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SFRC
Basic concept and
High demand storage building application

By Torpong Thanadka

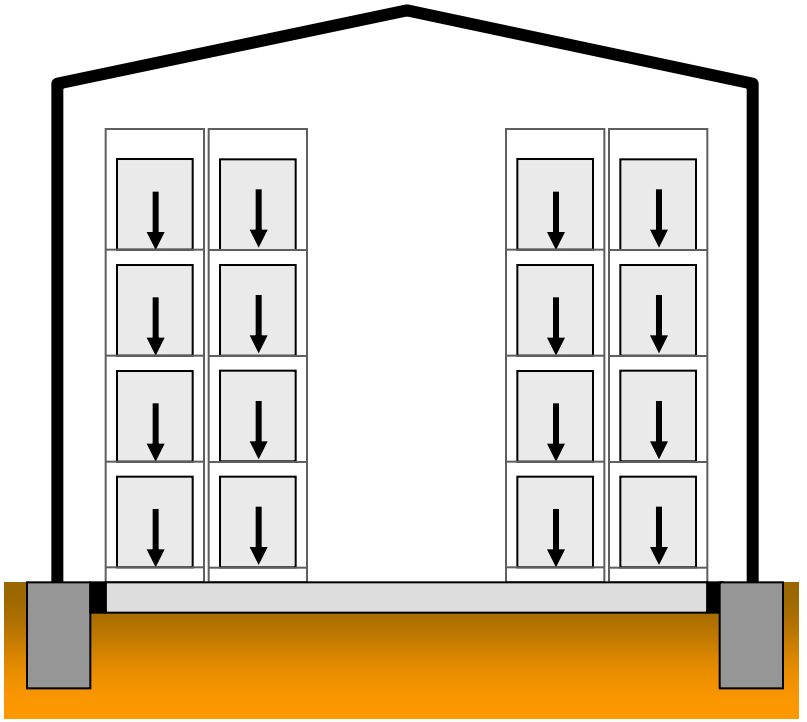
Technical Sales Manager, SEA


16
KOMFORT

Typical construction for

- ✓ load bearing
- ✓ stabilised
- ✓ insensitive to settlement
- ✓ dry

Floor subbase



3D Dramix®

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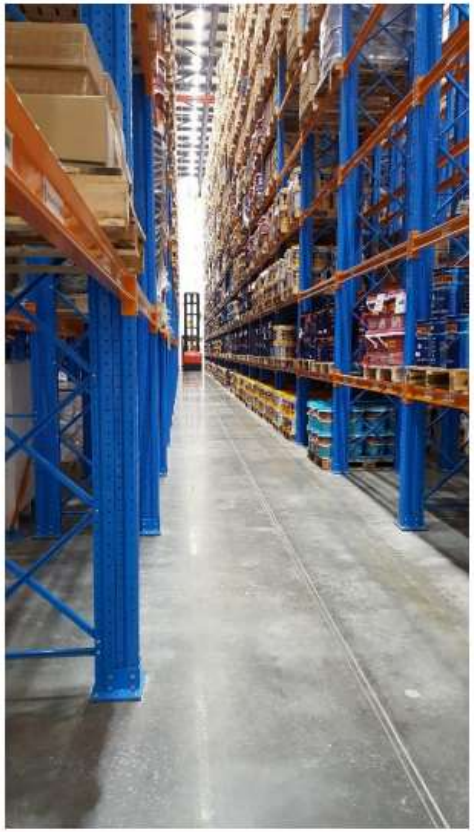

Unseen levels of performance

5D Dramix®

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Unseen levels of performance

5D Dramix


03/06/2014 09


BASF Synthetic Lube

Australian Container Freight Services at the Port of Brisbane

50,000m^2 of completely seamless

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Table of content

ABOUT BEKAERT

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Bekaert at Glance

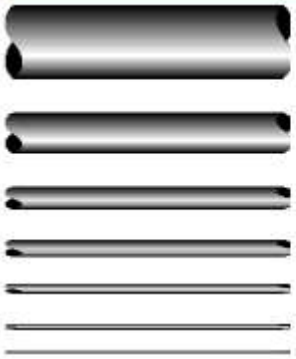
- Founded in 1880 by Leo Leander Bekaert
- World market and technology leader in steel wire transformation and coating technologies
- Customers in 120 countries and in the most diverse industry sectors
- Global manufacturing platform
- Almost 30 000 employees worldwide
- Consolidated sales of € 3.6 billion (2015)
- Annual revenue of € 4.4 billion (2015)
- Listed on Euronext® Brussels – BEL20®

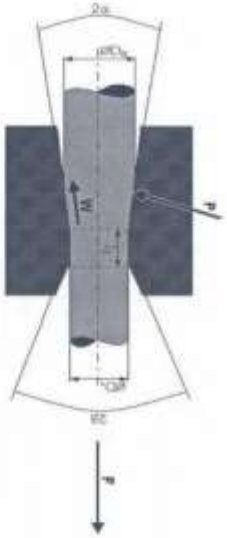
Bekaert core competences

Steel wire transformation

from wire rod

6.5 mm





1 µm

to metal fibers

Coatings

from traditional coatings

Adhesion
Corrosion resistance
Wear resistance
Anti-fouling

to advanced coatings

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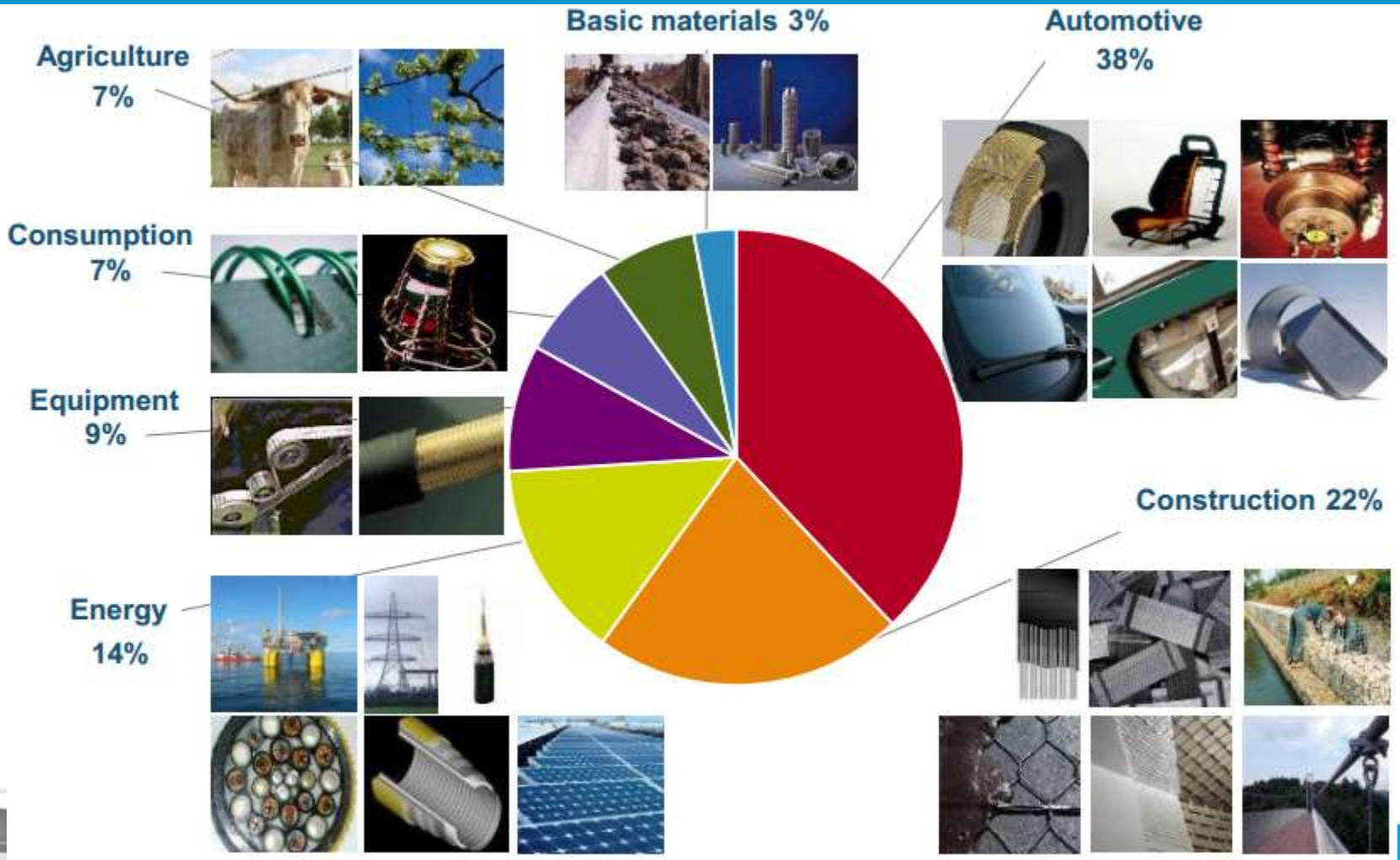
Bekaert market leadership in diverse sectors



ABOUT BEKAERT

PTBI Milestones

Ground breaking April 1997

Start Steelcord

Acquisition Advanced Filtration

Start galvanized wire

Acquired 6.4 ha plot of land, make-up a total of 19.4 ha

Closing JV Bekaert +SS Group Forming PT BSW

Fencing Project 2012

Integration Dramix and ISW Organization

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Land Acquisition 13000m2

Start Sawing Wire activity

Start Dramix®

Move BAF to Karawang

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Key facts about steel fiber

- Bekaert is No. 1 in fiber business
- More than 15 Millon square meter supplied in South East Asia
- More than 100,000 Tons a year fiber supplied

Benefit of Steel Fiber

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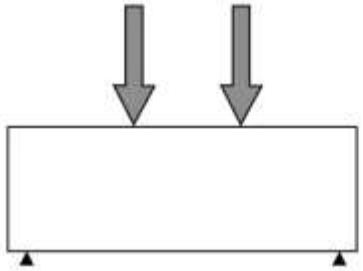
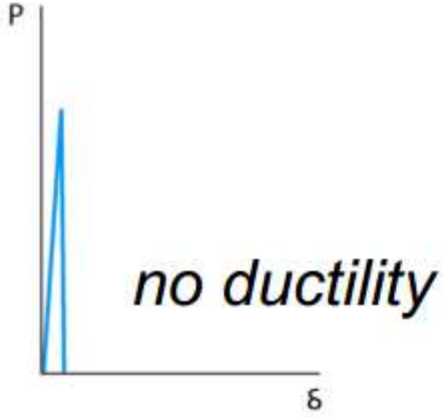
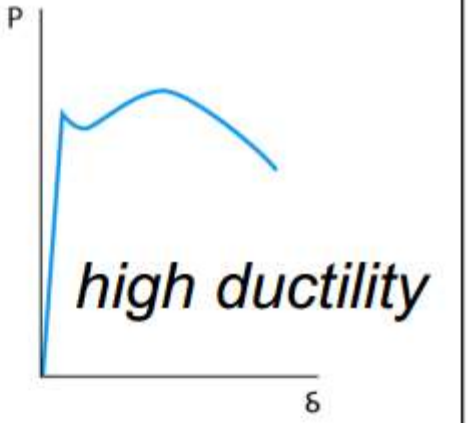
Benefit of Steel Fiber

