CHAPTER 12
SPECIAL CONCRETES

page

120.0 SPECIAL CONCRETES

121.0 High Performance Concrete

General

High performance concrete is a concrete whose ingredients, proportions and production methods are specifically chosen to meet special performance and uniformity requirements. The special higher performance requirements may be in terms of high Durability requirements, high abrasion/erosion resistance, higher strength or higher resistance to shrinkage etc.High

C121 Ways for improving specific performance

Resistance to Abrasion/erosion

To ensure good performance against abrasion and erosion, following points should be considered:

a) Use of higher grades of concrete;
b) Use of good quality strong aggregate;
c) Use of silica fume; and
d) Use of steel fibres (suited for increasing abrasion resistance in spillways/glacis, etc).

Test methods for measuring abrasion resistance are:

1) Revolving disc type test.
2) Under water abrasion resistance test using steel balls.

For further details regarding test methods and criteria, specialist literature may be referred.

Improving Performance in Flexure, Shear, Impact, Ductility and Energy Absorption

Resistance to impact is generally increased when the strength of concrete is high and energy absorption is high. Energy absorption and toughness can be increased by use of steel fibres in concrete. Whereas addition of steel fibres, glass or carbon fibres improves flexural and shear strength also, the use of synthetic fibres like polypropylene fibres do not significantly improve the above properties. Polypropylene fibres do however reduce shrinkage cracking and are suitable for concrete/ mortar used for concrete repairs. For checking impact resistance, falling weight impact test can be used, wherein number of blows for crack initiation in small concrete slab panel are counted.

For further details regarding test methods and criteria, specialist literature may be referred.

Improving performance w.r.t. specific Durabilty Requirements

Procedure for improving performance w.r.t to specific Durability requirements is covered in chapter no. …… - Limit state - Durabiliity

strength concrete generally improves performance of all above parameters. The concrete mix proportioning for high strength concrete may be carried out in accordance with the good practice. However special measures are needed to further improve the specific performance requirements. For further details, expert literature may be referred.

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122.0 STEEL FIBER REINFORCED CONCRETE (SFRC)

Steel fiber reinforced concrete is a composite material having fibers as the additional ingredients, dispersed uniformly at random in percentages between 0.3% and 2.0% by volume in plain concrete.

C122 Following properties of concrete can be improved by using SFRC:
a) Ductility,
b) Toughness and energy absorption,
c) Abrasion, and
d) Flexural strength and shear strength.

Compressive and direct tensile strength gain in flexural and direct tensile strength is very significant when higher percentage of steel fibres are used which give the concrete a strain hardening effect (increase in ultimate load after initial crack). However significant improvements are achieved in strain softening zone also.

Steel fibres having aspect ratio 60 to 80 may be incorporated in concrete of different grades to improve the ductility of concrete where needed specifically. Fibre content varying from 0.5 to 2.0 percent volume may be incorporated in to the concrete to improve different mechanical and durability characteristics. However higher addition can also cause problems in uniform mixing and placing of concrete which need to be checked at mix proportioning stage before using the mix. Corrosion of steel fibres can also occur particularly in lower grades, so use of coated fibres and higher grades of concrete are recommended. Alternatively, a plain concrete cover of few mm can also be provided.

122.1 Flexure and shear :

Where SFRC is used to improve properties other than flexure and shear, design for flexure and shear shall generally be done ignoring effect of steel fibres and no reduction of flexure and shear reinforcement will be made.

Where SFRC is adopted specifically to take part of flexure and shear to reduce reinforcement congestion, specific approval of engineer in charge is to be obtained and design is to be carried out using expert literature and international practices for similar type of structure. Design will be based on strain softening SFRC only and strain hardening effect will not be considered for flexure and shear design. SFRC flexure and shear Design Provisions given in our National Building Code may also be referred in such cases.

122.2 Properties of SFRC

SFRC shall be classified in terms of both its characteristic compressive strength and its characteristic residual tensile strength.

122.2.1 Compressive Strength

The characteristic compressive strength of SFRC at 28 days shall be determined in accordance IS:516 (Part-I) Sec-1-2021.

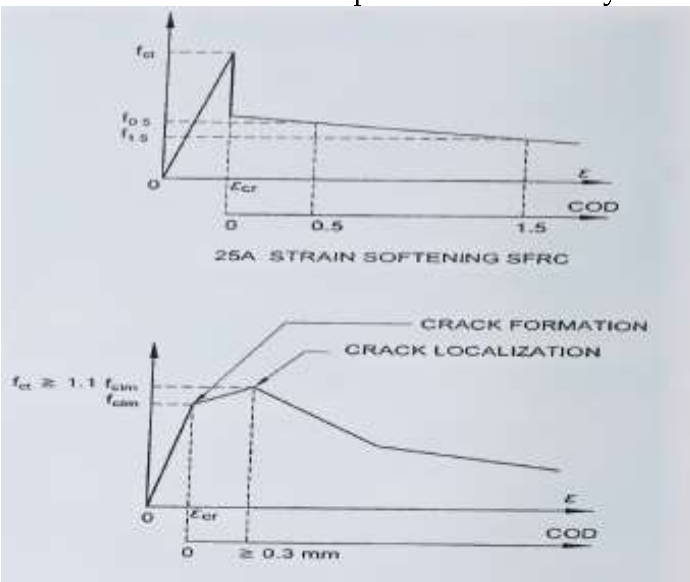
122.2.2 Tensile Properties

Classification

SFRC shall be classified as either softening or hardening as shown in Fig.----. A hardening SFRC is outside the scope of this code.

Notes

1. A hardening material is defined as one with a tensile strength equal to or greater than 1.1 times the strength of the matrix without fibres and taken at a crack opening displacement (COD) of equal to or greater than 0.3 mm.
2. A hardening material is one where multiple cracks can occur prior to crack localization. For material hardening to occur, the fibre dosage is typically such that the strength of the SFRC is at least 10 percent greater than the strength of the same concrete mix without fibres. The value of COD of 0.3 is sufficiently high such that matrix contribution to the strength of the composite is minimal and the tension at this point is substantially taken by the fibres alone.



