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सत्यमेव जयते

भारत सरकार - Government of India

रेल मंत्रालय - Ministry of Railways

तैयार कंक्रीट

READY MIXED CONCRETE

केमटेक/2022/सि/आरएमसी/1.0
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अअमा सं RDSO
रेल अग्रदूत Transforming Railways

An ISO 9001-2015 Certified Organisation
उच्च अनुरक्षण प्रौद्योगिकी केन्द्र
EXCELLENCE IN MAINTENANCE

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READY MIXED CONCRETE

Foreword

In civil engineering structures, concrete work plays an important role in construction of major bridges, long tunnels, washable aprons, ROB/RUB/LHS, etc. over Indian Railways, while maintaining quality and strength of the concrete.

The document prepared by CAMTECH on Ready Mixed Concrete is informative and serves as a ready reference to railway supervisor to monitor quality control.

I hope that this document will be quite helpful to field engineers of open line, who are engaged in construction of Civil Engineering Structures in Indian Railways.

CAMTECH/Gwalior ***(Jitendra Singh)***
---- October, 2022 ***Principal Executive Director***

Preface

Timely completion of infrastructure projects with quality is the need of the time. Since concrete is the most used material in Civil Engineering projects, the quality of concrete is mostly responsible for the performance of a structure. Ready mixed concrete (RMC) fulfills the requirement of assured quality and uniform consistency with higher rate of production.

In current document, the aspects related to the role of railway supervisor deputed at plant to supervise/ or monitor the various processes during concrete production and its transportation to the site of work are covered in details to achieve good quality concrete. The document also provides checklist which will enable that no important point is overlooked in the process.

All important points right from the stage of selection of RMC plant and up to the sampling and testing of RMC at delivery point have been covered in the current document. It begins with discussing the format of purchaser's requirement based on the design requirement, workability, exposure conditions, etc. After that entire process has been divided into three stages. First stage deals with important aspects regarding selection of RMC plant and approval of design mix & quality assurance plan (QAP). Important aspects in the production of concrete in the plant have been dealt in next stage covering codal requirement & testing requirement of constituent materials; control of material storage; calibration of plant & equipment; batching, measurement & mixing & issuance of delivery ticket. Last stage deals with important points to monitor such as transportation and sampling & testing of concrete at delivery point.

It is expected that the document will be highly useful to railway supervisor deputed to supervise or monitor the quality of ready mixed concrete being produced in the plant.

The document is not statutory & contents are only for the purpose of knowledge dissemination. Most of the data & information in some form or the other are based on codal provisions of relevant IS Codes. For more in-depth information/knowledge, the relevant detailed literature, BIS Codes, etc. available on the subject may be referred to.

I am grateful for the assistance given by Shri K.C. Shakya, SSE/Civil for his continuous study, hard work, sincere efforts & dedication to make this publication useful for the field engineers.

We welcome valuable suggestions from our readers for further improvements of this document.

CAMTECH/Gwalior ***(Deepak Mehra)***
12th October, 2022 ***Joint Director/Civil***

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संशोधन पर्चियों का प्रकाशन
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इस हस्तपुस्तिका के लिए भविष्य में प्रकाशित होने वाली संशोधन पर्चियों को निम्नानुसार संख्यांकित किया जाएगा :

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Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

प्रकाशित संशोधन पर्चियाँ
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1.0 INTRODUCTION

In Indian Railways, a large numbers of projects of national importance involving important & major bridges, long tunnels, washable aprons, ROB/ RUB/ LHS, etc are being executed. These projects need good quality concrete in large quantities. Ready mixed concrete (RMC) qualifies for the role as it is produced in controlled condition with higher rate of production and also provides assured quality and uniform consistency.

Ready Mixed Concrete (RMC) is nothing but a simple concrete with a predetermined mixture of cement, aggregates, admixtures, if any and water. *IS 4926* defines the ready mixed concrete as the concrete mixed in a stationary mixer in a central batching and mixing plant or in a truck-mixer and supplied in the fresh condition to the purchaser either at the site or into the purchaser's vehicles.

As mentioned above, the major advantage in using ready mixed concrete is its assured quality and uniform consistency of concrete, production under controlled conditions, higher rate of production and environment friendliness. However, to achieve these objectives, few important parameters such as selection of a good RMC Plant, use of good quality raw material, quality control during production of concrete, good delivery mechanism of concrete at site, sample testing of RMC should be ensured. Deputation of competent railway representative at plant becomes necessary to reduce/avoid malpractices or shortcuts, if any, adopted by producer during production of concrete.

The current document is meant to serve as a ready reference to field personnel to take fast and better decision in the process right from the stage of selection of RMC plant and up to the sampling and testing of RMC at delivery point. It also provides checklist which will enable that no important point is overlooked in the process.

1.1 Scope of Document

The scope of this document is limited only to cover the ready mixed concrete (based on designed mix specified by purchaser) produced from stationary or central mixers and delivered to the site through truck mixers. Thus ready mixed concrete for prescribed mixes and that produced in truck mixer has not been covered in this document. Further, this document does not cover the aspects related to placing, compaction and curing of concrete.

2.0 PURCHASER'S REQUIREMENT

Before we go for selecting a suitable RMC plant and placing our order, we must be very clear of our requirement of concrete and its ingredients. Based on our design requirement, workability, exposure conditions, etc., purchaser's requirement containing all relevant information in the format given in **Annexure-1** should be completed and forwarded to the producer at the time of enquiry.

3.0 STAGE -1: FINALIZATION OF SUITABLE RMC PLANT

Once the purchaser's requirement is finalized, next step requires identifying a suitable RMC plant. RMC Plant should be well equipped to supply the concrete mix as per the desired quality

and in required quantity. The following points should be kept in mind by purchaser or his agent before finalization of the plant–

- All statutory permissions should be available with producer to run the plant.
- RMC Plant should be well equipped to supply the concrete mix as per the desired quality and in required quantity.
- A well documented plant maintenance procedure should be available for RMC Plant.
- Documentary evidence of regular plant inspection being carried out along with details of fault reported and rectification should be available.
- RMC Manufacturer should allow the Railway officers/ officials to supervise the operations involved in concrete production.
- RMC Manufacturer should agree to provide adequate facilities to Railway Officials to supervise the materials proposed to be used in production of concrete, the process of manufacture and the method of delivery of concrete.
- RMC Manufacturer should agree to provide adequate facility to the Railway officials to take samples for materials used, if required.
- RMC Manufacturer should agree to provide copy of the relevant documents of calibration, test certificates of ingredient materials, etc
- The producer should be able to demonstrate that a documented inspection and calibration procedure for the plant and all other equipment is prevalent.
- It should be ensured that proper Quality Assurance Programme is being followed by the manufacturer, to control quality at all the stages right from procurement of raw material to production of concrete.
- Plant should be capable of arranging all the materials (cement, aggregate, chemical admixture, water) conforming to the requirements of relevant IS codes.
- There should be separate storage for different types and grades of cement.
- Cement stored and stacked in bags should be kept free from the possibility of any dampness or moisture coming in contact with them.
- Stockpiles should be free draining and arranged to avoid contamination and to prevent intermingling with adjacent material. The bin should have hard floor to avoid contamination with soil/water.
- Fine aggregates should be stacked in a place where loss due to the effect of wind is minimum.
- Tanks or drums containing liquid admixtures should be clearly labelled for identification purposes and stored in such a way to avoid damage, contamination or the effects of prolonged exposure to sunlight (if applicable).
- Hoppers for weighing cement, mineral admixtures, aggregates and water and chemical admixture (if measured by mass) should consist of suitable containers freely suspended from a scale or other suitable load measuring device and equipped with a suitable discharging mechanism.
- Fully automatic production systems should be fitted with control equipment to allow the correct operation of the plant to be monitored during weighing and batching.
- Fully documented record along with details of any corrective action taken should be available for calibration of all scales.
- All personnel concerned with production, delivery and the function of the producer's quality system should have received training appropriate to the duties they perform.

- The testing of materials, proportioning of mixes and the production of concrete together with all its control testing should be under the overall supervision of an experienced concrete technologist.
- Operator who have received proper instructions on the equipment in use and who are able to comply with the required accuracy of batching should produce concrete.

4.0 APPROVAL OF DESIGN MIX CONCRETE & QUALITY ASSURANCE PLAN

Taking cognizance of the information supplied by Railway, the manufacturer shall design the mix. The design mix computation should be submitted in advance to the Railways by the RMC manufacturer. Based on the proposed design mix, cubes should be cast and tested under the supervision of Railway representative. In addition to strength, proposed design mix shall be tested for workability, initial setting time, permeability, total chloride content & sulphate content. Any testing to support the design mix shall be done by NABL accredited laboratory. Only after satisfying these requirements, the design mix shall be approved by the Railways.

It is extremely important that effect of transit time involved in transportation of concrete is taken care of in design mix. The increase in delivery time period should be specified clearly duly keeping some margin for hurdles in the way (i.e. level crossing/ check post/ heavy traffic congestion locations etc).

In case there is any change in ingredients or in the process/ plant, design mix shall be redesigned and got approved by Railways.

Railway specific Quality Assurance Plan to control quality at all the stages right from procurement of raw material to production of concrete should be prepared and got approved from Railway before the actual production of concrete.

5.0 STAGE – 2: PRODUCTION OF CONCRETE

In order to ensure that concrete produced is of desired quality, it is necessary that quality control is exercised at all the stages right from the receipt of raw material to delivery of concrete at site. A Railway supervisor should be deputed at centralised batching and mixing plant on the days on which Ready Mixed Concrete is produced for Railways.

The function of railway supervisor at RMC plant may be divided under following sub-heads.

5.1 Codal Conformance of Constituent Materials & their Testing and Storage

5.1.1 Specification & Testing of Constituent Materials

All the ingredients used for the preparation of the concrete should conform to Indian Standards specified. They should be thoroughly tested for their quality, physical, chemical, mechanical and other properties in a NABL accredited laboratory for conformity to relevant IS Codes in accordance with the details as provided in following table.

S. No.	Constituent Materials		Annexed as	Ref. to IS Code
1	**Cement**			
	(i)	Ordinary Portland Cement 33 Grade (OPC 33)	Annexure-2	*IS 269:2015*
	(ii)	Ordinary Portland Cement 43 Grade (OPC 43)		
	(iii)	Ordinary Portland Cement 53 Grade (OPC 53)		
	(iv)	Ordinary Portland Cement 43 Sleeper Grade (OPC 43S)		
	(v)	Ordinary Portland Cement 53 Sleeper Grade (OPC 53S)	Annexure-2	*IS 269:2015*
	(vi)	Portland Pozzolana Cement (Fly Ash Based)	Annexure-3	*IS 1489:2015 (Part 1)*
		Portland Pozzolana Cement (Calcined Clay Based)		*IS 1489:2015 (Part 2)*
	(vii)	Portland Slag Cement	Annexure-4	*IS 455:2015 (Reaffirmed 2020)*
	(viii)	Rapid hardening Ordinary Portland cement	Annexure-5	*IS 8041:1990 (Reaffirmed 2019)*
	(ix)	Low heat Portland cement	Annexure-6	*IS 12600:1989 (Reaffirmed 2019)*
	(x)	Sulphate Resisting Portland Cement	Annexure-7	*IS 12330:1988 (Reaffirmed 2019)*
	(xi)	Hydrophobic cement	Annexure-8	*IS 8043:1991 (Reaffirmed 2019)*
2	**Aggregate**			
	(i)	Coarse aggregate from natural sources	Annexure-9	*IS 383:2016*
	(ii)	Manufactured coarse aggregate	Annexure-9A	*IS 383:2016*
	(iii)	Fine aggregate from natural sources	Annexure-10	*IS 383:2016*
	(iv)	Manufactured coarse aggregate	Annexure-10A	*IS 383:2016*
3	**Chemical Admixtures**		Annexure-11	*IS 383:2016*
4	**Water for making concrete**		Annexure-12	*IS 456:2000 (Reaffirmed 2021)*

Unless otherwise agreed testing frequencies for cement, aggregates, admixtures and water may be taken as given in **Annexure – 14 to 16**.

5.1.2 Control of Material Storage

Materials should be stored in such a way so as to prevent the risk of contamination. The following points should be kept in mind while monitoring the adequacy of proper storage:-

- There should be separate storage for different types and grades of cement.
- Cement stored and stacked in bags should be kept free from the possibility of any dampness or moisture coming in contact with them.

- In case, the cement remains in storage for more than 3 months, the cement should be retested before use and should be rejected if it fails to conform to any of the requirements of relevant Indian Standard.
- Stockpiles should be free draining and arranged to avoid contamination and to prevent intermingling with adjacent material. The bin should have hard floor to avoid contamination with soil/water.
- Fine aggregates should be stacked in a place where loss due to the effect of wind is minimum.
- Tanks or drums containing liquid admixtures should be clearly labelled for identification purposes and stored in such a way to avoid damage, contamination or the effects of prolonged exposure to sunlight (if applicable).

5.2 Calibration of Plant & Equipment

It must be ensured that all weighing and batching equipment used in concrete production are calibrated for required accuracy and tolerance as desired by **Annexure – 13**. The valid documents of calibration should be available. The calibration must have been done by competent person. Documentary evidence of these records should be kept for record.

5.3 Batching, Measurement & Mixing

Once the availability of proper raw material and calibration of equipment is ensured, Railway supervisor will ensure that quality of concrete is being produced as per the requirement of Railway. The following points may be kept in mind to achieve the quality concrete:

- Availability of approved design mix of concrete of required grade should be ensured.
- All personnel concerned with production, delivery and the function of the producer's quality system should have received training appropriate to the duties they perform.
- The testing of materials, proportioning of mixes and the production of concrete together with all its control testing should be under the overall supervision of an experienced concrete technologist.
- Operator who have received proper instructions on the equipment in use and who are able to comply with the required accuracy of batching should produce concrete.
- It should be ensured that the test for Surface moisture content of coarse and fine aggregates is conducted daily.
- It should also be ensured that based on the test results of surface moisture content of aggregates, necessary adjustment in the quantity of aggregate and water has been determined and furnished to the plant operator.
- When more than one type or grade of cement is being used, the weighing device and discharge screw or other parts of the transfer system should be empty before changing from one type of cement to another.
- Cement should be measured by mass in a hopper or compartment separate from those used for other materials and on a scale of appropriate sensitivity, measurement being taken from a zero reading.
- Aggregates should be measured by mass, allowance being made for the free moisture content of the aggregates.
- The added water should be measured by volume or by mass.
- Any liquid chemical admixture (or paste) should be measured by volume or by mass and any solid admixture by mass.