1 Increase toughness-flexural strength

Test set-up	Plain concrete	Dramix® concrete
beam-test 		

Benefit of Steel Fiber

VDO Beam Test

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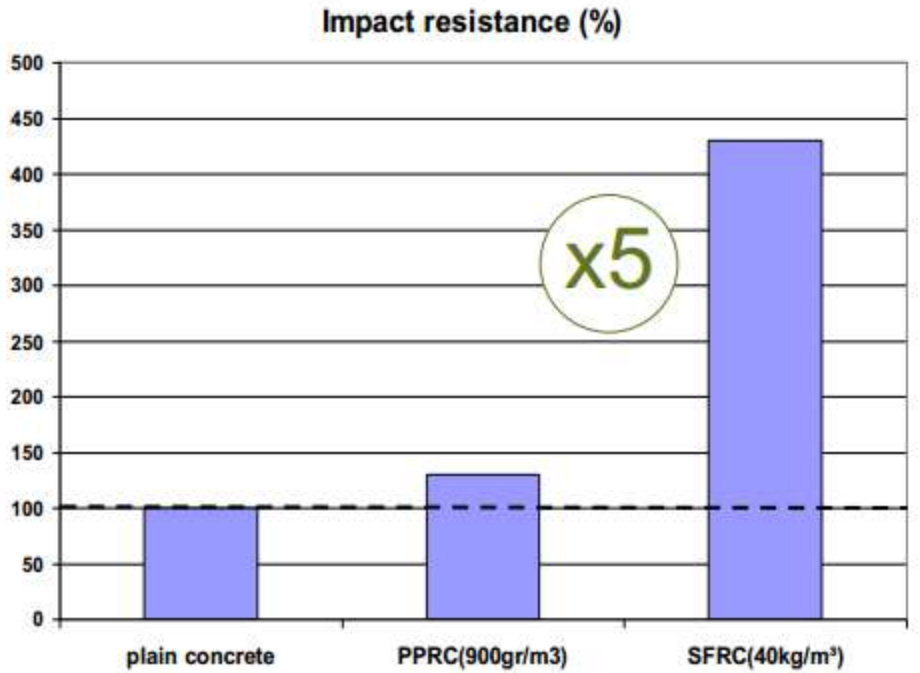
Benefit of Steel Fiber

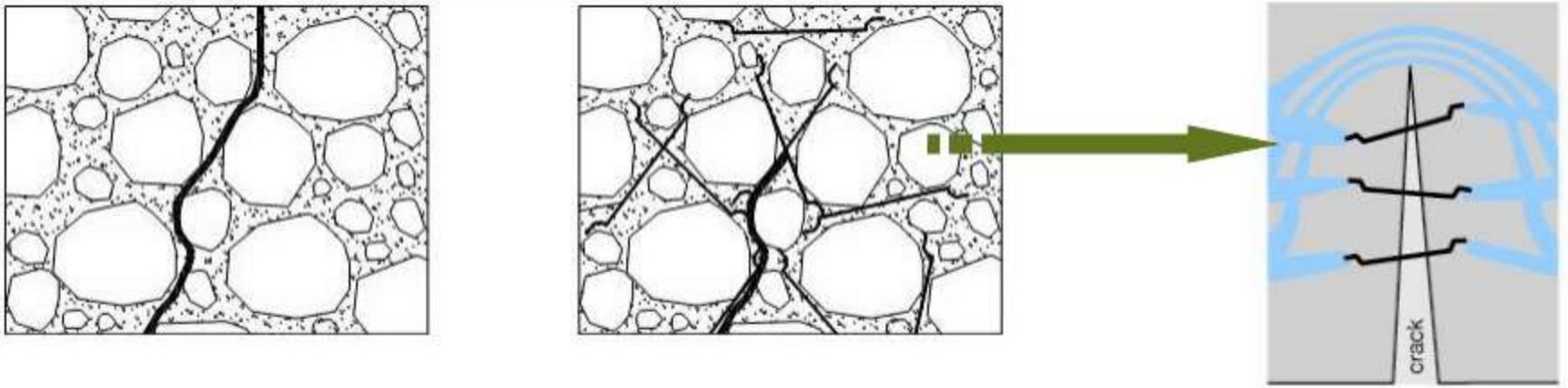
2 Increase impact resistance



Postpone and reduce the crack happening and increase the post-crack stiffness and load carrying capacity.

Benefit of Steel Fiber

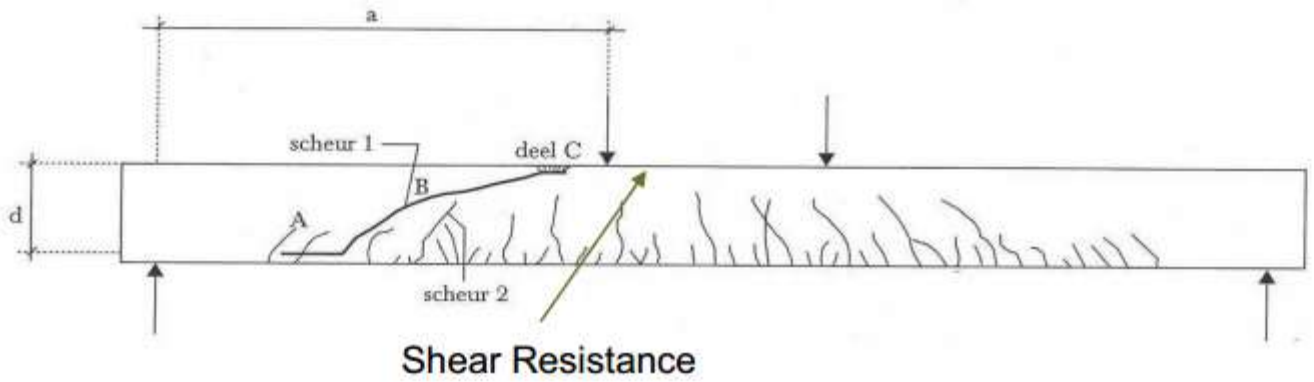
3 Resist crack formation



- ✓ High quantity and dispersion, make concrete ductility.
- ✓ A good ductility resist crack arising by temperature and shrinkage stress.
- ✓ High tensile strength ≥1100MPa and long anchorage.
- ✓ Well redistribute stress and keep crack fine.

Benefit of Steel Fiber

4 Increase shear strength



Shear Resistance

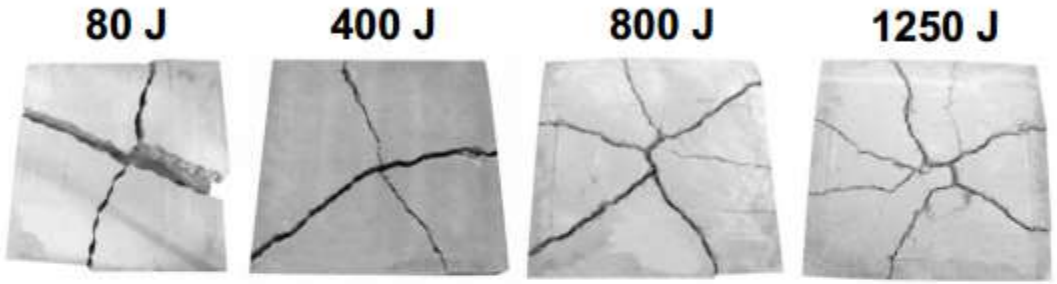
CECS38-2004

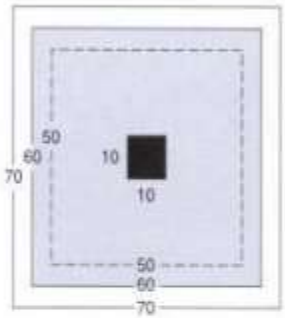
$$Vfcs = Vfc + Vsv - Vfc = Vc\,(1+\beta_v+\lambda_f)$$

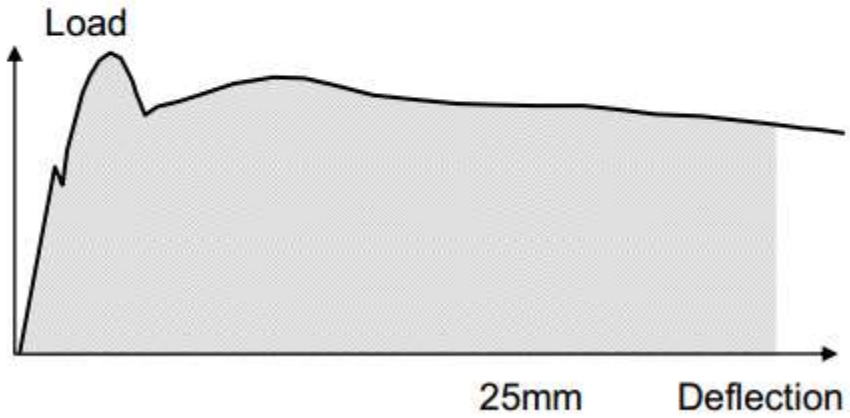
20kg/m^3 (0.25%), RC80/60BN, 12% increase!

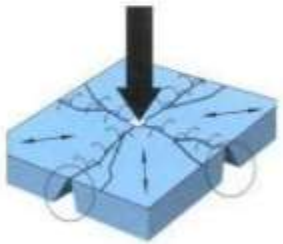
Benefit of Steel Fiber

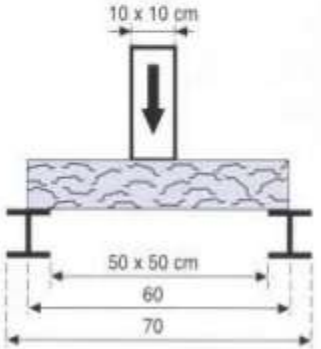
5 Increase energy absorption - Test set-up Efnarc-panel





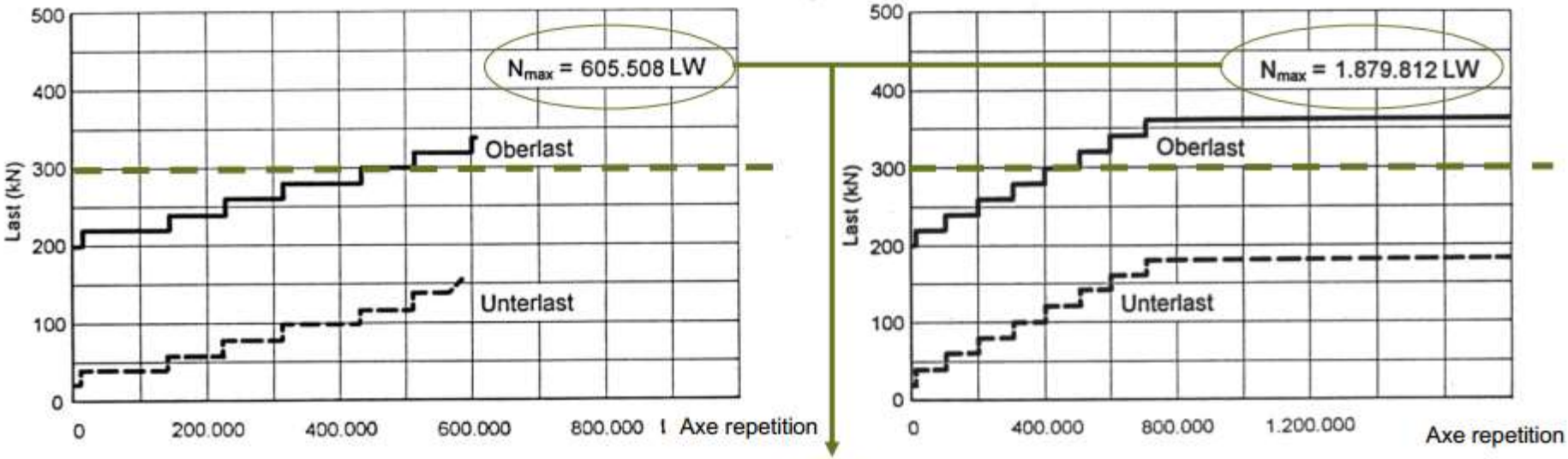






Benefit of Steel Fiber

6 Increase fatigue resistance



Plain concrete road pavement

x3

Dramix® reinforced road pavement

3x more Axe repetition

Benefit of Steel Fiber

7 Increase durability

- ✓ Small crack width avoids chloride ion penetration
- ✓ No concrete spalling problems due to small increase in volume if corroded fibres

30 years old Dramix® galvanised fibres prove:

- ✓ no rust
- ✓ no spalling

Slab on Grade Design Concept

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Slab on Grade Design Concept

Design principles

Ultimate limit state design

- ✓ Check on structural integrity of the slab by using the failure yield line model.
- ✓ Material safety factors + load factors.

