ReforceTech™

Mineral Fiber Reinforcement Technology

Åpent faglig møte i Bergen - Kompositt, Basalt og AR Glass

For eksempel i kai/marine konstruksjoner og andre konstruksjoner i korrosive miljøer. Kompositt armering korroderer ikke, er lett, fleksibel og har høy strekkfasthet.

Selskapet ReforceTech produserer og selger kompositt armering, MiniBars™ og BasBars™ som erstatning for armeringsstål både i form av strukturell makro fiber og tradisjonelle stenger. Produktene er sertifisert fra Kontrollrådet og DnV med tilhørende dimensjoneringsveileder.

I dette foredraget kommer man inn på produkttyper, produksjon, virkemåte, egenskaper som strekkfasthet, heftegenskaper, brannmotstand etc. Ulike aktuelle bruksområder blir også presentert.

Per Cato Standal og Len Miller, ReforceTech

norsk betongforening

19.04.2018

ReforceTech™

Mineral Fiber Reinforcement Technology

Complete solutions in Durable High Strength Composite reinforcement for concrete

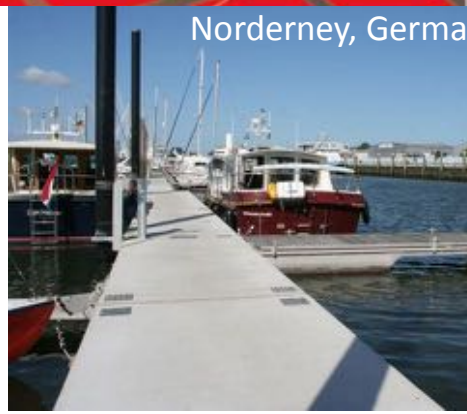
- Material and labor cost savings
- Productivity gain
- Design freedom
- Weight savings
- Does not corrode, longer life span

norsk betongforening

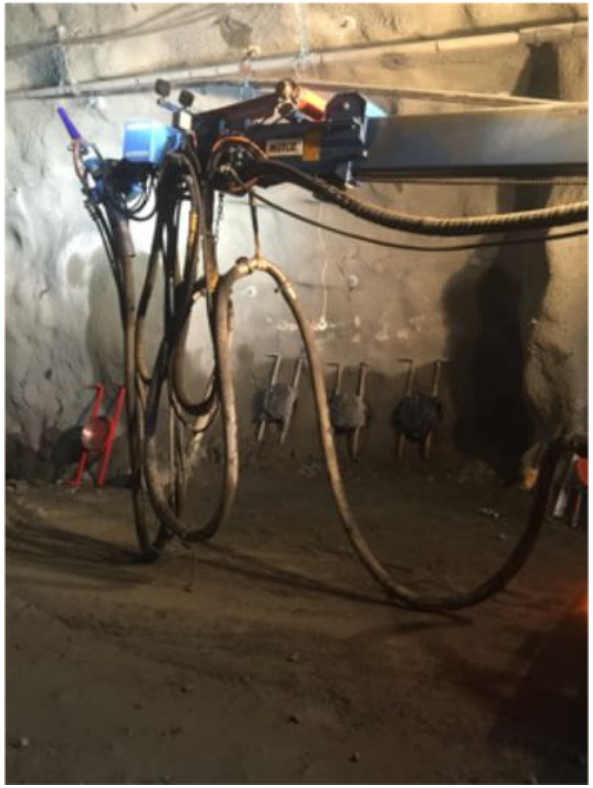
19.04.2018

ReforceTech™

Mineral Fiber Reinforcement Technology



Transforming one the worlds largest commodity markets with innovative solutions



Shotcrete
&
Rockbolts

Application examples

Market application areas and references

1. Marine and floating
   - Pontoons
   - Barges
   - Keys and Jetties, seawalls
   - Sea weights
2. Pre-cast
   - Sandwich panels
   - Façade elements
   - Architectural precast
   - Inner walls
   - Barrier walls, concrete fences
   - Balconies
   - Pressure tanks and liquid containment tanks
   - HPC and UHPC applications
   - Non-conductive utility Poles
3. Infrastructure
   - Tunnel elements
   - Concrete Pipes
   - Bridge decks and edge beams
   - Slab on ground and roads and driveways
   - Pavements
   - Rail infra-structure
   - Non-conductive tram switches
4. Construction and in-situ
   - Slab on ground
   - Foundations and rafts
   - Screed
   - Inner Walls
   - Façade walls
   - Retaining walls
   - Piles
   - MRI suites
5. Shot Crete
6. Rock Anchors

Application Examples

TUNGE TING

Application Examples

SF MARINA

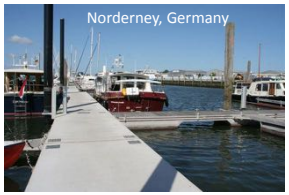
Floating Infrastructure
New Innovations by SF Marina

- Lower material cost, lower costs to produce, ship and maintain
- Corrosion Free
- 40% lighter
- Installations in Norway, Sweden, Germany, and Middle East

Started with bars and nets in 2008.
Moved to Carpets in 2009.
Now produced with pre-tensioned BasBars™ and MiniBars™.
Large Pontoons and small pontoons.
40mm walls, higher freeboard.

SF MARINA

BASALT (x-line)



Application Examples

Vollen by Telebryggen

- Installed Oct 2008
- Built with BFRP BasBars™
- Tendons and Nets

Pontoons for Telebryggen built exclusively by SystemBlokk in Norway

MiniBars™
Development route in Precast Insulated Wall Panels

- **MiniBars™** solution is in use on projects in Norway, Sweden, UK, USA, Canada

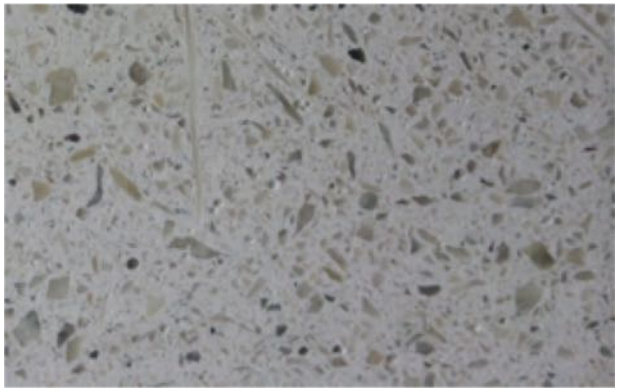
- **Market trend for thinner panels** driven by Architects
- Construction Industry seeks **new wall panel design and solution**

- This leads to **thinner & lighter panels**, bringing **manufacturing and logistic cost saving**, as well as **improved and simplified installation** by contractor, and last but not least **allowing weight saving** for the whole building driving to **lighter foundation**

- **Typical development route includes 2 phases**:
  - Immediate Applications
    - Target to reduce thickness of outer concrete layer by 50%, typically from 80mm (3”) to 40mm (1 ½”)
    - Structural Performance of inner concrete layer remains the same
    - Lowers manufacturing costs up to 30%
    - Panels with white polished concrete finish show up to 65% savings
    - Use of composite rebar at stress concentration areas such as the inside corners of windows and door openings
  - Second step
    - Target to reduce thickness of inner concrete layer by 50%

MiniBars™
Development route in Precast Insulated Wall Panels

- **MiniBars™** macrofiber can be used with different types of finish:
  - Form finish
  - Polished surface
  - Sand blasted
  - Form liner
- After polishing or sand blasting, fiber laid out on the surface might be visible
- Fiber will not pull out with Sand Blasted finish



MiniBars™ | Case Studies

ICA Shopping Center, Ljungskile Sweden

Entrance detail with thinner outer layer

Mineral Fiber Reinforcement Technology

Store Entrance

Project Profile:

