**ArcelorMittal Sheffield Ltd**
Vulcan Works
Birley Vale Close
Sheffield S12 2DB
Tel: 0114 239 2601 Fax: 0114 264 2514
e-mail: steelfibres@arcelormittal.com
website: www.arcelormittal.com/steelfibres

BBA APPROVAL INSPECTION TESTING CERTIFICATION
TECHNICAL APPROVALS FOR CONSTRUCTION

Agrément Certificate
**09/4677**
**Product Sheet 1**

# ARCELORMITTAL STEEL-FIBRE-REINFORCED CONCRETE

## PRODUCT SCOPE AND SUMMARY OF CERTIFICATE

This Certificate relates to ArcelorMittal Steel-Fibre-Reinforced Concrete, for the construction of ground-supported floor slabs, foundations and pile-supported ground beams in domestic and similar types of buildings cast on the ground in locations not subject to clay heave.

## AGRÉMENT CERTIFICATION INCLUDES:

- factors relating to compliance with Building Regulations where applicable
- factors relating to additional non-regulatory information where applicable
- independently verified technical specification
- assessment criteria and technical investigations
- design considerations
- installation guidance
- regular surveillance of production
- formal three-yearly review.

## KEY FACTORS ASSESSED

**Structural performance** — concrete incorporating HE+1/50 steel fibres at a dosage rate of 40 kgm$^{-3}$ can be designed to resist the loads associated with the intended use (see section 5).

**Durability** — concrete designed in accordance with BS 8500-2 : 2006 is not affected by the incorporation of HE+1/50 steel fibres at a density of 40 kgm$^{-3}$ (see section 7).

The BBA has awarded this Agrément Certificate to the company named above for the product described herein. This product has been assessed by the BBA as being fit for its intended use provided it is installed, used and maintained as set out in this Certificate.

On behalf of the British Board of Agrément

Date of First issue: 14 August 2009

Brian Chamberlain
Head of Approvals — Engineering

Greg Cooper
Chief Executive

*The BBA is a UKAS accredited certification body — Number 113. The schedule of the current scope of accreditation for product certification is available in pdf format via the UKAS link on the BBA website at www.bbacerts.co.uk*

*Readers are advised to check the validity and latest issue number of this Agrément Certificate by either referring to the BBA website or contacting the BBA direct.*

# Regulations

In the opinion of the BBA, ArcelorMittal Steel-Fibre-Reinforced Concrete, if used in accordance with the provisions of this Certificate, will meet or contribute to meeting the relevant requirements of the following Building Regulations:

**The Building Regulations 2000 (as amended) (England and Wales)**

| | | |
|---|---|---|
| Requirement: | A1 | Loading |
| Comment: | | Floors and foundations incorporating the product can be designed to sustain and transmit dead and imposed floor loads to the ground. See sections 5.1 to 5.11 of this Certificate. |
| Requirement: | Regulation 7 | Materials and workmanship |
| Comment: | | The product is an acceptable material. See section 7 and the *Installation* part of this Certificate. |

**The Building (Scotland) Regulations 2004 (as amended)**

| | | |
|---|---|---|
| Regulation: | 8(1)(2) | Fitness and durability of materials and workmanship |
| Comment: | | The product can contribute to a construction satisfying this Regulation. See sections 6 and 7 and the *Installation* part of this Certificate. |
| Regulation: | 9 | Building Standards – construction |
| Standard: | 1.1(a)(b) | Structure |
| Comment: | | Floors and foundations incorporating the product can satisfy this Standard, with reference to clauses 1.1.1(1)(2), 1.1.2(1)(2), 1.1.3(1)(2) and 1.1.4(1)(2). See sections 5.1 to 5.11 of this Certificate.<br>(1) Technical Handbook (Domestic).<br>(2) Technical Handbook (Non-Domestic). |

