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STEEL FIBRE REINFORCED CONCRETE (SFRC) FLOORING

A. Terminology:

Steel Fibre Reinforced Concrete:

Steel fibre reinforced concrete is a concrete where the inter-granular mortar (the origin of all cracking) is controlled by steel fibres. For a concrete with a 20mm aggregate the distance between adjacent fibres should be kept to between 18 and 20mm when casting.

When the fibre spacing falls below 18mm, the concrete will become difficult to pump requires modification to the mix design.

To control shrinkage in the concrete, a minimum fibre dosage of 12-25kg/m³ is required , and shall be calculated as per design calculations . Fibre dosages of below this will not provide effective control of shrinkage within the concrete.

Steel fibres act like small pieces of rebar. The fibre therefore needs an anchoring device such as the Tabix undulated shape or the HE hooked end. A round section has a higher modulus of rigidity when compared to flat rectangular or half-moon sections. This will help to stiffen or increase the anchorage of the fibre into the cement paste.

Fibre diameter effects anchorage. A fibre of 1 mm diameter has tensile rupture strength of 780 N compared to only 500 N for a 0.8 mm diameter fibre. The 1mm fibre therefore has better anchorage.

Thinner fibres are also harder to use as they tend to reduce slump and make pumping and finishing more difficult.

The steel fibre length should be generally between 45 and 60 mm to allow it to bridge the cement paste between two large adjacent pieces of aggregate.

The steel wire should have a minimum tensile strength of 1000 N/mm². The fibre should be stiff so that it is difficult to bend between two fingers and the thumb.

A stiffer steel fibre of 1 mm diameter is less prone to showing at the surface of the finished floor as it is pushed back underneath the surface by the levelling and finishing tools rather than being bent and springing back. Stiffer fibres also tend to show less at saw cuts. Less flexible fibres have the advantage of not causing concrete slump loss with the likelihood of increased shrinkage due to the addition of water or Superplasticizer.

B. Scope of Work

The Scope of work contained in this specifications together with all the drawings which form part of the contract documents provide the instructions necessary to carry out that part of the contract which includes providing, laying, protection, guarantees, testing and, maintaining up to the defects liability period for Steel Reinforced Concrete Flooring, structures, and associated works and accessories.

C. Steel Fibre Concrete Mix

1. Ready mixed concrete shall be in accordance with Contract requirements and meeting applicable requirements of IS- 4926 : 2003 / ASTM C 94.   (proposed grade of concrete M 35)

2. The ready mix trucks shall be in good condition, kept clean of hardened concrete and other foreign materials in injurious amounts. Schedule delivery of the concrete to avoid delays in placing after mixing or holding dry mixed materials too long in the mixer prior to adding mix water at location of pour. The correct quantity of water shall be contained in the mixer and adding additional water at the pour location shall not be permitted.

3. Ready-mixed concrete shall be supplied having the quality in accordance with the requirements agreed with the purchaser or Engineer in charge. Not with-standing this, the concrete supplied shall generally comply with the requirements of 1S:456.

4. All proportioning is to be carried out by mass except water and admixture, which may be measured by volume.

5. Ready-mixed concrete shall be transported from the mixer to the point of placing as rapidly as practicable by methods that will maintain the required workability and will prevent segregation, loss of any constituents or ingress of foreign matter or water.

6. The concrete shall be placed as soon as possible after delivery, as close as is practicable to its final position to avoid rehandling or moving the concrete horizontally by vibration. If required by the purchaser the producer can utilize admixtures to slow down the rate of workability , however this does not remove the need for the purchaser to place the concrete as rapidly as possible. The purchaser should plan his arrangements so as to enable a full load of concrete to be discharged within 30 min of arrival on site.

7. The general requirement is that concrete shall be discharged from the truck-mixer within 2 hours 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 shall 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.