Category:	Retail Store
Owner & Developer:	ICA Grocery Stores
Structural Engineer:	AFG Consulting Engineers
General Contractor:	Kynningsrud
Precaster:	Kynningsrud
Completion:	December 2015

Technical details:

Precast Element:	Precast Insulated Wall Panels 40mm (1 ½") outer concrete layer White polished concrete finish
Concrete Type:	C50/60 – 7250 psi Concrete
Composite reinforcement solution:	Cem-FIL MiniBars™ 43mm @ 5,7 Kg/m³ – 9.6 lbs/yd³ Composite bars to strengthen corners at windows & doors and FRP connectors to connect wythes
Other:	Unique corner design with polished surfaces at 90 degree end panels

Project description:

- For this project, the challenge was to supply precast insulated wall panels for the front entrance that were less weight and thinner profile than standard panels
- By replacing all WWR steel mesh with MiniBars™ corrosion-free composite macrofiber, the need for cover concrete was reduced
- The outer concrete layer thickness went down by 50% from 80mm (3") to 40mm (1 ½") and then polished further to 35mm (1 3/8")
- Composite bars were used to strengthen the panels at stress concentration points
- FRP composite wythe connectors were also used so that there is no metallic reinforcing in the layer of concrete exposed to weather and no heat transfer points for maximum insulation value.

MiniBars™ | Case Studies

Rasmirent Kungsängen Sweden

Horizontal stacked precast insulated panels

Warehouse and Office

Project Profile:

Category:	Commercial Building
Owner & Developer:	Kilenkrysset
Structural Engineer:	AFG Consulting Engineers
General Contractor:	Kilenkrysset
Precaster:	Kilenkrysset
Completion:	2015

Technical details:

Precast Element:	Precast Insulated Wall Panels 40mm (1 ½") outer concrete layer Stucco-style finish, painted black or white 60mm (2 ¼") inner concrete layer
Concrete Type:	C50/60 – 7250 psi
Composite reinforcement solution:	Cem-FIL MiniBars™ 43mm @ 5.7 Kg/m^3 – 9.6 lbs/yd^3 Composite bars strengthening at corners in window and door openings
Other:	-

Project description:

- For this 2-story front office and 3-story warehouse project, the challenge for Kilenkrysset was to supply precast insulated wall panels that were 50% less weight and thinner profile than standard panels
- By replacing WWR steel mesh with MiniBars™ corrosion-free composite macrofiber, the need for concrete cover was reduced so that the thickness of both the outer and inner concrete layer were 50% less.
- The outer layer was reduced from 80mm (3") to 40mm (1 ½").
- The inner layer was reduced from 120mm (4 ¾") to 60mm (2 ¼")
- Composite bars were used to strengthen the panels at stress concentration points at the inside corners of doors and windows
- Horizontally oriented panels do not require prestressed steel reinforcing that is typically used in vertical panels

MiniBars™ | Case Studies

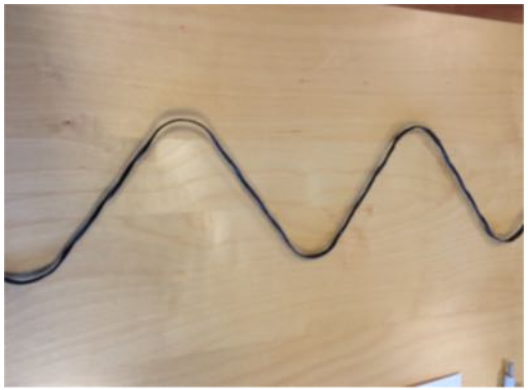
Gate Precast, Ashland City, TN

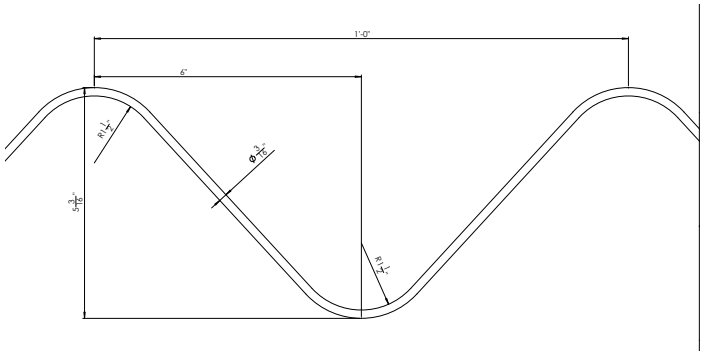
Project description:

- Non Insulated façade panel
- 6’ (1,8m) tall by 30’ (9,0m) long architectural panel
- 2” (50mm) general thickness and deeper ribs (6”/150mm) around the perimeter for structural stiffness and appearance
- This panel would normally be 4” to 5” (100 to 125 mm) thick throughout

Application Examples

ReforceTech BasWave™ Connector





Complete solutions in Durable High Strength Composite reinforcement for concrete

Value Proposition:

- Combination of High Performance Composite Macro-Fibers MiniBars™ and BasBars™ reduce or eliminate the need for reinforcing with steel or steel mesh
- Reducing the complexity of the casting and manufacturing process
- Making Concrete casting easier and allowing design freedom
- Corrosion resistant – allowing use in concrete structures exposed to marine or corrosive environment.

- **Customer Value Drivers:**
- Material & Labor Cost savings
- Productivity gain
- Design freedom
- Weight savings, lighter elements
- Longer life span solution

Complete reinforcement system for concrete
Durable high performance composite reinforcement

High Performance Composite BasBars™ - Rebars, Mesh and kits

ReforceTech unique rebar system is given Certificate of Fitness from DnV-GL and comes with approved designed guidelines.

Rebars

Ties & Stirrups

Mesh, carpets

Customised geometrics

High Performance Composite Macro-Fibers MiniBars™

New highly competitive breakthrough technology for the large commodity market: **Pre-Reinforced Concrete**

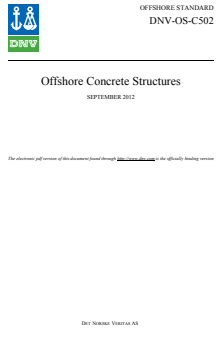
- ReforceTech MiniBars™ enable the concrete to be designed for loadbearing capacity with high flexural tensile strength and average residual strength
- MiniBars™ are mixed directly in concrete to make it ductile and eliminate or reduce the need for reinforcing with steel and wire welded mesh.

Certificates and Guidelines

Guidelines

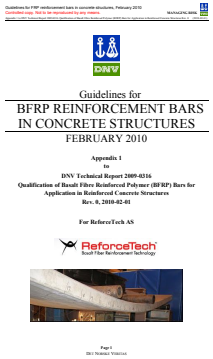
DNV-OS-C502: Fibre reinforced concrete (**MiniBars™**) and fibre reinforced rods (**BasBar™**)) replacing steel reinforcement as reinforcement in concrete structures.

