The Range distribution centre, Avonmouth, Bristol

GHW Consulting Engineers was engaged by Konfloor Industrial Flooring to design and detail the suspended steel-fibre-reinforced concrete (SFRC) ground-floor slab to a new regional distribution centre in Avonmouth, Bristol. Konfloor was engaged by McLaren Construction who is the main contractor on the project. ***Andy Worship*** *of* ***GHW Consulting Engineers*** *reports.*

The overall project was 107,000m^2 of distribution warehouse, offices, external works and drainage. However, the appointment of GHW was limited to the specialist design, detailing and construction of the suspended ground-floor slab only.

The design of industrial ground-floor slabs, while well documented, is generally only carried out by a small number of consulting Engineers in the UK. The design of SFRC suspended floors to Concrete Society Technical Report 34 4th Edition(1) is a specialist area and requires in-depth knowledge of design, detailing, concrete and construction to ensure successful floor slab construction.

The building is 480m long and 219.68m wide with dock leveller access to both sides of the building and additional internal office accommodation. Some 27,000m^3 of SFRC concrete was installed in less than 60 days to a surface level tolerance of FM2.

Design

At tender stage, GHW undertook around 30 initial designs for a variety of pile grids, edge spans, pile head sizes, concrete strength and steel fibre choice/dosage.

The floor loading specified from the client was for a uniform distributed load of 50kN/m^2 and racking leg loads of 100kN placed back to back 300mm apart together with material handling equipment (MHE) wheel loads of 45kN.

In the final design, a 255mm floor slab was adopted based on a C35/45 concrete, 45kg/m^3 of Arcelor Mittal HE 1/60 steel fibres, 900mm-diameter pile heads and a pile grid of 2.8m × 2.8m with a 2.1m edge span.

GHW has developed its own Excel based software to efficiently carry out the design checks to TR34 for all design cases including serviceability and punching shear.

The C35/45 strength class has been adopted based on experience and use of SFRC concrete. When using a high steel fibre dosage, you add surface area, which in turn requires more fines and therefore more cement. This has to be balanced within the correct sieve curve for a stable concrete to ensure integration of the fibres, a homogeneous mix and good finishing with a little bleed water. Trial mixes were undertaken to give assurance on the 28-day concrete strength without over specifying the cement content which could lead to greater shrinkage.

Critical within any SFRC TR34 design is the availability of F_{r1} and F_{r4} results from notched beam tests to BS EN 14651(2). Beam test results are specific to the choice of steel fibre, dosage and concrete mix. Test results from different manufactures cannot be used

Isedio Armourjoint

Top: Close-up of SFRC.
Middle: Steel fibres are added to the concrete.
Above: Dry shake topping is applied.

on, results extrapolated, but only interpreted between dosage rates of 10kg/m^3. The initial design was undertaken on historic results although this was verified during construction with site-specific material being shipped to the testing laboratory.

Assessment of the moment capacity is based on the simplified stress–strain relationship. The ultimate moment capacity is dependent on the strain at the extremity of the section. On the compression face, the strain is limited to 0.0035, as is the case for conventional reinforced concrete sections. On the tension face, the strain is limited to 0.024.

Detailing

Many things contribute to the success of a concrete floor, but good detailing is key. This starts with the piling layout. GHW undertook the setting out of the piles to ensure the correct spacing was maintained throughout the floor and around perimeter edge spans.

With a building of this size you are looking to construct jointless panels of around 35 × 35m, position the steel armoured Isedio day joints at ¼ pile spacing, no joints to run longitudinally under the racking, avoid joints down the centre of isles and avoid unstable slab panels to the rear of dock levellers. It is important to limit aspect ratios to 1/1.5 and ensure concrete delivery capacity.

This resulted in 84 main slab panels plus offices and dock leveller infills down the full length of both sides of the building and close to 27,000m^3 of concrete being installed.

The requirements described above were met with minimal compromise, which allowed fast and efficient large-pour laser-screed construction to take place.

The areas around the dock levellers are prone to heavy use, restrained by the precast concrete biscuit slabs, have irregular shapes with re-entrant corners and are generally outside the 1/1.5 aspect ratio. These areas are still suspended and have to integrate with the main floor therefore they have additional fabric reinforcement to help control any cracking plus saw cuts from the corners of the dock to the armour to help limit the aspect ratio. The span of the slab was also limited to 1.8m to ensure robustness.

Floor joints are vital to allow large floors to move laterally in two directions during drying shrinkage of adjacent panels, provide no vertical movement and shear load transfer via the plate dowel bars, contain the concrete pour to the required depth and side forces during construction and provide steel armoured arris protection during the life of the floor. The Isedio Armourjoint provides all these functions in one simple joint system.

Columns throughout the building while vital for the structure, provide a point of restraint to the industrial floor design as they rarely coincide with day joints and pile spacing to suit all the requirements. To minimise against restraint a thin steel plate is fixed across the column flanges and 30mm of miothene provided as a soft joint. Corner crack reinforcement is then provided in excess of the $300mm^2$ in a 0.5m zone by using a combination of A193 fabric and two H12 bars.

Concrete

The quality and design of the concrete is paramount to achieving a good floor. This has to meet the required design strength, be durable, shrink as little as possible, be consistent throughout the pour and allow for integration of the steel fibres on-site following the addition of fourth-generation plasticiser.

The concrete mix design was limited to a cement content of 360kg/m^3 (252kg of CEM I 52.5N and 108kg ggbs) and a water/cement ratio of 0.5 with a target slump of S2.

Regular concrete cubes are taken during the construction to monitor the seven, 14 and 28-day compressive strength results. The 28-day results showed a cube strength range of 45.4–62MPa with an average of 53.7MPa. All 28-day results were in excess of the design strength of 45MPa.