Serviceability limit state

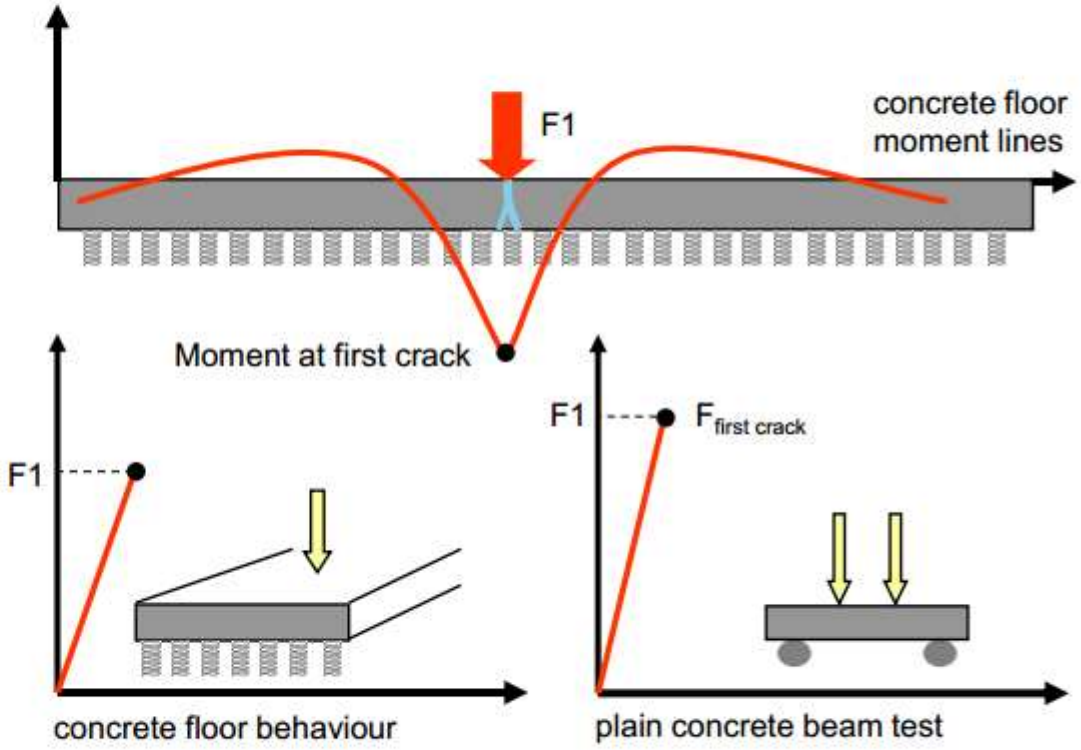
- ✓ Check on integrity of the slab assuming loads + moments resulting from shrinkage, temperature gradient and settlements.
- ✓ Check on deflection.
- ✓ No material safety factors/load factors.

Plain Concrete Design Concept

B. Allowable stress check

Plain concrete: failure mode

Moment at first crack



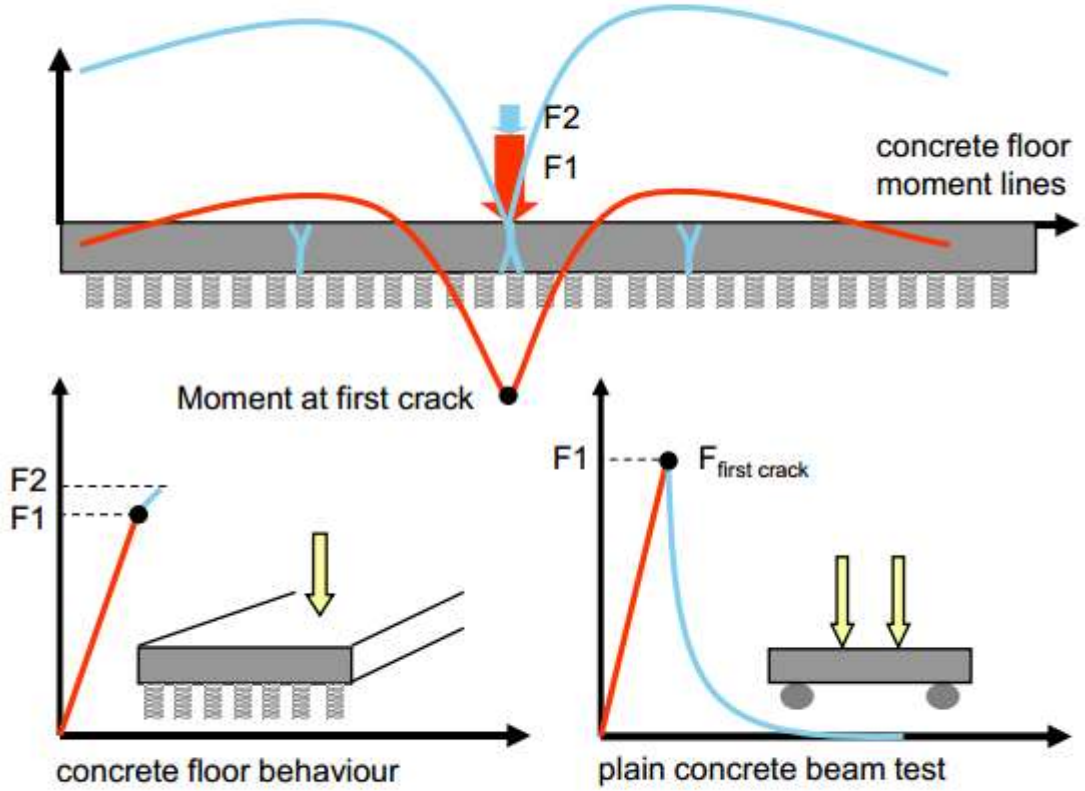
Brittle failure of un-reinforced concrete

