GOVERNMENT OF HIMACHAL PRADESH

HANDBOOK ON QUALITY CONTROL

Part-A

Public Works Department

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PREFACE

The Government of H.P. felt its necessity that IQCS may be constituted to have an independent quality check and positioned in CM office. The squad shall be headed by the Team Leader and ably assisted by specialist/expert having vast experience in Civil Engineering works, Mechanical, Electrical works and IPH works being executed by the various departments.

WAPCOS Ltd., A Govt. of India Undertaking, Ministry of Jal Shakti, Chandigarh office has been entrusted with the task of implementing this program for total quality management concept aimed at embedding awareness of quality in all infrastructure departments of Govt. of H.P. including but not limited to PWD, IPH, HPSEB, Urban development, Forest, Tourism, RDD and HPSIDC etc.

In this respect this handbook has been prepared which is brief, handy and instant helpful at site for field engineers. It is an effort just like to express too much in too few words. It summarizes all quality assurance, specifications and prepared on basic sources viz HPPWD specifications for building and roads, rural road manual, MORTH and handbook of quality control Vol. -1 and Vol.-2. The IPH contents have been taken from CPEHEEO, AWWA manual, Pollution Control Board and Relevant Standard codes etc. The handbook has been prepared by in cooperating relevant extract from HPPWD specification keeping in view subsidiary departments also and prevalent practice being followed at present.

In preparing this handbook the sincere efforts have been made by the team of WAPCOS Ltd. along with the officers of Public Works Department, Himachal Pradesh.

We dedicate this effort to the state and hope this handbook shall be very useful for all the field engineers for various departments of Govt. of HP and advised that it may always be kept with them at site as ready and instant reference. We are further hopeful that the state authorities would evolve suitable mechanism to implement the needed quality assurance plan with objective of achieving the economic and social development of the State and improving the quality of life of people.

WAPCOS Limited
A Govt. of India Undertaking
Ministry of Jal Shakti
Chandigarh Office

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HANDBOOK ON QUALITY CONTROL

PART-A
(PUBLIC WORKS DEPARTMENT)

CHAPTER-1

QUALITY ASSURANCE & QUALITY CONTROL

1.1 General:

Quality Assurance, in its wide sense, represents a system which, in the context of Highway Engineering, is aimed at ensuring that the end product is a road with the desired level of serviceability and that it would serve the traffic at the design level of riding over the service life for which it is designed.

Quality Assurance enters all the broad aspects of road development: Design, Construction and maintenance right at the design stage, the quality assurance system needs to be considered since the choice of materials in the various layers of the pavement and thickness of these layers would significantly influence the riding quality. Thereafter, during construction and maintenance also, quality assurance plays a vital role in making sure that the quality envisaged at the design stage is indeed realized over its service life.

Quality control and specifications in road construction must cover workmanship and materials. The two most important means of specifying a finished product are:

- By method
- By end result

The more reliable is the latter, but there are circumstances where this cannot be applied and a method specification must be used. An example is in the production of concrete. It is usual to require an end product (a set strength for the concrete that the designer can rely on his design). While it is possible to test the end product by cutting and testing cores, it is more usual to control the production by method (gauging the aggregate, cement and controlling the amount of water added and the mixing time). Check testing is carried out during production, with the finished product, which are crushed after curing to ensure compliance as a check. However, control of production is largely by method.

1.2 Quality Control in India:

1.2.1 Present practice: Under the systems presently practiced in India, quality control work is generally carried out under a 2-tier system or even a 3-tier system depending on the total workload of a particular Department at a particular time.

1.3 Primary or Division Level Control: Working on the principle that the unit responsible for construction should also be responsible for its quality, the primary level of control and check testing is entrusted with the Engineer-in-Charge of the work and his staff. Generally it will be Executive Engineer under whose jurisdiction the work falls.

The primary level check consists of:

a) Carrying out at least the minimum number of mandatory tests in respects of all materials and processes.
b) Ensuring that only materials duly approved by a competent authority and from approved sources (borrow area, quarry, etc.) and those manufactured materials having an

appropriate certificate of quality from the manufacturer have been incorporated into the works.

c) The equipment used is as per specification, and is in good working order and processes followed are as specified.

1.4 Supervisory or Circle Level Control: The second level of quality control is at the supervisory level under the control of Superintending Engineer-in-Charge of the circle, or by his staff.

The work of the team includes:

a) Carrying out random checking of the quality of materials including verification of the use of approved products or materials from approved sources.
b) Verification that records of field tests are being kept properly.
c) Carrying out important tests (in the regional laboratory) if equipment and arrangement for such tests are not available in the field laboratory.

1.5 Third Level (Optional) Quality Control: The third level of quality control, where considered necessary, may be carried out by the Core Cell under the charge of the Chief Engineer of the project.

The Core Cell may monitor the effectiveness of the control being exercised by the circle and Division Level units and carry out such tests, as it deems necessary.

The Core Cell also acts as an apex body in respect of all quality problems and may lay down norms for modification/updating of updating of control and test procedures as well as changes in Specifications for future works.

1.6 Elements of Quality Assurance System: The need for Quality Assurance System is the client desire to have value for his investments in terms of best design criteria, specification, construction practices, control and inspection over construction. Thus, the elements of a Quality Assurance System for a Highway Project are as under:

a) Assessment of requirement of road project
b) Choice of quality materials and design
c) Development of technical specifications and acceptance criteria
d) Choice of construction method/equipment/plant
e) Field supervision and quality control
f) Assessment of quality of finished road
g) Periodic inspection and maintenance measures

1.7 Choice of Quality Materials and Design: More often than not, there would be alternative materials of different engineering characteristics available for the project. A choice of the materials to be incorporated in the pavement crust would largely depend on the design riding quality requirements. Both the thickness (pavement crust) and composition (selected materials) requirement can be worked out by following a suitable design procedure for the assessed traffic, sub-grade soil and climatic conditions.

1.8 Development of Technical Specifications and Acceptance Criteria: Technical specifications embodying the best practices of construction, selection of materials and use of equipment are standardized by P.W.D.

Additional specifications have been drawn up, based on practices elsewhere for similar works. Depending on the type of road facility and related acceptance criteria for various items of work have been set forth. The bid document specifies the Technical Specifications to be followed as per CPWD/MORD /MORTH specification.

1.9 Choice of Equipment/Plant: The selection of the right type of equipment/plant is the key to the achievement of good results.

1.10 Field Supervision and Quality Control: The quality of a work is generally influenced by the nature of the field supervision and the organization structure responsible for it. Duties and responsibilities must be carefully demarcated. Quality Control is the task of:

a) Inspection and testing of materials, production process and the end product
b) Measuring variations from the pre-determined standards
c) Taking corrective action to minimize adverse variations
d) Accepting or rejecting the work.

1.11 Responsibility for Quality: Quality is something like health and cannot be isolated or pinpointed in the functioning of any one particular organ or limb of the body. It has to be present in the entire body system and it depends upon the well being and smooth functioning of all the constituent components of the body. The common misconception about achieving quality in work by getting the job done only by hiring tough inspectors is fast wearing out. The personnel involved are:

a) The owner
b) The designer/engineers
c) The contractor
d) The quality monitor

1.12 Methodology for Quality Assurance:

a) Systemic control shall be exercised on all operations from the selection and production of material to the completion of the curing of concrete in order to take care of all technical specifications.
b) The quality of product is ensured and maintained by following a documented “Quality Plan” which sets out specific quality practices, including Quality Control, which are operational techniques of controlling the quality.
c) Quality assurance includes all those planned actions necessary to provide adequate confidence that the product will meet the requirements and is essentially a system of planning, organizing and controlling human skills to ensure quality.

1.13 Quality Assurance Plan for Road: It should eventually comprise of the following aspects:

a) Organization
b) Control of data & documentation, both product (road) related documents and quality records
c) QA procedure for setting out works and temporary works.
d) Methodology of working
e) Control of materials
f) Calibration (of HMP, Batching and mining plant, lab, equipments, survey equipments etc.)

g) Control of workmanship aspects.
h) Protection during construction stage.
i) Non-conforming products.
j) Quality audits i.e. the process of systematic examination of a quality system. The QA plan will be submitted by the contractors. Basically it is gist of A to Z of delivery of quality products. However since the DPR is prepared by the Employee the contractor is mainly concerned with quality control of each activity of road/bridge work.

1.14 Quality Assurance Plan for Basic Construction Materials: Every construction activity starts with the use of basic materials which may be either in raw shape like stone aggregate, sand, stones, bricks etc. or manufactured materials like cement, steel and bitumen. Some basic material to be procured at site for use is concerned in the following chapters with there as per Punjab/HPPWD technical specifications during execution. In all cases however it is important that all uses of this handbook understand that the contract documents including the specifications are the controlling documents for the supervision of the construction.

1.15 Procedure for Conducting Inspection: Primary purpose of conducting inspections and control should be the fulfillment of the specification requirement. Field inspection and testing of materials and operations shall be carried out according to a preplanned schedule.

a) Supervision:
b) Daily inspection reports: on all major projects, the W.I. or Engineer-in-Charge shall make a daily inspection report to the Executive Engineer on the format devised by the organization. The daily report should include condition and progress of the work important factors affecting such condition and progress and daily test data. The test data should include frequency; type and location of samples taken as per the design mix/job mix formula.

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

CHAPTER-2

MAINTENANCE AND CALIBRATION OF EQUIPMENTS

Heavy investments are made on procurement of road construction machinery. It is obvious that the machinery will require maintenance after regular use. It is also likely that the machines will go out of calibration with frequent use. It must be ensured that adequate maintenance and calibration facilities are available. Some of the factors requiring attention are as under:

2.1 General:

a) Appropriate equipments are to be positioned at appropriate locations.
b) Conditions of equipments checked positioning/use.
c) Conditions of equipments must be safe, secure and away from dangerous areas.
d) Adequate spares, right types of fuel/oils are available.
e) Well trained mechanics for periodical maintenance are required during
    i. Idle period
    ii. Operation

2.2 Effect of Cold on Mechanical Equipments & Counter Measures at low temperatures

a) Metal develops brittleness, welds tend to fracture.
b) Moving parts becomes sluggish.
c) Many parts like pins, screws, nuts etc become loose.
d) Rubber materials, hoses, fan belts, tyres etc harden and crack.
e) Insulation of electric cable fails.
f) Spring loose tension & fails due to fatigue.
g) All plants should have heated cabins for efficient operations.
h) Efficiency of operators is 35% in cold but in heated cabin is 75%.

2.3 Safety of men and machines is necessary

a) All machines/men are deployed in dispersed manner to guard against avalanches. At the end of the day, they parked safely.
b) Anti freeze chemicals are added to radiator water and draining radiators in the night are necessary measures.
c) Winter grade diesel, fuels, and equipments should be used.

2.4 Efficiency

a) 10% decrease in efficiency of mechanical equipment for every 1000 m above mean sea level.
b) There's a need to indigenize the machinery equipment. Machines imported from abroad, are not according to Indian conditions and face maintenance problems, which are frequent and difficult.
c) Calibration of Equipments (MORT&H Specifications of sections 1000, clause 1015.4 Testing of approval plant and equipment)

All plants & equipments used for

a) Preparing

b) Testing
c) Production of materials shall be in accordance with manufactures specifications and shall be got approved by the Engineer before use. This statement binds both Contractor and Engineer:
   i. Before use-&-during use (Time to Time make sure that specifications are not lost because of use)
   ii. Hence, before use- equipments not outdated are below standards.
   iii. The manufacturer has to be reliable.

Calibration certificates for the laboratory & equipments are necessary and kept at site for inspection by the concerned authorities.

"Quality means doing it right when no one is looking. "

Henry Ford

SPECIFICATIONS FOR BUILDINGS

CHAPTER-3

MATERIALS FOR BUILDINGS

3.1 The following Indian Standards shall be followed:

a) IS: 383-1970 Coarse and fine aggregate from natural sources for concrete.
b) IS: 1542-1960 Sand for plaster.
c) IS: 2386-1963 (Part I to VIII) Methods of test of aggregates for concrete.
d) IS: 3466-1967 Masonry cement.
e) IS: 5640-1970 Method of test for determining aggregate impact value of soft coarse aggregate.
f) IS: 5913-1970 Method of test for asbestos cement products.

3.2 General: Aggregate most of which is retained on 4.75 mm. I.S. Sieve and containing only as much final material as is permitted for the different types are described as coarse aggregates. This shall be broken from hard stone obtained from the approved quarry. The quarry shall be approved by the Executive Engineer. The aggregates shall be hard, strong, dense, durable clean, free from veins, adherent coatings, injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky, scoriaceous and elongated pieces shall be avoided; it shall also be free from soft, friable, thin, elongated or laminated pieces and shall be roughly cubical in shape. It shall be clear from dirt. If coarse aggregates contain more than the prescribed limits of clay or mud etc. It shall be properly washed and dried before mixing with other ingredients to make concrete.

3.3 Aggregate: Most of which is retained on 4.75mm I.S. sieve.

Do's	Don't
Course aggregate shall be hard, clean and graded	Flaky and elongated avoided.
	Aggregate containing harmful impurities such as iron pyrites, coal, mica and clay.

3.3.1 Important test on material: Aggregate will be tested for its different quality control tests:

I. **Aggregate crushing value:** The aggregate crushing value, when determined in accordance with IS: 2386 (Part IV)-1963, shall not exceed 45% for aggregate used for concrete other than for wearing surfaces, and 30% for concrete for wearing surfaces, such as runways, roads and pavements.
II. **Aggregate impact value:** The aggregate impact value may be determined in accordance with the method specified in IS: 2386 (Part IV)-1963. The aggregate impact value shall not exceed 45% by weight for aggregates used for concrete other than for wearing surface and 30% by weight for concrete for wearing surfaces, such as runways, roads and pavements.
III. **Aggregate abrasion value:** Unless otherwise agreed to between the purchaser and the supplier, the abrasion value of aggregates, when tested in accordance with the method specified in IS: 2386 (Part IV)-1963 using Los Angles machine, shall not exceed the following values:

a) For aggregate to be used in concrete for wearing surfaces ---- 30%
b) For aggregate to be used in other concrete ---- 50%

IV. Soundness of aggregate: For concrete liable to be exposed to the action of frost, coarse and fine aggregates shall pass a sodium or magnesium sulphate accelerated soundness test specified in IS: 2386 (Part V)-1963, the limits being set by agreement between the purchaser and the supplier, except that aggregates failing in the accelerated soundness test may be used if they pass a specified freezing and thawing test satisfactory to the user.

3.3.2 Aggregate Crushing Value: As an alternative, the aggregate impact value may be determined in accordance with the method specified in IS: 2386 (Part IV)-1963. The aggregate impact value shall not exceed 45 percent by weight for aggregates used for concrete other than for wearing surfaces and 30 percent by weight for concrete for wearing surfaces, such as runways, roads and pavements.

3.4 Size and Grading of Aggregates: The coarse aggregates shall be supplied in the nominal size as given in table.

COARSE AGGREGATES

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

3.4.1 Recommended coarse aggregate for different items

S. No.	Item of Construction	Maximum nominal size of coarse Aggregate
1	RCC well curb, RCC well steining and RCC piles	40 mm
2	PCC well steining	63 mm
3	Well cap or pile cap, Solid type piers, abutments, and wing walls and their pier caps.	40 mm
4	RCC works in cross girders, deck slab, wearing course kerb, light posts, ballast walls, approach	20 mm

	slab etc. and hollow type piers, abutments, wing walls and the pier caps.	
5	RCC bearing	20 mm
6	For any other item of construction not covered by item (1) to (5) above.	As specified on the drawings or as desired by the Engineer-in-Charge in case it is not specified on drawings.

The coarse aggregates proposed to be used for the concrete work shall be got approved from the Engineer-in-Charge before the start of the work. All subsequent supplies shall preferably be obtained from the same source.

ALL – IN – AGGREGATE

3.5 General: All in aggregate shall be composed of fine and fine and coarse aggregates collected directly from pit, riverbed or crushing plants.

If combined aggregate containing both fine and coarse aggregate are available. These need not be separated into fine and coarse but necessary adjustments shall be made in the grading by addition of single-sized aggregates/fine aggregates to obtain the specified grading. For 40mm and 20mm nominal size of all-in-aggregate, the final grading shall be as under:

I.S. Sieve Designation	Percentage passing for all – in aggregate of:-	
	40 mm	20 mm
	Nominal size	Nominal size
80 mm	100	-
40 mm	95 to 100	100
20 mm	45 to 75	95 to 100
4.75 mm	25 to 45	30 to 50
600 micron	8 to 30	10 to 35
150 micron	0 to 6	0 to 6

3.6 Water: Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

The *p*H value of water shall be not less than 6. The seawater is not recommended for mixing or curing of concrete because of presence of harmful salts in water. Under unavoidable circumstances seawater may be used for mixing or curing in plain concrete with no embedded steel.

3.7 Sand: It shall be hand clean and free from organic matter. Sand which contains 90% of particles of size greater than 0.06mm and less than 0.2mm is fine sand. Sand which contains 90% of particles of size greater than 0.6mm and less than 2.0mm is coarse sand.

The grading of fine aggregates, when determined as described in (IS: 2386 (Part I)-1963 shall be within the limits given in the below table and shall be described as fine aggregates, Grading Zones I, II, III and IV.

Zoning: Acc. To IS: 383:1970

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

Note1: Where concrete of high strength and good durability is required, fine aggregate conforming to any one of the four grading zones may be used, but the concrete mix should be properly designed. As the fine aggregate grading becomes progressively finer, that is, from Grading Zones I to IV, the ratio of fine aggregate should be progressively reduced. The most suitable fine to coarse ratio to be used for any particular mix will, however, depend upon the actual grading, particle shape and surface texture of both fine and coarse aggregates.

Note2: It is recommended that fine aggregate confirming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

Grading of coarse sand:

IS Sieve Designation	% By weight passing IS Sieve
4.75mm	100
2.36mm	90-100
1.18mm	70-100
600 micron	30-100
300 micron	5-70
150 micron	0-15

3.7.1 Fineness Modulus: Fineness modulus is a ready index of coarseness or fineness of the material. It is an empirical factor obtained by adding the cumulative percentage of aggregate retained on each of the standard sieve ranging 80 mm to 150 micron and dividing this sum by arbitrary number 100.

Greater is the fineness modulus – coarser is the material. Its limit 2.0 to 3.5 (Page No. 368 of section 1008 of MORTH specification 4th revision).

The following example illustrates the computation of fineness modulus of a sample of sand:

Sieve description as per IS	% Retained on each sieve respectively	Commutative retained on successive sieve	Percentage
4.75mm		0	---
2.36mm		1.0	1.0

1.18mm		10.5	11.5
600 micron		49.0	60.5
300 micron		33.5	94.0
150 micron		5.0	99.0
Pan		1.0	266.0
		100.0	**266.0**
	Fine Modulus	**266.0**	
		100.0	
		2.66	

Don'ts:

I. Should not be containing harmful impurities, which affect the ductility of concrete.
II. Used for work where reinforcement is used shall not contain any material liable to affect the steel reinforcement.

3.8 Cement: It shall conform to the following I.S. specification:

a. Ordinary Portland cement, (ii) Rapid hardening Portland cement and (iii) low heat Portland cement shall conform to IS: 269: 1976.
b. Portland blast furnace slag cement shall confirm to IS: 455:1976.
c. Portland pozzolana cement shall confirm to IS: 1489-1976.
d. Masonry cement shall conform to IS: 3466-1967.
e. White Portland cement shall conform to IS: 8042-1976.