8. No water from the truck water system or elsewhere shall be added after the initial introduction of mixing water for the batch except when on arrival at the job site the slump of the concrete is less than specified. If additional water is added the drum shall be turned an additional 30 revolutions, minimum.

9. The adding of water reducing agents shall be performed as required and with the control and record data as specified. Reduction in cement content shall not be allowed because of higher strengths attained due to admixtures.

10. After checking slump, "Steel Fibers" at equal temperature to mixed concrete, and/or super-plasticizer must be placed into mix at jobsite, with one additional adjustment to mix, before any other quality assurance tests are performed.

Concrete mix design should aim to minimize shrinkage in the concrete and to avoid quick setting and excessive bleeding. These conditions are quite difficult to deal with and increase the level of risk as they require more work and more specialized understanding of plastic concrete properties.
Specific mix design will always depend on the local materials available but must follow the basic guidelines with respect to aggregate grading, cement, a water/cement ratio of 0.50 -0.55, and super-plasticizer when required. Generally, the cement content should be between 300 and 350 kg/m^3 of specified grade. The plain concrete slump before the addition of steel fibres and superplasticizer should be consistent at 50 mm.

D. Adding Steel Fibres into Ready Mix Concrete

Steel fibres can be added into the ready-mix truck at either the batching plant or on the job site. Some ready-mix suppliers have suitable facilities for loading the steel fibres into the mixer at the batching plant. Where these do not exist, the fibres can be added at the batching plant using conveyor belts or 'blast' machines similar to those used for adding the fibres on site. When using conveyor belts it is important to remember that the fibres land freely in the concrete and are then mixed throughout the concrete using proper mixing procedures. Blast Machines have the advantage of spreading the fibres at a consistent high velocity into the concrete mix giving an even distribution of the steel fibres into each load of concrete. When steel fibres are added at the batching plant or on the job site without the use of blast machines, fibres may "ball" up in clumps. This is the result of an uneven distribution of the fibres in the concrete and requires additional mixing time to correct.

There are two common types of fibre balls that can form in the concrete.

1) Dry balls most often occur when the steel fibres are dumped in clumps into the ready-mix truck resulting in balling due to the fibres not being allowed to integrate into the concrete mix properly.
2) Wet balls or clumps of steel fibres often occur when the concrete has been mixed too long and or too fast. Wet balls can also occur when a small diameter steel fibre has been used at an excessive dosage rate.

Blast machines and conveyor belts should always be installed and set up for operation prior to the arrival of the first truck mixer.

E. When adding fibres into the ready-mix trucks the following guidelines should be used :

1. Adding steel fibres to the concrete will reduce the slump. It is important therefore to increase the slump of the concrete with superplasticizer to above the level required for placing the concrete prior to adding the fibres. The amount by which the slump should be increased will depend up the type of fibre used and the dosage rate.

2. The steel fibres should be added a rate of 30-40 kg per minute.

3. When a conveyor belt is used, the fibres need to be spread out on the belt rather than simply heaped in a pile, to prevent clumps of fibres.

4. The maximum drum rotation speed should be 12-15 revolutions per minute.

5. Each truck mixer should be rotated at full speed for 8 – 12 minutes after adding the fibres.

Prior to introducing the steel fibres into each ready-mix truck all the boxes required for that load need to be counted and clearly identified so that there is no mistake in the dosage rate or the fibre type for the load. The addition of steel fibres into the ready-mix truck is best accomplished by using designated labour following a laid down procedure. Based on a concrete delivery rate of four trucks per hour using one skilled person to load the steel fibres into the trucks, approximately 6000 kg of fibres can be added in an eight hour day. Using a team of two men will ensure a smoother transition of loading from one truck to another. It will also ensure better site recording. This is particularly important on larger pours. A team of two men should be able to load 12 – 14 tons per shift.

