

**Steel Fibre Reinforced Concrete (SFRC)
For Industrial Floors
Especially
Slabs without Joints and
Slabs on Piles**

A Practical Guide

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The use of steel fibre reinforcement offers numerous advantages for industrial 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.

To achieve the best results when designing and installing a SFRC floor, the following simple guidelines should be followed.

What is 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 a joint free floor (TAB-Floor) or a piled suspended slab (TAB-Structural) and between 22 to 24mm for jointed (TAB-Fibre) floors.

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 20kg/m³ is required. Fibre dosages of below this will not provide effective control of shrinkage within the concrete.

For joint free (TAB-Floor) floors a minimum fibre dosage of 40 kg/m³ when using 1 mm diameter fibres is mandatory.

For suspended floors on piles (TAB-Structural) a minimum dosage of 45 kg/m³ TABIX+ 1/60 fibres is required.

Example

Assuming $S = 122 \times D / \sqrt{V}$

where S = Fibre Spacing (mm), D = Fibre Diameter (mm) and V = Fibre Dosage rate (kg/m³)

for

- 40kg/m³ of Tabix 1/50 - $S = 122 \times 1 / \sqrt{40} = 19.3\text{mm}$
- 45kg/m³ of Tabix 1/60+ - $S = 122 \times 1 / \sqrt{45} = 18.2\text{mm}$

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.

Steel Fibre Concrete Mix

Concrete mix design should aim to minimise 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 laid down by Arcelor with respect to aggregate grading, cement, a water/cement ratio of 0.50 -0.55, and superplasticizer when required.

Generally, the cement content should be between 300 and 350 kg/m³ of CEM I, CEM III or CEM II/A and in accordance with paragraph 4 of the technical file in the Avis Technique.

The plain concrete slump before the addition of steel fibres and superplasticizer should be consistent at 50 mm.

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.

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

- 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.
- For 1 mm diameter thick and 50 mm long fibres the following table shows a guide to slump loss for different dosage rates.

Fibre Dosage (kg/m ³)	20	25	30	35	40	45
Reduction in Slump (mm)	20	25	35	50	60	75

- The steel fibres should be added a rate of 30-40 kg per minute.
- 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.
- The maximum drum rotation speed should be 12-15 revolutions per minute.
- 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.

Installing a Steel Fibre Reinforced Concrete Floor

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

- Who is responsible for the design of the floor?
- 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.
- The final design document and calculations showing the floor thickness, fibre type and dosage rate (kg/m³) joint spacing and type of joints to be used. 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.
- 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:

- The sub base must have a minimum k-value of 0.03N/mm³.
- 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 minimise their effect.
- The sub base should be damp not soaked or with standing water.
- If required a polythene sheet can be installed beneath the slab
- Nothing on the sub base will restrain movement in the slab causing cracks to form.
- 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.
- If constructing a joint free slab (no saw cuts) the bay size should be a maximum 2,500m² with a maximum length / width ratio of 1 to 1.5.
- The floor thickness will be within the specified tolerance.
- 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

- The steel fibre concrete should be fresh and no older than 60 minutes from batch time with a maximum temperature of 25°C.
- 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.
- The concrete slump at arrival to the jobsite should be constant and consistent within a tolerance of +/- 25mm of the specified slump.
- If an increased slump is required, for example when pumping, the concrete should be superplasticized to achieve the proper slump for the pumping operation.
- 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.

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

4) Finishing the Steel Fibre Concrete

- After placing the concrete to the correct level, use a skip or Bull-Float over the surface
- All edges should be finished by hand and be completed first as these will generally tend to set quicker than other areas of the slab.
- A curing compound should be applied to the finished slab. This should be done immediately after all of the required finishing steps are completed.
- When saw cut joints are needed, cut them as soon as the concrete is strong enough to resist tearing by the blade. This can be between 4 and 12 hours after the concrete hardens. Exact timing is dependent on the rate at which the concrete hardens.

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 general description of the site conditions and any relevant details of the sub base prior to and during the concrete pour.
- The weather conditions on site.
- Details of the numbers of men placing and finishing the concrete.
- The start and finish times for the concrete pour.
- The start and end times of the trowelling or finish process along with the curing compound application start and end times.
- 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.
- Any anomalies that occur during the concrete pour should be noted on the delivery ticket as well as documented in detail elsewhere.

The following tests must be made during the concrete pour

- Slump test should be performed periodically during a concrete pour according to the specifications of the Avis Technique. These tests should include the mix design number or identification along with batch time, delivery time and delivery ticket.
- 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 $\frac{1}{4}$, middle and the last $\frac{1}{4}$ 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. Allowed deviation from target rate as well as the frequency of the measurement is given in the Avis Technique.

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

- The condition of the sub-base to include the level and compaction or density levels.
- When yield and weight test are done, the concrete weight should be a minimum of 23.5 kN/m³. It should be noted that the lighter the concrete the higher the water/cement ratio which produces more shrinkage. A denser concrete mix yields less shrinkage as it has a lower water/cement ratio.

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.

Types of shrinkage

- **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.

- **Plastic shrinkage**
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.
- **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 at 30kg/m³ dosage rate or more.

Concrete Curling

Curling is caused by changes in temperature and moisture loss. Curling is not only a function of slab depth. A thicker concrete slab will simply tend to curl more slowly and less than a thinner slab.

Saw cuts may over time, increase the likelihood of curling and, in areas of significant loading and vehicular traffic, cracking.

Curling in saw cut joint slabs can be controlled to some degree if a dosage rate of more than 30 kg/m³ is used together with the maximum spacing between saw cuts being limited to 6 m and the saw cut depth limited to 25% of the slab depth. It is often preferable to see a few cracks that can be repaired rather than a badly curled slab that is impossible to repair.

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.

TAB-Floor (a SFRC ground bearing joint free floor) and TAB-Structural (a SFRC pile suspended slab) have been designed to address all the issues regarding shrinkage, cracking, sawn cuts and curling associated with industrial concrete flooring. TAB-Floor and TAB-Structural specifications provide full outlines of these systems. This document is to be considered as an addendum with further explanations.

Troubleshooting Guide

Problem: Concrete cannot be pumped

- Incorrect mix design. The quantity of fines smaller than 200 microns is less than 450kg/m³.
- Segregation of concrete in mixer truck during transit.
- Pump line diameter reduction from 125mm down to 100mm.
- Variations in concrete setting time
- Inconsistent concrete slump
- Overdose of superplasticizer.
- Variations in transit time for the concrete.

Problem: Cold joints

- Quick setting of the concrete
- Plant breakdown
- Poor management of job or unskilled operatives
- Too wide pour face

Problem: Loss of edges

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

Problem: Settlement cracks

- Inadequate base or sub-base.
- Wet ground
- Low K-value
- Poor compaction
- Expansive soil

Problem: Cracking from construction overloads

- Using slab for construction storage
- Early installation of racking.

Problem: Delaminating

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

Problem: Breakdown of joints

- Inadequate joint type without shear transfer device.
- Excessive saw cut joint spacing
- Edge loading.
- Poor finishing technique at joint edge.
- Lack of joint filler.
- Hard wheel traffic.

Problem: Crazeing

- Overworking the surface.
- Drying and dusting the surface with cement.
- Drying before strength develops.
- Thermal shock, and or wetting and drying at early age.
- Inadequate curing.

Problem: Surface Dusting

- Excessive bleed water.
- Poor mix design.
- Too slow hardening.
- Exhaust gas.

Problem: Steel fibre showing

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

For more information or help, please contact

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