- After measurement all materials shall be discharged into the mixer without loss.
- Batching control should be such that process identification at every stage and back traceability (later on) can be ensured. It is desirable to have automation in batching process and its controls.
- Before loading concrete materials or mixed concrete into either a stationary mixer or truck mixer any water retained in the mixing drum for washing out purposes should be completely discharged.
- The mixing time should be measured from the time all the materials required for the batch, including water, are in the drum of the mixer.
- The mixing time should not be less than that recommended by the manufacturer.
- Stationary and truck mixers should be maintained in an efficient and clean condition with no appreciable build up of hardened concrete or cement in the mixing drum, on the mixing blades, or on the loading hopper or discharge chutes.
- Each load of mixed concrete should be inspected before dispatch and prior to discharge.
- Where the rated capacity of a batching plant mixing cycle is less than 2.0 m^3, additional precautions should be taken to ensure that the correct numbers of batches are loaded into the truck mixer.
- The workability of the concrete should be controlled on a continuous basis during production and any corrective action necessary taken.
- Concrete mixes should be randomly sampled and tested for workability, and where appropriate, plastic density, temperature and air content.
- It is important to maintain the water cement ratio constant at its correct value. Any change in water content due to change in aggregate grading should be taken care of by suitable modifications to mix design.
- There should be a record of material stock to enable verification of total quantities used and to confirm that only approved materials have been received.
- For each load, written, printed or graphical records should be made of the mass of the materials batched, the estimated slump, the total amount of water added to the load, the delivery ticket number for that load, and the time the concrete was loaded into the truck.
- Immediately before discharging the concrete at the point of delivery, the producer or his representative should provide the purchaser with a pre-printed delivery ticket for each delivery of concrete on which is printed, stamped or written the minimum information. The information to be included in the Delivery Ticket to accompany the load to the purchaser is given in **Annexure – 17**.

6.0 STAGE – 3: POST PRODUCTION OF CONCRETE

Once the Ready-mixed concrete is despatched from the plant for the site of work along with the Delivery Ticket, the Railway supervisor at site of work will supervise the quality of concrete, sampling and testing of concrete and will ensure that it is placed within specified time.

6.1 Transport of Concrete

The following points should be borne in mind while receiving the RMC at site:

- It is the responsibility of producer that concrete should be transported from the mixer to the point of placing as rapidly as practicable by maintaining the required workability and preventing segregation, loss of any constituents or ingress of foreign matter or water.

- Concrete should be transported in a truck-mixer and discharged to the site within 2 hour of the time of loading. However, a longer period may be permitted if retarding admixtures are used or in cool humid weather or when chilled concrete is produced.
- The time of loading should start from adding the mixing water to the dry mix of cement and aggregate or of adding the cement to the wet aggregate whichever is applicable.
- Concrete received after the transit time, as specified above, shall not be accepted.
- The following information should be recorded when the concrete through truck mixer has arrived on site –
  - Time of arrival on site.
  - Time when discharge was completed.
  - Any water/admixture added by the supplier to meet the specified workability.
  - Any extra water/admixture added at the request of the purchaser of the concrete, or his representative, and his signature.
  - Pouring location.
  - Signature of the purchaser or his representative confirming discharge of the load.
- After arrival of RMC at site, additional dose of admixture, only if provided for in approved mix design, should be added in the presence of Railway supervisors.
- The purchaser (site supervisor) should plan his arrangements so as to enable a full load of concrete to be discharged within 30 minute of arrival on site.
- When a truck mixer is used for transporting concrete which has been mixed before leaving the plant, the concrete should be agitated during transit and re-mixed at the site for at least 2 minute so that the concrete is of the required uniformity.
- The agitating speed of the truck mixer/ agitators during transit should not be less than 2 revolutions per minute nor more than 6 revolution per minute.
- No additional water, other than the amount required to produce the specified workability, should be added to the truck mixer drum before discharge unless specifically specified.

6.2 Sampling and Testing of RMC

The concrete should be tested for the required workability and strength at the time of placement. The sampling and tests on the sample should be carried out in the presence of Railway supervisor.

The following points should be ensured:

- The sample should be representative and sampling should be carried out jointly by the purchaser and the supplier with its frequency mutually agreed upon.
- The RMC brought by truck-mixer at delivery point (i.e. construction site) should be checked for strength and workability (i.e. slump).
- For the assessment of compliance of ready-mixed concrete, the point and time of sampling should be

  a) at discharge from the producer's delivery vehicle or
  b) from the mixer to the site or
  c) when delivered into the purchaser's vehicle

- Samples from fresh concrete delivered at point of sampling should be taken for testing of strength of concrete.

- On reaching the point of placement (i.e. construction site), the truck-mixer should remix its contents and –
  - Allow at least the first one-third of a cubic meter of concrete to be discharged prior to taking any samples.
  - Take at least 4 incremental samples from the remainder of the load avoiding sampling the last cubic metre of concrete.
  - Thoroughly re-mix this composite sample either on a mixing tray or in the sampling bucket and proceed with the required testing.
- Unless otherwise agreed between the purchaser and producer, the minimum testing frequency to be applied by the producer should be one sample for every 50 m^3 of production or every 50 batches, whichever is the greater frequency.
- The purchaser should inform the producer, if his requirements for testing are higher than that mentioned above. Further assistance may be taken from Clause 15.2.2 of IS 456 for frequency of sampling of concrete of each load.
- Three test specimens should be made for each sample for testing at 28 days.
- Any testing to support the design mix shall be done by NABL accredited laboratory.
- The test strength of the sample should be the average of the strength of three specimens. The individual variation should not be more than ± 15 percent of the average. If more, the test results of the sample are invalid.
- **Acceptance Criteria for Compressive Strength of Concrete**: The concrete shall be deemed to comply with the strength requirements when both the following conditions are met:
  a) The mean strength determined from any group of four consecutive test results complies with the limits in column A of table below.
  b) Any individual test result complies with the limits in column B of table below.

Characteristic Compressive Strength (f_{ck}) Compliance Requirements

Specified Grade	**A** **Mean of the group of 4 Non-Overlapping Consecutive Test Results**	**B** **Individual Test Results**	**Remark**
M20 & above	$\geq f_{ck}$ + 0.825 X established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 4 N/mm^2, whichever is greater	$\geq f_{ck}$ – 4 N/mm^2	*Table 11 of IS 456 (Cl. 16.1 & 16.3)*
NOTE- In the absence of established value of standard deviation, the values given in *Table 8 of IS 456* may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.			

- **Loss of Workability:** The workability at the point of sampling should be within the following limits on the specified value as appropriate:

Slump	± 25 mm or ± 1/3 of the specified value, whichever is less	*Cl. 6.2.1 of IS 4926*
Compacting factor	± 0.03, where the specified value is 0.90 or greater,	
	± 0.04, where the specified value is less than 0.90 but more than 0.80	
	± 0.05, where the specified value is 0.80 or less.	
The range of slump required at the site for pumping the concrete is 50 to 100 mm as per *Cl. 7.1 of IS 456:2000* for medium degree of workability.		

- If discharge from the producers' vehicle is delayed on site due to lack of preparedness on behalf of the purchaser then the responsibility passes to the purchaser after a delay of more than 30 min.
- Flow table test may be specified for concrete, for very high workability. Acceptance criteria for spread (flow) are to be established between the supplier and the purchaser.

7.0 CHECKLIST ON READY MIXED CONCRETE

A checklist based on best practices and relevant Indian Standards is prepared and annexed at **Annexure – 18** to help Railway supervisor in taking quick decision during the stages of plant finalisation, production of concrete and concrete discharged at site.

***

Annexure – 1

CONCRETE MIX INFORMATION TO BE SUPPLIED BY THE PURCHASER

(Ref. – Annex D of Cl 7.2 & 7.3.1 of IS 4926:2003)

RMC : ----------
Contractor : ----------
Site : ----------

Mix Code				
Grade (N/mm^2) (Characteristic strength)				
Minimum Cement Content (kg/m^3)				
Mineral Additives (pulverized Fuel Ash/Slag/Others) (kg/m^3)				
Maximum Free Water – Cement Ratio				
Nominal Maximum Aggregate Size				
Cement Type and Grade (if preferred)				
Target Workability [Slump(mm)]				
Target Workability at Site				
Maximum Temperature of Concrete at the Time of P1acing				
Class of Sulphate Resistance (if applicable)				
Exposure Condition (if applicable)				
Class of Finish (inapplicable)				
Mix Application				
Method of Placing				
Any Other Requirements (Early strength workability retention, permeability testing, chloride content restriction, maximum cement content, etc)				
Concrete Testing (Frequency)				
Material's Testing (any non-routine requirements)				
Alternatives to be Offered: YES/NO				
Method of Curing to be Used by Contractor				
Quantity (m^3)				

NOTE—Additional proforma for further information may be used, such as for specific test rates to be achieved for concrete or raw materials, exact method statements of the contractors proposed site practice.

***

Annexure – 2

REQUIREMENT FOR ORDINARY PORTLAND CEMENT

SN	Material / Test	Requirement as per IS 269: 2015					
		Method of Test, Ref to	**OPC 33**	**OPC 43**	**OPC 43S©**	**OPC 53**	**OPC 53S©**
1	**PHYSICAL TESTS** (*Table 3 of IS 269:2015)*						
A	**Fineness**, m^2/kg, *Min* *By Blaine's air permeability method. (Specific surface in m^2/kg)*	IS 4031 (Part 2)	225	225	370	225	370
B	**Soundness:**						
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*	IS 4031 (Part 3)	10	10	5	10	5
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*		0.8	0.8	0.8	0.8	0.8
	Note: In the event of cements failing to comply with any one or both the requirements of soundness as specified, further tests in respect of each failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80 percent of a total period of 7 days. The expansion of cements so aerated shall be not more than 5mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively. For OPC 43S and OPC 53S, the requirement of soundness of unaerated cement shall be maximum expansion of 5 mm when tested by Le-Chatelier method.						
C	**Setting time:**						
	a) Initial, minutes, *Min*	IS 4031 (Part 5)	30	30	60	30	60
	b) Final, minutes, *Max*		600	600	600	600	600
	Note: If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall be not less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall conform to the values given above.						
D	**Compressive Strength**, MPa (N/mm^2):						
	a) 72 ± 1 h, *Min*	IS 4031 (Part 6)	16	23	23	27	27
	b) 168 ± 2 h, *Min*		22	33	37.5	37	37.5
	c) 672 ± 4 h, *Min*		33	43	43	53	53
	c) 672 ± 4 h, *Max*		48	58	-	-	-
E	**Transverse Strength** (optional)	IS 4031 (Part 8)	Mutually agreed to between the purchaser and the supplier at the time of placing the order				
2	**CHEMICAL TESTS** (*Table 2 of IS 269:2015)*						
A	Ratio of percentage of lime to percentages of Silica, Alumina and Iron Oxide, when calculated by the formula: $\frac{Cao - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$	IS 4032	0.66 - 1.02	0.66 - 1.02	0.80 - 1.02	0.80 - 1.02	0.80 - 1.02
B	Ratio of percentage of Alumina to that of Iron Oxide, *Min*		0.66	0.66	0.66	0.66	0.66
C	Insoluble residue, percent by mass, *Max*		5.0	5.0	2.0	5.0	2.0

D	Magnesia, percent by mass, *Max*		6.0	6.0	5.0	6.0	5.0
E	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass, *Max*	IS 4032	3.5	3.5	3.5	3.5	3.5
F	Loss of ignition, percent by mass, *Max*		5.0	5.0	4.0	4.0	4.0
G	Chloride content, percent by mass, , *Max*		0.1	0.1	0.1	0.1	0.1
			0.05*	0.05*	0.05*	0.05*	0.05*
			* (for prestressed structures)				
H	Alkali content expressed as Sodium oxide (Na_2O+ 0.658 K_2O)		< 0.6%				
	Note: On large and important jobs where concrete is likely to be exposed to humid or wetting action, it is advisable that the aggregate to be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.6 percent expressed as sodium oxide (Na_2O + 0.658 K_2O), is recommended.						
I	Tricalcium aluminate content (C_3A) [C_3A = 2.65 (Al_2O_3)-1.69 (Fe_2O_3)], percent by mass, *Max*	IS 4032	-	-	10.0	-	10.0
J	Tricalcium silicate (C_3S) [C_3S=4.07(Ca)-7.6(SiO_2)-6.72(Al_2O_3)-1.43(Fe_2O_3)-2.85(SO_3), percent by mass, *Min*		-	-	45.0	-	45.0

© **Para 3.2.1 of T-39 (Sixth Rev – March 2021) of RDSO:** Cement shall be OPC 53-S conforming to IS: 269 (as amended up to date). However, upper limit of SO_3 and C_3A content in 53-S grade cement is revised as 3.3% & 9.0% respectively for improvement in quality of PSC sleepers on IR. Upper limit of initial setting time (IST) of 53-S grade cement is specified as 120 minutes preferably but not more than 150 minutes.

Note: Mineral admixtures listed below may be used as part replacement of Ordinary Portland Cement. Uniform blending of the mineral admixtures with the cement should be ensured.