BasBar™ is certified by DNV-GL, including material certificate
MiniBars™ are certified by DIBt, and Kontrollrådet


OFFSHORE STANDARD
DNV-OS-C502

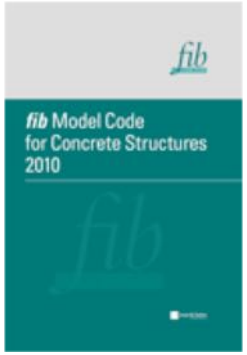
Offshore Concrete Structures

SEPTEMBER 2012


Guidelines for
BFRP REINFORCEMENT BARS
IN CONCRETE STRUCTURES
FEBRUARY 2010

Appendix 1
to
DNV Technical Report 2009-0316
Qualification of Basalt Fibre Reinforced Polymer (BFRP) Bars for Application in Reinforced Concrete Structures
Rev. 0, 2010-02-01

For ReforceTech AS



Rilem TC 162 TDF	Design of Steel fibre reinforced concrete – Method, recommendations, Material and Structures, 2002
DBV DAfStb-guideline	FRC to DIN 1045, part 1 to 3 and EN 206-1, mars 2010, Final version, 03/2010.
Eurocode 2 ; BS EN 1992	Design of concrete structures
FIB Model Code 2010	Design of FRC members and slabs
Eurocodes 2;1	design of concrete strucutures, appendix 3

Certificates


DET NORSKE VERITAS
CERTIFICATE OF FITNESS FOR SERVICE

Basalt Fibre Reinforced Polymer (BFRP) bars


Allgemeine bauaufsichtliche Zulassung


SERTIFIKAT

Det bekreftes med dette at

ReforceTech AS

Luftveien 4, 3440 Royken

har etablert og følger et system for produksjons-kontroll som tilfredsstiller:

Kontrollrådet's " Produksjons system for produksjonskontroll (PKS) - Februar 2017"

Sertifikatet gjelder for fremstilling av følgende produkter:

Basalt Mini Bars og AR Glass Mini Bars - en fiberforsterket, ikke metallisk armering for betong - i samsvar med vedlagte Tekniske spesifikasjon fra ReforceTech AS datert 05.09.2017.

Sertifikatet utgår senest

2020.09.30

Sertifikat nummer: PROD-122
Utstedt første gang: 2017.09.05
Fornyet dato:

Sertifiseringsleder

KONTROLLRÅDET


CERTIFICATE

It is hereby certified that:

has established and implemented a quality system in compliance with:

The Certificate appplies to the manufacture of the following products:

The Certificate expires at the latest

Certificate number:
Initially issued:

Certification Manager

KONTROLLRÅDET

Shotcrete development and cooperation

Proceedings of the World Tunnel Congress 2017 – Surface challenges – Underground solutions. Bergen, Norway.

MiniBars™ – A non-corroding macro mineral fiber for rock support

Sindre Sandbakk
Norconsult AS/Dr. Techn. Olav Olsen AS, Trondheim, Norway.
Leonard William Miller and Per Cato Standal
ReforceTech AS, Røyken, Norway.

ABSTRACT: ReforceTech has developed a macro fiber type, MiniBars™, made of Alkaline Resistant-Glass or Basalt, as a durable alternative for shotcrete in tunnels. By use of MiniBars™, the material use can be reduced, and thereby the CO_2 footprint will be reduced. MiniBars™ has no electrical conductivity, has a density close to concrete (2100 kg/m3) and mixes easily into the concrete in sufficient large volumes to meet the specified energy absorption criteria. Due to the density, it does not float and pollute in underwater tunnels, nor does it clog the water pumps. The MiniBars™ have four bonding mechanisms; length, helix, fiber roughness and diameter. All these four parameters can be tailored to optimize the performance for a given application. Recently, an experimental program has been carried out to quantify the necessary fiber amount to reach E700 and E1000 per the Norwegian Concrete Association's Publication No 7.

8 CONCLUSION

MiniBars™ have been subjected to extensive investigations to be approved for use in structural and/or non-structural applications. The investigations have been primarily focused on durability and possible degradation of both the fiber and the concrete. No such signs are found, meaning that concrete reinforced with MiniBars™ is durable, even in areas where the concrete is cracked!

The field testing at Kongsberg, and the following NB 7 testing at SINTEF, demonstrates that there are no difficulties in mixing, pumping and spraying MiniBar™ reinforced concrete in energy class E700 and E1000.

Field test of MiniBars™ for Shotcrete

SINTEF

SINTEF Byggforsk
Postadresse:
Postboks 124 Blindern
0314 Oslo
Besøksadresse:
Forskningsveien 3b
Oslo
Sentralbord: 73593000
byggforsk@sintef.no
http://www.sintef.no/Byggforsk/
Foretaksregisteret:
NO 948007029 MVA

NORSK AKKREDITERING
Test 107

Prøvingsrapport

Prøving av sprøytebetong i hht NB7:2011

Materiallaboratoriet Oslo

Dato:
2016-10-31

Prosjektleder/forfatter(e):
Arne Gunnar Bruun

Oppdragsgiver(e):
Norconsult AS (eier)
Statens Vegvesen (bestiller)
Veidekke og ReforceTech (bidragsytere)

Oppdragsgivers referanse:
Sindre Sandbakk
NB 7- prøving ReforceTech
Minibars

Prosjektnummer:
102014634

Antall sider og vedlegg:
4 + 1 vedlegg

Sammendrag:

SINTEF Byggforsk mottok 2016-09-29 18 stk. plateprøver (Ø600 × 100 mm). Prøvene ble tildelt merkingen V-471 ved ankomst. Heretter omtalt ved prøve 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 ,11, 12, 13, 14, 15, 16, 17 og 18

Prøvene er tilvirket uten SINTEFs medvirkning.

Tabell 1: Oversikt over prøvemetoder

Metode	Akkreditert	Beregnet måleusikkerhet
Energiabsorpsjon, NB7:2011	Ja	± 3 %

Prosjektleder/forfatter:
Arne Gunnar Bruun
Signatur

Kontrollert av:
Kari Aarstad
Signatur

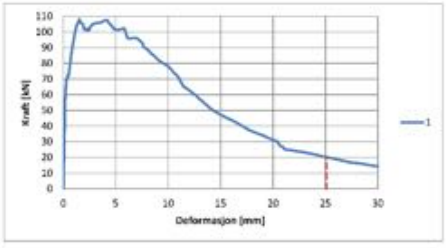
Rapportnr:
SBF2016F0491

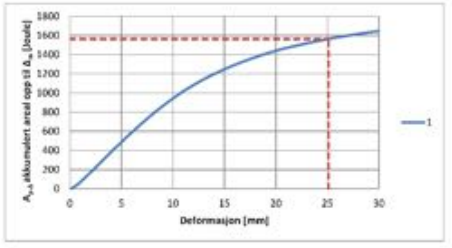
Gradering:
Fortrolig

Test results

Tabell 3: Resultat – energiabsorpsjon panel 1, 2 og 3

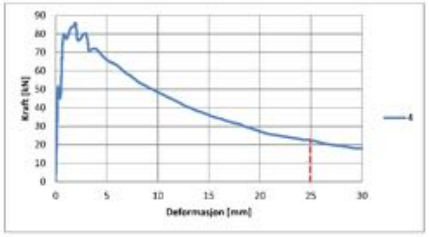
Panel	*t* [mm]	*d* [mm]	Antall brudd	Skjærbrudd	P_{max} [kN]	P_{rest} [kN]	E_{abs} [J]
1	100	600	9	Ja	108,2	20,1	1172,5
2	101	599	8	Nei	98,9	26,4	1085,5
3	102	600	6	Ja	95,0	14,5	958,3
Middel	101	600			**100,7**	**20,3**	**1072,1**

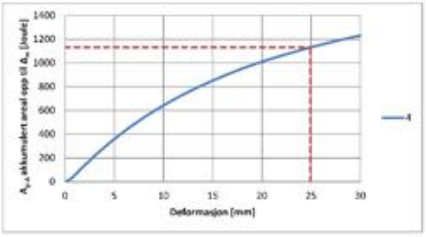




Tabell 4: Resultat – energiabsorpsjon panel 4, 5 og 6

Panel	*t* [mm]	*d* [mm]	Antall brudd	Skjærbrudd	P_{max} [kN]	P_{rest} [kN]	E_{abs} [J]
4	100	600	6	Nei	86,0	22,5	847,3
5	100	600	5	Nei	69,9	14,7	669,1
6	101	600	6	Nei	66,3	14,6	641,3
Middel	100	600			**74,1**	**17,3**	**719,2**





E700 was reached with 15 kg/m3 MiniBars™, and E1000 with 25 kg/m3 MiniBars™, corresponding to 933 J and 1333 J according to EN 14488-5.