**The Building Regulations (Northern Ireland) 2000 (as amended)**

| | | |
|---|---|---|
| Regulation: | B2 | Fitness of materials and workmanship |
| Comment: | | The product is an acceptable material. See section 7 and the *Installation* part of this Certificate. |
| Regulation: | B3(2) | Suitability of certain materials |
| Comment: | | The product is an acceptable material. See section 6 of this Certificate. |
| Regulation: | D1 | Stability |
| Comment: | | Floors and foundations incorporating the product can be designed to sustain and transmit dead and imposed floor loads to the ground. See sections 5.1 to 5.11 of this Certificate. |

**Construction (Design and Management) Regulations 2007**

**Construction (Design and Management) Regulations (Northern Ireland) 2007**

Information in this Certificate may assist the client, CDM co-ordinator, designer and contractors to address their obligation under these Regulations.

See sections: 2 *Delivery and site handling* (2.1) and 8 *Site preparation* (8.2)

# Non-regulatory Information

## NHBC Standards 2008

NHBC accepts the use of ArcelorMittal Steel-Fibre-Reinforced Concrete, when installed and used in accordance with this Certificate, in relation to *NHBC Standards*, Chapters 2.1 *Concrete and its reinforcement*, 4.4 *Strip and trench fill foundations*, 4.5 *Raft, pile, pier and beam foundations*, 5.1 *Substructure and ground bearing floors* and 5.2 *Suspended ground floors*.

## Zurich Building Guarantee Technical Manual 2007

In the opinion of the BBA, ArcelorMittal Steel-Fibre-Reinforced Concrete, when installed and used in accordance with this Certificate, satisfies the requirements of the *Zurich Building Guarantee Technical Manual*, Section 3 *Substructure*.

# General

ArcelorMittal Steel-Fibre-Reinforced Concrete is assessed as suitable for use in fully-supported, ground-bearing slab applications, foundations, pile-supported ground beams and in slabs supported on foundation walls provided the stresses are limited to those given in Table 2. This Certificate does not cover the use of suspended slabs with cavities beneath.

The fill material below the concrete must have a minimum bearing capacity of 20 $kNm^{-2}$ and soil stiffness of 30 $MPa.m^{-1}$ (*K* value) — approximately equivalent to a clay or sandy clay [defined as Type III in Approved Document A (Building Regulations — England and Wales), Table 10].

Construction joints should be avoided wherever possible, with large areas up to 900 $m^2$ constructed in a single pour.

Services can be provided for without special detailing or cutting of reinforcement as might be required for conventional reinforced concrete.

Although outside the scope of this Certificate, it should be noted that where radon or other harmful gases are present, additional care is required to ensure provision of taped and sealed membrane joints and effective sealing of services passing through the floor. Steps should be taken to ensure compliance with the relevant national Building Regulations in areas where harmful gases are present. Guidance is given in:

***England and Wales*** — BR Report 211 (BR 211 : 1999) *Radon : Guidance on protective measures for new dwellings*

***Scotland*** — BRE Report (BR 376 : 1999) *Radon : Guidance on protective measures for new dwellings in Scotland*

***Northern Ireland*** — BRE Report (BR 413) *Radon : Guidance on protective measures for new dwellings in Northern Ireland.*

# Technical Specification

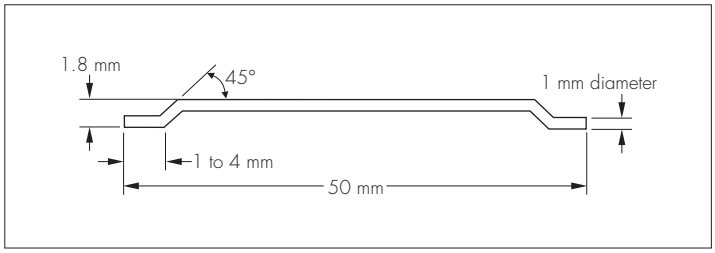
## 1 Description

1.1 ArcelorMittal Steel-Fibre-Reinforced Concrete consists of a concrete to a standard structural grade in accordance with BS 8500-2 : 2006, with the addition of a super-plasticiser(1) to BS EN 934-2 : 2001, and incorporating HE+1/50 steel fibres at a dosage rate of 40 $kgm^{-3}$.