25A STRAIN SOFTENING SFRC

25B STRAIN HARDENING SFRC

FIG. 25 CLASSIFICATION OF SFRC

Flexural Tensile Strength

The flexural tensile strength of the softening SFRC shall be obtained as per IS:516 (Part-I) Sec-1-2021. The characteristic flexural tensile strength of SFRC shall be calculated in accordance as follows:

$fcr = 0.7 \sqrt{fck}$

Where,

fcr flexural tensile strength, in N/mm^2; and

fck = characteristic compressive strength of concrete, in N/mm^2.

NOTE — For strain softening SFRC, the peak strength of the composite may be approximated as the strength of the concrete mix without fibres.

Residual Tensile Strength

The standard characteristic residual tensile strength grades are 0.4 MPa, 0.6 MPa, 0.8 MPa, 1.2 MPa, 1.6 MPa and 2.0 MPa. The characteristic residual tensile strengths of concrete at 28 days ($f'_{1.5}$) shall be determined statistically from tests carried out in accordance 1.2.1.3.3.4

NOTE-The characteristic residual tensile strength depends on the fibre-matrix bond strength, which is usually a function of the compressive strength of the parent concrete, as well as the fibre content.

122.1.3.3.4 Determination of Strength by Direct Testing

The characteristic residual tensile strength ($f'_{1.5}$) shall be obtained using direct tensile tests as specified in Appendix…..cl 1.0

122.1.3.3.6 Residual Tensile Strength-Residual Flexural Strength Relationship

Alternatively, where matched direct and indirect testing (residual flexural tensile strength test) has been undertaken in accordance with appendix…cl 2.0 for similar SFRC mixtures, the characteristic residual tensile strength may be determined as:

$$f'_{1.5} = k_{R,4}.f'_{R,4}$$

Where $f''_{R\,4}$ is determined in accordance with appendix… and calculated statistically, and the factor k_{R4} determined from appendix…. Cl 3.0

For the purposes of this clause, similar SFRC mixtures are defined as having the same,

a) fibre type and content,

b) water to cementitious material ratio,

c) maximum aggregate particle size, and

d) compressive strength (f'c).

The relationship between residual tensile strength and the residual flexural strength shall be obtained by matched tests using the same SFRC mixture. Residual tensile strength specimens shall be prepared and tested in accordance with appendix…. Residual flexural tensile tests shall be in accordance with the procedure given in appendix…..

NOTE — The residual tensile strength (as obtained from a direct tensile test) is a fundamental material property of SFRC. This clause allows the concrete producer and steel fibre manufacturer to correlate the direct tensile strength of their particular SFRC mix design with the flexural tensile strength.

122.1.3.3.6 Determination of Strength by Indirect Testing

The characteristic residual tensile strength (f'1.5) may also be obtained using indirect tests (flexural residual tensile strength test) and calculated as:

$$f'_{1.5} = 0.4f''_{R,4}-0.07f'_{R,2}$$

122.1.3.4 Modulus of Elasticity

The modulus of elasticity at the appropriate age (E_{cj}) be determined in accordance with as per IS:516 (Part-I) Sec-1-2021.

NOTE: The addition of steel fibres to concrete in conventional dosages (100 kg/m^3 and less) does not change the elastic modulus of the concrete.

122.1.5 Durability

The minimum concrete grade and cover for SFRC in respective exposure classification shall be as for concrete without fibres and shall apply to the steel reinforcement only. SFRC shall not be used in exposure classification Cl or C2. (needs to be correlated with durability exposure classes in durability chapter)

NOTES

1 Steel fibres do not require concrete cover as specified for steel reinforcement.

2 SFRC may not be suitable in some exposure classification of environments.
3 Fibres close to the surface are subject to corrosion and may result in surface staining. This will not impact durability.

122.1.7 Production of Sfrc
122.1.7.1 Fibres
Steel fibres shall comply with accepted standard. The 'Certificate of Conformity' shall be supplied on request to the relevant authority.

NOTE — Till the availability of a separate Indian Standard Specification for Steel Fibres, reference may be made international literature.

122.1.7.2 Mixing of Fibres
Fibres of the type and quantity specified shall be added in a controlled process ensuring that they are dispersed uniformly through the concrete mix. If added after the main mixing process, the concrete shall be remixed until the fibres have been completely dispersed throughout the batch.

NOTES
1. Balling of fibres should be avoided. Visual inspection of mixed concrete for balling of fibres should be done and if ball formation noticed the batch should be discarded.

2. A record of fibre content should be recorded for each batch.

122.1.7.3 Determining the Steel Fibre Content
Steel fibre content shall be measured from samples taken from the production concrete, by volume of concrete.
In addition,
a) A sample shall be taken from the batch of concrete at unloading from the first third, middle third and final third of the batch;
b) Each sample shall be a minimum of 10 litre;
c) The sample container shall be filled in one continuous pour and where possible directly from the discharge chute; and
d) Wash out or magnetic separation only shall be used.
The conformity of the correct steel fibre dosage is proven if the criteria in Table 2 are met.

Table 2

CRITERIA OF ACCEPTANCE FOR STEEL FIBRE DOSAGE

Frequency	Test control	Criteria
Each sample	Each partial test	≥ 0.80 of the specified target dosage
Average of three samples from the batch	Each test	≥ 0.80 of the specified target dosage
Continuous control: average of >3 tests	Continuous control: average of >3 tests	≥ 0.90 of the specified target dosage

123 STRUCTURAL LIGHT WEIGHT CONCRETE

123.1 General

Lightweight aggregates are natural or synthetic with in-place density (unit weight) between 1440 to 1840 kg/m^3. The lightweight is due to the cellular or high internal porous structure, which gives this type of aggregate a low specific gravity. They have high absorption values, which requires a modified approach to concrete proportioning.