ReforceTech
Mineral Fiber Reinforcement Technology

ReforceTech in collaboration with

OWENS CORNING normet

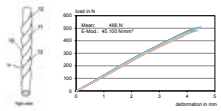
MiniBars™ - A non corroding macro mineral fiber for rock support

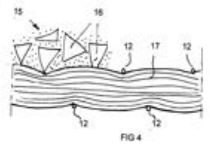
Sindre Sandbakk
Norconcult AS / Dr Techn. Olav Olsen AS,
Trondheim, Norway

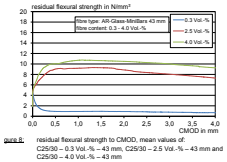
Leonard Miller
ReforceTech AS
Røyken, Norway

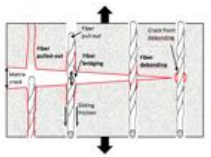
Per Cato Standal
ReforceTech AS
Røyken, Norway

How a MiniBar™ Works







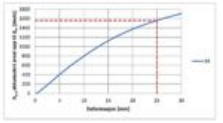


- **MiniBars™** solution is a **High-Strength Composite Macro Fiber** to reinforce concrete consisting of 1200 fibers glued together to create the MiniBar™
- Density of MiniBars is 2,1 similar to concrete meaning excellent workability and high fiber count
- 4 bonding mechanisms, length, diameter, helical shape and rough surface
- Elastic mechanical behavior combined with bonding and pull out resistance results in immediate load capacity
- Designed to **bring post-cracking performance** to Concrete
- Dosage can be tailored to meet design specifications
- **MiniBars™** macro fibers enable the concrete to be designed for load bearing capacity with high Flexural Tensile Strength and high Average Residual Strength

Proven Durability in Concrete

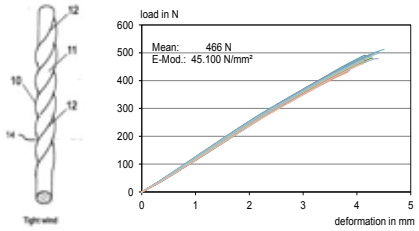
- **Certified by DIBt Z-3.72-2098 to DIN – EN 14889-2**
- **Certified harmless in concrete**
- **Static Performance proven and certified and characterized in accordance to EN14651 from 0,25 to 3% VF**
- **Class A1 Flammability rating in accordance to DIN 4102 Class A1 up to 3VF% (63Kg/M3)**
- **Proven durability in accordance with DIBt certification process.**
  - CemFil AR Glass from Owens Corning with over 45 years proven field experience
  - >16,5% Zirconia mineralogy to be classed as AR Glass
  - 100% amorphous (non crystalline)
  - Contains none of the three known reactive forms of silica susceptible to alkali attack, Opal, Chalcedony nor Tridymite
- **Accelerated age testing demonstrated in IBAC (Aachen University) in accordance with the DIBt to demonstrate the MiniBar™ reinforced concrete has the long term durability required for structural reinforcement.**

Proven Shotcrete Performance



- **Field testing at Kongsberg, and the following NB 7 testing at SINTEF, demonstrates that there are no difficulties in mixing, pumping and spraying MiniBar™ reinforced concrete in energy class E700 and E1000.**
- **E700 was reached with 15 kg/m3 MiniBars™, and E1000 with 25 kg/m3 MiniBars™, corresponding to 933 J and 1333 J according to EN 14488-5.**
- **Fiber count in fresh concrete demonstrated remarkably low values of variation. This is due to the density of the MiniBars™, resulting in low variations in performance.**
- **The standard deviation was 5 % on average for 5 different deliveries.**

How a MiniBars™ Works



Single Fiber Tensile Tension – 20°C – AR-Glass MiniBars

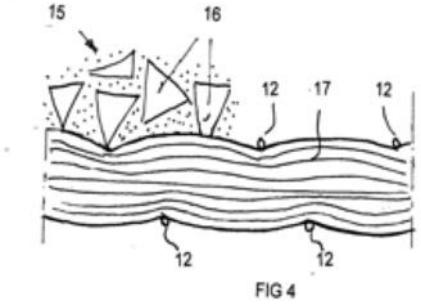


FIG 4

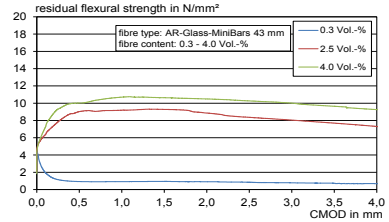
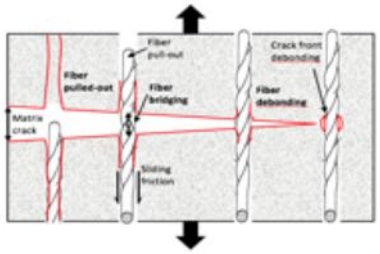


Figure 8: residual flexural strength to CMOD, mean values of: C25/30 – 0.3 Vol.-% – 43 mm, C25/30 – 2.5 Vol.-% – 43 mm and C25/30 – 4.0 Vol.-% – 43 mm



- **MiniBars™** solution is a **High-Strength Composite Macro Fiber** to reinforce concrete consisting of 1200 fibers glued together to create the MiniBar™
- Density of MiniBars is 2,1 similar to concrete meaning excellent workability and high fiber count
- 4 bonding mechanisms, length, diameter, helical shape and rough surface
- Elastic mechanical behavior combined with bonding and pull out resistance results in immediate load capacity
- Designed to **bring post-cracking performance** to Concrete
- Dosage can be tailored to meet design specifications
- **MiniBars™** macro fibers enable the concrete to be designed for load bearing capacity with high Flexural Tensile Strength and high Average Residual Strength

DIN 4102-1 fire test to building material - Test Method

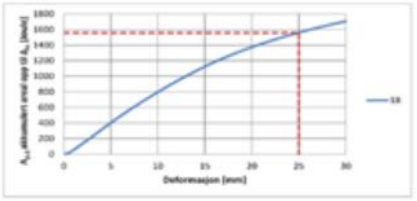
When the material's fire behaviour has been determined in accordance with the standard, it divides into:

Building material class		Designation
Class A	A1	Non-combustible materials
	A2	
Class B	B1	Not easily flammable
	B2	Flammable
	B3	Easily flammable

Proven Durability in Concrete

- **Certified by DIBt Z-3.72-2098 to DIN – EN 14889-2**
- **Certified harmless in concrete**
- **Static Performance proven and certified and characterized in accordance to EN14651 from 0,25 to 3% VF**
- **Class A1 Flammability rating in accordance to DIN 4102 Class A1 up to 3VF% (63Kg/M3)**
- **Proven durability in accordance with DIBt certification process.**
  - CemFil AR Glass from Owens Corning with over 45 years proven field experience
  - >16,5% Zirconia mineralogy to be classed as AR Glass
  - 100% amorphous (non crystalline)
  - Contains none of the three known reactive forms of silica susceptible to alkali attack, Opal, Chalcedony nor Tridymite
- **Accelerated age testing demonstrated in IBAC (Aachen University) in accordance with the DIBt to demonstrate the MiniBar™ reinforced concrete has the long term durability required for structural reinforcement.**