(1) Super-plasticisers are outside the scope of this Certificate.

1.2 The hooked-end steel fibres type HE+1/50 are CE marked to EN 14889-1 : 2006 and have the characteristics given in Figure 1.

*Figure 1 Typical detail of hooked-end*




1.3 The fibres are for use in a range of mix specifications. As a minimum, the mix design must comply with the specification defined in Table 1 and Figure 2 and will depend on the exposure class of the intended application as shown in Table 1.

*Table 1 Concrete specifications*

| Material/characteristic (description/unit) | Value |
|---|---|
| Concrete grade (minimum) | C30/C37 |
| Cement content (minimum) ($kgm^{-3}$) | 350 |
| Aggregate grading | See footnote(1) |
| Water-reducing agent content(2) | According to the manufacturer's recommendations |
| Super-plasticiser content(2) | According to the manufacturer's recommendations |
| Slump(3) (mm) | 50–100 |
| Slump(4) (mm) | 180–220 |

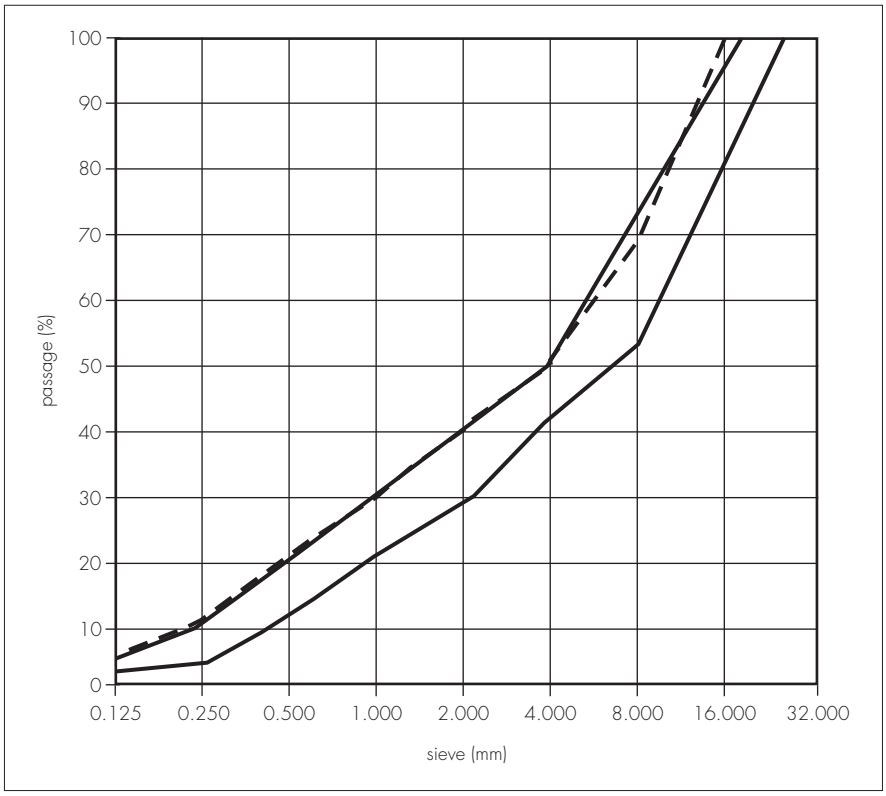
(1) The Certificate holder recommends a review of the aggregate grading reports and sieve curve analysis for each of the aggregates proposed for use to ensure the performance capability of a given mix, and will provide a sieve curve analysis based on this information to fully investigate the suitability of a given mix (see Figure 2).

(2) The water-reducing agent and the super-plasticiser should be sourced from the same manufacturer and used in accordance with that manufacturer's recommendations.

(3) Before the addition of steel fibres and super-plasticiser.