1. Pozzolanas

   i. Fly Ash conforming to Grade 1 of IS 3812
   ii. Silica Fume
   iii. Rice husk ash
   iv. Metakaoline conforming to IS 16354

2. Ground Granulated Blast Furnace Slag conforming to IS 16714

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Annexure – 3

REQUIREMENT FOR PORTLAND POZZOLANA CEMENT (FLY ASH BASED & CALCINED CLAY BASED)

SN	Material / Test		Requirements as per IS 1489: 2015 (Part 1 & 2)		
			Method of Test, Ref to	Fly Ash Based PPC	Calcined Clay Based PPC
1	**PHYSICAL TESTS**			*Table 2 of IS 1489: 2015 (Part 1 & 2)*	
A	**Fineness**, m^2/kg, *Min* *By Blaine's air permeability method. (Specific surface in m^2/kg)*		IS 4031 (Part 2)	300	300
B	**Soundness:**				
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*		IS 4031 (Part 3)	10	10
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*			0.8	0.8
	Note: In the event of cements failing to comply with any one or both the requirements of soundness as specified, further tests in respect of each failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80 percent of a total period of 7 days. The expansion of cements so aerated shall be not more than 5mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively.				
C	**Setting time:**				
	a) Initial, minutes, *Min*		IS 4031 (Part 5)	30	30
	b) Final, minutes, *Max*			600	600
	Note: If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall be not less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall conform to the values given above.				
D	**Compressive Strength**, MPa (N/mm^2):				
	a) 72 ± 1 h, *Min*		IS 4031 (Part 6)	16	16
	b) 168 ± 2 h, *Min*			22	22
	c) 672 ± 4 h, *Min*			33	33
E	**Transverse Strength** (optional)		IS 4031 (Part 8)	Mutually agreed to between the purchaser and the supplier at the time of placing the order	
F	**Drying shrinkage percent** *Max*		-	0.15	0.15
2	**CHEMICAL TESTS**			*Table 1 of IS 1489: 2015 (Part 1 & 2)*	
A	Insoluble residue, percent by mass,	*Max*	IS 4032	$[x+ 4.0(100-x)/100]^1$	$[x+ 4.0(100-x)/100]^2$
		Min		0.6x	0.6x
	[1]Where x is the declared percentage of fly ash in the given Portland pozzolana cement. [2]Where x is the declared percentage of pozzolana in the given Portland pozzolana cement.				
B	Magnesia, percent by mass, *Max*		IS 4032	6.0	6.0

C	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass, *Max*		3.5	3.5
D	Loss of ignition, percent by mass, *Max*		5.0	5.0
E	Chloride content, percent by mass, , *Max*		0.1	0.1
			0.05*	0.05*
			* (for prestressed structures)	
F	Alkali content expressed as Sodium oxide (Na_2O+ 0.658 K_2O)	IS 4032	< 0.6%	< 0.6%
	Note: On large and important jobs where concrete is likely to be exposed to humid or wetting action, it is advisable that the aggregate to be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.6 percent expressed as sodium oxide (Na_2O+ 0.658 K_2O), is recommended. However, in the case of cement having a minimum fly ash content of 30%, a maximum alkali content of 0.9% as sodium oxide (Na_2O+ 0.658 K_2O) is recommended.			

In reference to Para 4.1.1 of INDIAN RAILWAYS' CONCRETE BRIDGE CODE (Reprint - September 2014) (Incorporating A & C 1 to 13),

1. Vide Note 2, Portland Pozzolana cement shall not be used for PSC works. When Portland Pozzolana cement is used in plain and reinforced concrete, it is to be ensured that proper damp curing of concrete at least for 14 days and supporting form work shall not be removed till concrete attains at least 75% of the design strength.
2. Vide Note 4, the rate of development of strength is slow in case of blended cement i.e. Portland pozzolana cement, as compared to ordinary Portland cement. This aspect should be taken care while planning to use blended cement. Accordingly stage of prestressing, period of removal of form work and period of curing etc. should be suitably increased.
3. Vide Note 5, compatibility of chemical admixtures and super plasticizers with Portland Pozzolana cement shall be ensured by trials before use.
4. Vide Note 6, some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to take the same value as those used for concrete made with OPC.

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Annexure – 4

REQUIREMENT FOR PORTLAND SLAG CEMENT

SN	Material / Test	Requirements as per IS 455:2015 (Reaffirmed 2020)	
		Method of Test, Ref to	**Portland Slag Cement**
1	**PHYSICAL TESTS** (*Table 2 of IS 455:2015)*		
A	**Fineness**, m^2/kg, *Min* *By Blaine's air permeability method. (Specific surface in m^2/kg)*	IS 4031 (Part 2)	225
B	**Soundness:**		
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*	IS 4031 (Part 3)	10
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*		0.8
	Note: In the event of cements failing to comply with any one or both the requirements of soundness as specified, further tests in respect of each failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80 percent of a total period of 7 days. The expansion of cements so aerated shall be not more than 5mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively.		
C	**Setting time:**		
	a) Initial, minutes, *Min*	IS 4031 (Part 5)	30
	b) Final, minutes, *Max*		600
	Note: If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall be not less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall conform to the values given above.		
D	**Compressive Strength**, MPa (N/mm^2):		
	a) 72 ± 1 h, *Min*	IS 4031 (Part 6)	16
	b) 168 ± 2 h, *Min*		22
	c) 672 ± 4 h, *Min*		33
E	**Transverse Strength** (optional)	IS 4031 (Part 8)	Mutually agreed to between the purchaser and the supplier at the time of placing the order
2	**CHEMICAL TESTS** (*Table 1 of IS 455:2015)*		
A	Insoluble residue, percent by mass, *Max*	IS 4032	4.0
B	Magnesia, percent by mass, *Max*		10.0
C	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass, *Max*		3.5
D	Sulphide sulphur (S), *Max*		1.5
E	Loss of ignition, percent by mass, *Max*		5.0
F	Chloride content, percent by mass, *Max*		0.1
			0.05*
			* (for prestressed structures)
G	Alkali content expressed as Sodium oxide (Na_2O+ 0.658 K_2O)		< 0.6%

	Note: On large and important jobs where concrete is likely to be exposed to humid or wetting action, it is advisable that the aggregate to be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.6 percent expressed as sodium oxide (Na_2O+ 0.658 K_2O), is recommended. However, in the case of cement having a minimum slag content of 50%, a maximum alkali content of 0.9% as sodium oxide (Na_2O+ 0.658 K_2O) is recommended.

In reference to Para 4.1.1 of INDIAN RAILWAYS' CONCRETE BRIDGE CODE (Reprint - September 2014) (Incorporating A & C 1 to 13),

1. Vide Note 4, the rate of development of strength is slow in case of blended cement i.e. Portland slag cement, as compared to ordinary Portland cement. This aspect should be taken care while planning to use blended cement. Accordingly stage of prestressing, period of removal of form work and period of curing etc. should be suitably increased.
2. Vide Note 5, compatibility of chemical admixtures and super plasticizers with Portland blast furnace slag cement shall be ensured by trials before use.
3. Vide Note 6, some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to take the same value as those used for concrete made with OPC.

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Annexure – 5

REQUIREMENT FOR RAPID HARDENING PORTLAND CEMENT

SN	Material / Test	Requirements as per IS 8041:1990 (Reaffirmed 2019)	
		Method of Test, Ref to	Rapid Hardening Portland Cement
1	**PHYSICAL TESTS**		Cl. 6 of IS 8041:1990
A	**Fineness**, m^2/kg, *Min* *By Blaine's air permeability method. (Specific surface in m^2/kg)*	IS 4031 (Part 2)	325
B	**Soundness:**		
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*	IS 4031 (Part 3)	10
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*		0.8
	Note: In the event of cements failing to comply with any one or both the requirements of soundness as specified, further tests in respect of each failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80 percent of a total period of 7 days. The expansion of cements so aerated shall be not more than 5mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively.		
C	**Setting time:**		
	a) Initial, minutes, *Min* (*By Vicat apparatus method*)	IS 4031 (Part 5)	30
	b) Final, minutes, *Max* *(By Vicat apparatus method)*		600
	Note: If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall be less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall conform to the values given above.		
D	**Compressive Strength**, MPa (N/mm^2):		
	a) 24 h ± 30 minutes	IS 4031 (Part 6)	* ≮ 16
	b) 72 ± 1 hours		*≮ 27
	*The average compressive strength of at least three mortar cubes (area of face 50 cm^2 composed of one part of cement and three parts of standard sand (conforming to IS 650:1966) by mass and P/4 + 3.0 percent (of combined mass of cement and sand) water, and prepared, stored and tested in the manner described in IS 4031 (Part 6):1988. P is the percentage of water required to produce a paste of standard consistency.		
E	**Transverse Strength** (optional)	IS 4031 (Part 8)	Mutually agreed to between the purchaser and the supplier at the time of placing the order
2	**CHEMICAL TESTS**		*Table 1 of IS 8041:1990*
A	Ratio of percentage of lime to percentages of Silica, Alumina and Iron Oxide, when calculated by the formula: $\frac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$	IS 4032	≯ 1.02 and ≮ 0.66
B	Ratio of percentage of Alumina to that of Iron Oxide		≮ 0.66

C	Insoluble residue, percent by mass	IS 4032	≯ 4.0
D	Magnesia, percent by mass		≯ 6.0
E	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass		*≯ 2.5 when C_3A is 5 % or less by mass *≯ 3.0 when C_3A present is more than 5 % by mass
	* In this case, the Tricalcium aluminate content is calculated by by the formula: C_3A = 2.65 (Al_2O_3)-1.69 (Fe_2O_3), where each symbol in brackets refers to the percentage (by mass of total cement) of the oxide, excluding any contained in the insoluble residue referred at SN (C).		
F	Loss of ignition, percent by mass	IS 4032	≯ 5.0
G	Chloride content, percent by mass	IS 12243	• ≯ 0.05 % (for prestressed structures) • Mutually agreed to between purchaser & manufacturer (For plain & Reinforced concrete structures)
H	Alkali content expressed as Sodium oxide (Na_2O+ 0.658 K_2O)	IS 4032	< 0.6%
	Note: On large and important jobs where concrete is likely to be exposed to humid or wetting action, it is advisable that the aggregate to be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.6 percent expressed as sodium oxide (Na_2O+ 0.658 K_2O), is recommended.		

In reference to Para 4.1.1 of INDIAN RAILWAYS' CONCRETE BRIDGE CODE (Reprint - September 2014) (Incorporating A & C 1 to 13), vide Note 6, some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to take the same value as those used for concrete made with OPC.

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Annexure – 6

REQUIREMENT FOR LOW HEAT PORTLAND CEMENT

SN	Material / Test	Requirements as per IS 12600:1989 (Reaffirmed 2019)	
		Method of Test, Ref to	**Low heat Portland Cement**
1	**PHYSICAL TESTS**		-
A	**Fineness**, m²/kg, *Min* *By Blaine's air permeability method. (Specific surface in m²/kg)*	IS 4031 (Part 2)	320
B	**Soundness:**		
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*	IS 4031 (Part 3)	10
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*		0.8
	Note: In the event of cements failing to comply with any one or both the requirements of soundness as specified, further tests in respect of each failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80 percent of a total period of 7 days. The expansion of cements so aerated shall be not more than 5mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively.		
C	**Setting time:**		
	a) Initial, minutes, *Min*	IS 4031 (Part 5)	60
	b) Final, minutes, *Max*		600
	Note: If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall be <u>less than</u> 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall conform to the values given above.		
D	**Compressive Strength**, MPa (N/mm^2):		
	a) 72 ± 1 h	IS 4031 (Part 6)	*≮ 10
	b) 168 ± 2 h		*≮ 16
	c) 672 ± 4 h		*≮ 35
	*The average compressive strength of at least three mortar cubes (area of face 50 cm^2 composed of one part of cement and three parts of standard sand (conforming to IS 650:1966) by mass and P/4 + 3.0 percent (of combined mass of cement and sand) water, and prepared, stored and tested in the manner described in IS 4031 (Part 6):1988. P is the percentage of water required to produce a paste of standard consistency (obtained by the method described in IS 4031 (Part 4):1988)..		
E	**Transverse Strength** (optional)	IS 4031 (Part 8)	Mutually agreed to between the purchaser and the supplier at the time of placing the order
F	**Heat of Hydration**	IS 4031 (Part 9)	a) ≯ 272 kJ/kg for 7 Days b) ≯ 314 kJ/kg for 28 Days
2	**CHEMICAL TESTS**		*Table 1 of IS 12600: 1989*
A	Ratio of percentage of Alumina to that of Iron Oxide	IS 4032	≮ 0.66
B	Insoluble residue, percent by mass		≯ 4.0
C	Magnesia, percent by mass		≯ 6.0

D	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass	IS 4032	*≯ 2.5 when C_3A is 5 % or less by mass *≯ 3.0 when C_3A present is more than 5 % by mass
	* In this case, the Tricalcium aluminate content is calculated by by the formula: $C_3A = 2.65 (Al_2O_3)-1.69 (Fe_2O_3)$, where each symbol in brackets refers to the percentage (by mass of total cement) of the oxide, excluding any contained in the insoluble residue referred at SN (B).		
E	Loss of ignition, percent by mass	IS 4032	≯ 5.0
G	Chloride content, percent by mass, *Max*		Mutually agreed to between purchaser & manufacturer (For plain & Reinforced concrete structures)
H	Alkali content expressed as Sodium oxide ($Na_2O+ 0.658 K_2O$)		< 0.6%
	Note: On large and important jobs where concrete is likely to be exposed to humid or wetting action, it is advisable that the aggregate to be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.6 percent expressed as sodium oxide ($Na_2O+ 0.658 K_2O$), is recommended.		

In reference to Para 4.1.1 of INDIAN RAILWAYS' CONCRETE BRIDGE CODE (Reprint - September 2014) (Incorporating A & C 1 to 13), vide Note 6, some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to take the same value as those used for concrete made with OPC.