F. Installing a Steel Fibre Reinforced Concrete Floor

1) Prior to arriving at the jobsite the contractor should check:

a) The concrete floor specification. This should include a summary of ground conditions, loadings, tolerances, type of floor and the type of construction joints and joint spacing.

b) The final design document and the floor thickness, fibre type and dosage rate (kg/m^3). Alpha, omega or delta type joints are preferred to the use of dowels, which can be out of alignment and cause a contraction movement, restraint and cracking.

c) All of the latest and approved for construction drawings and specifications with all the details contained in or referred to in the construction drawings and the concrete mix design for the floor.

2) On arrival at the jobsite the contractor should make the following checks to the site:

a) The sub base must be as per specifications.

b) The sub base has no soft spots, puddles or rutting and should be stable under construction traffic. If during placement of the concrete, ruts develop from vehicle traffic, these should be repaired if possible to minimize their effect.

c) The sub base should be damp not soaked or with standing water.

d) If required a polythene sheet can be installed beneath the slab

e) Nothing on the sub base will restrain movement in the slab causing cracks to form.

f) Installation of all detailing is completed before the pour starts. Door details, construction joints, detail around manholes, loading dock details and supplemental rebar must all be in place.

g) If constructing a joint free slab (no saw cuts) the bay size should be a maximum 2,500m^2 with a maximum length / width ratio of 1 to 1.5.

h) The floor thickness will be within the specified tolerance.

I) The building in which the floor is to be constructed is weather tight and has no strong air flows in it as these can cause surface cracking or crazing as the floors surface dries more quickly than the rest of the concrete matrix.

3) Pouring the Steel Fibre Concrete

a) The steel fibre concrete should be fresh and no older than 60 minutes from batch time with a maximum temperature of 25°C.

b) The concrete should be delivered at a constant and consistent rate throughout the pour. Concrete delays should be avoided where possible and
when they do occur the condition of the previously placed concrete should be monitored closely.

c) The concrete slump at arrival to the jobsite should be constant and consistent within a tolerance of +/- 25mm of the specified slump.

d) If an increased slump is required, for example when pumping, the concrete should be super-plasticized to achieve the proper slump for the pumping operation.

e) When pumping steel fibre concrete the minimum hose size should be no less than 125 mm in diameter with no reducers in the pump line.

f) The installation and set up of the pump must be completed before the arrival of the first truckload of concrete.

4) Curing Concrete

a) Thoroughly and completely cure and seal as specified. Fully protect freshly placed concrete from the elements including drying by the sun and wind, and wash by rain.

b) Start initial curing as soon as free water has disappeared from concrete surface after placing and finishing. Weather permitting; keep continuously moist for not less than 7 days.

c) Slabs-on-grade shall be wet cured by use of water fogging covered by burlap cloth made from jute or kenaf, weighing approximately 9 oz. /sq yd dry, white burlap-polyethylene sheet or other type of moisture retaining blanket approved by the Owner's Representative.

d) Curing methods during hot weather shall be accordance with the provisions of ACI 305.

e) Curing methods during cold weather, protect concrete from freezing and cure in accordance with ACI 306 requirements.

f) No curing and sealing compound or method shall be used which will impair bond or penetration of subsequently applied finishes or materials. Coordinate with material manufacturers.

g) Prohibit pedestrian traffic from newly placed slabs for a minimum of 24 hours. Prohibit vehicular and other construction traffic from newly placed slabs for a minimum of 7 days.

5) Finishing the Steel Fibre Concrete

a) Concrete slabs shall be brought to proper lines of level or pitch by tamping, screeding power floating or minimal toweling; remove humps and hollows to produce true, even surfaces. Concrete floor slabs to remain exposed or receive resilient tile or carpeted finish shall have steel trowel finish.

b) Slabs to receive Polished Concrete Process flooring shall be floated level.

i. Float Finish: Consolidate surface with floats. Level, cut down high spots, and fill low spots with cream & fines only. Repeat float passes and leveling until surface is left with a uniform, smooth texture of cream & fines.

ii. Trowel Finish: After applying float finish, apply first toweling and consolidate concrete by hand or power-driven trowel.