3.8.1 Tests for physical property:

Soundness: Expansion by the Le Chatelier test not more than 100mm or 5mm after 7 days aeration, time of boiling being 3 hrs.

3.8.2 Setting time:

a. Initial setting time not less than 30 mins for OPC
b. Final setting time not more than 600 mins for OPC

3.9 Compressive strength: The average compressive strength of at least three mortar cubes of the cement.

a. 3 days not less than 115 kg/cm^2
b. 7 days not less than 175 kg/cm^2

3.10 Quantity of Cement: Minimum quantity of cement to be used in controlled concrete shall be not less than 220kg/cum in plain concrete and not less 300kg/cum in RCC structural members. The minimum quantity of cement for pre-stressed concrete work shall not be less than 360 kg/cum of concrete nor it shall be more than 540 kg/cum of concrete.

CHAPTER-4

CONCRETE WORK

4.0 The following Indian Standards shall be followed:

a) IS: 383-1970 Aggregate coarse and fine from natural sources for concrete.
b) IS: 432-1966 (Part-I) Mild steel and medium tensile steel bars.
c) IS: 1139-1966 Deformed bars for concrete reinforcement and rolled mild steel and medium tensile.
d) IS: 1789-1966 Cold twisted steel bars for reinforcement concrete.
e) IS: 2090-1962 High tensile steel bars used in pre-stressed concrete.
f) IS: 6003-1970 Indented wire for pre-stressed concrete.
g) IS: 6006-1970 Uncoated stress & relieved strand for pre-stressed concrete.
h) IS: 3384-1965 Bitumen primers for use in water proofing and damp proofing.
i) IS: 456-1964 Plain and reinforced concrete code of practice.
j) IS: 1799-1959 Sampling and analysis of concrete.
k) IS: 1200-1974 (Part-II) Measurement of building and Civil Engineering work method, concrete work.
l) IS: 1516-1959 Method of test for strength of concrete.
m) IS: 2386-1963 Test for particle size and shape (Part-I)

The cement concrete shall be classified as:

a) **Ordinary Cement Concrete:** The cement concrete in which the proportion of aggregate to cement and water is not designed by preliminary tests of the materials to be used.
b) **Controlled Cement Concrete:** The cement concrete in which the proportions of aggregate to cement and water are determined by lab test, so as to give concrete of the specified crushing strength.

4.1 Grades of Concrete: The controlled concrete shall be in different grades, designated as M200, M250, M300, M350, M400, M450, M500, M550 and M600.

In case of ordinary concrete, it shall be in four grades designated on M100, M150, M200 and M250.

Strength Requirements of Concrete		
All values in kg/cm2		
Grades of concrete	**Compressive Strength of 15 cm cubes at 28 days**	
	Preliminary test min.	**Works test min.**
M100	135	100
M150	200	150
M200	260	200
M250	320	250
M300	380	300
M350	440	350
M400	500	400

Note 1 Preliminary Test: A test conducted in a laboratory on the trail mix of concrete produced in the laboratory with the object of:

- Designing a concrete mix before the actual concreting operation starts.
- Determining the adjustments required in the designed mix when there is a change in the materials used during the execution of work.
- Verifying the strength of concrete mix.

Note 2 Works Test: A test conducted either in the field or in a laboratory on the specimens made on the works, out of the concrete being used on the works.

4.2 Admixtures: Admixtures are the special ingredients added during concrete mixing to enhance the properties and performance of fresh concrete. Various types of admixtures are available in the market, which is used in construction work.

Functions of Admixtures:

a. To accelerate or retard the setting time of fresh concrete.
b. To improve the workability or flow ability of concrete.
c. To increase the strength and durability of concrete.
d. To reduce the heat of hydration.
e. To reduce the segregation and bleeding.
f. To decrease the permeability.
g. To achieve other desired properties.

Types of Admixtures:

a. Accelerating Admixtures
b. Retarding Admixtures
c. Air-Entraining Admixtures
d. Water Reducing Admixtures

Special Admixtures:

a. Super plasticizing admixtures.
b. Corrosion-inhibiting admixtures.
c. Grouting admixtures.
d. Coloring admixtures etc

4.3 Proportioning: Proportioning shall be done by volume. Boxes of suitable size shall be used for measuring sand aggregate. The size of the boxes (materials) shall be 35x25cm and 40cm deep. The unit of measurement for cement, shall be a bag of cement weighing 50 kgs and this shall be as 0.035 cubic meter. While measuring the aggregate and sand the boxes shall be filled without shaking, ramming or hammering. The proportioning of sand shall be on the basis of its dry volume.

4.4 Concrete mixes used for various types of works: Concrete mix shall be as specified in the contract. If nothing is mentioned in the contract, it shall be as specified by the Engineer-in-Charge in writing. A rough guide regarding the use of nominal mixes is given below:

Nominal size	Type of work for which used
1:8:16	Foundations of buildings and light structures.
1:6:12	Base course of floors.
1:5:10	Foundations of heavy buildings, plum concrete, hearting of abutments and piers and retaining walls with stone faces in hilly areas.
1:4:8	Mass concrete and foundations of hydraulic works.
1:3:6	Mass concrete, bedplates, concrete blocks, canal lining.
1:2:4	General RCC buildings and similar works namely beams, slabs panel walls,

	stairs, columns retaining walls, pavements, floors, bedplates.
1:1.5:3	Important RCC structures, piles arches, impermeable construction against water heads.

4.5 Mixing of Concrete: Mixing of cement concrete shall, as a rule is done in a mechanical mixer. However, the Engineer-in-Charge may permit hand mixing in specific cases where in his opinion it is not practicable to resort to mechanical mixing either on account of the quantity of cement concrete required is small or for any other reason. In such cases he should ensure that the inferior quality of concrete produced by hand mixing will not adversely affect the structure.

4.6 Mechanical vibration: The number and type vibrators shall be subject to the approval of the Executive Engineer. If nothing is specified, only, vibrators of the internal type of shall be used. Mechanical vibrator shall be adequately powered and capable of transmitting vibrations of the required frequency to the concrete. A sufficient number of mechanical vibrators shall be provided on the batch so that each batch may be thoroughly compacted immediately after placing and that there will be no delay in placing and compacting of ensuing batches. The intensity and duration of vibration shall be sufficient to cause complete settlement and compaction without any stratification of the successive layers or separation of ingredients.

Types of vibrations:

a) **Internal vibrators:** Which consist of metal spud or rod, which is inserted into newly, placed concrete and which vibrates while it is being withdrawn.
b) **External or 'Form' vibrators:** Which are attached to form work and external shuttering of walls, column etc. Forms transmit the vibrating action to the concrete.
c) **Surface vibrators:** Which are mounted on screeds or platforms and which are chiefly used for consolidating road slabs, floors etc.
d) **Vibrating tables:** Which are used for precast products.

4.7 Strength Requirement of Concrete: The compressive strength requirement for various grades of controlled concrete as well as ordinary shall be as given in table below. Where rapid hardening Portland cement is used, the 28 days compressive strength requirements specified in table below shall be met at 7 days.

For controlled concrete, the mix shall be so designed as to attain in preliminary tests or strength of at least 33% higher than that required on work tests. Preliminary tests need not be made in case of ordinary concrete.

Grade of Concrete	**Compressive Strength of 15 cm Cubes at 28 days**	
	Preliminary Test Min.	**Works Test Min.**
M100	135	100
M150	200	150
M200	260	200
M250	320	250
M300	380	300
M350	440	350
M400	500	400

Grade of Concrete	Compressive Strength of 15 cm Cubes Min. at 7 days	Modulus of Rupture by beams Test, Min.	
		At 72 ± 2hous	At 7 days
M100	70	12	17
M150	100	15	21
M200	135	17	24
M250	170	19	27
M300	200	21	30
M350	235	23	32
M400	270	25	34

4.8 Proportioning: Proportioning shall be done by volume. Boxes of suitable size shall be 35*25*40 cm deep. The unit of measurement for cement will be its weight 50 kgs and which shall be as 0.35 cum. The proportioning of sand and aggregate shall be on the basis of its dry volume and filled without shaking or ramming.

4.9 Compaction: Concrete when deposited shall have a temperature of not less than 4.5^0C and not more than 38^0C. It shall be compacted in its final position within 30 minutes of its discharge from the mixer unless carried in properly designed agitators, operating continuously, when this time shall be within 2 hours of the addition of cement of the mix and within 30 minutes of its discharge from the agitator.

Except where otherwise agreed to by the Engineer-in- Charge, concrete shall not be deposited in horizontal layers to a compacted depth of not more than 0.45 meter when internal vibrators are used and not exceeding 0.30 meter in all other cases.

Unless otherwise agreed by the Engineer-in-Charge, concrete shall not be dropped into place from a height exceeding 2 meters. When trucking or chutes are used they shall be kept clean and used in such a way as to avoid segregation.

4.10 Consistency: Quantity of water shall vary in the field with the quality of aggregate. Consistency required and surface water present in the aggregate. Therefore the amount of water required shall be determined in the field by carrying out slump/V.B. consistometer test. The following slumps are adopted for different works.

S. No.	Type of work	Slumps	
		When vibrators are used.	When vibrators are not used.
1	Mass concrete in foundations, footings, retaining walls and pavements.	10mm to 25mm	30mm to 75mm
2	Thin floorings of less than 74mm thickness.	25mm to 40 mm	75mm to 100mm
3	Reinforced Cement Concrete work.	75-125mm	

4.10.1 Slump Test for Concrete Consistency:

i) The test specimen shall be formed in a mould in the form of the frustum of the cone with internal dimension as follow:
   a) Bottom diameter 20cm

b) Top diameter 10 cm
c) Height 30 cm

ii) Care shall be taken to ensure that a representative sample is taken.

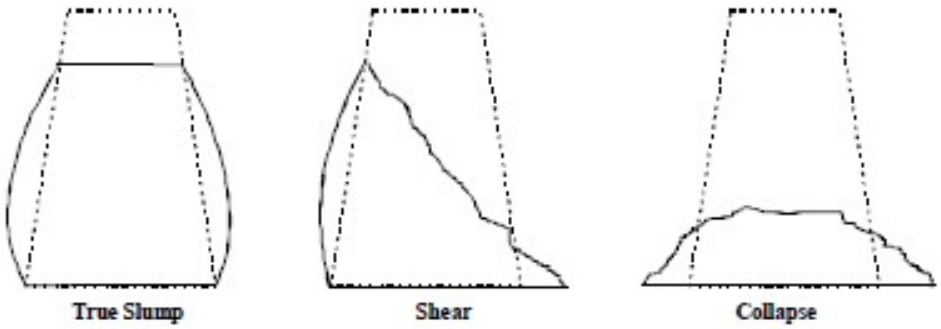
iii) Samples of concrete for test shall be taken from the mixer or ready mixed concrete. Such samples shall be obtained by repeatedly passing a scope or pail through the discharging stream of concrete starting the sampling operation of the beginning of discharge and repeating the operation until the entire batch is discharged. The sample thus obtained shall be taken to the moulding of the specimen and to counteract segregation. The concrete shall be mixed with shovel.

iv) The internal surface of the mould shall be thoroughly clean, dry and free from set cement.

Procedure: The mould shall be placed on a smooth flat surface. The mould shall be filled to about one fourth of its height with the concrete and tempted using 25 strokes of 16mm dia steel rod, o.6m long and bullet painted at the lower end. The mould shall than be removed by rising vertically immediately after filling. The moulded concrete then be allowed to subside and the height of the specimen measured after coming to rest. The consistency shall be recorded in millimeter of subsidence of the specimen during the test, which is known as the slump.

The slumped concrete takes various shapes and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated.

Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which the slump test is not appropriate. Very dry mixes having slump 0 – 25 mm are typically used in road making, low workability mixes having slump 10 – 40 mm are typically used for foundations with light reinforcement, medium workability mixes with slump 50 – 90 mm, are typically used for normal reinforced concrete placed with vibration, high workability concrete with slump > 100 mm is typically used where reinforcing has tight spacing, and/or the concrete has to flow a great distance.



Workability	Compaction Factor	Slump (mm)
Very Low	0.78	0 - 25
Low	0.85	25 - 50

Medium	0.92	50 - 100
High	0.95	100 – 175

Placing conditions	Degree of Workability	Slump (mm)
Building concrete, shallow sections	Very low	See note 2
Mass concrete; lightly reinforced sections in slabs, beams, walls, columns, floors, hand placed pavements, canal lining, strip footings	Low	25-75
Heavily reinforced section in slabs, beams, walls columns	Medium	50-100
Slip form work, pumped concrete	Medium	75-100
Trench fill, in situ pilling	High	100-150
Tremie concrete (watertight pipe)	Very high	See note 3

Note 1: For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of the reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used.

Note 2: In the 'very low' category of workability where strict control is necessary, e.g. pavement concrete, measurement of workability by determination of compacting factor will be more appropriate than slump (see IS: 1199) and a value of compacting factor of 0.75 to 0.80 is suggested.

Note 3: In the 'very high' category of workability, measurement of workability by determination of flow will be appropriate (IS: 9103).

4.11 Tests for Compression Strength of Concrete: This method comes compression tests on concrete made in accordance with IS: 516. Each test shall be conducted on ten specimens, five of which shall be tested at seven days and the remaining five at 28 days. The samples concrete shall be taken on each day of concreting and cubes shall be made at the rate of one for every 5 cum of concrete or as part thereof. However if concreting done in a day is less than 15 cum, the minimum no. of cubes can be reduced to 6 with the specific permission of the Engineer-in-chief. The average strength of the group of cubes cast for each day shall not be less than the specified works cube strength. The results shall be recorded in the register maintained at for record.

4.11.1 Additional Tests for Concrete: In case concrete fails when tested for compression of concrete following check tests may be carried out at the direction of Engineer to satisfy the strength of the concrete laid. All testing expenditure shall be done by the contractor. For purpose of payment the cube results shall be the criteria:

a) **Cutting Cores:** This method involves drilling and testing cores from the concrete for determination of compressing strength. In suitable circumstances the compressive strength of the concrete in the structure may be assessed by drilling

cores from the concrete and testing. The procedure used shall comply with the requirements of IS: 119-1959 and IS: 516-1959.

b) **Ultra sonic test:** If an ultrasonic apparatus is regularly used by trained personnel, and continuously maintained individual charts are kept showing a large number of readings, the relation between the reading and strength of cubes made from the same batch of concrete, such charts may be used to obtain approximate indications of the strength of concrete in the structure.

c) **Rebound hammer test**: If a rebound hammer is regularly used by trained personnel and continuously maintained individual charts are kept showings a large number of readings, the relation between the readings and strength of concrete cubes made from the same batch of concrete, such charts may be used in conjunction with hammer readings to obtain an approximate indication of the strength of concrete in a structure or element. When making rebound hammer tests each result should be the average of at least six readings. Readings should not be taken within 25mm of the edge of concrete members.

d) **Load tests on individual present units**: The load tests described in this clause are intended as check on the quality of the units and should not be used as a substitute for normal design procedures. Where members require special testing such special testing procedures shall be in accordance with the specifications. The test loads shall be applied and removed incrementally.

4.12 Sampling procedure: A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested. It means sampling should be spread over the entire period of concreting and covers all mixing units.

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

Sr. No.	Quantity of Concrete in work m^3	No. of Samples
1	1-5	1
2	6-15	2
3	16-30	3
4	31-50	4
5	51 and above	4 plus one additional sample for each additional 50 cum or part there of

Do's:

a) The proportion of the ingredients in concrete shall be determined through preliminary tests on concrete made from representative sample of ingredients.

b) The water cement ratio for specified compressive strength should be determined by lab tests.

c) Slump shall be determined at the point of placement after the concrete has been deposited.

d) The amount of bulk cement and all aggregates shall be directly weighed for batching.

Don'ts:

a) Cement in standards sacks or bags need not to be weighed.

b) Water should not be in abundance as to avoid exceeding the proper slump.

c) To avoid segregation, concrete should not be dropped from a height more than 1 meter.

d) To avoid sticking of concrete, formwork should be oiled before concreting.

4.13 Concreting Under water: Concrete shall not be placed in water having a temperature below 5^0C. The temperature of the concrete, when deposited, shall be not less than 16^0C and not more than 40^0C.

Concrete shall contain 10 percent more cement than that required for the same mix placed in the dry. The materials shall be so proportioned as to produce a concrete having a slump of not less than 100 mm, and not more than 180 mm.

Cofferdam or forms shall be sufficiently tight to ensure still water conditions and shall be sufficiently tight to prevent loss of mortar through the joints in the walls. Concrete shall be deposited continuously until it has been brought to the required height. Drop bucket method or any other method approved by the Engineer may be used for depositing concrete under water.

4.14 Working in Extreme weather: Where concrete is to be deposited at or near freezing temperatures, precautions shall be taken to ensure that at the time of placing, it has a temperature of not less than 5^0C and that the temperature after the concrete has been placed and compacted is maintained above 4^0C until is has thoroughly hardened. When, necessary the concrete ingredients shall be heated before mixing but the cement shall not be heated artificially other than heat transmitted to it from other ingredients of the concrete.

Generally heating of the mixing water alone may be sufficient for this purpose. The temperature of water shall not however be more than 65^0C. The concrete shall be carefully protected after placing.

Salt or other chemicals shall not be used to prevent water from freezing. No frozen material or materials containing ice shall be used. All concrete damaged by the frost shall be removed. It is recommended that concrete exposed to freezing weather shall have entrained air and water cement ratio shall not be more than 0.60.

When depositing concrete in very hot weather, precautions shall be taken so that the temperature of wet concrete does not exceed 40^0C while placing. This shall be achieved by stacking aggregates under the shade and keeping them moist, using cold water, reducing the time between mixing and placing to the minimum, cooling the form work by sprinkling water and restricting concreting, as far as possible, to early mornings and late evenings. When ice is used to cool mixing water, it will be considered a part of the water for the purpose of working out the water-cement ration in the mix.

4.15 Construction joints: Concreting shall be carried out continuously up to the construction joints, the position and details of which shall be shown on approved drawings or as directed by the Engineer-in-Charge. Such joints shall, however, be kept to the minimum.

For a critical construction joint, a stopping board shall be fixed previously at the pre-determined position and shall be properly stayed for sufficient lateral rigidity to prevent its displacement or plugging when concrete is compacted against it. Concreting shall be continued right up to the board. The board shall not be removed before the expiry of the specified period for removal of vertical forms.

Before resuming work at any construction joint when concrete has not yet fully hardened, all laitance shall be removed thoroughly, care being taken to avoid dislodgement of coarse aggregates.

When work has to be resumed on a surface which has hardened it shall be thoroughly hacked, swept clean, wetted and covered with a layer of neat cement grout. The neat cement grout shall be followed by a 13mm thick layer or mortar mixed in the same proportion as in concrete and concreting resumed immediately thereafter. The first batch of concrete shall be rammed against the old work to avoid formation of any stone pockets, particular attention being paid to corners and close spots.

4.16 Tests and standard of acceptance: For controlled concrete preliminary tests shall consist of three sets of separate tests, and in each set, tests shall be conducted on six specimens. Not more than one set of six specimens shall be made on any particular day. On the six specimens in each set, three shall be tested at seven days and the remaining three at 28 days. The preliminary tests at 7 days are intended only to indicate the strength likely to be attained at 28 days.

All work shall be carried out under the supervision of a qualified and a competent Engineer who will supervise proportioning, placing and compacting of concrete at all stages.