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Annexure – 7

REQUIREMENT FOR SULPHATE RESISTING PORTLAND CEMENT

SN	Material / Test	Requirements as per IS 12330:1988 (Reaffirmed 2019)	
		Method of Test, Ref to	Sulphate Resisting Portland Cement
1	**PHYSICAL TESTS**		-
A	**Fineness**, m^2/kg, *Min* *By Blaine's air permeability method. (Specific surface in m^2/kg)*	IS 4031 (Part 2)	225
B	**Soundness:**		
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*	IS 4031 (Part 3)	10
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*		0.8
	Note: In the event of cements failing to comply with any one or both the requirements of soundness as specified, further tests in respect of each failure shall be made as described in IS 4031 (Part 3), from another portion of the same sample after aeration. The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80 percent of a total period of 7 days. The expansion of cements so aerated shall be not more than 5mm and 0.6 percent when tested by Le-Chatelier method and autoclave test respectively.		
C	**Setting time:**		
	a) Initial, minutes, *Min*	IS 4031 (Part 5)	30
	b) Final, minutes, *Max*		600
	Note: If cement exhibits false set, the ratio of final penetration measured after 5 min of completion of mixing period to the initial penetration measured exactly after 20 second of completion of mixing period, expressed as percent, shall less than 50. In the event of cement exhibiting false set, the initial and final setting time of cement when tested by the method described in IS 4031 (Part 5) after breaking the false set, shall conform to the values given above.		
D	**Compressive Strength**, MPa (N/mm^2):		
	a) 72 ± 1 h	IS 4031 (Part 6)	*≮ 10
	b) 168 ± 2 h		*≮ 16
	c) 672 ± 4 h		*≮ 33
	*The average compressive strength of at least three mortar cubes (area of face 50 cm^2 composed of one part of cement and three parts of standard sand (conforming to IS 650:1966) by mass and P/4 + 3.0 percent (of combined mass of cement and sand) water, and prepared, stored and tested in the manner described in IS 4031 (Part 6):1988. P is the percentage of water required to produce a paste of standard consistency (obtained by the method described in IS 4031 (Part 4):1988).		
F	**Sulphate Expansion**	Cl 5.4.2 of IS 12330:1988	*≯ 0.45% at 14 days
	*This test is optional and shall be carried out by agreement between the purchaser and manufacturer at the time of placing order.		
2	**CHEMICAL TESTS** *(Table 1 of IS 12330: 1988)*		
A	Ratio of percentage of lime to percentages of Silica, Alumina and Iron Oxide, when calculated by the formula: $\frac{Cao - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$	IS 4032	≯ 1.02 and ≮ 0.66
B	Insoluble residue, percent by mass		≯ 4.0
C	Magnesia, percent by mass		≯ 6.0
D	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass		≯ 2.5
E	Loss of ignition, percent by mass		≯ 5.0

F	Tricalcium aluminate content (C_3A) [$C_3A = 2.65 (Al_2O_3)-1.69 (Fe_2O_3)$], percent by mass		≯ 5
G	Tetracalcium alumina ferrite phase plus twice the tricalcium aluminate (C_4AF+2C_2A), percent by mass		≯ 25

In reference to Para 4.1.1 of INDIAN RAILWAYS' CONCRETE BRIDGE CODE (Reprint - September 2014) (Incorporating A & C 1 to 13),

1. Vide Note 3, the sulphate resisting cement conforming to IS:12330 shall be used only in such conditions where the concrete is exposed to the risk of excessive sulphate attack e.g. concrete in contact with soil or ground water containing excessive amount of sulphate. It shall not be used under such conditions where concrete is exposed to risk of excessive chlorides and sulphate attack both.
2. Vide Note 6, some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to take the same value as those used for concrete made with OPC.

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Annexure – 8

REQUIREMENT FOR HYDROPHOBIC PORTLAND CEMENT

(OBTAINED BY INTERGRINDING 33 GRADE OPC CLINKER WITH CERTAIN HYDROPHOBIC AGENTS THAT WILL IMPART TO CEMENT A WATER REPELLING PROPERTY)

SN	Material / Test	Requirements as per IS 8043:1991 (Reaffirmed 2019)	
		Method of Test, Ref to	**Hydrophobic Portland Cement** (obtained by grinding OPC 33 with an additive)
1	**PHYSICAL TESTS**		
A	**Fineness**, m^2/kg, *Min* *By Blaine's air permeability method. (Specific surface in m^2/kg)*	IS 4031 (Part 2)	350
B	**Soundness:** *In accordance with IS 269*		
	Expansion of unaerated cement in mm, a) By Le-Chatelier Method, mm, *Max*	IS 4031 (Part 3)	10
	Expansion of unaerated cement in percentage b) By Autoclave Test Method, percent, *Max*		0.8
C	**Setting time:** *In accordance with IS 269*		
	a) Initial, minutes, *Min*	IS 4031 (Part 5)	30
	b) Final, minutes, *Max*		600
D	**Compressive Strength**, MPa (N/mm^2):		
	a) 72 ± 1 h, *Min*	IS 4031 (Part 6)	*15.69
	b) 168 ± 2 h, *Min*		*21.57
	c) 672 ± 4 h, *Min*		*30.40
	*The average compressive strength of at least three mortar cubes (area of face 50 cm^2 composed of one part of cement and three parts of standard sand (conforming to IS 650:1966) by mass and P/4 + 3.0 percent (of combined mass of cement and sand) water, and prepared, stored and tested in the manner described in IS 4031 (Part 6):1988. P is the percentage of water required to produce a paste of standard consistency.		
E	**Transverse Strength** (optional)	IS 4031 (Part 8)	Mutually agreed to between the purchaser and the supplier at the time of placing the order
2	**CHEMICAL TESTS** (*In accordance with IS 269*)		
A	Ratio of percentage of lime to percentages of Silica, Alumina and Iron Oxide, when calculated by the formula: $\frac{Cao - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$	IS 4032	0.66 - 1.02
B	Ratio of percentage of Alumina to that of Iron Oxide, *Min*		0.66
C	Insoluble residue, percent by mass, *Max*		5.0
D	Magnesia, percent by mass, *Max*		6.0
E	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass, *Max*		3.5
F	Loss of ignition, percent by mass, *Max*		5.0
G	Chloride content, percent by mass, , *Max*		0.1
			0.05 (for prestressed structures)
H	Alkali content expressed as Sodium oxide ($Na_2O + 0.658\ K_2O$)		< 0.6%
	Note: On large and important jobs where concrete is likely to be exposed to humid or wetting action, it is advisable that the aggregate to be tested for alkali aggregate reaction. In the case of reactive aggregates, the use of cement with alkali content below 0.6 percent expressed as sodium oxide ($Na_2O + 0.658\ K_2O$), is recommended.		

In reference to Para 4.1.1 of INDIAN RAILWAYS' CONCRETE BRIDGE CODE (Reprint - September 2014) (Incorporating A & C 1 to 13), vide Note 6, some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to take the same value as those used for concrete made with OPC.

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Annexure – 9

REQUIREMENT FOR COARSE AGGREGATE FROM NATURAL SOURCES

SN	Material / Test	Method of Test, Ref to	Permissible Limits/ variations:
1	**Gradation test**	IS 2386 (Part 1)	As per table below

Coarse Aggregates –

(i) Graded coarse aggregates may be supplied in the nominal sizes given in table below. *(Table 7 of IS 383:2016)*

SN	IS Sieve Designation	Percentage passing for single-sized Aggregate of Nominal size						Percentage passing for Graded Aggregate of Nominal size			
		63mm	40mm	20mm	16mm	12.5mm	10mm	40mm	20mm	16mm	12.5mm
1	80mm	100	-	-	-	-	-	100	-	-	-
2	63mm	85- 100	100	-	-	-	-	-	-	-	-
3	40mm	0-30	85-100	100	-	-	-	90-100	100	-	-
4	20mm	0-5	0-20	85-100	100	-	-	30-70	90-100	100	100
5	16mm	-	-	-	85-100	100	-	-	-	90-100	-
6	12.5mm	-	-	-	-	85-100	100	-	-	-	90-100
7	10mm	0-5	0-5	0-20	0-30	0-45	85-100	10-35	25-55	30-70	40-85
8	4.75mm	-	-	0-5	0-5	0-10	0-20	0-5	0-10	0-10	0-10
9	2.36mm	-	-	-	-	-	0-5	-	-	-	-

(ii) Coarse aggregate for mass concrete works shall be in sizes specified in table below. *(Table 8 of IS 383:2016)*

SN	Class and Size	IS Sieve Designation	Percentage Passing
1	Very large, 150 mm to 80 mm	160 mm	90-100
		80 mm	0-10
2	Large, 80 mm to 40 mm	80 mm	90-100
		40 mm	0-10
3	Medium, 40 mm to 20 mm	40 mm	90-100
		20 mm	0-10
4	Small, 20 mm to 4.75 mm	20 mm	90-100
		4.75 mm	0-10
		2.36 mm	0-0.2

(iii) All-in-Aggregate: Material composed of fine aggregate and coarse aggregate. Grading shall be in accordance with sizes specified in table below. *(Table 10 of IS 383:2016)*

SN	IS Sieve Designation	Percentage passing for All-in-Aggregate of	
		40mm Nominal Size	20mm Nominal Size
1	80mm	100	-
2	40mm	95 to 100	100
3	20mm	45 to 75	95 to 100
4	4.75mm	25 to 45	30 to 50
5	600µm	8 to 30	10 to 35
6	150µm	0 to 6	0 to 6

2	**Test for Deleterious Materials**				
A	**Limits of Deleterious Materials –** As per table below *(Table 2 of IS :383:2016)*				
	SN	Deleterious Substance	Test Procedure, Ref Code	Coarse Aggregate Percentage by Mass, Max	
				Uncrushed	Crushed
	(i)	Coal & lignite	IS 2386 (Part 2)	1.0	1.0
	(ii)	Clay lumps	IS 2386 (Part 2)	1.0	1.0
	(iii)	Materials finer than 75 micron IS sieve	IS 2386 (Part 1)	1.0	1.0
	(iv)	Soft fragments	IS 2386 (Part 2)	3.0	-
	(v)	Total of percentage of all deleterious materials including SN (i) to (iv) for uncrushed/crushed coarse aggregate	-	5.0	2.0
3	**Combined Flakiness & Elongation index**	IS 2386 (Part 1)	≯ 40% for uncrushed or crushed aggregate.		

4	**Tests for Mechanical Properties** *(Cl. 5.4 of IS :383:2016)*		
A	Aggregate Crushing Value/ Ten Percent Fines Value OR	IS 2386 (Part 4)	≯ 30% for aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water having flow velocity more than 6 m/s, spillways and stilling basins).
			In case the aggregate crushing value exceeds 30% for aggregates to be used in concrete other than for wearing surfaces, then the test for 'ten percent fines' should be conducted and the maximum load for the ten percent fines should be 50KN.
	Aggregate Impact Value (As an alternative to Aggregate Crushing Value/ Ten Percent Fines Value)	IS 2386 (Part 4)	≯ 30% for aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water having flow velocity more than 6 m/s, spillways and stilling basins).
			≯ 45 for aggregates to be used in concrete other than for wearing surfaces.
	For concrete of grades M 65 and above, stronger aggregates are required and hence the maximum aggregate crushing value and aggregate impact value shall not exceed 22 percent.		
B	Aggregate Abrasion Value	IS 2386 (Part 4) using Los Angeles Machine	≯ 30% for aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water having flow velocity more than 6 m/s, spillways and stilling basins).
			≯50 for aggregates to be used in concrete other than for wearing surfaces.
5	**Test for Soundness of Aggregate** (Only for concrete liable to be exposed to the action of frost)		
A	Sodium or magnesium sulphate accelerated soundness test	IS 2386 (Part 5)	The limits to set by agreement between the purchaser and supplier. However, as a general guide, it may be taken that the average loss of mass after 5 cycles shall not exceed 12% when tested with sodium sulphate (Na_2SO_4), and 18% when tested with magnesium sulphate ($MgSO_4$).
6	**Alkali Aggregate Reaction –** 1. Some aggregates containing particular varieties of silica may be susceptible to attack by alkalies (Na_2O and K_2O) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. 2. The aggregates containing more than 20 percent strained quartz and undulatory extinction angle greater than 15°, causing deleterious reaction and also possibly showing presence of microcrystalline quartz is known as slowly reactive aggregates. 3. Petrographic analysis of aggregate should be carried out to find out the strained quartz percentage, undulatory extinction angle and its mineral composition before conducting these tests.		
A	**Chemical Method** [This method (for determination of potential reactivity) is not found to be suitable for slowly reactive aggregates or for aggregate containing carbonates or magnesium silicates, such as antigorite]	IS 2386 (Part 7)	If test results indicate deleterious or potentially deleterious character, the aggregate should be tested using mortar bar method to verify the potential for expansion in concrete.
B	**Mortar Bar Method**		Permissible limits for mortar bar expansion
	Using 38 degree C temp regime (Not suitable for slowly reactive aggregate)	IS 2386 (Part 7)	0.05 % at 90 days & 0.1 % at 180 days
	Using 60 degree C temp regime (for slowly reactive aggregates)		0.05 % at 90 days & 0.06 % at 180 days

C	Accelerated mortar bar method (The test is found to be specially suitable for slowly reactive aggregate)	IS 2386 (Part 7)	Expansion < 0.10 % at 16 days after casting - Indicative of innocuous behavior in most cases. Note- Some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in this test was less than 0.10 percent at 16 days after casting. With such aggregate, it is recommended that prior field performance be investigated. In absence of field performance data, mitigative measures should be taken.
			Expansion > 0.20 % at 16 days after casting - Indicative of potentially deleterious expansion
			Expansion between 0.10% & 0.20% at 16 days after casting - Includes both aggregate that are known to be innocuous and deleterious in field performance. - It may be useful to support this test with test by mortar bar method at 38°C and 60°C, as applicable.

INFORMATION TO BE FURNISHED BY THE SUPPLIER

When requested by the purchaser or his representative, the supplier shall provide the following particulars:

a) Source of supply, that is, precise location of source from where the materials were obtained;
b) Trade group of principal rock type present, in case of aggregates from natural sources*;*
c) Physical characteristics, in case of aggregates from natural sources*;*
d) Presence of reactive minerals;
e) Service history, if any, the name of projects where used and the performance including in recently completed projects.

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Annexure – 9A

REQUIREMENT FOR MANUFACTURED COARSE AGGREGATE

Aggregates are important components for making concrete and properties of concrete are substantially affected by various characteristics of the aggregates used. Although, the aggregates from natural sources form the major variety used for making concrete, mortar and other applications, but the scarcity in availability of aggregates from natural sources is being faced in some parts of the country. This may require supplementing the use of aggregates from natural sources with the use of aggregates from other sources.

Therefore, quality requirements and those relating to the extent of utilization of manufactured coarse aggregates such as iron slag, steel slag, bottom ash from thermal power plants, recycled concrete aggregates (RCA) and recycled aggregate (RA), have been covered in this booklet.

Coarse aggregate is aggregate most of which is retained on 4.75 mm IS Sieve and contains only so much finer material as is permitted for the various types. Manufactured coarse aggregates are manufactured from other than natural sources, by processing materials, using thermal or other processes such as separation, washing, crushing and scrubbing. Manufactured coarse aggregate may be Recycled Concrete Aggregate (RCA) or Recycled Aggregate (RA).

The manufactured aggregates shall be permitted with their extent of utilization as percent of total mass of coarse aggregate as indicated in Table below against each, for use in plain and reinforced concrete and lean concrete. Manufactured aggregates shall not be permitted for use in pre-stressed concrete. *(Ref. Cl. 4.2 of IS 383-2016)*

Type of Aggregate	Maximum Utilization		
	Plain Concrete (%)	**Reinforced Concrete (%)**	**Lean Concrete (< M15 Grade) (%)**
Iron slag aggregate	50	25	100
Steel slag aggregate	25	Nil	100
Recycled concrete aggregate (RCA)	25	20 (Only up to M25 Grade)	100
Recycled aggregate (RA)	Nil	Nil	100

I It is desirable to source the recycled concrete aggregates from sites being redeveloped for use in the same site.
2 In any given structure, only one type of manufactured coarse aggregate shall be used.
3 The increase in density of concrete due to use of steel slag aggregates need to be taken into consideration in the design of structures.
4 While using manufactured aggregate as part replacement for natural aggregate, it should be ensured that the final grading meets the requirements specified in Table overleaf for single-sized & graded aggregates and aggregates for mass concrete.