(4) After the addition of steel fibres and super-plasticiser.

*Figure 2 Aggregate grading – Sieve analysis*




1.4 The product can be used directly against the ground or in conjunction with void formers, approved by the Certificate holder, to form a waffle slab. Such void formers have not been assessed by the BBA and their suitability will need to be verified by the engineer responsible for the structural design of the floor.

### 2 Delivery and site handling

2.1 The steel fibres in 25 kg lots are supplied in cardboard boxes; pallets of 36 or 48 boxes are wrapped in polythene sheeting, and weigh 900 kg or 1200 kg respectively. Each box is marked with the legend 'B'. The specified number of 'B' boxes of fibres is incorporated into the concrete at the stage of concrete batch production by the concrete manufacturer.

2.2 The boxes of fibres must be stored away from moisture.

2.3 Concrete intended to have the fibres incorporated must be produced in ready-mix concrete batching plants in accordance with the recommendations of the Certificate holder and be approved by the Certificate holder. The quality assurance procedures at these plants must be accredited by a third-party certifying body such as the Quality Assurance Scheme for Ready Mixed Concrete or BSI. The procedures must describe the steps taken to ensure compliance with specified quality and dosing for each component of the concrete and in particular the fibre.

## Assessment and Technical Investigations

The following is a summary of the assessment and technical investigations carried out on ArcelorMittal Steel-Fibre-Reinforced Concrete.

## Design Considerations

### 3 Use

ArcelorMittal Steel-Fibre-Reinforced Concrete is for use in the construction of ground-floor slabs designed as suspended but cast against the ground, foundations and pile-supported slabs in domestic and similar types of buildings.

### 4 Practicability of installation

This product should only be installed by installers who have been trained and approved by the Certificate holder.

### 5 Structural performance

5.1 Concrete incorporating the fibres at a dosage rate of 40 $kgm^{-3}$ can be considered to have enhanced properties such that, unlike plain concrete, the failure mode is ductile in nature rather than brittle. This is confirmed by testing.

5.2 Concrete used to the specification defined in this Certificate will have the strength and resistances given in Table 2.

*Table 2 Basic characteristics of steel fibre-reinforced concrete*

| Characteristic (unit) | Value |
|---|---|
| Compression strength (grade) | C30/C37 |
| Permissible service load tensile stress ($Nmm^{-2}$) | 4.01 |
| Permissible ultimate load tensile stress ($Nmm^{-2}$) | 4.52 |
| Permissible shear stress ($Nmm^{-2}$) | 0.5 |

## Ground-supported slabs

5.3 Conventional structural analysis based on the concrete resistances given in Table 2 may be used to verify structural performance. The moment of resistance ($M$ kNm), depending on the limit state, with a slab thickness of $h$ (m) can be calculated from the equations:

*Service limit state* $M = 4010\ (h^2/6)$

*Ultimate limit state* $M = 1800\ (0.45\ h^2)$.

**ArcelorMittal Design Method** (using Tables 4 and 5)

5.4 In waffle slabs in accordance with Figure 3, and the following detailed dimensions, the mean slab thickness ($h$) of 170 mm may be used in the above equations:

