Bridge Works. In the absence of Indian Standards for any test, reference may be drawn from any other appropriate international code of practice such as BS, ASTM etc. A list of suggested codes of practice for various tests to be conducted on naturally occurring materials in original/crushed form is given in **Section 8** whereas the same for factory manufactured materials/finished products is furnished in **Section 5**.

6.3.6 *Test Procedures*

Test procedures shall be drawn from the suggested Codes of Practice in Para 6.3.5 above and included in the Quality Assurance Plan. Further, all the procedures shall be converted in to brief work instructions and displayed near the individual test facility.

6.3.7 *Documentation and Records*

All the formats to be used for recording the results of various tests shall be included in the Quality Assurance Plan. A copy of the QAP shall be made available in the central/main & plant laboratories. Test results shall be promptly entered in suitable registers and/or forms (paper/electronic) soon after conducting the tests. All the linked test reports and RFIs, if applicable, shall be filed in a single location so that the records can be effectively retrieved at the time of future investigations. Quality records should be properly indexed and linked to suitable strip maps for traceability. They should be stored in an orderly manner in the safe custody of the laboratory-in-charge. An electronic copy of the records shall be maintained in a form that facilitates quick and easy retrieval.

6.4 Project Preparation

It is preferable that the design consultants carry out the tests in their own laboratories as far as possible. In case, the Consultants do not have their own laboratories, they shall arrange to conduct the tests in the laboratories of reputed academic institutions or in accredited third party laboratories consistent with the requirements of this Manual.

6.5 Construction

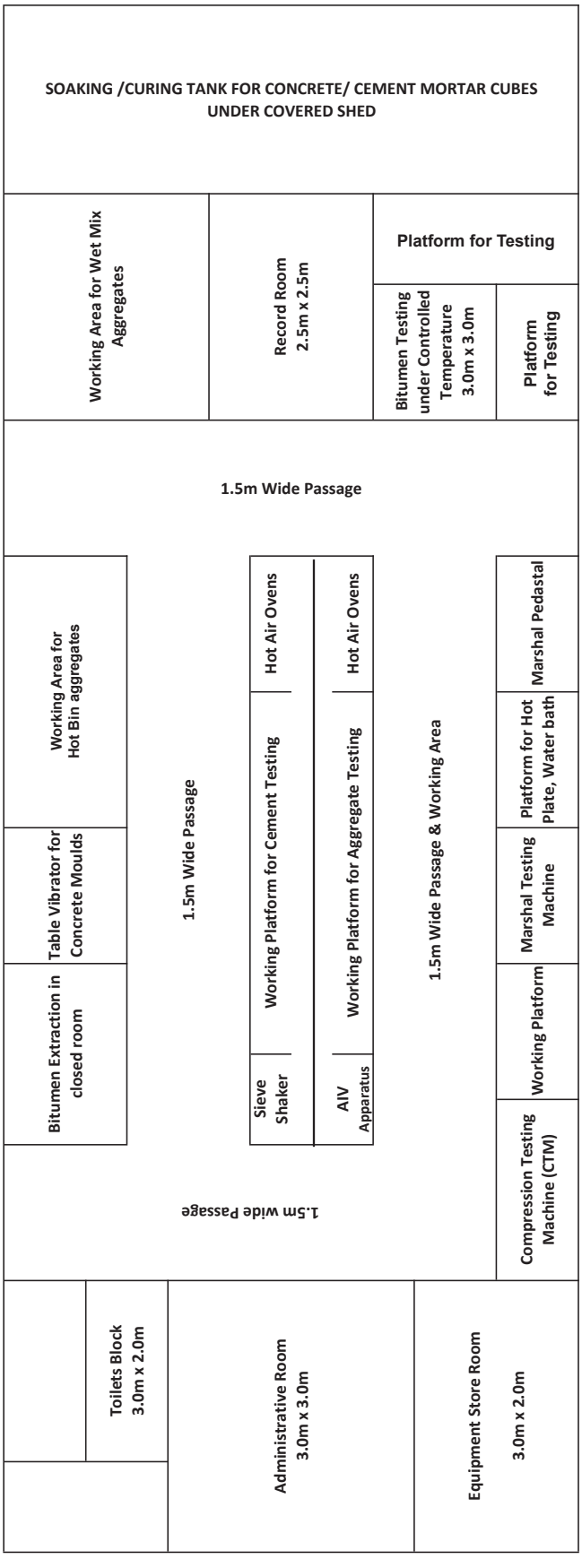
During Construction, the Contractor is required to conduct tests on every material that is being incorporated in to the Project including raw materials, processed materials, manufactured materials, proprietory materials etc. Laboratories shall be established as per the requirement of the Project with all the equipment listed in the Contract / Section 100 of MORTH. Plant laboratories shall be established as per site requirement i.e wherever a plant or group of plants is established.

6.6 Upkeep and Manitenance

The laboratories shall be adequately lit, ventilated and well maintained with proper water supply and sanitary arrangements. The equipment / apparatus requiring temperature controlled environment shall be housed in air conditioned rooms. The tests that use infammable substances shall be conducted in separate room having adequate ventillation / windows.

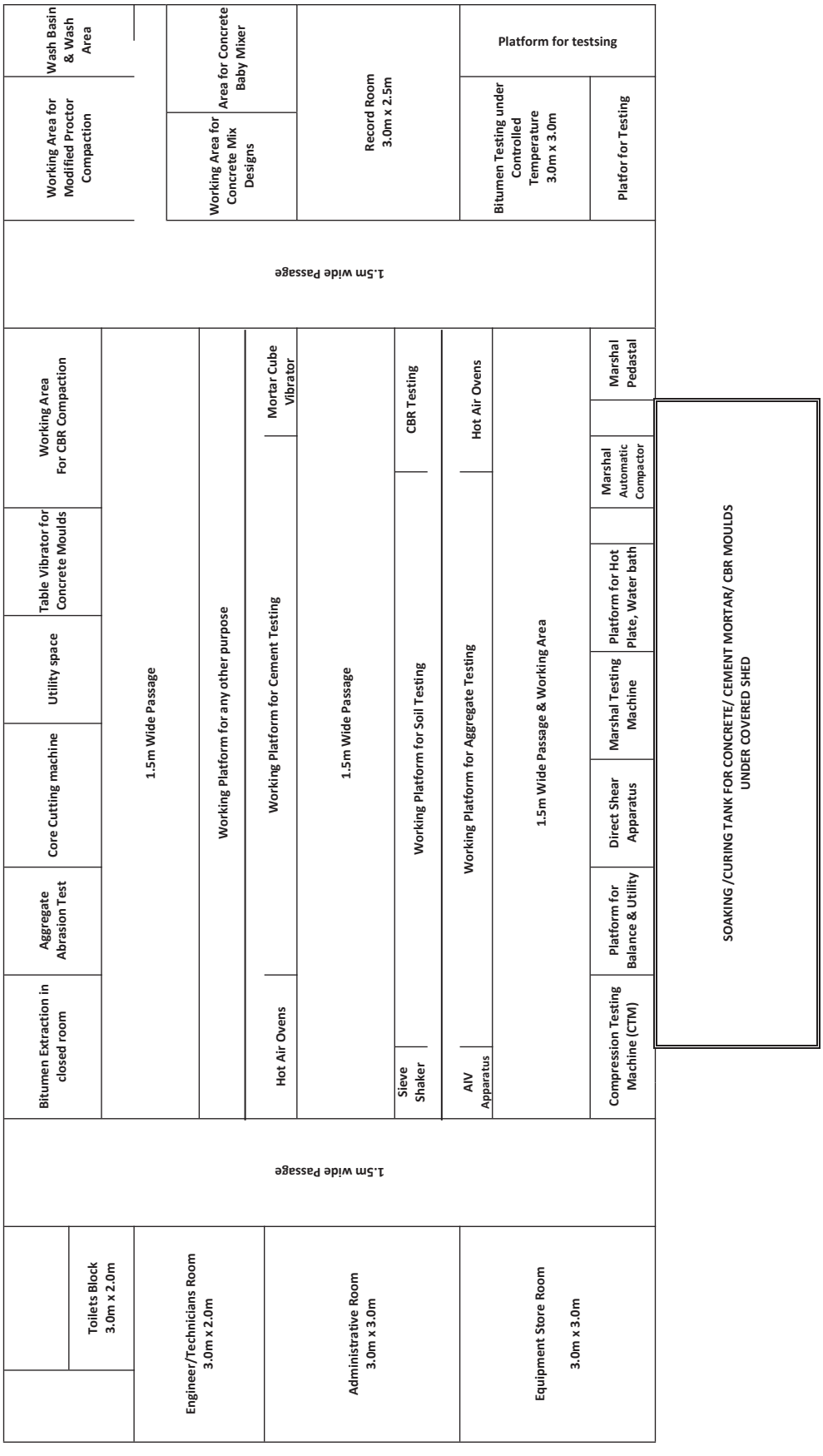
All the equipment provided in the central/main as well as the plant laboratories shall be checked periodically for their functioning and serving the intended purpose. To ensure this, maintenance for all the equipment shall be carried out at fixed intervals through authenticated service provider and also as and when the equipment warrants repair or maintenance. Calibration of measuring equipments shall be carried out as per specified frequency or whenever the equipment undergoes repair. Thus all the time, all the equipment set in the laboratory shall be in working condition within the tolerable limits. Any inspection, measurement and testing equipment that undergoes excessive wear and tear and requires calibration more frequently than the frequency recommended by the manufacturer shall be replaced. Similarly, all the dial gauges, pressure gauges and similar equipment, whose actual readings vary by more than **25%** of the indicated readings shall be replaced. Equipment which may be more than 15 years also may be considered for replacement unless it is certified by the accredited laboratoried to be fit for use.

Annexure 6.1 Layout Plan for Plant Laboratory (15.0m X 7.0m)
(CONCRETE BATCHING, WMM & HOT MIX PLANTS)



Note: For the laboratory at a Concrete Batching Plant, other equiment stand deleted and vice versa.

Annexure 6.1 Layout Plan for Central/ Main Laboratory (20.0m X 10.0m)



Annexure 6.2

LIST OF EQUIPMENTS FOR CENTRAL/MAIN LABORATORY

1. Soil Testing Equipment

a. Weigh Balances
   i. 5 -20 kg capacity Electronic type – Accuracy 1 gm
   ii. 500 gm capacity Electronic type – Accuracy 0.01 gm
   iii. Electronic 5 kg capacity Accuracy 0.5 gm
   iv. Chemical Balance 100 gm capacity accuracy 0.001 gm

b. Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

c. IS Sieves: 200 mm internal dia (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid.

d. Sieve shaker capable of shaking 200mm dia sieves- electrically operated with time switch.

e. Stop watches 1/5 sec. Accuracy

f. Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc)

g. Enamel trays
   i. 600 mm x 450 mm x 5 mm
   ii. 450 mm x 300 mm x 40 mm
   iii. 300 mm x 250 mm x 40 mm

h. Liquid Limit device with ASTM grooving tools as per IS:2720(Part 5).

i. Sampling pipettes fitted with pressure and suction inlets, 10 ml. capacity.

j. Compaction apparatus (Proctor) as per IS:2720 (Part 7) complete with collar, base plate and hammer and all other accessories.

k. Modified AASHTO compaction apparatus as per IS:2720 (Part 8) or heavy compaction

l. Sand pouring cylinder with conical funnel and tap and complete as per IS:2720 (Part 28) including modern equipment.

m. Natural sand passes through 1 mm and retained on 600 mm as per IS: 2720 Part 28.

n. Sampling tins with lids 100 mm dia x 75 mm ht. ½ kg capacity and miscellaneous items like moisture tins with lid 50 gm etc.

o. Lab CBR testing equipment for conducting CBR testing, load frame with 5 Tonne capacity, electrically operated with speed control as per IS:2720 (Part 16) and consisting of following
   i. CBR moulds 150 mm dia – 175 mm ht
   ii. Tripod stands for holding dial gauge

iii. CBR plunger with settlement dial gauge
iv. Surcharge weight 147 mm dia 2.5 kg wt. spacers disc 148 mm dia 47.7 mm ht. with handle
v. Perforated plate (Brass)
vi. Soaking tank for accommodating CBR moulds
vii. Proving rings capacity of 10kN, 20 kN, 25kN and 30kN.
viii. Dial gauges 25 mm travel – 0.01 mm/division

p. Dynamic cone penetration test equipment
q. Nuclear moisture density meter or equivalent
r. Speedy moisture meter complete with chemicals
s. Rifle Box
t. Differential Free Swell Index as per IS: 2720 (Part 40)
u. Hydrometer & Hydrometer jar

2. Aggregate Testing Equipment

a. Sieves: as per IS:460
   i. IS sieves of required sizes (450 mm internal dia) sets as per BIS complete with lid and pan
   ii. IS sieve 200 mm internal dia (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid
b. Sieve shaker capable of shaking 200mm, 300 mm and 450mm dia sieves-electrically operated with time switch
c. Enamel trays
   i. 600 mm x 450 mm x 50 mm
   ii. 450 mm x 300 mm x 40 mm
   iii. 300 mm x 250 mm x 40 mm
   iv. Circular plates of 250 mm dia
d. Flakiness and Elongation index test apparatus
e. Aggregate impact test apparatus as per IS:2386 (Part 4)
f. Los-Angeles abrasion test apparatus as per IS:2386 (Part 4)
g. Apparatus for determination of specific gravity of fine and coarse aggregate as per IS:2386(Part 3)
h. 3 liter,15 liter and 30 liter cylinder as per IS:2386 Part 3 for checking bulk density of aggregate with tamping rod.
i. Electronic balance of 500 gm,2.0 kg,5.kg and 10.0 kg sensitive to 0.1gm

3. Cement and Cement Concrete Testing Equipment

a. High frequency mortar cube vibrator for cement testing
   i. Cement motor moulds (70.6 mm W x 70.6 mm L x 70.6 mm H)

b. Vicat needle apparatus for setting time with plungers as per IS:269
c. Soundness testing apparatus for cement (Le Chattlier)
d. Weigh Balances
    i. 5 -20 kg capacity electronic type – accuracy 1 gm
    ii. 500 gm capacity electronic type – accuracy 0.01 gm
    iii. Electronic 5 kg capacity accuracy 0.5 gm
    iv. 50 kg capacity electronic type – accuracy 2 gm
e. Concrete mixer power driven, 1 cft capacity
f. Moulds
    i. 150 mm x 300 mm ht. cylinder with capping component along with the capping set.
    ii. Cube 150 mm and 100 mm (each size)
g. Appartus for slump test
h. Variable frequency and amplitude vibrating table size 1m x 1m as per the relevant British standard
i. Compression and Flexural strength testing machine of 2000 KN capacity with additional dial for flexural testing
j. Core cutting machine with 10cm dia. diamond cutting edge
k. Lechatelier flask

4. Bitumen Testing Equipment

a. Constant temperature bath for accommodating bitumen test specimen, electrically operated and thermostatically controlled (to accommodate minimum six specimens)
b. Penetrometer automatic type, including adjustable weight arrangement and needles as per IS:1203
c. Bitumen laboratory mixer including required accessories (20 ltrs.)
d. Ductility meter
e. Furol Viscometer
f. Softening Point Test Apparatus (Ring and Ball app)
g. Digital thermometer
h. Rifle box
i. Thin film oven test apparatus for modified binder either with PMB or CMRB
j. Mastic Asphalt hardness testing equipment
k. Sand equivalent test apparatus
l. Thermometers
m. Gas Stove and Cylinder
n. Soxhlet extraction or centrifuge type apparatus complete with extraction thimbles with solvent and filter paper

o. Glass ware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc and metallic thermometers range up to 300°c.)

p. Hot plates 200 mm dia (1500 watt)

q. Oven-electrically operated, thermostatically controlled(including thermometer), stainless steel interior from 0°C to 220°C

r. Cannon Manning Viscometer for determination of Absolute viscosity and Cannon Fenske Viscometer for determination of Kinematic viscosity.

s. Marshall stability test apparatus as per ASTM-D6927 with 25 KN and 50 KN proving ring and automatic compactor and mould for marshall and modified Marshall test.

t. Core cutting machine suitable for up to 150 mm dia core.

5. Sub-Soil Testing Equipment

a. Direct shear test apparatus having 12 variable speed and 2 KN proving ring with all the accessories given in IS:2720 Part 13.

b. Weigh Balances

   i. Electronic 5 kg capacity accuracy 0.5 gm

   ii. 500 gm capacity electronic type accuracy 0.01 gm

c. Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220 °C

d. Sieves: as per IS:460 IS sieve 200 mm internal dia (brass frame and steel/ or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid and pan.

e. Liquid limit device with ASTM grooving tools as per IS:2720(Part 5)

f. Sampling pipettes fitted with pressure and suction inlets, 10 ml. Capacity.

g. Sampling tins with lids (100 mm dia x 75 mm ht.) of 500gm capacity and miscellaneous items like moisture tins with lid 50 gm etc.

LIST OF EQUIPMENTS FOR PLANT LABORATORY

1. Wet Mix Plant

a. Sieves: as per IS:460

i. IS sieves of required sizes (450 mm internal dia) sets as per BIS complete with lid and pan

ii. IS sieve 200 mm internal dia. (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid and pan.

b. Sieve shaker capable of shaking 200 mm and 450 mm dia sieves-electrically operated with time switch.

c. Apparatus for testing Aggregate Impact Value (AIV), Soundness, Flakiness & Elongation Index, Stone Polishing Value.

2. Hot Mix Plant

a. Sieves: as per IS:1460

i. IS sieves 450 mm internal dia. of sieve sets as per BIS of required sieve sizes complete with lid and pan

ii. IS sieve 200 mm internal dia. (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid

b. Sieve shaker capable of shaking 200 mm and 450 mm dia. sieves- electrically operated with time switch

c. Aggregate Impact Value (AIV), Soundness, Crushing Value, Flakiness & Elongation Index, Polished Stone Value.

d. Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

e. Constant temperature bath for accommodating bitumen test specimen, electrically operated, and thermostatically controlled (to accommodate minimum six specimens).

f. Penetrometer automatic type, including adjustable weight arrangement and needles as per IS:1203.

g. Furol Viscometer

h. Softening point(Ring and Ball app)

i. Distant reading thermometer

j. Mastic Asphalt Hardness testing equipment

k. Sand Equivalent test apparatus

l. Thermometers

m. Gas Stove and Cylinder

n. Soxhlet extraction or centrifuge type apparatus complete with extraction thimbles with solvent and filter paper

o. Glassware compressing beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc and metallic thermometers range up to 300°C)

p. Hot plates 200 mm dia (1500 watt)

q. Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interior from 0°C to 220°C

3. Concrete Batching Plant

a. Moulds
   i. 150 mm x 300 mm ht. cylinder with capping component along with the capping set.
   ii. Cube 150 mm and 100 mm (each size)

b. Apparatus for slump test

c. High frequency mortar cube vibrator for cement testing
   i. Cement motor moulds (70.6 mm W x 70.6 mm L x 70.6 mm H)

d. Vicat needle apparatus for setting time with plungers as per IS:269-1967

e. Soundness testing apparatus for cement(Le Chattlier)

f. Weigh Balances
   i. 5 -20 kg capacity Electronic type – Accuracy 1 gm
   ii. 500 gm capacity Electronic type – Accuracy 0.01 gm
   iii. Electronic 5 kg capacity - Accuracy 0.5 gm
   iv. 50 kg capacity Electronic type – Accuracy 2 gm

g. Variable frequency and amplitude vibrating table size 1 m x 1 m as per the relevant British standard

h. Compression and Flexural strength testing machine of 2000 KN capacity with additional dial for flexural testing

i. Lechatelier flask

Annexure 6.3

SUGGESTED INVENTORY OF CONSUMABLES

1. Soil Testing

Distilled water, Filter Paper, Sodium hexameta phosphate and Sodium carbonate, Kerosene,

2. Aggregate Testing

Sodium Sulphate, Magnesium Sulphate,

3. Cement Testing

Cement, Admixtures, Distilled water,

4. Bitumen Testing

Bitumen, Benzene, gas cylinder, filter paper,

5. Concrete Testing

Nil

6. Sub-Soil Testing

Distilled water, Filter Paper, Sodium hexameta phosphate and Sodium carbonate, Kerosene

SECTION 7

CALIBRATION OF INSPECTION, MEASURING AND TESTING EQUIPMENT

7.1 Introduction

Most of the equipment listed in **Section 6** of this Manual contain/involve use of measuring devices namely proving rings, extension meters, dial gauges, temperature gauges, load cells, weighing pads /scales etc. which measure the values of various test parameters.

The accuracy of the equipment/measuring devices degrade over time. This is typically caused by normal wear and tear. However, changes in accuracy can also be caused by electric or mechanical shock or a hazardous working environment. Depending on the type of the instrument and the environment in which it is being used, it may degrade very quickly or over a long period of time. The bottom line is that, calibration restores the accuracy of a measuring device as prescribed by the manufacturer and thereby reliability of the material/ mix/finished product in terms of quality is ensured.

To ensure valid results, the measuring equipment shall be calibrated or verified prior to use and also at specific intervals normally as specified by the equipment manufacturer, against measurement stadards traceable to national or international measurement stadards, and where such standards do not exist, the basis for calibration or verification needs to be documented.

7.2 Objective

Calibration is a comparison between a known measurement (the standard) and the measurement using the instrument to be calibrated.

Primary objective of calibration is to check and ensure that the measurements made by the IMT equipment has the same accuracy as specified by the equipment manufacturer. In practice, calibration also includes repair of the device. A report is provided by the calibration expert, which shows the error in the measurements with the measuring device before and after the calibration.

Hidden costs and risks associated with the un-calibrated measuring device could be much higher than the cost of calibration. Therefore, it is absolutely essential that the IMT equipment/measuring devices are calibrated regularly, to ensure that errors associated with the measurements are in the acceptable range.

7.3 Scope

All the IMT equipment, which is used for inspection, measuring and testing during project preparation, construction and operation & maintenance fall within the purview of calibration. Besides production units such as Hot Mix Plant, Wet Mix Plant, Batching Plant, Crusher etc. also need to be calibrated. Further, the measuring devices of laying units such as asphalt paver, concrete paver need to be calibrated. Calibration of the machine parts does not fall

within the purview of this Manual. However, the Contractor needs to ensure that the Plant, Equipment and the Machinery deployed on the Project are well maintained and calibrated for the intended use. The scope of calibration in all the three stages of Project Development, Construction and O&M are detailed below:

7.3.1 *Project Preparation and Project Development*

The Design Consultants, who carry out the feasibility study or prepare detailed project reports for the client, carry out various investigations as a part of their assignment, including Topographic Surveys, Pavement Investigations, Traffic Sudies, Sub-Soil investigations, Hydrographic Surveys (where applicable), laboratory tests, field tests on materials etc., where different kinds of IMT equipment is used. GPS, Total Station, Auto Levels, Staff, Tape used in topographic surveys, FWD, BBD equipment, Bump Integrator, thermometers, dial gauges used in pavement investigations, Traffic Counters & Weighing pads used in traffic surveys, proving rings, load gauges, dial gauges / extensometers, weights, simple / physical/electronic balances, theromometers, thermostats, used in the laboratories etc. need to be calibrated prior to carrying out the measurements or tests periodically for its continuing accuracy by appropriate means.

The Design Consultants shall use standard and approved equipment for carrying out various studies and well established laboratories for carrying out the tests. All the IMT equipment being used in the assignment shall be calibrated as per the requirements of this section.

7.3.2 *Construction*

The Contractor, Engineer and Employer/Authority need to carry out various tests in the field and the laboratory during construction. Apart from the IMT equipment required to carry out quality control tests, there are some important Plants, which require calibration to produce the desired mixes including cement concrete mixes, asphalt mixes and wet mix macadam. The most commonly used IMT equipment require calibration of proving rings, load gauges, dial gauges / extensometers, weights, simple / physical / electronic balances, the romometers, thermostats etc., which are used in testing of soil, cement, aggregate, bitumen, asphalt / concrete mixes, pavement and sub-soil investigations.

7.3.3 *Operation & Maintenance*

During the Operation & Maintenance, the agencies are required to carry out maintenance and repair works as a part of routine and periodic maintenance. In order to verify compliance to the requirements of maintenance schedules and annexes, the Contractor/Engineer have a mandate to conduct BBD and roughness measurements periodically. Various materials/ mixes/works are required during Operation & Maintenance. All the IMT equipment specified in the preceding para are used during this stage, and would require calibration.

7.3.4 IMT equipment may be used in various stages of the Project but, the calibration requirements, calibration procedure, frequency and the acceptability criteria continue to be same.

7.4 Type of Calibration

All the IMT equipment/measuring devices require frequent / routine inspection and verification for dimensions, weight, clearances etc., which are specified in the codes of practice for each individual test. When some of the parameters are found to be deviating from the codal requirements, the following options emerge:

a. Adjust – when the load cells / balances do not show the appropriate reading, the load cells / balances may be adjusted by the equipment manufacturer to show the correct reading with reference to the required standard.

b. Calibrate – when the load gauges in the compression testing machine do not show the correct reading, the load gauge shall be verified against a master proving ring. Indicated load gauge readings will be compared with those of the master proving ring and a graph or chart is drawn between the indicated gauge readings and the actual readings.

c. Replace – for example, when the appurture of the sieves does not conform to the requirements, the sieve should be rejected and replaced by a new sieve conforming to the national standards. When the size of a mould does not conform to the required size, when the graduations on a measuring jar, or scale fade away, they should be replaced. Further, when a device can neither be adjusted nor calibrated, it should be replaced.