Light weight aggregates namely sintered fly ash aggregates may be used for making light weight structural concrete (a type of special concrete). However use of lightweight aggregates for structural concrete should be limited to normal structures up to four storey height only. Its use in prestressed concrete and special structures like chimneys and cooling towers etc should be avoided. Sintered flyash coarse aggregates when used shall conform to IS 9142 (Part 2)-2018. Other light weight aggregates not conforming to this standard may be used only for non structural purpose with permission of competent project authority only.

Note: For Design and Durability considerations using any other light weight aggregate, specialist literature should be referred.

> **C123** The structural grade sintered fly ash lightweight coarse aggregate conforming to IS 9142 (Part 2)-2018 are produced by pelletization and sintering done at temperature range of 1 100 to 1 300°C. The burning of carbon in the pallets and loss of moisture creates a cellular structure bonded together by the fusion of fine ash particle. Structural lightweight-aggregate concrete (SLC) is made with structural lightweight aggregate conforming to this standard. The concrete has density less than 2000 kg/m^{3}and consists entirely of lightweight aggregate or a combination of lightweight and normal weight aggregate. These guidelines may be followed for design of structural grade sintered fly ash lightweight concrete made with lightweight coarse aggregate and normal weight fine aggregate.

123.2 Production of Lightweight Aggregates

Manufactured lightweight aggregates are produced in manufacturing plants from raw materials, including suitable shales, clays, slates, fly ashes or blast-furnace slags. Naturally occurring lightweight aggregates are mined from volcanic deposits that include pumice and scoria. Pyroprocessing methods include the rotary kiln process (a long, slowly rotating, slightly inclined cylinder lined with refractory materials similar to cement kilns); the sintering process wherein a bed of raw materials, including fuel, is carried by a traveling grate under an ignition hood; and the rapid agitation of molten slag with controlled amounts of air or water.

123.3 Guidelines for Sintered Fly Ash Lightweight Coarse Aggregate in Structural Concrete

Sintered flyash coarse aggregates when used shall conform to IS 9142 (Part 2)-2018.

NOTE — The combination of lightweight fine aggregate and normal weight fine aggregate together in concrete is not usually recommended.

123.3.1 Mechanical Properties of Sintered Fly Ash Lightweight Aggregate Concrete
Lightweight concrete up to grade M35 and below may be made and used for structural use in non-wearing surfaces.There is normally little gain of strength beyond 28 days. The design should be based on 28 days characteristic strength of concrete.

The flexural and splitting tensile strengths shall be obtained as described in IS 516 and IS 5816, respectively. When the designer wishes to use an estimate of the tensile strength from the compressive strength, the following formula may be used:

$$\text{Flexural strength, } f_{cr} = 0.6 \sqrt{f_{ck}} \text{ N/mm}^2$$

Where, f_{ck} is the characteristic cube compressive strength of concrete in N/mm^2

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate. The modulus of elasticity of concrete can be assumed as follows:

$$E_c = 3\ 000 \sqrt{f_{ck}}$$

Where E_c is the short term static modulus of elasticity in N/mm^2. Actual measured values may differ by ± 20 percent from the values obtained from the above expression.

Poisson's ratio of lightweight concrete by resonance methods varies between 0.16 and 0.25 with the average being 0.21. While this property varies slightly with age, test conditions, and physical properties of the concrete, a value of 0.20 may be usually assumed for practical design purposes.

The linear thermalexpansion coefficients for lightweight concrete ranges from 7 to 11 x 10^{-6} mm/mm/°Cdepending on the amount of natural sand used.

123.2.2 Durability of Lightweight Aggregate Concrete
One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. The factors influencing durability include a) Environment; b) Cover to embedded steel; c) Type and quality of constituent materials; d) Cement content and water/cement ratio of the concrete; e) Workmanship, to obtain full compaction and efficient curing; and f) Shape and size of the member.

Use of lightweight concrete is not recommended in ………. and ……. exposure classes.

123.2.2.1 Exposure to Sulphate Attack
~~Exposure classification with respect to sulphate attack and~~ recommendations for the type of cement, minimum cement content and other precautions in case of very high sulphate concentrations in ~~class 5~~, which are required at different sulphate concentrations in near-neutral ground water having *p*H of 6 to 9 shall be as per IS 456. However, the maximum free water/cement ratio shall be further low by 0.05 in all classes.

123.2.2.2 Requirement of Concrete Cover
The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete. The nominal cover to the reinforcement to meet the durability requirement in case of lightweight concrete shall be increased by 10 mm over and above as provided in ~~Table 16 of~~ IS 456

123.3.3 Concrete Mix Proportions

The free water-cement ratio is an important factor in governing the durability of concrete and should always as low as possible. Appropriate values for minimum cement content given in ~~Table 5~~ …….of IS 456 for different exposure conditions shall also be applicable for lightweight concrete. However, the maximum free water-cement ratio given in ~~Table 5~~ ….of IS 456 shall be further reduced by 0.05 in all exposure classes.

~~**1.3.3.1 Maximum Cement Content**~~

~~Cement content not including fly ash and ground granulated blast furnace slag in excess of 450 kg/m3 shall not be used as specified in IS 456.~~

~~**1.3.3.2 Chloride in Concrete**~~

~~Whenever there is chloride in concrete there is an increased risk of corrosion of embedded metal. The total amount of chloride content (as Cl) in the concrete at the time of placing shall be as given in Table 7 of IS 456.~~

~~**123.3.4 Sulphate in Concrete**~~

~~Excessive amounts of water-soluble sulphate present in the mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as sulphuric anhydride (SO3) shall not exceed 4 percent by mass of the cement in the mix, as specified in IS 456~~

123.3.5 Other aspects

Specialist literature should be consulted to take into consideration the important aspects of design such as development length, durability, cover for fire resistance, shear and torsion resistance of beams, deflection of beams, additional moments in slender columns etc. when lightweight aggregates are used.