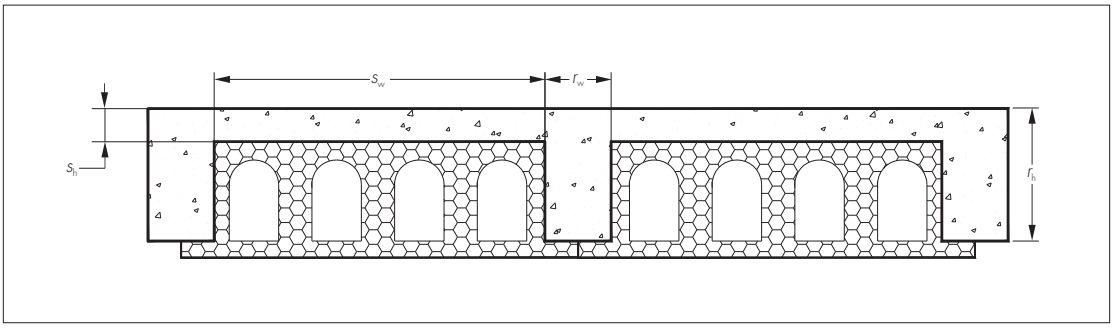
Minimum slab thickness $s_h = 100$ mm

Distance between ribs $s_w = 1050$ mm

Thickness of rib $r_w = 150$ mm

Depth of rib $r_h = 400$ mm.

*Figure 3 Typical waffle slab detail*




5.5 The procedure for establishing the suitability of a ground-supported raft foundation to withstand the loading for particular projects should be carried out thus:

- the average ultimate pressure on the ground over the whole foundation area including below the edge beams and internal ribs is determined and the average over the complete area ($A_F$) is calculated. This is the sum of the factored dead load (1.4 x DL) and the factored design live load (1.6 x LL) for each zone.
- the global load factor ($\gamma_q$) is determined by calculating from the formula:
  $\gamma_q = \{(1.4 \times DL)+(1.6 \times LL)\}/(DL+LL)$
- the average unfactored service pressure ($\rho_m$) is calculated from the formula:
  $\rho_m = \{(1.4 \times DL)+(1.6 \times LL)\}/(\gamma_q \times A_F)$
- the values are compared with those given in Table 3, to verify that the slab can sustain the ultimate load and service load for the applicable clear span between beams.

*Table 3 Ground pressure resistance allowed for ground-supported ribbed slabs*

| | Span between beams[1] (m) | | | | | |
|---|---|---|---|---|---|---|
| | 4.45 | 4.75 | 5.10 | 5.60 | 6.30 | 7.25 |
| Maximum average pressure onto the ground (service) ($kNm^{-2}$) | 40 | 35 | 30 | 25 | 20 | 15 |
| Maximum average pressure onto the ground (ultimate) ($kNm^{-2}$) | 55 | 50 | 40 | 35 | 30 | 20 |

(1) Up to a design limit of L/500.

5.6 The suitability of the edge beams and internal beams in a ground-supported raft foundation will depend on the beam dimensions and the loads applied. The procedure used to confirm the members have adequate load capacity is:

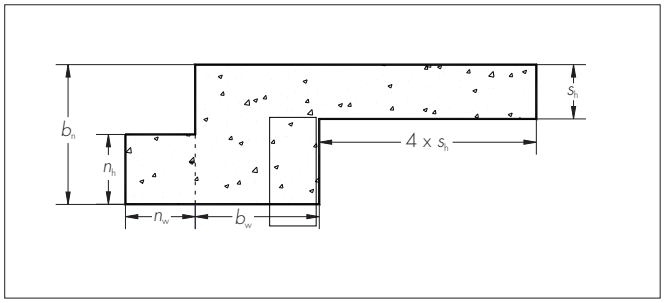
- the service and ultimate loads on the edge and internal beams, including the weight of the concrete raft, are determined
- the values are compared with those given in Table 4 which are based on the slab and edge beam being dimensioned in accordance with Figure 4.

*Table 4 Load capacity of internal and edge beams[1] (see Figure 4)*

| Size (mm) ($b_w$ x $b_h$) | Edge beam (kNm$^{-1}$) | | Internal beam (kNm$^{-1}$) | |
|---|---|---|---|---|
| | Service | Ultimate | Service | Ultimate |
| 300 x 450 | 64 | 91 | 27 | 38 |
| 350 x 450 | 70 | 100 | 31 | 44 |
| 450 x 450 | 80 | 114 | 39 | 55 |
| 450 x 600 | 140 | 199 | 96 | 136 |
| 600 x 600 | 160 | 227 | 127 | 180 |

(1) The following conditions apply to the values in this table:
- edge beam nib dimensions: $N_w$ = 225 mm and $N_h$ = 225 mm
- the slab is assumed to have an average thickness of 170 mm, and a 680 mm width of the slab contributes to the resistance of the edge beam
- allowance is not made for the contribution of the adjacent slab for internal beams
- the worst case for design is taken as the formation of a 3 m diameter sinkhole below the internal beam.
- the values account for ultimate loads (1.4 x dead load + 1.6 x imposed load), service loads and a material factor of 1.25
- the values cover bending, shear and deformation.