7.4.1 Calibrations and checks to be carried out on IMT equipment/measuring devices can be classified into four categories:

a. Visual check – where the item is inspected to provide assurance that the equipment meets the requirement of appropriate standard, but no measurements are required. This can be done as frequently as possible but not later than 6 months.

b. Physical check – which may be performed by the competent staff in-house, using appropriately calibrated equipment to a documented procedure

c. Inhouse calibration – which may be performed to a documented method by competent staff inhouse, using appropriate reference standard / equipment. The reference standard / equipment will need to be calibrated by a laboratory that can demonstrate competence, measurement capability and traceability e.g. NABL accredited calibrating facility.

d. External calibration – which is carried out by the laboratory accredited by NABL for the measurement concerned and for which NABL has issued certificate.

7.4.2 Some of the calibrations can be done at site by an external agency, which is qualified and acceredited to perform a specific calibration. Static Weigh bridge shall be calibrated by the legal metrology department at site itself. Compressing Testing Machine can be calibrated against a master proving ring at site itself by competent external agencies. Similarly, the load cells in the Concrete Batching Plant or Asphalt Batching Unit can be calibrated at site only. But, the proving rings used for measuring CBR, Marshal Stability, dial gauges, thermometers, electronic balances etc. will have to be sent to the accredited laboratories for calibration.

The IMT equipment which can be calibrated with inhouse facilities shall be identified and suitable methodologies shall be drawn for the approval of the Competent Authority.

7.5 Requirements for Calibration

In order to carry out the calibration, it is necessary to have the required Master Calibrating Devices, ambient conditions and trained man power. Master Calibrating Device is the instrument having capacity higher than the instrument/ equipment to be calibrated and whose measurements are already verified and certified by authenticated master calibration, whose details are traceable.

Typically, the accuracy of the standard should be ten times the accurate of the measuring device being tested. However, accuracy ratio of 3:1 is acceptable by most standards organizations.

7.6 Frequency of Calibration

As a general rule, the IMT equipment/measuring devices shall be calibrated at the frequency specified by the manufacturers of the specific equipment. In some of the cases, frequency depends on the use and wear and tear of the equipment. For example, the Bump Integrator may have to be calibrated after running a specific distance (km). Calibration shall also be done invariably after repair or mechanical maintenance of the equipment.

For each of the measuring and testing equipment the manufacturer specifies the time interval for its calibration. In addition to manufacturers' recommendations, depending upon the usage wear and tear that takes place to the instrument/equipment and the limitations on master calibrating unit, certain interval shall be fixed for individual equipment/instruments. Details of calibration requirements and intervals are listed in **Annexure 7.1**. Wherever time interval for calibration specified by the manufacturer is smaller than the time interval indicated in the **Annexure 7.1**, the manufacturer's recommendation shall be followed.

7.7 Calibration Records

Calibration records shall be maintained and associated with a unique identifier of each piece of equipment. These records shall include:

- Identity of item of equipment
- Name of the manufacturer
- Serial number
- Date of calibration
- Current location
- Manufacturer's instructions
- Reference standard, and reference used for calibration
- Copies of all reports, results of calibration and certificate of calibration
- Maintenance plan and due date of next calibration
- Identity of the individual performing the calibration

Status of calibration and the calibration certificate shall be displayed near the respective IMT equipment.

7.8 Recall Procedures

Soon after recalibration of the IMT equipment, it shall be verified whether there is any major difference in the old and new calibrations, and if they would affect the readings taken in the past. Any borderline results deduced from the readings of the equipment under reference in the past 3-6 months may be verified against the new calibration. If there is any point of concern, then the corresponding elements or components may be identified for carrying out suitable confirmatory tests in field. On review of the field tests and on verification of their compliance with the specifications and standards, if necessary, suitable action will be iniated as per the requirements of **Section 11** of this Manual. To this extent, it is recommended that the agency shall maintain a separate record of all the borderline cases in a separate location so that positive recall procedures can be easily applied, when found necessary.

Annexure-7.1

CALIBRATION REQUIREMENTS & FREQUENCY

S. No.	Category	IMT Equipment	Calibration or check	Level	Interval	Type of Certificate
1	Load Measuring Devices	Compression Testing machine, CBR, Marshall Stability Machines Proving Rings	Check rate of loading, calibrate in accordance with ISO 7500: Part 1	External	Should not exceed 1 year	NABL – at site External
2	Length Measuring Devices	Micrometers Calipers Steel rules Dial gauges	Calibrate in accordance with BS EN 10002: Part 4, over the entire extension range or working range. Check for readability and wear	External Inhouse	Should not exceed 1 year every 3 months	NABL Inhouse
3	Temperature Measuring Instruments	Thermometers Ovens Water baths	Calibrate for precision in the range of measurement required with calibrated reference thermometer Check at ice point	External Internal	Annual Before use	NABL Inhouse
4	Time Measuring Devices	Stop Watches	Check against BT speaking clock	Check	Annual	Inhouse
5	Weighing machines	Physical, electronic and common balances, Weights	To be calibrated in accordance with the procedures of weights under measures	External	Annual / Biannual based on the use	NABL
6	Plants	Hot Mix Plant Wet Mix Plant Batching Plant	Calibration of individual gate openings and the batching unit	Inhouse	Every 3 months	Inhouse

SECTION 8

INSPECTION AND TESTING

8.1 Introduction

Inspection and Testing is an integral part of the construction activities. All the materials being incorporated in the product, all the processes being followed and all the finished products will be subjected to inspection and testing to ensure conformity of the product with the standards and specifications. The Contractor shall submit the Quality Assurance Plan at commencement and carry out quality control during the currency of contract through inspection and testing at various hold points specified therein.

8.2 Objective

The primary objective of inspection and testing at various stages is to ensure that the all the materials being incorporated in the product and the end product fulfill the quality requirements of the MORTH Specifications for Road and Bridge Works. Contractor is responsible for the Quality Assurance and Quality Control i.e planning and conducting the inspection and testing activities. Other entities will perform their roles as envisaged in the contract agreement.

8.3 Scope

The current section specifies the inspection and testing requirements during project preparation, construction and operation & maintenance. It covers the stages of inspection, codes, test procedures to be followed, documentation and records to be maintained.

8.4 Project Preparation

During the project preparation, the Design Consultants need to carry out various surveys and investigations including pavement investigations, sub-soil investigations, material investigations etc. as per the Manual for Surveys, Investigation and Preparation of Road Projects IRC:SP:19. Inspection and Testing requirements will be as per the Terms of Reference (TOR) of the consultancy contract. When the TOR is silent about the frequency of testing, the same shall be as per good industry practice. Various tests to be conducted and the performance and acceptance criteria are given in **Table 8.1**.

Table 8.1

S. No.	Test	Applicable Code of Practice	Acceptance Criteria
A	**Pavement investigations**		
1	Visual Condition Survey	IRC:81	IRC:81
2	Bump Integrator	IRC:SP:16; IS:3073	IRC:SP:16; IS:3073
3	BBD	IRC:81	IRC:81
4	FWD	IRC:115	IRC:115

S. No.	Test	Applicable Code of Practice	Acceptance Criteria
5	Subgrade Strength	IS:2720, Part-16	IRC:37 & CA
6	Pavement Composition	ASTM C 174/ 174M & MS 23 Manual	
B	**Sub-Soil Investigations**		
1	Collection of UDS	IS:1892 & 2132	MORTH Specifications for Road & Bridge Works
2	Standard Penetration Test	IS:2131	
3	Triaxial Test	IS:2720, Part-11 & Part -13	
4	UCS	IS:2720, Part-10	
5	Consistency limits	IS:2720, Part-5	
6	Classification of Soils	IS:1498	
7	Silt factor	IS:2720, Part-4 & IRC:78	
8	Direct Shear Test	IS:2720-13	
C	**Borrow Areas (Soil)**		
1	Sieve Analysis	IS:2720, Part-4	MORTH Specifications for Road & Bridge Works
2	Atterberg's Limits	IS:2720, Part-5	
3	Compaction Test	IS:2720, Part-7 & 8	
4	CBR	IS:2720, Part-16	
5	Free Swell index	IS:2720, Part-40	
D	**Quarries (Aggregate)**		
1	Sieve Analysis	IS:2386, Part-2	MORTH Specifications for Road & Bridge Works Section 1000
2	Impact Value	IS:2386, Part-4 or IS:5640, Part-4	
3	Abrasion Value	IS:2386, Part-4	
4	Soundness	IS:2386, Part-5	
5	Stripping Value	IS:6241	MORTH Specifications for Road & Bridge Works Section 500
6	Water absorption	IS:2386, Part-3	MORTH Specifications for Road & Bridge Works Sections: 400, 500, 600 & 1000
7	Polished Stone Value	BS 812 Part-114	MORTH Specifications for Road & Bridge Works Section 500
8	Sand Equivalent value	IS:2720, Part-37	MORTH Specifications for Road & Bridge Works Section 500

S. No.	Test	Applicable Code of Practice	Acceptance Criteria
9	Ten percent Fines value & Crushing value	IS:2386, Part-4	MORTH Specifications for Road & Bridge Works Section 400
E	**Cement**		
1	Consistency	IS:4031, Part-4	MORTH Specifications for Road & Bridge Works Section 1000
2	Setting Time	IS:4031, Part-5	
3	Compressive Strength	IS:4031, Part-6	
4	Fineness	IS:4031, Part-1	
5	Soundness	IS:4031, Part-3	
F	**Bitumen**		
1	Penetration	IS:1203	IS:73
2	Softening Point	IS:1205	
3	Ductility	IS:1208	
4	Viscosity	IS:1206 (Part II & III)	
5	Specific Gravity	IS:1202	
G	**Concrete Mix Design**		
1	Sampling	IS:10262	MORTH Specifications for Road & Bridge Works Section 1700
2	Mix Design	IS:10262 IRC:SP:23 & IRC:112	
3	Workability	IS:1199	
4	Compressive Strength	IS:516	
5	Flexible Strength	IS:516	
G	**Asphalt Mix Design**		
1	Mix Design	MS-2	MORTH Specifications for Road & Bridge Works Section 500
2	Stability testing		
3	Void Analysis		
I	**RE Wall**		
1	Fill	IS:2720,Part-13, Part-4 & Part-5	MORTH Specifications for Road & Bridge Works Section 3100

Note: *Latest versions of the codes indicated above shall be used.*

8.5 Construction

All the tests prescribed in MORTH Specifications for Road & Bridge Works shall be conducted at various stages and frequencies stipulated therein, during the construction stage. Besides

additional tests shall be conducted for factory manufactured materials, products and specialized items as per **Section 5** of this Manual. Requirement and procedure of testing during different stages of construction are given below:

8.5.1 *Approval of Sources*

The Contractor will identify the sources of raw materials viz., soil, morrum, sand, fly ash, quarry stone etc. and thoroughly inspect the sources for adequacy of quantity, quality and consistency including the history of usage of the material from the quarry, details of the projects where the material was used and the problems observed if any. Subsequently, Contractor shall collect the samples and subject them to the prescribed tests to verify their conformity with the requirements. The proposed sources of manufactured materials viz., Cement, Steel, Bitumen, Emulsions, Admixtures etc. also shall be subjected to tests as detailed in **Section 5** of this Manual at the site laboratories or third party labortories as applicable. The Contractor shall submit the test results along with the location and layout of the borrow pit or quarry and the locations of the samples and the depth of collection. For manufactured materials the test results shall be submitted along with the further details as specified in **Section 5** of this Manual. The Engineer will determine the necessity of further tests at the site laboratory or elsewhere and communciate the approval for the sources. Unless the approval is received, the Contractor shall not procure the material. Engineer shall communciate his approval expeditiously to avoid delay in procurment of the material. The Contractor shall plan the activities carefully so that approval of the sources is done well ahead of the actual construction.

8.5.2 *Testing of Sources of Materials*

The Contractor shall subject all the raw materials and the manufactured materials to testing as per the procedures and frequencies stipulated in **Section 900** for road works and other applicable sections for bridges and structures of MORTH Specifications for Road & Bridge Works.

For soil and moorum materials, adequate number of samples shall be collected from the borrow areas so that the entire borrow pit is representated in both area and depth. If the Contractor intends to collect samples from a deeper level, samples shall suitably cover the entire depth. After mapping the densities, consistency and strength properties of the material, the borrow area will be segragated based on their properties and an average density value is determined for different parts for the purpose of verifying the degree of compaction achieved in the field. If there is any considerable variation in the densities or visible change in the quality of material, the material in the borrow pits will be retested and the reference density is revalidated.

Samples of aggregates shall be collected from stock piles in the stacking area or the crushers. Sample size depends on the quantity of stock pile and the guidelines given in IS:383 and IS:2386 for condcting various tests. All manufactured materials Viz., cement, steel and bitumen procured from pre-approved sources shall be tested prior to use. Manufacturer's Test Certificates and other details specified in **Section 5** of this Manual pertaining to the lot received shall be submitted by the Contractor for reference. In addition, the Engineer shall determine the tests to be conducted at the site laboratory and the 3rd party laboratory as

relevant, as per the Qulaity Assuarnce Plan approved for the project. Only after obtaining the approval of the Engineer, the materials shall be incorporated in the works, as concrete elements and bituminous courses are irreversible in nature and if any test fails, it is difficult to rectify.

8.5.3 *In-Process Inspection & Testing*

It is advisable that test sections are prepared using any material or mix being incorporated in the pavement, sub-grade and filling and all the parameters are verified. This will not only be useful in optimising the compaction effort i.e the number passes, rolling pattern, overlaps, speed etc. but also to train the team in verification of process parameters viz., temperature, moisture, line, level etc. The compaction factor can be determined for a specific borrow area or the mix so that loose material can be accordingly laid in a manner that the desired levels are achieved at the required degree of compaction.

Test sections also ensure that the performance of the plant and equipment used for producing the mix and laying the mix is verified and confirmed with the requirments of the specifications. Material shall be collected from the cold bins/hot bins of the WMP/HMP/Concrete Batching Plant etc. to verify the calibration of the motors/load cells and tested for conformance to the mix proportions envisaged in the design. The mix finally delivered in the hopper shall be collected and verified for the proportions and respective properties of the ingradients and mixes.

The performance of the paver or grader etc., in producing the desired workmanship and finished properties shall be verified in the field and suitable corrections shall be made to the equipment / processes. The plant or equipment, which is unable to produce the desirable quality at site shall be removed and replaced with the approved equipment as per Contract.

All the ingredients of the concrete, GSB, WMM and Asphalt courses shall be tested on a day to day basis at various stages including in stock piles, bins, dry mix, final mix loaded in the truck and at field as applicable and relevant. This will clearly isolate the deficiency and provide insignts in to the reasons for variation in quality.

Samples shall be collected from the pavement layers prior to compaction and routine tests shall be conducted to verify the reference density and other properties if necessary. These control tests will explain the variation in the degree of compaction if compaction is done under controlled conditions, duly verifying all the process parameters. The results of the control tests shall be documented and monitored.

Generally, the reference values shall be those obtained during the mix design process. But, if necessary and found advisable, the reference densities may be obtained on a day to day basis from the material actually laid at site.

Process parameters viz., moisture, temperature, line and level shall be checked prior to compacting the layers so that the end product fulfills the requirements of the specifications. Record of such inspection and verification shall be maintained in relevant check lists and formats.

For concrete works various pre-concrete and post-concrete checks shall be made as per the provisions of applicable codes and good industry practice. It shall be ensured that the staging

conforms to pre-approved designs and all the joints are tight and safe. Further, the shuttering shall be as per the lines and levels given in the drawings and the joints are sealed to prevent leakage. It shall also be ensured that chairs and cover blocks are placed to achieve the spacing of reinforcement and the concrete cover respectively. All the arrangements shall be verified against the checklists provided in the QAP.

Reinforced Earth Walls require thorough inspection during the erection of panels itself as correction of the deficiency after construction is extremely difficult. Horizontal and vertical alignment shall be checked at each stage by appropriate means i.e total station and plumb bob. The c, φ and density of the reinforced soil fill should be checked regularly. Further, the grids or the strips should be protected from exposure to fire, sun etc. as per the manufacturer's specifications and kept adequately covered. Adequate earth cushion should be ensured to prevent damage of the grids while compacting. Low capacity compactors should be used while compacting near the panels. Casting, storing and erection of friction crash barriers should be done with adequate care to ensure a good finish. It is emphasized that adequate care should be taken at each step during the construction itself.

8.5.4 *Final Inspection & Testing*

It is important that the final product conforms to the requirements of the specification and standards and the same is verified prior to taking up the next component.

In case of road works, each layer shall be inspected and put to tests as required by **Section 900** of MORTH Specifications for Road and Bridge Works. Initially, the layer shall be visually inspected for its workmanship, uniformity in texture, undulations, roller marks, segregation, pumping etc. All the cross sectional elements including the width of the carriageway, paved shoulder, earthen shoulder, toe width, camber, side slope, surface regularity shall be measured and verified. Any defects shall be corrected prior to taking up final testing. Levels, thickness and degree of compaction of the layer shall be checked at prescribed spacing and intervals and checked whether they are within the specified tolerances. Any nonconformance shall be identified and corrected before proceeding to the next stage. NCRs shall be issued in case of any irreversible processes and the required corrective and preventive actions shall be initiated and disposed as per the provisions of **Section 11** of this Manual.

All concrete works shall be inspected after the removal of the false work, staging, shuttering and inspected for undulations, segregation, bleeding etc. and suitable rectification shall be carried out, if necessary. All elements shall be verified for lines, levels, dimensions and surface regularity for conformity to the tolerances. It shall also be verified if the concrete fulfills the other acceptance criteria of compressive and / or flexural strength which is generally verified by casting cubes, beams, cylinders etc. as required during the casting of concrete. In case of any shortfall in strength properties, NCR shall be issued and cores shall be collected from the respective components to verify the corresponding properties and the required corrective and preventive actions as necessary, shall be initiated and disposed as per the provisions of **Section 11** of this Manual.

8.6 Operation & Maintenance

During the O&M stage, the Contractor shall carry out rountine inspection of the highway at the time and intervals specified in the contract agreement and identify the defects and deficiencies

to be rectified. Generally, the contract specifies a definite time period of rectification for each type of distress. Accordingly, the Contractor shall prepare a maintenance programme and carry out the rectification accordingly.

Engineer shall inspect the works at all the 3 stages i.e. before, during and after rectification and verify compliance to the requirements of the Specifications. The requirements of sub-section 8.5 of this Manual shall apply mutatis mutandis to the various inspection and test requirements during O&M.

Any other tests or surveys required during O&M viz., visual condition surveys, BBD / FWD and roughness tests shall be carried out in accordance with relevant codes and conformance to the requirements of the agreement shall be verified and ensured. Any non-conformance shall be processed as per **Section 11** of this Manual.

8.7 Third Party testing

Some of the tests may have to be conducted in the third party laboratories in case of special tests and also if the Contractor does not have the test equipment and expertise to carry out the tests, which include special tests on Cement, Bitumen, Steel, Bearings, Agregate, Geogrid, other forms of soil reinforcement, RE fill, stone polishing value of aggregate etc. In some cases the Employer/Authority or the Engineer may like to order confirmatory tests in external laboratories, even though the Contractor has the test facility at site. Such cases may also include extensive and poorly explained failure of structural and pavement elements.

Sampling shall be carried out jointly by the parties including the Authority, Contractor and the Engineer and the samples shall be carefully numbered for unique identification and packed for despatch. If the laboratory allows, the tests shall also be conducted in the presence of the parties who sampled the materials. The external laboratories shall fulfill the requirements of **Section 5** and **6** of this Manual.

8.8 Sampling

Sampling of the materials should be done with utmost care as the right product may fail on account of preparing and / or testing a wrong sample and vice versa. Moreover, the consituent materials of road are of heterogeneous quality and further subjected to heterogeneous processes. Hence, sampling done at adjacent locations may still yield different results. Hence, statistical procedures shall be applied for sampling and testing as per **Section 10** of this Manual.

8.8.1 *Sampling of Quarries*

While sampling the stone quarries, the entire quarry shall be visually inspected for its homogenity of surface, quality and the quality and extent of over burden. Representative sample shall be carefully selected for conducting various tests. If the quarry is being used in any of the crushers, crushed aggregared shall also be collected from the crushers for approval of the source.

8.8.2 *Sampling of Borrow Pits*

The extent of the borrow pit shall be identified and marked for delineating the area in to various sections of atleast 25 m X 25 m. Samples shall be collected from each such section

with an excavator if possible. Sample should represent the entire depth up to which the Contractor proposes to extract. Approval shall indicate the plot number and the depth of such plot.

8.8.3 *Sampling of Stock Piles*

Material is generally segregated in the stock piles. The extent of segregation depends on the size of the stock pile. Well Stocked piles up to a height 2 m do not pose much problems. But, huge stock piles of 10 to 20 m also are sampled at times. A back hoe can be used for collection of samples from such piles. Samples should be collected from all the sides and from deep inside the stock pile. Surface samples are generaly segregated. Alternatively, front end loaders can be used to take out samples from deep inside and the required quantity can be collected from each such scoop. The material so collected shall be subjected to quartering and coning to arrive at the required sample for testing. The number and quantity of sample shall be as per IS:383.

8.8.4 *Sampling of Trucks and Pavers*

Segregation is possible at each location in the process. Material shall be dumped incrementally in the trucks or pavers to avoid segregation. Representative samples can be collected with ease if such loading process is followed. It is always ideal to collect the sample at site from behind the paver than the hopper.

8.8.5 *Sampling on layers*

Sample of adequate size shall be cut from the layer without affecting the size of the aggregates. In sampling an asphalt layer, it is always better to cut a rectangular section than the core, if we want to carry out tests for gradation and bitumen content. Core, cuts the aggregates and the gradation or bitumen content found from such samples is not correct.

8.8.6 *Statistical Sampling*

Sample locations on the road layers can be chosen by way of random numbers to be generated by some electronic gadgets. The numbers can be applied on the length and width sequentially, to choose the locations. This prevents the bias of the testing personnel in selecting the location. However, all the defects shall be rectified prior to taking up the testing so that sampling is representative and reflects the quality of the layer.

8.9 General Guidelines for Inspection & Testing

In-process inspection and final inspection are very important aspects in Quality Assurance and Control. Inspection should be done against a standard checklist at all important hold points, requiring final or stage approvals. The check list shall include all the steps and parameters indicated in the method statements and the MORTH Specifications for Road & Bridge Works. The work carried out using a set of equipment, materials and conditions in a day can be grouped for the purpose of determing the frequency / no. of tests, irrespective of the spread of the locations. If the frequency specified in the codes result in excessive puncturing of the layer or component, the frequency may be suitably reduced subject to prior approval of the Engineer. Reduction in number of destructive tests may be compensated by conducting more non-destructive tests like nuclear density tests etc.

