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1. **CBEs**
   All Indian Railways.

2. **Managing Directors**
   IRCON, RVNL, DFCCIL, RITES, KRCL, MRVC

विषय: Guidelines for the use of High Performance Concrete including Self Compacting Concrete (SCC) in bridges

संदर्भ:
1. RDSO letter No. CBS/PCB, Dated 27.09.2022
2. Guidelines for the Use of High Performance Concrete in Bridges issued vide BS-89, March-2008

"**Guidelines for the Use of High Performance Concrete in Bridges**" was issued by RDSO in 2008. In view of recent developments in concrete technology changes in relevant BIS and other Codes, the same has been revised. Self-Compacting Concrete (SCC) has also been incorporated in this revision.

The revised draft guideline was sent to Railways for feedback/comments vide ref (1). The final guideline BS-89R is attached for information.

Encl: BS-89R (Guideline)

Digitally Signed by Rajesh Kumar Srivastava
Date: 19-12-2022 10:58:44
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Copy to:- Executive Director / Civil Engg (B&S), Railway Board, New Delhi for information please.

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GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

GUIDELINES FOR THE USE OF HIGH PERFORMANCE CONCRETE INCLUDING SELF-COMPACTING CONCRETE IN BRIDGES

REPORT NO. BS- 89R

March– 2008

First Revision:- December- 2022

Issued by

BRIDGE & STRUCTURES DIRECTORATE RESEARCH DESIGNS & STANDARDS ORGANISATION MANAK NAGAR, LUCKNOW –226011

PREFACE

BS-89: "Guidelines for the Use of High Performance Concrete in Bridges" was issued by RDSO in 2008. It is observed that the use of High Performance Concrete (Concrete Grade M65 and above) is very rare in Railways. There is a need to revise these guidelines in view of recent developments in concrete technology, changes in relevant BIS and other Codes. Self-Compacting Concrete (SCC) has been also incorporated in this revision. Efforts have been made to align these guidelines in line with various BIS Codes to encourage use of High Strength Concrete and Self-Compacting Concrete by Zonal Railways and user agencies in the field.

The contents of this compilation by RDSO are available based on the latest provisions in various BIS and other Codes.

Executive Director (B&S)

CONTENTS

GUIDELINES FOR THE USE OF HIGH PERFORMANCE CONCRETE (INCLUDING SELF-COMPACTING CONCRETE) IN BRIDGES

1. INTRODUCTION

1.1 High Performance Concrete (HPC)

The massive construction program that is under execution in the railway sector, it is necessary to update/revise the existing guidelines on High Performance Concrete (HPC) synonymous with High Strength Concrete (HSC), which is not adequately covered in the existing IRS: CBC (Railway codes). Concrete that has characteristic strength of 65 MPa or more with improved properties is generally known as high performance concrete.

1.2 Self-Compacting Concrete (SCC)

Self-Compacting Concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling every corner of formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Self-Compacting Concrete offers a rapid rate of concrete placement, with faster construction time. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure.

Self-Compacting Concrete (SCC) has been also incorporated in this revision, which was not part of the original guideline.

2. SCOPE

2.1 High Performance Concrete (HPC) is one, whose ingredients, proportions and production methods are specially chosen to meet special performance and uniformity requirements that cannot be always achieved routinely by using only conventional materials, like, cement, aggregates, water and chemical admixtures, and adopting normal mixing, placing and curing practices. These performance requirements can be high strength, high early strength, high workability (including self-compacting concrete) low permeability and high durability for severe service environments, etc. or combinations thereof. Production and use of such concrete in the field necessitates high degree of uniformity between batches and very stringent quality control.

2.2 Self-Compacting Concrete (SCC) is a concrete that fills uniformly and completely every corner of formwork by its own weight and fluidity without application of any vibration, without segregation, whilst maintaining homogeneity. It is suitable in situations where;

- Reinforcement is very congested.
- Access to allow vibration is not available.
- Complicated geometry of the formwork.
- Pouring is possible only from a single point.
- Speedy placement is required.

SCC can be produced using the same ingredients as that of normal concrete. However, a closer tolerance is required to ensure strict control of workability characteristics. The proportioning of SCC mix is much more scientific than that of conventional concrete mixes. SCC mix requires high powder content, lesser quantity of coarse aggregate, high range superplasticizer and VMA (Viscosity Modifying Agent) to give stability and fluidity to concrete mix. It has also the other advantages of no noise due to vibration and no requirement of finishing.