124 POLYMER MODIFIED CONCRETE

General

Polymer-modified cementitious mixtures, also called polymer modified concrete (PMC) or polymer portland-cement concrete (PPCC) and latex modified concrete (LMC). They are defined as hydraulic cement combined at the time of mixing with organic polymers that are dispersed or redispersed in water, with or without aggregates.

An organic polymer is a substance composed of thousands of simple molecules combined into large molecules. The simple molecules are known as monomers, and the reaction that combines them is called polymerization. The polymer may be a homopolymer if it is made by the polymerization of one monomer, or a copolymer when two or more monomers are polymerized.

The organic polymer is supplied in three forms: as a dispersion in water that is called latex; as a redispersible powder; or as a liquid that is dispersible or soluble in water. Dispersions of polymers in water and redispersible polymer powders have been in use for many years as admixtures to hydraulic-cement mixtures. These admixtures are called polymer modifiers. The dispersions of these polymer modifiers are called latexes.

Polymer

Polymers are long molecules, built by combination of single units called monomers. Polymers are essentially hydrocarbons. The process of conversion of monomers into polymer is called polymerisation.

Types of Polymer

a) Latexes—Much of the PMC placed today uses a polymer in latex form. Latex is defined as a dispersion of organic polymer particles in water. The average particle size varies from 3.9×10^{-6} to 78×10^{-6} (100 to 2000 nm). Most latexes are made by a process known as emulsion polymerization, where the polymer particles are formed in water. The surfactants used to stabilize these latexes are usually non-ionic, such as polyvinyl alcohol or alkyl phenols reacted with ethylene oxide.

Polyvinyl acetate—This type of latex should not be used in PMC because of the poor water resistance.

Vinyl acetate copolymers—Typical comonomers are ethylene, BA, and the vinyl ester of versatic acid (VEOVA). The incorporation of these comonomers reduces the tendency of the vinyl acetate to hydrolyze, and the reaction products are less water soluble.

Acrylic esters and copolymers (PAE and S-A)— These latexes have been used for many years, primarily in tile adhesives, floor overlayments, stuccos, exterior insulation finish systems (EIFS), and repair of concrete. Acrylic esters are the latex of choice where colour and colour fastness are important

Styrene-butadiene copolymers (S-B)— This type of latex is widely used where either adhesion or water resistance is required, and providing colour fastness is not a requirement.

b) Redispersible powders – A substantial portion of PMC uses polymers in powdered form that redisperse when mixed with water or aqueous mixtures. Typically, the polymer powder is premixed with the cement and aggregates, and water is added at the job site. This operation allows for more accurate mixture proportioning and is more convenient than using a two-component latex system.

c) Epoxy resins—Epoxy resins have been used as polymer modifiers for Portland cement mixtures.

124.3 General Requirements of polymer modifier to be used in concrete

The polymer modifier shall produce polymer modified concrete (PMC) which conforms to the requirements as listed in table 1 for the general use.

Table 1: Requirements for Concrete Made With Polymer Modifier

Sr.No.	Characteristic	Requirements	Method of test
1.	Air Content, % maximum	7.0	IS 1199 Part4
2.	Time of Setting, allowable deviation from reference mixture *, hr:min:		IS 1199 Part7
	Initial:		
	not more than, earlier	1:00	
	nor, later	3:30	
	Final:		
	not more than, earlier	1:00	
	nor, later	3:30	

3.	Compressive Strength, minimum % of reference mixture* at each age	80	IS 516
4.	Indication of Chloride Ion penetration, maximum % of reference mixture* at each age	25	IS 516 Part2..

Note 1. These requirements do not apply to epoxy resins

Note 2. *Proportioning of concrete

1 Concrete Mixture Proportioning – Make the test and reference concrete with proportions similar to those shown for a nominal cubic-meter batch.

2 Test Concrete – Make the test concrete conforming to the following requirements:

Materials	Parts by Mass, kg
Portland cement	390 ± 3
Fine aggregate (saturated surface dry)	975 ± 6
Coarse Aggregate (saturated surface dry)	780 ± 6
Polymer Modifier	a
Water	b

a. The level recommended by the manufacturer.
b. The amount of water to give a slump of 90 ± 15.

3 Reference Concrete - Make the reference concrete to give an air content within 2 % of the test concrete and not exceeding 7 % , conforming to the following requirements:

Materials	Parts by Mass, kg
Portland cement	390 ± 3
Fine aggregate (saturated surface dry)	975 ± 6
Coarse Aggregate (saturated surface dry)	780 ± 6
Potable water	a

a. The amount of water to give a slump of 90 ± 15.

4 The concrete shall be made in a mechanical power-driven mixer and shall be compacted as per IS 1199 part 5.

124.4 Mixture proportioning

The proportioning of ingredients and mixing procedures are similar to those for unmodified mixtures. Specific mixture proportioning depends on the particular application and the type of polymer being used. In general, polymer levels of 10 to 25% by mass of the hydraulic cement are required for optimum performance.

The w/cm of PMC is typically 0.30 to 0.40 parts by mass. These low ratios result from the water-reducing qualities attributable to the polymers. When latexes are used, the water content of the latex should be included when calculating the w/cm.