4.17 Damp proof course: It is of two types namely horizontal and vertical. Horizontal D.P.C. shall usually consist of cement concrete 1:2:4 or cement mortar 1:2 as specified. In temporary and inferior buildings, the horizontal D.P.C. may consist of cement mortar. In important buildings and in special localities, the thickness of the cement concrete layer may be as per the approved drawings/direction of the Engineer-in-Charge.

Vertical D.P.C. may also be provided as per the approved drawings/direction of the Engineer-in-Charge.

Concrete or the plaster layer shall in all cases be covered with two layers of bitumen.

Unless otherwise stated, horizontal D.P.C. in external brick walls shall be located about 75 to 15 cm above the final ground level. In internal brick walls, damp proof course shall be located at the ground floor level. Damp proof courses of the external and internal walls shall be joined up by means of bonding, bricks or concrete blocks soaked in bitumen. To prevent the ingress of moisture from the soil under floor, the inside of the external wall shall be provided with vertical damp proof course, extending from horizontal damp proof course to floor level.

Damp proof course shall not be laid until level of work/stone work have been checked and the brickwork or masonry work have been passed by the Assistant Engineer.

The surface of brickwork or stone works shall be leveled and prepared before laying cement mortar/cement concrete. All exposed surfaces of damp proof course shall be finished smooth and flush with masonry surface. Side shuttering shall consist of wooden forms and shall be strong and properly fixed so that it does not get disturbed during compaction and the mortar does not leak through. When the sides are removed, the surface should come out smooth without any honeycombing. If holes show up, they shall be grouted up flush with surface. The upper and inside surface shall be left rough to afford a key to the plaster and masonry above.

Damp proof course shall be cured for at least 7 days after which it shall be allowed to dry.

The concrete or plaster will be allowed to dry for one day after curing, and to course of bitumen then given after dusting of the surface. If the concrete or plaster does not dry up fully in cold season, the first coat shall consist of bitumen emulsion in lieu of bitumen. The bitumen shall be heated to the specified temperature and spread on the concrete in two coats using 1.70 kg/sqmt bitumen of damp proof course. The layers of bitumen must be sanded immediately they are laid. The bitumen shall be applied over the dried up surface of cement concrete, properly cleaned with brushes and finally with a piece of cloth soaked in kerosene oil. The bitumen shall be applied uniformly all over so that no blank spaces are left anywhere.

4.18 Requirement of Concrete Cover: The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete.

4.19 Transportation:

a) The procedure of mixing, transporting, placing and compacting concrete should not take more than 90 minutes in any case.
b) No water shall be lost from the mix during transportation.
c) The permissible time of transport of concrete should be determined within the laboratory.
d) The concrete combine should be protected from drying in hot weather and from rain during transport from the place of mixing to the position of placing.

4.20 Curing: Curing is the process of preventing loss of moisture from the concrete. When water is mixed in concrete a chemical reaction called hydration takes place. This hydration continues rapidly for first few days, after the concrete is placed, for this hydration to take place without interruption, favorable temperature and moisture conditions are to be maintained. The act of protection of hydration in concrete is in broad terms called curing. Thus, it can be concluded that to facilitate the hydration in cement, the water that is added in concrete during the construction should be prevented from evaporation.

Effect of curing in achieving the strength in concrete		
Sr. No.	**Curing days**	**Compressive strength percent of 28 days moist cured concrete**
1	No curing after laying	50% to 55%
2	Just 3 days curing	75% to 80%
3	7 days curing	95% to 100%
4	Full 28 days curing	120% to 125%

Note: Freshly laid concrete shall be protected from rain by suitable covering.Concrete should not be placed during rain.

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4.21 Reinforcement: All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances, which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean reinforcement. Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures.

4.22 Bending of Reinforcement: Bars shall be bent cold to the specified shape and dimensions or as directed by the Engineer-in-Charge using a proper bar bender, operated by hand or power to attain proper bend.

Bars shall not be bent or straightened in a manner that will injure the material.

Bars bent during transport or handling shall be straightened before being used on work, they shall not be heated to facilitate bending, unless permitted by Engineer-in-Charge.

Unless otherwise specified a U type hook at the end of each bar shall invariably be provided. The radius of the bend shall not be less than twice the diameter of the round bar and the length of the straight part of the bar beyond the end of the curve shall be at least four times the diameter of the round bar. In the case of bars which are not round and in the case of deformed bars, the diameter shall be taken as the diameter of a circle having an equivalent effective area.

The hook shall be encased to prevent any splitting of the concrete.

4.23 Laps in Bars: The length of lap in bars shall not be less than:

a) For bars in tension:

Bar diameter	Permissible Stress
	Four times the bond stress given in table IS: 456 or 30 bar diameters whichever is greater.

b) For bars in compression:

Bar diameter	Permissible Stress
	Five times the bond stress given in table IS: 456 or 24 bar diameters whichever is greater.

4.24 Distance between reinforcement bars:

a) The distance between two parallel reinforcement bars shall be except as provided under not less than the greatest of the following three distances: -

i. The diameter of either bar, if their diameter is equal.

ii. The diameter of the larger bar, if the diameter is unequal.

iii. 6 mm more than the nominal maximum size of the coarse aggregate comprised in such concrete.

Note: A greater distance should be provided when convenient.

b) The vertical distance between two horizontal main steel reinforcements, or the corresponding distance at right angles to two inclined main steel reinforcements shall be not less than 13mm except at a splice or lap and except where one of such reinforcements is transverse to the other.

c) The pitch of the main bars in a reinforcement concrete solid slab shall not be more than four times the effective depth of such slab.

d) The pitch of distributing bars in a reinforcement concrete solid slab shall not be more than four times the effective depth of such slab.

4.25 Nominal Cover to Reinforcement:

a) However for a longitudinal reinforcing bar in a column nominal cover shall in any case not be less than 40 mm, or less than the diameter of such bar. In the case of columns of minimum dimension of 200 mm or under, whose reinforcing bars do not exceed 12 mm, a nominal cover of 25 mm may be used.

b) At each end of a reinforcing bar not less than 25mm nor less than twice the diameter of such rod or bar.

c) For longitudinal reinforcing bar in a beam, not less than 25mm nor less than the diameter of such rod or bar.

d) For tensile, compressive, shear or other reinforcement in a slab, not less than 13mm nor less than the diameter of such reinforcement.

e) For any other reinforcement, not less than 13mm nor less than the diameter of such reinforcement.

f) For all external

For footings minimum cover shall be 50 mm.

4.26 Joints: Joints shall be provided as shown in the drawings or as directed by the Engineer-in-Charge.

4.26.1 Construction Joint: For large works, where it is not practicable to carry on concreting continuously, the position of leaving off points or construction joints and the details of which shall be shown in the drawings or as directed by the Engineer-in- Charge. Such joints shall be kept to the minimum and shall not be located in

valleys. The joints shall be kept at places where the shear force is the minimum and these shall be straight and at right angles to the direction of main reinforcement. In case of columns the joints shall be horizontal and 10 to 15 cm below the bottom of the beam running into the column head and the portion of the column between the stepping off level and the top of the slab shall be concreted with the beam.

When stopping the concrete on a vertical plane in slab and beams, an approved stop-board shall be placed with necessary slots for reinforcement bars to pass freely without bending or any other obstruction. The construction joint shall be keyed by providing a triangular or trapezoidal fillet nailed on the stop-board. Inclined or feather joints of stop-board be removed soon after the initial set. When concrete is stopped on a horizontal plane, the surface shall be roughened and cleaned after the initial set.

Walls shall be left off at any convenient height but the last layer shall be at the same level all round the structure.

When the work has to be resumed, on a surface, which has hardened (i.e. more than 48 hours old), the joint shall be thoroughly cleaned with wire brush and loose particles removed. It shall then be covered with a 13 mm layer of freshly mixed mortar comprising of cement and coarse sand in the same ratio as the cement and coarse sand in the concrete mix shall be applied before fresh concrete is laid.

When the work has to be resumed on a surface, which has not fully hardened (i.e. less than 48 hours old) the joint shall be thoroughly cleaned with wire brush and loose particles removed. The surface shall first be thoroughly wetted and all free water removed. A coat of neat cement slurry at the rate of 2.75 kg of cement per square meter shall then be applied on the roughened surface before fresh concrete is laid.

4.26.2 **Expansion Joints:** Expansion joints shall be provided as shown in drawing or as directed by the Engineer-in-Charge. The filling of these joints with bitumen filler, bitumen felt or any such material and the provision of copper or brass plate etc. (as may be specified) shall be described and paid for separately.

4.26.3 **Expansion Joints in Bridges:** Wherever, expansion joints are provided in the main structure of a bridge, expansion joints must be provided in the concrete flooring immediately above them, such joints should be constructed with two sheets of tarred paper previously laid on the support and be filled with preformed plastic material 13 mm thick which should be placed in the forms before concrete is laid so as to give a projection above the top surface of the concrete; this projection being trimmed of flush with the surface after the concrete has set.

CHAPTER-5

STONE MASONRY

5.0 The following Indian Standards shall be followed:

a) IS: 1125-1974 Method of test for weathering of natural building stones.

b) IS: 1126-1974 Method of test for durability of natural building stones.

c) IS: 1129-1972 Dressing of natural building stones.

d) IS: 1200:1979 (Part-IV) Method of measurements of stones.

e) IS: 1597-1967 Code of practice for construction of stone masonry.

f) IS: 1597-1967 (Part-I) Code of practice for construction of Rubble stone masonry.

g) IS: 1597-1967 (Part-II) Code of practice for construction of Ashlar stone masonry.

h) IS: 4101-1967 (Part-I) Stone facing

i) IS: 2185-1967 Code of practice for hollow cement concrete blocks.

Stone used for stone masonry shall comply with the specifications as below:

5.1 Quarried stone in Blocks (undressed): The stone shall be of the specified variety (such as granite, sand stone, quartzite etc.). The stone shall be hand sound, durable and free from defects like cavities, cracks or soft material etc. the minimum crushing strength of building stone shall be 200 kg/cm2 unless higher minimum strength is specified in any particular case.

5.2 Through Bond Stone and Quoins: The bond stones or through stones running right across the thickness of the walls shall be provided in walls up to 600mm thick. In thicker walls 2 stones overlapping each other by at least 150mm shall be provided across the thickness of the wall to form bond stone. There shall be at least 1 bond stone for 0.5m2 of wall surface. The bond stone marked by the distinguishing latter during construction for subsequent verification and shall be laid in staggered in subsequent layers.

Where bond stones of suitable lengths are not available CC block of 1:3:6 min shall be used.

5.3 Quoins: A quoin is the external angle of a wall or building. The quoin or corner stone shall be selected neatly dressed with hammer/chisel to form required corner angle and laid header and stretcher alternately. No quoins stone shall be smaller than 0.025 cum in volume and it shall not be less than 300 mm in length, 25% of it being not less than 500 mm in length.

5.4 Joints: Joints parallel to the external pressure must be staggered and should not be continuous. In other words, the stone in any course shall overlap the joint in the course below. All stones shall be laid full in mortar both in bed and in vertical joints. Clean chips and spalls shall be wedged into the mortar joints and beds wherever necessary to avoid thick beds or joints of mortar.

5.5 Stone for wire crates: The stone used shall be fairly regular and subject to marked deterioration by water or weather shall not be used.

The size of stone shall be as large as possible. In no case any fragment shall be less than 40 kg. The specific gravity of stones shall be as high as possible and it shall not be less than 2.50.

5.6 Testing of Stone:

a) **Water Absorption:** Stone with round surface shall not be more than 5% when tested for water absorption in accordance with IS: 1124-1974.

b) **Crushing Strength:** The minimum crushing strength of building stone shall be 200 kg/cm^{2}under higher minimum strength is specified in any particular case.

5.7 Dry Rubble Masonry: Dry rubble masonry shall be used in c/o breast wall and retaining walls, revetments walls and parapets.

In appearance dry rubble masonry will be like squared rubble built to courses. Each course shall be built through the entire thickness of the wall without mortar but with chips and spalls. The stones shall be roughly dressed to secure the maximum bedding surface without unduly reducing the size of stones. The largest stones shall be used in such construction, the larger being used in the lower courses. The face stone's average breadth shall not be less than the height and average length not less than 1½ times the height for stones up to 20 cm height and not less than 1-1/3rd the height or 30 cm whichever is more, for stones exceeding 20 cms in height. Dry stonewalling should not have a face batter steeper than 1:12 and until otherwise specified, batter shall be 1:4. The back of the wall shall be vertical; foundations as well as the courses must run at right angles to the face batter and not horizontally. Through or bond stones shall be provided in each course at intervals of 5 feet (2 meters) with specifications.

Dry stonewall higher than 20 feet (6 meters) should be strengthened by laying three consecutive courses of squared rubble masonry coursed in lime or cement mortar at every 10 feet(3 meters) interval.

5.8 Long walls: Long length of dry rubble walls should be divided into panels separated from one another by short lengths of walls 2 meters long built with squared rubble courses in lime or cement mortar at intervals of say 6 to 9 meters in order to confine damage, if any, only to the panels affected and thereby to minimize the repairs required.

5.9 Weep holes: It shall be provided in dry stonewalling when built against earth or hill slopes subject to saturation by surface or ground water flow. Weep holes shall be backed by coarse gravel and important walls by graded filters composed of coarse sand and gravel.

Filling immediately behind dry stonewall must, wherever possible consist of stone refuse or chips or coarse gravel clayey and silly soil should not be used where stone refuse or gravel is available.

5.10 Random Rubble Masonry: Random rubble masonry consists of stones, which are not squared but are of irregular shapes and are laid in specified mortar.

In this type of work scrabbled or quarry dressed stones are used and no further dressing is done except to knock off weak or angular corners. Care is taken to select stones of as uniform a shape as possible. Each stone will be laid on its quarry bed and will be wedged or pinned strongly into position in the walls by spalls or chips.

5.10.1 Polygonal Random Rubble Masonry: In this type of random rubble masonry the face stones are of very irregular shape most of them forming polygons. The stones are used as they come out of the quarry and if sufficient stones with polygonal faces are not forth coming some of the stones are hammer dressed to give polygonal faces.

Stones are laid to a random arrangement. Care being taken to lay them as close to each other as possible.

In all other respects, the work will conform to specification for random rubble masonry.

5.10.2 Stonework Individual Items:

a) Dry Random Rubble Masonry (Uncoursed/Bought to Course): Dry Random Rubble Masonry or dry stone walling shall be used in constructing breast and retaining walls, revetments walls and parapets.

The stone shall not be less than 15cms in any direction except the packing stone. The face stone's average breadth shall not be less than the height and average length not less than 1½ times the height for stones up to 20 cm height and not less than 1-1/3rd the height or 30 cm whichever is more, for stones exceeding 20 cms in height.

b) Dry polygonal random rubble masonry: In this type of masonry the face stones are of very irregular shape most of them forming polygons. The stones are used as they come out of the quarry and if sufficient stones with polygonal faces are not forthcoming some of the stones are hammer-dressed to give polygonal faces. Polygonal random rubble masonry of this type can either be uncoursed or it can be brought up to course by leveling after 45cms to 60 cms vertical interval.

c) Coursed rubble masonry first sort/coursed rubble masonry second sort: For first sort coursed rubble masonry, face stones shall be hammer dressed so as to give approximately rectangular blocks. They shall be squared on bed and side joints. The bed joints shall be rough chisel dressed for a depth of at least 50mm back from the face, and the side joints shall be so dressed to a depth of at least 40mm back from the face, such that no portion of the dressed surface is more than 6mm from a straight edge held against the surface. The bushing on the face shall not project by more than 40mm on an exposed face and 10mm on a face to be plastered. The hammer dressed stone shall also have a rough tooling for a minimum width of 25 mm along the four edges of the face of the stone. All the courses shall be laid truly horizontal. The height of course shall not be less than 150 mm nor more than 300mm.

d) For second sort coursed rubble masonry the stones shall be dressed as for first sort masonry described above except that no portion of dressed surface shall show a depression of more than 10mm (as against 6mm for first sort) from the straight edge placed against the dressed surface.

5.11 Precast Block Masonry:

5.11.1 Hollow Cement concrete blocks:

a) These shall conform to IS: 2185-1967 and shall be made of concrete mix as specified in the respective items.

b) A hollow block can have one or more than one hole or cavity passing through the block and having solid material between 50 percent and 75 percent of the total volume of block calculated from the overall dimensions.

c) All blocks shall be sound free from cracks, broken edges, honey combing and other defects that would interfere with the proper placing of blocks or impair the strength or performance of the structure.

5.11.2 Solid cement concrete block:

a) Solid cement concrete blocks shall be precast with concrete of specified mix.

b) A block shall be deemed to be solid if the solid material is not less than 75 percent of the total volume of the block calculated from the overall dimensions.

c) The concrete mix used for blocks shall not be richer than one part by volume of cement to 6 parts by volume of combined aggregate.

d) The material used for concrete shall conform to relevant I.S. Specifications. The size of the blocks shall be of one of the following size:

Size Designation	Nominal size cm.			Actual size cm.		
	Length	Breadth	Height	Length	Breadth	Height
Size A	40	30	20	39	30	19
Size B	40	20	20	39	20	19
Size C	40	10	20	39	10	19

Sizes other than these specified may also be used with the approval of the Engineer-in-Charge.

1. The blocks may be either machine made or handmade. The concrete mix, the mixing of concrete, the manufacture of blocks, curing and drying shall be in accordance with para 6 to 10 under IS code 2185-1967.

2. Faces of the blocks shall be flat and rectangular. Surface finish shall be rendered smooth or plastered with cement mortar 1:3 (1 cement : 3 course sand).

3. The average compressive strength of eight blocks when determined in manner described in IS: 2185-1967 shall not be less than 50kg/cm^2 of the gross area. The

strength of the lowest individual block shall not be less than 75 per cent of the average compressive strength of eight blocks.

5.12 Laying:

a) The blocks need to be wetted before or during laying in the walls. In case climatic conditions so require the top and the sides of block may only be slightly moistened so as to prevent absorption of water from the mortar and ensure the development of the required bond with the mortar.

b) Operations of laying of precast cement concrete block masonry shall be carried out in accordance with instructions detailed in IS: 6042-1962 para 10.2

5.13 Quoins and closers: Specials quoins blocks (with a return face equal to length to half the normal face) shall be cast for all building blocks and slabs for external work. Proper half-length closers shall be cast and not cut from full size blocks. The returned ends of blocks for door and window reveals and quoins shall be finished with a fair face in the moulds.

5.14 Do's:

a) Dressing of stones shall be as per the specifications for an individual type of masonry work.

b) Through and bond stones shall broadly be stacked separately from ordinary building stones.

c) All stones for masonry in cement mortar must be thoroughly wetted before laying.

d) Stones shall be laid on their natural quarry beds.

e) Cross walls must be carefully bonded into main wall.

f) Joints in masonry shall be staggered i.e. the stone in any course shall overlap the joint in the course below.

Don'ts:

a) Filling up the space between the masonry faces with fine, small or dry stone backing shall not be permitted.

b) No dry or hollow space shall be left anywhere in the masonry.

c) No mortar should fall or left on stone and should be immediately removed

CHAPTER-6

BRICK WORK

6.0 The following Indian Standards shall be followed:

a) IS: 3102-1971 Classification of burnt clay solid bricks.

b) IS: 3495-1973 (Part I to IV) Clay building bricks-method of tests.

c) IS: 1200-1974 (Part-III) Measurements of building and Civil Engineering works: method of brickwork.

d) IS: 2212-1962 Brick work code of practice.

e) IS: 1077-1970 Common burnt clay-building bricks.

f) IS: 5454-1269 Method for sampling of clay building bricks.