*Figure 4 Edge beam details*




5.7 Insulation used should have the minimum properties given in Table 5.

*Table 5 Minimum properties of insulation*

| Property | Value |
|---|---|
| Compressive strength (10% compression) (kPa) | 150 |
| Compressive strength (1% nominal strain) (kPa) | 70 |
| Bending strength (kPa) | 200 |
| Water vapour diffusion resistance factor (μ) | 30–70 |
| Water vapour permeability (mg Pa$^{-1}$h$^{-1}$m$^{-1}$) | 0.010–0.024 |
| Vapour resistivity (MNsg$^{-1}$) | 238 |
| Thermal conductivity at 10°C (Wm$^{-1}$K$^{-1}$) | 0.035 |
| Thermal resistivity (mKW$^{-1}$) | 28.57 |

## Design method for pile-supported slabs with internal suspended floors

5.8 This method covers situations where the concrete is used over piles to form edge beams, internal beams and a ribbed two-way spanning slab, and is appropriate for situations where the:
- slab and beams have dimensions in accordance with Figures 3, 4 and 5
- minimum size of the piles is 180 mm diameter
- maximum unfactored imposed live load on the floor area is 8.65 kNm$^{-2}$
- maximum distance between piles is 6 m
- maximum ultimate load per pile is 300 kN.

5.9 The service and ultimate loads on the edge and internal beams are determined. The permissible loads that can be carried by the ground beams and internal beams are indicated in Table 6.

*Table 6 Load capacity of edge and internal beams of pile-supported slabs[1] (see Figure 4)*

| Beam section (width x depth) (mm) | Location | Load capacity ($kNm^{-1}$) Span between piles (m) | | | | |
|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 |
| | | s/u[2] | s/u[2] | s/u[2] | s/u[2] | s/u[2] |
| 300 x 450 | Internal | 62/88 | 23/32 | 10/14 | n/a | n/a |
| | edge | 155/220 | 65/92 | 34/48 | 19/27 | n/a |
| 350 x 450 | Internal | 80/114 | 30/42 | 13/18 | n/a | n/a |
| | edge | 168/238 | 70/99 | 36/51 | 20/28 | n/a |
| 450 x 450 | Internal | 122/173 | 50/71 | 24/34 | 12/17 | n/a |
| | edge | 190/269 | 77/109 | 41/58 | 23/32 | n/a |
| 450 x 600 | Internal | 208/295 | 87/123 | 54/77 | 25/35 | 14/19 |
| | edge | 330/468 | 142/201 | 75/106 | 44/62 | 28/39 |
| 600 x 600 | Internal | 252/359 | 106/150 | 54/76 | 30/42 | 17/24 |
| | edge | 378/536 | 162/230 | 85/120 | 51/72 | 30/42 |

(1) These figures are based on the following assumptions:
- edge beam values assume nib dimensions of: $n_w$ = 225 mm and $n_h$ = 225 mm (see Figure 4)
- ground beams are assumed to be simply supported between the piles verified as statically determinate between two adjacent piles and allowable service strengths are based on section 5.3 of this document.

(2) s/u = service limit state/ultimate limit state.

5.10 Slabs and rafts[1] greater than 200 $m^2$ with re-entrant corners larger than 1 m by 1 m, and a length to width (*L*/*w*) ratio smaller than 1.5, will not require additional reinforcement at the re-entrant corners. Slabs outside these criteria will need to incorporate wiremesh (A252) reinforcement 1 m by 0.8 m at the re-entrant corners placed at 45° and the Certificate holder's advice should be sought.