124.5 Curing

The curing regime for Polymer modified concrete requires initial moist curing to prevent plastic-shrinkage cracking, followed by air curing. PMC specimens should be immediately covered with polyethylene bag/ plastic sheet and store at 27 ± 2°C for 24 hours. Thereafter,

> **C 124**
>
> Polymer modified concrete have been used to replace conventional concrete due to specific properties in terms of reduced shrinkage and better bnding to old cement concrete. The extent of improvement in desired properties depends largely on type of polymer modifier used and the dose of modifier. Dosage should be decided based on test results of proposed concrete mix for desired property.
>
> The advantages of using polymeric resins are that it possesses high mechanical strengths, long durability, and resistance to chemical attack. However other properties like tensile strength and creep may get adversaly affected in some cases. Choice of type of latex will depend upon desired properties, cost and placing/curing temperatures etc

polyethene bag cover/ plastic sheet should be removed and the specimens should be stored in laboratory environment at 27 ± 2°C and RH 65±5% (i.e. air curing) until age of testing.

125 SELF-COMPACTING CONCRETE

Self-compacting concrete (SCC) is highly flowable, non-segregating concrete that fills uniformly and completely every corner of formwork by its own weight and encapsulate reinforcement without any vibration, whilst maintaining homogeneity

125.2 Features of fresh Self Compacting Concrete

A concrete mix can only be classified as Self-Compacting Concrete if the requirements for all below mentioned characteristic are fulfilled:

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

The above tests shall be carried out as per IS 1199 (Part 6).

Filling Ability (flowability)

This is the ability of fresh concrete to flow into and fill all spaces within the formwork, under its own weight. Slump-flow test is performed to test the flowability. Slump-flow value describes the flowablity of a fresh mix in unconfined condition. Visual observation during the test can be additional information on the segregation resistance and uniformity. The following are typical slump-flow classes for a range of applications:

SF1 (slump flow 550 mm - 650 mm) :This class of SCC is appropriate for:

a) Unreinforced or lightly reinforced concrete structures that are cast from the top with free displacement from the delivery point (for example, housing slabs)
b) Casting by a pump injection system (for example, tunnel linings)
c) Sections that are small enough to prevent long horizontal flow (for example, piles and some deep foundations).

SF2 (slump flow 660 mm - 750 mm): This class of SCC is suitable for normal applications (for example, walls, columns)

SF3 (slump flow 760 mm – 850 mm): This class of SCC is used for vertical applications in heavily reinforced structures, structures with complex shapes, or for filling under formwork. SF3 will often give better surface finish than SF 2 for normal vertical applications but segregation resistance is more difficult to control.

Passing Ability (free from blocking at reinforcement)

Passing ability describe the capacity of the fresh mix to flow through confined spaces and narrow openings such as areas of congested reinforcement without segregation. If there is little or no reinforcement, there may be no need to specify passing ability as a requirement. L-box test is performed to check the passing ability. The minimum ratio of the height in the horizontal section relative to the vertical section is considered to be 0.8. If the SCC flows as freely as water, it will be completely horizontal, and the ratio will be equal to 1.0.

Segregation Resistance (Stability)

The ability of fresh concrete to remain homogeneous in composition while in its fresh state. Segregation resistance (sieve) test is performed to check this property of fresh concrete. After sampling, the fresh concrete is allowed to stand for 15 min and any separation of bleed water is noted. The top part of the sample is then poured into a sieve with 4.75 mm square apertures. After 2 minute, the weight of material which has passes through the sieve is recorded. The segregation ratio (SR) is then calculated as the proportion of the sample passing through the sieve.

There are two classes of segregation resistance, namely SR1 & SR2. SR1 is generally applicable for thin slabs and for vertical applications with a flow distance of less than 5 m and a confinement gap greater than 80 mm. SR2 is preferred in vertical applications if the flow distance is more than 5 m with a confinement gap greater than 80 mm in order to take care of segregation during flow. Segregation resistance becomes an important parameter with higher slump-flow classes and/or the lower viscosity class, or if placing conditions promotes segregation. If none of these apply, it is usually not necessary to specify a segregation resistance class. For SR1 class segregation resistance should be 15 to 20 percent and for SR2 it should be less than 15 percent.

Viscosity

Viscosity can be assessed by the V-funnel flow time as per IS 1199 (Part 6). Concrete with a low viscosity will have a very quick initial flow and then stop. Concrete with a high viscosity may continue to creep forward over an extended time.

A V-shaped funnel is filled with fresh concrete and the time taken for the concrete to flow out of the funnel is measured and recorded as the V-funnel flow time. The viscosity is divided into two classes, that is, V1 & V2. V1 has good filling ability even with congested reinforcement. It is capable of self-leveling and generally has the best surface finish. V2 class viscosity is more likely to exhibit thixotropic effects, which may be helpful in limiting the formwork pressure or improving segregation resistance. But it may cause negative effects on surface finish and sensitivity to stoppages or delays between successive lifts.

For V1 class, the time taken to pass the concrete from V-funnel should be ≤8 s and for V2 class the time taken to pass the concrete from V-funnel should be between 9 s to 25 s.

C125

Application Area

Self-compacting concrete (SCC) may be used in precast concrete applications or for concrete placed on site. SCC is used to cast sections with highly congested reinforcement and areas that present restricted access to placement and consolidation, including the construction of tunnel lining sections and the casting of hybrid concrete-filled steel tubular columns. It may be manufactured in a site batching plant or in a ready-mixed concrete plant and delivered to site by truck mixer. It may be placed either by pumping or pouring into horizontal or vertical forms.

Typical Ranges of Mix Constituents:

a) Sufficient amount of fines (< 0.125mm) preferably in the range of 400 kg/m^3 to 600 kg/m3. This can be achieved by having sand content more than 48 percent of total aggregate weight and/or using mineral admixtures to order of 25 percent to 50 percent by mass of cementitious materials content.

b) Water content between 150 to 210 kg/m^3.

c) Coarse aggregate content - 750 – 1000 kg per $m^3$of concrete.

d) Water/powder ratio by solid volume – 0.85 to 1.10.

e) Paste volume – 300 – 380 litres/ m^3.

f) Use of high range water reducing admixture like polycarboxylate ether based high range water reducing admixture (water reduction > 30percent)

125.3 Physical Properties of SFRC

Physical properties of SFRC are generally same as of normal concrete except some properties like creep and shrinkage for which relevant clauses of tthis code and specialist literature should be referred.