RA is made from Construction & Demolition waste which may comprise concrete, brick, tiles, stone, etc, and RCA is derived from concrete after requisite processing. RA can be used as coarse aggregate and RCA can be used as coarse aggregates in accordance with the requirements of IS 383-2016.

Iron Slag Aggregates – Iron slag is obtained as a byproduct, while producing iron in blast furnaces or basic oxygen furnaces in integrated iron and steel plants. The lime in the flux chemically combines with the aluminates and silicates of the iron ore and coke ash to form a non-metallic product called iron/blast furnace slag. The molten slag at a temperature of approximately 1500°C is taken out of the furnace and cooled to form different types of slag products.

- Air Cooled Iron Slag Aggregate: It is formed when molten slag is allowed to flow from the furnace into open pits located beside the furnaces where the material is quenched with water to facilitate cooling and crystallization. The slag after cooling can be further crushed and screened to produce different sizes of aggregates. During its usage, care should be taken to ensure that the slag passes the test for 'iron unsoundness' and is pre-wetted prior to its use.

Steel Slag Aggregate - Steel slag is a byproduct produced in steel making operations in integrated iron and steel plants, where calcined lime used as flux combines with the silicates, aluminum oxides, magnesium oxides, manganese oxides and ferrites to form steel furnace slag. Slag is poured in a cooling yard from the furnace at a temperature of 1400 °C - 1700°C and cooled by air and sprinkling of water. Steel making slag contains about 10 to 20 metallic iron percent by mass, and is recovered by magnetic separation. The metal free slag is crushed and screened to different sizes for use as aggregates.

- For use as aggregates, the steel slag is subjected to weathering process (natural or accelerated) to reduce the free lime content in the slag.
- This is important during construction, as the moisture condition of the aggregate will impact workability and early-age, shrinkage-related cracking, if the aggregate is not kept sufficiently moist prior to batching.

Construction and Demolition (C&D) Waste – The aggregates obtained from construction and demolition (C&D) waste may be of two types namely Recycled Aggregate (RA) and Recycled Concrete Aggregate (RCA). The concrete rubble has to be properly processed, including scrubbing to remove the adhered hydrated cement as much as possible

- Recycled concrete aggregate (RCA), which is derived from concrete after requisite processing, contain not only the original aggregate, but also hydrated cement paste adhering to its surface. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity of RCA leads to a higher absorption. RCA can be used as coarse aggregates.
- Recycled aggregate (RA), which is made from C&D waste comprising of concrete, brick, tiles, stone, etc, will typically have higher absorption and lower specific gravity than natural aggregate. RA can be used as coarse aggregate.

The requirements for manufactured coarse aggregate for use in production of concrete are tabulated as under:

<table>
<tr><th>SN</th><th colspan="2">Material / Test</th><th>Method of Test, Ref to</th><th colspan="10">Permissible Limits/ Variations</th></tr>
<tr><td>1</td><td colspan="2">Gradation test</td><td>IS 2386 (Part 1)</td><td colspan="10">As per table below</td></tr>
<tr><td rowspan="20">A</td><td colspan="13">Coarse Aggregates –
(i) Graded coarse aggregates may be supplied in the nominal sizes given in table below. (Table 7 of IS 383:2016)</td></tr>
<tr><td rowspan="2">SN</td><td rowspan="2">IS Sieve Designation</td><td colspan="6">Percentage passing for single-sized Aggregate of Nominal size</td><td colspan="4">Percentage passing for Graded Aggregate of Nominal size</td></tr>
<tr><td>63mm</td><td>40mm</td><td>20mm</td><td>16mm</td><td>12.5mm</td><td>10mm</td><td>40mm</td><td>20mm</td><td>16mm</td><td>12.5mm</td></tr>
<tr><td>1</td><td>80mm</td><td>100</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>100</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>2</td><td>63mm</td><td>85- 100</td><td>100</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>3</td><td>40mm</td><td>0-30</td><td>85-100</td><td>100</td><td>-</td><td>-</td><td>-</td><td>90-100</td><td>100</td><td>-</td><td>-</td></tr>
<tr><td>4</td><td>20mm</td><td>0-5</td><td>0-20</td><td>85-100</td><td>100</td><td>-</td><td>-</td><td>30-70</td><td>90-100</td><td>100</td><td>100</td></tr>
<tr><td>5</td><td>16mm</td><td>-</td><td>-</td><td>-</td><td>85-100</td><td>100</td><td>-</td><td>-</td><td>-</td><td>90-100</td><td>-</td></tr>
<tr><td>6</td><td>12.5mm</td><td>-</td><td>-</td><td>-</td><td>-</td><td>85-100</td><td>100</td><td>-</td><td>-</td><td>-</td><td>90-100</td></tr>
<tr><td>7</td><td>10mm</td><td>0-5</td><td>0-5</td><td>0-20</td><td>0-30</td><td>0-45</td><td>85-100</td><td>10-35</td><td>25-55</td><td>30-70</td><td>40-85</td></tr>
<tr><td>8</td><td>4.75mm</td><td>-</td><td>-</td><td>0-5</td><td>0-5</td><td>0-10</td><td>0-20</td><td>0-5</td><td>0-10</td><td>0-10</td><td>0-10</td></tr>
<tr><td>9</td><td>2.36mm</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>0-5</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="13">(ii) Coarse aggregate for mass concrete works shall be in sizes specified in table below. (Table 8 of IS 383:2016)</td></tr>
<tr><td>SN</td><td colspan="3">Class and Size</td><td colspan="4">IS Sieve Designation</td><td colspan="4">Percentage Passing</td></tr>
<tr><td rowspan="2">1</td><td colspan="3" rowspan="2">Very large, 150 mm to 80 mm</td><td colspan="4">160 mm</td><td colspan="4">90-100</td></tr>
<tr><td colspan="4">80 mm</td><td colspan="4">0-10</td></tr>
<tr><td rowspan="2">2</td><td colspan="3" rowspan="2">Large, 80 mm to 40 mm</td><td colspan="4">80 mm</td><td colspan="4">90-100</td></tr>
<tr><td colspan="4">40 mm</td><td colspan="4">0-10</td></tr>
<tr><td rowspan="2">3</td><td colspan="3" rowspan="2">Medium, 40 mm to 20 mm</td><td colspan="4">40 mm</td><td colspan="4">90-100</td></tr>
<tr><td colspan="4">20 mm</td><td colspan="4">0-10</td></tr>
</table>

	4	Small, 20 mm to 4.75 mm	20 mm	90-100
			4.75 mm	0-10
			2.36 mm	0-0.2
2	**Test for Deleterious Materials**			
A	**Limits of Deleterious Materials** – As per table below *(Table 2 of IS :383:2016)*			
	SN	Deleterious Substance	Test Procedure, Ref Code	Coarse Aggregate Percentage by Mass, Max
				Manufactured
	(i)	Coal & lignite	IS 2386 (Part 2)	1.0
	(ii)	Clay lumps	IS 2386 (Part 2)	1.0
	(iii)	Materials finer than 75 micron IS sieve	IS 2386 (Part 1)	1.0
	(iv)	Soft fragments	IS 2386 (Part 2)	3.0
	(v)	Total of percentage of all deleterious materials (including SN (i) to (ii)	-	2.0
3	**Combined Flakiness & Elongation index**		IS 2386 (Part 1)	≯ 40% for uncrushed or crushed aggregate.
4	**Tests for Mechanical Properties** *(Cl. 5.4 of IS :383:2016)*			
A	Aggregate Crushing Value/ Ten Percent Fines Value OR		IS 2386 (Part 4)	≯ 30% for aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water having flow velocity more than 6 m/s, spillways and stilling basins).
				In case the aggregate crushing value exceeds 30% for aggregates to be used in concrete other than for wearing surfaces, then the test for 'ten percent fines' should be conducted and the maximum load for the ten percent fines should be 50KN.
	Aggregate Impact Value (As an alternative to Aggregate Crushing Value/ Ten Percent Fines Value)		IS 2386 (Part 4)	≯ 30% for aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water having flow velocity more than 6 m/s, spillways and stilling basins).
				≯ 45% for aggregates to be used in concrete other than for wearing surfaces.
	For concrete of grades M 65 and above, stronger aggregates are required and hence the maximum aggregate crushing value and aggregate impact value shall not exceed 22 percent.			
B	Aggregate Abrasion Value		IS 2386 (Part 4) using Los Angeles Machine	≯ 30% for aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water having flow velocity more than 6 m/s, spillways and stilling basins).
				≯50% for aggregates to be used in concrete other than for wearing surfaces
B	**Additional test for slag aggregates**			
	(i)	Iron Unsoundness (for aggregates having Ferrous oxide ≥ 3.0 % and Sulphur content ≥ 1.0%)	Annex D of IS 383-2016	≯1 %
	(ii)	Volumetric expansion ratio	Annex E of IS 383-2016	≯2.0
	(iii)	Unsoundness due to free lime (for use of iron slag for production of aggregate)	Petrographic examination or quantitative x-ray diffractometry	Iron slag from a new source or when significant changes in furnace chemistry occur in an existing source which may result in the presence of free lime, the potential for pop-out formation shall be assessed by determining the free-lime content of the slag by test as specified. If the number of particles containing free lime exceeds 1 in 20, then weathering of the slag stockpile (in moist condition or at/near saturated surface dry condition) represented by the test

				sample shall be continued until further testing shows that the level has fallen below 1 in 20.
6	**Alkali Aggregate Reaction –** 1. Some aggregates containing particular varieties of silica may be susceptible to attack by alkalies (Na_2O and K_2O) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. 2. The aggregates containing more than 20 percent strained quartz and undulatory extinction angle greater than 15°, causing deleterious reaction and also possibly showing presence of microcrystalline quartz is known as slowly reactive aggregates. 3. Petrographic analysis of aggregate should be carried out to find out the strained quartz percentage, undulatory extinction angle and its mineral composition before conducting these tests.			
A	Chemical Method [This method (for determination of potential reactivity) is not found to be suitable for slowly reactive aggregates or for aggregate containing carbonates or magnesium silicates, such as antigorite]		IS 2386 (Part 7)	If test results indicate deleterious or potentially deleterious character, the aggregate should be tested using mortar bar method to verify the potential for expansion in concrete.
B	Mortar Bar Method			Permissible limits for mortar bar expansion
	Using 38 degree C temp regime (Not suitable for slowly reactive aggregate)		IS 2386 (Part 7)	0.05 % at 90 days & 0.1 % at 180 days
	Using 60 degree C temp regime (for slowly reactive aggregates)			0.05 % at 90 days & 0.06 % at 180 days
7	**Manufactured aggregates shall meet the additional requirements as given below**			
A	**For All Manufactured Aggregates -** As per table below *(Table 3 of IS :383:2016)*			
	Total alkali content as Na_20 equivalent		-	≯ 0.3%
	Total sulphate content as $S0_3$			≯ 0.5%
	Water soluble chloride content			≯ 0.04%
	Water absorption			≯ 5% For recycled concrete aggregate and recycled aggregate, higher water absorption up to 10 percent may be permitted subject to pre-wetting (saturation) of aggregates before batching and mixing.
	Specific gravity			2.1 to 3.2 The limits are intended for use of aggregate in normal weight concrete.
B	**For Iron and Steel Slag Aggregates -** As per table below *(Table 4 of IS :383:2016)* ▪ Crushed slag aggregate should be stockpiled in moist condition at or near the saturated surface dry (SSO) condition before use, with the moisture condition being maintained by sprinkling with water.			
	Calcium oxide as CaO		-	≯ 45.0%
	Total sulphur as S			≯ 2.0%
	Total iron as FeO			≯ 3.0%
C	**For Electric Furnace Oxidation Slag Coarse Aggregate -** As per table below *(Table 5 of IS :383:2016)*			
	Calcium oxide as CaO		-	≯ 40%
	Magnesium oxide as MgO			≯ 10%
	Total iron as FeO			≯ 50%
	Basicity as CaO/SiO_2			≯ 2%

INFORMATION TO BE FURNISHED BY THE SUPPLIER

When requested by the purchaser or his representative, the supplier shall provide the following particulars:

a) Source of supply, that is, precise location of source from where the materials were obtained;

b) In case of manufactured aggregates, the brief manufacturing process, source of parent; material and special characteristics having bearing on concrete properties, such as presence of adhered coating in case of recycled concrete aggregate, to the extent possible.
d) Presence of reactive minerals;
e) Service history, if any and in particular, in case of manufactured aggregates, the name of projects where used and the performance including in recently completed projects;
f) In case of manufactured aggregates, special precautions, if any, to be observed during concrete production.