Proven Shotcrete Performance



- **Field testing at Kongsberg, and the following NB 7 testing at SINTEF, demonstrates that there are no difficulties in mixing, pumping and spraying MiniBar™ reinforced concrete in energy class E700 and E1000.**

- **E700 was reached with 15 kg/m3 MiniBars™, and E1000 with 25 kg/m3 MiniBars™, corresponding to 933 J and 1333 J according to EN 14488-5.**

- **Fiber count in fresh concrete demonstrated remarkably low values of variation. This is due to the density of the MiniBars™, resulting in low variations in performance.**

- **The standard deviation was 5 % on average for 5 different deliveries.**

PRODUCTION IN RØYKEN, NORWAY

MiniBars™ and BasBar™ Production in Røyken, Norway

MiniBars™ machine output

- Nominal Output of 500 MT of MiniBar's per year on 3 shifts 5 days
- MiniBar™ diameters 0.7mm dia.
- MiniBar lengths variable from 12mm to 60mm

BasBar™ machine output

- Straight Bars
- Windings and angles
- Kits

MINIBARS™

HIGH PERFORMANCE COMPOSITE MACROFIBER

TECHNICAL CHARACTERISTICS

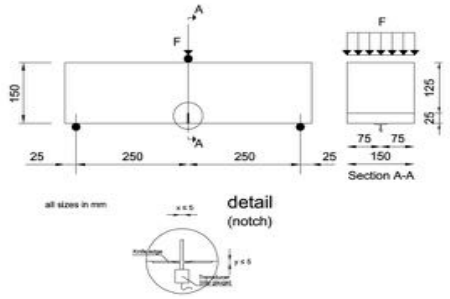
Material	Fiber Length	Fiber Diameter	Specific Gravity	Modulus of Elasticity	Tensile Strength
Alkali-resistant glass+ thermoset resin	43 +/-2 mm* 1.7 +/- 0.08 in.	0.70 mm 0.03 in.	2.0 ± 0.1	42 GPa 6,091,585 psi	> 1000 MPa / 145,038 psi

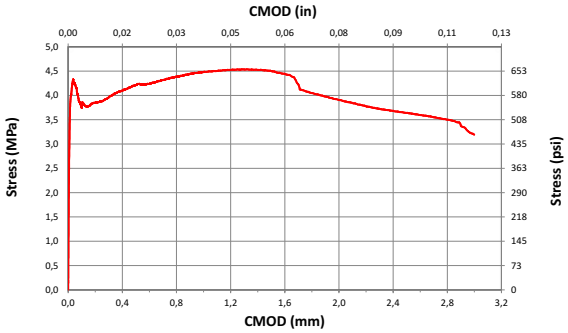
* Shorter or longer fibers are available on request

MECHANICAL PERFORMANCE

The fundamental mechanical performance of fiber reinforced concrete can be obtained from a three-point bending test performed on a prismatic beam of 150×150×550mm (6×6×22in.) including a notch at mid-span (EN 14651). The displacement-controlled testing system introduces a specific deflection or CMOD (Crack Mouth Opening Displacement) rate, and records load and displacement up to a CMOD limit of 3.5 mm (0.14 in). The fiber reinforced concrete performance is evaluated by means of residual flexural strength values at 0.5, 1.5, 2.5, and 3.5mm (0.02, 0.06, 0.10, and 0.14in.) of CMOD, namely f_{R1}, f_{R2}, f_{R3} and f_{R4}, respectively.

According to the fib Model Code 2010, the constitutive law of the material in tension is defined by means of the tensile stresses f_{Fts} and f_{Ftu}, calculated from f_{R1} and f_{R3} for service and ultimate limit state, respectively.





The sketch shows the basic configuration of the test.

The following curve shows a typical Load-CMOD response of a C30/37 concrete (4400 psi) reinforced with 10 kg/m³ (17 lbs/yd³) of MiniBars™. The table presents the mean values of residual strength.

Concrete Description :
EN206-1 C30/37 XC3/XC4 Dmax20 S4 CL 1.00, Slump=22 cm
ACI 211| 4400 PSI Concrete, C1/F1 exposure class, 8 ½" max. aggregate, 8 ¾" slump

Mean flexural performance (prism 100x100x400mm | 4x4x16 in)	MPa (mean)	psi (mean)
f_c (100 mm / 4 in cube)	46.9	6800
f_L	4.35	631
f_{R1}	3.67	532
f_{R2}	3.99	579
f_{R3}	3.61	524
f_{R4}	3.12	453
ARS= (f_{R1}+ f_{R2}+f_{R3}+ f_{R4})/4	3.60	520

Note: using a 100×100×400mm (4x4x16 in), f_{R1}, f_{R2}, f_{R3}, and f_{R4}, are calculated at 0.4, 1.2, 2.0, and 2.8mm of CMOD, respectively

Application Area

Case Studies
Out door roads and infrastructure

Performance Criteria

Corrosion Free, Non Conductive, Crack Control

	Gothenburg City 2012	Holmestrand Station 2016/17
Engineering	AFconsult	Rambøll, Concribe
Description	MiniBar reinforced concrete used as the 20cm top layer of road surface at tram switching and signalling intersections.	MiniBar reinforced concrete used as the 20cm top layer of road surface at bus station and train station entrances. Non conductive to protect against electrical and signalling issues.
Concrete and Dosage	52,5Kg/m3 dosage of MiniBar in C35 grade of concrete.	10Kg/m3 dosage of MiniBar in C35 grade of concrete.

Application Area

Case Studies
ST1 Tank Farms, Secondary Containment system

Performance Criteria

Corrosion Free, Crack Control, Structural

ST1 Tank Farms, Engineering phase

Engineering — Multiconsult, Concribe

Description — MiniBar reinforced concrete used as the 20cm slab on grade surrounding the tanks. Posttensioned concrete secondary containment wall. Durable and non corroding solution.

Concrete and Dosage — 7 Kg/m3 dosage of MiniBar in C35 grade of concrete.

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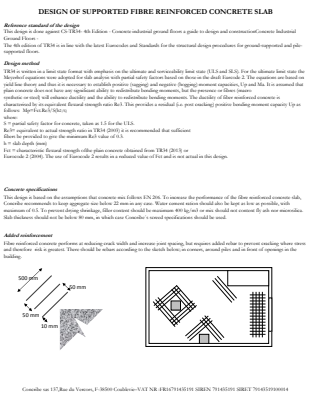
DESIGN OF SUPPORTED FIBRE REINFORCED CONCRETE SLAB

Reference standard of the design

This design is done against CUR-TR34 4th Edition - Concrete industrial ground floors a guide to design and construction(Concrete Industrial Ground Floors -

The 4th edition of TR34 is in line with the latest Eurocodes and Standards for the structural design procedures for ground-supported and pile-supported floors.

Design method

TR34 is written in a limit state format with emphasis on the ultimate and serviceability limit state (ULS and SLS). For the ultimate limit state the Meyerhof equations were adopted for slab analysis with partial safety factors based on those in the draft Eurocode 2. The equations are based on yield line theory and thus it is necessary to establish positive (sagging) and negative (hogging) moment capacities, Up and Mn. It is assumed that plain concrete does not have any significant ability to redistribute bending moments, but the presence or fibres (macro synthetic or steel) will enhance ductility and the ability to redistribute bending moments. The ductility of fibre reinforced concrete is characterised by its equivalent flexural strength ratio Re3. This provides a residual (i.e. post cracking) positive bending moment capacity Up as follows: Mp=Fct.Re3.Wel/γc

where:

γ = partial safety factor for concrete, taken as 1.5 for the ULS.