126 ROLLER COMPACTED CONCRETE

Roller-compacted concrete (RCC) is a concrete of no-slump consistency in its unhardened state that is transported, placed, and compacted using vibratory roller. Roller-Compacted Concrete (RCC) can be considered as both a construction material and a construction method. It is mainly used in mass concrete, roadway and paving applications. The layer thickness can vary from 150 mm to 300 mm. It should be ensured that equipment used for compaction is capable of properly compacting the adopted layer thickness.

126.1 Mix Design

Mix design for RCC is totally different from the design of mix for a conventional cement concrete pavement as the Abrahm's water/ cement ratio law does not hold good. RCC is a no-slump concrete.

The mix shall be proportioned by weight of all ingredients such that the desired target mean strength is achieved. The moisture content shall be selected so that the mix is dry enough to support the weight of a vibratory roller, and yet wet enough to permit adequate distribution of paste throughout the mass during mixing, laying and compaction operations. The water content by weight may be in the range of 4 -7 per cent and shall be determined by trial mixes having water content changing at intervals of 0.5 percent. The optimum water content is determined using a loaded vee bee test apparatus or Modified proctor density test. Loaded Vee Bee time for RCC to be used in dams is generally in the range of 20±10 seconds and for pavements a the range of loaded veebee time is 50+10 sec. Wet Density achieved shall also be determined and compared with theoretical air free density. For pavements where RCC is used for top layer and no wearing course is proposed, a drier mix is preferred which gives less undulations. In this case Modified proctor test is preferred over loaded vee beetest to determine Optimum water content. The coarse aggregates by volume shall be in the range of 52 - 56 percent and the volume of sand shall be varied to optimize the strength by trials. The fly-ash/ cement ratio and the water/cementitious material (cement + fly ash) ratio shall be selected so as to achieve the required strength. Fly-ash quantity shall be so proportioned that it replaces cement to an extent of 20 - 50 per cent by weight.

126.2 Construction

120.6.2.1 General

Prior to starting the main construction works, it is strongly recommended that the proposed RCC is mixed in the concrete plant and then placed, spread and compacted in a full-scale trial using the same equipment and procedures intended for construction. A full-scale trial can also be used to visually examine the segregation potential of the RCC mix under the specific site conditions, the condition of the lift surfaces, the necessary treatment for those surfaces and any other aspects of construction that may require review.

120.6.2.2 *Batching, Mixing, Transportation, Laying, Compaction and Curing*

The batching and mixing shall be done in a batching plant capable of proportioning the materials by weight each type of material being weighed separately. The capacity of the batching and mixing plant shall be at least 25 percent higher than the proposed capacity for laying the concrete for structure. The batching and mixing shall be carried out preferably in a forced-action central batching and mixing plant having necessary automatic controls to ensure accurate proportioning and mixing. The weighing balances shall be calibrated by weighing the aggregates, cement. fly-ash and water on a large weighing machine.

Concrete shall be discharged from the mixer and transported directly to the point where it is to be laid. The capacity of the transport equipment shall match the production capacity of the batching plant and the laying equipment to ensure construction to go on at a uniform speed in an uninterrupted manner.

The concrete shall be laid by a paver, with electronic sensors. The paver shall be capable of laying the material in one layer in an even manner without segregation.

Compaction shall be carried out immediately after the material is laid and levelled. Rolling shall be done with a vibratory roller of the double drum smooth wheel type. The number of passes required to obtain the maximum compaction shall be determined during the trial run by increasing the in-situ density. In addition to the number of passes required for compaction, there shall be a preliminary pass without vibration to bed the concrete down, and again a final pass without vibration to remove the roller marks and to smoothen the surface.

The spreading, compacting and finishing of the concrete shall be carried out as rapidly as possible and the operation shall be so arranged as to ensure that the time between the mixing of the first batch of concrete in any transverse section of the layer and the final finishing of the same shall not exceed 90 minutes when the concrete temperature is above 25°C and below 30°C, and 120 minutes if less than 25°C. This period may be reviewed in light of the results of the trial run, but in no case shall it exceed 2 hours. Work shall not proceed when the temperature of the concrete exceeds 30°C. If necessary, chilled water or addition of ice may be resorted to for bringing down the temperature. It is desirable to stop concreting when the ambient temperature is above 35°C. After compaction has been completed, the roller shall not stand on the compacted surface for the duration of the curing period, except during commencement of next day's work near the location where the work was terminated the previous day. If the RCC is too wet or too dry for compaction upon laying, the water content shall be adjusted at the plant to correct this. Only minor changes in water content from the design mix should be made; otherwise a new mix design may be needed.

In view of the low water content in RCC, soon after the compaction is over, depending upon weather, wind velocity and humidity, curing shall start within one hour to two hours or alternatively curing compound can also be used.

126.2.3 *Joints*

The bond between the layers of RCC is produced by two mechanisms: cementitious (chemical) bond and penetration of the aggregates from the new layer into the surface of the previously placed layer (mechanical bond). As the open exposure time between placementof the layers increases, the chemical bond becomes the most prevalent factor, because the potential for mechanical penetration of the aggregates decreases faster than the chemical bond. The treatment of the joint surfaces between RCC layers differs from traditionally placed mass concrete, because bleeding does not normally occur in RCC with a reasonable water/cementitious ratio. However, it is common for the full compaction / consolidation of RCC layers to bring paste to the surface, which if properly cured, does not have to be removed prior to placement of the next layer. In addition, the joint surfaces must be kept scrupulously clean. Cold Joints can significantly increase the construction time and as they cannot be completely avoided, the necessary actions must be
taken to minimise these in number and their total area.