Annexure 8.1

SAMPLE FORMATS

Sl. No	Description	Format ID
1	Test Frequency Schedule	A-1
2	Formwork Inspection Checklist	B-1
3	Reinforcement Inspection Checklist	B-2
4	Inspection Checklist before approval to concrete	B-3
5	Proforma for Concrete Delivery and Pour Record	B-4
6	Post Concreting Inspection	B-5
7	Grain Size Analysis	C-1
8	Determination of Particle Size by Hydrometer Method	C-2
9	Liquid Limit & Plastic Limit	C-3
10	Free Swell Index	C-4
11	Soil Specific Gravity Test	C-5
12	Compaction Test	C-6
13	CBR Test Results & CBR Test	C-7 & C-8
14	Direct Shear Test	C-9
15	Triaxial Shear Test	C-10
16	Consolidation Test	C-11
17	Soil Permeability Test - Constant Head Method & Variable Head Method	C-12 & C-13
18	Swell Pressure Test by Constant Volume Method	C-14
19	Unconfined Compressive Strength	C-15
20	Aggregate Impact Value - AIV	C-16
21	Flakiness Index & Elongation Index	C-17
22	Individual Gradation of Coarse Aggregate	C-18
23	Sieve Analysis of Fine Aggregate	C-19
24	Deleterious Material and Organic Impurities	C-20
25	Point Load Test	C-21
26	Soundness Test by using Sodium Sulphate	C-22
27	Specific Gravity & Water absorption of Fine Aggregate	C-23
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Sl. No	Description	Format ID
29	10% Fines Value Test	C-25
30	Uniaxial Compression Strength test	C-26
31	Fineness of Cement	C-27
32	Normal Consistency of Cement	C-28
33	Initial & Final Setting Time of Cement	C-29
34	Soundness of Cement by Le-Chatelier Method	C-30
35	Specific Gravity of Cement	C-31
36	Compressive Strength of Mortar Cubes	C-32
37	Compressive Strength of Concrete Cubes	C-33
38	Penetration Value of Bitumen	C-34
39	Bitumen Specific Gravity	C-35
40	Determination of Softening Point	C-36
41	Determination of Viscosity	C-37
42	Gradation Aggregate Sector Binder Content Paving Mixtures Centrifuge Method BC/DBM/BM	C-38
43	Flash & Fire Point	C-39
44	Marshall Test Result	C-40
45	Core Test	C-41
46	Field Density Test Core Cutter Method	C-42
47	Benkelman Beam Deflection (BBD) Survey	C-43
48	Pavement Roughness Survey using Bump Integrator	C-44
49	Dynamic Cone Penetrometer Test (Pavement DCP)	C-45
50	Determination of Dry Density of Soil in place (Sand Replacement Method)	C-46
51	Falling Weight Deflectometer	C-47
52	Calibration Chart for Batching Plant for Aggregate Gauge	D-1
53	Calibration Chart for Batching Plant for Water Meter	D-2
54	Calibration Chart for Batching Plant for Cement Gauge	D-3
55	Calibration Report (Cube Testing Machine)	D-4
56	Material Quality Surveillance Form	E-1
57	Product Quality Surveillance Form	E-2

Sl. No	Description	Format ID
58	Surveillance form Pre-Concreting Operation	E-3
59	Quality Surveillance form for Workmanship of Concrete	E-4
60	Surveillance Form for Pavement Layers	E-5
61	Particulars of Work	F-1
62	Register of Drawings	F-2
63	Cement Register	F-3
64	Consumption of Cement on Different Items of Works (Theoretical and Actual)	F-4
65	Records of Calibration of Equipment	F-5
66	Daily Progress Report	F-6
67	Register of Inspection Notes	F-7
68	Register of Observations, Memos issued from Quality Control Cell	F-8
69	Bitumen Register	F-9
70	Record of Pre-Stressing Work	F-10
71	Grouting Record	F-11
72	Proforma for Result Analysis (Cement)	F-12
73	Proforma for Result Analysis (Concrete)	F-13

TEST FREQUENCY SCHEDULE

Consignment Identification No.	Specified Test	Performance standard	Performing Agency	Quality Assurance Agency	Frequency of Performance	Frequency of Assurance	Frequency of Audit
	a) Chemical Properties b) Physical Properties c) Special Requirements (As specified)						

1) Admixture shall be stored as per direction of manufacture in a 10 ton cylinder horizontal container specially designed to take pressure and to minimize wastage.

2) Admixture shall be agitated once in a day and solids if any shall not be allowed to settle.

3) Monthly statement of consumption of admixture shall be maintained.

4) Total chloride, sulphate content and pH value of admixture when 4 kg of admixture is added to 160kgs of water shall not exceed permissible limits of chloride, sulphate content and pH value of mixing water calculated separate.

Signed

Date

Prepared by
(For Contractor)

Signed

Date

Approved by
(For QA Engineer)

Category B: Inspection Proforma B-1

FORMWORK INSPECTION CHECK LIST

LOCATION: DATED:

CONTRACTOR'S INSPECTION REQUEST NO.

CONTRACTORS DRG OR SKETCH NO.

S. NO.	DESCRIPTION	YES	NO	N.A.
1	Formwork design/drawing/sketch approved including de-shuttering arrangements			
2	Trial panel approved(if required)			
3	Formwork alignment correct			
4	Formwork levels correct, including screeds			
5	Formwork dimensions correct			
6	Formwork member spacing correct			
7	Formwork member material quality acceptable			
8	False work member sizes correct			
9	False work member spacing correct			
10	False work member material quality acceptable			
11	Gaps between primary and secondary members closed/ wedged			
12	Face boarding/plywood/metal thickness correct			
13	Joints between panels closed (no gaps)			
14	Joints between panels flush(no steps/lips)			
15	Panel flatness acceptable			
16	Gaps between secondary members and face panels closed			
17	Tie rod material and sizes correct			
18	Tie rod spacing correct			
19	Tie rods tight, face cones flush			
20	Spacers between shutter surface tightly fitting			
21	Box outs, cast-in items, ducts fixed correct, securely			
22	Pre-stressing, sheathing and vents, alignments and spacing of supports acceptable			
23	Empty sheathing secured against floatation			
24	Pre-stressing anchorage positions and fixing acceptable			

S. NO.	DESCRIPTION	YES	NO	N.A.
25	Chamfers/fillets sizes, straightness, fixing acceptable			
26	Form work clean			
27	Form work release oil material approved			
28	Form work release oil applied correctly			
29	Construction joint preparation satisfactory			
30	Contraction/expansion joint preparation satisfactory			
31	Safe access constructed			
32	Adequate workspace provided for labour, equipment			
33	Shutter vibrators (if required) location and fixing arrangements approved			

Inspected by: Name: Signed: Date:
(For Contractor)

Approved by: Name: Signed: Date:
(For Engineer)

Category B: Inspection Proforma B-2

REINFORCEMENT INSPECTION CHECKLIST

LOCATION: DATED:

CONTRACTORS INSPECTION REQUEST NO.:

REF DRG NO.:

S. No.	DESCRIPTION	YES	NO	N.A.
1	Working drawing checked & approved			
2	Latest revision being used			
3	Bar schedules approved			
4	Reinforcing steel material approved			
5	Bar bending & cutting satisfactory			
6	Corrosion treatment of bars if required, satisfactory			
7	Bar sizes correct			
8	Bar spacing correct			
9	Bar lap lengths correct			
10	Bar laps at correct locations			
11	Bar tied as specified			
12	Bar assembly rigid and adequately supported (including spacers/chair supports)			
13	Cover to bottom bars correct			
14	Cover to side bars correct			
15	Cover to top bars correct			
16	Cover blocks approved including fixing			

Inspected by: Name: Signed: Date:
(For Contractor)

Approved by: Name: Signed: Date:
(For Engineer)

Category B: Inspection Proforma B-3

INSPECTION CHECKLIST BEFORE APPROVAL TO CONCRETE

LOCATION: DATED:

CONTRACTOR'S INSPECTION REQUEST NO.:

S. NO.	DESCRIPTION	YES	NO	N.A.
1	Method statement approved			
2	Batching plant mixtures in working order (separate dispenser for admixture, if required, available)			
3	Stand-by batcher in working order			
4	Water, sand, coarse aggregate, admixture, cement stock approved			
5	Water, sand, coarse aggregate, admixture, cement stock sufficient			
6	Concrete conveying arrangement (including transit mixtures) available in working condition and of sufficient capacity			
7	Formwork approved			
8	Reinforcement approved			
9	Pre-stressing sheathing approved			
10	Concreting equipment in working order			
11	Stand-by crane, vibrators present			
12	Tromie in working order (for under water work)			
13	Concrete gang present, including carpenter, steel fixer, mechanics and electricians			
14	Access provided			
15	Safety arrangements adequate			
16	Lighting provided			
17	Communications between various points provided			
18	Arrangements for arranging suspension/stoppage of concrete provided			
19	Curing arrangements made			
20	Laboratory notified			

Inspected by: Name: Signed: Date:
(For Contractor)

Approved by: Name: Signed: Date:
(For Engineer)

Category B: Inspection Proforma B-4

PROFORMA FOR CONCRETE DELIVERY AND POUR RECORD

1. CONCRETE BATCHING DELIVERY TICKET NO:

Location of pour	:	Date	:
Concrete grade	:	Mix Temp	:
W/C ratio	:	Slump	:
Cement contents	:	No. of cubes taken	:
Max. Aggregate size	:		
Admixture (Type and dosage)	:		
Batching started, Hrs	:	Batching finished, Hrs	:
Quantity batched, Cum	:	Truck no	:

2. TRUCK ARRIVED ON SITE :

Slump test result(S)	:	Hrs	
Discharge started	:	mm at	Hrs
Placement completed	:	Hrs	
No of site cubes taken	:	Hrs	
Place where cubes taken	:	Hrs	
Placement temperature of concrete	:		
Ambient temp	:		
Weather condition	:		

Inspected by: (For Contractor)	Name:	Signed:	Date:
Approved by: (For Engineer)	Name:	Signed:	Date:

Category B: Inspection Proforma B-5

POST CONCRETING INSPECTION

Note: Post concreting inspection shall be carried at various stages such as after stripping of side shuttering, each stage of pre-stressing, decentring and/or as per designer stipulation.

Location :

Date of pour : Stage of Inspection :

Specified class : Date of inspection :

S or NS*

S. No	Observation	Type of remark (S or NS*)	
1	Position/Dimensions of member	Alignment Levels Dimensions	S or NS S or NS S or NS
2	Surface defects (honey combing/sand streaks/air bubbles/cold joints)	No defects Minor defects Major defects	(Note type and extent of defect)
3	Class of finish	S or NS	
4	Cracks	No cracks Cracks Nature of cracks:	Date first observed
5	Any other defect		
6	Non-conformance report no.	Report no / Not applicable	

Remarks:

In case of NS report in item (1) to (5), it should be examined by competent authority before approval or non-approval. If required, a separate non-conformance report (including sketches, photographs, etc.,) shall be prepared for further action.

*S = Satisfactory, NS = Not satisfactory

Inspected by: Name: Signed: Date:
(For Contractor)

Approved by: Name: Signed: Date:
(For Engineer)

Category C: Testing proforma C-1

GRAIN SIZE ANALYSIS (IS:2720 PART-4)

Lab location :

Sampled Location/Chainage :

Date of Testing :

Weight of Sample Taken :

Wt. of Sample retained on 0.075mm Sieve :

Empty weight of Container(g)(W_1):

Wt. of Water ($W_4=W_2-W_3$) :

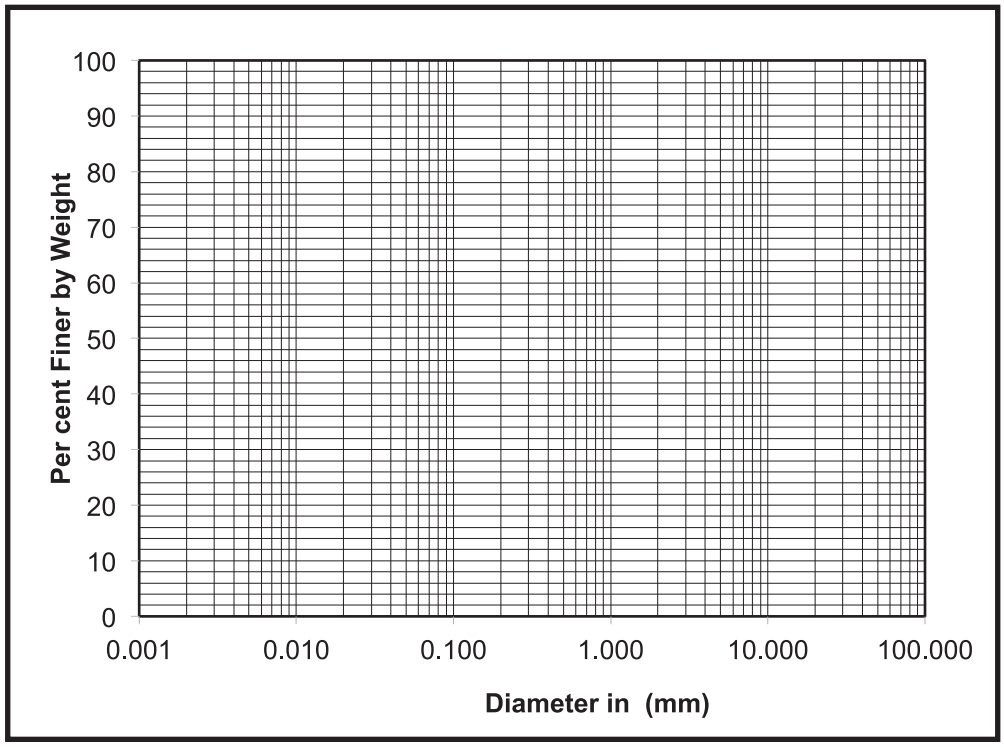
Wt. Container + Wet Soil (g) (W_2) :

Wt. of Container+dry Soil(g)(W_3) :

Moisture Content $(w_4)/(w_3)-(w_1))*100$

I.S Sieve Designation (mm)	Weight of Soil retained (g)	Cumulative Wt. of Soil retained (g)	Cumulative Percentage retained (%)	Cumulative Percentage Passing (%)	Results
100.000					Gravel =
75.000					
60.000					
40.000					
19.000					
10.000					
4.750					Sand =
2.000					
1.180					
0.425					
0.075					Silt & Clay =
Pan					

Grain size distribution curve



Remarks:

Type of soil:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-2

DETERMINATION OF PARTICLE SIZE BY HYDROMETER METHOD (IS:2720 PART-4)

a)	Percentage of soil passing 75m IS Sieve:	Height of the bulb (h):	cm
b)	Mass of sample taken for sedimentation Analysis:	Volume of the Hydrometer (vh)l:	ml
c)	Specific Gravity (G):	Cross sectional area of the Cylinder (A) :	Sq cm
d)	Meniscus Correction (cm):	Constant = (1/2(h-(Vh/A))	

	Observations					Calculations							
S. NO	Elapsed Time (t) min	Hydrometer Reading (Rh')	Meniscus correction C_m	Temperature (t)	Composite Correction (C)	Corrected Reading (Rh) = Rh'+C_m (2)+(3)	Height (He) cm	R=Rh'+C	Value (η) in poise	Factor (M) = $\sqrt{30\eta/g(G-1)}$	Particle Size D = (M$\sqrt{}$He/t)mm	% Finer (N') = 100*G/(Ms* (G-1))*R	% finer based on whole weight N=N'*(w'/w)
	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
2													
3													
4													
5													

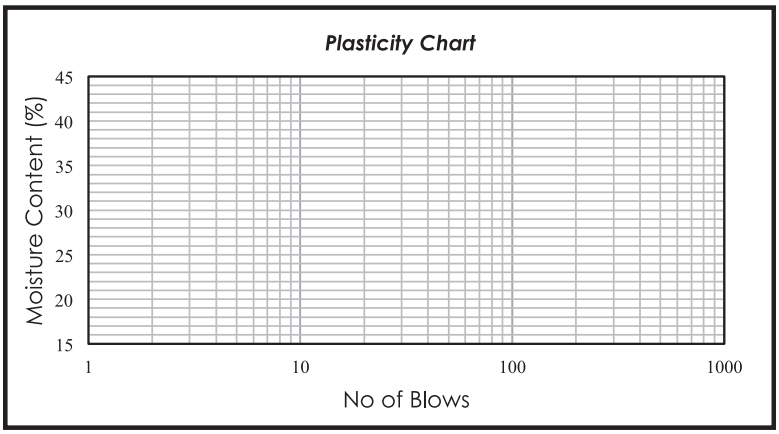
Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-3

LIQUID LIMIT AND PLASTIC LIMIT (IS:2720 PART-5)

Lab location	:	Sampled Location/Chainage	:
Date of Testing	:	Weight of Sample Taken	:

Liquid Limit :-								**Plastic Limit :-**		
Determination no.		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**
No. of Blows										
Container no.										
Wt. of empty Container(g)										
Wt. of Container + wet soil (g)										
Wt. of Container + dry soil (g)										
Wt. of Water (g)										
Wt. of oven dry soil (g)										
Moisture Content (%)										



Test Results
Liquid Limit (LL%):
Plastic Limit (PL%) : (Average Value)
Plasticity Index:
(LL-PL)

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-4

FREE SWELL INDEX (FSI) (IS:2720 PART-40)

Section/Lab location :

Sampled Location/Chainage :

Date of Testing :

Weight of Sample Taken :

S. No.	Chainage/Side/Depth	Date of Sampling	Date of Testing	Duration in Hrs	Wt. of Sample (g)	Volume of Soil in Water (W_1 cc)	Volume of Soil in Kerosene (W_2 cc)	FSI = $(W_1 - W_2)/W_2$ (%)

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-5

SOIL SPECIFIC GRAVITY TEST (IS:2720 PART-III/II)

Section/Location of Lab :

Date of Sampling :

Location/Chainage :

Source of Material :

Date of Testing :

Sample Code/No :

S. No.	Description	Trial 1	Trial 2	Trial 3	Average
1	Wt. of Density Bottle with Lid (W_1)				
2	Wt. Density Bottle + soil (W_2)				
3	Wt. Density Bottle + Soil + Water (W_3)				
4	Wt. Density Bottle + Water (W_4)				
5	Weight of Soil (W_2-W_1)				
6	Specific Gravity (G)= $W_5/(W_4-W_1) -(W_3-W_2)$				

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-6

COMPACTION TEST (IS:2720 PART-8)

Sampled Location :

Source of Sample :

Date of testing :

Volume of Mould :

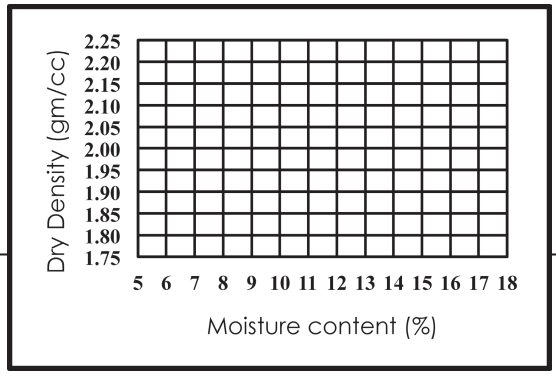
Type of Compaction :

Serial No.		**1**	**2**	**3**	**4**	**5**	**6**
Wt. of Mould	(g)						
Wt. of Mould + Soil	(g)						
Wt. of Soil	(g)						
Wet Density	(g/cc)						
Container No.							
Wt. of Container	(g)						
Wt. of C + Wet Soil	(g)						
Wt. of C + Dry Soil	(g)						
Wt. of Wet Soil	(g)						
Wt. of Dry Soil	(g)						
Wt. of Moisture	(g)						
Moisture Content	(%)						
Dry Density	(g/cc)						

Test Results:

Maximum dry density (MDD) g/cc =

Optimum moisture content (OMC) % =

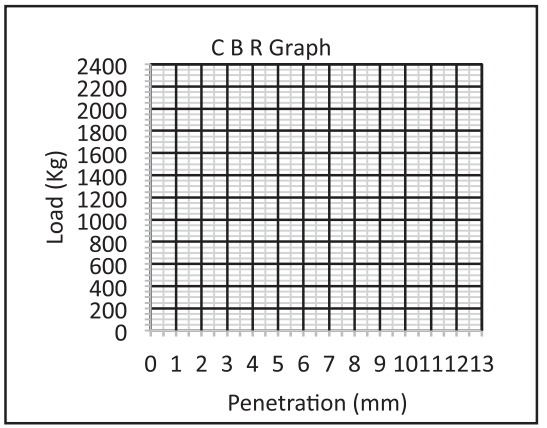
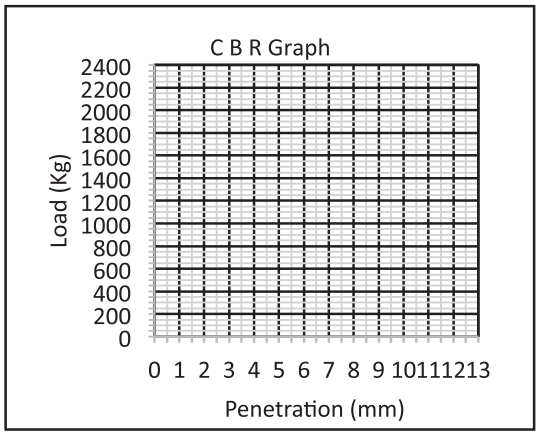
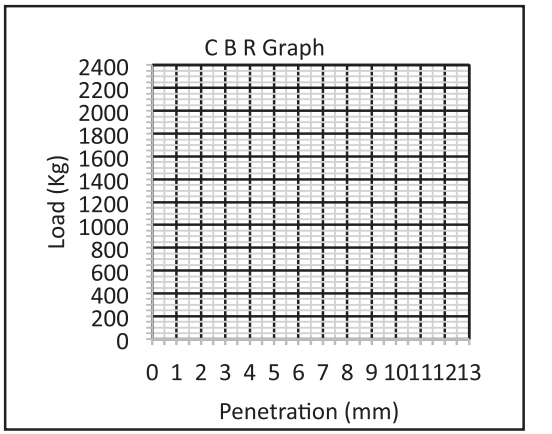


Remarks:

Prepared by **Checked by** **Approved by**

CBR TEST RESULTS (AASHTO T 193)

Location of Sample :						**Proving Ring Capacity (kN):**			
Type of Test			**: Soaked/ Un-soaked**			**Date of Testing:**			
Mould No	**10**			**30**			**65**		
No of Blows									
Dry Density (g/cc)									
Penetration (mm)	**Proving Ring Reading (div)**	**Load (Kg)**	**CBR Value (%)**	**Proving Ring Reading (div)**	**Load (Kg)**	**CBR Value (%)**	**Proving Ring Reading (div)**	**Load (Kg)**	**CBR Value (%)**
0.00									
0.50									
1.00									
1.50									
2.00									
2.50									
3.00									
4.00									
5.00									
7.50									
10.00									
12.50									

CBR Graph for 10 Blows	CBR Graph for 30 Blows	CBR Graph for 65 Blows
		
CBR (%) at 2.5mm =	CBR (%) at 2.5mm =	CBR (%) at 2.5mm =
CBR (%) at 5mm =	CBR (%) at 5mm =	CBR (%) at 5mm=

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-8

C B R TEST (IS:2720 PART-16)

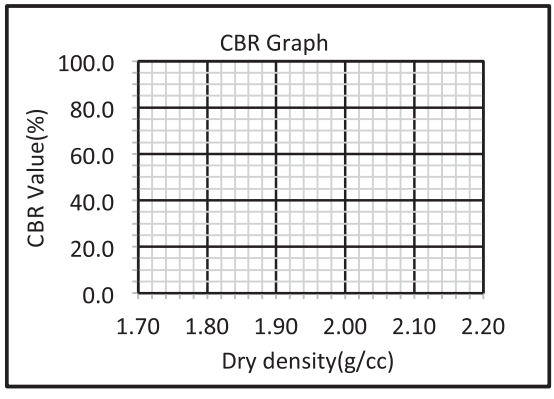
Section/Location of Lab	:		Surcharge Wt.	:	
Location of Sample	:		O.M.C/N.M.C (%)	:	
Type of Test	:	Un-Soaked/Soaked	M.D.D/F.D.D (g/cc)	:	
Date of Moulding	:		97% OF M.D.D (g/cc)	:	
Date of Testing	:		Type of Compaction	:	

C.B.R. Compaction :-

No. of Blows	**10**	**30**	**65**
Mould No			
Moisture Determination			
Wt. of Mould (g)			
Wt. of Mould + Soil (g)			
Wt. of Soil (g)			
Volume of the mould (cc)			
Bulk density (g/cc)			
Container No.			
Wt. of Container (g)			
Wt. of C + Wet Soil (g)			
Wt. of C + Dry Soil (g)			
Moisture Content (%)			
Dry density (g/cc)			

TEST RESULTS:

On Remoulded and Un-Soaked/ Soaked Sample		
No of Blows	**Dry density (g/cc)**	**CBR (%)**
10		
30		
65		



CBR Value @ 97% of MDD =

Remarks:

Prepared by **Checked by** **Approved by**

DIRECT SHEAR TEST (IS:2720 PART-13)

Section/Lab Location :

Sample Location :

Testing Date :

Method of Test : U.U Test

Proving Ring Constant kg/ div :

Preparation of Test Specimen:

O.M.C. (%) (from Modified Proctors test) :

Wt. of wet sample Required(grams) g_d x 90 x (1+w/100) :

M.D.D. (g/cc) (from Modified Proctors test) :

Wt. of Dry Sand/Soil Required in case of U.U. Test (grams) :

F.D.D from core cutter method(g/cc) :

Wt. of Dry Sand/Soil taken (grams) :

Required Max. dry density g_d (g/cc) (95% of MDD) :

Volume of Water added (ml) :

Volume of the mould (6x6x2.5) : 90

Rate of Strain Applied (mm/minute) :

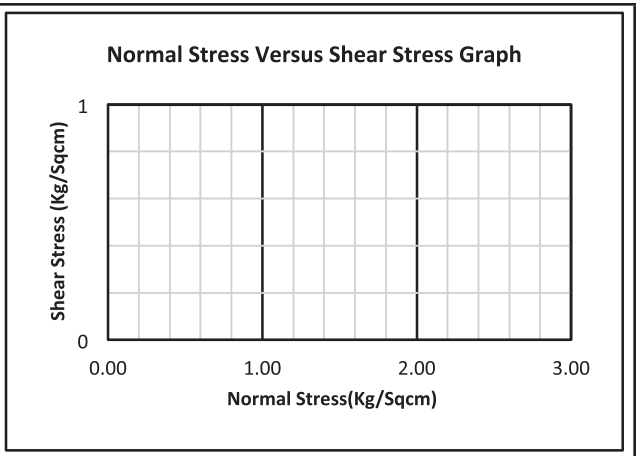
Cross sectional Area -A (cm^2) : 36

Test Observations:

Sl. No.	Horizontal Displacement (d) cm	Corrected Area (A-dx6)cm^2	Normal Stress (kg/cm^2) =0.5			Normal Stress (kg/cm^2) =1.0			Normal Stress (kg/cm^2) =1.5		
			Shear Load from Proving Ring		Shear Stress kg/cm^2	Shear Load from Proving Ring		Shear Stress kg/cm^2	Shear Load from Proving Ring		Shear Stress kg/cm^2
			Divisions	kg		Divisions	kg		Divisions	kg	
1											
2											
3											
4											
5											
6											