Plain Concrete Design Concept

B. Allowable stress check

Plain concrete:
failure mode

Brittle failure of
un-reinforced concrete



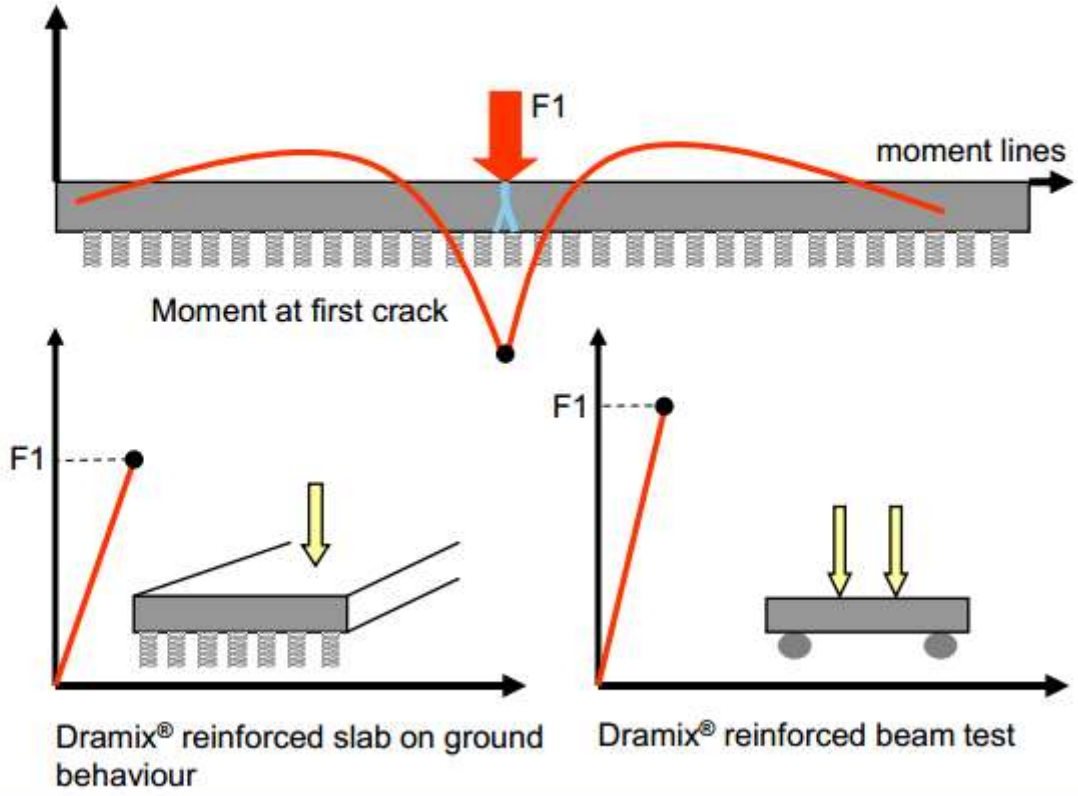
SFRC Design Concept

B. Allowable stress check

Steel fibre concrete:
yield lines

bottom

Load at first crack

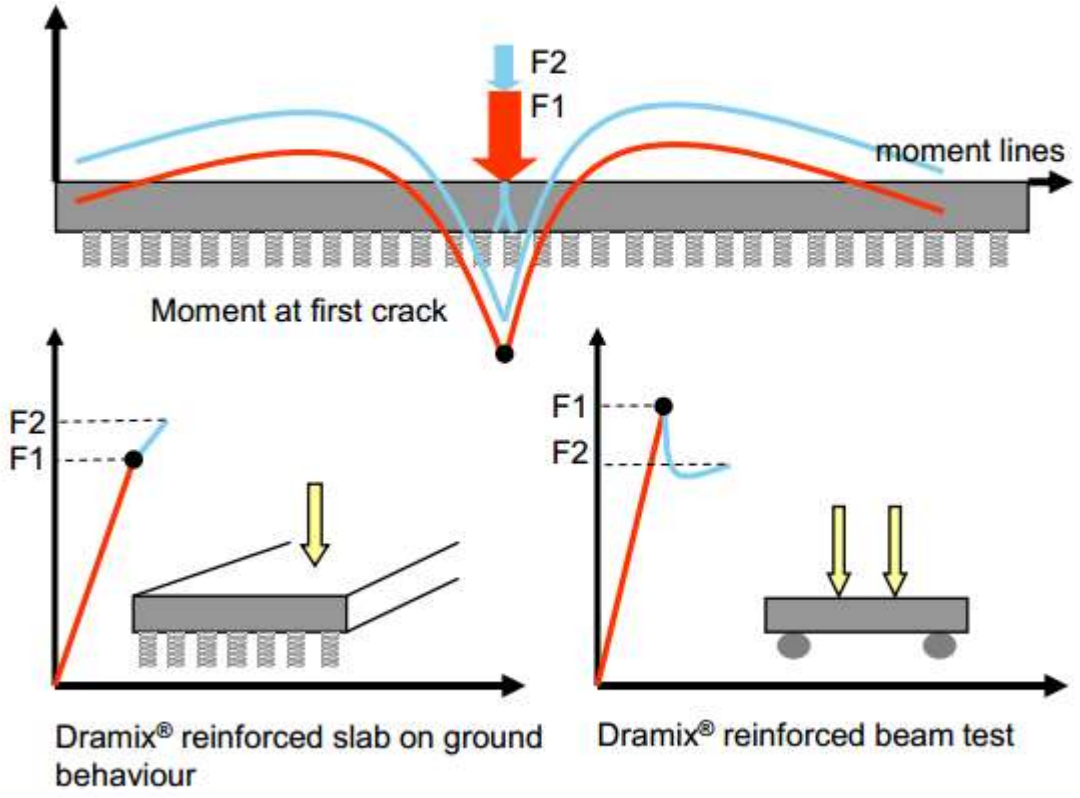


Slab on Grade Design Concept

SFRC Design Concept

B. Allowable stress check

Steel fibre concrete:
yield lines



Moment redestribution due to ductility

Slab on Grade Design Concept

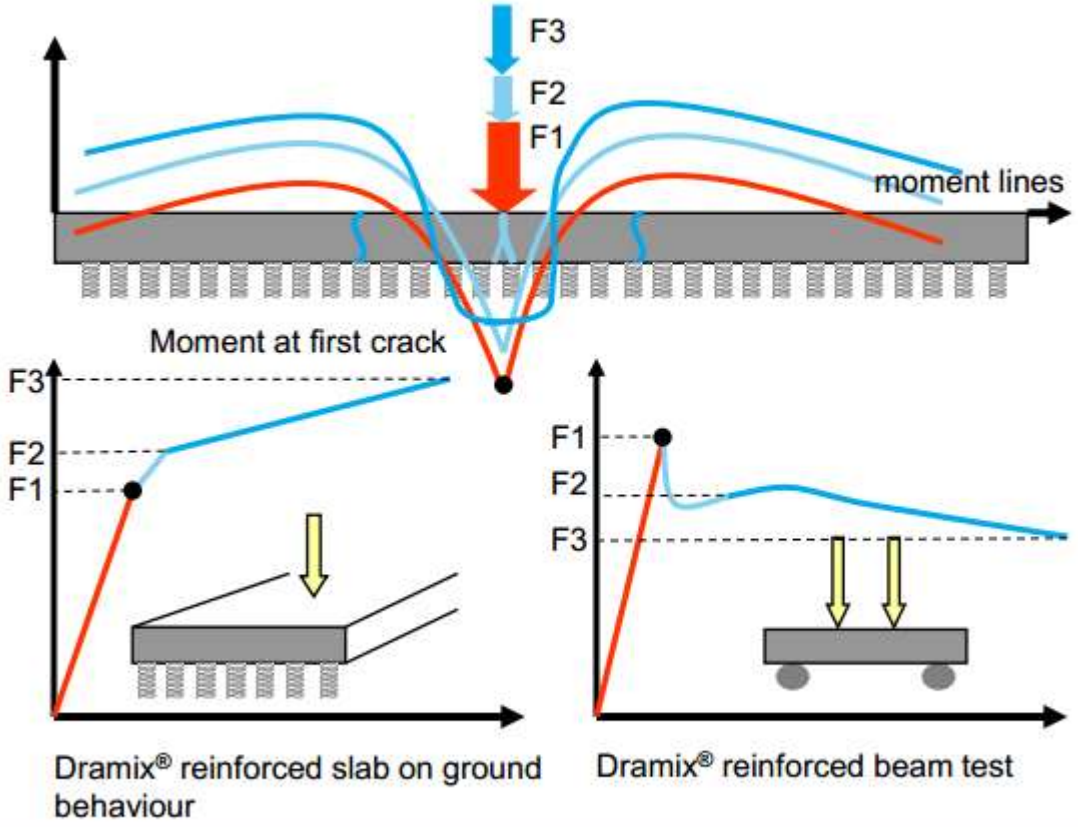
SFRC Design Concept

B. Allowable stress check

Steel fibre concrete:
yield lines

top

Moment at full ductility



Dramix® reinforced slab on ground behaviour

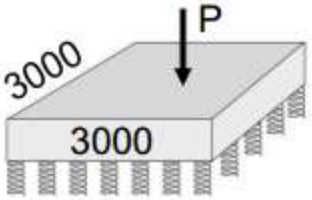
Dramix® reinforced beam test

SFRC Design Concept

B. Allowable stress check at ULS

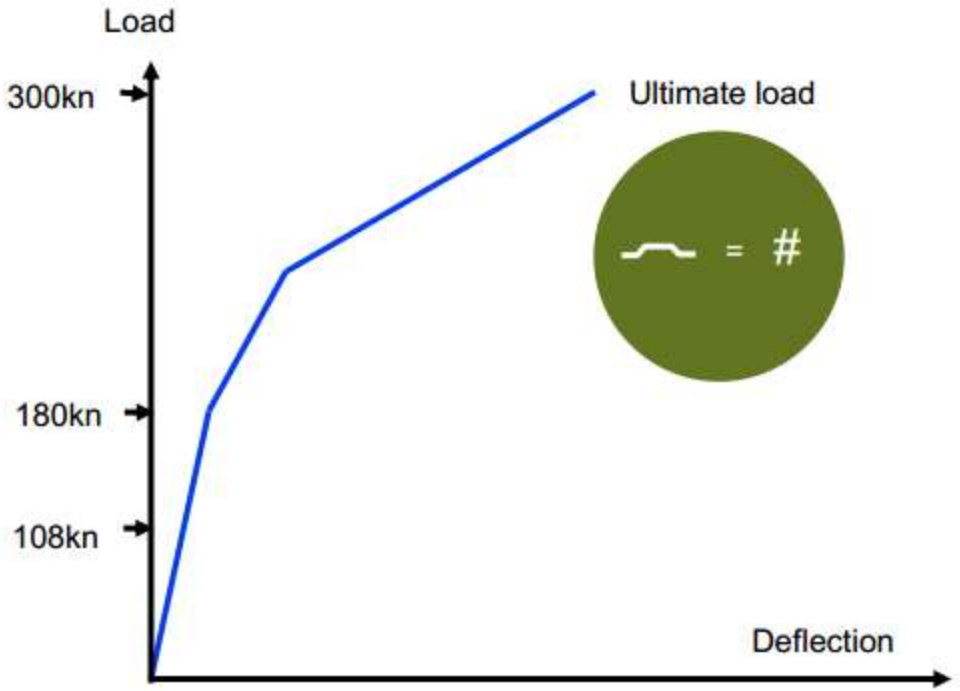
How to compare with rebar & mesh

Test programm



d = 0,15 m
k = 0,03 N/mm³

20 kg/m³ RC-65/60-BN ⌒
double mesh top/bottom #



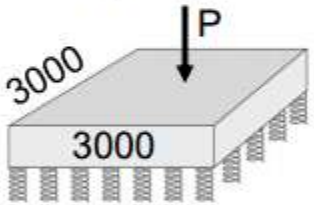
Ultimate load (ULS) for 20 kg/m³ RC-65/60-BN = same as for double mesh

Slab on Grade Design Concept

B. Allowable stress check at ULS

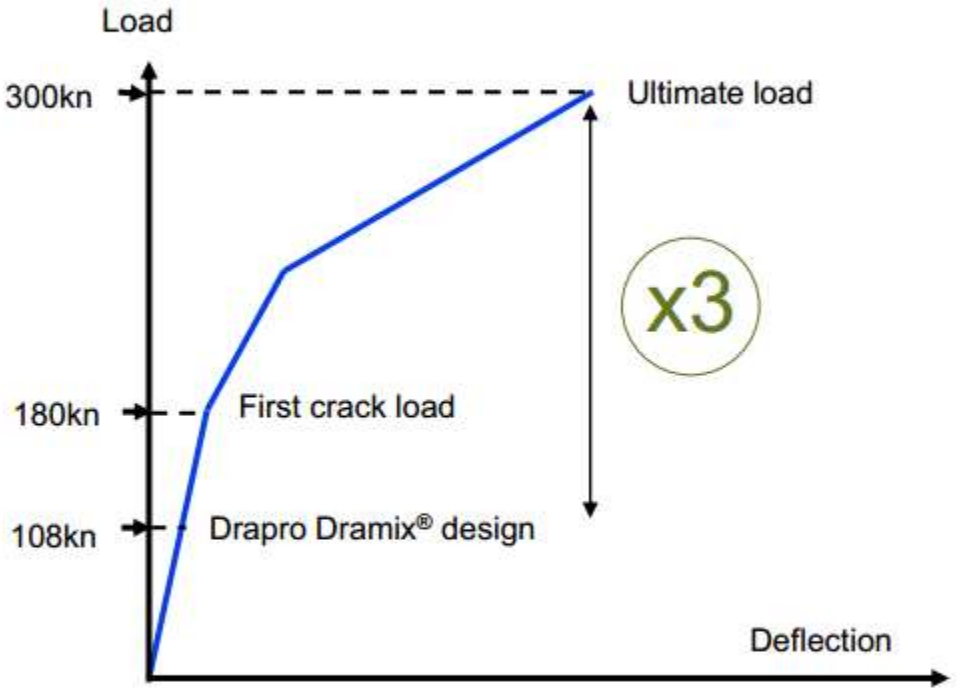
What is the total design safety

Test programm



180 kN first crack load
300 kN ultimate load

20 kg/m³ RC-65/60-BN:
108 kN max. allowable load



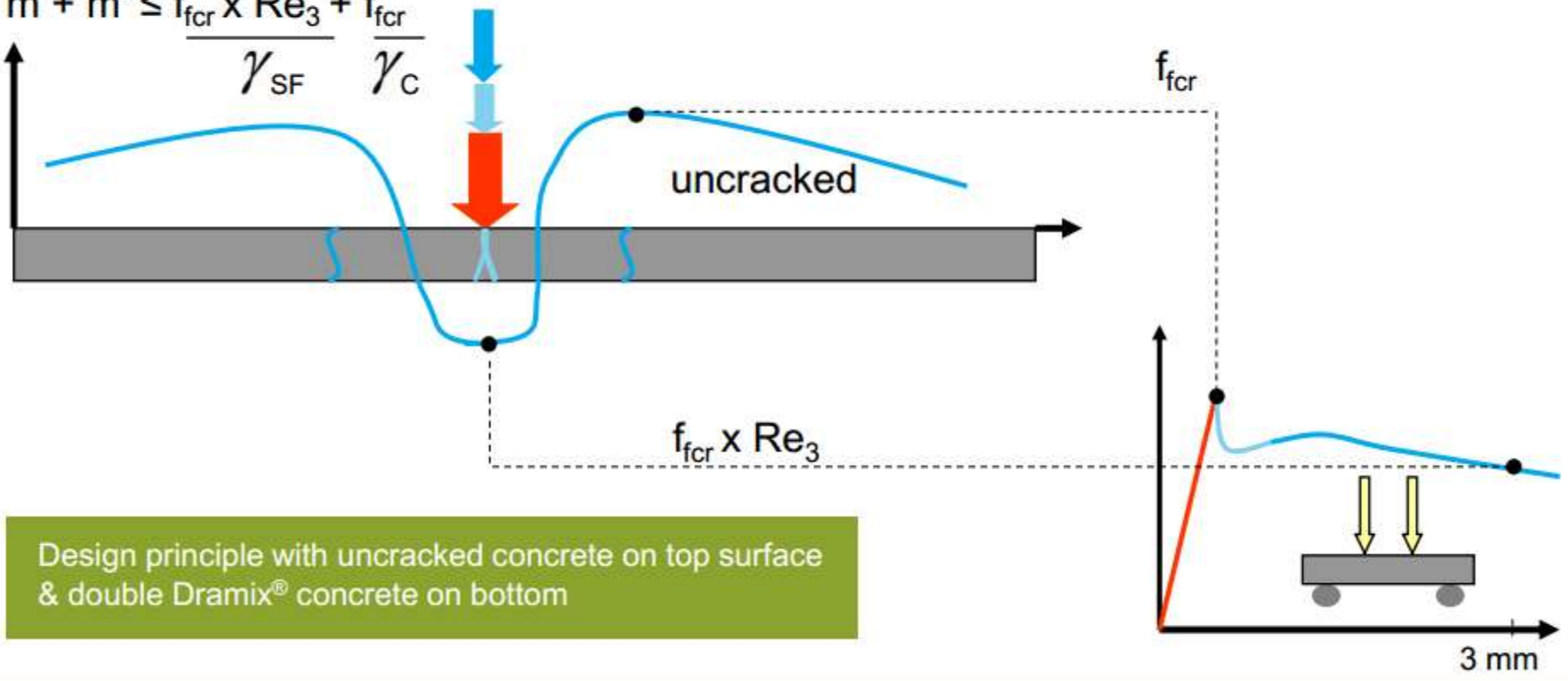
Total design safety = factor 3

Slab on Grade Design Concept

SFRC Design Concept

B. Allowable stress check

$$m + m' \leq \frac{f_{fcr} \times Re_3}{\gamma_{SF}} + \frac{f_{fcr}}{\gamma_C}$$



Design principle with uncracked concrete on top surface & double Dramix® concrete on bottom

Slab on Grade Design Concept

"Practical Yield Line Design" by Kennedy & Goodchild
http://wsmurti.lecture.ub.ac.id/files/2012/10/Perencanaan-Praktis-Garis-Leleh1.pdf

GUIDE TO DESIGN OF SLABS-ON-GROUND (ACI 360R-10)

11.3.3 *Thickness design methods*—Five methods available for determining the thickness of steel FRC slabs-on-ground are described in this section:

1. The PCA, WRI, and COE thickness design methods;
2. Elastic method;
3. Yield line method;
4. Nonlinear finite modeling; and
5. Combined steel FRC and bar reinforcement.