126.2.4 *Contraction Joints And Crack Control*

The current practice for RCC design is to control temperature cracking with contraction joints. Contraction joints are installed using several methods. One method that has been used on several RCC construction projects is to create a crack or joint in the RCC by installing a galvanized steel sheet into the compacted RCC lifts at and along a predetermined joint location. This galvanized steel sheets act as a crack inducer. Other methods include the use of alternative bond breaker materials, such as plastic sheets.

126.3 Physical Properties of RCC

Physical properties of RCC are generally similar to normal concrete except that variation in strength and thus standard deviations may be higher. Ratios of tensile strength vs compressive strength may also differ and shall be determined at mix design stage.

127 Alkali Activated Concrete

Alkali activated concrete or Geopolymer concrete is a type of concrete that is made by reacting aluminate and silicate bearing materials such as fly ash or slag from iron and metal production with an alkaline activator. It can be a suitable substitute for ordinary Portland cement (OPC).

The advancements in material sciences have led to development of altogether alternative binding material to concrete in the form of alkali activated concrete or geopolymer concrete (which is considered part of broad group of alkali activated materials). Alkali activated concrete are a relatively newer class of building material. Owing to increased environmental concerns as well as diminishing natural resources alkali activated concrete are spotted as a valuable alternative for Portland cement. Alkali activated concrete can have similar cementing characteristics as Portland cement, but they can be produced out of by-products from other industry (for example, fly ash) or less energy craving and CO2 emitting materials (for example, calcined clay) using alkali activators.

The alkali activated concrete can be used for manufacture of precast unreinforced products for non structural applications like paver blocks, kerb stones, blocks, etc as per guidelines given in IS : 17452 - 2020. The grades shall be limited up to M 40 .

Appendix ….

…. 1.0 Residual Tensile Strength Test

The residual tensile strength shall be obtained using the testing arrangement shown in Fig. 27 and with the following criteria:

a) The critical section shall be where the cross- sectional area is a minimum.

b) The SFRC mix shall be batched to ensure a uniform distribution of fibres, and shall be placed in the moulds in a manner that does not interfere with the distribution of the fibres. The SFRC shall be compacted using lightly applied external vibration.

c) The specimen shall be connected to the testing machine in such a manner that the machine does not apply a load to the specimen during the process of tightening of the grips and prior to testing.

d) One end of the specimen shall be connected to the testing machine through a universal joint such that no moment is applied to the end of the specimen.

e) Displacement measurements shall be taken on each of the four sides with the COD taken as the average of these measurements.

f) A minimum of twelve specimens shall be tested.

g) Tests where the failure of the specimen is outside of the testing region, or where the results are influenced by the test specimen boundaries, shall be retested.

h) The characteristic values of the tensile strength $f_{0.5m}$ and $f_{1.5m}$, corresponding to CODs of 0.5 mm and 1.5 mm, respectively, shall be determined statistically as the 95 percentile confidence value assuming the population is normally distributed.

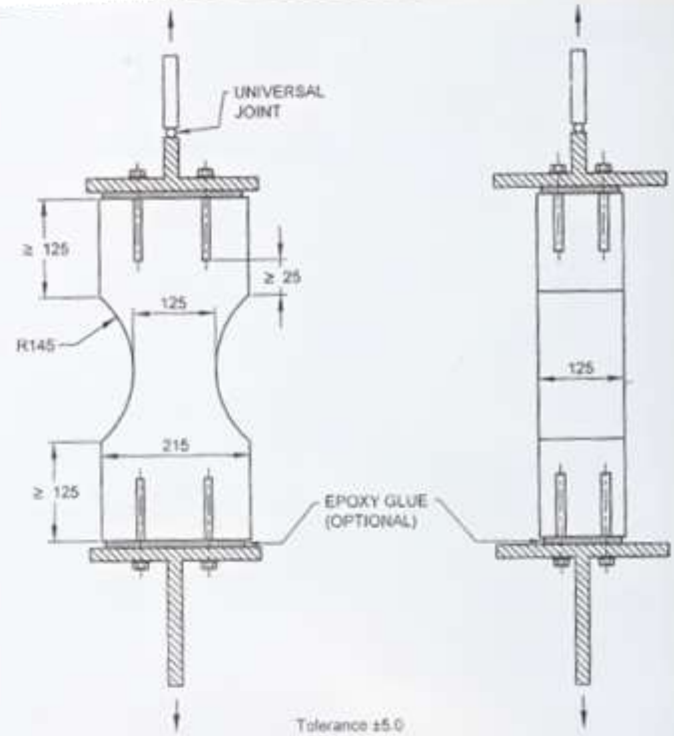
j) The mean values of $f_{0.5m}$ and $f_{1.5m}$ corresponding to CODs of 0.5 mm and 1.5 mm, respectively, shall be determined statistically as the 50th percentile confidence value assuming the population is normally distributed.

The stress results obtained from the test shall be multiplied by the three-dimensional orientation factor k1, where,

$$k1 = \frac{1}{0.94 + 0.6lf/b} \leq 1$$

And l_f is the length and b is taken as the average of the width and depth of the specimen taken at the critical section.

NOTE —The factor k_1 removes the influence of the boundaries on the fibre distribution and converts the results of the test to a state where the fibres can be considered to be randomly orientated in three-dimensional space.



Tolerance ±5.0

All dimensions in millimetres.

NOTE — There is considerable discussion in the literature on whether the ends of the specimens should be fixed at each end, pinned at each end or fixed at one end and pinned at the other. The adoption of one pinned and one fixed end is a pragmatic decision between the ideal condition (fixed at each end) and limitations in manufacturing of specimens that are perfectly square at their ends for alignment within the testing machine. With both ends fixed any misalignment induces a moment in the specimen during gripping. This moment can induce a tensile stress on one side of the specimen, weakening the specimen. In some situations, the moment induced may be sufficient to crack the concrete. The inclusion of the universal joint at one end eliminates residual tensions that may result from the gripping procedure.