Sl. No	Max. Normal Stress (kg/cm^2)	Max. Shear Stress (kg/cm^2)
1	0.50	
2	1.00	
3	1.50	

Results from Graph		
1	Angle of Internal Friction F°	
2	Cohesion 'C' kg/cm^2	



Remarks:

Prepared by **Checked by** **Approved by**

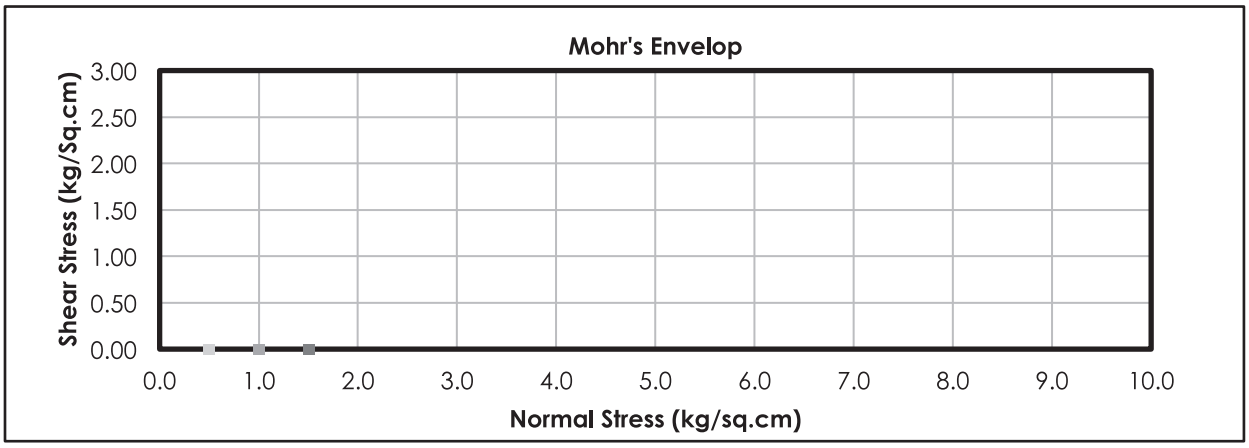
Category C: Testing proforma C-10

TRIAXIAL SHEAR TEST (IS:2720 PART-11, IS:2720 PART-12, ASTM-D 7181)

Section/Lab Location :		Sample Dia	: 3.8 cm
Sample Type & Location:		Sample Height (l)	: 7.6 cm
Type of Test (UU/CD/CU): UU		Proving Ring Constant	: kg/div
Depth of Sample:		Volume of mould	: 86.19 cc
Date of Testing:			

Sl. No.	Strain Dial Gauge Reading (dl) mm	Proving Ring Readings (div) @ Cell Pressure (s3)			Load in Kg (Prov Const. X Prov. Ring Reading)			Length of Specimen (cm)	Corrected Area (cm^2) [A/(1-dl/l)]	Normal Stress ($\sigma_1 - s_3$) kg/cm^2 @ Cell Pressure (s3)			Axial Strain %
		0.5	1.0	1.5	0.5	1.0	1.5			0.5	1.0	1.5	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.0												
2	0.2												
3	0.4												
4	0.6												
5	0.8												
6	1.0												
7	1.2												
8	1.4												
9	1.6												
10	1.8												
11	2.0												
12	2.2												
13	2.4												
14	2.6												
15	2.8												
16	3.0												
17	3.2												
18	3.4												
19	3.6												
20	3.8												

21	4.0												
22	4.2												
23	4.4												
24	4.6												
25	4.8												
26	5.0												
27	5.2												
28	5.4												
29	5.6												
30	5.8												
31	6.0												
32	6.2												
33	6.4												
34	6.6												
35	6.8												
36	7.0												
37	7.2												
38	7.4												
39	7.6												
40	7.8												
41	8.0												
42	8.2												
43	8.4												
44	8.6												
45	8.8												
46	9.0												
47	9.2												
48	9.4												
49	9.6												
50	9.8												
51	10.0												



Test Results from graph:

1 Cohesion 'c': kg/cm^2

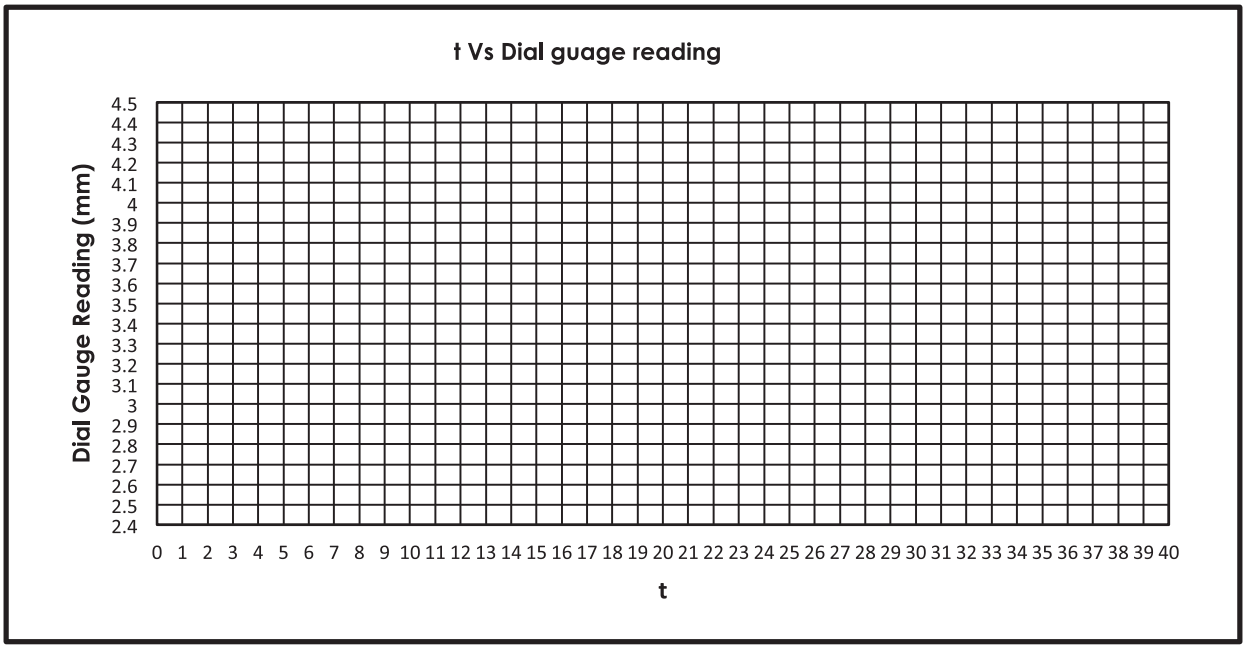
2 Angle of internal friction 'F': degrees

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-11

CONSOLIDATION TEST (IS: 2720 (PART-15)					
Section/Lab Location :		Sample Dia :			
Sample Type and No :		Height :			
Sampling Date :		Sampling Date :			
Testing Date :					
Time in Min. (t)	**√t**	**Dial Gauge Readings in (mm) for Diff. Pressures kg/cm²**			
0	**0**	**0.5**	**1**	**1.5**	**2**
0.25	0.5				
1	1				
2.25	1.5				
4	2				
6.25	2.5				
9	3				
12.25	3.5				
16	4				
20.25	4.5				
25	5				
36	6				
49	7				
64	8				
100	10				
144	12				
196	14				
225	15				
252	15.9				
1440	37.9				



Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-12

SOIL PERMIABILITY TEST -CONSTANT HEAD METHOD
(IS:2720 PART-17)

Lab location	:	Sampled Location/Chainage	:
Date of Testing	:	Weight of Sample Taken	:
NMC or OMC	:	Depth	:
Diameter of mould(D)	:	FDD or MDD	:
Length of mould (L)	:	Dia of Stand Pipe (d)	:
Area of mould(A)	:	Area of stand pipe (a)	:

S. No	Head (h)	Time (t)	Quantity of water (ml)	Avg. Quantity of water (ml)	Coefficient of permeability (K)

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-13

SOIL PERMIABILITY TEST -VARIABLE HEAD METHOD
(IS:2720 PART-17)

Section Lab location	:	Sampled Location/Chainage	:
Date of Testing	:	Weight of Sample Taken	:
NMC or OMC	:	Depth	:
Diameter of mould(D)	:	FDD or MDD	:
Length of mould (L)	:	Dia of Stand Pipe (d)	:
Area of mould(A)	:	Area of stand pipe (a)	:

S. No	Initial Head (h1)	Final Head (h2)	Initial Time (t1)	Final Time (t2)	Net Time (t)	Coefficient of permeability (K)
1						
2						
3						

Calculation:

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-14

SWELL PRESSURE TEST BY CONSTANT VOLUME METHOD
(IS:2720 PART-41)

Lab location	:	Sampled Location/Chainage	:
Date of Testing	:	Weight of Sample Taken	:
		Proving Ring Constant	: Kg/Div.
		Area of Specimen	: Sq.cm

OMC = **Dry density:**

Date	Time	Strain dial Gauge Reading before Adjustment	Proving Ring Readings	Load in Kg	Swell pressure in Kg/cm^2	Swell Pressure in kN/m^2

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-15

UNCONFINED COMPRESSIVE STRENGTH
(IS:2720 PART-10)

Section/Location of Lab	:	Date of Testing	:
Initial Height of Sample	:	Rate of Strain	:
Initial Dia. of Sample	:	Sample Code	:
OMC %	:	MDD(g/cc)	:

Sample No.	Vol. of Sample	Weight of Sample	Container No	Container Wt	Wt. of Container + Wet Soil	Wt. Container + Dry Soil	M.C %	g_{dry} g/cc
1								
2								
3								

Sl. No.	Strain Dial Gauge Reading (mm)	Stress Dial Gauge Readings (div.)		
		Sample 1	Sample 2	Sample 3
1	0.0			
2	0.2			
3	0.4			
4	0.6			
5	0.8			
6	1.0			
7	1.2			
8	1.4			
9	1.6			
10	1.8			
11	2.0			
12	2.2			
13	2.4			
14	2.6			
15	2.8			
16	3.0			

Sl. No.	Strain Dial Gauge Reading (mm)	Stress Dial Gauge Readings (div.)		
		Sample 1	Sample 2	Sample 3
17	3.2			
18	3.4			
19	3.6			
20	3.8			
21	4.0			
22	4.2			
23	4.4			
24	4.6			
25	4.8			
26	5.0			
27	5.2			
28	5.4			
29	5.6			
30	5.8			

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-16

AGGREGATE IMPACT VALUE
IS: 2386 (PART-IV)

Location/Secion of Lab	:	**Source of Material**	:
Sample Location	:	**Date of testing**	:
Purpose of Use	:		
Sample size	: **12.5 mm Passing & 10 mm retained**		

Description	Symbol	unit	Determinations		
			1	2	3
Weight of aggregate(dry) passing through IS Sieve12.5 mm & retained on 10 mm	W_1	g			
Weight of fraction retained on 2.36 mm IS sieve	W_2	g			
Weight of fraction passing through 2.36 mm IS sieve	$W_3 = W_1-W_2$	g			
$W_4=W_1-(W_2+W_3)$ (if W_4>1g, discard and carryout fresh test)	W_4	%			
Aggregate Impact value	$(W_3/W_1)*100$	%			
Average Aggregate Impact value					

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-17

FLAKINESS INDEX AND ELONGATION INDEX
(IS:2386 PART-I)

Section/Location of Lab:		Purpose of Use	:
Sampling location	:	Date of Sampling	:
Source of Materials	:	Date of Testing	:
Type of Material	:		

IS:Sieve Size mm		Total Weight of Aggregate taken (g)	Weight of Aggregate retained on Thickness gauge (g)	Weight of Aggregate passing through Thickness gauge (g)	Weight of Aggregate retained on length gauge after retained on Thickness gauge (g)
Passing	**Retained**				
63	50				
50	40				
40	31.5				
31.5	25				
25	20				
20	16				
16	12.5				
12.5	10				
10	6.3				
Total (gm)		**A=**	**B=**	**C=**	**D=**

Flakiness Index (C/A) = **Elongation Index (D/B) =**

Combined Flakiness and Elongation Indices = ((C/A) + D/B)) X 100 =

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-18

INDIVIDUAL GRADATION OF COARSE AGGREGATE
(IS:383)

Location of Lab :

Location/Chainage :

Date of Testing :

Date of Sampling :

Source of Material :

Total wt. of sample (g) :

Sieve size(mm)	Wt. Retained (g)	Cumulative wt. Retained = (g)	% Cumulative wt. Retained	% passing	Specified % of passing			
					40mm	20mm	12.5mm	10mm
63mm					100	-	-	-
40mm					85-100	100	-	-
20mm					0-20	85-100	-	-
16mm					-	-	100	-
12.5mm					-	-	85-100	100
10.0mm					0-5	0-20	0-45	85-100
4.75mm					-	0-5	0-10	0-20
2.36mm					-	-	-	0-5

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-19

SIEVE ANALYSIS OF FINE AGGREGATE

Location of Lab :

Date of Sampling :

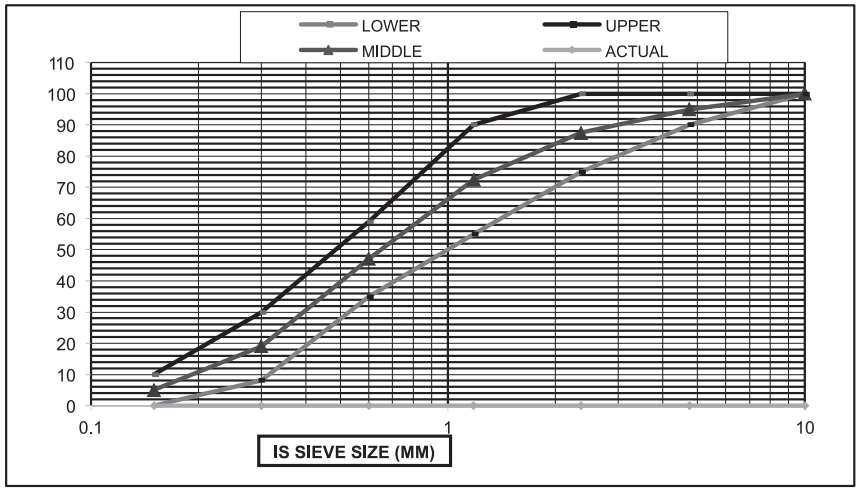
Location/Chainage :

Source of Material :

Date of Testing :

Total wt. of sample (g) :

IS Sieve Size (mm)	Wt; of Material Retained (gm)	Cum.Wt. of Material Ret. (gm)	Cum. % of Material Retained	Percentage Weight of Passing			
				As per Test	Specification Limits (1000-2)		
					ZONE-I	ZONE-II	ZONE-III
10.00					100	100	100
4.75					90-100	90-100	90-100
2.36					60-95	75-100	85-100
1.18					30-70	55-90	75-100
0.60					15-34	35-59	60-79
0.30					5-20	8-30	12-40
0.15					0-10	0-10	0-10
FINENESS MODULUS							



Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-20

DELETERIOUS MATERIALS AND ORGANIC IMPURITIES
(IS:2386 PART-II)

Section/Location of Lab	:	Purpose of Use	:
Location/Chainage	:	Date of Sampling	:
Source of material	:	Date of testing	:
Description of material	:		

S. NO	DETERMINATION NO.	1	2	AVERAGE
1	Total weight of sample (W) g			
2	Total weight of sample after removing clay lumps (R) g			
3	Percentage of clay (%); (L = (W – R)/(W) x 100)			

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-21

POINT LOAD TEST (IS:8764)

Section/Location of Laboratory :

Location : Bore Hole No :

Sample No : Depth :

Date of Sampling : Date of Testing :

Sl. No.	Description	Trial 1	Trial 2	Trial 3	Trial 4
1	Ave. Height of the specimen (H) mm				
2	Ave. Dia. of Specimen (D)mm				
3	Area of the specimen (A) mm^2				
4	Failure Load (P) kN				
5	Standard Core Diameter (mm)				
6	Point Load Strength Index kg/cm^2 $I_S = P/(sqrt(D^{1.5} X D^*)$				
7	Uniaxial Compressive Strength t/m^2 $Q_C = 22XI_S(50)$				
8	Average Value neglecting Highest and Lowest values				

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-22

SOUNDNESS TEST BY USING SODIUM SULPHATE
(IS:2386 (PART-V)

Location of Lab	:	Date of Sampling	:
Location/Chainage	:	Source of Material	:
Type of material	:	Tested by	:
Date of Testing	:	Proposede Use	:

COARSE AGGREGATE

Passing sieve size	Retained sieve size	Grading of Orignal Sample Percent	Weight of Test Fraction Before Test (gm)	Weight of Test Fraction After Test (gm)	Percentage Passing Finer Sieve After Test (Actual Percentage Loss)	Weighted Average (Corrected Percent Loss)
63mm	40mm					
40mm	20mm					
20mm	10mm					
10mm	4.75mm					
Total						

Passing sieve size	Retained sieve size	Grading of Orignal Sample Percent	Weight of Test Fraction Before Test (gm)	Weight of Test Fraction After Test (gm)	Percentage Passing Finer Sieve After Test (Actual Percentage Loss)	Weighted Average (Corrected Percent Loss)
600 mic	300mic					
1.18 mm	600mic					
2.36mm	1.18mm					
4.75mm	2.36mm					
10mm	4.75mm					
Total						

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-23

SPECIFIC GRAVITY & WATER ABSORPTION OF FINE AGGREGATES
IS:2386 (PART-III)

Section/Location of Lab	:		
Source	:	Date of sampling	:
Location	:	Date of testing	:
Proposed Use	:		

BY PYCNOMETER METHOD

Description	1	2	3
Pycnometer Bottle Number			
Weight of SSD Sample (W_1) (g)			
Weight of Pycnometer bottle + water + Sample(W_2) (g)			
Weight of Pycnometer bottle + water (W_3) (g)			
Weight of oven dry sample (W_4) (g)			
Bulk Specific Gravity = $W_4/(W_1 – (W_2 – W_3))$			
Apparent Specific Gravity = $W_4/(W_4 - (W_2 – W_3)$			
Water Absorption = $(W_1 – W_4) / W_4 * 100$			
Average Specific Gravity			
Average Water absorption (%)			

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-24

SPECIFIC GRAVITY & WATER ABSORPTION OF COARSE AGGREGATES IS:2386 (PART-III)			
PROJECT	:		
Type of Sample	: (Rock sample/ Aggregate)		
Sample Location	:		
Co-ordinate/Chainage	:		
Date of Sampling	:		
Date of Testing	:		
Determination			
Before Soaking			
Weight of sample in air (W_1)g			
Weight of sample in water (W_2)g			
Volume of Specimen ($V = W_2 – W_1$) cc			
After Soaking			
Weight of SSD sample in water (W_3)g			
S.S.D weight of sample (W_4)			
Volume of specimen $V=(W_4-W_3)$ cc			
Bulk Density of sample			
Weight of Oven dried Sample (W_5)g			
Moisture Content (w)%			
Dry density $\gamma d = \gamma b/1+(w/100)$			
Specific Gravity of sample (G)			
Apparent Specific gravity(G_m)			
Water Absorption			
Void ratio (e)			
Porosity = (e/1+e)*100			
Remarks:			
Prepared by	**Checked by**		**Approved by**

Category C: Testing proforma C-25

10% FINES VALUE TEST
(BS: 812 PART-III)

Location of Lab	:	Date of sampling	:
Location/Chainage	:	Source of Material	:
Date of Testing	:	Proposed Use	:
Proposed Use	:		

Determination	Trial No		
	1	2	3
Weight of Saturated surface dry Sample passing IS Sieve 14 mm and retained on IS Sieve 10mm (A) g			
Oven dried weight of fraction retained on IS Sieve 2.36 mm after the test (g)			
Oven dried weight of fraction passing IS Sieve 2.36 mm after the test (B) g			
The Maximum force 'X' (Tonne)			
Y = % of material passing IS Sieve 2.36 mm at the maximum force (B/A X100)			
10 % Fines Value (TFV) = 14X/ (Y+4) (kN)			
Average Value of 10 % Fines Value (kN)			

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-26

UNIAXIAL COMPRESSION STRENGTH TEST
(IS:9143-1979)

Section Location of Lab :
Location :
BH No. : Depth(m) :
Piece No :

Sample No:	Dia. of sample (D) m	Height of Sample (H) m	Area (m^2)	Load at Failure (kN)	Compression Strength (kN/m^2)
1					
2					
3					
				Compression strength (t/m^2)	

Young's Modulus (IS:7317-1974)

Dia. of Sample (m) : **Height of sample(m) :** **Area (m^2) :**

S. No.	Dial Gauge reading	Deformation (Δl) (mm)	Strain (Δl/(l*1000)	Load Dial Reading (kN)	Stress (kN/m^2)
0	0				
1	10				
2	20				
3	30				
4	40				
5	50				
6	60				
7	70				
8	80				
9	90				
10	100				
11	110				

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-27

FINENESS OF CEMENT
(IS:4031 PART-1)

Section/Location of Lab :

Description of cement : Date of Sampling :

Week No. : Date of testing :

OBSERVATIONS:

S. No.	DESCRIPTION	1	2	3	AVERAGE (%)	SPECIFIED LIMITS AS PER IS: 8112
1	Wt. of Sample taken (W_1) gm					Max. 10%
2	Wt. of residue on 90µ sieve (W_2) gm					
3	Fineness (%) (W_2/W_1) X100					

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-28

NORMAL CONSISTENCY OF CEMENT
(IS:4031 PART-V)

Section/Location of Lab :

Description of cement : Date of Sampling :

Week No. : Date of testing :

Temperature (°C) : 28°C

NORMAL CONSISTENCY

Sl. No.	Weight of Cement taken (g)	Weight of water taken (g)	Plunger penetration from bottom of Mould (mm)	Time taken from adding of water to Cement (min)	Consistency of Cement (%)
1					
2					
3					
4					
5					

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-29

INITIAL AND FINAL SETTING TIME OF CEMENT
(IS:4031 PART-V)

Location of Lab :

Description of cement :

Week No. : Date of Sampling :

Temperature (°C) : 28°C Date of testing :

A) INITIAL SETTING TIME

Weight of Cement taken (g) :

Weight of water added = 0.85 of Normal Consistency:

A) INITIAL SETTING TIME

S. No.	Time of water added	Needle penetration (mm)	Initial Setting Time (min)
1			
2			
3			
4			
5			

B) FINAL SETTING TIME

S. No.	Time of water added	Needle penetration (mm)	Final Setting Time (min)
1			
2			
3			
4			
5			

Initial Setting time: **Final Setting time:**

Acceptance Criteria:

Initial Setting Time : ≥ 30min

Final Setting Time : ≤ 600min

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-30

SOUNDNESS OF CEMENT BY LE-CHATELIER METHOD
(IS:4031 PART-III)

Section/ Location of Lab	:		
Description of cement	:	Sample Code	:
Week No.	:	Date of testing	:
Temperature (°C)	: 28^0C	Date of testing	:
Quantity of Water Added (0.78*Standard Consistency)	:	Quantity of Cement Added	:

SOUNDNESS OF CEMENT:

S. No.	Initial Distance Between Indicators (L_1)	Distance Between Indicators after 24 hrs of submersion in water at 27+2^0C(L_2)	Distance Between Indicators after submersion in boiling water for three hours(L_3)	Soundness of cement (L_2-L_3)-(mm)
1				
2				
3				
4				
5				

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-31

SPECIFIC GRAVITY OF CEMENT (IS: 4031)

Section/Location of Lab :

Name/ Brand of cement : Date of Sampling :

Grade of Cement : Date of testing :

Week No. :

Determination	Trial No.			
	1	2	3	Average
Weight of bottle (w_1)				
Weight of bottle with sample (w_2)				
Weight of bottle with sample and kerosene (w_3)				
Weight of bottle with water (w_4)				
Weight of bottle with kerosene (w_5)				
Specific Gravity of Kerosene(w_6) $=(w_5-w_1)/(w_4-w_1)$				
Specific Gravity of Sample= $(w_2-w_1)\ *w_6/(w_2-w_1)-(w_3-w_5)$				

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-32

COMPRESSIVE STRENGTH OF MORTAR CUBES
(AS PER IS:516)

Section/Location of Lab :

Description of cement : Date of Casting :

Week No. : Date of testing :

Size of Mortar Cube : Grade of Cement :

Sl. No	Age in Days	Weight (g)	Density (g/cc)	Load at Failure (kN)	Compressive Strength of Individual Sample (f_1) in (N/mm^2)	Average Compressive Strength (f_{avg}) in (N/mm^2)

f_{ck} : Characteristic Compressive Strength of Cement

Remarks:

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Category C: Testing proforma C-33

COMPRESSIVE STRENGTH OF CONCRETE CUBES
(IS:516)

Section/Location of Lab :

Grade of Concrete : Date of Casting :

Water-Cement Ratio : Date of testing :

Description of Cement : Structure location :

Size of Concrete Cube :