2.3 These Guidelines provide general aspects for production of HPC including mix design. General guidelines on mix design, tests and areas of the use of SCC are also provided. These Guidelines should be read in conjunction with relevant IS and IRS: CBC Specifications and Codes of Practice. It is recommended that the officials involved in the construction of concrete bridges are in possession of the latest codes/specification referred in this guideline.

3. TERMINOLOGY

3.1 Cementitious Materials:

Cementitious material means cement or cement mixed with mineral admixtures like Pozzolanic Fly Ash (PFA), Silica fume, Grounded granulated blast furnace slag (GGBS) or Metakaoline etc.

3.2 Powder

Total mass of cement, other mineral admixtures and fine fraction of sand (of size less than 150 microns)

3.3 Admixtures

A material other than water, aggregates, hydraulic cement and additives like Pozzolana or slag and fiber reinforcement used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing to modify one or more of the properties of concrete in the plastic or hardened state.

3.4 Water/Cement Ratio (w/c)

The Water/Cement Ratio is calculated by dividing the mass of the mixing water by the mass of the cement.

3.5 Water/Cementitious Material Ratio (w/cm)

The Water/Cementitious Material Ratio (w/cm) is the ratio of mass of the mixing water and the mass of cement and other Cementitious materials.

4. MATERIALS

4.1 Cement

Any of the types of cement as per Table.1 may be used with prior approval of the engineer:

Table 1. Types of Cement

S.N	Type	Conforming
1.	Ordinary Portland Cement-Specification (Sixth Revision)	IS:269
2.	Rapid Hardening Portland Cement	IS:8041
3	Portland slag cement	IS:455
4	Portland Pozzolana Cement (Fly ash based)	IS:1489-part I
5	Portland Pozzolana Cement (Calcined clay based)	IS:1489-part II
6	Hydrophobic cement	IS:8043
7	Low heat Portland cement	IS:12600
8	Sulphate resistant Portland cement	IS:12330

4.2 Mineral Admixtures

Admixture plays an important role in the production of High Performance Concrete. Mineral Admixtures form an essential part of the High-Performance Concrete mix. They are used for various purposes depending upon their properties.

Any of the following mineral admixtures may be used as part replacement of Ordinary Portland Cement with the approval of the competent authority. Uniform blending with cement should be ensured by having dedicated facility and complete mechanized process control at the site to achieve specified quality.

For High Strength Mixes the recommended percentage of Mineral Admixtures Materials shall be in accordance with IS: 10262.-2019. The same is given below for reference in Table. 2

Table 2. Recommended percentage of Mineral Admixtures Materials for High Strength Mixes

S.N	Mineral Admixtures	Recommended Percentage by Mass of Total Cementitious Materials
i)	Fly Ash	15-30
ii)	Ground Granulated Blast furnace Slag	25-50
iii)	Metakaoline	5-15
iv)	Silica Fume	5-10

4.2.1 Fly ash

Fly ash conforming to IS: 3812 (Part-1)-2013 shall be used.

4.2.2 Ground Granulated Blast furnace Slag

Ground Granulated Blast furnace Slag (GGBS) conforming to IS: 16714-2018 shall be used.

4.2.3 Metakaoline

Metakaoline conforming to IS: 16354-2015 shall be used.

4.2.4 Silica Fume:

Silica fume is very fine, non-crystalline SiO_2 obtained as a by-product of Silicon or Ferro-Silicon alloy industries. It should conform to IS: 15388.

4.3 Chemical Admixtures

Chemical admixtures and super plasticizers conforming to IS: 9103 shall be used. Compatibility of the superplasticizer with the cement and any other pozzolanic or mineral admixtures as covered in Clause 4.2 (of this guidelines) being used, should be ensured by trials, so that the following problems are avoided:

- Large dosage of super plasticizer required to achieve the desired workability,
- Excessive retardation of setting,
- Excessive entrainment of large air bubbles,
- Unusually rapid stiffening of concrete,
- Rapid slump loss, and
- Excessive segregation and bleeding.

4.4 Aggregates

4.4.1 General: In high-performance concrete, the size of aggregates, shape, surface texture, mineralogy, and cleanness needs special attention. All coarse and fine aggregates shall conform to IS: 383 and shall be tested as per IS: 2386 Parts 1 to 8.