6.1 Sizes of Bricks: Unless otherwise specified bricks required for buildings or architectural works shall measure 19cm*9cm*9cm (actual) or 20cm*10cm*10cm (nominal) so that every 10 courses when laid with horizontal mortar joints shall measure one meter in height. A tolerance up to ± 6.5mm in length, ±3mm in width and ±3mm in height shall be permitted.

6.2 Classifications: Bricks shall be classified as follows:

a) **First class Bricks:** The first class brick shall conform to the following specifications:

i) They shall be made from good brick earth, free from saline deposits and shall be sand moulded.

ii) They shall be thoroughly burnt without being vitrified and shall have uniform deep red, chary or copper color.

iii) They shall be regular and uniform in shape and size with sharp and square arises and parallel faces.

iv) They must homogenous in texture and emit a clear ringing sound on being struck.

v) A first class brick shall not absorb water more than 20% of its own dry weight after 24 hours immersion in cold water.

vi) The first class bricks shall have a minimum crushing strength of 105 kg/cm^2 when tested. The crushing strength of any individual brick shall not fall below the average crushing strength by more than 20%.

vii) They shall not show any appreciable sign of efflorescence either in dry state or subsequent to soaking in water.

b) 2nd class brick:

i) They shall be as well burnt as first class brick or slightly over-burnt but not vitrified in any part.

ii) They must give a clear ringing sound when struck.

iii) They may have slight irregularities in size, shape and color provided these irregularities are not such as to give uneven courses when used for construction.

iv) The minimum crushing strength of second-class brick shall be 70kg/cm2 when tested. The crushing strength of an individual bricks shall not fall below the average strength by more than 20%.

v) They shall not show any appreciable sign of efflorescence either in dry state or subsequent to soaking in water.

c) 3rd class bricks:

i) These are not be so fully burnt as first or second class. These may be slightly under-burnt or slightly over-burnt.

ii) They may be distorted and have rounded edges and may not be uniform in shape. These defects, however, shall not be such as to cause difficulty in obtaining uniform courses with their use.

iii) They shall not absorb water more than 25% of their own dry weight after 24 hours, immersion in cold water.

iv) Third class bricks may show moderate signs of efflorescence when tested for efflorescence.

Third class bricks shall not be used anywhere without the specific orders of the Executive Engineer in writing.

6.3 Soaking: Bricks required for brickwork in cement or lime mortars, shall be thoroughly soaked in clean water immediately before use for one hour or till the complete cessation of air bubbles. Bricks shall be placed in the tank by hand, one at a time and not thrown or tipped in. The soaked bricks shall be kept on wooden planks or brick platforms to avoid earth being smeared on them. Bricks need not to be soaked for brickwork in mud mortar.

6.4 Laying:

a) Brickwork shall be laid in English bond i.e. alternate courses of header and stretcher unless otherwise specified with frogs upwards. Half or cut bricks shall not be used except where necessary to complete the bond. Closers in such cases shall be cut to the required size and used near the ends of the walls.

b) In exposed brickwork, selected bricks of the specified class shall be used for the face work.

c) A layer of mortar shall be spread in full width over a suitable length of the lower course. Each brick shall be properly bedded and taken up truly plumb.

d) All iron fixtures, pipes, outlets of water, hold fasts of doors and windows which are required to be built up into the walls shall be embedded in mortar or cement concrete.

e) The flue of the chimney shall be pargeted i.e. plastered with mud gobar mortar (3 mud: 1 gober) as the work proceeds. Nothing extra shall be paid for this par getting.

6.5 Half Brick Masonry:

a) When it is necessary to economics on space or to reduce dead weight partition walls of half brick thickness or even less are constructed. Such walls shall bear no weight except their own. When built on suspended floors, there must be a beam underneath to take the load or the floor itself designed to take its load.

b) Such walls of thickness 5cm or 7.5cm shall invariably be constructed with hoop iron reinforcement. Walls of thickness 10 cm shall be constructed without hoop iron reinforcement when any of the following conditions exist:

i) The height is not more than 2 meters.

ii) The supported length is not more than 3 meters.

iii) There are no doors and windows provided in the walls.

iv) The work is in first storey below plinth level.

In all other situations, these partition-walls of thickness 10 cm shall be reinforced with hoop iron. The hoop iron reinforcement shall be 25mm wide and 1.6mm thick. The hoop iron band shall be embedded in cement mortar as follow:

a) Walls constructed with metric bricks-every third course.

b) $4^{1/2}$" thick walls constructed by non-metric bricks every 4th course.

c) 3" brick walls constructed with non-metric bricks every 3rd course.

The hoop iron shall be hooked (give in double lap) with minimum of 20 cm hooks, at all angles junctions. Hoop iron band shall be continued for 20 cm into the main wall on which the partition wall abuts 5cm length of the hoop iron being bent up or down so as to take a firm grip of the brickwork.

Before laying the hoop iron, it shall be cleaned of rust and loose flakes with a wire brush. The hoop iron shall lie quite flat on the mortar. Half the mortar for the joint shall first be laid and other half laid after the hoop iron has been laid in position so that it is fully embedded in the mortar. When hoop iron is not available, the Engineer-in-Charge may allow equivalent reinforcement in the form of rods.

6.6 Cavity walls: Hollow walls or double with a cavity between them shall be built where specified, in order to exclude dampness or in order to keep the interior of the building cool in summer and warm in winter.

The cavity between the two walls shall not be less than 5cm. The outer wall should be half brick thick i.e. 10cm. in metric bricks 41/2" thick in non-metric walls. The bricks shall be provided for half brick thick masonry.

The internal may be half brick thick or one brick thick depending upon the load coming on the wall. The ratio of cement sand mortar in which the internal wall should be built will also depend upon this consideration. The normal rule is that combined thickness of the walls (excluding cavity) should be equal to the thickness demanded for any solid wall with the given conditions for height and lengths. If the internal wall is half brick thick, it shall be laid in cement sand mortar 1:4 and reinforced with hoop iron as the outer wall.

Where cavity walls have been specified to exclude dampness, the cavity must continue below the damp-proof course, which shall be at the ground level for the outer wall and at the plinth level for the inner wall.

6.7 Mortar Dropping: During construction of cavity wall, mortar droppings are quite likely to fall into the cavity and get lodged over ties and become a constant source of transmittance of moisture. For preventing this, a wooden batten should be kept over ties during the construction the construction of wall to catch any mortar droppings.

The batten should be lifted up every time when the next row of ties is reached and the process repeated as the construction of wall proceeds. The inner surface of outer leaf of the wall should not encourage splash of dripping water that may penetrate through the outer leaf and thus transmit dampness to the inner leaf. To avoid this, projections from outer leaf extending into the cavity should not be allowed.

6.8 Solids Portions: The cavity walls shall be built solid at the corners and either side of all openings for a width of half brick thickness i.e. 10 cm in case of metric bricks and 41/2" in case of non-metric bricks. The top of three courses under the roof shall also be built solid. The tops of arches or lintels shall be plastered during construction with neat cement so as to stop penetration of moisture into the inner wall.

6.9 Cleaning out Holes: Small openings shall be left in the exterior leaf approximately 2 meters apart at the start of masonry so as to facilitate hand cleaning out by means of a rake. These holes should be closed at the end of the construction of the wall after doing the necessary cleaning of the cavity.

6.10 Ventilation of Cavity: The cavity in hollow walls shall be ventilated at the bottom and near the top by providing airbricks or openings having 6mm x 6mm grating. The openings near the bottom shall be so placed as to allow the escape of any condensed moisture that may have collected.

6.11 Hollow Portion Walls: Hollow partition walls which do not carry any load except their own weight, shall be made 5cm thick each with 5cm cavity in between. In case of non-metric bricks, the thickness of each wall shall be 3 inches with 2 inches cavity in between. The brick work shall be reinforced every third course with bands of hoop iron as specified in case of half brick thick masonry. Instead of metal ties the two walls shall be bonded together by header bricks at every one-meter interval and in every alternate course.

6.12 Testing of Bricks:

6.12.1 Absorption Test on Bricks: Water absorption is an important property of the bricks since it has tremendous effect on the durability of the structure. Less value of water absorption indicates the more strength and durability.

Recommendation: For a good quality brick the amount of water absorption should not exceed 20% of weight of dry brick.

6.12.2 Strength Test on Bricks: A minimum value of compressive strength of a good brick as specified by IS: 3495 Part I, 1976 is 35 to 40 kg/cm^2.

Apparatus:

a) Compressive testing machine, the platens of which shall have a ball seating arrangement.

b) Two plywood planks of 3mm thick each.

Do's:

a) Bricks required for brickwork in cement mortar shall be thoroughly soaked in clean water.

b) Brickwork shall be laid in English Bond with frogs upward.

c) Thickness of joints shall be 8mm and shall not exceed 12mm.

d) For a surface, which is to be subsequently plastered or pointed, the joints shall be squarely raked out to a depth of 15mm.

e) Plastering shall be started from top and worked down.

Don'ts:

a) Bricks need not be soaked for brickwork in mud mortar.

b) The work done per day should not be more than one-meter height.

c) No portion of the surface to be plastered shall be left out initially to be patched up later on.

CHAPTER-7

MISCELLANEOUS BUILDING WORKS

7.1 Plinth Protection: Plinth protection shall be provided all-round the building in specified width. Plinth protection shall be of cement concrete or of bricks as specified in the item of work. Outer edge shall be lined with brick laid on edge and joints grouted with cement mortar. Plinth protection shall be laid with a minimum outward slow of 1 in 48.

7.2 Preparation of ground: The ground shall be prepared to the required slope around the building. The high portions of ground shall be cut down, hollows and depressions filled up to the required level from the excavated earth and rammed so as to give uniform out-ward slope. Bed shall be watered and rammed with heavy iron square rammers. Surplus earth, if any shall be disposed of, with in a lead of 50 meters.

7.3 Flag stone flooring: Flag stone flooring shall be over a bed of 15cm thick well-rammed earth. It shall be laid over a base of 75mm thick lean concrete 1:4:8 (1 cement: 4 sand: 8 graded stone aggregate 40mm and down gauge, the thickness of flag stone flooring shall be 40mm, with cement pointing 1:3 (1 cement: 3 sand). Stone used for flag stone flooring shall be got approved from the Engineer-in-Charge. Plinth protection shall be laid with minimum out ward slope of 1 in 48. The work shall be executed as per direction of Engineer-in-Charge.

7.4 Cement concrete plinth protection: It shall be laid over a base of 75mm thick lean concrete 1:4:8 (1 cement: 4 sand: 8 graded stone aggregate 40mm and down gauge). 50mm thick cement concrete 1:3:6 (1 cement: 3 coarse: 6graded stone aggregate 20mm nominal size) shall be laid in alternate panels as described in workmanship of section 'Paving and Flooring' except that the top shall not be finished with neat cement slurry but shall be finished with only wooden floats. The finished surface shall have a minimum outward slope 1 in 48.

7.5 Brick plinth protection: After the preparation of ground 75mm thick base of lean cement concrete 1:4:8 (1 cement: 4 sand: 8 graded stone aggregate 40mm and down gauge) shall be laid. Flooring with bricks (laid flat or on edge) of class I. modular or conventional as per specified in cement mortar 1:6 (1 cement: 6 sand) shall be laid as described in Section 'Paving and Flooring.

The pointing shall be done in cement mortar 1:2 (1 cement: 2 fine sand) as described in section 'Plastering and Pointing' Plinth protection shall be laid with minimum outward slope of 1:48.

7.6 Brick edging: Brick edging will be done with the bricks of class I modular or conventional as specified. Trenches of required depth shall first be made along the edge of the plinth protection to receive bricks. The bed of trenches shall be compacted to a firm and even surface and then bricks shall be laid true to line with lengths parallel and abutting against the plinth protection with their tops flush with the concrete surface. The joints shall be grouted with cement mortar 1:4 (1 cement: 4 fine sand).

7.7 Laying: Fire clay refractory bricks shall be dipped into water immediately before use. Its inside face shall buttered with a layer of fire clay mortar and bricks laid in contact with each other. A layer of thin paste of fire clay enough to fill up the irregularities of their faces and give them a

solid baring shall be spread on a lower course and each brick placed in position and set home by gentle tapping with the handle of trowel or wooden mallet. The fire clay mortar shall be mixed up so thin that it cannot be well laid on with trowel, an iron spoon being preferable.

7.8 Joints: Fire clay refractory bricks shall be so laid that all the joints are quite full of fire clay mortar. The joints shall be struck flush and finished at the time of laying. The face of fire clay refractory brick work shall be cleaned and all mortar droppings removed.

PAVING AND FLOORING

7.9 General Specification:

7.9.1 Sand filling: The earth filling shall be stopped at such a height so as to allow to full thickness of sand, of cement concrete and the correct thickness of surfacing. In areas, where the water table is near the ground surface, a suitable treatment shall be provided to prevent the rise of moisture into the floor. This treatment shall be paid for separately.

7.9.2 Base Concrete: Base concrete shall be laid in accordance with the specifications laid in one operation in a uniform layer, absolutely true and parallel to what is required on the finished surface and to the satisfaction of Engineer-in-Charge.

7.9.3 Leveling: A reference level mark shall be marked around on the walls (15 cms) or so above the floor level with the help of a water level. Water level consists of a can of water connected with rubber tubing to a glass tube, which shows the level of water in the can. With the help of this level truly horizontal lines can be marked with string and lime on the walls. These horizontal can be marked with string and lime on the walls. These horizontal lines shall serve as a datum from which all levels for base layer and topping etc. shall be measured off.

7.9.4 Paving to bond with base concrete: The finishing surface or paving shall not be laid before the base concrete has set for at least seven days. While the surface is still soft enough to receive and retain the impression, it should be brushed with stiff-bristled broom. This is very necessary in order to remove laitance, scum and inadequately embedded coarse aggregate. In addition to the brushing, scour and pits the surface so as to provide a mechanical bond for the topping. During the interval between the finish, the base shall be thoroughly cured and protected from the deposition of grease, pitch, paint or any other foreign subsistence.

7.9.5 Levels and Slopes: Unless otherwise specified, all floors shall be perfectly leveled, except bathroom and verandah floors, which shall have an outward slope 1 in 60. The layers of sand concrete shall be uniform in thickness and any slope required is to be obtained by making the outer walls lower than the inner ones by the necessary amounts.

7.9.6 Straight edges and spirit levels: The contractor shall provide and keep available wherever flooring work is proceeding, straight edges of a length not less than 2.5 meters

and with parallel sides, as well a 25 cms spirit level for the purpose of testing the trueness of the floor being laid.

7.10 Precast Interlocking Paver Blocks: Precast concrete Paver blocks shall be conforming to IS 15658:2006 – Specification for Precast concrete blocks for paving. Paver blocks shall be sound and free from cracks or other visual defects. The tolerance on length or breadth of paver blocks shall be +2mm and tolerance on thickness of tiles shall be +3mm. Water absorption shall not be more than 6 percent by mass.

Shapes shall be triangular, Zigzag, Hexagon or other shape as indicated. Color of paver blocks shall be as indicated or as decided by Engineer-in-Charge. Thickness and grade of concrete of paver blocks is decided based on intensity of traffic, which is as under:

Traffic Category	Paver block thickness	Grade of concrete
Light traffic	60mm	M-35
Medium traffic	80mm	M-40
Heavy traffic	100mm	M-40

7.11 White Glazed tiles in flooring, treads of step and landings

7.11.1 Sub-grade: Sub grade shall be of concrete or of R.C.C. slab.

7.11.2 Bedding: Bedding over which the tiles shall be laid shall be of 12 mm average thickness in cement mortar 1:3 (1 cement: 3 coarse sand).

7.11.3 Laying: Sub grade shall be cleaned, wetted and mopped. The bedding shall be laid evenly over the surface, tamped and corrected to desired levels and allowed to harden enough to offer a rigid cushion to tiles and to enable the mason to place wooden planks across and squat on it. Before laying the tiles grey cement slurry of honey like consistency at 3.3 kg/square meter shall be applied over the bedding at a time. Area to accommodate about twenty tiles shall be applied with cement slurry. Tiles shall then be washed clean and fixed in the grout one after the other, each tiles being gently tapped in line with adjoining tile. The joints shall be as thin as possible in straight line or as per the pattern.

7.11.4 Jointing and Finishing: The joints shall be cleaned of grey cement grout with wire brush or trowel to a depth of 5mm and all dust and loose mortar removed. White cement shall then be used for flush pointing the joints. The floor shall be cured for seven days. The surface then be washed and cleaned. The surface shall not sound hollow when tapped.

7.12 Cement Concrete flooring with Metallic Hardener Topping

7.12.1 General: Wherever floors are required to withstand heavy wear and tear, use of floor hardeners shall be avoided as far as possible by using richer mixes of concrete unless the use of a metallic hardener is justified for reasons of cost. Where metallic hardener topping is used, it shall be 15mm thick.

7.12.2 Metallic Hardening Compound: The compound shall be of approved quality consisting of uniformly graded iron particles, free from ferrous metal particles, oil grease, sand and soluble alkaline compounds.

7.12.3 Under-Layer: The under-layer shall consist of cement concrete (1:2:4) of specified thickness with 20mm nominal size aggregate and the top surface shall be roughened with brushes while the concrete is still green and the forms shall be kept projecting up 15mm over the concrete surface, to receive the metal hardening compound topping.

7.12.4 Topping: This shall consist of 15mm thick layer of mix 1:2 (1cement: 2 stone aggregate 6mm nominal size) by volume or as otherwise specified with which metallic hardening compound is mixed in the ratio of 1:4 (1 metallic concrete hardener: 4 cement) used by weight. Concrete hardener shall be dry mixed thoroughly with cement on a clean dry pucca platform. This dry mixture shall be mixed with stone aggregate 6 mm nominal size or as otherwise specified in the ratio of 1:2 (1cement: 2 stone aggregate) by volume, and well turned over.

7.13 Kota stone Flooring

7.13.1 Bedding: Bedding for the marble slabs shall either is lime mortar 1:1:1 (1 lime putty: 1 surkhi: 1 coarse sand) of average thickness 20mm or cement mortar 1:4 (1 cement: 4 coarse sand) of average thickness 20mm as given in the description item.

7.13.2 Laying: Sub grade shall be cleaned, wetted and mopped. Mortar of the specified mix and thickness shall then be spread on an area sufficient to receive one slab. The slab shall be washed clean before laying. It shall be laid on top, pressed and tapped gently to bring to bring it in level with the other slabs. It shall then be lifted and laid a side. Top surface of the mortar at hollows or depressions. The mortar is then allowed to harden a bit. Over this surface, cement slurry of honey like consistency @4.4 kg of cement per square meter shall be applied. The edges of the slabs already paved shall be buttered with gray cement with pigment to match the shade of the Kota stone slabs as given in the description item. The slab shall then be gently placed in position and tapped with wooden mallet till it is properly bedded in level with close to the adjoining slab. The joint shall be as fine as possible. Surplus cement on the surface shall be removed. The slabs fixed in the floor adjoining the walls shall enter not less than 10 mm under the plaster, skirting or dado.