Part of Structure

Sl. No	Age in Days	Weight (g)	Density (g/cc)	Load at Failure (kN)	Compressive Strength of Individual Sample (f_1) in (N/mm^2)	Average Compressive Strength (f_{avg}) in (N/mm^2)

f_{ck} : Characteristic Compressive Strength of Concrete

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-34

PENETRATION VALUE OF BITUMEN
(TEST METHOD IS:1203-1978)

Location of Lab	:	Date of Sampling	:
Location/Chainage	:	Source of Material	:
Date of Testing	:	Sample Code/No	:
Bitumen grade	:	Proposed Use	:

Sl. No	Test temp (°C)	Dial Reading (0.1 mm)		Penetration (0.1mm)	Remarks
		Initial	Final		
1					
2					
3					
Average					

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-35

BITUMEN SPECIFIC GRAVITY
(IS:1202-1978)

Source of Material :

Location :

Date of Sampling :

Date of Testing :

Proposed Use :

S. No.	Description	Trial 1	Trial 2	Trial 3
1	Weight of Pycnometer (W_1) g			
2	Weight of Pycnometer + Sample (W_2) g			
3	Weight of Pycnometer + Sample + Water (W_3) g			
4	Weight of Pycnometer + Water (W_4) g			
5	Weight of Sample (W_2 - W_1) g			
6	Specific Gravity of Sample = $(W_2 - W_1)/(W_4 - W_1) - (W_3 - W_2)$			
	Average			

Remarks:

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Category C: Testing proforma C-36

DETERMINATION OF SOFTENING POINT
(IS:1205-1978)

Section/Location of Lab :

Source of Material : Date of Sampling :

Bitumen Grade : Date of Testing :

Apparatus Used : Ring and Ball Apparatus

Period of Cooling at Room Temperature (min) : 30°C

Period of Cooling in Water bath @ 5°C Temperature (min) :

Rate of Heating : 5°C ± 0.5°C

Time (min)	Temperature of water bath °C	Time (min)	Temperature of water bath °C
1		7	
2		8	
3		9	
4		10	
5		11	
6		12	

Description	Bill No. 1	Bill No. 2	Mean Value of Softening Point
Temperature at which sample touches the bottom plate (°C)			

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-37

DETERMINATION OF VISCOSITY
(IS:1206-1978)

Section/Location of Lab	:		
Source	:	**Date of Sampling**	:
Sample Location	:	**Date of Testing**	:
Bitumen Grade	:		
Observations			
Pouring Temperature, °C	:		
Test Temperature, °C	:		
Size of Orifice (mm)	:		
Viscosity in (sec)	:		
Viscosity in (Cst)	:		

(Note 1: 1 sec = 400 Cst for 10 mm Orifice)
(Note 2 : 1 sec = 13.2 Cst for 4 mm Orifice)

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-38

GRADATION AGGREGATE FACTORS BINDER CONTENT PAVING MIXTURES CENTRIFUGE METHOD BC /DBM/ BM
(IRC:SP:11)

Section/Location of Lab :

Date of Sampling : **Date of Location :**

Date of Testing : **Layer :**

BINDER CONTENT TEST

S. No.	Details		Sample No.	
			1	2
1	Weight of Mix	: W_1 g		
2	Initial weight of filter paper	:		
3	Weight of Aggregate after extraction	: W_2 g		
4	Weight of filter paper after extraction with fine materials	: W_3 g		
5	Increased weight of filter	: W_4 g		
6	Weight of Binder $W_1-(W_2+W_4)$	: W_5 g		
7	Binder Content (BC) = W_5/W_1X100	: BC %		

GRADATION OF AGGREGATE FRACTION (BC - MoRT&H Table 500-18), (DBM - MoRT&H Table 500-10)&(BM - MoRT&H Table 500-4)

Sieve size (mm)	Wt. retained (g)	Cumulative Wt. retained (g)	% Retained	% Passing	JMF LIMITS	Grading 1	Grading 2
						Nominal Size Aggregate =	Nominal Size Aggregate =
						Layer thickness =	Layer thickness =

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-39

FLASH AND FIRE POINT TEST
(IS:1209-1978)

Section/Location of Lab :

Source : **Date of sampling :**

Location : **Date of testing :**

Proposed Use :

1. Bitumen grade/ Cutback type & grade:

2. Type of equipment: Closed cup/ Open cup

Rate of heating

Time, minutes	1	2	3	4	5	6	7	8	9	10	11	12	
Temperature, °C													

Test property	Test Number			Mean value
	1	2	3	
1. Flash point				
2. Fire point				
3. Mean value				

Remarks:

Prepared by **Checked by** **Approved by**

MARSHALL TEST RESULTS
(ASTM: D – 1559)

Type of Mix:

Max. Sp. Gr of Paving Mix(G_{mm}):

Date of Testing :

Grade of Bitumen:

Compaction : 75 Blows (Both Sides)

BC Trial -1 Blend:

Specific Gravity of Bitumen (G_b) :

Size (mm)	Size-1	Size-2	Size-3	Size-4
% Feed				

Bulk Sp.Gr. of Aggregates(G_{sb}) :

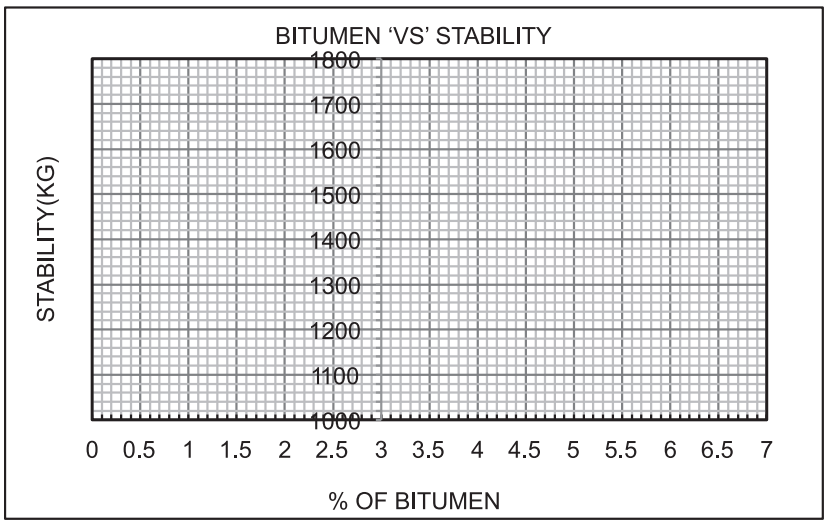
Effective Sp.Gr. Of Agg.(G_{se}):

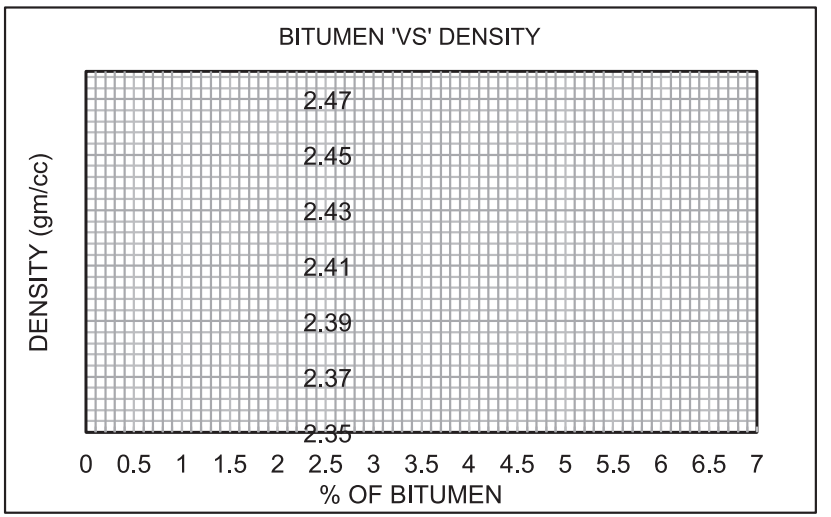
% Bitumen by Wt. of Mix.	Specimen No	% of Agg.	Spec. Ht. (mm)	Mass in grams.			Properties						Stability in kg.			Flow
				In Air	In Water	SSD	Bulk Volume (cc)	Bulk Density (g/cc)	Max. Sp.Gr.	Air Voids (%)	VMA (%)	VFA (%)	Measured Kgs	Corr. factor	Adjusted	(mm)
	Average															
	Average															
	Average															

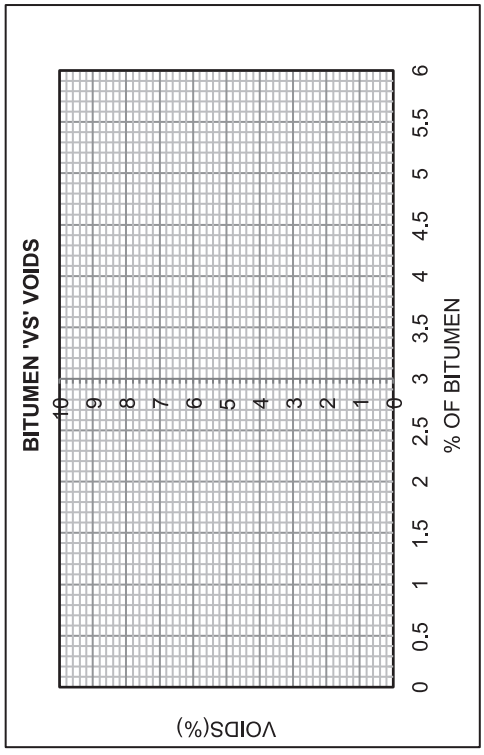
	Average															
	Average															

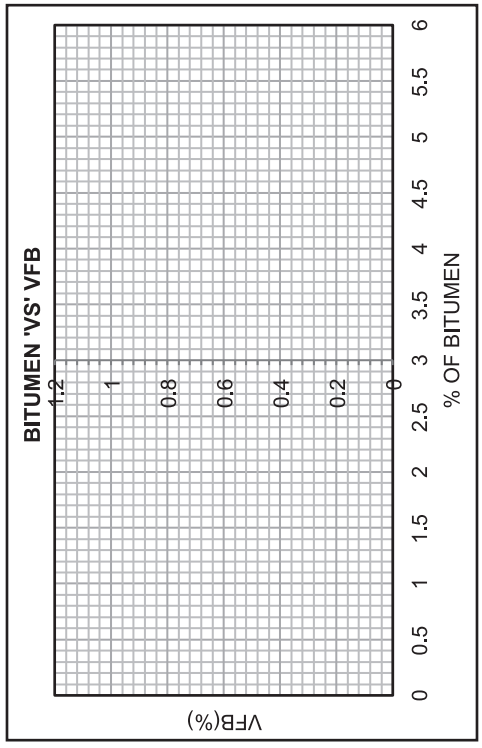
Marshal Test Results					
Bitumen Content (%)	**Stability (kN)**	**Flow (mm)**	**Air Voids V_a (%)**	**VMA (%)**	**VFB (%)**

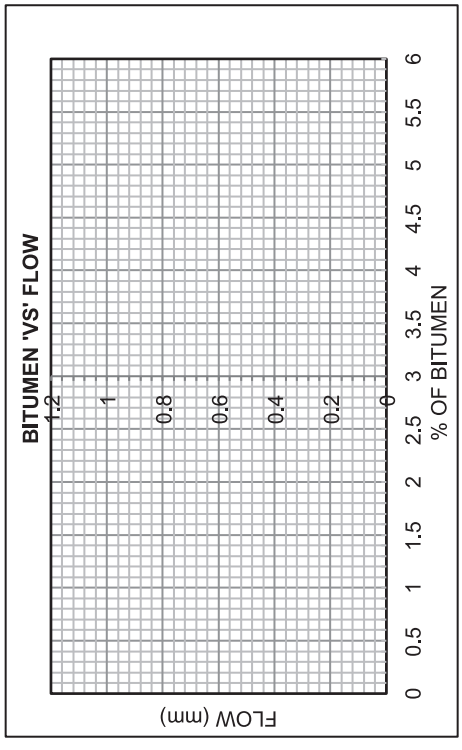
MARSHALL CURVES

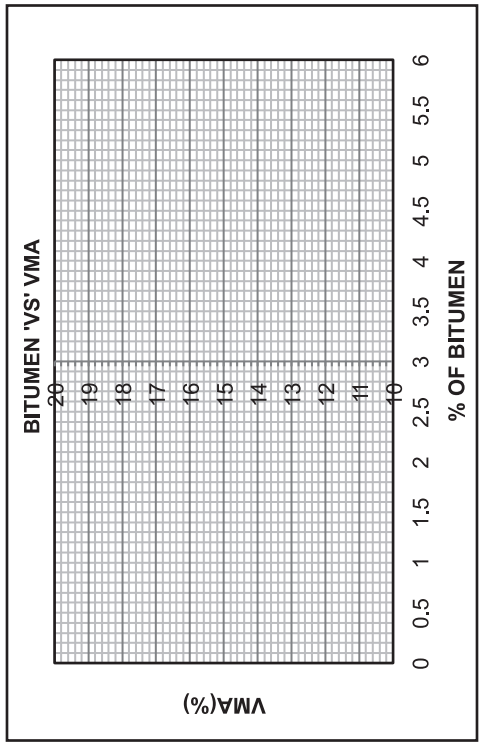





BITUMEN 'VS' VOIDS
VOIDS(%)
% OF BITUMEN
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
0 1 2 3 4 5 6 7 8 9 10


BITUMEN 'VS' VFB
VFB(%)
% OF BITUMEN
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
0 0.2 0.4 0.6 0.8 1 1.2


BITUMEN 'VS' FLOW
FLOW (mm)
% OF BITUMEN
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
0 0.2 0.4 0.6 0.8 1 1.2


BITUMEN 'VS' VMA
VMA(%)
% OF BITUMEN
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
10 11 12 13 14 15 16 17 18 19 20

Narrow Range Acceptable Limit						
Stability						
Flow						
Density						
Air Voids						
VFB						
VMA						
3.50%	**4.00%**	**4.50%**	**5.00%**	**5.50%**	**6.00%**	**6.50%**
% of Bitumen						

Final Optimum Bitumen Content (Narrow Strip Method)

Bitumen % @ Max Stability	=	Properties of Mix at Average Bitumen Content of %		Specific Limits
Bitumen % @ Max Density	=	Stability (Kg)	=	
		Density (g/cc)	=	
		Air Voids (%)	=	
Bitumen % @ 4% voids	=	V.F.B (%)	=	
		V.M.A (%)	=	
Average (%)	=	Flow (mm)	=	

Remarks:

Prepared by **Checked by** **Approved by**

CORE TEST							
LOCATION : DATE SAMPLED : DATE TESTED : Material Description : DBM/AC							
Density Determination	**Core**	**JMF dens**					
SAMPLE NO.	**UNIT**	**1**	**2**	**3**	**4**	**5**	**6**
1. Core no.							
2. Core chainage	Km						
3. Core Thickness	mm						
4. Wt. in air	Gms						
5. Wt. in water	Gm						
6. Volume	cc						
7. Density	Gm/cc						
8. Compaction (Core)	%						
Remarks:							
Prepared by **Checked by** **Approved by**							

*JMF: Job Mix Formula

Category C: Testing proforma C-42

FIELD DENSITY TEST BY CORE CUTTER METHOD

Reduced level : Bulk Density : gm/cc		Layer No. Layer Thickness			MDD = gm/cc OMC = %		
No.	**CHAINAGE**	**Unit**	**1**	**2**	**3**	**4**	**5**
1	Mass of mould+Compacted soil	Gms					
2	Mass of mould	Gms					
3	Mass of compacted soil (2-1)	Gms					
4	Volume of mould	CC					
5	Wet Density of soil (3/4)	Gms/CC					
	Moisture Determination	-					
6	Wt. Wet soil	Gms					
7	Wt. Dry soil	Gms					
8	Wt. Water (6)-(7)	Gms					
9	Moisture content (8)/(7)x100	%					
10	Field Dry density of soil (5)/1+(9)/100	Gms/CC					
Degree of compaction (10/MDD x 100)		%					

Average degree of Compaction :

Standard Deviation :

REMARKS:

Prepared by **Checked by** **Approved by**

BENKELMAN BEAM DEFLECTION (BBD) SURVEY

Section/Location of Lab : No of Traffic lanes : Date of Test :

Section : Climatic Condition :

Chainage (km) of Test Point	Location of Lane (LHS/RHS)	Temperature °C		Type of Soil & PI	Subgrade Moisture (%)	Dial Gauge Readings					Differential Reading (mm)	Differential Reading (mm)	True Deflection (mm)	Temp Correction	Moisture content Correction	Corrected Deflection (mm)	Mean Deflection (mm)	Standard Deviation	Characteristic Deflection (mm)
		Ambient	Pavement			Do	Di	Df	Do-Di	Do-Df									

Remarks:

Prepared by **Checked by** **Approved by**

Note: Kindly Highlight the NMC chainage with Bold for reference

Category C: Testing proforma C-44

PAVEMENT ROUGHNESS SURVEY USING BUMP INTEGRATOR

Name of the Project :

No. of Lanes : Date :

Climatic Condition : Vehicle Speed :32 ± 0.5 km per hr.

Carriageway Surface : Tyre Pressure: 30 Psi

Chainage (km)		Distance (m)	Bump Integrator Reading (No. of Bumps in cm)					Corrected Unevenness Index (UI in mm/km)		Remarks
From	To		LHS		RHS		Average	For Two Lane	Mean Value	
			Trial-1	Trial-2	Trial-3	Trial-4				

Specifications: Vehicle operating speed shall be 32 +/- 0.5 kmph and tyre pressure shall be 2.1kg/cm^2 or 30lb/sq.in

Observed Roughness or UI (mm/Km) = BI Counter Reading (Cm) X 10 X Distance Reading per Km/ Distance Counter Reading in Test Length

Calibration Equation from CRRI: [Y = 1.1529 (X) + 3.0188]; where Y is Calibrated roughness in mm/km and X is the observed roughness with ARUR (No. STECO-94) in mm/km

Remarks

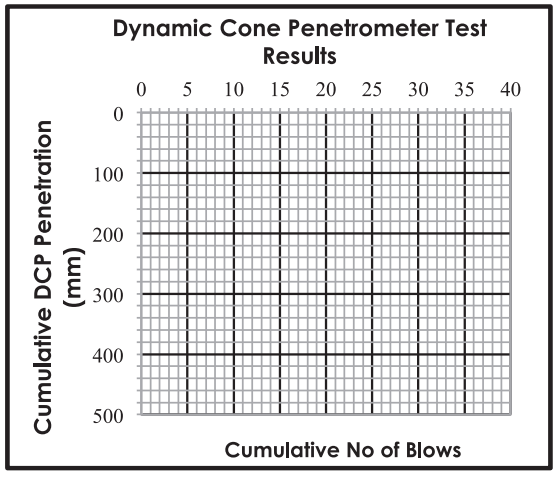
Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-45

DYNAMIC CONE PENETROMETER TEST
(PAVEMENT DCP)

Section/Location of Lab	:
Location	:
Date of Testing	:
Angle of Cone Used in Test	: 60°

No of Blows	Cumulative No of Blows	Scale Reading (mm)	Penetration (mm)	Cumulative Penetration (mm)



Rate of Penetration Per Blow in mm for 1st layer =				
Rate of Penetration Per Blow in mm for 2nd layer =				
CBR From Correlation Curves for 60-degree cone (%):				
For 1st layer				
For 2nd layer				

Remarks:

Prepared by **Checked by** **Approved by**

Category C: Testing proforma C-46

DETERMINATION OF DRY DENSITY OF SOIL IN-PLACE (SAND REPLACEMENT METHOD)
AS PER IS:2720-PART 29

Source/Location of Lab:

Material Source Details

1	Borrow area Name/ Pit No /Any other Reference	Date:
2	Optimum Moisture Content (OMC) % :	MDD. (g/cc):

Pre-Test Data

1	Chainage of Stretch (From Km - To Km)
2	Layer No:
3	Bulk Density of Sand, g_s (g/cc)
4	Weight of sand in Cone w_3 (grams from lab)

Field Density Determination

Sl. No.	Description	Unit	Observations at Pit Location					
1	Chainage & Pit location	g						
2	Weight of wet soil from hole W	g						
3	Weight of sand with cylinder before pouring (W_1)	g						
4	Weight of sand with cylinder after pouring (W_2)	g						
5	Weight of sand in hole (W_s=W_1-W_2-W_3)	g						
6	Volume of the hole V = W_s/g_s	g						
7	Bulk Density of Soil g_{bulk} = (W/V)	g/cm^3						
Moisture Content Determination								
1	Container No.	-						
2	Weight of Container (W_4)	gms						
3	Wt. of Container + wet soil (W_5)	gms						
4	Weight of Container + dry Soil (W_6)	gms						
5	Moisture Content 'w' = (W_5-W_6)/(W_6-W_4) x100	%						
Test Results								
1	Dry Density g_d= g_{bulk}/(1+w/100)	g/cm^3						
2	Percentage Compaction= (g_d/MDD) x 100	-						
3	Mean Density (g/cc)							
4	Compaction Density Required (g/cc) (97% of MDD)							
5	Standard Deviation, SD							
6	Acceptance Criteria {Mean > Required Compaction+ [1.65- (1.65/(No of Samples)$^{0.5}$] x SD}							

Remarks

Prepared by **Checked by** **Approved by**

FALLING WEIGHT DEFLECTORMETER
(IRC:115-2014)

No. of Lanes & Carriageway Type: Date of Testing:

Location/Homogenous Section: Chainage:

From: To:

Sl. No.	Lane Position	Location of test point		Peak Normalized Deflection (mm) observed at a radial distance (mm) of							Back calculated Moduli (Mpa)			Corrected Back Calculated Moduli (Mpa)			Remarks
		Chainage	Distance from Carriage way edge (m)	0	300	600	900	1200	1500	1800	Bituminous Layer	Granular Layer	Subgrade	Bituminous Layer	Granular Layer	Subgrade	

Remarks

Prepared by **Checked by** **Approved by**

Category D: Calibration Proforma D-1

CALIBRATION CHART OF BATCHING FOR AGGREGATE GUAGE

CALIBRATED DATE:

LOAD APPLIED (KG)	DIAL GUAGE READINGS						
	TRIAL-1		TRIAL-2		TRIAL-3		AVERAGE
	LOADING	UNLOADING	LOADING	UNLOADING	LOADING	UNLOADING	
0							
50							
100							
150							
200							
250							
300							
350							
400							
450							
500							
550							
600							
650							
700							
750							
800							
850							
900							
950							
1000							
1050							
1100							
1150							

REMARKS:

For Contractor **For Engineer**

Category D: Calibration Proforma D-2

CALIBRATION CHART OF BATCHING PLANT FOR WATER METER

CALIBRATED DATE:

SL. NO.	TRIAL-1		TRIAL-2		TRAIL-3		AVERAGE
	METRE READING (LTRS)	WATER MEASURED (LTRS)	METRE READING (LTRS)	WATER MEASURED (LTRS)	METRE READING (LTRS)	WATER MEASURED (LTRS)	
1	10		10		10		
2	20		20		20		
3	30		30		30		
4	40		40		40		
5	50		50		50		
6	60		60		60		
7	70		70		70		
8	80		80		80		
9	90		90		90		
10	100		100		100		
11	110		110		110		
12	120		120		120		
13	130		130		130		
14	140		140		140		
15	150		150		150		

REMARKS:

For Contractor **For Engineer**

Category D: Calibration Proforma D-3

CALIBRATION CHART OF BATCHING FOR CEMENT GUAGE

CALIBRATED DATE:

DIAL GUAGE READINGS							
LOAD APPLIED (KG)	TRIAL-1		TRIAL-2		TRAIL-3		AVERAGE
	LOADING	UNLOADING	LOADING	UNLOADING	LOADING	UNLOADING	
0							
50							
100							
150							
200							
250							
300							
350							
400							
450							
500							
550							
600							
650							
700							
750							
800							
850							
900							
950							
1000							
1050							
1100							
1150							

REMARKS:

For Contractor **For Engineer**

Category D: Calibration Proforma D-4

CALIBRATION REPORT
(CUBE TESTING MACHINE)

DATE OF CALIBRATION :

TEMP. :

GAUGE NO. :

CAPACITY :

EQUIPMENT :

MODEL :

FORCE MEASURING DEVICE :

SL. NO. :

CERTIFIED BY :

PLACE :

REF :

SL. NO.	DEFLECTION IN DIAL GAUGE IN PROVING RING	ACTUAL LOAD APPLIED	AVERAGE OF THREE READING	INDICATED LOAD IN GAUGE ERROR
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

NOTE: To obtain correct result positive (+) error to be subtracted, negative (-) error to be added to the indicated load readings on machine gauges.