(1) Slabs and rafts covered by this Certificate.

5.11 Movement joints should be included as required by the structural engineer. In general, joints are required when:

- the slab area is greater than 900 $m^2$, or
- the length to width ratio > 1.5, or
- the length of the slab exceeds 30 m.

## 6 Maintenance

As the product is inaccessible once installed and has suitable durability (see section 7), maintenance is not required.

## 7 Durability

From independent test data, it is confirmed that the durability of concrete reinforced with fibres will be at least equivalent to that of plain concrete of the same grade. There may be some discoloration on exposed surfaces but this will not penetrate into the concrete provided it is designed and used in accordance with this Certificate. The concrete (as specified in section 1.3) will have adequate durability for the stipulated use.

# Installation

## 8 Site preparation

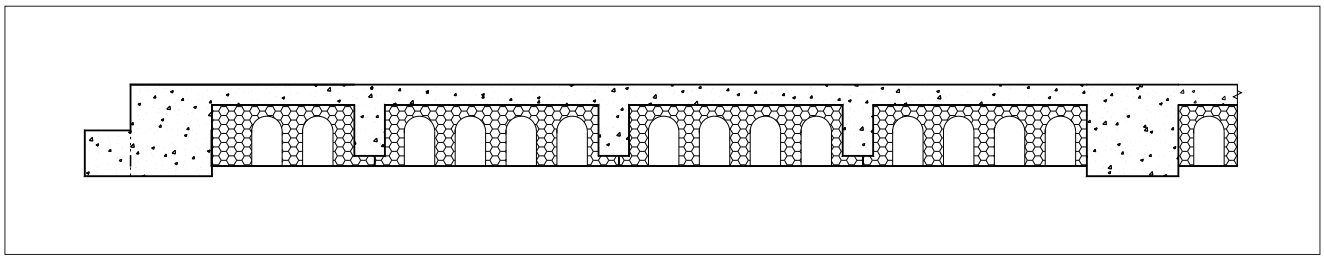
8.1 The ground beneath the ArcelorMittal Steel-Fibre-Reinforced Concrete should be free of topsoil and vegetation and should have adequate resistance to the average ground pressure (see Table 3). Generally, consolidated ground beneath the slab should be at least 150 mm thick and, under thickened edges, at least 225 mm thick (see section 5).

8.2 The required foundations should be made to the correct level using conventional methods. Excavations must be carried out in accordance with BS 6031 : 1981, paying particular attention to safety procedures.

## 9 Procedure

9.1 Typical installation details for a ground-bearing slab using the product are given in Figure 5.

*Figure 5 Typical installation details*



9.2 When using strip foundations to support loadbearing walls, the slab may be formed by the methods described in sections 9.3 and 9.4. For larger slabs, the methods described in the Concrete Society Technical Report No 34 *Concrete industrial ground floors: a guide to design and construction* should be used.

9.3 The foundations are installed and the wall built up to an appropriate level for the slab. The excavation is backfilled externally with excavated material and internally with compacted granular fill.

9.4 Prior to the pour, provision must be made for services where they penetrate the slab.

9.5 A blinded sub-base to smooth the surface as for industrial floors is considered acceptable.

9.6 A damp-proof membrane (dpm) is laid over the blinding extending by 500 mm beyond the face of the perimeter walls, ensuring that at corners, joints and services, the membrane is folded and sealed in accordance with the manufacturer's recommendations. If the dpm is placed above the insulation and below the slab, it acts as a slip membrane/grout barrier.

9.7 The appropriate grade of insulation (not covered by this Certificate) is placed over the area to be concreted using butt joints. This may be solid insulation or waffle construction.

9.8 Depending on the construction detail, concrete is poured onto the dpm or slip membrane/grout barrier. Where self-levelling concrete is not used, beam vibration and tamping methods are used to provide the floor finish to line and level.