4.4.2 Coarse aggregate: Coarse aggregates shall consist of clean, hard, strong, dense, nonporous, equi-dimensional (i.e., not much flaky or elongated) and durable pieces of crushed stone, crushed gravel, natural gravel or a suitable combination thereof.

Based on the strength requirement, the maximum size of aggregates is generally restricted to 20mm, however for grades M80 and above, aggregates of maximum size 10.0 mm to 12.5 mm may be preferable.

4.4.3 Fine aggregate: Fine aggregate shall consist of hard, strong, clean, durable particles of natural sand, crushed stone or crushed gravel. Suitable combinations of natural sand and crushed stone or crushed gravel can be permitted. They shall not contain dust; lumps, soft or flaky particles, mica or any other deleterious materials in such quantities as would reduce the strength or durability of concrete. Fine aggregate of Zone II or III is preferable.

4.5 Water

Water for mixing and curing should conform to provisions of Clause 5.4 of IS: 456 - 2000.

Testing of water to be used for cement concrete shall conform to provisions of IS: 3025.

4.6 Storage of Material

Storage of Materials shall in accordance with in IS: 4082.

4.7 Concrete

4.7.1 Grades of concrete

The concrete shall be in grades designated in Table.3, where the characteristic strength is defined as the strength of concrete below which not more than 5 per cent of test results are expected to fall.

Table 3. Characteristic Compressive Strength (Ref. Code IS 456:2000.)

Group	Grade designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 days (MPa)
Standard Concrete	M30	30
	M35	35
	M40	40
	M45	45
	M50	50
	M55	55
	M60	60
High Strength Concrete	M65	65
	M70	70
	M75	75
	M80	80
	M85	85
	M90	90
	M95	95
	M100	100

NOTES

1. In the designation of concrete mix M refers to the mix and number to the specified characteristics compressive strength of 150mm size cubes at 28 days, expressed, in Mpa.
2. For concrete of grades M 65 and above, design parameters given in the IRS Concrete Bridge Code may not be applicable and the values may be obtained from specialized literature and experimental results.

4.7.2 The Minimum and Maximum Cement content of concrete shall be in accordance with provisions of IS: 456 -2000.

Maximum Cement content excluding mineral admixtures in excess of 450 kg/m^3 should not be used unless special consideration has been given in design to the increased risk of cracking due to drying shrinkage in thin sections, or to early thermal cracking and to the increased risk of damage due to alkali silica reactions.

4.7.3 The ratio of water/ (cement + all cementitious materials) (w/cm) ratio for high strength concrete made with High Range Water Reducing Admixtures (HRWRA) conforming to IS: 9103 shall be adopted as per clause 6.2 of IS: 10262 -2019.

4.7.4 Workability: The concrete mix proportions chosen for HPC should be such that the concrete is of adequate workability for placing conditions and congestion of reinforcement, to ensure proper placement without segregation or honey combing, and thorough compaction.

Suggested range of workability of concrete shall be in accordance with IS: 456 -2000.

4.8 Durability

Concrete should be durable to provide satisfactory performance in the anticipated exposure conditions during service. The materials and mix proportions specified and used, and the workmanship employed should be such as to maintain its integrity and to protect embedded metal from corrosion.

One of the main characteristics influencing the durability of concrete is its impermeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship employed in making the concrete. A suitably low permeability is achieved by having an adequate cement content, sufficiently low water-cement ratio, dense packing of fine particles, by ensuring thorough compaction of the concrete, and by timely and adequate curing.

The general environment to which the concrete will be exposed during its working life is classified in three levels of severity that is, moderate, severe and extreme, as described below-

ENVIRONMENT	EXPOSURE CONDITION
Moderate	Concrete surface protected against weather or aggressive conditions. Concrete surface sheltered from severe rain or freezing whilst wet. Concrete exposed to condensation, concrete structure continuously under water. Concrete in contact with non-aggressive soil/ground water.
Severe	Concrete surface exposed to severe rain, alternate wetting and drying or occasional freezing or severe condensation. Concrete exposed to aggressive sub-soil/ ground water or coastal environment.
Extreme	Concrete surface exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete structure surfaces exposed to abrasive action, surfaces of members in tidal zone. All other exposure conditions which are adverse to exposure conditions covered above.

4.8.1 Total water-soluble sulphate (SO_3) content of the concrete mix, expressed as (SO_3) shall not exceed 4 per cent by mass of cement used in the mix.