Re3= equivalent to actual strength ratio in TR34 (2003) it is recommended that sufficient

Wel = elastic section modulus to give the maximum Re3 value of 0.5.

h = slab depth in mm

Fct =Characteristic flexural strength ofthe plain concrete obtained from TR34 (2013) or

Eurocode 2 (2008). The use of Eurocode 2 results in a reduced value of Fct and is not actual in this design.

Concrete specifications

This design is based on the assumptions that concrete mix follows EN 206. To measure the performance of the fibre reinforced concrete slab, Concribe recommends to keep aggregate size below 22 mm in any case. Water cement ratios should also be kept as low as possible, with maximum of 0.5. To prevent drying shrinkage, fibre content should be minimum 400 kg/m3 or min should not content fly ash nor microsilica. Slab thickness should not be below 90 mm, in which case Concribe's tested specifications should be used.

Added reinforcement

Fibre reinforced concrete performs at reducing crack width and increase joint spacing, but requires added rebar to prevent cracking where stress and therefore with is greatest. There should be rebars according to the sketch below, so corners, around piles and in front of openings in the building.

ConCribe

Treatment of concrete surface

the use of plastic film or curing product, but water, is mandatory to prevent early drying-shrinkage. Curing should satisfy the requirements of ASTM C309, Type 1.

Joints

Jointing should follow the recommended bay size on this design. Joints can be either saw cut or untreated. Saw cut jointing should respect the saw cut depth in the design and be executed within 24 hours after concrete pour , untreated joints should be according to supplyers specifications following this design.

Liability

Concribe is unable to have straight on the correctness of the data which the design is based on. This design is therefore only valid for the given data, and screened by Concribe professional indemnity for design and personal damages due to failed design. As Concribe obviously does not have straight on or control over execution of the slab, liability declines for all losses and/or damages consequently.

Fiber reinforced concrete performance

The strength of fibres is measured as a residual flexural tensile strength.This can be done by performing crack strenth opening displacement (CMOD) tests. A CMOD test is a deformation controlled loading test, where the crack opening is measured at a horizontal deflection. The test setup requires a beam, notched to prevent horizontal cracking, and devices for recording the applied load and the crack opening, which is referred to as CMOD. The EB model code proposes that it is to be done in accordance with EN 14651 (2005).

Design of slabs — *TR34 4TH edition 2013*

assumptions: tensile strength of concrete is ignored

Project:	ST1 A2	**Designed by:**	PBE
Part:	slab on grade	**Customer:**	Reforcetech
		Reviewed by	ABO
		Date	9/18/2017

eLade version 8 2017

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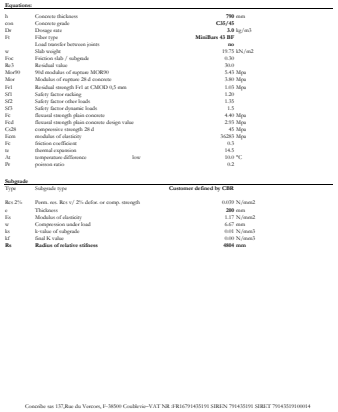
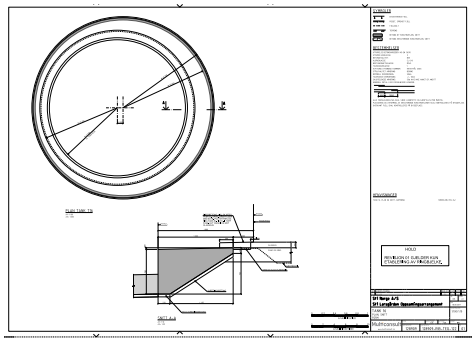


Equations:		
h	Concrete thickness	700 mm
ccm	Concrete grade	C35/45
Dr	Dosage rate	3.0 kg/m3
Ft	Fiber type	MiniBar 43 RF
	Load transfer between joints	no
w	Slab weight	19.75 kN/m2
Fsc	Friction slab / subgrade	0.50
Re3	Residual value	30.0
Mr450	Mid modulus of rupture MOR90	5.43 Mpa
Mor	Modulus of rupture 28 d concrete	3.80 Mpa
Fr1	Residual strength Fr1 at CMOD1/3 mm	1.03 Mpa
Sf3	Safety factor racking	1.20
Sf2	Safety factor other loads	1.35
Sf5	Safety factor dynamic loads	1.5
Fc	flexural strength plain concrete	4.40 Mpa
Fcd	flexural strength plain concrete design value	2.93 Mpa
C28	compressive strength 28 d	45 Mpa
Ecm	modulus of elasticity	36283 Mpa
Fc	friction coefficient	0.5
ac	thermal expansion	10.5
At	temperature difference low	10.0 °C
Rv	poisson ratio	0.2

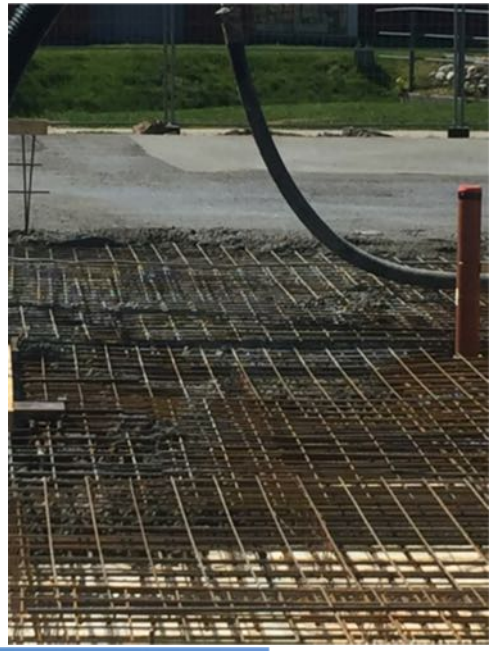
Subgrade		
Type	Subgrade type	Customer defined by CBR
Rec 2%	Poem. rec. Rec v/ 2% defor. or comp. strength	0.050 N/mm2
s	Thickness	200 mm
Es	Modulus of elasticity	1.17 N/mm2
w	Compression under load	6.47 mm
ks	k-value of subgrade	0.01 N/mm3
kf	final K-value	0.00 N/mm3
Rr	**Radius of relative stiffness**	**4804 mm**