Steel fibres

The steel fibres are manufactured by Arcelor Mittal at its plant in Sheffield. The fibres are hook end (HE) 1.0mm diameter and 60mm long (1/60). Their tensile capacity is 1100MPa. The dosage rate used for this project was 45kg/m^3. This equates to 117,000 fibres per cubic metre.

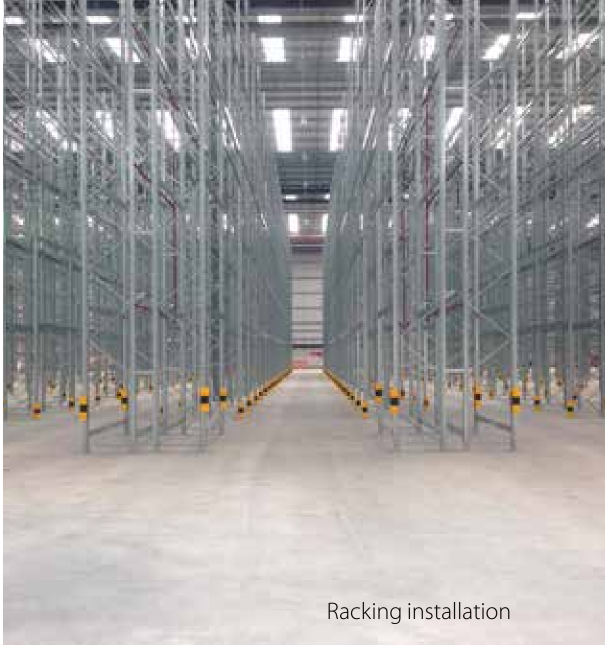
The steel fibres are manufactured from drawn wire that starts out at 500MPa at 5.0mm diameter before being drawn down to 1.0mm and 1100MPa. They are boxed by weight in 25kg boxes and stored on pallets for delivery to site.

The fibres are manufactured in accordance with BS EN 14889-1[3] type 1 (cold drawn wire) and ASTM A820/A820M-04[4] type 1 (cold drawn wire).

The steel fibres are added on-site via a conveyor with the number of boxes required for the volume of concrete rounded up to

Laser Screed Telescopic Boom.


Part view of finished floor.


Racking installation

a full box. This work was carried out by Konfloor. The concrete truck is then mixed for the required time to ensure full integration and distribution. The addition of the superplasticiser on-site also helps to optimise the working window of high slump concrete to increase integration and placing.

In terms of steel fibre beam testing to BS EN 14651[2], it is not a requirement of TR34[1] to verify the actual site concrete as long as the tested and site mix are similar. The decision was taken to carry out further beam testing to verify the design even further.

Site material including cement, sand, aggregate, steel fibres and plasticiser were taken to the concrete lab to undertake a series of 2 × 12 SFRC beams and 2 × 6 plain concrete beams, measuring 150 × 150 × 550mm, in order to verify the limit of proportionality at first crack. The results of the site concrete virtually matched previous laboratory results.

Further independent on site-testing was undertaken in the form of washout tests to BS EN 14721[5] to weigh the steel fibres from a 10 litre concrete sample from first, middle and third of the load. This again showed full compliance with the required deviation from the target load.

Construction

Construction took place in large jointless panels on a 1200-gauge slip membrane.

The 900mm-diameter pile heads were constructed ahead of the floor slab pour by the groundworks contractor to a tolerance of ±10mm with a crossfall of ±3mm. These were surveyed for compliance by the groundworker. The standard of construction for these pile caps on this site was the highest seen by the whole project team.

Konfloor would undertake the final 50–75mm of sub-base grading prior to the pour and set-out of the Isedio Armourjoint day joints to the required positions indicated on the drawings. Further checks were then undertaken to measure the depth of the floor from sub-base to top of joint. This work was all carried out on the day before the concrete pour and signed off.

When the concrete arrives to site, its arrival time, truck registration and batch time are logged. The slump is checked, superplasticiser added, mixed, steel fibres added, mixed again and then the concrete is discharged directly in the required position.

The laser screed boom is extended and the concrete is tamped and levelled in one smooth operation. A bull-float is pushed across the concrete to further level the slab and push down any steel fibres that may be close to the surface. A dry-shake fibre suppressant topping is then applied via a controlled telescopic spreading machine.

The slab edges are tamped and hand trolled for compaction and flatness.

Around four hours after initial laying, the walk-behind power float work begins. This is a very skilled operation and relies on the experience of the finisher to know exactly how much speed and choice of float to use and when to step up the larger twin-bladed ride on power floats. This operation achieves the final flatness and dense durable power float finish that we see in all warehouse floors.

Finally, a spray application of curing/sealing agent is applied to the floor and the curing process begins.

The whole of the 107,000m^2 of floors was completed in less than 60 days on-site and ahead of schedule between 18 December 2016 and 27 April 2017.

The Range distribution centre, Avonmouth, Bristol

Main contractor	McLaren Construction Ltd
Specialist floor joint supplier	Isedio
SFRC floor slab design and detail	GHW Consulting Engineers Ltd
Industrial floor slab contractor	Konfloor Industrial Flooring Ltd

Project summary

The design, detailing and construction of this project would not have taken place in such an efficient manner with conventional cut/bent or fabric reinforcement. This would have been in the region of twice the cost to install and taken three times as long to construct.

The use of SFRC has enabled fast-track, large-pour construction at minimal floor depths saving time, materials, CO_2, preliminaries, programme and cost, yet still delivering the required flatness tolerance and minimum joints to give the end use a high-quality, low-maintenance floor slab.

Minimum joints mean less damage and maintenance to forklift trucks and less impact damage to the operator. ■

References

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