4.8.2 In order to safeguard concrete against Chloride attack, total Chloride content by weight of cement needs to be controlled. It may be determined as per BS: 1881 Pt.124 and restricted as given below-

a) For prestressed concrete works

i) Under extreme and very severe environment 0.06%
ii) Under severe, moderate and mild environment 0.10%

b) For RCC works 0.15%

4.9 Design Mix Concrete

4.9.1 General: Choice of materials, concrete mix design and field practices are quite critical, so that optimum performance can be extracted of each of the ingredients. The procedure of mix proportioning of normal grades of concrete may not be adequate. Relationships between the compressive strength of concrete and water-cement ratio (or water-cement+cementious materials) ratio, and between water content and workability will have to be established by laboratory trials for the grade of concrete, the materials to be used, and the water reducing efficiency of the super-plasticizer.

4.9.2 Target Mean Strength for Mix Proportioning: The target mean strength of concrete mix should be done in accordance with IS: 10262-2019.

4.9.3 Field Trial Mixes: Mix proportions arrived at by laboratory trials shall, in addition, be verified to be satisfactory under field conditions and necessary adjustments made. Field trial mixes shall be prepared for all grades of concrete, using samples of approved materials. Sampling and testing procedures shall be in accordance with Para 4.12.

4.9.4 The temperature of concrete at the time of placement shall not exceed 25°C. The temperature of concrete at the mixing stage should be lower, to allow for rise in temperature during transport. When considerable distance of transport is involved, particular attention should be paid to ensure retention of slump as targeted for placement.

4.9.5 Prototype testing/Use of mock-up testing: Further mock-up trails or prototype testing may be carried out to ensure that the concrete can be satisfactorily placed and compacted, taking into account the location of placement and provision of reinforcement, and adjustments made in concrete mix design and/or detailing of reinforcement accordingly.

4.10 Production of Concrete

For production of concrete, quality Assurance Measures, Batching, Mixing, provisions of as per IS: 456 -2000, shall be adopted.

4.10.1 Curing: High Performance Concrete containing silica fume is more cohesive than normal mixes hence, there is little or no bleeding and no bleed water to rise to the surface to offset water lost due to evaporation. Plastic shrinkage cracking is possible, if curing is not proper. Initial curing should commence soon after initial setting of concrete. Concrete should be covered with moist covers (sacking, canvas or hessian), opaque colour plastic sheets or suitable curing compound. Final moist curing should commence after final setting of concrete and continue for at least 14 days.

4.11 Quality Assurance

The methods and procedures of Quality System shall be followed. Extra High Quality Assurance class shall be adopted for the 'Materials' and 'Workmanship' items.

In order that the performance of the completed structure be consistent with the requirements and assumptions made during the planning and design, stringent quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long-term durability. In particular, it should be aimed to ensure uniformity and to lower the variability between batches of production, as evidenced by the standard deviation in test results.

4.12 Sampling and Testing

Sampling and testing of fresh concrete shall be done in accordance with IS: 1199 Part-6 -2018.

4.13 Acceptance Criteria

4.13.1 The acceptance criteria shall be in accordance with IS: 456 -2000.

4.13.2 Acceptance testing on site shall not be restricted to tests for compressive strength of concrete alone. Where durability of concrete is the main reason for adopting High Performance Concrete, Rapid Chloride Permeability Test as per ASTM C-1202 or AASHTO T-277 shall be carried out.

4.13.3 Additional durability tests, such as, Water Permeability Test as per DIN: 1048 Part 5-1991 or Initial Surface Absorption test as per BS: 1881 Part 5 can also be specified. The permissible values in such tests shall be decided taking into account the severity of the exposure conditions.

5. SELF- COMPACTING CONCRETE

5.1 Constituents

In Self-Compacting Concrete, super-plasticizers provide the fluidity, and Viscosity Modifying Admixtures (VMA) is used to help reduce segregation, and sensitivity of the mix due to variations in other constituents, especially to moisture content. Other materials are as in Clauses 4.1 to 4.5.

VMA's are hydrophilic, water-soluble polymers having high molecular weight. Such polymers can form a network of large molecules extending throughout the mass. The dimensions of the polymers or particles are in colloidal range; hence these are called 'colloidal admixtures'. These can also be used as 'anti-washout' admixtures for underwater placement.

5.2 Properties in the Fresh State

The filling ability and stability of self-compacting concrete in the fresh state can be defined by four key characteristics. A concrete mix can only be classified as Self Compacting Concrete, if the requirements for all below mentioned characteristics are fulfilled:

a) Filling ability (Flow ability),
b) Passing ability,
c) Segregation resistance, and
d) Viscosity

Each characteristic can be assessed by one or more test methods. The above test shall be carried out as per IS: 1199 (Part-6), the range of permissible limits are given in table 4.