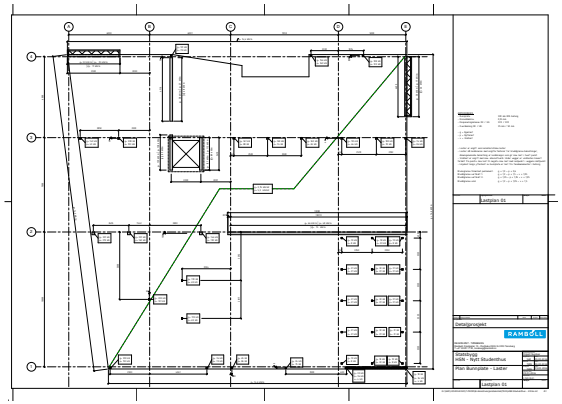
ConCribe

Loads				
Rolling or live	**none**	**0 kN**		
	axles	n		
A1	axle load	1 kN		
W1	wheel load	0.5 kN		
Wd	wheel distance	3500 mm		
Ad	axle distance	2000 mm		
Rca	radius of contact area	1.50 mm		
Q1	design load 1	0.75 kN		
Q2	design load 2	kN		*if 2h>Ad only
Q3	design load 3	1 kN		
Q4	design load 4	0.50 kN		
		center edge	**corner**	
su	**Corresponding stress**	**0 0**	**0**	
UDL	**uniformly distributed load - static load**	**100 kN/m2**		
Mudl	Moment due to UDL	75.9772 kNm/m		
su	**Corresponding stress**	**0.73 N/mm2**		
Ll	**line Load**	**1 kN/m**		
Ll2	second line load	1 kN/m		
dl	distance between loads	0 mm		
y	Amplitude parameter	0.15 m		
Cy	deflection	1.0000 m		
Ml	Moment	0.84 kNm/m		
su	**Corresponding stress**	**0.01 N/mm2**		
Pll	**point load**	**1000.00 N**		
dp1	distance to joint	0.00 mm		
mxp	Max distance between loads	0.00 mm		
mxp	Max distance between loads	0.00 mm		
dm	influence load center	0.00	0.00 100.00	
dc	influence load edge	100.00	100.00 100.00	
dc	influence load corner	100.00	100.00 100.00	
Cp	contact pressure	0.40 N/mm2		
Lr	loading radius	423.21 mm		
Er	equivalent radius	421.04 mm		
		Pk	RL	UDL	LL
su	**internal stress**	**0.0258**	**0**	**0.73**	**0.01**
	edge stress	**0.0050**	**0**		
	corner stress	**0.0045**	**0**		
	Load transfer corner	1.0000			
	Load transfer edge	1.0000			
Sc	**sollicitation center**	**1 N/mm2**			
Se	**sollicitation edge**	**1 N/mm2**			
So	**sollicitation corner**	**1 N/mm2**			
Cs	**combined sollicitation**	**1.52 N/mm2**	*Design validated*		



Application Area	***Case Studies*** ***Rafts***
Performance Criteria	***Corrosion Free, Water Tight Crack Control***
	Porsgrunn, Student Center
Engineering	Rambøll, Concribe
Description	MiniBar reinforced concrete used as the water tight raft. 32cm steel reinforced slab with MiniBars to ensure crack control eliminating nets at the top and bottom surface.
Concrete and Dosage	5Kg/m3 dosage of 55mm MiniBar in 45MPa grade of concrete.



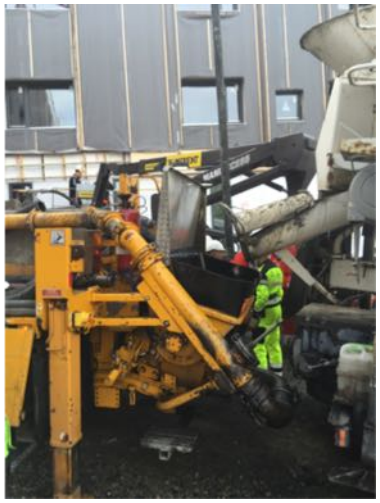


Application Area

Case Studies
Screed, thin screed and structural screed

Performance Criteria

Corrosion Free, Crack Control



Multi Story Hospital, Fosshagen

Engineering

Veidekke

Description

MiniBar reinforced concrete used as the 5 cm top layer. Multiple sites

Concrete and Dosage

5 Kg/m3 dosage of MiniBar in C35 grade of concrete, 5 to 8cm thickness

Engineering Support

Concribe delivers designs to ground supported slabs, elevated slabs, jointless slabs, walls, rafts and precast elements with ReforceTech MiniBar™

Engineering Support

Gulv på grunn beregninger, Nye NB 15 og FIB Model code 2010 / TR34

Eksempel 1	**Nye NB15, Gulv klasse 2**		**FIB MC 2010 / TR34**
Industriklasse	lett		lett
Nett	335 mesh 8mm dia		ingen nett
MB dose	5kg m3		5kg m3
Rissvidde	0,47mm		0,3mm
Gulv tykkelse 100mm og opp	ja		ja
Godt komprimert underlag	ja		ja
Eksempel 2	**Nye NB15, Gulv klasse 3**		**FIB MC 2010 / TR34**
Industriklasse	lett		lett
Nett	ingen nett		ingen nett
MB dose	8kg m3		5kg m3
Rissvidde	Ikke kalkulert, definert som 1,0mm		0,35mm
Gulv tykkelse 100mm og opp	ja		mindre tykkelse mulig
Godt komprimert underlag	ja		ja

ConCribe

INDUSTRIGULVE DIMENSIONERING EFTER NB 15 I SLADE

- GENERELLE BEMÆRKNINGER

  Gulvklasse III Fiberbetong har risvidde på 1 mm uanset, kan ikke beregnes

  Gulvklasse II armering og fiberbetong har en risvidde på 0,5 mm, som kan beregnes

  Der er ingen linielast i NB 15, men kan påføres i SLADE efter CS TR 34 3rd 2010

  Man kan kombinere armeringsnet og fiberbetong

- GULVETS BÆREEVNE OG RISVIDDE

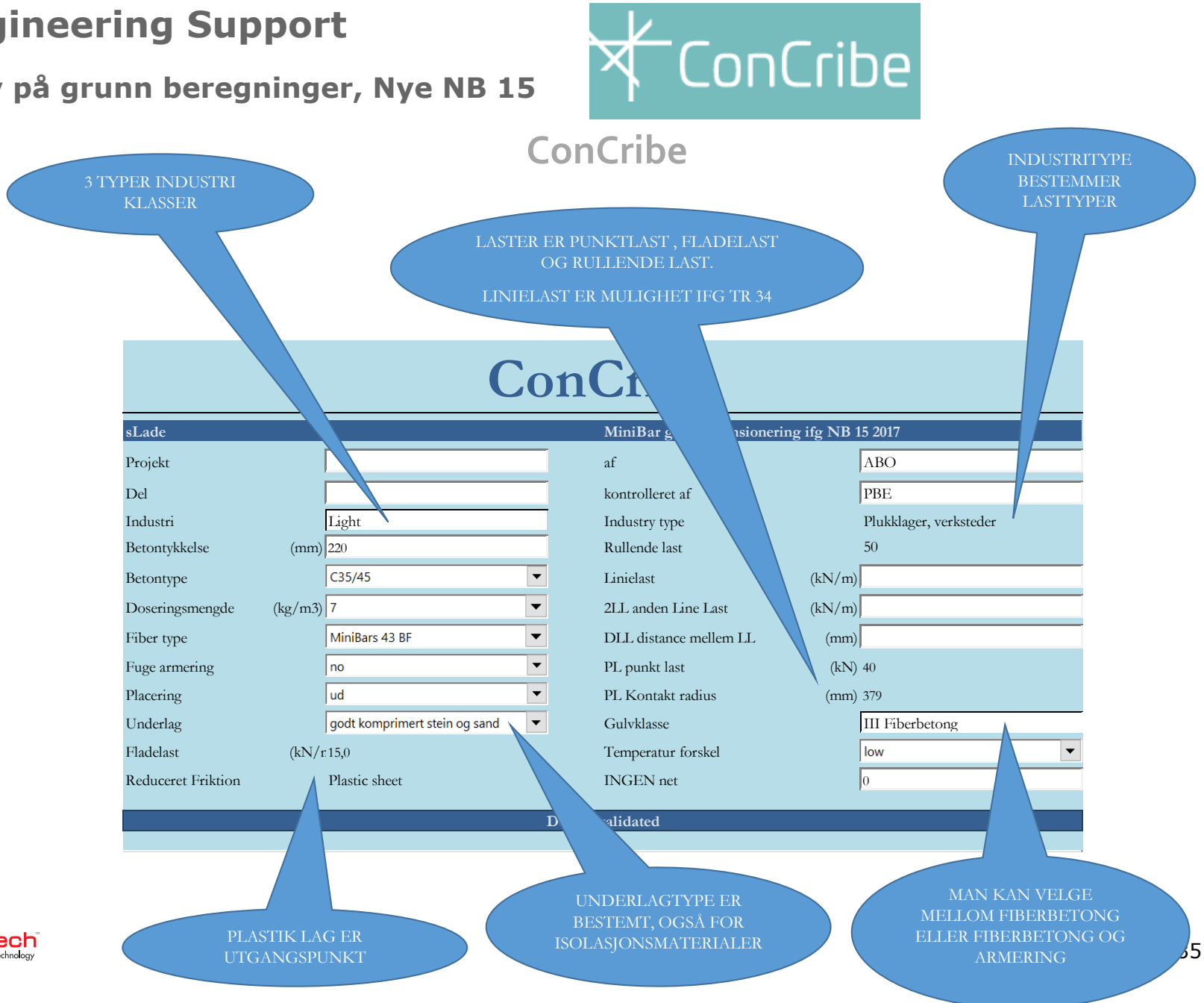
  Moment beregning er baseret på CMOD ved 2,5 mm