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Annexure – 10

REQUIREMENT FOR FINE AGGREGATES FROM NATURAL SOURCES

SN	Material / Test	Method of Test, Ref to	Permissible Limits/ variations
1	**Gradation test**	IS 2383 (Part 1)	As per table below

Fine Aggregates –
The grading of fine aggregates shall be within limits as given table below. (*Cl. 6.3 & Table 9 of IS :383:2016*)

SN	IS Sieve Designation	Percentage Passing			
		Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
1	10 mm	**100**	100	100	100
2	4.75 mm	90-100	90-100	90-100	95-100
3	2.36 mm	60-95	75-100	85-100	85-100
4	1.18 mm	30-70	55-90	75-100	90-100
5	**600 µm**	15-34	35-59	60-79	80-100
6	300 µm	5-20	8-30	12-40	15-50
7	150 µm	0-10	0-10	0-10	**0-10**

Note:
1 Where the grading falls outside the limits of any particular grading zone of sieves other than 600 µm IS Sieve by an amount not exceeding 5 percent for particular sieve size, (subject to cumulative amount of 10 percent), it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing 600 µm IS Sieve or to percentage passing any other sieve size on the coarse limit of Grading Zone I or finer limit of Grading Zone IV.
2. For crushed stone sands, the permissible limit on 150 µm IS Sieve is increased to 20 percent. This doesn't affect the 5 percent allowance permitted in Note 1 above.
3. It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

2 **Test for Deleterious Materials** *(Table 2 of IS :383:2016)*

Limits of Deleterious Materials – Fine Aggregates

SN	Deleterious Substance	Test Procedure, Ref Code	Fine Aggregate Percentage by Mass, Max	
			Uncrushed	Crushed
(i)	Coal & lignite	IS 2386 (Part 2)	1.0	1.0
(ii)	Clay lumps	IS 2386 (Part 2)	1.0	1.0
(iii)	Materials finer than 75 micron IS sieve	IS 2386 (Part 1)	3.0	15.0 (for crushed sand) 12.0 (for mixed sand)
(iv)	Shale	Presence and extent of shales shall be determined by petrography at the time of selection and change of source.	1.0	-
(v)	Total of percentage of all deleterious materials (except mica) including SN (i) to (iv)	-	5.0	2.0
(vi)	Mica, percent by mass (Where no tests for strength & durability are conducted)	-	1.0	1.0
(vii)	Mica (muscovite type), percent by mass Mica (for both muscovite and biotite), percent, maximum by mass [Where tests are conducted to ensure adequate workability, satisfactory strength, permeability and abrasion (for wearing surfaces)]	-	3.0 5.0	3.0 5.0

	(viii)	Total of percentage of all deleterious materials (including mica) including SN (i) to (iv) and (vi) or (vii)	-	8.0	5.0
3	**Tests for Soundness** (Only concrete liable to be exposed to the action of frost)				
A	Sodium or magnesium sulphate accelerated soundness test		IS 2386 (Part 5)	The limits to set by agreement between the purchaser and supplier. However, as a general guide, it may be taken that the average loss of mass after 5 cycles shall not exceed 10% when tested with sodium sulphate (Na_2SO_4), and 15% when tested with magnesium sulphate ($MgSO_4$).	
4	**Alkali Aggregate Reaction –** 1. Some aggregates containing particular varieties of silica may be susceptible to attack by alkalies (Na_2O and K_2O) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. 2. The aggregates containing more than 20 percent strained quartz and undulatory extinction angle greater than 15°, causing deleterious reaction and also possibly showing presence of microcrystalline quartz is known as slowly reactive aggregates. 3. Petrographic analysis of aggregate should be carried out to find out the strained quartz percentage, undulatory extinction angle and its mineral composition before conducting these tests.				
A	**Chemical Method** [This method (for determination of potential reactivity) is not found to be suitable for slowly reactive aggregates or for aggregate containing carbonates or magnesium silicates, such as antigorite]		IS 2386 (Part 7)	If test results indicate deleterious or potentially deleterious character, the aggregate should be tested using mortar bar method to verify the potential for expansion in concrete.	
B	**Mortar Bar Method**			Permissible limits for mortar bar expansion	
	Using 38 degree C temp regime (Not suitable for slowly reactive aggregate)		IS 2386 (Part 7)	0.05 % at 90 days & 0.1 % at 180 days	
	Using 60 degree C temp regime (for slowly reactive aggregates)			0.05 % at 90 days & 0.06 % at 180 days	
C	Accelerated mortar bar method (The test is found to be specially suitable for slowly reactive aggregate)		IS 2386 (Part 7)	Expansion < 0.10 % at 16 days after casting - Indicative of innocuous behavior in most cases. Note- Some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in this test was less than 0.10 percent at 16 days after casting. With such aggregate, it is recommended that prior field performance be investigated. In absence of field performance data, mitigative measures should be taken.	
				Expansion > 0.20 % at 16 days after casting - Indicative of potentially deleterious expansion	
				Expansion between 0.10% & 0.20% at 16 days after casting - Includes both aggregate that are known to be innocuous and deleterious in field performance. - It may be useful to support this test with test by mortar bar method at 38°C and 60°C, as applicable.	

INFORMATION TO BE FURNISHED BY THE SUPPLIER

When requested by the purchaser or his representative, the supplier shall provide the following particulars:

a) Source of supply, that is, precise location of source from where the materials were obtained;
b) Trade group of principal rock type present, in case of aggregates from natural sources*;*
c) Physical characteristics, in case of aggregates from natural sources*;*
d) Presence of reactive minerals;
e) Service history, if any, the name of projects where used and the performance including in recently completed projects;

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Annexure – 10A

REQUIREMENT FOR MANUFACTURED FINE AGGREGATES

Aggregates are important components for making concrete and properties of concrete are substantially affected by various characteristics of the aggregates used. Although, the aggregates from natural sources form the major variety used for making concrete, mortar and other applications, but the scarcity in availability of aggregates from natural sources is being faced in some parts of the country. This may require supplementing the use of aggregates from natural sources with the use of aggregates from other sources.

Therefore, quality requirements and those relating to the extent of utilization of manufactured fine aggregates such as iron slag, steel slag, copper slag, recycled concrete aggregates (RCA), have been covered in this booklet.

Fine aggregate is aggregate most of which passes 4.75 mm IS Sieve and grading and content of coarser material for different Grading Zones shall be within the limits given in *Table 9 of IS 383-2016*. Manufactured fine aggregates are manufactured from other than natural sources, by processing materials, using thermal or other processes such as separation, washing, crushing and scrubbing. Manufactured fine aggregate may be Recycled Concrete Aggregate (RCA).

The manufactured aggregates shall be permitted with their extent of utilization as percent of total mass of fine aggregate as indicated in Table below against each, for use in plain and reinforced concrete and lean concrete. Manufactured aggregates shall not be permitted for use in pre-stressed concrete. *(Ref. Cl. 4.2 of IS 383-2016)*

Type of Aggregate	**Maximum Utilization**		
	Plain Concrete (%)	**Reinforced Concrete (%)**	**Lean Concrete (< M15 Grade) (%)**
Iron slag aggregate	50	25	100
Steel slag aggregate	25	Nil	100
Copper slag aggregate	40	35	50
Recycled concrete aggregate (RCA)	25	20 (Only up to M25 Grade)	100
Bottom Ash from Thermal Power plant	Nil	Nil	25

1. It is desirable to source the recycled concrete aggregates from sites being redeveloped for use in the same site.
2. In any given structure, only one type of manufactured fine aggregate shall be used.
3. The increase in density of concrete due to use of steel slag aggregates need to be taken into consideration in the design of structures.
4. While using manufactured aggregate as part replacement for natural aggregate, it should be ensured that the final grading meets the requirements specified in Table overleaf for fine aggregates.

RCA is derived from concrete after requisite processing and can be used as fine aggregate in accordance with the requirements of IS 383-2016.

Iron Slag Aggregates – Iron slag is obtained as a byproduct, while producing iron in blast furnaces or basic oxygen furnaces in integrated iron and steel plants. The lime in the flux chemically combines with the aluminates and silicates of the iron ore and coke ash to form a non-metallic product called iron/blast furnace slag. The molten slag at a temperature of approximately 1500°C is taken out of the furnace and cooled to form different types of slag products.

Depending upon type of cooling, it is categorized as

(i) **Air Cooled Iron Slag Aggregate:** It is formed when molten slag is allowed to flow from the furnace into open pits located beside the furnaces where the material is quenched with water to

facilitate cooling and crystallization. The slag after cooling can be further crushed and screened to produce different sizes of aggregates. During its usage, care should be taken to ensure that the slag passes the test for 'iron unsoundness' and is pre-wetted prior to its use.

(ii) **Granulated Iron Slag Aggregate:** It is formed when molten slag is allowed to flow through the launders into a granulation plant, where molten slag is quenched rapidly with large volume of water. This results in vitrified (glassy) material with a sand-like appearance, with particles typically 1 mm to 5 mm size. It is a light weight aggregate, which needs further processing to improve the bulk density to more than 1.35 kg/l for its use as normal weight aggregate.

Steel Slag Aggregate - Steel slag is a byproduct produced in steel making operations in integrated iron and steel plants, where calcined lime used as flux combines with the silicates, aluminum oxides, magnesium oxides, manganese oxides and ferrites to form steel furnace slag. Slag is poured in a cooling yard from the furnace at a temperature of 1400°C - 1700°C and cooled by air and sprinkling of water. Steel making slag contains about 10 to 20 metallic iron percent by mass, and is recovered by magnetic separation. The metal free slag is crushed and screened to different sizes for use as aggregates.

- For use as aggregates, the steel slag is subjected to weathering process (natural or accelerated) to reduce the free lime content in the slag.
- This is important during construction, as the moisture condition of the aggregate will impact workability and early-age, shrinkage-related cracking, if the aggregate is not kept sufficiently moist prior to batching.

Copper Slag Aggregates – Copper slag is produced as a byproduct from copper smelter, while producing copper from copper concentrate (copper pyrite) through pyrometallurgical process. In the process of smelting, the iron present in the copper concentrate combines chemically at 1200°C with silica present in flux materials such as river sand/silica sand/quartz fines to form iron silicate, which is termed as copper slag. The copper slag thus generated is quenched with water to produce granulated copper slag. Copper slag is a blackish granular material, similar to medium to coarse sand having size ranging from 150 μm to 4.75 mm. This aggregate has potential for use as fine aggregate.

Construction and Demolition (C&D) Waste – The aggregates obtained from construction and demolition (C&D) waste may be of two types namely Recycled Aggregate (RA) and Recycled Concrete Aggregate (RCA). The concrete rubble has to be properly processed, including scrubbing to remove the adhered hydrated cement as much as possible

- Recycled concrete aggregate (RCA), which is derived from concrete after requisite processing, contain not only the original aggregate, but also hydrated cement paste adhering to its surface. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity of RCA leads to a higher absorption. RCA can be used as fine aggregates.

The requirements for manufactured fine aggregate for use in production of concrete are tabulated as under:

SN	Material / Test		Method of Test, Ref to	Permissible Limits/ Variations			
1	**Gradation test**		**IS 2386 (Part 1)**	**As per table below**			
A	**Fine Aggregates –** The grading of fine aggregates shall be within limits given table below. (*Table 9 of IS 383:2016*)						
	SN	IS Sieve Designation	Percentage passing				
			Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV	
	1	10 mm	**100**	100	100	100	
	2	4.75 mm	90-100	90-100	90-100	95-100	
	3	2.36 mm	60-95	75-100	85-100	85-100	
	4	1.18 mm	30-70	55-90	75-100	90-100	
	5	**600 μm**	15-34	35-59	60-79	80-100	

	6	300 µm	5-20	8-30	12-40	15-50
	7	150 µm	0-10	0-10	0-10	**0-10**

Note:

1. Where the grading falls outside the limits of any particular grading zone of sieves other than 600 µm IS Sieve by an amount not exceeding 5 percent for particular sieve size, (subject to cumulative amount of 10 percent), it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing 600 µm IS Sieve or to percentage passing any other sieve size on the coarse limit of Grading Zone I or finer limit of Grading Zone IV.
2. For crushed stone sands, the permissible limit on 150 µm IS Sieve is increased to 20 percent. This doesn't affect the 5 percent allowance permitted in Note 1 above.
3. It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

2 Test for Deleterious Materials

Limits of Deleterious Materials – Fine Aggregates *(Table 2 of IS :383:2016)*]

	SN	Deleterious Substance	Test Procedure, Ref Code	Fine Aggregate Percentage by Mass, Max
				Manufactured
A	(i)	Coal & lignite	IS 2386 (Part 2)	1.0
	(ii)	Clay lumps	IS 2386 (Part 2)	1.0
	(iii)	Materials finer than 75 micron IS sieve	IS 2386 (Part 1)	10.0
	(iv)	Shale	Presence and extent of shales shall be determined by petrography at the time of selection and change of source.	1.0
	(v)	Total of percentage of all deleterious materials (except mica) including SN (i) & (ii)	-	2.0
	(vi)	Mica, percent by mass (Where no tests for strength & durability are conducted)	-	1.0
	(vii)	Mica (muscovite type), percent by mass Mica (for both muscovite and biotite), percent, maximum by mass [Where tests are conducted to ensure adequate workability, satisfactory strength, permeability and abrasion (for wearing surfaces)]	-	3.0 5.0

3	**Test for Soundness of Aggregate** (Only for concrete liable to be exposed to the action of frost)		
A	Sodium or magnesium sulphate accelerated soundness test	IS 2386 (Part 5)	The limits to set by agreement between the purchaser and supplier. However, as a general guide, it may be taken that the average loss of mass after 5 cycles shall not exceed 10% when tested with sodium sulphate (Na_2SO_4), and 15% when tested with magnesium sulphate ($MgSO_4$)

B	**Additional test for slag aggregates**			
	(i)	Iron Unsoundness (for aggregates having Ferrous oxide ≥ 3.0 % and Sulphur content ≥ 1.0%)	Annex D of IS 383-2016	≯1 %

	(ii)	Volumetric expansion ratio	Annex E of IS 383-2016	≯2.0
	(iii)	Unsoundness due to free lime (for use of iron slag for production of aggregate)	Petrographic examination or quantitative x-ray diffractometry	Iron slag from a new source or when significant changes in furnace chemistry occur in an existing source which may result in the presence of free lime, the potential for pop-out formation shall be assessed by determining the free-lime content of the slag by test as specified. If the number of particles containing free lime exceeds 1 in 20, then weathering of the slag stockpile (in moist condition or at/near saturated surface dry condition) represented by the test sample shall be continued until further testing shows that the level has fallen below 1 in 20.
4	**Alkali Aggregate Reaction –** 1. Some aggregates containing particular varieties of silica may be susceptible to attack by alkalies (Na_2O and K_2O) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. 2. The aggregates containing more than 20 percent strained quartz and undulatory extinction angle greater than 15°, causing deleterious reaction and also possibly showing presence of microcrystalline quartz is known as slowly reactive aggregates. 3. Petrographic analysis of aggregate should be carried out to find out the strained quartz percentage, undulatory extinction angle and its mineral composition before conducting these tests.			
A	**Chemical Method** [This method (for determination of potential reactivity) is not found to be suitable for slowly reactive aggregates or for aggregate containing carbonates or magnesium silicates, such as antigorite]		IS 2386 (Part 7)	If test results indicate deleterious or potentially deleterious character, the aggregate should be tested using mortar bar method to verify the potential for expansion in concrete.
B	**Mortar Bar Method**			Permissible limits for mortar bar expansion
	Using 38 degree C temp regime (Not suitable for slowly reactive aggregate)		IS 2386 (Part 7)	0.05 % at 90 days & 0.1 % at 180 days
	Using 60 degree C temp regime (for slowly reactive aggregates)			0.05 % at 90 days & 0.06 % at 180 days
C	Accelerated mortar bar method (The test is found to be specially suitable for slowly reactive aggregate)		IS 2386 (Part 7)	Expansion < 0.10 % at 16 days after casting - Indicative of innocuous behavior in most cases. Note- Some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in this test was less than 0.10 percent at 16 days after casting. With such aggregate, it is recommended that prior field performance be investigated. In absence of field performance data, mitigative measures should be taken.
				Expansion > 0.20 % at 16 days after casting - Indicative of potentially deleterious expansion
				Expansion between 0.10% & 0.20% at 16 days after casting - Includes both aggregate that are known to be innocuous and deleterious in field performance. - It may be useful to support this test with test by mortar bar method at 38°C and 60°C, as applicable.