Slab on Pile Design Concept

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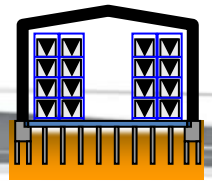
The theory

- SLS verification
  - slenderness
  - absolute dimensions
  - relative dimensions
- ULS verification
  - individual load cases are designed
  - superposition of racks and single axle
  - bending
    - folded plate, uniform load distribution
    - folded plate, non-uniform load distribution
    - fan above piles
  - shear
    - punching shear
  - rotation capacity
- Result
  - based on worst design situation



The theory

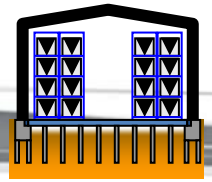
- Yield line theory

Slab design for flexure at the ultimate limit state is based on yield line theory, which requires adequate ductility to achieve the assumed plastic behaviour. It follows that at ultimate loads, they are in a cracked state, that is to say, the load induced stresses are being resisted by steel fibres or combined reinforcement. A full explanation of the method is available in ***Kennedy and Goodchild***

- utilize 5D performance
  - combined reinforcement
    - patches
    - continuous top reinforcement
  - fibres only

→ The bending hardening properties of Dramix 5D reinforced concrete does allow for “fibre only” solutions now.

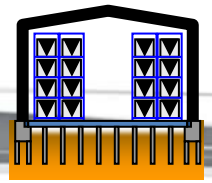
- utilize 4D performance
  - combined reinforcement
    - continuous top reinforcement



The theory ; safety factors

- different sets of possible safety factors
  - EC2
    - ✓ when the floor is considered as a structural element, e.g. in Germany
  - UK
    - ✓ In line with Technical Report 4th edition (2013)
  - CUR111
    - ✓ In line with the Dutch “Floor on piles” design recommendation.

Safety Concept	G	Q	γ_f	γ_s	γ_c	α_c	
	permanent load	variable load	steel fibre concrete	reinforcing steel	concrete	concrete long term	
EC 2	1,35	1,5	1,5	1,15	1,5	0,85	Europe
TR 34	1,2	1,35	1,5	1,15	1,5	0,85	UK
CUR111	1,2	1,35	1,25	1,15	1,5	0,85	The Netherlands



The theory ; virtual works principle

- all Point Loads F are converted to equivalent UDL q_{eq}
  - principle of virtual work:
    - both load types need to result in the same bending moments
    - or: the virtual work of F needs to equal the virtual work of q_{eq}
  - just dividing the point loads by the panel size would underestimate the UDL_{eq} and thus give unsafe designs
  - for a single point load, a factor of 2 has to be applied

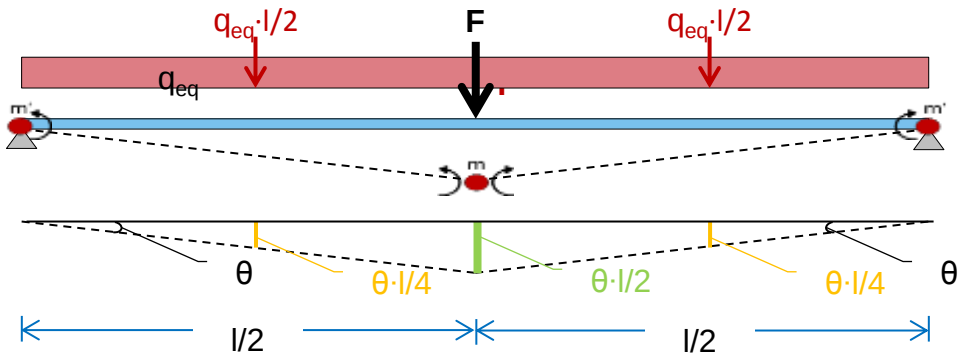
$$2 \cdot \left(q_{eq} \cdot \frac{l}{2} \cdot \theta \cdot \frac{l}{4} \right) \cdot b = F \cdot \theta \cdot \frac{l}{2}$$

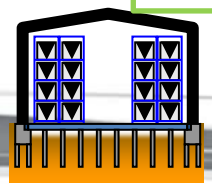
$$\Rightarrow$$

$$q_{eq} = \frac{2 \cdot F}{b \cdot l}$$

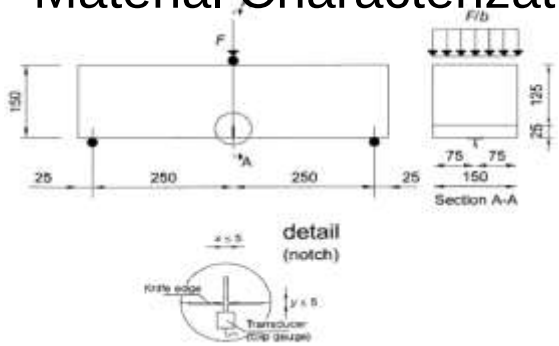
~~$$q_{eq} = \frac{1 \cdot F}{l \cdot b}$$~~

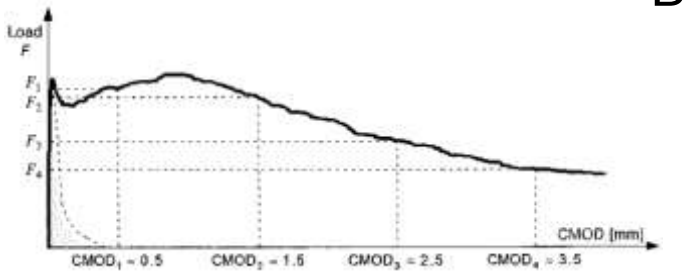
b = panel width
θ = virtual rotation





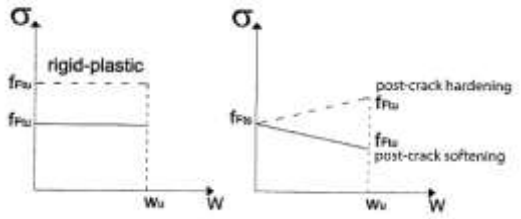
Material Characterization *(EN 15845-1)*

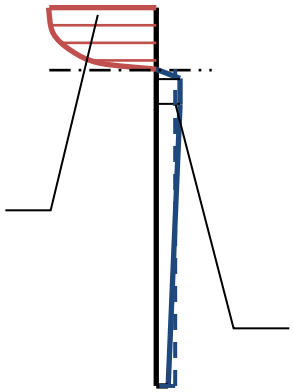




Bending stresses

Constitutive law *(Model Code 2010)*



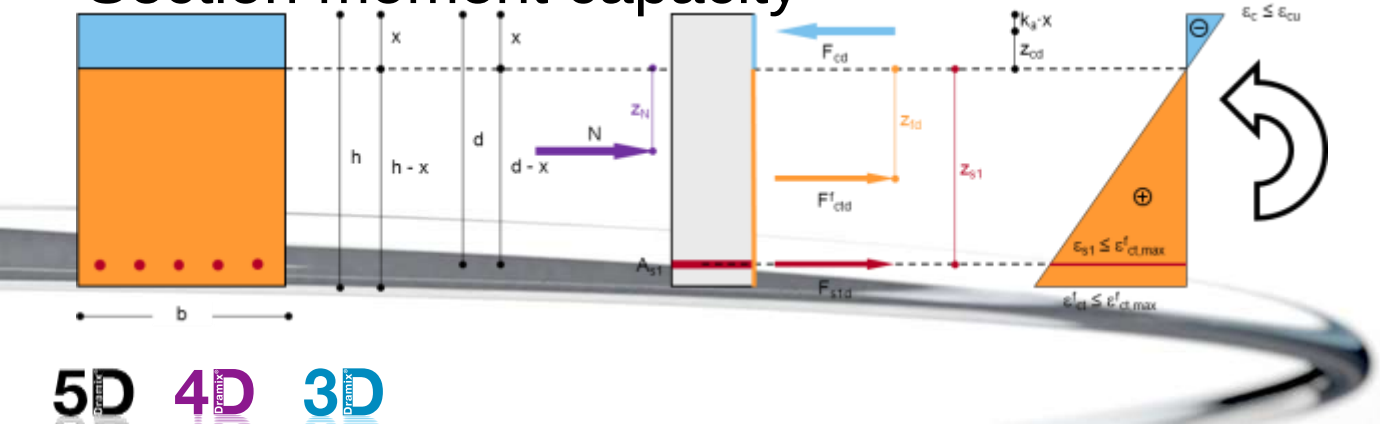


compression zone

tension zone (steel fibers)

Tension stresses

Section moment capacity



Internal moment capacity M_{rd}

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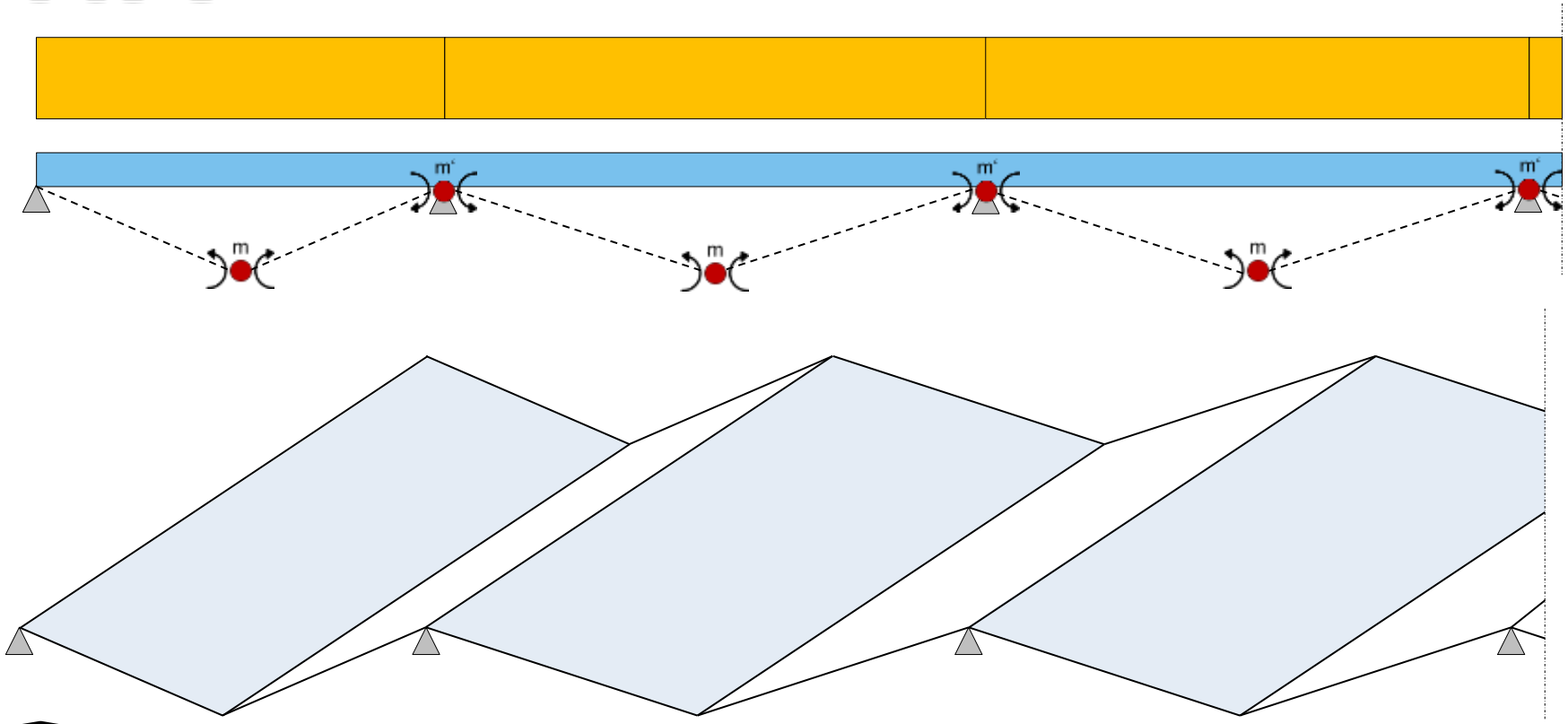
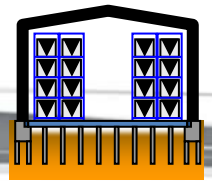
5D 4D 3D