FIG. 27 TESTING ARRANGEMENT FOR DIRECT TENSION

….. 2.0 Residual Flexural Tensile Strength

The residual flexural tensile strength $f_{R,j}$ shall be determined from 3 point notched bending tests on 150 mm square section prisms. The notch depth shall be 25 mm and the test conducted in accordance with 1.2.1.3.3.6. The force F shall be plotted against the crack mouth opening displacement (CMOD), as shown in Fig. 28, and the residual flexural stress calculated as:

$$fR,j = \frac{3FrjL}{2bhsp^2}$$

where
b = width of the specimen, in mm;
h_{sp} = distance between tip of the notch and top of cross-section, in mm;
L - span, in mm; and
F_{Rj} = load recorded at $CMOD_j$ (see Fig. 28).

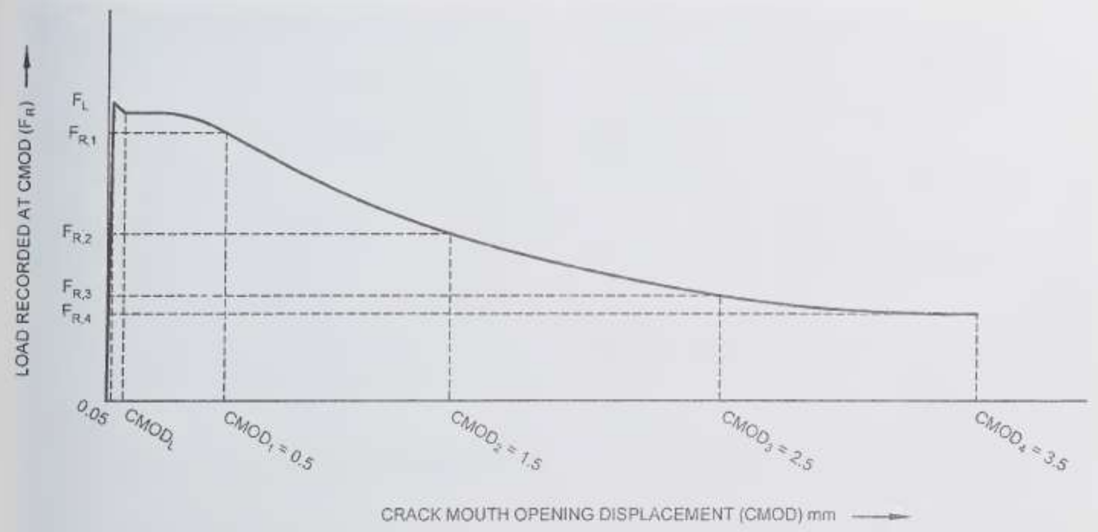


Fig. 28 Load *Versus* CMOD for Residual Flexural Tension

The average width of the specimen and distance between the tip of the notch and the top of the specimen in the mid-span section shall be determined from two measurements to nearest 0.1 mm width and distance in the notch port of the specimen using callipers.

When the CMOD is measured, the displacement transducer shall be mounted along the longitudinal axis at mid width of test specimen such that the distance 'y' between the bottom of specimen and line of measurement is 5 mm or less as mentioned in Fig. 26.

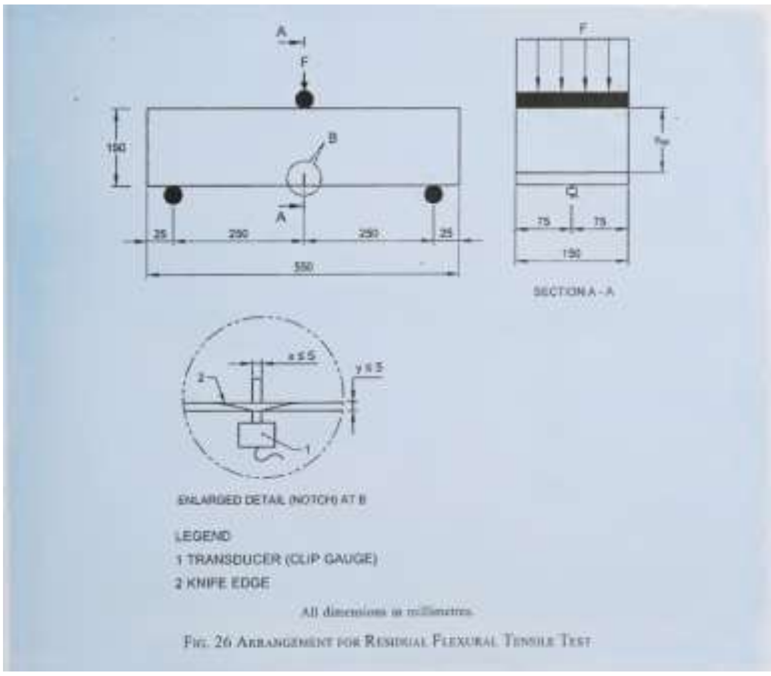


FIG. 26 ARRANGEMENT FOR RESIDUAL FLEXURAL TENSILE TEST

a) The concrete mix shall be batched to ensure a uniform distribution of fibres, the SFRC shall be placed in the moulds in a manner that does not interfere with the distribution of the fibres and, the SFRC shall be compacted using lightly applied external vibration; and

b) A minimum of 12 specimens shall be tested.

…. 3.0 The reference factor $k_{R,4}$

The reference factor $k_{R,4}$ shall be determined as:

$$k_{R,4} = f_{1.5m} / f_{R,4m}$$

where

$f_{1.5m}$ = mean residual tensile strengths corresponding to a COD of 1.5 mm determined in accordance with ……… above

$f_{R,4m}$ = mean residual flexural tensile strengths corresponding to a CMOD of 3.5 mm, determined in accordance with ……… above