For Contractor **For Engineer**

Category E: Surveillance Proforma E-1

MATERIAL QUALITY SURVEILLANCE FORM

Contractor	Contract No.	
Manufacturer/supplier/ Source	Purchase order	Inspecting Agency

Inspected at	Inspection Certificate	Delivery Challan	Distinguishing Mark	Date of MFR. /supply

Shipping storage and other Remarks	(Satisfactory/Not satisfactory)

TEST RECORD

Sl. No	Test	Method of test	Acceptance range	Obtained value	Remarks

Remarks:

Inspected by: **Name:** **Signed:** **Date:**
(For QA Engineer)

In presence of: **Name:** **Signed:** **Date:**
(For Contractor)

Category E: Surveillance Proforma E-2

PRODUCTS QUALITY SURVEILLANCE FORM

NAME OF PRODUCT:

Contractor		Contract to	
Manufacturer/supplier/ Source		Purchase order	Inspecting Agency
Inspection certificate	Delivery challan	Distinguishing mark	Date of manufacture /supply
Drawing Nos.			Tender specification clause

Shipping storage and other Remarks

Sl. no	Test	Method of test	Acceptance range	Obtained value	Remarks

Inspected by: **Name:** **Signed:** **Date:**
(For QA Engineer)

In presence of: **Name:** **Signed:** **Date:**
(For Contractor)

Category E: Surveillance Proforma E-3

SURVEILLANCE FORM FOR PRE-CONCRETING OPERATIONS

CONTRACTOR		CONTRACT NO.
ELEMENTS OF STRUCTURE	IDENTIFICATION NO.	LOCATION

SURVEILLANCE OBSERVATIONS

WORK DESCRIPTION	
1	Line, level and Dimension as per Drg
2	Availability of adequate Approved material
3	Placing of reinforcement (Including supports/spacers etc.)
4	Formworks and scaffolding as per drawing
5	Box outs/embedded parts, if any
6	Cleaning of forms
7	Arrangements of plant & equipment
8	Walkway for pouring and inspections
9	Safety arrangements
10	Curing arrangement

Inspected by: (For QA Engineer)	**Name:**	**Signed:**	**Date:**
In presence of: (For Contractor)	**Name:**	**Signed:**	**Date:**

Category E: Surveillance Proforma E-4

QUALITY SURVEILLANCE FORM FOR WORKMANSHIP OF CONCRETE

CONTRACTOR		CONTRACT NO.
ELEMENTS OF STRUCTURE	IDENTIFICATION NO.	LOCATION

SURVEILLANCE OBSERVATIONS

The following items should be observed during concrete pour by the QA surveillance team.

(1) Mixing of concrete

- Check the concrete class and the respective mix design already approved.
- Check the condition of aggregates to be used.
- Check the weighing and water dispensing methods adopted during the mixing.
- Check that the mixer machine has been cleaned properly.
- Check that the required mixing time is allowed.

(2) Transportation/conveyance (as specified, but generally to cover following)

- Check if the equipment is in proper working order.
- Check if the specified methods are being followed.
- Check if the stipulated time limits are observed.
- Check if the non-conforming wet concrete is being rejected and disposed off.

(3) Placing of concrete
Check that:

- The concrete is not segregated during pour. The height of dropping is controlled.
- The concrete is poured in layers.
- The vibrators are being applied systematically to compact uniformly and adequately, avoiding over vibration.
- The concrete is not being pulled or pushed. Pouring is being done lose to the final position.
- The cold joints are not allowed to be developed.
- The underwater concrete is being poured only by tremies or pipeline.
- The forms are not getting displaced or deformed during the concrete pour and vibrating.
- No cement slurry is getting lost. Suitable numbers of carpenters are present to watch and repair formwork during pour, if required.
- The concrete is being poured within the allowable time limits from the time of batching.
- The concrete cubes are taken as required.

- The curing arrangements are satisfactory.
- The equipment is in working condition.
- The equipment is cleaned properly.
- The quality of wet concrete is as per specifications (slump, homogenous mix etc.)
- Continuous supply of concrete is assured.

Inspected by: **(For QA Engineer)**	**Name:**	**Signed:**	**Date:**
In presence of: **(For Contractor)**	**Name:**	**Signed:**	**Date:**

Category E: Surveillance Proforma E-5

SURVEILLANCE FORM FOR PAVEMENT LAYERS

SURVEILLANCE OBSERVATIONS

PAVEMENT LAYER DESIGNATION	LAYER NO./REQUIRED LEVEL	LOCATION
Materials/Workmanship **Earth works/Granular sub-base** 1. Check material is from approved borrow 2. Free from roots and other perishable material 3. Grading is acceptable 4. Spread layer thickness is acceptable 5. Moisture is near optimum prior to compaction 6. Lines/levels are within tolerance **Equipments** Check 1. Adequate for the work 2. In condition	**Wet mix macadam** 1. Conforms to job mix formula 2. Free from deleterious materials 3. Spread layer thickness is acceptable 4. Moisture is near optimum prior to compaction 5. No segregation during transport 6. No segregation during paving 7. Lines and levels within tolerance **Equipments** Check 1. Adequate for the work 2. In condition	**Asphalt** 1. Conforms to job mix formula 2. Free from deleterious materials 3. Spread layer thickness is acceptable 4. Temperature at break down rolling is within specs 5. No segregation during transport 6. No segregation during paving 7. Lines and levels within tolerance **Equipments** Check 1. Adequate for the work 2. In condition

Inspected by: **Name:** **Signed:** **Date:**
(For QA Engineer)

In presence of: **Name:** **Signed:** **Date:**
(For Contractor)

Category F: Proforma for Registers and Records F-1

PARTICULARS OF WORK

Name of work :

Name of contractor :

Address of contractor :

Contract agreement no. :

Contract amount :

Applicable schedule of rates :

Period of Completion :

Date of Work order :

Stipulated date of completion :

Actual date of starting of work :

Extensions

(1) _____

(2) _____

INCUMBANCY

Sl. No	Designation*	Name	Period	
			From	To

*Departmental officers' designations covering all officers having execution responsibilities for the project

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-2

REGISTER OF DRAWINGS

Name of work :

Name of contractor :

1. Receipt of drawings

Sl. No	Drawing No./ Date	Revision No	Brief title	Issued by/ (source)	Date of receipt	No. of copies	Status of drgs	Further action	Signature and date

2. Issue of drawings

Sl. No	Drawing No./ Date	Revision No	Brief title	Sl.no of receipt register	Issued to	No. of copies	Status of drgs	Drg supersedes Drg no (if any)	Signature

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-3

CEMENT REGISTER

1. Weekly Receipt Issue (For week from_____to_____)

Name of Work :

Name of Contractor:

Closing Balance at the Site of Work from

Previous week_____bags.

Date	Quantity Received Bags/MT Source	Qnty. Used Bags/ MT	Purpose	Closing balance at the end of day (bags/MT)
Total				

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

CONSUMPTION OF CEMENT ON DIFFERENT ITEMS OF WORKS
(THEORETICAL AND ACTUAL)

Name of work :

Name of contractor :

(A) Weekly record of items of works

Sl. No	Item of work	Quantity of work done during the week

(B) Abstract for the week ending : (Indicate cement consumption)

S. No.	Item of work	Quantity of work done		Rate of cement per unit (Bags/MT)	Cement required to be consumed theoretically (Bags/MT)	Actual Cement consumed (Bags/MT)
		Quantity	Unit			

For Contractor

Name :

Signed : Date:

For Engineer

Name :

Signed : Date:

Category F: Proforma for Registers and Records F-5

RECORDS OF CALIBRATION OF EQUIPMENT

Name of Work :

Name of Contractor :

ITEM	DATE CALIBRATED & PERSON CERTIFYING(FOR VENDOR OR CONTRACTOR)	*DATE OF NEXT CALIBRATION	DATE OF INSPECTION & PERSON APPROVING (FOR DEPARTMENT)	RESULT OF INSPECTIONS

*Frequency of calibration for different equipment to be specified in advance.

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-6

DAILY PROGRESS REPORT

Name of Work :

Name of Contractor :

Date	Activity Location	Item of work	Weather Condition	Special problems/ Difficulties	Remarks	Signature with date	
						Recorded	Checked

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-7

REGISTER OF INSPECTION NOTES

Name of Work :

Name of Contractor :

No. of Inspection Note	No. and date under which received	Reviewed by	Signature	Number & date of compliance submitted	Reviewed by	Signature	Remarks

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-8

REGISTER OF OBSERVATIONS MEMOS ISSUED FROM THE QUALITY CONTROL CELL

Name of Work :

Name of Contractor :

Year	Observation Memo No.	No. and date under which received	Reviewed by	Signature	Number & date of compliance submitted	Reviewed by	Signature	Remarks

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-9

BITUMEN REGISTER

1. Weekly Receipt/Issue (For week from _____ to _____)

Name of Work :

Name of Contractor :

Closing Balance at site of work :

Previous week _____ MT/Packs

Date	Quantity Received		Source	Quantity used MT	Purpose	Closing Balance at the end of day (Packs/MT)
	MT	Grade				
Total						

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-10

RECORD OF PRESTRESSING WORK

1. Name of work :
2. Name of contractor :
3. Span length :
   (indicate avg cube strength at 7 and 28 days as per design)
4. Span number :
5. Name and number of component :
6. Date of Casting :_____
7. Gauge pressure not to exceed : _____

Date of pre-stressing	No. of cable or wire or pair of wires	Side …….				
		Gauge Reading	Initial extension in mm	Locking pressure	Slip observed in mm	Final Extension
1	2	3(i)	3(ii)	3(iii)	3(iv)	3(v)

Guage reading	Side …….				Total final extension in mm	Calculated extension in mm for an initial pull per cable/wire/ pair of wire
	Initial extension in mm	Locking pressure	Slip observed in mm	Final Extension		
4(i)	4(ii)	4(iii)	4(iv)	4(v)	5	6

Theoretical Extension required in mm	Losses or gain Extension in mm	Progressive Loss or gain Extension in mm	Slip observed, if any, after 10 days	Remarks	Signatures		
					AE	EE	Contractors Representative
7	8	9	10	11	12(i)	12(ii)	12(iii)

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-11

GROUTING RECORD

Name of the work :

Name of Contractor : Cable No. :

Span No. : Date of Grouting :

Date of Cable Installation :

Type of Cement OPC/IISOPC :

Week & Year of Manufacture of OPC/IISOPC :

W/C Ratio :

Name & Amount of admixture used, if any :

Temp : Mixing Water _____ Grout _____

Time : Start _____ Finish _____

Equipment : Grout Mixer _____ Grout Pump _____

Cable Duct : Diameter _____ Length _____

Volume of Grout in liters _____ Regrouting _____

Grouting pressure _____

Cement consumption Theoretical _____ Actual _____

Pre-grouting checks:

Free of blockage Inlet : Yes/No Outlet : Yes/No

Vents : Yes/No Cable duct : Yes/No

Leakage observed Yes/No Sealed : Yes/No

If cable duct blocked: Remedial measures _____

Grouting observations :

Passage of grout through vents : Yes/No

Passage of grout through outlet : Yes/No

Any equipment failure Post grouting checks : _____

Probing by stiff wire : _____

Remarks : _____

Signatures of officers present during grouting

For Contractor For Engineer

Name : Name :

Signed : Date: Signed : Date:

Category F: Proforma for Registers and Records F-12

PROFORMA FOR RESULT ANALYSIS (CEMENT)

Name of work :

Name of contractor :

Type of Cement : Grade of Cement :

S. No.	Consignment No./Date	Sample Reference No./ Date	Results of Chemical Test C3A, Etc.	Results of physical test (Fineness, Strength etc.)	Results of special tests, if any
No. of samples Mean Standard Deviation Range					
Remarks:					

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

Category F: Proforma for Registers and Records F-13

PROFORMA FOR RESULT ANALYSIS (CONCRETE)

Name of work :

Name of contractor :

Type of Cement : Grade of Cement :

Sl. No.	Sample Ref No.	Structure Element	Wet Concrete properties		Hardened Concrete Properties Strength at age in days		
			Temp	Slump	3 days	7 days	28 days
No. of sample Mean Standard Deviation Range Comments							

For Contractor

Name :

Signed :

Date:

For Engineer

Name :

Signed :

Date:

SECTION 9

DOCUMENTATION AND COMMUNICATION

9.1 Introduction

During implementation and upon completion of a road project, several documents are required to be prepared. Communication among Authority/Employer, Engineer and Concessionaire/ Contractor is a part of operational requirements of a Contract. The interaction takes places on issues like project execution, progress reporting, quality of works, invoicing, revised plans, change of scope, statutory and regulatory requirements as per Contract and any other requirements of Authority/Employer, Engineer and Concessionaire/Contractor.

9.2 General Principles of Documentation and Communication

9.2.1 *Overview of documentation*

Documentation is involved in the process of planning, design, reviews, procurement, storage & issue of materials, plant and machinery operations, changes, amendments, approvals, subcontracting, payment, accounting and control of obsolete documents. It also includes methods of controlling records, which are generated as a part of Quality Management System during project implementation. All the stakeholders shall ensure that the documents are legible, readily available and retrievable at alter date.

9.2.2 *Overview of communication practices*

Communication practices should be such that there is quick and objective interaction among all stake-holders for the day-to-day needs. For this purpose, e-tools may be the preferred option for the communication. The internal and external communication needs are required to be identified with respect to what will be communicated, when, with whom and how- related to all aspects of project implementation including total quality management of the project.

9.2.3 *Requirement of Digital Technology in documentation*

Document digitization is the process of converting manual documents into digital formats. In the process of document digitization, any type of document like text, images and videos are digitized and converted into digital formats such as .txt, .html, .xml, .pdf, .doc, .xls, .gif, .jpeg or .tif. Some of the advantages of digitization are perpetual preservation of vulnerable physical documents, quick and easy retrieval, easy access and easy to share.

All original records must be examined for their digitization suitability prior to the digitization process. This process will determine the extent of preparation required and ensure that successful images are obtained from the digitization process

9.2.4 *Requirement of E-Tools in communication*

E-Tools or electronic tools imply the application of modern ICT (Information and Communication Technology) tools to automate certain tasks. E-Tools is a generic term, which covers usage of a combination of computer hardware, software, communication tools and technologies for

a specific purpose or application. Key benefits of E-Tools are:

- Better quality, speed and effective flow of information.
- Improved accuracy and consistency of documentation.
- Paperless interaction – environment friendly.
- Builds transparency and accountability at all levels.

E-Tools should be preferred and used for communication as far as possible.

9.3 Guidelines for establishing mechanism for documentation

9.3.1 *Project preparation*

During the course of DPR preparation, several discussions are made at site as well as office, which impact different aspects of the project. Both Authority and Consultant shall maintain records of all such discussions/meetings and related communication held for finalization of the alignment and various provisions/components of the project in a systematic and chronological manner. All volumes/parts forming part of DPR shall have proper index and the main report shall contain consolidated index of all volumes/parts. All revisions to DPR/ any particular part of it shall be properly identified and a table inserted in the main report chronicling each revision. The soft and hard copies of various reports (like DPRs, Feasibility Reports, LA plans) submitted by the Consultant shall be maintained at the site office of Authority.

9.3.2 *Construction*

(i) **Drawings, Specifications, Work related documents:** The issuing authority should maintain the records of drawings/documents giving information about reference number, revision, reference, title, date of issue, to whom issued, number of copies issued, status of issue, date of approval, purpose of issue etc. Receiving officer to whom documents are issued at site should maintain similar record.

(ii) **Inspection Proforma:** These are used for the purpose of seeking approvals from the 'Engineer or his representative' before commencing any operation, such as, pour cards for concrete, approval to reinforcement, approval to formwork, approval to setting out, approval to pre-stressing, approval to grouting, etc. These are usually supplemented by standard checklists which have to be verified by the 'Engineer' and after he is satisfied about contents, approval is then accorded on that form.

(iii) **Test Results:** The results of day-to-day tests carried out in accordance with the requirements or specifications should be recorded in the prescribed Proforma. The Proforma are usually maintained in two forms - one for recording the observations during each test and calculation of quality characteristics. The second is for recording the summary of test results to facilitate later analysis.

(iv) **Method Statements:** The method statements give a detailed proposal of the constructing agency for carrying out each and every activity in the

Project. These are written in form of various steps in a particular sequence supplemented by suitable sketches to be self-explanatory. These method statements shall be approved by Engineer prior to implementation.

(v) **Daily Dairy of Work and Quantity Records:** Records are required to be maintained at site for the day-to-day operations, activities and events taking place at the site of work, such as equipment deployed, manpower deployed, activities carried out, different types of materials consumed, detailed observations of the activities at site (foundation strata, tilts, shifts, etc.), visits by senior level engineers and follow-up of their instructions. These records will enable preparation of the completion report as well as investigation of any unusual observations, which come to notice afterward.

(vi) **Non-conforming Products:** Detailed statements have to be prepared describing the procedures to be followed as soon as any result not conforming to the requirements is obtained. Such statements include the (a) procedures to be adopted for rectification of a particular component where such result has been noticed, (b) the long term corrective action, (c) immediate preventive action in other similarly affected activities till the long term corrective actions are implemented and (d) dismantling/removal/disposal of unsuitable components/materials.

For the quality of the finished work, it is necessary for the materials and workmanship to fully comply with the work requirement.

Special situations may, however, arise where non-conformance may only be known after sometime e.g., strength of concrete 28 days after casting. Separate recall procedures should be laid out for dealing with such non-conforming situations.

(vii) **Quality Audit Records:** The audit programme shall assign qualified personnel to perform such audits and define the frequency and procedure of audit. The method of reporting the findings and recommendations and the means for corrective actions shall be documented.

(viii) **Mechanism** shall also be developed for recording and maintaining documents with regards to other aspects of construction such as procurement, storage and issue of materials, operation of plant and machinery, payment, accounting, approvals, traffic diversion, safety and environmental safeguards measures etc.

9.3.3 *After Construction*

a) The As-built drawings/plans:

The conditions of Contract/Concession Agreement provide all information and the required content of “As-built Drawings”, and responsibilities for their preparation. It is the Contractor’s/Concessionaire’s responsibility to prepare the As-built Drawings. The Engineer must supervise, monitor, and check the preparation of the As-built Drawings. The preparation of these drawings must be performed during the course of the works and must not be left until

"substantial completion" to commence. As the works are completed they are to be surveyed / measured and the drawings prepared.

b) Final Completion report

Although final documentation is to be submitted on completion of a section / mile stone and/or at the end of Contract, they have to be prepared as work progresses, and finalized when works near completion.

9.3.4 *Operation*

Records of all the maintenance activities carried out during Operation Period should be prepared by the Contractor and checked by the Engineer. A copy of such records should be maintained at site office of Authority.

9.4 Guidelines for security/authentication of documents

The documents need to be authenticated by Engineer. The authenticated documents should be kept under the safe custody of site office of Authority after completion of the work.

9.5 Sample formats for communication

9.5.1 *Request for Inspection Form (RFI)*

The Concessionaire/Contractor shall submit Request for Inspection Form (RFI) to the Engineer in advance. A sample of the RFI is given in **Annexure 9.1**.

9.5.2 *Forms for Reports and Records*

Sample forms for Reports and Records are in **Annexure 9.2**.

REQUEST FOR INSPECTION FORM

Package _____ Section _____ Contractor _____

Activity Location	Chainage	Item	Activity Description	Schedule		Inspection Result/Remarks
				Date	Time	

Requested by: _____ _____

Contractor Date/Time

Comments:

_____

_____

_____

_____

_____

Notes:

1. Contractor to submit the Request by minimum of 48 hours in advance of work requirements.
2. Engineer to return approved or disapproved original and one copy to the contractor before the work proceeds.

Request to begin activity is:
APPROVED/DISAPPROVED
Name :
Designation:
Signature :
Date:

Annexure 9.2
FORM II-1

DRAWING ISSUE FORM

Sheet No. of

		DATE OF ISSUE											
		Day											
		Month											
		Year											
DRAWING TITLE	DRAWING NO.	DRAWING REVISION NO.											
NO. OF DRAWINGS ISSUED TO:													
Legend		Client											
		Contractor											
		Site Office											
		Other											
PURPOSE OF ISSUE		Information											
		Approval											
		Comment											
		Construction											
		Other											

Attached drawings have been checked and agreed with above list

Issued by: _____ Receipt Acknowledged : _____

FORM II-2

DAILY REPORT

DATE: _____ Weather ----------A.M.

PAGE: _____ ---------- P.M.

BILL NO.

_____

ACTIVITIES (Item No., description, locations, quantity or work, etc.)
MANPOWER (Engineers, foremen, skilled laborers, operators, others)
EQUIPMENT (Type, No. working/idle)
PROBLEMS/ISSUES ENCOUNTERED (Disturbances, accidents, etc.)
REMARKS (Inspecting officers, site instructions, emergency work orders, etc.)

FOR EPC CONTRACTOR (If applicable)	FOR CONCESSIONAIRE (If applicable)	FOR ENGINEER
Name :	Name :	Name :
Designation:	Designation	Designation
Signature :	Signature :	Signature :
Date:	Date	Date

FORM II-3

INSPECTION REPORT FOR MECHANICAL PLANT /MACHINERY

Contractor _____ Package No_____

Inspection Date _____ Time _____

Plant Machine Type _____ Model No. _____

Manufacturer _____ Manufacturer date _____

General Conditions

Description	Condition O.K./Poor/Not O.K.	Remarks/Defects
Overall Appearance		
Tyres/Drums/Tracks		
Steering Brakes		
Operator/Understanding/Training		
Environmental Condition		

Specification Requirements

Spec. Clause No.	Description Specification requirement	Rating O.K./Poor/Not O.K.	Remarks/Defects

Final Recommendations:

_____

_____

_____

FOR EPC CONTRACTOR (If applicable)	FOR CONCESSIONAIRE (If applicable)	FOR ENGINEER
Name :	Name :	Name :
Designation:	Designation	Designation
Signature :	Signature :	Signature :
Date:	Date	Date

SECTION 10

STATISTICAL ANALYSIS

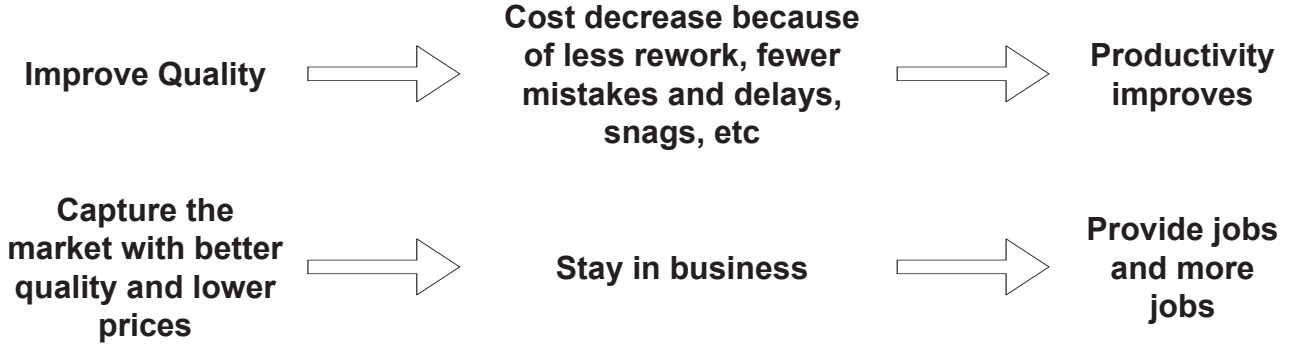
10.1 Introduction

10.1.1 *History of Statistical Quality Control*

Prior to second decade of 20th century, industrial quality control meant inspection of products and removing defective ones. Dr. Shewhart started the Process Control while working in Western Electric Company in the year 1924 and further developed it when he moved to Bell Laboratories. A physicist, engineer and statistician by profession, Dr. Shewhart is also called father of Statistical Process Control.

Shewhart framed the problem in terms of *assignable-cause* and *chance-cause* variation and introduced the control chart as a tool for distinguishing between the two. Shewhart stressed that bringing a production process into a state of statistical control, where there is only chance-cause variation, and keeping it in control, is necessary to predict future output and to manage a process economically.

The next leap in quality control was Total Quality Management, which was developed in post war Japan under the aegis of William Edwards Deming a protégée of Shewhart. Apart from his statistical prowess,it was Deming's philosophy to manage a "system" to achieve a high quality product or service that resulted in the grand success of Japanese manufacturing industry. Deming's chain reaction is given below:



The next step forward in quality management is six-sigma (6σ). A six sigma process is one in which 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects (3.4 defective features per million opportunities). Introduced by Bill Smith while working at Motorola in 1986, it was substantially developed by Jack Welch at General Electric in 1995.

The fundamental concept of six sigma process is that upper and lower specification limits (marked USL and LSL) are kept at a distance of 6σ from the mean. Because of the properties of the normal distribution, values lying that far away from the mean are extremely unlikely: approximately 1 in a billion too low, and the same too high. Even if the mean were to move

right or left by 1.5σ at some point in the future, there is still a good safety cushion. This is why Six Sigma aims to have processes where the mean is at least 6σ away from the nearest specification limit.

Specific management tools are employed in all the 3 methods mentioned above by monitoring certain statistical parameters in different stages of manufacturing.