7.13.3 Grinding, Polishing and Finishing: Grinding shall normally be commenced after 14 days of laying the tiles except for skirting or small areas. Machine shall be used for the purpose. First grinding shall be done with carborundum stone of 48 to 60-grade grit fitted in the machine. Water shall be properly used during grinding. Pinholes are covered with a thin coat of grey or white cement, mixed with or without pigment to match the color of the toppings of the tile. This grout shall be kept moist for a week. There after second grinding shall be started with carborundum of 120 grit. Grouting and curing shall follow again. Final grinding shall be done when other works are finished. The machine shall be fitted with carborundum of grit 220 to 350 using water in abundance. The floor shall then be washed clean with water. Oxalic acid power shall be dusted at 33 grams per square meter on the surface and the surface rubbed hard with pad of woolen rages. The floor

shall be washed clean and dried with a soft cloth or linen. The finished floor shall not sound hollow when tapped with a mallet.

If any tile is disturbed or damaged, it shall be refitted or replaced, properly jointed and polished.

Don’ts:

1. First polishing with coarse grade carborandum stone shall not be done.
2. Cement slurry with or without pigment shall not be applied to the surface before polishing.

"The social and cultural aspect of a road is not in any way less important than the economic aspects. The traffic of ideas also takes place through social intermingling, which is made possible by roads. This last aspect of roads is, in my opinion, of fundamental importance, particularly for a country like ours."

Dr. Rajendra Prasad

SPECIFICATIONS AND QUALITY CONTROL FOR STATE/RURAL ROADS.

LIST OF IS CODES FOR ROADS AND BRIDGES

The following Indian Standards shall be followed:

1. IRC 019-2005 Standard Specifications and Code of Practice for Water Bound Macadam.
2. IRC 109-1997 Guidelines for Wet Mix Macadam.
3. IRC 014-2004 Recommended Practice for Open Graded Premix Carpet (Third Revision).
4. IRC 016-2004 Standard Specifications and Code of Practice for Prime and Tack Coat (Second Revision).
5. IRC 028-1967 Tentative Specifications for the Construction of Stabilized Soil Roads with Soft Aggregate in Areas of Moderate and High Rainfall.
6. IRC 034-2011 Recommendations for Road Construction in Areas Affected by Water Logging, Flooding and/or Salts Infestation.
7. IRC 037-2012 Tentative Guidelines for the Design of Flexible Pavements.
8. IRC 047-1972 Tentative Specification for Built-Up Spray Grout
9. IRC 056-2011 Recommended Practice for Treatment of Embankment and Roadside Slopes for Erosion Control (First Revision).
10. IRC 082-1982 Code of Practice for Maintenance of Bituminous Surfaces of Highways.
11. IRC 090-2010 Guidelines of Selection, Operation and Maintenance of Bituminous Hot Mix Plant (First Revision).
12. IRC 110-2005 Standard Specifications and Code of Practice for Design and Construction of Surface Dressing.
13. IRC 112-2011 Code of Practice for Concrete Road Bridges.
14. IRC SP 013-2004 Guidelines for the Design of Small Bridges and Culverts.
15. IRC SP 042-2014 Guidelines on Road Drainage (First Revision).
16. IRC SP 063-2004 Guidelines for the Use of Interlocking Concrete Block Pavement.
17. IRC SP 075-2008 Guidelines for Retrofitting of Steel Bridges by Prestressing.
18. IRC SP 097-2013 Guidelines on Compaction Equipment for Road Works.
19. IS: 2720-1970 Method of test for soils.

CHAPTER-8

EMBANKMENT & SUB GRADE

8.1 Methodology:

8.1.1 Suitable soil: Which can be compacted and is stable.

Unsuitable fill material:

a) Materials from swamps, marshes and bogs (spongy ground).
b) Peat, log, perishable material, any soil classified as OL, OI, OH or Pt (IS 1498).
c) Instantly combustible.
d) Sodic soils pH > 8.5
e) Clay with LL > 70
   PI > 45
   Free swelling index > 50
f) Frozen material
g) Soils having soluble sulphates content more than 1.9gms of sulphates (as SO3) per liters or total sulphate content more than 0.5% (as SO3) by wt. of soil. These eat away the cement and make the mortar like powder, when in contact with concrete structures.

- Suitable soil – {Local and Imported}
- Stack 150mm top-agricultural-mineral rich soil for re-spread.
- Embankment any height 97% light compaction.
- Sub grade top 300mm 100% light compaction.
- Layers not > 150mm thick compacted.
- Compaction at OMC {+1%, -2%}
- If clayey/BC soils at OMC {-Nil, +2%}

8.1.2 Sub grade: The construction is similar to embankment. The CBR requirement is higher and the degree of compaction is minimum 100% of normal proctor density. When CBR is poor such as on BC soil, the improved sub grade with lime, cement stabilization or mechanical stabilization can be used to improve the CBR, if it is cost effective vis-à-vis replacement with good soil.

8.1.3 Compaction: It is the volume change produced artificially by momentary load application such as rolling, tamping or vibration. The air present is expelled with 5-10% voids left. Coming of grains together increases the load carrying capacity of the soil. The soil grains are packed closer. The weight of roller and number of passes has a great role to play to get the desired compaction.

8.1.4 Speed of Roller: It can be from 3km/hr to 6km/hr. It depends upon nature of the soil, thickness of layer and weight of roller.

10 ton smooth wheel roller having minimum of 54.5kg/ linear cm moving at 4km/hr with 8 passes should be adequate for compacting about 200mm layer.

For clayey soil, clayey silts, Sheep Foot Roller (SFR) are suggested. For all other soils vibratory roller is best.

8.2 Quality Control Requirements:

1. Materials:

a. The size of coarse material shall not ordinarily exceed 75mm when placed in embankment and 50mm when placed in sub grade.

b. The materials should satisfy the density requirements given in Table

Density requirement of embankment/sub grade materials

Sr. No.	Type of work	Max. Laboratory dry unit weight
1.	Embankment not subject to flooding - Height up to 3m - Height more than 3m	 Not less than 1.44gm/cc Not less than 1.52gm/cc
2.	Embankment subject to flooding	Not less than 1.52gm/cc
3.	Sub grade, earth shoulders	Not less than 1.65gm/cc

2. **Horizontal Alignment:** The alignment will be reckoned with respect to the centre line of the carriageway. The edges of the roadway as constructed shall be correct within a tolerance limit of (±) 30m there from.

3. **Surface levels:** The tolerance in surface level for sub grade will be (±) 25mm.

4. **Surface regularity:** The maximum permitted number of surface irregularities shall be given in table:

Irregularities	4mm		7mm	
Length (m)	300	75	300	75
Number of irregularities	50	25	6	3

5. **Density of Compaction:** The density of compaction should satisfy the requirements given in table:

Sr. No.	Type of work/material	Relative compaction
1.	Sub grade and earth shoulders	Not less than 100% standard proctor
2.	Embankment	Not less than 97% standard proctor

Acceptance criteria shall be subject to the condition that the mean density is not less than the specified density plus $(1.65 - \frac{1.65}{\sqrt{\text{No. of samples}}})$ × standard deviation.

8.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	For borrow pits along the road, ridges of minimum 8m width should be left at	The material for earthwork in embankment should not contain any logs,

	intervals not exceeding 300m. Small drains should be cut through the ridges to facilitate drainage.	stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the sub grade.
2	The depth of borrow pits should be so regulated that their bottom does not cut an imaginary line having a slope of 1 vertical to 4 horizontal projected from the edge of the final section of the bank, the maximum depth in any case be limited to 1.5m.	The following types of material should not be permitted. ▪ Materials from swamps and marshes. ▪ Peat, log, stump and perishable material. ▪ Materials susceptible to spontaneous combustion. ▪ Materials in frozen condition. ▪ Clay having LL exceeding 70 and PI exceeding 45. ▪ Materials with salt resulting in leaching. ▪ Expansive clay having free swelling index exceeding 50. (Where the ground on which an embankment is to be built has any of the above materials, such material must be removed to a depth of at least 500mm and replaced with acceptable fill material before commencing work of embankment.
3	The area of the embankment foundation should by kept dry.	No damage should be caused to works, crops or other property while discharging stagnant water found in the embankment foundation.
4	Test the material (soil) for embankment at least 7 days before commencement of compaction.	Do not allow clods or hard lumps of earth larger than 75mm when spreading soil for each layer of embankment.
5	Maintain a camber/cross fall of 4% during construction for effective drainage and prevention of ponding of water.	

8.4 Quality Control Test (Frequency):

The quality control tests and their frequency for earthwork in embankment/sub grade.

Tests and their frequency		
Sr.No.	**Test**	**Frequency**
A	**Borrow Area**	
i.	Sand content	1 test per 4000cum.
ii.	Plasticity Index	1 test per 4000cum.
iii.	Compaction	1 test per 4000cum.
iv.	Natural moisture content	1 test per 500cum.

v.	CBR	1 test per 5000cum.

B	Construction Operation	
i.	Moisture content prior to compaction	1 test / 250 cum/min. 4tests per day.
ii.	Thickness of layer	Regularly
iii.	Density of compaction	1 set of tests per 2000sqm comprising 6 measurements.

CHAPTER-9

GSB

9.1 Methodology

- Approve source a month advance
  - Natural (sand, moorum, gravel)
  - Crushed (stone, slag, brick, metal, kankar)
- Compaction layer thickness
  - 100mm 3-pin roller (80-100 kN wt.)
  - 150mm-225mm vibratory roller of 80-100kN wt.
    98% heavy at OMC + 1%
    (Atleast100% compaction) - 2%
- Level tolerance
  - +10mm
  - -20mm
- Surface regularity
  - Longitudinal 12mm
  - Transverse 10mm
- Engineer's Specific Approval.
  - Crushed slag
  - Brick bats
  - Concrete rubble
  - Kankar
- Grading prefers coarse grading: Grade-I.
- Remove vegetation from sub grade.
- Light water sprinkle and two passes of roller.
- Spread GSB with tractor toed blade.
- Water to be added with truck/tractor toed water tanker filled with perforated spray bar.

9.2 Quality Control Requirements:

1. **Materials:**
   - Fraction passing 425 micron
     - LL not > 25%
     - PI not > 6%
     - Soaked CBR not > 20% (15% with specific approval of Engineer if material is not suitable within economic load)
     - Wet AIV not > 50
   - Density of compacted layer – 2000 sq.m(6 sets)
   - CBR - 1 in 1000 cubic m
   - Grading of coarse graded GSB:

Sieve	Grade I % passing	Grade II	Grade III
75mm	100	-	-
53mm	-	100	-
26.5mm	55-75	50-80	100
4.75mm	10-30	15-35	25-45
0.075mm	<10	<10	<10
0.025mm	<5	<5	<5 on clayey sub grades
CBR	30	25	20

Note: It will be seen that gradation of GSB Gr.I and drainage layer are same except on sieve of 75 micron.

2. **Horizontal Alignment:** The edges of the sub-base shall be correct within a tolerance limit of (±) 30mm.

3. **Surface levels:** The tolerance in surface level for granular sub-base will be (±) 20mm. (A grid of 10-15mm may be formed to check the surface level).

4. **Surface regularity:** The maximum permitted number of surface irregularities shall be given in table:

Irregularities	**4mm**		**7mm**	
Length (m)	300	75	300	75
Number of irregularities	50	25	6	3

5. **Density of Compaction:** Minimum value of field density shall be 98% of IS heavy compaction density. Acceptance criteria shall be subject to the condition that the mean density is not less than the specified density plus (1.65- $\frac{1.65}{\sqrt{\text{No. of samples}}}$) × standard deviation.

9.3 Do's and Don'ts:

Sr. No.	**Do's**	**Don'ts**
1.	Look for soft patches, if any, and rectify them by removing or adding fresh material and compacting the same thoroughly.	Do not permit organic or other deleterious materials.
2.	While preparing the sub base/ base, where predominant exists, make sure that the surface profile is corrected before spreading the gravel/ soil-aggregate mix.	Do not use materials like crushed slag, crushed concrete, brick metal and kankar without specific approval of the Engineer.

9.4 Quality Control Test (Frequency):

Sr. No.	**Test**	**Frequency**
1	Gradation	Two tests per 500 cum or per day
2	Atterberg limits	Two tests per 500 cum or per day
3	Moisture content prior to construction	Two tests per 500 cum or per day
4	Compacted thickness	Regularly
5	Density of compacted layer	One set of tests per 2000 sqm comprising 6 measurements
6	CBR Test	One test per 5000 cum

CHAPTER -10

WATER BOUND MACADAM

10.1 Methodology:

- Prepare the surface true to profile.
- Template at 6m interval and spread material uniformly.
- Roll the surface with three wheeled roller 80-100 kN wt. or tandem or vibrating roller of same weight and start applying screening after partial rolling.
- Light sprinkle of water, sweep screening to fill interstices and roll till aggregates are keyed in, 2-3 operations. Ensure an overlap of half width of roller in successive passes.
- After application of screening water shall be copiously sprinkled, wet screening broomed in & rolled.
- Apply binding material in two-three layers (PI 4-6) if screenings are non-crushable type.
- No screening for soft aggregates (brick metal, kanker etc.)
- No rolling if sub grade is soft.
- No traffic till curing of WBM.
- Binding materials normally have PI 4 to 6. It should pass 100% through 425-micron sieve.

10.2 Quality Control Requirements:

1. Materials:

Coarse Aggregates:

- **AIV** Not > 50% (sub base)
  Not > 40% (base)
  Not >30% (unsurfaced roads)
- **Flakiness index** Not > 30% sub base
  Not > 25% base
- **Water absorption** Not > 6% sub base (as per Rural Road Manual)
  Not > 3% base

Grading Requirements of Course Aggregates for WBM

Grading No.	Size Range	IS Sieve Designation	%age by weight passing
1.	90mm to 45mm	125mm	100
		90mm	90-100
		63mm	25-60
		45mm	0-15
		22.4mm	0-5
2.	63mm to 45mm	90mm	100
		63mm	90-100
		53mm	25-75
		45mm	0-15
		22.4mm	0-5
3.	53mm to 22.4mm	63mm	100
		53mm	95-100
		45mm	65-90
		22.4mm	0-10
		11.2mm	0-5

NOTE: The compacted thickness for layer with Grading 1 shall be 100mm while for layer with Grading 2 and 3, it shall be 75mm. For base course, Grading 2 and 3 may be preferred. Grading 1 will be used for sub base only.

Grading for Screening

Grading Classification	Size of Screenings	IS Sieve Designation	%age by weight passing the IS Sieve
A	13.2mm	13.2mm	100
		11.2mm	95-100
		5.6mm	15-35
		180 micron	0-10
B	11.2mm	11.2mm	100
		5.2mm	90-100
		180 micron	15-35

2. Surface Level:

The tolerance in surface levels of the WBM would be as under:

a) Sub base course ±20mm
b) Base course
   i. Machine laid ±10mm
   ii. Manually laid ±15mm
   (A grid of 10-15m may be formed to check the surface levels).

3. Surface regularity:

The maximum permitted number of surface irregularities shall be given in table:

Irregularities	**4mm**		**7mm**	
Length (m)	300	75	300	75
Number of irregularities	50	25	6	3

4. Rolling: Rolling shall be done with 80-100kN roller from lower to higher edge & continue till road metal is thoroughly keyed and creeping of stone ahead of roller not visible, light water sprinkle be given.

10.3 Do's and Don'ts:

Sr. No	Do's	Don'ts
1	Check aggregates for grading, Los Angeles Abrasion Value or Aggregate Impact Value, Water Absorption and Soundness and Screenings for grading, LL and PI.	Do not use material other than crushed or broken stone or crushed slag.
2	Use templates at about 6m apart to prepare surface to profile.	Coarse aggregates should not contain excess flat, elongated soft disintegrated particles, dirt and deleterious material.
3	Ensure an overlap of half width of roller in successive passes.	Do not use screenings if aggregate is soft. (E.g. brick metal, kankar, etc.)

4	Build shoulders simultaneously along with WBM courses.	Do not allow segregation or pocket of coarse/fine material on the layer.
5		Do not spread coarse aggregate more than 3 days in advance of any subsequent operations.
6		Do not roll if sub grade is soft or yielding or causes a wave like motion while rolling.
7		Do not use screenings to make up depressions.
8		Do not allow traffic till macadam is fully set.

10.4 Quality Control Tests Frequency:

Sr. No	Test	Frequency
1	Aggregate impact value	1 test per 250 cum or per day
2	Grading of aggregate and screenings	2 tests per 250 cum or per day
3	Flakiness index	1 test per 250 cum or per day
4	Atterberg limits of binding material, if required	1 test per 50 cum or per day
5	Water absorption	1 test per source (three representative specimens for each source)
6	Thickness	Regularly

CHAPTER-11

WET MIX MACADAM

11.1 Methodology:

Material passing 425 micron shall have PI<6

Mixing: In pan type mixer or other suitable mixing plant.

Optimum moisture content on size 4.75mm to 22.4 mm

Spread with paver/ motor grader.

Rolling: with vibratory roller

From lower edge to higher edge.

Q.C. in laying & compacting by camber templates/3M st.edge

Thickness control: by thickness block

Surface regularity checked with 3M st. edge 12mm.

11.2 Quality Control Requirements:

- Crushed graded aggregate and granular material premixed with water to a dense mass on a prepared sub grade/ sub base/ base or existing pavement laid with ordinary/vibratory 80kN and 100 kN road roller.
- Thickness 75mm with ordinary roller
  225mm with vibratory road roller.
- AIV 30%
- FI+Elong. 30% (SH/NH)
- Water absorption 2

If more than 2 have soundness test.

Grading

IS Sieve Designation	%age by wt. passing IS Sieve
53.00mm	100
45.00mm	95-100
26.50mm	----
22.40mm	60-80
11.20mm	40-60

4.75mm	25-40
2.36mm	15-30
600 micron	8-22
75 micron	0-8

11.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	Ensure compliance of all material and plant requirements.	Do not use material other than crushed stone.
2	Check aggregate for soundness test when water absorption is more than 2%.	Do not allow segregation or pockets of coarse/fine material on the layer.
3	Build shoulders simultaneously along with WMM layers.	Do not allow any traffic on the WMM surface without covering it with a wearing course.
4	Remove BT surface before WMM is laid on an existing road.	

11.4 Quality Control Test Frequency:

Sr. No.	Type of Test	Frequency
1	Grading test	At least one test per day
2	Aggregate impact value	At random one test per km
3	Placement moisture content	At least three tests per day
4	Density of compacted layer	At least three tests per day
5	Thickness of compacted layer	At random

CHAPTER-12

MAINTENANCE

12.1 General: Condition of the roads is generally poor due to inadequate maintenance & lack of proper resources. Scientific approach is necessary for proper maintenance to ensure optimal utilization of available resources. Budgetary constraints & low priority for road maintenance are usual in management circles.

12.2 Prioritizing Maintenance: Normally, the practices of prioritizing or estimating the maintenance requirement are mainly based on visual survey & thumb level method. Therefore the actual requirements of maintenance need cannot be compared technically. This leads to improper maintenance & failure of roads very often. In facts, it is necessary to have a priority model based on several interrelated parameters along with pavement condition. The system should be based on saving system for maintenance on priority ratings, which includes overall condition of the pavement & distress.

Suggested weightage factors for different Parameters		
Sr. No.	**Parameters**	**Suggestive relative weight (%)**
1.	Road surface condition	20
2.	Population served	15
3.	Regional development	15
4.	Socio-Economic development	10
5.	Traffic volume	10
6.	Relative importance of road (in terms of service)	10
7.	Safety	10
8.	Political aspects	10

12.3 Pavement Management System:

Modern methods of highway maintenance make use of good management principles, which are invaluable aids in planning, and programming of maintenance operations. Many Pavement Management System (PMS) have been developed and are extensively used worldwide. A PMS is a computer package, which facilitates advance planning of maintenance operations and optimal allocation of resources. Its main elements are:

1. A basic road data bank, built-up and updated periodically by road inventories and condition surveys.
2. A pavement performance model, which predicts the future performance of a given pavement system.
3. A transportation cost model, which calculates the road user costs for the given condition of the pavement.
4. Selection of intervention levels.
5. Prioritizing the maintenance needs (renewal and overlay) for a given budget.