9.9 Standard finishing and curing techniques are used. Protruding fibres are snipped flush where necessary.

9.10 The dpm is lapped with the damp-proof course (dpc) in the mortar joint of the inner leaf of the wall and trimmed to ensure it does not protrude into the cavity.

# Technical Investigations

## 10 Investigations

10.1 An assessment was made of the durability of the dosed concrete.

10.2 An examination was made of data relating to the structural performance of the steel-fibre-reinforced concrete, including:

- reports of full-scale tests
- flexural strength
- tensile strength
- resistance to punching shear.

10.3 Calculations based on procedures defined in BS EN 1992-1-1 : 2004, sections 2.5 and 2.6, were verified and permissible load/span data confirmed for each proposed type of application.

## 11 Other investigations

11.1 Site visits were made to assess the practicability of installation.

11.2 An examination was made of the production control procedures.

11.3 A review was undertaken of the data on CE Marking in accordance with EN 14651 : 2005.

# Bibliography

BS 6031 : 1981 *Code of practice for earthworks*

BS 8500-2 : 2006 *Concrete — Complementary British Standard to BS EN 206-1 — Specification for constituent materials and concete*

BS EN 1992-1-1 : 2004 *Eurocode 2 : Design of concrete structures. General rules and rules for buildings*

EN 14651 : 2005 *Test method for metallic fibre concrete — Measuring the flexural tensile strength (limit of proportionality [LOP], residual)*

EN 14889-1 : 2006 *Fibres for concrete — Steel fibres — Definitions, specifications and conformity*

ASTM A820/A820M 06 *Standard Specification for Steel Fibers for Fiber-Reinforced Concrete*

## 12 Conditions

12.1 This Certificate:

- relates only to the product/system that is named and described on the front page
- is granted only to the company, firm or person named on the front page — no other company, firm or person may hold or claim any entitlement to this Certificate
- is valid only within the UK
- has to be read, considered and used as a whole document — it may be misleading and will be incomplete to be selective
- is copyright of the BBA
- is subject to English law.

12.2 Publications and documents referred to in this Certificate are those that the BBA deems to be relevant at the date of issue or re-issue of this Certificate and include any: Act of Parliament; Statutory Instrument; Directive; Regulation; British, European or International Standard; Code of Practice; manufacturers' instructions; or any other publication or document similar or related to the aforementioned.

12.3 This Certificate will remain valid for an unlimited period provided that the product/system and the manufacture and/or fabrication including all related and relevant processes thereof:

- are maintained at or above the levels which have been assessed and found to be satisfactory by the BBA
- continue to be checked as and when deemed appropriate by the BBA under arrangements that it will determine
- are reviewed by the BBA as and when it considers appropriate.

12.4 In granting this Certificate, the BBA is not responsible for:

- the presence or absence of any patent, intellectual property or similar rights subsisting in the product/system or any other product/system
- the right of the Certificate holder to manufacture, supply, install, maintain or market the product/system
- individual installations of the product/system, including the nature, design, methods and workmanship of or related to the installation
- the actual works in which the product/system is installed, used and maintained, including the nature, design, methods and workmanship of such works.

12.5 Any information relating to the manufacture, supply, installation, use and maintenance of this product/system which is contained or referred to in this Certificate is the minimum required to be met when the product/system is manufactured, supplied, installed, used and maintained. It does not purport in any way to restate the requirements of the Health & Safety at Work etc Act 1974, or of any other statutory, common law or other duty which may exist at the date of this Certificate; nor is conformity with such information to be taken as satisfying the requirements of the 1974 Act or of any statutory, common law or other duty of care. In granting this Certificate, the BBA does not accept responsibility to any person or body for any loss or damage, including personal injury, arising as a direct or indirect result of the manufacture, supply, installation, use and maintenance of this product/system.

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British Board of Agrément
Bucknalls Lane
Garston, Watford
Herts WD25 9BA



tel: 01923 665300
fax: 01923 665301
e-mail: mail@bba.star.co.uk
website: www.bbacerts.co.uk