Slab on Pile Design Concept

The theory ; virtual works model





Basic folded plate model

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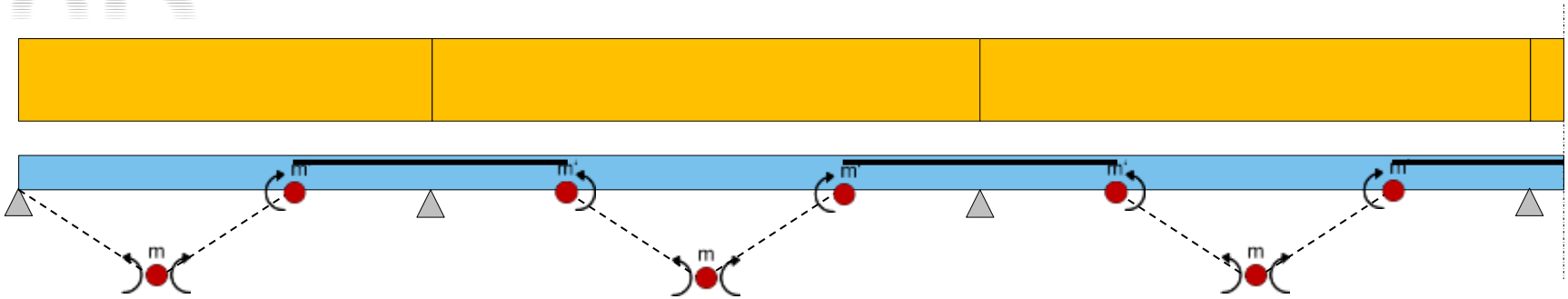
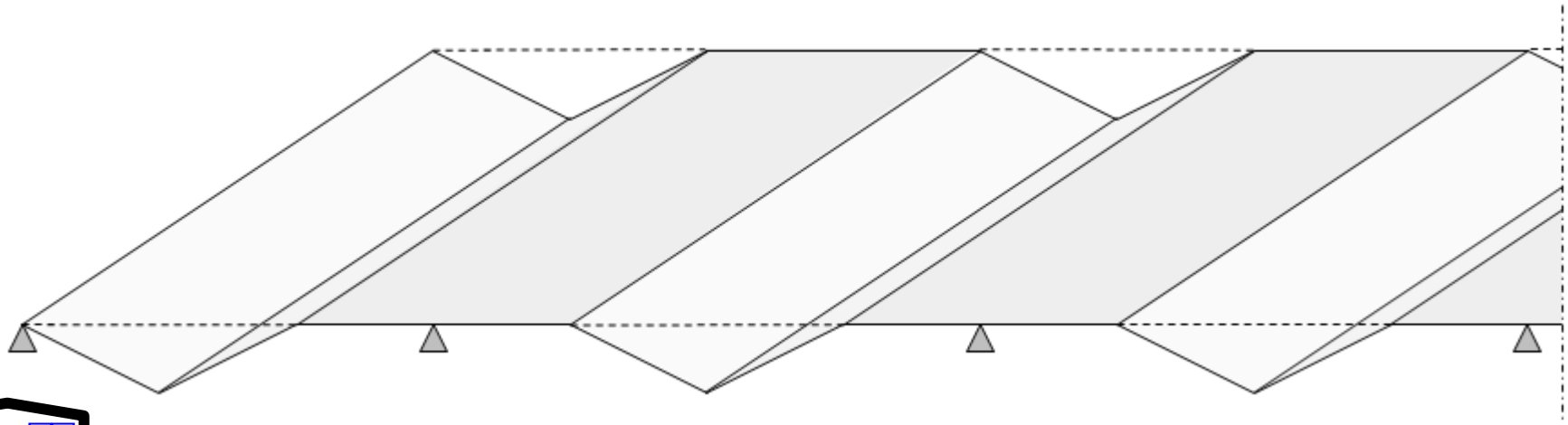
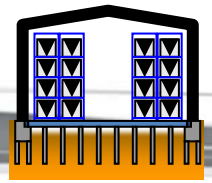
Slab on Pile Design Concept

The theory : virtual works models





All possible failure model are considered



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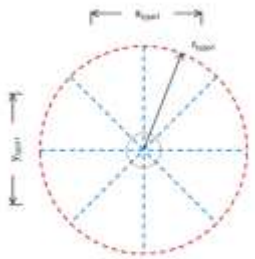
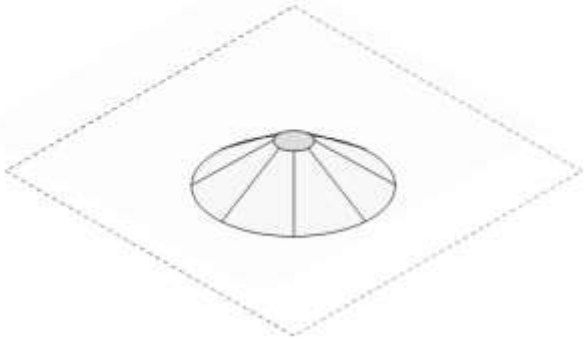
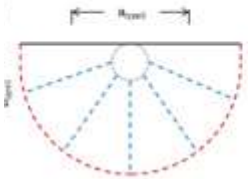
The theory ; virtual works models

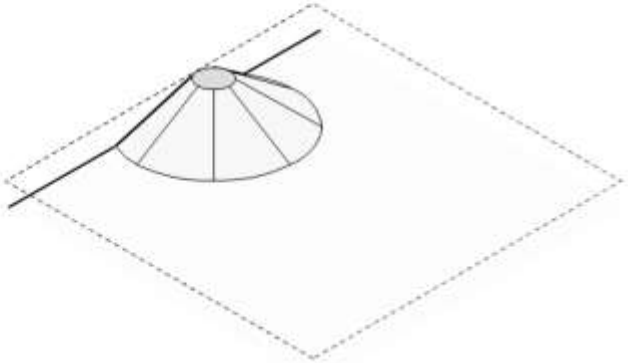
Inner Pile



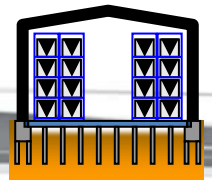


: Free Edge or Joint



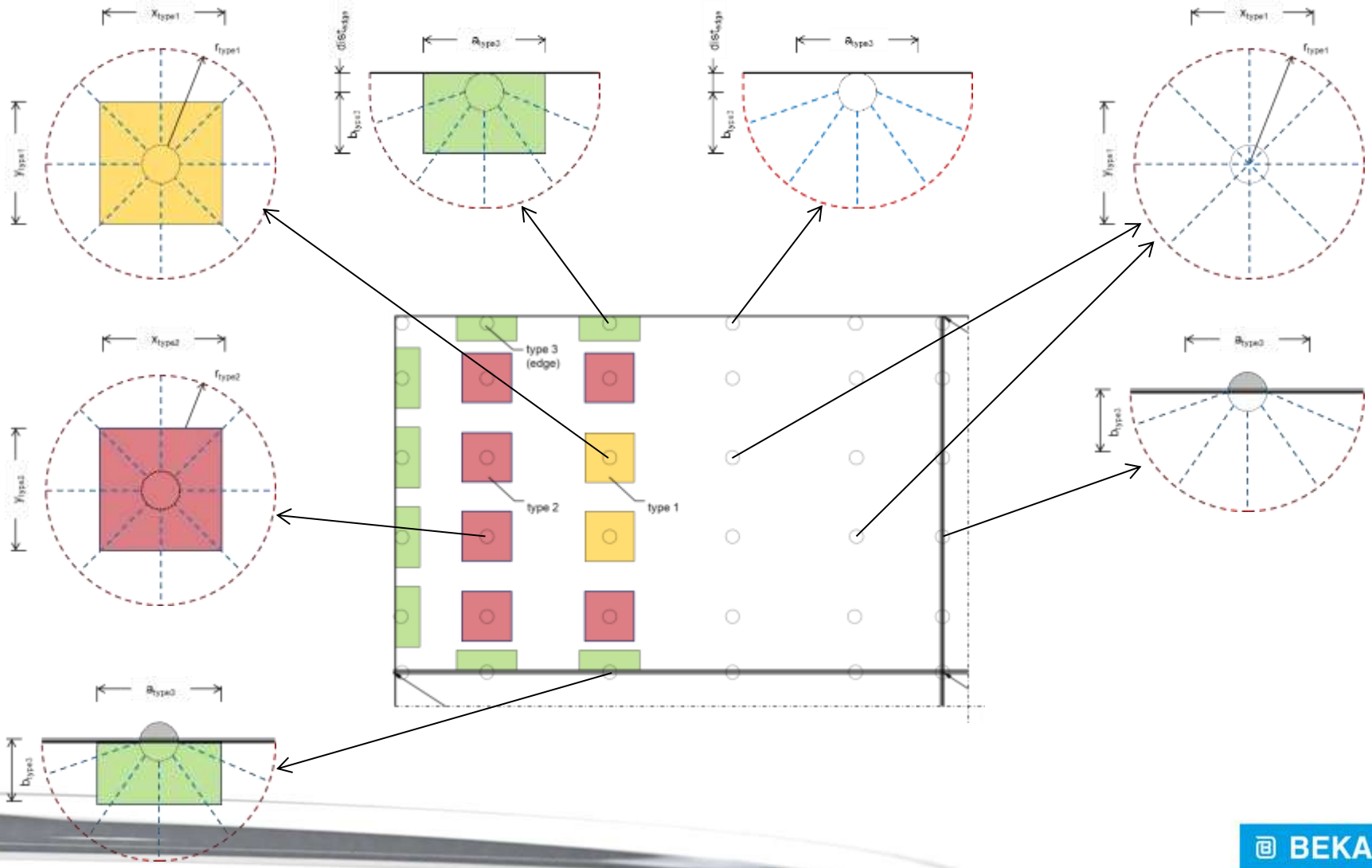


In addition to the folded plate model the “fan” failure model is also considered. This for all pile locations ; center, edge, corner, joints,…



Slab on Pile Design Concept

Fan Pattern – Combined Reinforcement + Fibre Only



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Introduction to Seamless Slab

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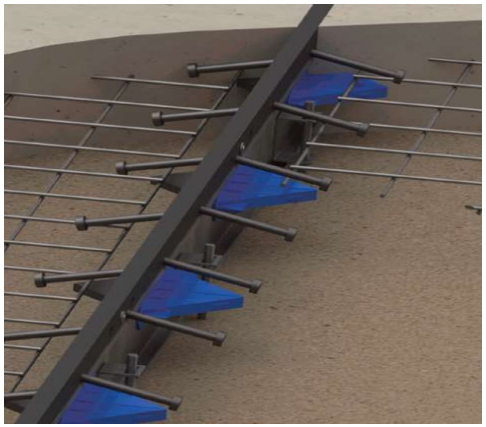
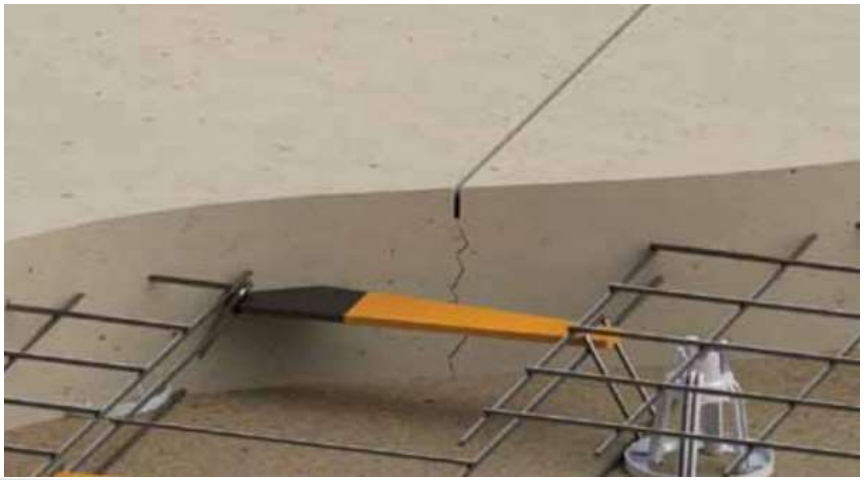
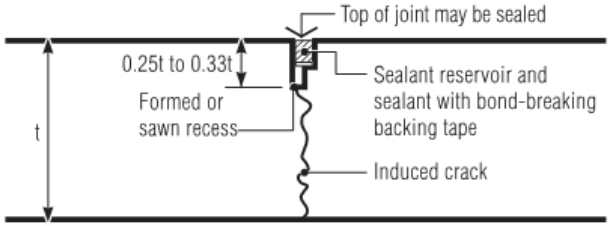
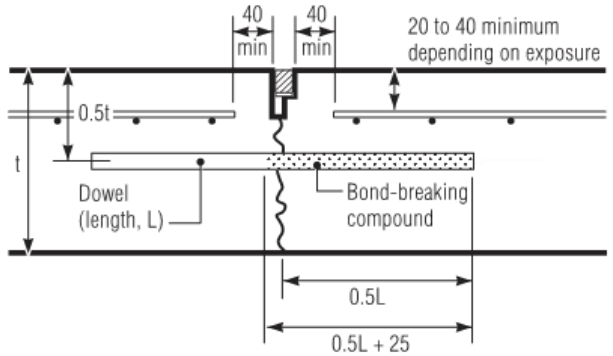