It should be noted that for the survey data to be accurate, a stable system of longitudinal marking along the road is necessary to readily locate and identify the areas referred to in the condition survey. For example the person doing the visual inspection survey, must be able to

accurately identify the chainage at any point on the road, in order that the maintenance team can readily find the location.

Clearly, maintenance of the road pavement alone is not, and should not be, the only concern of any roads authority. Therefore, in order to allow the wider issues to be addressed in a properly structured manner, it is usual for the Pavement Management System to be an integral part of a larger overall Road Maintenance Management System (RMMS).

12.4 Failures: No matter how well & scientifically the roads may have been designed planned & constructed failures do occur. They may be:

- **Premature failures:** Roads not gone through full service/life.
- **Terminal failure:** Full life/mature failure. Such failures are anticipated.
- **Accidental failures:** Like from floods earthquake landslide vehicular accidents etc.

12.4.1 Causes of failure: It is important to know causes of failure so that actions could be taken accordingly. In general they are:

1. Defective materials and construction method.
2. Inadequate drainage.
3. Traffic intensity.
4. Environmental factors.
5. Other quality control measures.

12.5 Symptoms of Defects:

a. **Surface Defects:** It includes fatty surfaces, smooth surfaces, streaking and hungry surfaces.
b. **Cracks:** It includes hair-line cracks, alligator cracks, longitudinal cracks, edge cracks, shrinkage cracks and reflection cracks.
c. **Deformation:** Under this are grouped slippage, rutting, corrugations, shoving, shallow depressions and settlements and up heals.
d. **Disintegration:** Covering stripping, loss of aggregates, raveling, pot-holes and edge breaking.

12.6 Classification of Maintenance Operations: Maintenance operations can be classified into three groups:

1. Routine maintenance which is the day-to-day work that is necessary to preserve and keep a pavement as close to as constructed condition as possible. It embraces activities such as pothole patching, sealing of cracks etc.
2. Periodic Maintenance, which is the work, carried out periodically every few years to prevent deterioration of a payment. It covers work such as applying a seal or thin resurfacing course.
3. Rehabilitation and strengthening, which are substantially major works intended to restore or upgrade the pavement. The work covers thick overlays.

12.7 Periodicity of Maintenance & Calendar Thereof:

The various important items of maintenance activities and their execution schedule.

Maintenance Activities and Execution Schedule

Sr. No.	Description Of Item	Frequency of operations in One year	Maintenance Calendar
1.	Clearing of road side drains	Twice	Before & after rains
2.	Pot-holes filling (WBM & BT)	Make road pot holes free	As and when developed
3.	Filling of edges of asphalt surface of excavating borrow pit	Make road pot holes free	As and when developed
4.	Dressing of berms	Twice	Immediately before and after rains
5.	White washing guard stones	Twice	Immediately before and after rains
6.	Fixing disturbed caution board/ name board/ speed limit board etc.	Once	As and when developed specially after rain
7.	Re-fixing displaced guard stones	Once	As and when developed specially after rain
8.	White washing Geroo painting of trunks	Once	As and when developed specially after rain
9.	Cutting of branches of trees etc.	Once	As and when developed specially after rain
10.	Maintenance of catch water drains	Once	As and when developed specially after rain
11.	Clearance of CD works	Twice	As and when developed specially after rain
12.	Clearing of wild seasonal growth on berms	Once	As and when developed specially after rain
13.	White washing parapets of CD works	Once	As and when developed specially after rain
14.	Earth work in berms, desilting of drains etc.	Twice	Before and after rain

12.8 Identification of Defects & recording formats:

One register should be maintained by every JEN for recording inspection details of roads of his section under defect liability period.

The recording of defects shall be made in the proper format. If no defects are noticed, then a simple remark of this effect is written in the defect liability register.

12.9 Communication of Defects to agency:

As soon as maintenance defects are noticed, they shall be conveyed to the contractor asking for their rectification of defects is not done by the contractor, then those shall be attended by the department at the Risk & Cost of Contractor, as per agreement provisions.

Up keeping & maintenance of roads during the defect liability period is the top priority job, therefore, it is advised to follow given instructions strictly.

CHAPTER-13

PRIME COAT

13.1 Methodology:

- Bituminous primer should be slow setting bitumen emulsion, use of cutback being restricted to areas having subzero temperature or for emergency operations.
- The prime coat should be applied only on the top most granular base layer, over which bituminous treatment is to be applied. The granular base surface should be swept clean of dust and loose particles and where required.
- The primer should be sprayed uniformly over the dry surface of absorbent granular base, using suitable bitumen pressure distributor or sprayer capable of spraying primer at specified rates and temperature so as to provide a uniformly unbroken spread of primer. Normal temperature range of spraying emulsion should be 20^0C to 60^0C.
- A very thin layer of coarse sand may be applied to the surface of the surface of the primer to prevent it from getting picked up under the wheels of vehicles delivering materials for construction of bituminous layer.
- The surface should be allowed to cure preferably for 24 hours. Spread sand over the portions found uncured.

13.2 Quality Control Requirements:

- The viscosity requirements for bitumen emulsion will depend upon the type of surface as already given in table.

Rate Of Application of Bituminous Emulsion For Prime Coat				
Porosity	**Type of surface**	**Viscosity at 60^0C**		**Rate of application per 10 sq m (kg)**
		Kinematic Viscosity (Centistokes)	**SayboltFurol (seconds)**	
Low	WMM/WBM	30-60	14-28	6-9
Medium	Cement stabilized soil base	70-140	33-66	9-12
High	Gravel base	250-500	117-234	12-15

13.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	Use slow setting emulsion and restrict the use of cutback to subzero temperature conditions or emergency operations.	Do not apply primer when the atmospheric temperature in shade is less than 10^0C or when the weather is foggy, rainy or windy.
2	Use only pressure sprayers.	Do not allow pouring of primer using perforated cans.
3	Preferably lay a trail section.	Do not allow traffic on primed surface.
4	The contractor to demonstrate at a spraying trial to ensure that the equipment is capable of producing a uniform spray.	Do not apply bituminous material to a wet surface.

13.4 Quality Control Tests Frequency:

Quality Control Tests During Construction		
Sr. No.	**Type of Test**	**Frequency**
1	Temperature of binder, when cutback is used	Regularly
2	Rate of spread of binder	At least two tests per day
3	Curing of primer	Before any subsequent treatment.

CHAPTER-14

TACK COAT

14.1 Methodology:

- The surface on which tack coat is to be applied should be clean, free from dust, dirt and any extraneous materials and dry.
- The binder should be sprayed uniformly over the surface using suitable bitumen pressure sprayer capable of spraying bitumen and emulsion at specified rates and temperature so as to provide a uniformly unbroken spread of bitumen emulsion. For smaller jobs, a pressure hand sprayer may be used. Normal range of spraying temperature should be 20^0C-60^0C in case of emulsion and 50^0C-80^0C in case of cutback. The rate of application depends upon the type of surface.
- The surface should be allowed to cure until all the volatiles have evaporated.
- The surface should be allowed to cure preferably for 24 hours.
- The bituminous binder should be bituminous emulsion (rapid or medium setting). The use of cutback (RC-70 or MC-70) should be restricted to areas with subzero temperature.

14.2 Quality Control Requirements:

- Binder for Tack Coat: Rapid setting bituminous emulsion Grade RS-1 complying with IS: 1887 as specified in contract. For sites at sub-zero temperature: Cutback bitumen (Medium Curing Grade) as per IS: 217.

Rate of Application of Tack Coat		
S. No.	**Type of surface**	**Rate of application/10sqm**
1	Bituminous surfaces	2.5kg
2	Granular (primed)	3.0kg

14.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	Plan the work so that no more than the necessary tack coat for the day's operation is placed on surface.	Do not apply tack coat when atmospheric temperature is less than 10^0C or when weather is foggy, rainy or windy.
2	Handle bituminous cutback carefully to avoid fire mishap.	Do not apply tack coat on a wet surface.
3		Do not allow any equipment or vehicles on tack coat.

14.4 Quality Control Test Frequency:

Sr. No	Test	Frequency
1	Quality of binder	1 test per lot or 10 tones
2	Temperature of binder	Regular close intervals
3	Rate of spread of binder	2 tests per 1000 sqm or per day

CHAPTER-15

SURFACE DRESSING

15.1 Methodology:

- Prepare the base on which surface dressing is to be laid to the specified lines, grade and cross- section. If the base is of granular material, a prime coat should be applied.

- Apply the binder (at specified temperature) as per rate of spread of binder or as designed with an appropriate bitumen distributor fitted with a spray bar. Binder shall be sprayed/distributed uniformly over the prepared base, with self propelled or towed sprayer, capable of supplying the binder at specified rate.

Nominal Rates of spread of Binder And Chippings			
Nominal chipping size (mm)	**Binder (Penetration grade bitumen) kg/m^2**	**Bitumen emulsion (kg/m^2)**	**Aggregate (cum/m^2)**
13.2	1.0	1.5	0.010
9.5	0.9	1.4	0.008
6.3	0.75	1.1	0.004

- The application temperature for the penetration grade binder used shall be as specified in table.

Spraying Temperatures For Binders				
Binder Grade	**Whirling spray jets**		**Slot Jets**	
	Min^{0}C	**Max^{0}C**	**Min^{0}C**	**Max^{0}C**
VG 10	180	200	165	175

- Immediately after application of binder, spread clean dry stone aggregate at the rate or as designed with the help of a mechanically operated chip spreader, in a single layer. In case of emulsion as a binder, the aggregate may be slightly damp.

- Immediately after spreading of aggregates, roll the surface with the help of suitable road rollers. Commence rolling from the edges and progress towards the center except in super elevated portions where it shall proceed from the lower edge to the higher edge. Each pass should have an overlap of not less than one-third of the track made in the preceding pass. Spread additional stone chips to make up irregularities, if any. Rolling should continue until all aggregate particles are firmly embedded in the bituminous binder and present a uniform closed surface.

- Where two-coat surface dressing is specified in the contract, the second coat should be applied after the first coat is exposed to traffic for 2 to 3 weeks. Procedures stated here in above will apply. The road may be opened to traffic 24 hours after the work of rolling is complete. In exceptional circumstances, traffic may be allowed immediately after rolling provided the traffic speed is limited to 20 km/h until the following day.

- Where use of precoated chips is specified, the first step will be to precoat chips. The stone chips will be heated to 160^0C and mixed with 0.75 to 1% of paving bitumen by weight heated to its application temperature. The precoated chips shall be cured for one week or till such time as they become non-sticky.

15.2 Quality Control Requirements:

1. Materials

(a) Stone Chippings

(i) Physical requirements: Stone chippings should satisfy the requirements given in table except that water absorption shall be 1% maximum.

(ii) Grading: The stone chippings should conform to the Grading given in table.

IS Sieve Designation (mm)	**Cumulative % by weight of total aggregate passing for the following nominal size (mm)**		
	13.2	9.5	6.3
19.0	100	--	--
13.2	85-100	100	--
9.5	0-40	85-100	100
6.3	0-7	0-35	85-100
4.75	--	0-10	--
3.35	--	--	0-35
2.36	0-2	0-2	0-10
0.60	--	--	0-2
0.075	0-1.5	0-1.5	0-1.5
Min. 65% by weight of aggregate	Passing 13.2mm retained 3.35mm	Passing 13.2mm retained 3.35mm	Passing 13.2mm retained 3.35mm

(b) Bitumen: The binder should be bituminous material, which may be as per the contract, or as decided by the Engineer.

- Paving grade bitumen (IS 73)
- Modified bitumen (IS 15462)
- Rapid setting bitumen emulsion (IS 8887)

(c) Where aggregate fails to pass the stripping test, an approved adhesion agent may be added to the binder, in accordance with the manufacturer's instructions.

2. **Horizontal Alignment:** The edges of the Surface Dressing should be correct within a tolerance limit of (±) 20 mm in plain and rolling terrain and (±) 30 mm in hilly terrain.

3. **Surface Level:** The tolerance in surface level of the surface dressing would be (±) 6 mm for machine laid and (±) 10 mm for manually laid surface dressing.

4. **Surface Regularity:** The maximum allowable difference between the pavement course and a 3 m straight edge shall not exceed 10 mm for longitudinal profile and 12 mm for cross profile respectively.

15.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	Ensure correct rate and uniform spread of binder based on field trials.	Do not carry out work when atmospheric temperature is less than 10^0C or when weather is foggy, rainy or windy.
2	Add approved Anti-Stripping agent to binder where aggregate fails to pass the stripping test.	Do not carry out the work on wet surface.
3	Alternatively use precoated chips. Correct any excessive deposit of bitumen by blotting before spreading the chips.	Do not resort to excessive rolling as that may crush the stone chips.
4	Maintain the temperature prescribed for the time of spraying on the surface.	Do not allow traffic immediately after the work of rolling is over.

15.4 Quality Control Test Frequency:

Sr. No.	Type Of Test	Frequency
1	Rate of spread of binder	At least two tests per day
2	Rate of Spread of aggregate	-do-
3	Grading of Aggregate	At least one test per day
4	Temperature of binder during spraying	Regularly, at close intervals.
5	Storage stability Test for Bitumen Emulsion	One test per day
6	Aggregate impact value	At random one test per km

CHAPTER-16

PREMIX CARPET

16.1 Methodology:

- Prepare the base on which premix carpet is to be laid to the specified lines, grade and cross-section.
- Apply a prime coat followed by tack coat over a granular base preparatory to laying of the carpet.
- The quantities of material required for 20mm thick premix carpet should be indicated in table.

Quantities Of Material Required For 10m^2 Area		
S. No.	**Aggregate**	**Quantity**
1	Nominal size 13.2mm (passing 22.4mm sieve and retained on 11.2mm sieve)	0.18m^3
2	Nominal size 11.2mm (passing 13.2mm sieve and retained on 5.6mm sieve)	0.09m^3
	Total	**0.27m^3**
S. No.	**Binder**	**Quantity**
1	For 0.18m^{3}of 13.2mm nominal size stone at 52kg bitumen per m^3	9.5 kg
2	For 0.09m^{3}of 11.2mm nominal size stone at 56kg bitumen per m^3	5.1kg
	Total	**14.6 kg**

- Locate hot mix plant near the work site. The mixed material should be transported quickly to the site work and laid uniformly by suitable means.
- The premixed material shall be spread on the road surface with rakes.
- The temperature of bitumen at the time of mixing should be in the range of 150^{0}C to 163^{0}C and that of aggregates 155^{0}C to 163^{0}C, provided that the difference between the temperature of aggregate and the binder should not exceed 14^{0}C. The temperature at the time of discharge of the mixture should be 130^{0}C and 160^{0}C.
- Rolling with 80-100kN rollers (three-wheel or tandem type), beginning from the edge and progressing towards the centre longitudinally. (On super elevated portions, rolling should progress from lower to upper edge parallel to centre line of pavement). Each pass should have an overlap of at least one-third of the track made in the preceding pass.
- Correct any high spots or depressions noticed after the roller has passed over the whole area once by removing or adding premixed material and recompacting.
- Provide a seal coat to the surface immediately after laying the carpet.
- The road may be opened to traffic 24 hours after the work of laying the seal coat.

16.2 Quality Control Requirements:

- **Aggregates:** Aggregate shall confirm to the physical requirements indicated as below:

Physical Requirements of Stone Aggregate			
S. No.	**Property**	**Test**	**Specification**
1	Particle shape	Flakiness index	Max 25%
2	Strength	Aggregate impact value	Max 30%
3	Durability	Sodium Sulphate Magnesium Sulphate	Max 12% Max 18%
4	Water absorption	Water absorption	Max 1%
5	Stripping	Coating and stripping of bitumen aggregate mixture	Min retained coating 95%

- **Binder:** The binder shall be penetration grade bitumen of a suitable grade S-65/90 depending on climatic condition of the area or of the type as specified in the contract.
- **Horizontal Alignment:** The edges of the carriageway with Premix Carpet should be correct within a tolerance limit of (±) 20mm in plain and rolling terrain and (±) 30mm in hilly terrain.
- **Surface Level:** The tolerance in surface level of the surface dressing would be (±) 6mm for machine laid work and (±) 10mm for work executed manually.
- **Surface Regularity:** The maximum allowable difference between the pavement course and a 3m straight edge shall not exceed 8mm for both the longitudinal profile and the cross profile.

16.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	Ensure that aggregates for premix carpet and seal coat conform to the prescribed physical and grading requirements and are clean and dry.	Do not allow manual mixing.
2	Exercise strict control over mixing and laying temperature as per specifications using appropriate thermometers.	Do not undertake the work in foggy, rainy or windy weather or when the atmospheric temperature in the shade is less than 10^0C or when the surface is wet.
3	Rolling operations should be completed before the temperature of the mix falls below 100^0c.	Do not allow any traffic without laying seal coat over the premix carpet.
4	The vehicle used for transporting the mix should be clean.	Do not allow the roller to stand on newly laid material.

16.4 Quality Control Test Frequency:

Sr. No.	Test	Frequency
1	Quality of binder	1 test per lot or 10 tonnes
2	Aggregate impact value	1 test per 250 cum
3	Flakiness and Elongation Index	1 test per 250 cum or per day
4	Stripping value	1 test per source

5	Water absorption	1 test per source
6	Grading	1 test per 50 cum or per day
7	Soundness	1 test per source
8	Temperature of binder at application	Regular close intervals
9	Binder content	1 test per lot or 10 tonnes
10	Thickness	Regularly

CHAPTER-17

BUILT-UP SPRAY GROUT

17.1 Methodology:

- Prepare the base on which built-up spray grout course is to be laid to the specified lines, grade and cross-section.
- Apply tack coat over the base preparatory to laying of the built-up spray grout.
- Spread the coarse aggregates uniformly by mechanical means or other suitable method at the rate of 0.5 cum per 10 sqm area. Remedy all high spots and depressions by removing or adding aggregates.
- Commence rolling with 80-100 kN rollers (three-wheel or tandem type), beginning from the edge and progressing towards the centre longitudinally. On super elevated portions, rolling should progress from lower to upper edge parallel to centre line of pavement.
- Correct any irregularities noticed after the roller has passed over the whole area once by loosening the surface and removing or adding the coarse aggregates followed by rolling. Care should be taken not to over compact the aggregate layer which may prevent free and uniform penetration of bitumen.
- Heat the bitumen to the temperature appropriate to the grade of bitumen and spray uniformly on aggregate layer at the rate of 15 kg per l0 sqm (measured in terms of residual bitumen content) by mechanical sprayers. Any excessive deposits caused by starting or stopping of the sprayers or for any other reason must be removed and made good.
- Immediately after first application of bitumen, spread the second layer of coarse aggregates and repeat the process.
- Apply a second bitumen spray of 15 kg per l0 sqm uniformly on the second layer of aggregate.
- Immediately thereafter, spread the key aggregates uniformly and evenly at the rate of 0.13 cum per l0 sqm area so as to cover the surface completely and roll. Rolling should continue until the key aggregates are firmly embedded in position.
- Provide a wearing course immediately after laying the built-up spray grout. If there is any delay in laying of wearing course, a seal coat would be required before opening to traffic.