  Risvidde er baseret på CMOD ved 0,5 mm

  I gulvkasse II skal man kalkulere risvidde, som skal være mindre end 0,5 mm som akseptkriteria

Engineering Support

Gulv på grunn beregninger, Nye NB 15



ReforceTech
Mineral Fiber Reinforcement Technology

Engineering Support

Sandwich paneler

sAnd

Precast sandwich panels initial design tool - ConCribe 2018 - www.ConCribe.com

Insulation thickness	250	mm		Wind speed m/s (beaufort scale)	21	26,0 kg/m2	
Concrete thickness inner	80	mm		Span btw fixing points	7750	mm	A
Concrete thickness outer	40	mm		Height	5000	mm	B
Length	2650	mm		Load	60	kN/m	C
Dosage rate	12	kg/m3		Horizontal load	1,965	kN	
Initial temperature (concrete temperature at pouring)	18	°C	E	Concrete strength 28 days	40	Mpa	
Static safety factor	1,3			Final temperature	25	°C	D
Dynamic safety factor	1,5			Elasticity modulus of the panel	0,989383	mm4	
Inertia	1,62532E+14	mm4		Induced bending moment	24	kNm	
Rigidity	1,60806E+14			Loading coefficient	0,020833		
Deflection	0,12	mm		Deflection angle	0,003504	degrees	
crack width induced to outer panel	0,07	mm	*ok*	Tensile stress outer panel	0,20	Mpa	
Joint spacing FRC	171	m2	*ok*	Ultimate residual strength	2,30	Mpa	
Linear expansion	0,001099	mm		Coefficient of linear expansion - concrete	12	10-6*°C-1	
Internal shrinkage stress	0,90	Mpa	*ok*	Calculated Tensile strain	0,000144	%	
Excentricity	32,5	mm		Maximum concrete tensile strain to cracking	0,010	%	
Own weight bending under lifting	no		F	Crack width	0,5	mm	G

Design Valid

A Largest possible span between fixed points of the panel
B Height of the panel
C Loading per meter on the bearing inner wall from deck
D Estimated final temperature of the hardened concrete at 28 days - depends on how panels are stocked
E Initial temperature of fresh concrete at pouring

References : FIB Model code 2010 - Eurocodes 2 - Rilem TC 162

ReforceTech™
Mineral Fiber Reinforcement Technology

Engineering Support

Sandwich paneler

sAnd

Precast sandwich panels initial design tool - ConCribe 2018 - www.ConCribe.com

Insulation thickness	250	mm		Wind speed m/s (beaufort scale)	21	26,0 kg/m2	
Concrete thickness inner	80	mm		Span btw fixing points	7750	mm	A
Concrete thickness outer	40	mm		Height	5000	mm	B
Length	2650	mm		Load	60	kN/m	C
Dosage rate	12	kg/m3		Horizontal load	1,965	kN	
Initial temperature (concrete temperature at pouring)	18	°C	E	Concrete strength 28 days	40	Mpa	
Static safety factor	1,3			Final temperature	25	°C	D
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Excentricity	32,5	mm		Maximum concrete tensile strain to cracking	0,010	%	
Own weight bending under lifting	no		F	Crack width	0,5	mm	G

Design Valid

A Largest possible span between fixed points of the panel
B Height of the panel
C Loading per meter on the bearing inner wall from deck
D Estimated final temperature of the hardened concrete at 28 days - depends on how panels are stocked
E Initial temperature of fresh concrete at pouring

References : FIB Model code 2010 - Eurocodes 2 - Rilem TC 162

ReforceTech™
Mineral Fiber Reinforcement Technology

Boxes dumped into back of truck

Dumping boxes directly into a truck will result in MiniBars not dispersed into the concrete and result in balls.

The MiniBars need time to flow with the concrete away from the landing zone in the car.

Dumping a box is equivalent to dosing at a rate of 10Kg/5 sec.

Or

300Kg/min

The recommended rates are 10Kg/min when using a blower to broadcast the MiniBars over the concrete surface

OR

5Kg/min when using a conveyor

This is to allow the concrete to move the Minibars away from the landing zone where they fall into the drum

DO NOT DUMP a Box into the back of a truck

Recommendations to eliminate balls

Use a ReforceTech Blower at 10Kg/min

Ensure the MiniBars are dispersed over the concrete. Tube length is critical at this high dosage rate.

Zero balls

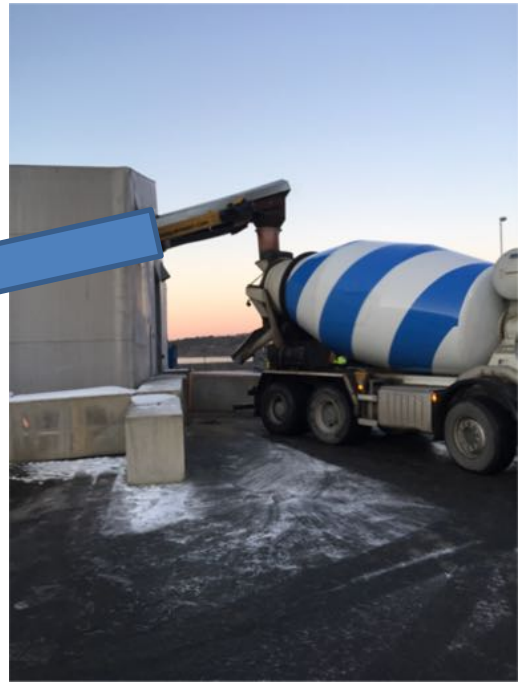
Recommendations to eliminate balls

Dosing using a conveyor – 5Kg/minute dose rate

Feed conveyor with even layer at 2 minutes per 10 Kg box

Conveyor with fixed high speed to move and throw the fibers into truck.

Truck mixer rotating at max speed to allow the concrete to move the MiniBars away from the landing zone into concrete.



Background Data & Conclusion

- **MB have 3 times the number of fibers to distribute INTO the concrete**
  - MiniBars 28850 MB per Kg of MB. 10kg/m3 = 290,000 MB per M3
  - SF 3000 to 5000SF per Kg of SF. 25Kg/m3 = 100,000 SF per M3

- **Nov 2017 at Unicon where drivers dumped boxes in for 10Kg/M3 resulted in massive balls. See slide 2.**
- **Dec 4 2017 at Unicon mixing 5Kg/m3**
- **Dosing at 20Kg per min (1 box in 30 seconds) on the conveyor and slow rotating speed resulted in 10 balls in first trucks.**
- **Dosing at 10Kg per min on the conveyor and slow rotating speed resulted in ZERO Balls.**
- **CONCLUSION, Dosing at 5Kg per min on the conveyor and with a HIGH rotating speed on the truck WILL result in zero balls.**