10.1.2 Variability is a reality in road construction like any other manufacturing process. It is like a settled order of the nature. Variability occurs in materials and processes used for road construction. It also occurs in different stages of road construction, has different dimensions and impact on quality of various components of road and bridge works in different manners. Limiting the variability is a prime objective of QA Plan but variability does exist and needs to be duly accounted for while evaluating quality of a component of road and bridge works for the purpose of its acceptance. Adding to the variability of materials and processes, there is also considerable variation in the process of sampling of materials carried out for testing and actual testing of materials resulting in measurement errors. Under such circumstances, statistical analysis helps in taking informed decisions about acceptance.While the guidelines stated elsewhere in this Manual shall be followed to achieve desired quality, the quality control test results of certain materials/layers/components as specified in Section 11 of this Manual shall be subjected to statistical analysis as stated in this Section for the purpose of acceptance of the particular material/layer/component. Essentially, statistical quality control for road and bridge works relates to statistical Lot inspection of an item of work and its acceptance.

10.2 Glossary of Terms

Before proceeding with a particular method of analysis, it is necessary to understand various terms associated with statistical analysis. Whereas some of the terms are common to all methods, some are unique to a particular method. The standard definitions as given in different international codes of practice, literature are given below:

Quality Characteristics: Quality Characteristics are parameters/properties, measured values of which define the quality of a product i.e. material/layer/component with reference to its functionality, reliability, usability, efficiency, maintainability, and portability.

Attributes: Characteristics that are measured as either “acceptable” or “not acceptable” are called Attributes. Thus Attributes have only discrete, binary, or integer values.

Variables: Characteristics that are measured on a continuous scale are called Variables.

Population: Population is a set of similar items or events, which is of interest for some question or experiment in statistics.

Lot: In statistical quality control for road & bridge works, Lot represents Population. For example it may be a section of a particular layer of pavement made from same type of materials and constructed on the same day.

Sample: Sample is a set of data collected and/or selected from a Lot by a defined procedure. The elements of a Sample are known as sample points, sampling units or observations.

Sample Space: In probability theory, the Sample Space of an experiment or random trial is the set of all possible outcomes or results of that experiment.

Random Sampling: Random Sample is a subset of a statistical population (Lot) in which each member of the subset has an equal probability of being chosen. A simple Random Sample is meant to be an unbiased representation of the Lot. The process of selecting a random sample is called Random Sampling.

Mean: Mean refer to a measure of the central tendency either of a Probability Distribution or of the Random Variable characterized by that distribution.

Variance: Variance measures how far a set of numbers is spread out. The variance of a Random VariableX is the expected value of the squared deviation from the Mean.

Standard Deviation: Standard Deviation (SD, also represented by the Greek letter sigma σ or s) is a measure that is used to quantify the amount of variation or dispersion of a set of data values. The Standard Deviation of a Random Variable, Statistical Population, data set, or Probability Distribution is the square root of its Variance.

Continuous Probability Distribution: A Probability Distribution is a statistical function that describes all the possible values and likelihoods that a Random Variable can take within a given range. If a Random Variable is a Continuous Variable, its probability Distribution is called a Continuous Probability Distribution. The equation used to describe a Continuous Probability Distribution is called a probability density function (pdf). All probability density functions satisfy the conditions i.e. (i) The Random Variable Y is a function of X; that is, Y = f(X), (ii) The value of Y is greater than or equal to zero for all values of X and (iii) The total area under the curve of the function is equal to one.

Normal Distribution: The Normal Distribution is a Probability Distribution that associates the normal Random Variable *x* with acumulative probability. Physical quantities that are expected to be the sum of many independent processes (such as measurement errors) often have distributions that are nearly normal. The Probability Density of the Normal Distribution is given by:

$$f(x \mid \mu, \sigma^2) = \frac{1}{\sigma\sqrt{2\pi}}\, e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where:

μ is mean or expectation of the distribution

σ is standard deviation

σ^2 is variance

Normal Distribution curve is flatter if variation of data from mean is more and vice versa.

Standard Normal Distribution is the simplest case where Mean is 0 and Standard Deviation is 1.

Specification Limit(s): The limiting value(s) placed on a Quality Characteristic around a nominal or target value of the characteristic that may be either an individual upper or lower specification limit, USL or LSL, called a single specification limit; or USL and LSL together, called double specification limits. Specification Limits set forth in MoRT&H Specifications

for Road and Bridge Works or in applicable code of practice in respect of additional Quality Characteristics mentioned in the Section 5 of this Manual are to be considered for the purpose of acceptance.

Quality Measure: Quality Measure is a tool used in statistical acceptance of a material/ layer/component with respect to a certain Quality Characteristic. There are several quality measures such as Percent Defective (PD), Percent Within Limits (PWL), Average Absolute Deviation, Moving Average, Conformal Index etc. However PD/PWL have been preferred in recent years because they simultaneously measure both the average level and the variability in a statistically efficient way.

Percentage Within Limit (PWL): PWL is the percentage of the Lot falling above the LSL, beneath the USL, or between the LSL and USL. Conceptually, it is similar to determining the area under the normal curve bounded by LSL and/or USL. PWL is estimated using the Sample Mean and the Population/Sample Standard Deviation. PWL is also function of sample size.

Percentage Defective (PD): 100-PWL

Average Absolute Deviation: The Average Absolute Deviation (or Mean Absolute Deviation) of a data set is the average of the absolute deviations from a central point, usually Mean. It is a summary statistic of statistical dispersion or variability.

Moving Average: Moving Average (rolling average or running average) is a calculation to analyze data points by creating series of averages of different subsets of the full data set. It is also called a moving mean or rolling mean and is a type of finite impulse response filter.

Conformal Index: Conformal Index is a measure of the dispersion of a series of results around a target or specified value, expressed as the square root of the quantity obtained by summing the squares of the deviations from the target value and dividing by the number of observations. The standard deviation is a measure of precision, but the CI is a measure of exactness (accuracy) or degree of conformance with the target.

Producer's Risk: Probability of the sampling and decision plan resulting in work of a satisfactory quality being rejected.

Consumer's Risk: Probability of the sampling and decision plan resulting in work of an unsatisfactory quality being accepted.

Operating Characteristic Curve: A curve corresponding to a particular PD. The Producer may increase the probability of his work being accepted by reducing the PD. Conversely any increase in PD will increase the probability of rejection. The relationship between the probability of acceptance and PD for a particular quality control scheme is referred to as its OC curve.

10.3 Sampling and Testing

10.3.1 Statistical quality control for road works involves statistical Lot inspection and acceptance or otherwise of the Lot but not rigorous statistical process control as used in industrial quality control. Like statistical analysis for any other product, statistical analysis for road works deal with samples to draw inference about Quality Characteristic of the Population (Lot).

10.3.2 *Salient Aspects of Sampling*

Following are the important aspects of sampling:

- Sampling plan has to be prepared for each Quality Characteristic.
- The purpose of acceptance sampling is to sentence Lots i.e. not to precisely estimate the Lot quality.
- The most effective use of acceptance sampling is not to "inspect quality into the product," but rather as an audit tool to ensure that the output of a process conforms to requirements.
- When testing is destructive, there is no substitute for sampling.
- Acceptance sampling often greatly reduces the amount of inspection/testing error.
- There are risks of accepting "bad" Lots and rejecting "good" Lots.
- Acceptance sampling requires rigorous planning and documentation of the acceptance-sampling procedure.
- Variables acceptance-sampling plans assume that the distribution of the Quality Characteristic is nearly normal. Any substantial departure of the distribution of the Quality Characteristic from being normal, adversely impacts reliability of the analysis.

10.3.3 *Lot Selection*

Lot selection is very important so that statistical analysis of samples presents good approximation of the Quality Characteristics of the Lot. The following criteria shall be followed in Lot selection for road works:

- The Lot must be defined before testing commences.
- The Lot may be of any size, but is restricted to a single day's production.
- The Lot must be homogeneous with only random variation in characteristics such as density, moisture content, thickness, colour and finish.

10.3.4 *Random Sampling*

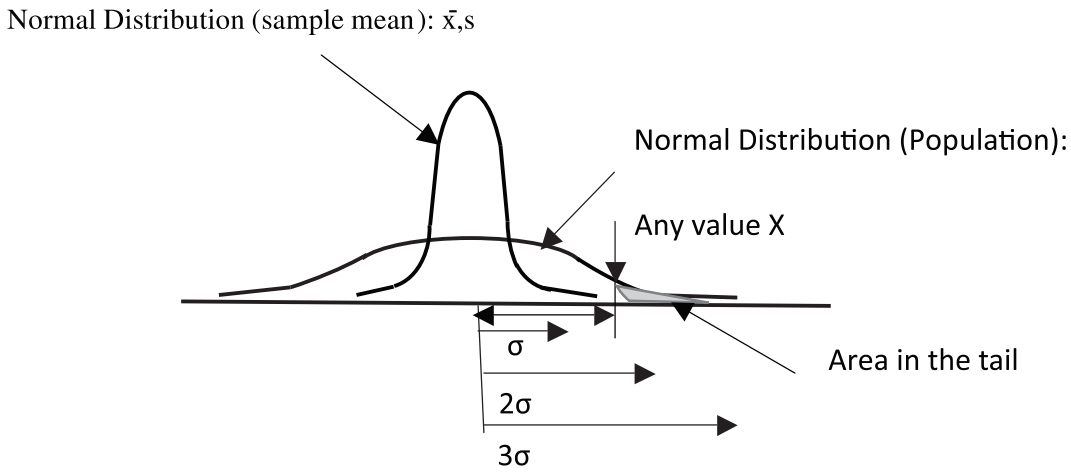
Random Sampling gives us a way to study Population characteristics without systematic bias. Random Sampling is not arbitrary sampling but there are defined ways to do it. In simple Random Sampling each possible Sample has equal probability of being drawn. Number of Samples to be taken from each Lot is specified in MoRT&H Specifications and to be followed although statistical tools are available to determine sample size for different conditions. The samples are collected in a relatively homogeneous set of conditions over time/space, which helps to separate "signal" from "noise".

10.4 Fundamental Principles of Statistical Analysis

The Bell-shaped normal probability distribution curve is symmetrical about the vertical axis. The intersection point of the vertical axis with the horizontal line asymptotic to the curve or the mid- point represents the mean ('μ'). The area of the curve is equal to unity representing probability of 1. Any value (x) of the variable can lie to the left (negative side) or right (positive

side) of the mean and its distance from the mean in terms of standard deviation (σ) represents the deviation from the mean (e.g. 1,2 or 3σ). No deviation beyond 3σ on either side is possible. The area of the curve bounded by two ordinates, representing two values, and the curve indicates the probability of the values lying between the two points (e.g. -1.6σ and +1.65σ). The area left in either of the tails beyond any ordinate indicates the probability of the variable not having a value that is greater than that value (if the ordinate is on the positive side) or less than that value (if the ordinate is on the negative side).

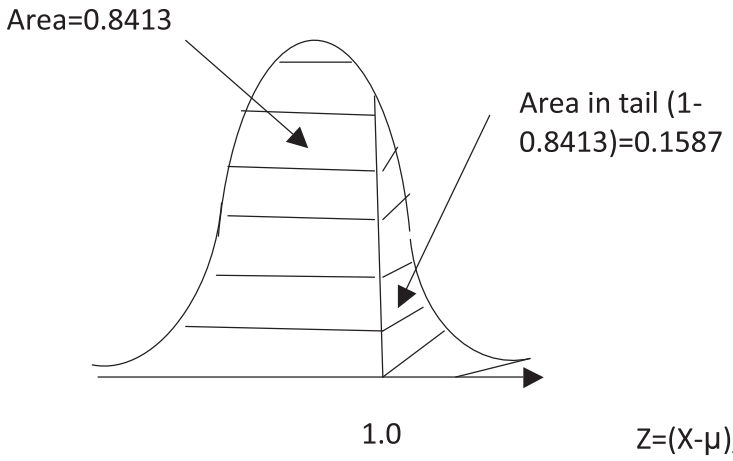
Normal distribution is represented by two parameters, mean and standard deviationμ and σ for population or x and s for samples. Larger the value of standard deviation (as in the case of population) flatter is the curve and smaller is its value (as in the case of samples), the sharper it is. (See the figure below).



Normal Distribution Curve for Population and Sample mean

Z statistic given by (x-μ)/σ is an indication of the deviation of the value of the variable from the mean. The areas bound by the ordinate at any X corresponding to the Z (or vice versa) are tabulated in standard Statistical Tables. For example, for Z=1, the area is 0.8413, which means the remaining area in the tail is 0.1587. The interpretation is that there is 84.13 per cent probability that the given value of the variable will not be exceeded and 15.87 per cent probability that it will be. If Z is equal to -1, by symmetry, it can be said that there is 84.13 per cent probability that the given value X will not fall below that value and 15.87 per cent probability that it will. If the areas in the two tails is deducted from 1, it will give the probability of the values lying between Z=+1 and -1, which in this case is 68.26 per cent.

In statistical quality control, the objective is to predict with a certain level of confidence the probability of a value of the desired variable (a) being exceeded or falling below this value, or (b) the value lying within a certain range. This confidence level in Statistics is called 'Confidence Interval'. The probability of non-occurrence of any event, as explained above is equal to the area in the tail and that is called the 'significance level' in Statistics. Two sets of values of Z, (+/-) 1.65 and (+/-) 1.96 are of special importance as these relate to 95 per cent and 97.5 per cent Confidence Interval of any value of variable being exceeded or falling below that value (ref (a) above), which is the main concern in quality control.



The Table below presents a compilation drawn from the Standard Statistical Tables of the areas under the curve and the tail for various Z and their interpretation.

Z= (x-μ)/σ	Area under the Curve for different Z (A)	Area under the tail beyon d x= μ+/-Zσ (1-A)=B	Area excluding both tails A-B= C	Probability of x not exceeding its present value= Ax1/100	Probability of x lying between the two tails (%) Cx1/100	Interpretation
+1	0.8413	0.1587	0.6826	84.13	68.26	84 % probability that x will not exceed mean plus σ, 16% probability that it can go as low as μ- σ and 68% probability that it will lie between μ +/-σ
+1.64	0.9495	0.0505	0.8990	94.95	89.90	95 % probability that x will not exceed mean plus 1.64 σ, 5 % probability that it can go as low as μ-1.64 σ and 90% probability that it will lie between μ +/- 1.64 σ
+1.96	0.9750	0.0250	0.9500	97.50	95.00	97.50 % probability that x will not exceed mean plus 1.96σ, 2.5 % probability that it can go as low as μ-1.96 σ and 95 % probability that it will lie between μ +/- 1.96 σ

+2	0.9772	0.0228	0.9544	97.72	95.44	97.7 % probability that x will not exceed mean plus 2σ, 2.23% probability that it can go as low as μ-2 σ and 95.4% probability that it will lie between μ +/- 2 σ
+3	0.9998	0.0002	0.9996	99.98	99.96	100 % probability that x will not exceed mean plus 3σ, 0.02 % probability that it can go as low as μ-3σ and 100% probability that it will lie between μ +/- 3 σ

The discussion so far has been on population mean and standard deviation, which refers to the 'lot' in this document. Samples are drawn from the lot and tested. A number of tests (say 6 or 8) are carried out on each set of sample and every set will throw up a sample mean and the sample standard deviation. How to predict the lot from these tests is the question. This problem is solved in three steps, viz.

(i) Each test, if carried out with uniform procedure, equipment and personnel, i.e. without any bias in the testing procedure, can be considered to follow a normal distribution with the sample mean (x) and sample standard deviation (s). At 95 per cent Confidence interval, it can be said that no test value can fall below 1.65 s.

(ii) It is an established statistical principle that the samples follow normal distribution with sample mean and standard deviation of s/√n. This would mean that the lowest value obtained by (i) above (mean -1.65s) can further go down by 1.65s/√n.

(iii) Thus at 95 per cent Confidence Interval the total deviation possible from the sample mean is (1.65-1.65/√n) times s. In other words, if this quantity is subtracted from the sample mean, the value obtained should be more than the value specified for quality.

Explanation: If Specification requirement is compaction to 98 per cent density and the mean of 4 tests in a set of sample comes to 99 per cent with standard deviation of 3, the predicted lot density will be 99 -1.65 (1- 1/√4) 3, i.e. 97.525, which is less than 98 and hence unacceptable. However, if the variability in the tests is low and s is equal to 1.5 the predicted density would be 98.089 and the sample would pass.

SECTION 11

ACCEPTANCE/NON CONFORMANCE/RECTIFICATION

11.1 Introduction

Any material/product/specialized item received/manufactured at site and any work carried out at site has to be finally either accepted for the work or rejected. Rejected work may however be reworked to meet acceptance process. The acceptance process typically comprises of the following steps:

i) Identification of Attribute as well as Variable Quality Characteristics for acceptance
ii) Selection of Lot
iii) Sampling
iv) Testing
v) Statistical Analysis, if applicable
vi) Acceptance/Rejection

11.1.1 The Quality Characteristics of different materials/finished products/items of work are given in different Sections of MoRT&H Specifications for Road & Bridge Works whereas some additional Quality Characteristics of factory manufactured materials; products and specialized items are detailed in **Section 5** of this Manual.

11.1.2 Guidelines for Lot selection is described in **Section 10** of this Manual. It is also prescribed in MoRT&H Specifications for Road & Bridge Works (Section 900 for road works and respective sections for structures).

11.1.3 Sample size is prescribed in MoRT&H Specifications for Road & Bridge Works (Section 900 for road works and respective sections for structures). Guidelines for Random Sampling are described in **Section 10** of this Manual. Further sampling method prescribed in respective applicable BIS/International Codes of Practice for different Quality Characteristics of different materials/works shall be strictly followed.

11.1.4 Applicable test methods for Quality Characteristics of different materials/works are prescribed in MoRT&H Specifications for Road & Bridge Works whereas additional Quality Characteristics for factory manufactured materials, products and specialized items are detailed in **Section 5** of this Manual.

11.1.5 General aspects of Statistical Analysis are given in **Section 10** of this Manual. Applicability of Statistical Analysis to various Quality Characteristics of different materials/works is given in following paragraph.

11.1.6 General principles of Acceptance/Rejection are detailed in subsequent paragraphs, which shall be followed in conjunction with applicable provisions of MoRT&H Specifications for Road & Bridge Works.

11.2 Acceptance Criteria

Once the test result on the sample of a particular material/product/work is obtained for a particular Quality Characteristic, the following procedure shall be followed to check its acceptance or otherwise. Wherever multiple Quality Characteristics are specified in MoRT&H Specifications for Road & Bridge Works/Section 5 of this Manual for a particular material/ product/work, acceptance against each Quality Characteristic shall be established for final acceptance of the material/work.

11.2.1 In respect of the following materials/works, statistical analysis procedure given in Section 10 of this Manual shall be applied for the Quality Characteristics mentioned against such materials/works.

Sl No.	Material/work	Quality Characteristic(s)	Lot Size	Sample Size (nos.)
1	Earthwork for Embankment	Compaction (Field Density)	3000 sqm but limited to single day's production	10
2	Sub-Grade, Lime Treated Soil for Sub-Grade/Sub-Base	Compaction (Field Density)	2000 sqm but limited to single day's production	10
3	Cement Treated Soil/ Cement-Fly Ash Treated Sub-Base/ Base	Compaction (Field Density)	2000 sqm but limited to single day's production	10
4	Granular Sub Base	Compaction (Field Density)	2000 sqm but limited to single day's production	5
5	Wet Mix Macadam Sub Base/Base	Compaction (Field Density)	2000 sqm but limited to single day's production	6
6	DBM & BC	Compaction (Field Density)	3000 sqm but limited to single day's production	4
		VMA	400 MT but limited to single day's production	3

11.2.2 In respect of the other Quality Characteristic(s) of the materials/works listed in Clause 11.2.1 than those mentioned there in and materials/products/works not listed in Clause 11.2.1, acceptance is established if the value of the test results of the sample is more than the specified value/less than the specified value/within tolerance limits of the specified value as applicable to the given Quality Characteristic based on MoRT&H Specifications for Road & Bridge Works.

11.2.2.1 In respect of Quality Characteristic(s) of the materials/works listed in Clause 11.2.1, acceptance is established if the mean value of all the test results of the sample is more than the specified value/less than the specified value $\pm \left(1.65 - \frac{1.65}{(\text{no. of samples})\ 0.5}\right)$ times the standard deviation (more & + if it is LSL and less & - if it is USL).

11.2.2.2 Acceptance of additional Quality Characteristics for factory manufactured materials, products and specialized items as detailed in **Section 5** of this Manual is established if the value of the test result is more than the specified value/less than the specified value/within tolerance limits of the specified value as applicable to the given Quality Characteristic based on relevant Code of Practice.

11.3 Failure to meet acceptance criteria

Whenever, a material/work does not pass acceptance criteria pursuant to Clause 11.2 of this Section for all the applicable Quality Characteristic(s) as per MoRT&H Specifications for Road & Bridge Works and additional Quality Characteristics for factory manufactured materials, products and specialized items as detailed in **Section 5** of this Manual, the following options are available:

i) Item reworked to meet acceptance criteria: The Concessionaire/Contractor may rework the material/work to alter/enhance its properties so that the reworked item meets acceptance criteria. For example an aggregate stockpile failing gradation requirement for a particular work may be mixed with aggregates of suitable size so that the blended aggregates meet final gradation requirements or a compacted granular base layer failing compaction requirement may be loosened, mixed with additional water and re-compacted to required density. This option may not be applicable to all Quality Characteristics of a particular material/work or all the materials/works. The details of materials/works to be reworked for failing in acceptance criteria of specific Quality Characteristic(s) shall be provided in Quality Assurance Plan of the Concessionaire/Contractor along with procedure for reworking. In case of Quality Characteristic(s) of a particular material/work not included in QAP, reworking can only be done by the Concessionaire/Contractor with specific approval of Construction Supervision Consultant/Independent Engineer/Authority's Engineer along with procedure/methodology thereof.

ii) Accepted with reduced pay factor: This option can be exercised only if specifically provided for in conditions of contract following the procedure specified therein.

iii) Re-graded for alternate use: This option can be exercised only if specifically provided for in conditions of contract following the procedure specified therein. For example a material rejected for main carriageway may be utilized in service road after necessary correction in properties if allowed in contract.

iv) Rejected and replaced: A material/work failing to meet acceptance criteria shall be rejected and replaced if none of the options mentioned at i, ii & iii are applicable or if the reworked material still fails to meet acceptance criteria.

Applicability of a particular option to a particular material/work other than option i & iv shall be in accordance with conditions of contract if it is specifically mentioned therein.

11.4 Protocol for dealing with non-conformance works

Whenever a material/ work is found to fail acceptance criteria, Construction Supervision Consultant/Independent Engineer/Authority's Engineer will notify the Concessionaire/

Contractor of the non-conformance. Following the notice, the Concessionaire/Contractor and Construction Supervision Consultant/Independent Engineer/Authority's Engineer shall follow the protocol as detailed below:

11.4.1 *A log shall be maintained for all the NCRs.*

11.4.2 If the QAP indicates a plan for rectification of the particular nonconformance, Concessionaire/Contractor may indicate within 2 working days from the date of receipt of non-conformance notice, its intent for rectification to the Supervision Consultant/Independent Engineer/Authority's Engineer along with plan of action and time schedule for carrying out the rectification work.

11.4.2.1 Concessionaire/Contractor will complete the physical rectification works within 10 days from the date of receipt of non-conformance notice after which the material/work will be subjected to acceptance tests as per Clause 11.2 of this Section.

11.4.2.2 Inaction on the part of the Concessionaire/Contractor pursuant to Clause 11.4.2 & 11.4.2.1 of this Section or failure of the material/work to meet acceptance criteria after rectification shall make the material/work liable for rejection unless otherwise agreed to by the Engineer before the dateline.

11.4.3 If the QAP does not indicate a plan for rectification of the particular nonconformance, Concessionaire/Contractor may still indicate within 5 working days from the date of receipt of non-conformance notice, its intent for rectification along with methodology, plan of action and time schedule for carrying out the rectification work.

11.4.3.1 Engineer shall within 5 working days from the date of receipt of the proposal from the Concessionaire/Contractor shall either accept/reject the proposal with reasons recorded in writing.

11.4.3.2 Concessionaire/Contractor will complete the physical rectification works within 10 days from the date of approval of the Supervision Consultant/Independent Engineer/ Authority's Engineer after which the material/work will be subjected to acceptance tests as per Clause 11.2 of this Section.

11.4.3.3 Rejection of the proposal of the Concessionaire/Contractor by the Engineer or inaction on the part of the Concessionaire/Contractor pursuant to Clause 11.4.3.2 of this Section or failure of the material/work to meet acceptance criteria after rectification shall make the material/work liable for rejection unless otherwise agreed to by the Engineer before the dateline.

11.4.4 All the actions taken by all the parties in relation to non-conformance works shall be properly documented.

11.5 Standard Formats

Standard formats for following actions by the Construction Supervision Consultant/ Independent Engineer/Authority's Engineer are given in **Annexure 11.1**:

i) Acceptance/Rejection

ii) NCR

iii) Acceptance on compliance to NCR

Annexure 11.1

STANDARD FORMAT FOR ACCEPTANCE/REJECTION

Project Name:

Employer/ Authority:

IE/AE/Supervision Consultant:

Concessionaire:

Contractor:

Date of execution/completion:

RFI No.