1. Minimize pan trowling to flatten slabs receiving Polished Concrete process.
2. Do not over trowel surface of slab to receive Polished Concrete process.
3. Do not smooth edges of slabs with trowel in areas to receive Polished Concrete Process.
4. Do not allow foot traffic or miscellaneous debris on slabs receiving Polished Concrete Process

c) Tolerance adherence: Final work which is found to exceed tolerance limits as specified shall be removed and replaced at no additional cost to Owner.

d) Control joints at slab-on-grade shall be sawcut to 1/3 the thickness of the slab with a "Softcut G2000" saw at locations indicated on the Drawings, as soon as slab surface will bear the sawcut equipment and operator without damage (generally within 8 to 10 hours of pour). For areas to receive Polished Concrete Process coordinate joint cutting and filling with trades performing polishing, Project Manager and Owners representative for appropriate timing of this task..

i. After slab has cured for 7 days, fill sawcuts with approved material. Do not fill saw cuts with sand when slab will receive Polished Concrete Process.

ii. In areas to receive Polished Concrete Process fill joints with backer and sealant after polishing process is completed as directed by Project Manager and Owners representative.

e) Saw cut construction joints to 1/3 the thickness of the slab using wet diamond blades. Begin saw-cutting prior to time initial shrinkage cracks develop but not more than 8 hours after placement. Completely remove concrete and slurry resulting from saw-cutting operations from groove and from slab surfaces. Repair raveling and spalling along joint as directed by Architect/Engineer.

f) Place epoxy floor fill in slab voids where indicated. Strike fill area smooth to adjacent surfaces and steel trowel finish. Protect and cure as recommend by system manufacturer.

g) Exposed surfaces shall receive a liquid sealer/hardener/densifier applied in accordance with manufacturer's instructions unless otherwise directed by the Owner.

i. On surfaces not receiving polish concrete process, apply second coat after 7 day cure. Do not apply second coat to concrete that is less than 7 days old.

h) Concrete Polishing:

i. Polished Concrete Process is “cracking the cap” by diamond grinding the concrete surface, removing imperfections left by concrete installer, spraying on deep penetrating lithium chemistry densifier per manufactures instructions as specified, grinding off any densifier residue from surface of slab, begin diamond polishing to desired gloss meter reading requirements, spraying on final deep penetrating lithium poly silicate concrete sealer per manufacturers instructions and finish cleaning the polished slab with common scrubber, soft white nylon heads and neutral PH soap specifically designed to clean Polished Concrete surfaces. The result is a polished concrete floor that will not dust, is resistant to penetration from oils, provides an additional 35% or more reflected light and slip coefficients that surpass standard code requirements/ recommendations.

ii. Process may be either a proprietary system from specialty contractor or use specified products with acceptable detailed process in compliance with definition above and approved by Project Manager and Owners Representative.

iii. Examination: Polishing Trade and Contractor with Representatives of the Construction Manager and Owner shall inspect the areas to be polished.

a. Inspect for voids, holes, gouges or other imperfections that would be detrimental to achieving a polished finish. Holes and voids shall be filled with epoxy compound to match (or blend with) the adjacent surface

iv. Acceptable Diamond Grinding Methods: Equipment and techniques defined above that .produce documented results of concrete finishes meeting or exceeding the following: Required FF, FL, Gloss Meter readings, light reflected percentages as measured with a specular gloss measurement device and slip coefficient minimums as defined in this specification. Specifically, a min diamond grind of not less then 1/64 ” or as required, will be removed from the slab surface to eliminate imperfections left from the concrete finishing process i.e.: float ridges including swirl patterns and black scorch marks from concrete finishing.

v. Polishing: Process is intended to begin with polishing using a 100 grit resin bond pad and ending with a 400 grit resin bond pad or equal to achieve specified gloss; optimal 68 reading on a gloss meter