UNDOWELLED JOINT



DOWELLED JOINT

PD³™
Dowel Cradle

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4D
Dramix®
Combi Slab – steel fibres + mesh
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Introduction to Seamless Slab

Benefits:

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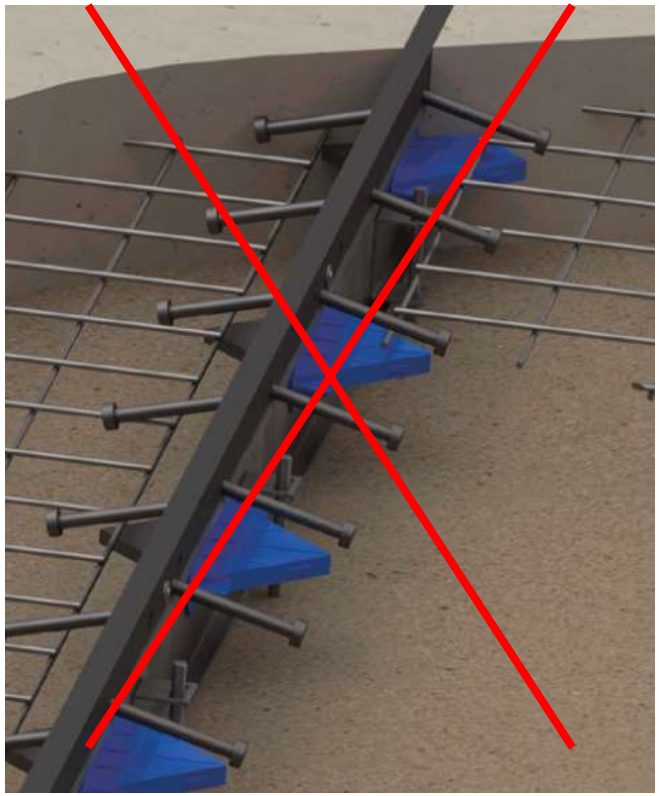
Introduction to Seamless Slab

Benefits:



No armor joint need = Cost saving

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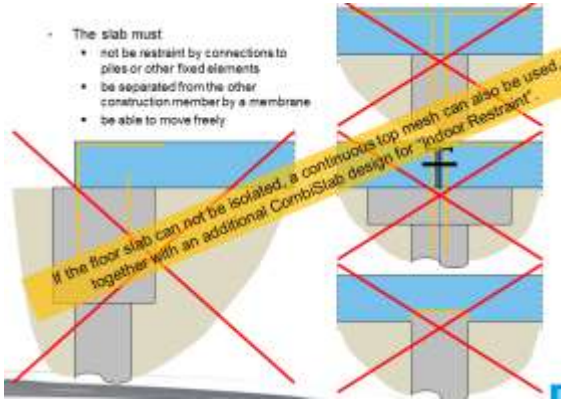
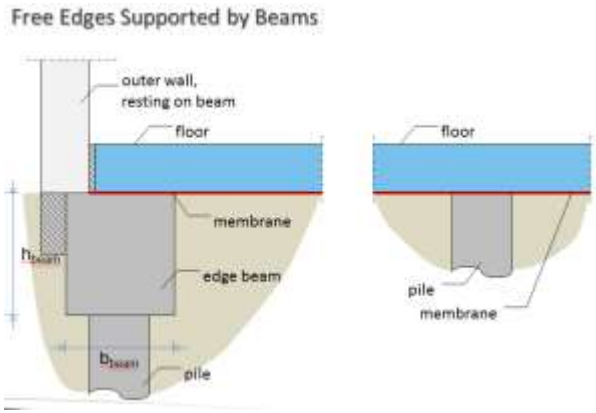
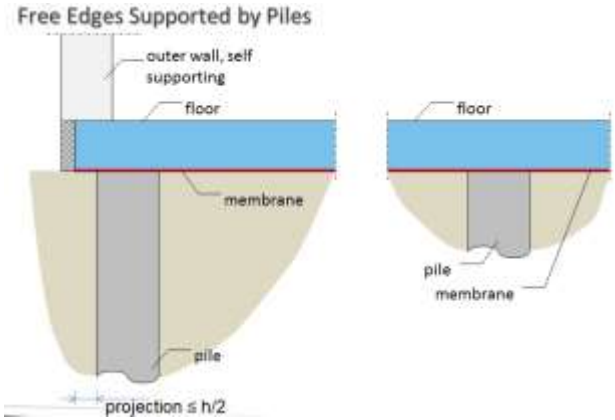
Benefits:







Less problem with slab restrain → **Simplify construction detail** → **Minimize onsite mistake**

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References

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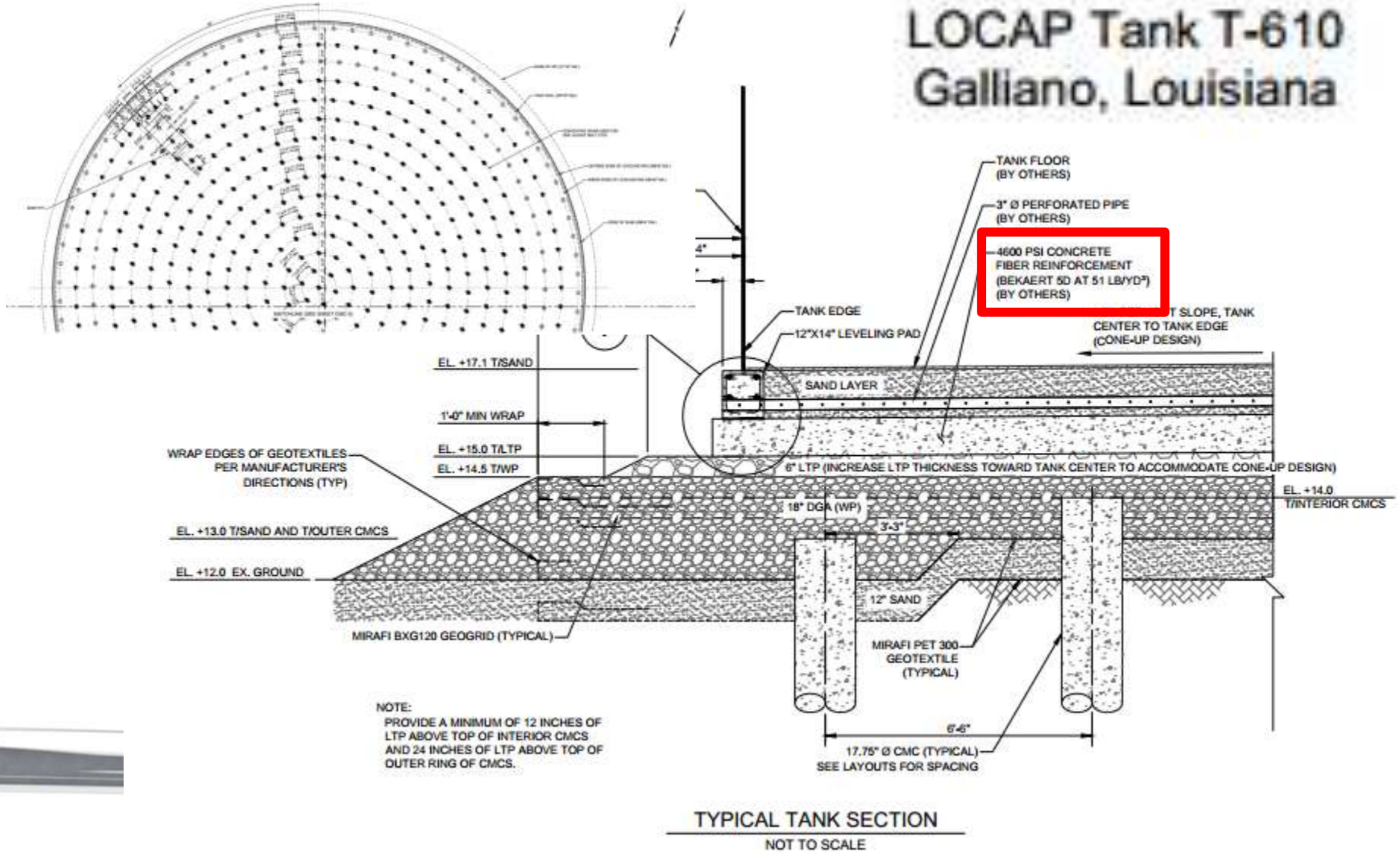
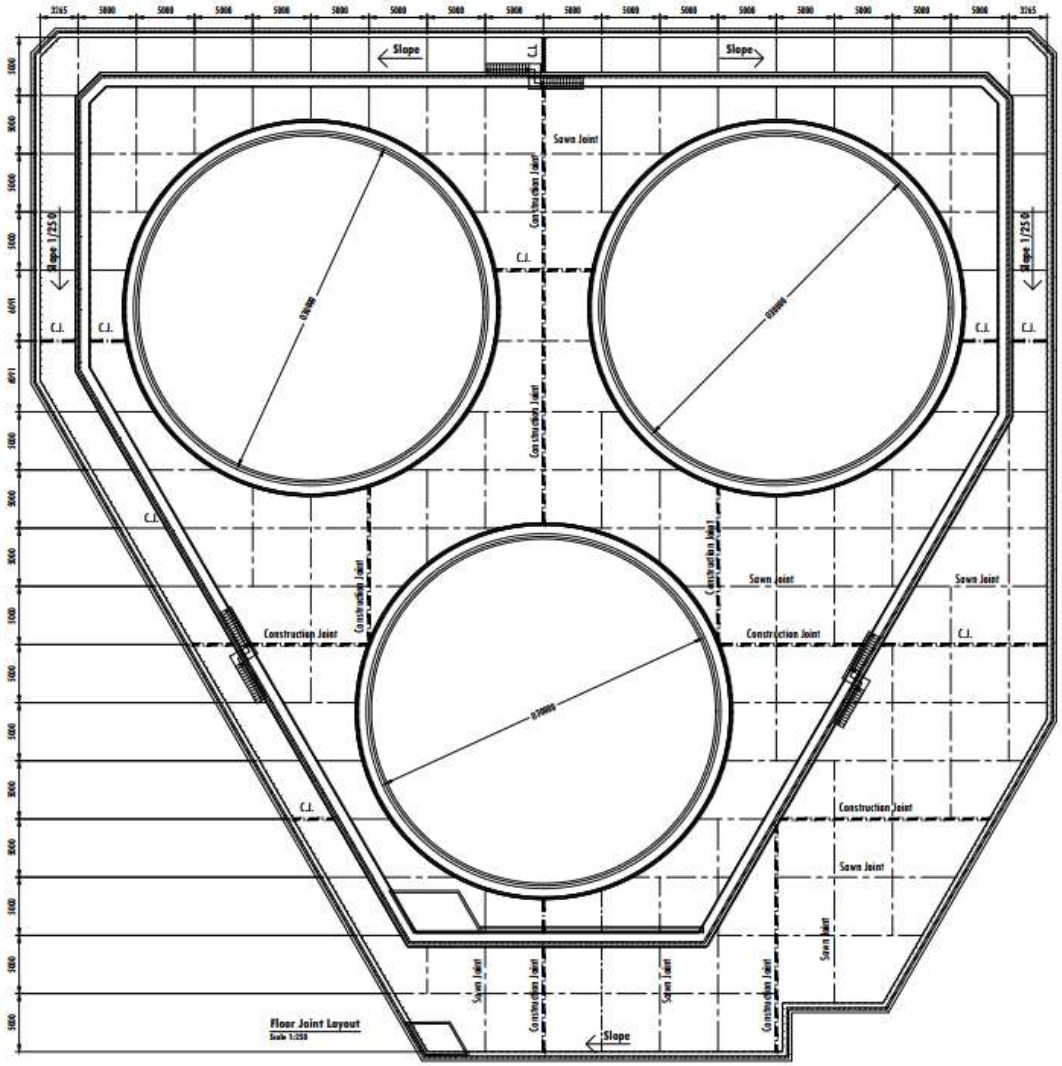
VDO Customer Testimonials