17.2 Quality Control Requirements:

a) Materials

i) Coarse Aggregates and Key Aggregates

- **Physical requirements:** Aggregates should satisfy various physical requirements.
- **Grading:** The coarse aggregates and key aggregate should conform to the grading.

ii) Bitumen: The binder should be paving bitumen of penetration grade complying with IS: 73 or an appropriate grade of emulsion complying with IS: 8887, where permitted or specified in the contract.

b) Horizontal Alignment: The edges of the Built-up Spray Grout layer should be correct within

a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

c) Surface Level: The tolerance in surface level of the Built-up spray grout should be (±) 6 mm.

d) Surface Regularity: The maximum allowable difference between the road surface and a 3 m straight edge should be 12 mm for longitudinal profile and 8 mm for cross profile.

Grading for course aggregates and key aggregates for built-up spray grout

IS Sieve Designation (mm)	Cumulative % by weight of total aggregate	
	Coarse Aggregate	Key Aggregate
53.0	100	--
26.5	40-75	--
22.4	--	100
13.2	0-20	40-75
5.6	--	0-20
2.8	0-5	0-5

17.3 Do's and Don'ts:

Sr. No.	Do's	Don'ts
1	Stone chippings for both built-up spray grout and seal coat should conform to grading specified and be dry and clean at the time of laying.	Do not undertake the work in foggy, rainy or windy weather or when the atmospheric temperature in the shade is less than 10^0C.
2	Maintain the temperature of bitumen as appropriate to the grade.	The difference between the temperature of stones chips and bitumen should not be more than 14^0C
3		Do not allow any traffic without laying wearing course or seal coat over the built-up spray grout.

17.4 Quality Control Test Frequency:

Sr. No	Type of Test	Frequency
1	Quality of Binder	1 test per lot or 10 tonnes
2	Temperature of binder at application	Regular close intervals
3	Aggregate Impact Value Test	One test per 250 cum or per day
4	Flakiness Index Test	One test per 250 cum
5	Stripping value	One test per source (3 representative specimens for each source)
6	Water Absorption	One test per source (3 representative specimens for each source)
7	Soundness	One test per source
8	Rate of spread	One test per 1000 sq m or per day
9	Grading	One test per 100 cum or per day

CHAPTER-18

BITUMINOUS MACADAM

18.1 Methodology:

- Prepare the base on which bituminous macadam course is to be laid and shape to the specified lines, grade and cross-section.
- Apply tack coat over the base preparatory to lay the bituminous macadam.
- Bituminous macadam should be prepared in a Hot Mix plant of adequate capacity.

Sr.	Bitumen Penetration	Bitumen mixing (^{0}C)	Aggregate mixing (^{0}C)	Mixed material (^{0}C)	Laying (^{0}C)	Rolling (^{0}C)
1	35	160-170	160-175	Max.170	Min.140	Min.110
2	65	150-165	150-170	Max.165	Min.130	Min.100
3	90	140-160	140-165	Max.155	Min.130	Min.100

- Transfer the mixed material quickly to site of work and lay by means of an approved self-propelled mechanical paver.
- Commence initial rolling with 80-100 kN rollers (three-wheel or tandem type), beginning from the edge and progressing towards the centre longitudinally. On super elevated portions, rolling should progress from lower to upper edge parallel to centre line of pavement. Thereafter, do intermediate rolling with vibratory or pneumatic tyred road rollers. This should be followed by final rolling while the material is still workable.
- Any high spots or depressions noticed after the roller has passed over the whole area once should be corrected by removing or adding premixed material. Rolling should recommence thereafter. Each pass should have an overlap of at least one-third of the track made in the preceding pass. Rolling should be continued till all roller marks have been eliminated.
- For single lane roads no longitudinal joint is required, while for double-lane roads longitudinal joints may be required depending on the paver width.
- For making longitudinal or transverse joint, cut the edges of the bituminous layer laid earlier to their full depth so as to expose fresh surface and apply a thin coat of binder. Lay adjacent new layer and compact flush with the existing layer.
- Cover the bituminous macadam with the wearing course within a period of 48 hours. If there is any delay in providing wearing course the bituminous macadam surface should be covered with a seal coat before opening to traffic.

18.2 Quality Control Requirements:

a) Material:

Physical Requirements for aggregates for Bituminous Macadam

Property	Test	Specification
Particle Shape	Flakiness index	Max. 25%
Strength	Aggregate impact value	Max. 30%
Durability	Soundness Loss in weight	

	Sodium Sulphate Magnesium Sulphate	Max. 12% Max. 18%
Water Absorption	Water Absorption	Max. 2%
Stripping	Coating and stripping of bitumen-aggregate mixtures	Min. retained coating: 95%

b) Horizontal Alignment: The edges of the bituminous macadam base should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

c) Surface Level: The tolerance in surface level of the bituminous macadam would be (±) 6 mm.

d) Composition of Bituminous Macadam:

IS Sieve (mm)	Cumulative % passing by weight of total Aggregate
26.5	100
19	90-100
13.2	56-88
4.75	16-36
2.36	4-19
0.03	2-10
0.075	0-5
Bitumen Content, % by weight of total mixture	3.3-3.5
Bitumen Penetration grade	35 to 90

e) Surface Regularity: The maximum allowable difference between the road surface and a 3 m straight edge would be 12 mm for longitudinal profile and 8 mm for cross profile.

18.3 Do's and Don'ts:

S. No.	Do's	Don'ts
1	Ensure that stone aggregate conforms to the physical requirements and grading requirements and are dry and clean.	Do not undertake the work in foggy, rainy or windy weather or when the atmospheric temperature in the shade is less than 10^0C.
2	In case the aggregate has poor affinity to bitumen use anti stripping agent with the approval of Engineer.	Do not allow the difference in temperature of binder and aggregate to increase beyond 14^0C at any time.
3	While transporting the mixture it should be suitably covered by tarpaulin.	Do not allow the premix material to adhere to the roller wheels. (Do not use excess water for the purpose. Light sprinkling should do.)
4	Rolling operations should be completed before the mix becomes unworkable	Do not use lubricating oil on the wheels of the roller to prevent mix from adhering.
5	Maintain strict control on temperature	Do not allow traffic until the mix has been

	while mixing and rolling.	covered with a wearing course.
6	Regulate the rate of delivery of material to paver to enable it to operate continuously.	Do not move roller at a speed more than 5 km/h.

18.4 Quality Control Test Frequency:

S.No.	Type Of Test	Frequency
1	Grading of Aggregate	At least one test per day.
2	Binder Content	Periodic or at least two tests per day.
3	Density of Compacted Layer	At least one test per day or 250cm^2
4	Temperature of Binder before mixing	Regularly
5	*Temperature of mix during laying and compaction	Regularly
6	Thickness of compacted layer	Regular, at close intervals
7	Aggregate impact value	At random one test per km or per 50m^3 of aggregate
8	Flakiness and elongation index	1 test per 250 cum or per day
9	Stripping value	One test per source (3 representative specimens for each source)

CHAPTER-19

BITUMINOUS CONCRETE

19.1 Methodology:

- Bituminous concrete layer is composed of a thoroughly compacted dense-graded bituminous mixture of very well graded coarse and fine aggregates with filler and relatively higher amount of bitumen compared to DBM and SDBC.
- The surface on which the bituminous concrete is to be laid shall be prepared as per the MOST clauses. The surface shall be thoroughly swept clean by mechanical broom and dust removed by compressed air.
- The application of tack coat shall be at the rate specified in the contract, and shall be applied uniformly. Before applying tack all the nozzles and valves of sprayer nozzle bar are thoroughly cleaned to get uniform distribution of tack coat.
- The thickness of the layer shall be 25mm/40mm/50mm.
- Bituminous material with a temperature greater than 145^0C, shall not be laid or deposited on bridge deck waterproofing systems, unless precautions against heat damage have been approved by the Engineer.
- When laying the binder course or wearing course approaching an expansion joint of a structure, machine laying shall stop 300mm short of the joint. It shall be laid by hand.

19.2 Quality Control Requirements:

a) Material:

Physical requirements for aggregates for bituminous concrete

Grading	**1**	**2**
Nominal aggregate size*	**19mm**	**13.2mm**
Layer thickness	**50mm-65mm**	**25/40mm**
IS Sieve (mm)	**Cumulative % by weight of total aggregate passing**	
45		
37.5		
26.5	100	
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix	**5.2**	**5.4**

19.3 Do's and Don'ts:

S. No.	Do's	Don'ts
1	Ensure that stone aggregate conforms to the physical requirements and grading requirements and are dry and clean.	Do not undertake the work in foggy, rainy or windy weather or when the atmospheric temperature in the shade is less than 10^0C.
2	In case the aggregate has poor affinity to bitumen use anti stripping agent with the approval of Engineer.	Do not allow the difference in temperature of binder and aggregate to increase beyond 14^0C at any time.
3	While transporting the mixture it should be suitably covered by tarpaulin.	Do not allow the premix material to adhere to the roller wheels. (Do not use excess water for the purpose. Light sprinkling should do.)
4	Rolling operations should be completed before the mix becomes unworkable	Do not use lubricating oil on the wheels of the roller to prevent mix from adhering.
5	Maintain strict control on temperature while mixing and rolling.	Do not allow traffic until the mix has been covered with a wearing course.
6	Regulate the rate of delivery of material to paver to enable it to operate continuously.	Do not move roller at a speed more than 5 km/h.

19.4 Quality Control Test Frequency:

S. No.	Type Of Test	Frequency
1	Grading of Aggregate	At least one test per day.
2	Binder Content	Periodic or at least two tests per day.
3	Density of Compacted Layer	At least one test per day or 250cm^2
4	Temperature of Binder before mixing	Regularly
5	*Temperature of mix during laying and compaction	Regularly
6	Thickness of compacted layer	Regular, at close intervals
7	Aggregate impact value	At random one test per km or per 50m^3 of aggregate
8	Flakiness and elongation index	1 test per 250 cum or per day
9	Stripping value	One test per source (3 representative specimens for each source)

CHAPTER-20

ROAD SAFETY

Safety on hill roads is of prime importance. It is necessary that appropriate measures are taken to ensure safety. It can be improved in a number of ways, as follow:

20.1 Safety can be improved by following:

a. providing geometric standards of roads as per specifications

b. adequate warning, cautionary and information signs

c. regular maintenance of road

d. construction of protective structure for traffic like parapets, railings, snow sheds, boulder net, etc.

e. appropriate road markings

f. adequate drainage system

g. enforcement of traffic discipline, traffic rules/ regulations

h. introduction of gate system of traffic on crucial road sectors

20.2 Causes of accidents: Driving in hills, especially in adverse and inclement weather conditions, is a very complex, difficult and tiring task. Accidents occur at places where the rhythm of motion changes unexpectedly for a driver. Such happenings are not infrequent on hill roads due to following:

a. Traveling over sharp curves of sub-normal radius in conditions of inadequate sight distance needs frequent deceleration and acceleration.

b. Curves have to be negotiated in varying speeds due to varying degrees of curvature and applying brake when entering a curve and accelerating at the exit.

c. Alternating entry from major valley into a side-valley, crossing of streams by narrow bridges, causeways, etc.

d. Steep grades and alternating UP and DOWN grades and negotiation of high altitudes.

Considering the above, the aim of the highway engineer should be to duly consider the usual driving errors and response of the vehicles and design a highway, which will eliminate such errors and reduce stress on the drivers. A well-designed and constructed road will always be less prone to accidents and will add to safety.

20.3 Safety of hill roads

- Safety on roads in hills, like in the plains, is dependent on the same factors i.e. Driver, Vehicle, Road and Environmental Conditions. However, environmental factors affect a hill road very much due to severity of climatic and terrain conditions like torrential rains and

consequent slides (mud flow, rock fall rolling boulders, etc.) snow fall, snow drifts, avalanche/glacier activity icing problems, fog chilly winds, blizzards, etc. measures to improve safety on hill roads follow the usual pattern of Engineering, Enforcement and Education measures. However, while dealing with engineering measures in detail, as relevant to this manual, others are proposed to be touched upon only.

- Road condition plays a very significant part in road safety. Studies based on wide spread scientific research, involving analysis of road accidents, examination of interaction between vehicles, different road conditions and driver reaction to highway situations, has established a clear relationship between road condition and safety.

- There are elements of roadway that have a direct effect on safety, which include cross-section, vertical and horizontal alignments, access control and system of layout, inter-section design, pavement surface, illumination, road signs and barriers. The effect of these in combination and not individually determines the level of safety.

20.4 Engineering measures: Engineering measures to improve safety in hill roads can be classified into four aspects as under:

a. Geometric design measures, which ensure adequate width, curve radii, easy grades and sight distance.

b. Engineering design measures to deal with specific and exclusive conditions in hills. This includes design and proviso of good drainage system, protection like parapets, railings, snow fences, snow shelters, rolling boulder buffer (netting), etc.

c. Traffic control devices like sign, signals, pavements markings, delineators, advance public warning system etc.

d. Maintenance response and safety monitoring.

20.5 Enforcement measures: There are laws enforcing traffic and vehicle discipline to be adhered to by all road user and drivers. Strict enforcement of these by the appropriate authorities and deterrent action on violations can be enhancing safety level. Some of these are mentioned below:

a. **Condition Of the vehicle:** the vehicle must be in a mechanically fit condition to operate on hill roads.

b. **Condition of driver:** The driver should be physically and mentally capable and alert to operate in the hills and undergo rigors of climate and toughness of terrain met with. Drunken driving should be checked.

c. **Overloading**: Overloading of vehicles (load carriers and passengers) has to be strictly prohibited. The practice of passengers traveling on bus top as also on heavily loaded truck or overcrowding in driver's cabin, which has to be curbed.

20.6 Education measures: Consciousness among the users about the road condition and necessity to adopt safety measures should be imparted by appropriate awareness system like pamphlets, mass media publicity and etc. Important aspects like "DON'T MIX DRINK & DRIVING", IT

TAKES CARE FROM TWO DRIVERS TO AVOID AN ACCIDENT" and "SAFE DRIVING TECHNIQUES" etc. can be imparted by training measures by traffic control and enforcing authorities. Private sector participation for erection of such slogan boards with their advertisement as per approved pattern on the reverse of board may be considered.

20.7 Bridge Approaches: Another serious accident-prone location in hill road is existence of bridge with curved approach combined with down gradient. Such locations are common sites of topping over of vehicle over the bridge. Such sitting of bridges should be avoided and bridge structure should follow the general flow of the alignment. However, short-term measures to improve safety are to increase visibility, use of reflective cautionary signs, use of speed control measures and strong guardrails to deflect out of control vehicles.

20.8 Rock fall, shooting boulders, unstable areas etc.: A common cause of accidents in some locations in hill roads is shooting boulders or rock fall. This is basically due to unstable upper slope. Some of the measures to improve safety of such locations are listed below and may be applied selectively depending on the situation.

a. Stabilize the upper slope by improving drainage, other erosion control measure and treatment of exposed rock face.

b. Planting of upper slopes with a belt of trees to stop the boulders short of the road.

c. Providing extra wide hillside shoulders with deep drain to catch these falling debris and carry away as the water flows.

d. Provide a shelter similar to snow shelter to allow the boulder to go over the road.

e. Provide deflection walls and buffer zone to divert boulders and impound them.

f. Design a wire net screen buffer to catch the boulders and subsequently dispose them off suitably.

g. Post appropriate warning signs to caution the traffic.

Slides, flow of excessive water and slope materials on roads are a common factor endangering safety on roads in hills during rainy season. Major slides block the road and smaller slides make the roads slushy and slippery. Water overflowing drain erodes the berms, jeopardizing safety. A combination of catch-water drains, chutes, catch pits with cross drains and adequate camber can channelize the drainage and improve safety on roads.

BRIDGE

CHAPTER-21

SUB STRUCTURE

21.1 General: Q.A. for construction indicating the following shall be submitted by the contractor for approval of the Engineer, well in advance.

1. Sources of material
2. Design, erection and removal of formwork
3. Production, transportation, laying and curing of concrete
4. Personnel employed for execution and supervision
5. Tests and sampling procedures
6. Lab equipments details

Arrangements for execution under water wherever necessary, shall be included in methodology.

21.2 Piers and Abutments: Masonry, formwork, concrete and reinforcement for piers and abutments shall conform to relevant section of the specifications. In case of concrete piers, the number of horizontal construction joints shall be kept minimum. Construction joints shall be avoided in splash zones unless specifically permitted by the Engineer and provided they are treated in accordance with special provisions. No vertical construction joint shall be provided.

In case of tall piers and abutment, use of slip form shall be preferred for which the design and specifications to be provided by the contractor.

In case of solid abutments, weep holes on shown in the drawings or as directed by the Engineer and the specification briefed in the manual.

21.3 Pier Cap and Abutment Cap: The locations and levels of pier cap/abutment cap/pedestals and bolts for fixing bearings shall be checked carefully to ensure alignment of the bridge.

The surface of cap shall be finished smooth and shall have a slope for draining of water. For short span slab bridges with continuous support on pier caps, the surface shall be cast horizontal. The top surface of the pedestal on which bearings are to be placed shall also be cast horizontal.

The surface on which elastomeric bearings are to be placed shall be wood float finished to a plane level. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25mm below the bottom level of bearings and as indicated on the drawings.

21.4 Dirt/Ballast wall, Return wall and Wing wall: Masonry, concrete and reinforcement shall conform to relevant previous chapter of these specifications.

In case of cantilever return walls, no construction joint shall generally be permitted.

For gravity type masonry and concrete return and wing wall, no horizontal construction joint shall be provided. Vertical expansion gap of 20mm shall be provided in return wall/wing wall at every 10 meters intervals or as directed by the Engineer.

CHAPTER-22

CONCRETE SUPERSTRUCTURE

REINFORCED CONCRETE CONSTRUCTION

22.1 Solid Slabs: Where adjacent span of slab has already been cast, the expansion joint and filler board shall be placed abutting the already cast span which shall form the shutter on that side of the new span to be cast The whole of the slab shall be cast with reinforcement embedded for the road kerb and railings.

Where wearing coat is requireto be provided, after the deck slab has been cast, the surface of the slab shall be finished rough, but true to lines and levels as shown on the drawings, before the concrete has hardened.

The top of the slab shall be covered with clean moist sand as soon as the top surface has hardened curing shall be carried out accordingly.

22.2 RCC T-Beam and Slab: Provision of construction joint shall conform to the drawings or as per directions of the Engineer. No construction joint shall be provided between the bottom bulb and the web. If not indicated on the drawing, construction joint may be provided at the junction of the web and the fillet between the web and the deck slab with the permission of the Engineer.

The portions of deck slab near expansion joints shall be cast along with reinforcements and embedments for expansion joints.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened.

22.3 Prestressed concrete construction:

1. **PSC Girder and Composite RCC Slab:** PSC Girder may be precast or cast-in-situ as mentioned on the drawing or as directed by the Engineer. Girders may be post-tensioned or pre-tensioned. Where precast construction is required to be adopted, selection of casting yard and details of methodology and of equipment for shifting and launching of girders shall be included in the method statement.

   In case of cast-in-situ construction, the sequence of construction including side shifting of girders, if applicable, and placing on bearings shall be in accordance with the drawings.

   The PSC girder constituting the top flange, web and the bottom flange shall be concreted in a single operation without any construction joint.

2. **Box Girder:** Box girders may be simply supported or continuous. Simply supported box girders shall have minimum construction joints as approved by the Engineer. In the case of continuous box girders the sequence of construction and location of construction joints shall strictly follow the drawings.