5	**Manufactured aggregates shall meet the additional requirements as given below**		
A	**For All Manufactured Aggregates -** As per table below *(Table 3 of IS :383:2016)*		
	Total alkali content as Na_20 equivalent	-	≯ 0.3%
	Total sulphate content as $S0_3$		≯ 0.5%
	Water soluble chloride content		≯ 0.04%
	Water absorption		≯ 5% For RCA & RA, higher water absorption up to 10 percent may be permitted subject to pre-wetting (saturation) of aggregates before batching and mixing.
	Specific gravity		2.1 to 3.2 - The limits are intended for use of aggregate in normal weight concrete. - Copper slag having higher specific gravity (up to 3.8) shall be permitted for part replacement of aggregates in accordance with their extent of utilization, such that the average specific gravity of the fine aggregate is not more than 3.2.
B	**For Iron and Steel Slag Aggregates -** As per table below *(Table 4 of IS :383:2016)* ▪ Crushed slag aggregate should be stockpiled in moist condition at or near the saturated surface dry (SSO) condition before use, with the moisture condition being maintained by sprinkling with water.		
	Calcium oxide as CaO	-	≯ 45.0%
	Total sulphur as S		≯ 2.0%
	Total iron as FeO		≯ 3.0%
C	**For Copper Slag Aggregate -** As per table below *(Table 6 of IS :383:2016)*		
	Calcium oxide as CaO	-	≯ 12.0%
	Total sulphur as S		≯ 2.0%
	Total iron as FeO		≯ 70.0%
	Chlorine as NaCl		≯ 0.03%

INFORMATION TO BE FURNISHED BY THE SUPPLIER

When requested by the purchaser or his representative, the supplier shall provide the following particulars:

a) Source of supply, that is, precise location of source from where the materials were obtained;
b) In case of manufactured aggregates, the brief manufacturing process, source of parent; material and special characteristics having bearing on concrete properties, such as presence of adhered coating in case of recycled concrete aggregate, to the extent possible.
d) Presence of reactive minerals;
e) Service history, if any and in particular, in case of manufactured aggregates, the name of projects where used and the performance including in recently completed projects;
f) In case of manufactured aggregates, special precautions, if any, to be observed during concrete production.

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Annexure – 11

REQUIREMENT FOR CONCRETE ADMIXTURES

Concrete made with admixtures when compared with identical concrete made without the admixture in accordance with the provisions of IS 9103 shall conform to the requirements appropriate to the type of admixture given in the following table.

Physical Requirement *(Table 1A of IS 9103.1999)*

SN	Requirement	Test Procedure, Ref Code	Accelerating Admixture	Retarding Admixture	Water Reducing Admixture	Air-Entraining Admixture	Super plasticising	
							Normal	Retarding type
1	Water content, percent of control sample, mix.	*IS 2386 (Part3)*	-	-	95	-	80	80
2	Slump	*IS 1199*	-	-	-	-	Not more than 15mm below that of the control mix concrete	
3	Time of setting allowable deviation from control sample hours.	*IS 8142*						
	Initial - Max.		-3	+3	±1	-	±1.5	+4
	Min.		-1	+1	-	-	-	+1
	Final - Max.		-2	+3	±1	-	±1.5	+3
	Min.		-1	-	-	-	-	-
4	Compressive strength percent of control sample, Min	*IS 516*						
	1 day		-	-	-	-	140	-
	3 days		125	90	110	90	125	125
	7 days		100	90	110	90	125	125
	28 days		100	90	110	90	115	115
	6 months		90	90	100	90	100	100
	1 year		90	90	100	90	100	100
5	Flexural strength, percent of control sample, Min.	*IS 516*						
	3 days		110	90	100	90	110	110
	7 days		100	90	100	90	100	100
	28 days		90	90	100	90	100	100
6	Length change, percent increase over control sample, Max.	*IS 1199*						
	28 days		0.010	0.010	0.010	0.010	0.010	0.010
	6 months		0.010	0.010	0.010	0.010	0.010	0.010
	1 year		0.010	0.010	0.010	0.010	0.010	0.010
7	Bleeding, percent increase over control sample, Max.	*IS 2386 (Part 3) & Annex D of IS 9103*	5	5	5	5	5	5
8	Loss of workability	*Cl. 7.2.1.2 of IS 9103:1999*	-	-	-	-	At 45 min the slump shall be not less than that of control mix concrete at 15 min	At 2 h, the slump shall be not less than that of control mix concrete at 15 min
9	Air content % Max. over control	-	-	-	-	-	1.5	1.5

Requirement for High Workability Test Mix *(Table 1B of IS 9103.1999)*

SN	Requirement	Test Procedure, Ref Code	Type of super plasticising admixtures	
			Normal	**Retarding type**
1.	Flow	*Cl. 7.2.1.1 of IS 9103:1999*	510-620 mm	510-620 mm
2.	Loss of workability on standing	*Cl. 7.2.1.2 of IS 9103:1999*	At 45 minute slump shall be not less than that of control mix concrete at 15 minute.	At 2 hours the slump shall be not less than that of control mix concrete at 15 minute.
3.	Minimum Compressive strength, Percent of control mix concrete 7 days 28 days 06 months 01 year	*IS 516*	 90 90 90 90	 90 90 90 90

Uniformity Test and Requirement of an Admixture *(Table 2 of IS 9103.1999)*

Any batch of admixture shall have the same physical state and composition, as that of admixtures tested for acceptance. To check the uniformity of composition, a representative sample of the batch shall be tested and shall satisfy the requirement given in table as under –

S. No.	Property	Test Procedure, Ref Code	Requirement reference
1.	Dry material content for liquid or solid admixtures	Annex E of *IS 9103:1999*	Within 3 percent of the value stated by the manufacturer
2.	Ash content		Within 1 percent of the value stated by the manufacturer
3.	Relative density		Within 0.02 percent of the value stated by the manufacturer
4.	Chloride ion content		Within 10 percent of the value or 0.2 percent whichever is greater as stated by the manufacturer
5.	Ph value		7-8

Note - Uniformity requirement for ash content is not applicable to accelerating admixtures, which may contain more than 1% chloride content.

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Annexure – 12

REQUIREMENT FOR WATER

As a guide the following concentrations represent the maximum permissible values: -

(a) To neutralize 200 ml sample of water, using phenolphthalein as an indicator, it should not require more than 2 ml of 0.1 normal NaOH. The details of test shall be as given in IS: 3025.
(b) To neutralize 200 ml sample of water, using methyl orange as an indicator, it should not require more than 10 ml of 0.1 normal HCl. The details of test shall be as given in IS: 3025.
(c) Permissible limits for solids when tested in accordance with IS: 3025 shall be as given in Table-1.

Table – 1 Permissible Limit for Solids
(Ref. – Table 1 of IS 456:2000)

Sl No.		Tested as per	Permissible Limit, *Max*
i)	Organic	IS 3025 (Part 18)	200 mg/l
ii)	Inorganic	IS 3025 (Part 18)	3 000 mg/l
iii)	Sulphates (as SO_3)	IS 3025 (Part 24)	400 mg/l
iv)	Chlorides (as Cl)	IS 3025 (Part 32)	2 000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforced concrete work
v)	Suspended matter	IS 3025 (Part 17)	2 000 mg/l

In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time tests as specified below:

- Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 percent of the average of strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with the requirements of IS: 516.
- The initial setting time of test block made with the appropriate cement and the water proposed to be used shall not be less than 30 min and shall not differ by ± 30 min from the initial setting time of control test block prepared with the same cement and distilled water.

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Annexure – 13

CALIBRATION AND WEIGHING EQUIPMENT ACCURACY

(*Annex E of IS 4926*)

The following limits shall apply to all ready-mixed concrete plants:

a) The accuracy, sensitivity and arrangement of the weighing devices shall be such as to enable the materials to be batched within the following tolerances:

1)	Cement and mineral admixtures	:	Within ± 2 percent of the quantity of constituents being measured
2)	Aggregate, chemical admixture and water	:	Within ± 3 percent of the quantity of constituent being measured

b) Analogue scales shall have scale increments not exceeding 5 kg for cement and mineral admixtures, 25 kg for aggregates and 2 kg or less for water.

c) Preset controls shall be calibrated in increments not exceeding 5 kg for cement and mineral admixtures, 10 kg for aggregates and 2 kg for water.

d) For continuous mixer plants, calibration shall be in increments not exceeding 10 kg/m^3 for cement and mineral admixtures, 25 kg/m^3 for aggregates and 10 litre /m^3 for water.

e) Digital read-outs shall have a scale increment not exceeding 2 kg for cement, 10 kg for aggregate and 1 litre for water.

f) At the time of installation, or reconditioning, the accuracy of the indicated mass at any point on the scale shall be within 0.25 percent of the full scale reading.

g) At any other time during operation the accuracy shall be within 0.50 percent of the full scale reading.

h) Chemical Admixture dispensers shall have scale increments not exceeding

Range of scale in kg/1	Scale increment in kg/1
0.1 -0.5	0.01
0.5- 1.0	0.02
1.0- 10.0	0.2
more than 10.0	0.4

i) All weighing and measuring equipment shall be tested and calibrated over its full working range at the intervals – (a) at least once every 2 months for Mechanical/ knife edge system (b) at least once every three months for Electrical/ load cell system. Adequate and identified facilities shall be provided for the application of test loads.

j) In the case of batch weighing systems testing and calibration shall be based on the application test loads to the weigh hoppers.

k) Checks on continuous weigh systems shall be based on comparison of preset quantities with those actually produced.

l) To achieve the required accuracy of calibration, a minimum of 500 kg of stamped weights are required, except that for low capacity scales an acceptable limit on the total mass of calibration weights would be 20 percent of the scale capacity.

m) When calibration of weighing equipment is carried out all personnel involved should be competent and fully trained, the procedures should be fully documented, and special attention should be paid to the health and safety aspects of the procedure.

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Annexure – 14

MINIMUM TEST FREQUENCIES OF CEMENT

S. No.	Material/Test	Frequency of Test
1	**Source approval for Cement :-**	
	Manufacturer Test Certificate containing all test results as in Annexure- 2 to 8	Once for Source
2	**Physical Tests:**	
a	Fineness, m^2/kg, Min	Manufacturer Test Certificate* or One test for each batch and if cement is used after 3 months of test, one more test before immediate use.
b	Soundness:	
	a) By Le-Chatelier Method	
	b) By Autoclave Test Method	
c	Setting time:	
	a) Initial,	
	b) Final	
d	Compressive Strength	
	a) 72 ± 1 h,	
	b) 168 ± 2 h	
	c) 672 ± 4 h, Min	
e	Transverse Strength (optional)	
3	**Chemical Tests**	
a	Ratio of percentage of lime to percentages of Silica, Alumina and Iron Oxide, when calculated by the formula: $\frac{Cao - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3}$	Manufacturer Test Certificate* or One test for each batch and if cement is used after 3 months of test, one more test before immediate use
b	Ratio of percentage of Alumina to that of Iron Oxide	
c	Insoluble residue, percent by mass	
d	Magnesia, percent by mass, Max	
e	Total Sulphur content calculated as Sulphuric Anhydride (SO_3), percent by mass,	
f	Loss of ignition, percent by mass	
g	Chloride content, percent by mass	
h	Alkali content expressed as Sodium oxide (Na2O+ 0.658 K2O)	

* For unimportant projects, Railway may accept the Manufacturer Test Certificate containing all the above tests. However, in that case periodic validation of the manufacturers' test results shall be carried out by testing the physical and chemical properties of cement in NABL-accredited lab at least once in a year.

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Annexure – 15

MINIMUM TEST FREQUENCIES OF AGGREGATES & WATER

Minimum Test Frequencies of Aggregates

S. No.	Aggregate Property/ Parameter		Type of Aggregate		Assessment of Typical Properties and *High Test Rate	Normal Monitoring and **Low Test Rate	Requirement for Normal Monitoring and Low Test Rate
1	Grading		Sand/fine		Weekly	Monthly	Last 8 results conform to IS 383 or representative values
			Coarse	Single sized	Weekly	Monthly	
				Graded	Weekly	Monthly	
2	Particle Density	Oven dry	All types		Weekly	3 Monthly	Last 4 results ± 0.04
		Saturated surface dry			Weekly	3 Monthly	
		Apparent			Weekly	3 Monthly	
3	Absorption		All types		Weekly	3 Monthly	Last 4 results ± 0.04 percent
4	Bulk Density	Loose	All types		Monthly	6 Monthly	Last 4 results ± 75 kg/m3
		Compacted	All types		Monthly	6 Monthly	
5	Fines (silt) Content		Sand		Weekly	Monthly	Last 10 results < 75 percent maximum allowed
			Coarse		Monthly	3 Monthly	
6	Aggregate Impact Value		Coarse		As specified	As specified	-
7	10% Fines		Coarse		Yearly	Yearly	-
8	Flakiness		Coarse		2 Weekly	6 Monthly	Last 3 results conform to standard
9	Chloride Content		All types		Weekly	6 Monthly	Last 3 results < 0.01 percent
10	Aggregate Abrasion Value (Los Angeles Method)		Coarse		-	Yearly/ Source change	-
11	Soundness		Fine and Coarse		-	Yearly/Source change	-
12	Potential Alkali Aggregate Reactivity including Petrography		Fine and Coarse		-	5 Yearly/Source change	-
13	Petrographic Description (General)		All types		-	5 Yearly	-

*1) To establish the typical characteristics of an aggregate, and 2) When significant changes in properties occur outside the tolerances for low test rates given.

**1) When the typical characteristics of the aggregate have been established, and 2) When subsequent tests lie within the tolerances for low test rates given.

Minimum Test Frequencies of Water

The minimum testing frequencies shall be as follows:

a) Mains Water – Water samples are taken from all sources of supply and tested for pH, chloride ion content, sulfate content and any other parameters in accordance with IS 456. The initial test rate shall be weekly until six results are obtained. Three monthly samples shall then be taken and compared against the average of the original six. Significant deviation shall require further investigation.

b) Non Mains Water – A sample shall be taken annually for routine records however if the chloride ion content is above 0.01 percent then the interval of testing shall be reduced to 3 monthly.