Table 4. Characteristics of SCC and Tests

Characteristics	Preferred Test Method(s)	Limit of Test Value
Flow ability	Slump-flow test	550 - 850 mm
Viscosity (assessed by rate of flow)	T5Q0 Slump flow test	2 sec
	V-funnel test	8-25 sec
Passing ability	L-box test	0.8
Segregation	Segregation resistance (sieve) test	15 - 20 per cent

5.3 Mix Design

Proportioning and mix design of SCC shall be done in accordance with IS: 10262-2019 as also illustrated by example at Annexure E (clause 8.4)

6. Precautions:

For concrete made with mineral admixtures, the setting time and rate of gain of strength may be different from those of concrete made with ordinary Portland cement alone. Cognizance of such modified properties shall be taken into account in deciding de-shuttering time, rate of movement of formwork in slip form construction, initial time of prestressing, longer curing period and for early age loading. The compatibility of chemical admixtures and cementitious materials should be ensured by trials.

Concrete containing mineral admixtures may exhibit an increase in plastic shrinkage cracking because of its low bleeding characteristics. The problem may be avoided by ensuring that such concrete is protected against drying, both during and after finishing.

7. REFERENCES

In this publication reference to the following Standards has been made. At the time of publication, the editions indicated are valid. All Standards are subject to revision and the parties to agreements based on these guidelines are encouraged to investigate the possibility of applying the most recent editions of the Standards indicated below:

Codes and Specifications:

1	IRS: CBC- 2008	Indian Railway Standard Code of Practice for Plain,Reinforced and Prestressed Concrete For General Bridge Construction (Concrete Bridge Code)
2	IRC: SP:47- 1998	Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
3	IRC: SP:70-2016	Guidelines for the use of High Performance Concrete (Including Self Compacting Concrete) in Bridges
4	IS: 383-2016 (Reaffirmed-2021)	Specification for Coarse and Fine Aggregates from Natural Sources for Concrete
5	IS: 455-2015 (Reaffirmed-2020)	Portland Slag Cement–Specification (Fifth Revision)
6	IS: 456-2000 (Reaffirmed-2021	Indian Standard: Plain and Reinforced Concrete- Code of Practice. (Fourth Revision)
7	IS: 1489-2015 Pt.1&2	Specification for Portland Pozzolana Cement-part 1 Fly ash based, part 2 Calcined Clay Based
8	IS: 1199-2018 pt-6	Fresh Concrete- Methods of Sampling, Testing and Analysis, Part 6 Tests on Fresh Self Compacting Concrete
9	IS:12089-1987 (Reaffirmed-2013)	Specification for Granulated Slag for the Manufacture of Portland slag Cement.
10	IS: 2386-1963 pt.1-8 (Reaffirmed- 2021)	Methods of test for Aggregate for Concrete
11	IS: 3812-2013	Pulverized Fuel Ash -Specification Part 2 for Use as Admixture in Cement Mortar and Concrete
12	IS: 15388-2003 (Reaffirmed- 2017)	Silica Fume-Specification
13	IS 9103:1999 (Reaffirmed-2018)	Concrete Admixtures-Specification
14	IS: 12330-1988 (Reaffirmed- 2020)	Specification for Sulphate Resisting Portland Cement
15	IS: 12600-1989 (Reaffirmed-2019)	Specification for Low Heat Portland Cement
16	IS: 8041-1990 (Reaffirmed-2019)	Rapid Hardening Portland Cement-Specification
17	IS: 8043- 1991, (Reaffirmed-2019)	Hydrophobic Portland Cement-Specification (Second Revision)
18	IS:16354-2015	Metakaoline for Use in Cement, Cement Mortar and Concrete – Specification
19	IS: 10262- 2019	Concrete Mix Proportioning-Guidelines (Second Revision)
20	BS: 1881 pt. 5-1970	Methods of Testing Concrete- Part 5: Methods of testing hardened concrete for other than strength
21	DIN:1048 pt.5-1991	Testing Concrete- Testing of Hardened Concrete (Specimens prepared in moulds)
22	ASTM C1202-1997	Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration
23	AASHTO T277	Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete
24	EFNARC: 2005	Specification and Guidelines for Self-Compacting Concrete