   The box section shall be constructed with a maximum of one construction joint located in the web below the fillet between the deck slab and web. If permitted by the Engineer, one

additional construction joint may be permitted and this construction joint shall be located in the web above the fillet between the soffit slab and web.

3. **Cantilever Construction:** Continuity of untensioned reinforcement from one segment to the next must be ensured by providing full lap length as necessary.

The design of the superstructure shall take into account the following aspects, which form an integral part of the construction operations:

a) Stability against over-turning for each statical condition, through which the assembly passes, shall be checked.

b) Stresses at each preceding segment joint with the addition of every segment or change of statical conditions shall be checked. The load of equipment as well as construction live load shall be taken into account

c) Precambering of the superstructure during construction shall be done in such a manner that the finally constructed structure under permanent load attains the final profile intended in the drawings.

22.4 TOLERANCES

1. **Precast Concrete Superstructure:**

Variation in cross-sectional dimensions		
a)	upto and including 2m	± 5 mm
	over 2m	± 5 mm
b)	Variation in length overall and length between bearings	shall not exceed ±10 mm or ±0.1 per cent of the span length, which-ever is lesser.
c)	Permissible surface irregularities when measured with a 3 m straight edge or template	5mm

2. **Cast-in-Situ Superstructure:**

a)	Variations in, thickness of top and bottom slab for box girders, top and bottom flange for T-girders or slabs	-5mm to ±10mm
b)	Variations in web thickness	-5mm to ±10mm
c)	Variations in overall depth or width	±5mm
d)	Variation in length overall and length between bearings	shall not exceed ±10mm to ±0.1 per cent of the span length, which-ever is lesser.
e)	Permissible surface irregularities when measured with a 3 m straight edge or template	5mm

CHAPTER-23

PRESTRESSING MATERIALS

All prestressing steel, sheathing, anchorages and sleeves or coupling must be protected during transportation, handling and storage. The prestressing steel, sheathing and other accessories must be stored under cover from rain or damp ground and protected from the ambient atmosphere if it is likely, to be aggressive. Storage at site must be kept to the absolute minimum.

23.1 Tendon: Wire, strand and bar from which tendons are to be fabricated shall be stored about 300mm above the ground in a suitably covered and closed space so as to avoid direct climatic influences and to protect them from splashes from any other materials and from the cutting operation of an oxy-acetylene torch or arc welding process in the vicinity. Under no circumstances, tendon material shall be subjected to' any welding operation or on site heat treatment or metallic coaling such as galvanizing. Storage facilities and the procedures for transporting material into or out of store shall be such that the material does not become kinked or notched. Wire or strand shall be stored in large diameter coils, which enable the tendons to be laid out straight. As a guide, for wires above 5mm dia, coils of about 2m dia without breaks or joints shall be obtained from manufacturer and stored. Protective wrapping for tendons shall be chemically neutral. All prestressing steel must be provided with temporary protection during storage.

23.2 Anchorage Components: The handling and storing procedures shall maintain the anchorage components in a condition in which they can subsequently perform their function to an adequate degree. Components shall be handled and stored so that mechanical damage and detrimental corrosion are prevented. The corrosion of the gripping and securing system shall be prevented. The use of correctly formulated oils and greases or of other corrosion preventing material is recommended where prolonged storage is required. Such protective material shall be guaranteed by the producer to be non-aggressive and non-degrading.

Prestressing steel shall be stored in a closed store having single door with double locking arrangements and no windows. Also the air inside the store shall be kept dry as far as possible by using various means to the satisfaction of the Engineer. Also instrument measuring the air humidity shall be installed inside the store. This is with a view to eliminating the possibility of initial rusting of prestressing steel during storage. The prestressing steel shall be coated with water solvable grease. The prestressing steel should be absolutely clean and without any signs of rust.

All prestressing steel shall be stored at least 30 cm above ground level and it shall be invariably wrapped by protective cover of tar paper or polythene or any other approved material.

The Contractor should see that prestressing steel should be used within 3 months of its manufacture. He should check out his programme in this respect precisely, so as to avoid initial corrosion before placing in position

23.3 Steel for Prestressing:

The prestressing steel shall conform to either of the following:

(a) Plain hard drawn steel wire conforming to IS: 1785 (Part I) and IS: 1785 (PartII).
(b) Cold drawn indented wire conforming to IS: 6003
(c) High tensile steel bar conforming to IS: 2090
(d) Uncoated stress relieved strands conforming to IS: 6006.

ANNEXURE-1

TESTS ON MATERIALS

Quality Control Tests For Earth Work and Sub grade

Sr.No.	Type of Construction	Test
A.	Earthwork for Embankment	1. Soil Classification as per IS:1498 I. Sieve Analysis (Wet sieve Analysis except for cohesionless soils) for determining the size of particles. II. LL, PL and PI for determining the consistency of soil related to water contents.
		2. Standard Proctor Compaction test (IS: 2720 Part 7) for determining the moisture content density relationship vis-à-vis-Max Dry Density.
		3. Free swell Index Test to determine mineral content in soil for expansion property. (IS: 2720 Part-40)
B	Earthwork for Subgrade	**1.** Tests at 1 to 3, under 'A' above. (In case the soil for embankment meets the prescribed requirements for the Subgrade, the above three tests need not be repeated.)
		2. CBR Test (IS: 2720 Part 16) soaked/ unsoaked as specified for determining the stability of soil subgrade.
		3. Placement Moisture Content (IS: 2720 Part2) Where facility for oven drying is not available, any of the following quick test Methods can be used: i) Sand bath method ii) Rapid moisture meter.
		4. Insitu Density Measurements (IS: 2720 part 28) (Each layer)
		5. Degree of compaction, surface regularity and transverse profile/ camber/ cross fall and super elevation for finished subgrade.

Quality Control Test For Sub-Base And Base Course

Sr.No.	Type of Construction	Test
A.	Granular Sub-Base	1. Soil classification as per IS: 1498. i) Wet Sieve Analysis, except for cohesion less soils for determining the size of particles. ii) Liquid and Plastic Limits to determine the consistency.

		2. Combined Grading and plasticity tests on materials from different sources, mixed in the design proportions. This shall be done when material from more than one source are combined.
		3. Proctor Compaction test (IS: 2720 Part7) for determining vis-à-vis-Max. Dry Density.
		4. Wet Aggregate Impact Value Test (IS: 5640) where soft/marginal aggregates are used e.g. Laterite, Kankar, Brick Ballast etc. for determining the toughness of aggregates.
		5. CBR test (IS:2720 Part 16) on representative sample compacted at 100% Proctor dry density for determining the stability of G.S.B. layer.
		6. Placement Moisture Content (IS: 2720 Part 2)
		7. Insitu Density Measurements.(IS 2720 Part 28)
		8. Degree of Compaction and surface regularity of finished G.S.B.
B.	**Water Bound Macadam for G_1, G_2 and G_3.**	1. Aggregate Impact Value Test (IS: 2386 Part 4) for evaluating the toughness of aggregates.
		2. Aggregate water absorption test (IS: 2386 Part 3) for determining the quantity of percentage water absorbed.
		3. L.L. and P.I. of Crushable Screening (IS: 2720 Part 5) (where Screenings are to be used from the same source as the Stone Aggregates this test is not needed).
		4. Grading of stone aggregates and screenings (IS: 2386 Part I) for determining the size of aggregates.
		5. Flakiness index of stone aggregates (IS:2386 Part I for determining percentage flaky material and percentage elongated material particles.
		6. LL AND PI of binding material when used.
C.	**Wet Mix Macadam**	1. Aggregate Impact Value test (IS: 2386 Part 4) for evaluating the toughness of aggregates.
		2. Flakiness Index Test (IS: 2386 Part I) for determining percentage flaky material and percentage elongated material particles.
		3. Water Absorption Test (IS: 2386 Part 3) for determining the quantity of percentage water absorbed.
		4. Grading Test (IS: 2386 Part I) for determining the size of aggregates.
		5. Atterberg Limits of portion of aggregate passing 425 micron sieve (IS: 2720 Part 5) for determining the clay content in soil.
		6. Proctor Compaction Test (IS: 2720 Part 7) after replacing the aggregate fraction retained on 22.4 mm sieve with material of 4.75 mm to 22.4 mm

		size) alongwith Dry Density-Moisture Content Relationship for determining the moisture content density relationship vis-à-vis-Max. Dry Density.
		7. Placement Moisture Content (IS: 2720 Part 2)
		8. Density of compacted layer (IS: 2720 Part 28)

Quality Control Test For Bitumen Work

Sr.No.	Type of Construction	Test
A.	**Dense Bituminous Macadam/Semi Dense Bituminous Concrete/ Bituminous Concrete**	1. Quality of binder (Penetration, Ductility and softening point test)
		2. Aggregate impact value/ Los Angeles Abrasion value for evaluating the toughness and hardness of aggregates.
		3.Flakiness index and Elongation index for determining percentage flaky material and percentage elongated material particles.
		4.Mix grading.
		5. Control of temperature of binder in boiler, aggregate in the dryer and mix at the time of laying and rolling.
		6. Control of binder content and grading of the mix.
		7. Rate of spread of mixed material.
		8. Density of compacted layer.

Quality Control Tests for Concrete Works

Sr.No.	Type of Construction	Test
A.	**Cement**	Minimum quantity (kg/m^3)
B.	**Coarse Aggregates**	1. Gradation for PCC works for determining the size of aggregates.
		2. Flakiness index (IS: 2386 Part 1) for determining percentage flaky material and percentage elongated material particles.
		3. Water absorption/ content (IS: 2386 Part 3) for determining the quantity of percentage water absorbed.
		4. Aggregate Impact value (IS: 2386 part 4) for determining the toughness of aggregates.
C.	**Fine Aggregates**	1. Moisture Content (IS: 2386 Part 3)
		2. Gradation (IS: 2386 Part I) for determining the size of aggregates.
		3. Fineness Modulus for sand.
D.	**Water**	Normally potable water is good enough for making concrete.
E.	**Concrete**	Mix Design (for each work) to be approved by EE for cement content, W/C ratio and use of

		plasticizers, if any.
		1. Workability-slump cone test (IS: 1199)
		2. Cube strength (IS: 516)
F.	**Pre-cast Concrete Block**	1. Size
		2. Cube strength of mix used for concrete block.
		3.Consistency and compressive strength of Mortar used.

Quality Control Tests for Steel Works

Sr.No.	Type of Construction	Test
A.	**Steel Reinforcement**	1. Grade, Percentage Elongation and Ultimate Tensile Strength (IS: 432 Part 1 and IS: 1786)
		2. Pitch of the ribs and Nominal Diameter (Clause 1002 of MoRI) Specifications
		3. Modulus of Elasticity

Quality Control Tests for Bricks

Sr.No.	Type of Construction	Test
A.	**Brunt Clay Brick**	1. Color and Dimension Check
		2. Minimum Compressive Strength
		3. Water absorption
		4. Efflorescence.
		5. Compressive strength of brick.
		6. Consistency and compressive strength of mortar (IS: 2250)

Quality Control Tests for Stone

Sr.No.	Type of Construction	Test
A.	**Stone**	1. Shape and dimension IS: 1597 Part-I
		2. Water absorption IS: 1124
		3. Dressing of stone. IS: 1129
		4. Compressive Strength of stone.
		5. Consistency and Compressive strength of mortar

Quality Control Tests for Structural Steel Works

1. Certification of its composition by the manufacturer I.S.O. approved.
2. Certification of its Mechanical properties by the manufacturer I.S.O. approved.

Quality Control Tests for Concrete Pipes

Sr.No.	Type of Construction	Test
A.	C.C. Hume Pipe.	1. Dimensions and grade.
		2. Tolerances (IS: 458)
		3. Three edge bearing test (IS: 3597)
		4. Laying, joining of pipes and longitudinal gradient.
		5. Cushion over pipes.

ANNEXURE-2

GUIDELINES ON SELECTION OF BITUMINOUS BINDER

Bitumen:

For surface dressing, premix carpet, mix seal surfacing, bituminous macadam, built-up spray grout and modified penetration macadam.

I. Paving grade VG-10 may be used:
   - in NE states
   - in high altitudes, snowboard areas
   - in areas where temperature variations throughout the year are more than 25^0C.

II. Paving grade VG-30 may be used:
   - in coastal regions
   - in areas with hot climate condition throughout the year.
   - in areas where the temperature variations throughout the year are less than 25^0C.

Modified Bitumen:

Certain additives or blend of additives can improve properties of bitumen. Selection criteria for these categories are given below. (Source IRC: SP53-2002).

Selection criteria for PMB, NRMB and CRMB based on Atmospheric Temperature				
Minimum Atmospheric Pressure		**Maximum atmospheric temperature**		
		<35^{0}C	**35^{0}C to 45^{0}C**	**>45^{0}C**
	<-10^{0}C	PMB/NRMB-120 CRMB-50*	PMB/NRMB-70 CRMB-55	PMB/NRMB-70 CRMB-55
	-10^{0}C to 10^{0}C	PMB/NRMB-70 CRMB-50	PMB/NRMB-70 CRMB-55	PMB/NRMB-40 CRMB-60
	>10^{0}C	PMB/NRMB-70 CRMB-55	PMB/NRMB-70 CRMB-55	PMB/NRMB-40 CRMB-60

* Note below – 15^0C

PMB – Polymer Modified Bitumen

NRMB – Natural Rubber Modified Bitumen

CRMB – Crumb Rubber Modified Bitumen

Emulsion

(i) For premix carpet, mix seal surfacing – Medium Setting (MS) type for all areas.
(ii) For surface dressing – Rapid Setting (RS) type for all areas.
(iii) For prime coat and tack coat – Slow Setting (SS) type for all areas.

Cut-Back: Cutback may be used under sub-zero temperature conditions. For surface dressing, it may be rapid curing. For prime coat, tack coat, premix carpet and mix seal surfacing, it may be medium curing.

Sampling Bitumen:

(i) Heat the bitumen inside the container or tank so that it comes to a liquid state.
(ii) Mix it with the sampling device, which has a long rod, attached to it.
(iii) Take sample from the top portion, middle portion and bottom portion in a container separately:
   a. **Top sample:** Sample taken at a level of one sixth of the depth from the top surface of the container.
   b. **Middle sample:** Sample taken at one half of the depth.
   c. **Lower sample:** Sample taken at a level of five – sixths of the depth.
(iv) For knowing the variation among these three samples, these can be collected in different containers and tested separately. A mixture of these samples can also be taken for testing.

Requirements for Paving Grade Bitumen:

Sr. No.	Characteristics	Grade VG-30	Grade VG-10
1	Penetration at 25^0C	60-70	80-100
2	Ductility	75cm min	75cm min
3	Softening Point	45^0C-55^0C	45^0C-55^0C
4	Specific Gravity at 27^0C	0.99	0.99
5	Water content	0.2%	0.2%
6	Flash point	175^0C	175^0C
7	Viscosity at 60^0C	2000±400	1000±400
8	Loss of heat	1%	1%
9	Solubility in Trichloroethylene	99%	99%
10	Wax content	4.5% max	4.5% max

Requirements for Emulsion:

Sr.No.	Characteristics	Rapid Setting (RS)	Medium Setting (MS)	Slow Setting (SS)
1	Sieve test	0.35% max	0.05% max	0.05% max
2	Stability to mixing with aggregate	Good to fair	Good to fair	Good to fair
3	**Viscosity**			
	At 25^0C	--	--	20-100
	At 50^0C	50-400	50-400	--
4	Storage stability	1% max	1% max	1% max
5	Particles charge	Positive	Positive	Positive
6	Miscibility with water	Nil	Nil	Nil
7	Stability with cement	--	--	2% max

ANNEXURE-3

EQUIPMENT FOR FIELD LABORATORY

The field laboratory should be equipped with essential equipment required for day-to-day tests for exercising quality control during construction. Further, only those test equipment, which are relevant to the project specifications, will be necessary. Where the Contractor is required to carry out the maintenance of road and structures, the field laboratory should have necessary equipment during maintenance period for exercising quality over maintenance activities.

List of Essential Equipment - For Earthwork, Granular Construction and other General Requirements:

1.	Post Hole Auger with extensions	One set
2.	Digging tools like pick axes, shovels etc.	One set
3.	IS Sieves with lid and pan (125 mm, 100 mm, 90 mm, 80 mm,75 mm, 63 mm, 53 mm, 50 mm, 45 mm, 40 mm, 31.5 mm, 26.5 mm, 25 mm, 22.4 mm 20 mm,19 mm, 16 mm, 13.2 mm, 12.5 mm, 11.2 mm, 10 mm, 9.5 mm, 6.3 mm, 5.6 mm, 4.75 mm, 3.35 mm, 2.36 mm, 2 mm, 1.18 mm, 600 micron, 425 micron, 300 micron, 180 micron, 150 micron, 90 micron and 75 micron)	One set
4.	Standard Proctor Density Test Apparatus with Rammer	One set
5.	Sand Pouring Cylinder with tray complete for field density test	One set
6.	Core Cutter (10 cm dia), 10 cm/15 cm height complete with dolly and hammer	One set
7.	Speedy moisture meter complete with chemicals	One set
8.	Straight Edges	Two nos.
9.	Liquid Limit and Plastic Limit testing apparatus	One set
10.	Gas Burner, sand bath	One set
11.	Camber Board	Two nos.
12.	Electronic/digital balance 1 kg with the least count of 0.01 g	One no.
13.	Electronic /digital balance 5 kg	One no.
14.	Pan balance with weight box, 5 kg	One no.
15.	Oven (200^{o}C), thermostatically controlled	One no.
16.	Enameled tray	Six nos.
17.	Measuring tape, spatula, spirit levels, glassware, porcelain dish, pestle mortar	One set
18.	Aggregate Impact Test Apparatus	One set
19.	Flakiness Gauge	Six nos.
20.	Essential survey equipment for checking surface levels	One set
21.	Lab CBR equipment	One set

22.	Uppal's Syringe for Plasticity Index	One set
23.	Pocket Penetrometer	One set

For other tests like Soundness of Aggregate, Deleterious Material, Sulphate Content etc. facilities at the District Laboratory will be used.

Additional Equipment for Bituminous Construction

1.	Digital Thermometers	Three nos.
2.	Water bath (ambient to 100^{o}C)	One no.
3.	Penetration apparatus (Bitumen)	One set
4.	Trays for measurement of tack coat quantity	Three nos.
5.	Bitumen extraction apparatus	One no.

For other tests like R&B Softening Point, Viscosity, Storage Stability, Ductility, Elastic Recovery and Separation Difference, facilities at the District Laboratory will be used.

Additional Equipment for Cement Concrete Works and Structures

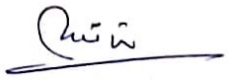
1.	Slump Cone	Two nos.
2.	Cube Moulds	Twelve nos.
3.	Core Cutting Machine	One no.

For other tests like physical and chemical tests on Cement, Alkali Aggregate Reactivity Test, Chemical Tests for Water, Compressive and Flexural Strength of Concrete etc., facilities at the District /Central Laboratory will be used.

NOTE

This Handbook has been approved as a reference by Public Works Department, Govt. of Himachal Pradesh vide letter no. PW-SE(QC&D)/EA-1/CM/QC.Cell/2020-3004-06 dated 02/12/2020. However, the provisions in the relevant manuals, CPWD Manual & relevant IS Codes with upto date amendments shall supercede the provisions in this handbook in case of any variation.

For WAPCOS Ltd.



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