G. Records and Tests to be made on site:

It is recommended that records of the following be maintained during the time spent on site:

a) A general description of the site conditions and any relevant details of the sub base prior to and during the concrete pour.

b) The weather conditions on site.

c) Details of the numbers of men placing and finishing the concrete.

d) The start and finish times for the concrete pour.

e) The start and end times of the trowelling or finish process along with the curing compound application start and end times.

f) The timing and rate of delivery of the concrete should be monitored and recorded throughout the concrete pour. This can be noted on the delivery ticket from each load of concrete but it is recommended that a separate record be also kept.

g) Any anomalies that occur during the concrete pour should be noted on the delivery ticket as well as documented in detail elsewhere.

H. The following tests must be made during the concrete pour:

a) Slump test should be performed periodically during a concrete pour according to the standard specifications. These tests should include the mix design number or identification along with batch time, delivery time and delivery ticket.

b) Fibre dosage rate must be checked by taking three samples of ten litres from a given load of concrete. This should be done by taking ten litres at the first ¼, middle and the last ¼ of the load when discharging the concrete. These samples should never be taken at the very beginning of discharge or at the very end of discharge of a load of concrete. Wash away the cement paste, sand, fines and other aggregates leaving behind the steel fibres. Fibres must be dried and then weighed. For a ten litre volume, the weight of the extracted can be multiplied by 100 to obtain the dosage rate per m3. The average weight can then be compared to the specified dosage rate.

I. The following tests can or should be made during the concrete pour:

a) The condition of the sub-base to include the level and compaction or density levels.

b) When yield and weight test are done, the concrete weight should be a minimum of 23.5kN/m^3. It should be noted that the lighter the concrete the higher the water/cement ratio which produces more shrinkage.

c) A denser concrete mix yields less shrinkage as it has a lower water/cement ratio.

J. Concrete Shrinkage

Steel fibres do not prevent shrinkage but help control it within acceptable limits, provided the recommendations included here are respected.Shrinkage is a function of the components in a given concrete mix that is effected by the density, shape, and size of the individual components and how much water on or in them is released, when it is released, along with other pressures brought to bear on a given piece of concrete during its life including heat of hydration.

All concrete shrinks to some degree. If shrinkage is not desirable, concrete should not be used.

a. Types of shrinkage

1. Thermal shrinkage.

Due to a high initial concrete temperature aggravated by heat released during the first steps of hydration followed by a lowering of the temperature soon after, which causes contraction in the concrete. This promotes wide early age cracking that is not controlled by reinforcement in the concrete.

Solution: Manage concrete temperature change on site. Make sure there is not any movement restraint to the slab.

2. Plastic shrinkage

It is caused due to early loss of vapour water from the surface of the fresh paste of the concrete. Plastic shrinkage produces lots of short, wide cracks like of a dried puddle in mud.

Solution: Protect the slab from early evaporation especially when there are high flows of air over the slab.

3. Hydraulic shrinkage

Loss of vapour out of the hardened concrete which produces long term cracking that can start as early as a few days after pouring the floor. These cracks can open significantly over time.

Solution: Apply a state of the art curing compound or method according to the product manufacturer's specification. Reinforce the slab using steel fibres high dosage rate.

K. Cracking in Concrete Floors

Industrial floors are designed primarily for practical reasons and not for aesthetic.
Cracks that are not of a structural nature are often better left without any remedial work.
Cracks of over 0.8mm opening in the top of slab should be repaired by resin injection where subjected to traffic.

L. Problems faced in concreting Process:

Following are the reasons for the problems , which arises during the process and should be checked and rectified:

Problem 1 : Concrete cannot be pumped

a) Incorrect mix design. The quantity of fines smaller than 200 microns is less than 450kg/m^3.
b) Segregation of concrete in mixer truck during transit.
c) Pump line diameter reduction from 125mm down to 100mm.
d) Variations in concrete setting time
e) Inconsistent concrete slump
f) Overdose of superplasticizer.
g) Variations in transit time for the concrete.