Date:

Inspected by:

Witnessed by (Name, Designation, signature):

Accepted/Rejection. (comments, if any)

Name, Designation, signature, Date

Copy

1. **File IE/AE/Supervision Consultant**
2. **Concessionaire/Contractor**
3. **Employer/Authority**

Standard Format for NCR

<table>
<tr><td colspan="4">Project Name:</td></tr>
<tr><td colspan="2">Employer / Authority
IE/AE/Supervision Consultant
Concessionaire
Contractor</td><td colspan="2">: ----------
: ----------
: ----------
: ----------</td></tr>
<tr><td colspan="4">Non Conformance Report</td></tr>
<tr><td colspan="2" rowspan="2">Inspected by :</td><td>Report</td><td></td></tr>
<tr><td>(N C R) No.</td><td></td></tr>
<tr><td colspan="2">RFI No. :</td><td colspan="2">Date :</td></tr>
<tr><td>Non Conformance:</td><td>Location:</td><td colspan="2">Details:</td></tr>
</table>

Detailed Description of Non Conformance :								
Name & Signature	NCR Category							
	1	2	3	4	5	6	7	8
Recommended Remedial Action:								
Issued by Name/ Designation / Signature						Completion Target Date:		
Copy **1 – File IE/AE/Supervision Consultant:** **2. Concessionaire** **3. Client:**								

Category:		
1. Safety Arrangements	**-**	**Minor /Major**
2. Defective Concrete works	**-**	**Minor /Major**
3. Defective Road Works	**-**	**Minor /Major**
4. Tests not conducted as specified	**-**	**Minor /Major**
5. Check lists and records not authenticated	**-**	**Minor /Major**
6. Non-compliance with specifications and standards	**-**	**Major**
7. Non-compliance with Recommendations	**-**	**Major**
8. Product not to acceptable standards. (Requires rejection).	**-**	**Major**

Standard Format for Acceptance on Compliance to NCR

Project Name :	
Employer / Authority	: ----------
IE/AE/Supervision Consultant	: ----------
Concessionaire	: ----------
Contractor	: ----------

Corrective Action Taken Report		
Inspected by :		Ref. Report (NCR) No.
RFI No. :		Date :
Non Conformance:	Location:	Details:
Detailed Description of Non Conformance :		

NCR Issued by (Name / Designation)	NCR Category							
	1	2	3	4	5	6	7	8
Remedial Action Taken :								
Witnessed by IE and Concessionaire (Name/ Designation / Signature)					Completion Date:			
Copy 1–File IE/AE/Supervision Consultant	**2. CONCESSIONAIRE**							**3.Client**
Category:								
1. Safety Arrangements	**-**				**Minor /Major**			
2. Defective Concrete works	**-**				**Minor /Major**			
3. Defective Road Works	**-**				**Minor /Major**			
4. Tests not conducted as specified	**-**				**Minor /Major**			
5. Check lists and records not authenticated	**-**				**Minor /Major**			
6. Non-compliance with specifications and standards	**-**				**Major**			
7. Non-compliance with Recommendations	**-**				**Major**			
8. Product not to acceptable standards. (Requires rejection).	**-**				**Major**			

SECTION 12

THIRD PARTY QUALITY AUDIT

12.1 Audit- Objectives and Principles

Audit is defined in ISO 9000-2005 as *"Systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which audit criteria are fulfilled".* Audit criteria and audit evidence are defined as follows:

Audit criteria: Set of policies, procedures or requirements used as a reference against which audit evidence is compared.

Audit evidence: Records, statements of fact or other information, which are relevant to the audit criteria and verifiable.

The principles of auditing should ensure that an audit is an effective and reliable tool in support of management policies and controls, by providing information on which an organization can act in order to improve its performance. The principles as outlined in ISO 19011:2011 include the following:

- Integrity
- Fair presentation
- Due professional care
- Confidentiality
- Independence
- Evidence-based approach

Scope of Audit is wide and varied. It applies to several management systems of an organization either individually or jointly. Audit is broadly classified into 3 types i.e. First Party Audit (the organization audits its own systems to measure the strengths and weaknesses of the management system against the system requirements), Second Party Audit (the customer or client audits the facilities of the organization with which it has a contract to supply goods and services) and Third Party Audit (carried out by an independent organization generally for the purpose of certification). Whereas the First Party Audit is an internal process, the Second Party Audit and Third Party Audit are external.

12.2 Third Party Quality Audit of Road Projects- General Overview

Whereas quality audit applies to several management systems of a Concessionaire/Contractor organization in implementation of a project, third party quality audit is generally carried out by an organization independent of the project implementation agencies i.e. Concessionaire/ Contractor, Supervision Consultant/IE/AE and Employer/Authority. A Third Party Quality Audit is a review by an independent entity (a separate firm/group of experts) of how well the key areas of a project quality plan is being followed and whether it's effective in getting the quality results originally envisaged. It is a value addition to the project and not just fault finding with the contractor. Normally audit scope covers safety adherence, occupational health and environmental compliance of the project apart from quality of works.

12.3 Selection of Projects for Third Party Quality Audit

Employer/Authority shall take a decision on case-to-case basis for Third Party Quality Audit of a road project depending upon its size and complexity. However, projects fulfilling any or all of the following criteria may be considered for Third Party Quality Audit:

i) Projects costing more than Rs. 1000 crore (cost of civil works at 2016 prices)

ii) Projects involving tunnel

iii) Projects involving at least one bridge having individual span length more than 100m or total bridge/viaduct length more than 2000m

iv) Projects involving cable stay/suspension cable/any other innovative bridge design

12.4 Scope of Third Party Quality Audit

Scope of Third Party Audit for a typical road project is given in **Annexure 12.1**. Scope may be modified considering complexity and special features of a particular project. If road safety auditor is engaged for a project, scope of Third Party Audit shall be suitably modified to exclude safety related issues. Third Party Quality Audit shall cover physical verification of all major items of work. Inception Report shall list all such items. The Quality Characteristics of a particular item of work and sample size for physical verification shall also be identified in Inception Report.

12.5 Audit Team

Typical composition of the TPA team and qualification and experience of the TPA team members is given in **Annexure 12.1**. Depending upon size and complexity of the project, composition of the team and qualification and experience of the members may be modified. Two requirements which are critical for meeting objective of Third Party Audit are (i) integrity of the team members and (ii) independence of the team. The bid documents for selection of consultant for TPA shall make adequate provision to prevent the experts with doubtful integrity from being selected. Further to ensure independence of audit team from any undesirable influence of the representative of [Employer/Authority] in charge of a particular project, selection of the consultant for TPA and administration of its contract shall be done by a special cell or Hqs of the Employer/Authority.

12.6 National Level Project Monitor

MoRT&H has empanelled/in the process of empanelment of some retired Govt. officers in the rank of Superintending Engineer and above as National Level Project Monitor (NLPM) to examinee issues such as inferior quality works, delay in completion, inadequate provisions in the project & poor services by the concessionaire and suggest remedial actions for them. Although exact scope of services of NLPMs shall be as per relevant guidelines/circular of MoRT&H, the aspects related to Quality Control shall be similar to what prescribed in this Section for Third Party Audit.

Annexure 12.1

STANDARD TERMS OF REFERENCE FOR THIRD PARTY QUALITY AUDIT OF HIGHWAY PROJECTS

1. Brief overview of the Project

(Give brief features of the project such as location, terrain, scope, cost, mode of contract, particulars of Employer/Authority, Concessionaire/Contractor, IE/AE)

2. The Consultancy Services ("The Services") include conducting Third Party Audit as outlined hereafter. [Employer/Authority] intends that periodic Quality Auditing are carried out by a third-party to enable the Employer/Authority assess critically the in-place quality of the project. Third Party Quality Audit is required to be carried out once every six months over a period of …..months. The audit will be comprehensive, and include examination of the quality of works executed and services carried out, compliance of road and bridge works with the technical specifications and standards described in the contract documents, compliance of social and environmental safeguards, compliance of safety requirements and furnishing of recommendations for improvements in quality of the project and project implementation as a whole.

3. Employer/Authority invites bid offers from consulting firms hereinafter to be called Third Party Auditor (TPA) to assist it in auditing quality of the project. The TPA shall include a team of qualified and experienced technical and other experts to be able to satisfactorily fulfill the objectives of the Audit.

4. Project Familiarization

The TPA should clearly understand the scope and complexities of the project by studying all contract documents including drawings, specifications, materials reports and conditions of contract. The TPA shall visit the project site to acquaint himself with the ground conditions. A report in the nature of a Project Familiarization shall be submitted within 2 months of commencing the assignment.

5. Scope of the Consultancy Services

5.1 The objectives of the Consultancy Services are to:

(i) Verify if the quality of the Works are consistent with contract conditions as well as technical specifications including compliance to the social and environmental safeguards, occupational health and safety requirements by independent assessment / audit of quality of works at various stages of construction; and,

(ii) Identify and recommend improvements to achieve the quality.

5.2 Tasks to be performed by the TPA

The TPA will undertake the following tasks but not limited to it. TPA may suggest improvement over the services mentioned here below, without any additional burden to Employer/Authority.

5.2.1 Task 1: Technical Examination of Works

a) The TPA shall verify the adequacy of the Contractor's field laboratories, plant, equipment and personnel and general fitness for purpose of such inputs, including the accuracy/calibration of testing equipment used for measurement.

b) The TPA shall review the Contractor's working practices e.g. material receipt, storing, consumption procedures, material testing, construction methods, and documentation system to assess whether sound practices are being employed to achieve quality.

c) The TPA shall review degree of quality control exercised during the construction by the Contractor (tests, numbers, frequency, approach, timing etc.) and documentation (QC registers, test reports, observations of supervisory staff, compliance etc) to assess whether the same is compliant to technical specifications.

d) The TPA shall review Contractor's plan and actual practices with respect to social and environmental safeguards, safety measures, working conditions, and employment legislation as stipulated under the contract and relevant national and state laws/regulations.

e) The TPA shall verify whether the quality of Works is in accordance with contract specifications. This verification is to be implemented through independent materials testing of at least 75% BOQ items using a sample size, which needs to be approved by the Employer/Authority. Verification shall include surface profile in case of different layers of roadway and deviations from dimensions in case of embankment, pavement and structures. The TPA shall verify actual implementation of EMP and carry out safety audit (both design and construction stage).

f) The TPA shall prepare Inspection Test Plans (ITPs), to be agreed with the Employer/Authority that set down the timetable and method for performing field inspections. The formats to be used in this assessment shall be provided in the Inception Report.

g) The TPA shall audit and assess the Supervision Consultant's/IE/AE quality control practices and documentation thereof.

h) The TPA shall under take follow up visits on a sample basis with prior intimation and approval of the Employer/Authority to verify actual compliance with previously identified quality enhancement measures and recommendations.

5.2.2 Task 2: Training

The TPA shall provide on the job training to PIU staff on quality control procedures, safety and environmental management etc.

6. The above assessments / information should be presented to the Employer/ Authority as a summary report biannually highlighting the following:

i) Quality enhancement measures

ii) Clear recommendation, if any Work is to be rejected/regraded for use

6.1 The Final Audit should commence at least six weeks before issuance of the Substantial Completion Certificate/Provisional COD is due.

7. Confidentiality

The TPA by virtue of their scope of work will come in contact with several confidential documents and their recommendations may have financial and legal implications. It is, therefore, essential that the TPA and its experts will exhibit and ensure highest sense of probity and integrity apart from knowledge and experience and maintain strict confidentiality.

8. Time frame

The TPA consultancy services will be for …….months. The expected date of commencement of Services is…….

9. Organization

The TPA should have the capability to carry out the job on its own strengths (in terms of skilled manpower, equipment, technical skills etc.) with adequate logistical support at the project location. To ensure that TPA objective is duly carried out, the Organization should have carried out at least two assignments of similar nature in the last 3 years.

10. Reporting Requirements

The TPA shall furnish its reports in soft and 3 hard copies. The TPA shall submit the following documents in pursuance of its services:

i) Inception Report (IR) containing the approach, methodology, audit/monitoring formats, etc. The report should contain a flow chart indicating the inputs / outputs by stages and type of work. The IR shall be submitted within 3 (three) weeks from the date of commencing the services. The TPA shall make a presentation to the Employer/Authority and modify the contents, if suggested by Employer/Authority.

ii) Six monthly Audit Report and draft Final Audit Report within 14 days from the date of completion of audit

iii) Final Audit Report within 21 days from the date of compliance of draft Final Audit Report findings by the Concessionaire/Contractor

iv) TPA shall make a presentation to the Employer/Authority in presence of Concessionaire/Contractor and Supervision Consultant/IE/AE.

11. Deliverables and Payment Schedule

The payment schedule will be based on the outputs delivered as shown in the following Table:

Sl. No.	Deliverable	Schedule of Submission from the start date	Payment Schedule (in % to the total Value)	Remarks
1	Inception Report	Three weeks from date of commencement of services	Nil	A mobilization advance of 10 per cent will be provided on request of TPA against Bank Guarantee
2	Six monthly Audit Reports	Within 14 days from the date of completion of audit	70% equally distributed among total half yearly periods	In case of extension of contract period, each half yearly payment to be suitably adjusted
3	Draft Final Audit Report	Within 14 days from the date of completion of audit	15%	
4	Final Audit Report	Within 21 days from the date of compliance of draft Final Audit Report findings by the Concessionaire/ Contractor	15%	

12. List of Key Experts

List of Key Experts required in the TPA team are given below along with their indicative man month for a 30 months period contract. The requirement may be modified for a particular contract keeping in view contract period, size and complexity of contract.

Position	Number	Period of deployment (months)
Team Leader cum Sr. Highway Engineer	1	10
Senior Bridge / Structural Engineer	1	3
Senior Material Engineer cum Pavement Specialist	1	3
Environmental Specialist	1	2
Road Safety Expert	1	2

13. Qualification / Experience of the Key Experts

These are senior positions calling for a very high level of probity in quality auditing. The qualification and experience requirement of key experts is given below:

Team Leader Cum Senior Highway Engineer:

The expert should be a graduate civil engineer preferably with master degree in construction management/transportation/highway engineering. Sound knowledge in construction and quality management practices is preferred. The overall experience should be more than 15 years in highway construction. He should have experience in third party quality auditing of at least 1 highway project of Rs. 200 crores magnitude at 2016 prices. Experience in having established Quality Control, Quality Management Systems in large sized highway projects will be essential. A good understanding of the contractual relationships between Concessionaire/ Contractors, Supervision Consultants/IE/AE and Employer/Authority is necessary.

Senior Bridge / Structural Engineer:

The expert should be a graduate civil engineer with master degree in structural/bridge engineering with 10 years of post- qualification experience in bridge construction/rehabilitation. Experience in quality control and quality assurance of bridge construction aspects such as foundation, formwork, launching, specialized components such as bearings, expansion joints etc. is essential.

Senior Material Engineer cum Pavement Specialist:

The expert should be a graduate civil engineer. He should have minimum 10 years of post-qualification experience in quality control/quality assurance. He should have thorough knowledge of relevant codes of practice for testing of different materials/finished products, testing apparatus, calibration, sampling, testing, recording test observations in proper formats and determination of test results. He should have good knowledge in pavement construction process, compaction, profile and pavement performance.

Environmental Specialist

The Environmental Expert must possess degree in environmental engineering/science or master degree in natural science. He should be familiar with national environmental regulations and guidelines of Ministry of Environment & Forests and Climate Change, Govt. of India. He must have at least 5 years of relevant experience, with minimum 3 years of experience in highway/ linear projects in India.

Road Safety Expert

The Road safety Expert must have a degree in civil engineering. He must have either post graduation in traffic/transportation engineering or a certified road safety auditor course. He must have 10 years of experience in highway projects involving highway geometrics design, traffic studies, road safety analysis intersection layout and design. He must have done road safety audit of at least 3 road projects involving design stage, construction stage as well as operation stage and should have reviewed and audited the road safety matters.

14. Duties of the Key Experts

The duties of the key experts are broadly mentioned as follows:

Team Leader Cum Senior Highway Engineer:

Team Leader will remain overall charge of planning the activities, checking adequacy of Quality Assurance Plan of Contractor, determining sample sizes of different items, monitoring of activities of other key experts, scrutiny of test results produced by other key experts, preparation of reports and presentation before the Employer/Authority. As senior highway engineer, he will also personally remain responsible to check geometrics, verify all survey records, checksurface profile and all other aspects not covered by other key experts.

Senior Bridge / Structural Engineer:

His duties will involve verifying working drawings of bridges/ROBs/flyovers and culverts with respect to contract drawings/schedules, verifying the as built features of foundation with reference to working drawings and actual bearing capacity of soil, verifying pre-stressing schedule, checking dimensions, checking the adequacy of form-work etc.

Senior Material Engineer cum Pavement Specialist:

Senior Material Engineer will check adequacy of Quality Assurance Plan of the Contractor, adequacy of site laboratory, ability and expertise of quality control personnel, calibration details of equipment, testing records etc. He will also carry out physical tests on samples including destructive and nondestructive tests on completed works.

Environmental Specialist

Environmental Expert will review the records related to fulfillment of Environmental Management Plan of the project, will carry out review as per the environmental regulations/ conditions to environmental clearance and forest land diversion relevant to the project. He will also make sample check of above compliances and those relating to social safeguards.

Road Safety Expert

Road Safety Expert will carry out safety audit of sample critical components based on accident records/blacklists.

15. Data, services, and facilities to be provided by Employer/Authority:

Apart from quality control and quality assistance records maintained by the Contractor and Engineer, copies of the civil works contract agreements and contract agreement with Supervision Consultant/IE/AE will be made available to the TPA.

SECTION 13

SAFETY, HEALTH AND ENVIRONMENT

13.1 Introduction

Road construction has significant impacts on nearby communities, their health and safety as well as the natural environment. People and properties may be in the direct path of road works and affected in a major way. People may also be indirectly affected by construction, through the disruption of livelihood, loss of accustomed travel paths and community linkages, increases in noise and pollution, and more road accidents. Disturbances to the natural environment may include soil erosion, changes to streams and underground water, and interference with natural habitats and plant life. Quality in Safety, Health and Environment at work places is therefore of paramount importance to the nearby communities, road users and construction workers during construction stage. These factors also impact nearby communities and road users post construction. Therefore, a set of guidelines has been given in this Section to ensure quality in Safety, Health and Environment at work places. It is further established that better care for Safety, Health and Environment at work places automatically enhances quality in road construction.

13.2 Transportation Planning & Health

Transportation planning can affect human health, either positively or negatively, in several ways. For example:

Safety: Motor vehicle crashes are a leading cause of death. Effective safety measures and responsible behaviors by all road users can reduce the number of fatalities and injuries. This is particularly important for vulnerable road users like pedestrians, bicyclists, children, differently abled persons and senior citizens.

Air Quality: Transportation planning that reduces vehicle emissions improves air quality for everyone. On the other hand improper planning and or implementation during construction stage deteriorates air quality during construction/ operation stage.

Noise: Alternatives can be designed to reduce noise and thereby prevent or reduce adverse health effects like hearing loss, sleep disturbances, cardiovascular problems, performance reduction, annoyance responses, and adverse social behavior - all of which are associated with exposure to varying levels of noise.

Transportation Planning and designing should take into account the above considerations for better health of society. Some of the aspects are also relevant during construction stage.

13.3 Safety, Health & Environmental Safeguards During Construction

Following are a set of suggestive actions for the Contractor during construction stage to safeguard safety, health and environment:

13.3.1 *General*

The contractor which includes its Sub-Contractors and any other agency/person engaged by it shall be deemed to have acquainted himself with the requirements of all the prevalent statutes, ordinances by laws, rules, regulation or their instruments having the force of law in India including without limitation those relating to protection of the environment, health and safety, importation of labour, demolition of houses, protection of environment and procurement, transportation, storage and use of explosives, etc.

13.3.2 *Site Requirements*

i) The contractor will not carry out any work on the site other than that necessary for the completion of the contract.

ii) The contractor will provide and maintain barriers fencing and lighting around the site and wherever necessary for the safety, security and convenience of the public including traffic on road and as otherwise needed to suit his working methods and timings.

iii) The contractor will provide and maintain all necessary temporary buildings including, office sheds, stores, storage areas, explosive magazines and water storage tanks without limitation.

iv) Contractor will be responsible for the provision and maintenance of all site services necessary for the execution of the works including, provision of electricity, water, and site communication facilities.

v) Contractor will maintain the site in safe, clean, tidy and sanitary condition. Contractor will also be responsible for cleaning all general rubbish and waste from whatever source generated during execution of the works.

13.3.3 *Safety and Health*

i) Near towns, villages and all frequented places, trenches and foundation pits shall be securely fenced, provided with proper caution signs and marked with lights at night to avoid accidents. The contractor shall take adequate protective measures to see that the excavation operations do not affect or damage adjoining structures. For safety precautions, guidance may be taken from IS: 3764.

ii) The contractor shall not use or generate any materials in the works, which are hazardous to the health of persons, animals or vegetation.

iii) The contractor will take all measures necessary to safeguard the safety, health and welfare of all persons entitled to be on site and will ensure that works are carried out in a safe and efficient manner.

iv) The contractor will provide, and ensure the utilization of appropriate personal protection equipment for all workmen and staff employed directly or indirectly by the contractor. Such equipment will include but not be limited to the safety helmets, goggles and other eye protectors, hearing protectors, safety harnesses, safety equipment for working over water, rescue equipment, fire

extinguishers and first-aid equipment. The personnel working at vulnerable locations at site will wear safety helmets and strong footwear.

v) The contractor will provide an adequate number of latrines and other sanitary arrangements at areas of the site where work is in progress and ensure that they are regularly cleaned and maintained in a hygienic condition.

13.3.4 *Protection of Environment*

i) The contractor will take all necessary measures and precautions and ensure that the execution of the works and all associated operations on site or offsite are carried out in conformity with statutory and regulatory environmental requirements including those prescribed in EMP.

ii) The contractor will take all measures and precautions to avoid any nuisance or disturbance to inhabitants arising from the execution of works.

iii) All liquid waste products arising on the sites will be collected and disposed of at a location on or off the sites and in a manner that will neither cause nuisance nor pollution.

iv) The contractor will at all times ensure that all existing water bodies and drains within and adjacent to the site are kept safe and free from any contamination.

v) The contractor will submit details of his temporary drainage work system (including all surface channels, sediment traps, washing basins and discharge pits) to the Employer/Authority for approval prior to commencing work on its construction.

vi) The contractor will arrange all the equipment in good condition to minimize dust, gaseous or other air-borne emissions and carry out the works in such a manner as to minimize adverse impact on air.

vii) Any vehicle with an open load-carrying area used for transporting potentially dust-producing material will have properly fitted side and tailboards. Materials having the potential to produce dust will not be loaded to a level higher than the side and tail boards and will be covered with a clean tarpaulin in good condition.

viii) The contractor will take all necessary measures to ensure that the operation of all mechanical equipment and condition processes on and off the site will not cause any unnecessary or excessive noise, taking into account applicable environmental requirements.

ix) The contractor will take necessary measures to maintain all plant and equipment in good condition.

x) Where the execution of the works requires temporary closure of road to traffic, the contractor will provide and maintain temporary traffic diversions subject to the approval of the Employer/Authority.

xi) Where the execution of the works requires single-lane operation on public road the contractor will provide and maintain all necessary barriers, warning signs and traffic control signals to the satisfaction of the Employer/Authority.

xii) Wherever traffic diversions, warning signs, traffic control signals, barriers and the like are required, the contractor will install them to the satisfaction of Employer/Authority prior to commencing the work, in that area.

xiii) Contractor will install asphalt plants and other machineries away from the populated areas as per laid down regulations.

13.3.5 *Traffic Safety and Control in Works Zone*

i) All traffic safety and control measures shall be pursuant to IRC:SP:55.

ii) The Contractor shall take all necessary measures for the safety of traffic during construction and provide, erect and maintain such barricades, including signs, marking, flags, lights and flagmen as may be required by the Engineer for the information and protection of traffic approaching or passing through the section of the project road under improvement. Before taking up any construction, an agreed phased programme for the diversion of traffic or closure of traffic on the highway shall be drawn up in consultation with the Employer/Authority.

iii) At the points where traffic is to deviate from its normal path (whether on temporary diversion or part width of the carriageway) the lane width path for traffic shall be clearly marked with the aid of pavement markings, painted drums or a similar device to the directions of the IE/AE/Supervision Consultant. At night, the passage shall be delineated with suitable light source.

iv) One-way traffic operation shall be established whenever the traffic is to be passed over part of the carriageway inadequate for two-lane traffic. This shall be done with the help of temporary traffic signals or flagmen kept positioned on opposite sides during all hours. For regulation of traffic, the flagmen shall be equipped with red and green flags and lanterns / lights.

v) On both sides, suitable regulatory / warnings signs as approved by the IE/AE/Supervision Consultant shall be installed for the guidance of road users. On each approach, at least two signs shall be put up, one close to the point where transition of carriageway begins and the other 120 m away.

vi) Signs, lights, barriers and other traffic control devices, as well as the riding surface of diversion shall be maintained in a satisfactory condition till such time they are required as directed by the Engineer. The temporary traveled way shall be kept free of dust by frequent applications of water, if necessary.

13.4 Quality Process to take care of Safety & Environment

Quality assurance planning should duly consider the nuances of safety and environment aspects of the project and make due provision for ensuring safety of all stakeholders and preserving environment. Similarly during actual quality control exercises, due attention shall be given to ensure that construction zone safety requirements are not violated.