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Annexure – 16

MINIMUM TEST FREQUENCIES OF ADMIXTURES

SN	Material / Test	Frequency of test
1	**Source approval for Admixture:-**	
a	All test to be conducted as mentioned	Once for New source
2	**Storage & Shelf Life**	Each Lot supplied at site
3	**Physical Tests:**	
a	Aspect, Physical State	For each lot
b	Dry Material Content	Manufacturer Test Certificate* for each lot/once in a six month
c	PH	
d	Relative density	
4	**Chemical Properties**	
a	Chlorides	Manufacturer Test Certificate* for each lot/once in a six month
b	Ash Content	

* For unimportant projects, Railway may accept the Manufacturer Test Certificate containing all the above tests. However, in that case periodic validation of the manufacturers' test results shall be carried out by testing the physical and chemical properties of cement in NABL-accredited lab at least once in a year.

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Annexure – 17

PROFORMA FOR DELIVERY OF RMC

The information to be included in the delivery ticket to accompany the load to the purchaser should be as follows:

Name or number of the ready-mixed concrete depot.	
Serial number of the ticket.	
Date.	
Truck number.	
Name of the Purchaser.	
Ordered Quantity in m^3	
Receipt Number	
Name and location of site.	
Number of Batches	
Batch size in m^3	
Grade or mix description of the concrete.	
Specified target workability.	
Minimum cement content (if specified).	
Type of cement and grade (if specified).	
Maximum free water-cement ratio (if specified).	
Nominal maximum size of aggregate.	
Generic type or name of any chemical and mineral admixtures included.	
Moisture percentage of each material at the time of batching	
Weighing chart for each type of component with total for each component independently	
Quantity of concrete delivered in m^3.	
Starting Time	
Time of loading.	
Transit mixer number and capacity	
Transit mixer driver's name	
A statement warning the purchaser of the precautions needed to be taken when working with cement and wet concrete.	
Signature of the RMC plant Representative.	
Signature of Railway Representative at RMC Plant	

On site following information to be added –

Time of arrival on site.	
Time when discharge was completed.	
Any water/admixture added by the supplier to meet the specified workability.	
Any extra water/admixture added at the request of the purchaser of the concrete, or his representative, and his signature.	
Pouring location.	
Signature of the purchaser or his representative confirming discharge of the load.	

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Annexure – 18

CHECKLIST ON READY MIXED CONCRETE
(Based on best practices and relevant Indian Standards)

S. No.	Items	Yes	No	Railway Supervisor's Observation, if any
Part A – Checklist on RMC Plant Finalisation				
1	Check whether all statutory permissions are available with the producer to run the plant.			
2	Check whether the RMC Plant is well equipped to supply the concrete mix as per the desired quality and in required quantity.			
3	Check whether a well documented procedure for plant inspection, maintenance is available with RMC producer.			
4	Check whether the producer has provided adequate facilities to Railway Officials to supervise the materials proposed to be used in production of concrete, the process of manufacture and the method of delivery of concrete.			
5	Check whether the producer has provided adequate facility to the Railway officials to take samples for materials used, if required.			
6	Check whether the producer has provided copy of the relevant documents of calibration, test certificates of ingredient materials, etc.			
7	Check whether the producer is able to demonstrate that a documented calibration procedure for the plant and all other equipment is prevalent.			
8	Check whether the plant is capable of arranging all the materials (cement, aggregate, chemical admixture, water) conforming to the requirements of relevant IS codes.			
9	Check whether silos/bins and the cement feeding area is weatherproof.			
10	Check whether storage facility for cement supplied in bags is the weatherproof, dampproof, well ventilated and reasonably free from dust.			
11	Check whether there is a separate storage system for different types of supplementary cementitous materials.			
12	Check whether there is separate storage for different types and grades of cement.			
13	Check whether cement stored and stacked in bags is kept free from the possibility of any dampness or moisture coming in contact with them.			
14	Check whether stockpiles are free draining and arranged to avoid contamination and to prevent intermingling with adjacent material.			
15	Check whether bins are provided with hard floor to avoid contamination with soil/water.			
16	Check whether fine aggregates are stacked in a place where loss due to the effect of wind is minimum.			
17	Check whether water storage facility has been protected to minimize the risk of contamination of deleterious substances.			
18	Check whether tanks or drums containing liquid admixtures are clearly labelled for identification purposes and stored in such a way to avoid damage, contamination or the effects of prolonged exposure to sunlight (if applicable).			

19	Check whether there is a proper system to identify, storage and disposal of the rejected materials.			
20	Check whether hoppers for weighing cement, mineral admixtures, aggregates and water and chemical admixture (if measured by mass) are consist of suitable containers freely suspended from a scale or other suitable load measuring device and equipped with a suitable discharging mechanism.			
21	Check whether fully automatic production systems are fitted with control equipment to allow the correct operation of the plant to be monitored during weighing and batching.			
22	Check whether fully documented record along with details of any corrective action taken is available for calibration of all scales.			
23	Check whether all personnel concerned with production, delivery and the function of the producer's quality system have received training appropriate to the duties they perform.			
24	Check whether testing of materials, proportioning of mixes and the production of concrete together with all its control testing are under the overall supervision of an experienced concrete technologist.			
25	Check whether operator who has received proper instructions on the equipment in use and who is able to comply with the required accuracy of batching, is capable to produce concrete.			
Part B – Checklist on Production of Concrete				
26	Check whether all the ingredients used for the preparation of the concrete are thoroughly tested for their quality, physical, chemical, mechanical and other properties in a NABL approved laboratory for conformity to relevant Indian Standard Codes.			
27	Check whether all weighing and batching equipment used in concrete production are calibrated for required accuracy and tolerance as desired by **Annexure – 13**.			
28	Check whether calibration is done by competent person.			
29	Check whether the test for surface moisture content of coarse and fine aggregates is conducted daily.			
30	Check whether necessary adjustment in the quantity of aggregate and water based on the test results of surface moisture content of aggregates has been determined and furnished to the plant operator.			
31	Check whether more than one type or grade of cement is being used, the weighing device and discharge screw or other parts of the transfer system are empty before changing from one type of cement to another.			
32	Check whether cement is measured by mass in a hopper or compartment separate from those used for other materials and on a scale of appropriate sensitivity, measurement being taken from a zero reading.			
33	Check whether aggregates are measured by mass, and allowance being made for the free moisture content of the aggregates.			
34	Check whether added water is measured by volume or by mass.			
35	Check whether any liquid chemical admixture (or paste) is measured by volume or by mass and any solid admixture by mass.			
36	Check whether all materials after measurement are discharged into the mixer without loss.			
37	Check whether any water retained in the mixing drum for washing out purposes is completely discharged before loading concrete materials or mixed concrete into either a stationary mixer or truck			

	mixer.			
38	Check whether mixing time is measured from the time all the materials required for the batch, including water, are in the drum of the mixer. The mixing time should not be less than that recommended by the manufacturer.			
39	Check whether stationary and truck mixers are maintained in an efficient and clean condition with no appreciable build up of hardened concrete or cement in the mixing drum, on the mixing blades, or on the loading hopper or discharge chutes.			
40	Check whether each load of mixed concrete is inspected before dispatch and prior to discharge.			
41	Check whether additional precautions are taken to ensure that the correct numbers of batches are loaded into the truck mixer, in case the rated capacity of a batching plant mixing cycle is less than 2.0 m^3.			
42	Check whether concrete mixes are randomly sampled and tested for workability, and where appropriate, plastic density, temperature and air content.			
43	Check whether water cement ratio is maintained constant at its correct value. Any change in water content due to change in aggregate grading should be taken care of by suitable modifications to mix design.			
44	Check whether there is a record of material stock to enable verification of total quantities used and to confirm that only approved materials have been received.			
45	Check whether written, printed or graphical records for each load are made of the mass of the materials batched, the estimated slump, the total amount of water added to the load, the delivery ticket number for that load, and the time the concrete was loaded into the truck.			
46	Check whether immediately before discharging the concrete at the point of delivery, the producer or his representative has provided the purchaser with a pre-printed delivery ticket for each delivery of concrete on which is printed, stamped or written the minimum information. The information to be included in Delivery Ticket to accompany the load to the purchaser is given in **Annexure – 17**.			
Part B – Checklist on Post Production of Concrete				
47	Check whether concrete transported from the mixer to the point of placing is as rapid as practicable by maintaining the required workability and preventing segregation, loss of any constituents or ingress of foreign matter or water.			
48	Check whether concrete is transported in a truck-mixer and discharged to the site within 2 hour of the time of loading. However, a longer period may be permitted if retarding admixtures are used or in cool humid weather or when chilled concrete is produced.			
49	Check whether time of loading is started from adding the mixing water to the dry mix of cement and aggregate or of adding the cement to the wet aggregate whichever is applicable.			
50	Check whether concrete is received on site after the transit time i.e. 2 hour of the time of loading. It should not be accepted.			
51	Check whether any water/admixture is added by the supplier to meet the specified workability.			
52	Check whether the concrete transported by truck mixer is agitated during transit and re-mixed at the site for at least 2 minute so that			

	the concrete is of the required uniformity.			
53	Check whether signature of the purchaser or his representative confirming discharge of the load is on the delivery ticket.			
54	Check whether sampling is carried out jointly by the purchaser and the supplier with its frequency mutually agreed upon.			
55	Check whether point and time of sampling is – a) at discharge from the producer's delivery vehicle or b) from the mixer to the site or c) when delivered into the purchaser's vehicle			
56	Check whether RMC brought by truck-mixer at delivery point (i.e. construction site) is checked for strength and loss of workability (i.e. slump).			
57	Check whether on reaching the point of placement (i.e. construction site), the truck-mixer has remixed its contents for the purpose of taking samples.			
58	Check whether samples from fresh concrete delivered at placing point are taken for testing of strength of concrete.			
59	Check whether at least one sample comprising of three cubes is taken from each load brought by truck-mixer.			
60	Check whether the minimum testing frequency to be applied by the producer is one sample for every 50 m^3 of production or every 50 batches, whichever is the greater frequency.			
61	Check whether three test specimens are made from each sample for testing at 28 days.			
62	Check whether test strength of the sample is the average of the strength of three specimens.			
63	Check whether individual variation is not more than ± 15 percent of the average. If more, the test results of the sample are invalid.			

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REFERENCES

S. No.	Description
1.	IS 4926 : 2003 (Re-affirmed 2017) Ready Mixed Concrete – Code of Practice (Second Revision)
2.	IS 456 : 2000 (Re-affirmed 2021) Plain And Reinforced Concrete - Code of Practice (Fourth Revision)
3.	IS 383 : 2016 Coarse and Fine Aggregate for Concrete – Specification (Third Revision)
4.	IS 269 : 2015 Ordinary Portland Cement – Specification (Sixth Revision)
5.	IS 1489: 2015 (Part 1- Fly Ash Based) Portland Pozzolana Cement – Specification (Fourth Revision)
6.	IS 1489: 2015 (Part 1- Calcined Clay Based) Portland Pozzolana Cement – Specification (Fourth Revision)
7.	IS 9103:1999 (Re-affirmed 2004) Concrete Admixtures – Specification (First Revision)
8.	IS 455:2015 (Reaffirmed 2020) Portland Slag Cement (Fifth Revision)
9.	IS 8041:1990 (Reaffirmed 2019) Rapid Hardening Portland Cement (Second Revision)
10.	IS 8043:1991 (Reaffirmed 2019) Hydrophobic Portland Cement (Second Revision)
11.	IS 12330:1988 (Reaffirmed 2019) Sulphate Resisting Portland Cement (Fourth Revision)
12.	IS 12600:1989 (Reaffirmed 2019) Low Heat Portland Cement (First Revision)
13.	BS-23 Guidelines on Use of Ready Mixed Concrete - RDSO
14.	Indian Railway's Concrete Bridge Code issued by RDSO, September 2014 (Incorporating A&C 1 to 13)
15.	SERIAL NO. T-39 - Indian Railway's Standard Specification for Pre-Tensioned Prestressed Concrete Sleepers for Broad Gauge, Metre Gauge And Narrow Gauge (Sixth Revision – March 2021)
16.	Integrated Test Plans For USBRL Project Northern Railway (*USBRL – ITP-Part -1 Rev 0 dated 26-02-2018)*
17.	Criteria for Production Control of Ready Mix Concrete for RMC Capability Certification (Issue 1/May 2013) published by Building Materials & Technology Promotion Council Ministry of Housing & Urban Poverty Alleviation Government of India New Delhi

NOTES

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गुणवत्ता नीति

आर. डी. एस. ओ. लखनऊ में हम सतत सुधार और ग्राहक मूल्यांकन प्राप्त करने हेतु गुणवत्ता प्रबंध प्रणालियों की आवधिक समीक्षा के माध्यम से रेलों में यात्री और माल यातायात की बढ़ती आवश्यकताओं, माँग और अपेक्षाओं को पूरा करने के लिए गुणवत्ता प्रबंध प्रणाली की व्यवहारिक आवश्यकताओं और अनवरत सुधारों को पूरा करने के समर्पण गुणवत्ता उद्देश्यों को निर्धारित करके अनुसंधान, अभिकल्पों और मानकों में उत्कृष्टता के माध्यम से वैधानिक और नियामक अपेक्षाओं का अनुपालन करते हुए सुरक्षित, आधुनिक और किफ़ायती रेल प्रौद्योगिकी विकसित करने हेतु सेवाओं को बनाए रखने और अद्यतन पारदर्शी मानकों हेतु प्रतिबद्ध हैं। इसे संगठन के अंदर संसूचित एवं लागू किया गया है तथा सभी संबंधित पक्षकारों को भी उपलब्ध कराया गया है।

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"We at RDSO Lucknow are committed to maintain and update transparent standards of services to develop safe, modern and cost effective railway technology complying with statutory and regulatory requirements, through excellence in research, designs and standards by setting quality objectives, commitment to satisfy applicable requirements and continual improvements of the quality management system to cater to growing needs, demand and expectations of passenger and freight traffic on the railways through periodic review of quality management systems to achieve continual improvement and customer appreciation. It is communicated and applied within the organization and making it available to all the relevant interested parties."

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Our Objective

To upgrade Maintenance Technologies and Methodologies and achieve improvement in productivity and performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability, and Utilisation.

***If you have any suggestion & comments, please write to us*:**

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