Problem 2 : Cold joints

a) Quick setting of the concrete
b) Plant breakdown
c) Poor management of job or unskilled operatives
d) Too wide pour face

Problem 3 : Loss of edges

a) Insufficient number of finishers or inexperienced finishers waiting too long to catch the edges
b) Incorrect mix design

Problem 4 : Settlement cracks

a) Inadequate base or sub-base.
b) Wet ground
c) Low K-value
d) Poor compaction
e) Expansive soil

Problem 5 : Cracking from construction overloads

a) Using slab for construction storage
b) Early installation of racking.

Problem 6 : Delaminating

a) Trapped bleed water or wrong dose of Superplasticizer
b) Excessive air content
c) Incorrect finishing technique that closes the surface of the concrete too soon

Problem 7 : Breakdown of joints

a) Inadequate joint type without shear transfer device.
b) Excessive saw cut joint spacing
c) Edge loading.
d) Poor finishing technique at joint edge.
e) Lack of joint filler.
f) Hard wheel traffic.

Problem 8 : Crazing

a) Overworking the surface.
b) Drying and dusting the surface with cement.
c) Drying before strength develops.
d) Thermal shock, and or wetting and drying at early age.
e) Inadequate curing.

Problem 9 : Surface Dusting

a) Excessive bleed water.
b) Poor mix design.
c) Too slow hardening.
d) Exhaust gas.

Problem 10 : Steel fibre showing

a) Mechanical trowelling began too early pulling the fibres out of the freshly levelled concrete.
b) Too large aggregate size when compared to spacing of the fibres in the mix
c) Too long and/or too flexible fibres.
d) Incorrect mix design.

M. Field Quality Control

a) General Contractor to employ an independent testing agency to perform tests and to submit test reports.

b) Test each continuous pour with not less than one test per day or not less than one test for each 150 cubic yards of concrete, except as otherwise required and approved. Each test shall consist of three specimen cylinders, with specimen cylinders cured at the laboratory. One of the cured specimen cylinders shall be tested at seven days and two at 28 days, and the 28 day test shall show not less than specified strength. Each 28 day cylinder shall show not less than the designed strength and the average of the cylinders shall show not less than 115% of the design strength. Provide casual labor and extend full cooperation as required.

c) Sampling, molding, curing and testing of cylinders shall conform to ASTM C 31.

d) Slump tests shall be made at the job site and written results shall be submitted for approval per ASTM C 143.

e) Where concrete does not conform to these requirements the Contractor may be required to provide the following at his own expense:

1. Complete plant inspection by testing agency.
2. Test of hardened concrete.

f) Testing for Flatness & Levelness shall be performed in conformance with ASTM E 1155 and a written report submitted to the Owner's Representative.

1. Testing for Flatness and Levelness in areas to receive Polished Concrete Process shall be in conformance with ASTM E 1155 and be preformed and applied from edge of pour to edge of pour with written report submitted to the Owners Representative

g) Non-Compliance Test Reports: Test reports indicating non-compliance shall be faxed immediately to all parties on the test report distribution list. Follow with mailed hard copies.

N. Protection of floor

a) Protection of floor after installation is responsibility main contractor;

O. Handing Over

a) Handing Over Protocol shall be prepared including list of defects;
b) Handing over testing Plan for level and de-lamination of floor hardener to be submitted prior to Handing Over.

P. Warranty Certificate

a) Minimum five (5) years warranty on entire floor system to be provided;
b) Yearly defects repair is accepted;

Q. Advantages of SFRC Floors:

The use of steel fibre reinforcement offers numerous advantages for concrete flooring:

1. SFRC provides greater moment, punch-out and shear reinforcement.
2. SFRC provides shrinkage control i.e. for crack control and limitation of curling but it cannot prevent shrinkage.
3. SFRC provides significant improvement in fatigue and dynamic resistance.
4. SFRC allows faster more efficient installation providing cost savings.