Oil & Gas Industry



Oil & Gas Industry



EPC CONTRACTOR: –

ARUN FABRICATORS
INDIA

CONTRACTOR: –

GENERAL CONSTRUCTION CO. LTD
BUILDING & CIVIL ENGINEERING CONTRACTORS
TEL : (230) 202 2000
FAX : (230) 208 8249
email : drawings@gcc.mu

PROJECT: –

TANK FARM DEVELOPMENT PROJECT
LES GRANDES SALINES

Central Electricity Board

ENGINEER: –

Mott MacDonald

ARCHITECT: –

YRDESIGNS
architects + associates

HFO TANK FARM
FLOOR JOINT LAYOUT AND JOINT DETAILS
AND RC DETAILS OF BUND WALL

Drawn : S.D.		Drawing No.	Rev.
Checked : C.N.		1139/210	
Approved :			
Date : 04/08/14			
Scale : 1:250, 1:30, 1:10			

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Oil & Gas Industry

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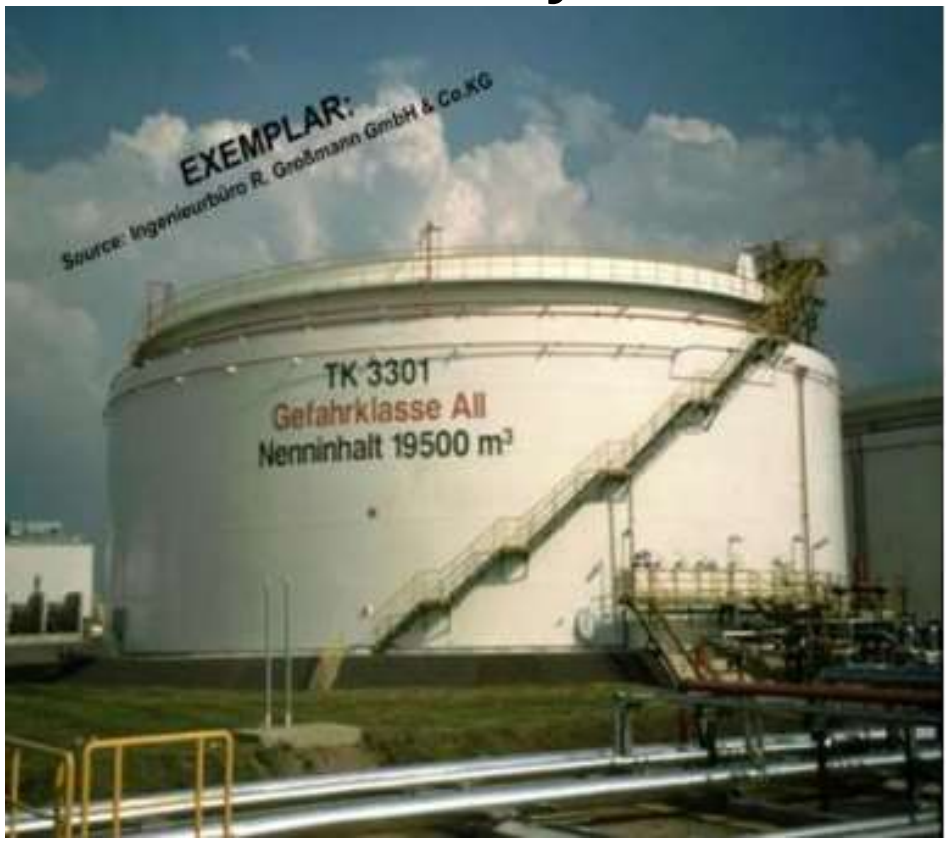

BASF Synthetic Lube

Project info

Date: March-May 2014
Location: Germany, BASF Ludwigshafen
Contactor: Heberger GmbH
Owner: BASF
Highly demanding structure

Technical solution

Dramix® 5D 65/60BG
30 kg/m³
Additional reinforcement (if any)
1550 mm
C35/45, Fluid-tight concrete
Prestressed walls

Unseen levels of performance

5D Dramix

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Oil & Gas Industry

COMBISLAB

COMBISLAB – CONTAINMENT BUND

The Dramix® CombiSlab solution enabled the design of a water tight layer and construction of the bund without any joints, using one layer of mesh plus Dramix®.

Leakage of containment bunds can be an issue and costly to put right. Typical design and construction has sealed joints and expensive water stops. However, if the bund cracks outside these control points then there commonly isn't enough reinforcing to control them to acceptable levels. Alternatively, heavy top and bottom reinforcing can be used to reduce the number of joints, this is expensive and difficult and time consuming to construct.

TYPE OF APPLICATION:
Joint free liquid tight slab

2012:
North Island, New Zealand

Technical solution

- Fibre type: Dramix®
- Concrete thickness: 120mm
- Concrete quality: C30/37
- Project size: 1,500m2
- Engineer: Calibre Consulting Engineers

CALL 1300 665 755 (AUS) OR 0800 665 755 (NZ)
VISIT BOSFA.COM

BOSFA Dramix

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Agriport te Middenmeer - Dakoplast

- *Project info*
  - *November 2013*
  - *Middenmeer, N.-Holland – the Netherlands*
  - *BNT bedrijfsgebouwen Wieringerwerf*
  - *Dakoplast b.v.*
- *Technical solution*
  - *Dramix® 5D 65/60BG*
  - *35 kg/m³*
  - *180 mm*
  - *C30/37*
  - *6000 m² - 37,8 ton*
  - *Max. joint distance 38 meter.*
- *Benefits*
  - *Cost and time saving*
  - *Design by Bekaert including piles (saving on engineering costs)*

KODACO NO. 3 PLANT

- *Project info*
  - *Oct 2013*
  - *South Korea*
  - *Hankook PCI/ABC Sangsa*
  - *KODACO*
  - *8270sqm*
- *Technical solution*
  - *Fibre type (Dramix® 5D 65/60 BG)*
  - *30kg/m3*
  - *Additional reinforcement - NONE*
  - *Slab thickness - 290mm*
  - *C30/37*
- *Benefits*
  - *Cost saving - NONE*
  - *Time saving – 25%*
  - *Other "value" gains – Direct discharge from trucks possible.*
  - *Higher durability – NO cracks.*

DinhVu Warehouse

- *Project info*
  - *November 2016*
  - *Hai Phong, VN*
  - *7000m2 GFA*
  - *Poor ground condition*

- *Technical solution*
  - *Fibre type (Dramix® 5D 65/60BG)*
  - *Dosage: 35 kg/m³*
  - *Additional reinforcement*
    - *Bottom mesh d8@200c/c on edge span*
  - *slab thickness: 230 mm*
  - *concrete quality: C30/37*
  - *Pile spacing 3.00x3.75m*
  - *Other relevant information*

- *Benefits*
  - *Cost saving (15%)*
  - *Time saving (35%)*
  - *Higher durability*

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References

Project info

- *April 2014*
- *Western Australia, Karratha*
- *Cooper & Oxley*
- *Komatsu Warehouse*
- *1500km North of Perth*

Technical solution

Fibre type (Dramix® 5D 65/60BG)
30kg/m³ (840m³ for 25.2tonne of fibre)
Additional reinforcement (Nil)
1500mm Deep Footings
32MPa
Traditional Reo N20 – N28 @ 200ctrs

KOMATSU - Karratha

References

MKW GmbH:
CladRack foundation

Project info

Date: October 2013
Location: Austria, Haag am Hausrück
Contractor: Strabag AG Direktion AV
Owner: MKW GmbH Austria

Technical solution

Dramix® 5D 65/60BG 30 kg/m³
320mm
C30/37
Only in the corner some bars in the bottom

References

Project info

Date: February 2013
Location: Slovakia, Bratislava
Contractor: Strabag /ZIPP Bratislava
Owner: Volkswagen Slovakia

Technical solution

Dramix® 5D 65/60BG
30 kg/m³
650mm
C30/37
Top and bottom mesh: 8mm/100mm/100mm, some additional bars in the corners

Unseen levels of performance

5D Dramix

VW Slovakia a.s.: CladRack foundation

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Pavement

Port of Brisbane (Australian Container Freight Service)

- Largest Seamless Floor (50,000 m2 no joint)
- Heavy loads from bulk containers storage and handling equipment
- High traffic

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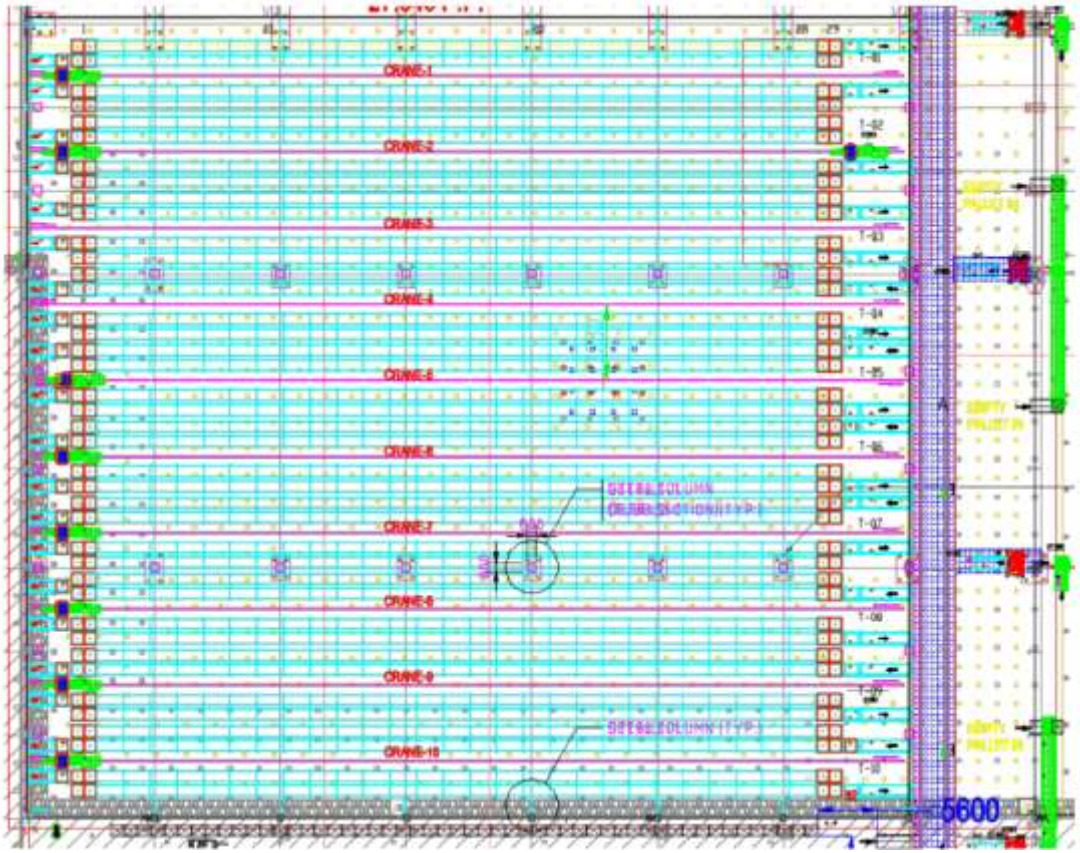
Pavement

Outdoor Pavement of Nahar Foundation Pvt. Ltd., Chennai, India

- 125 mm thickness
- Concrete: C30
- Dramix 3D 80/60BG

References



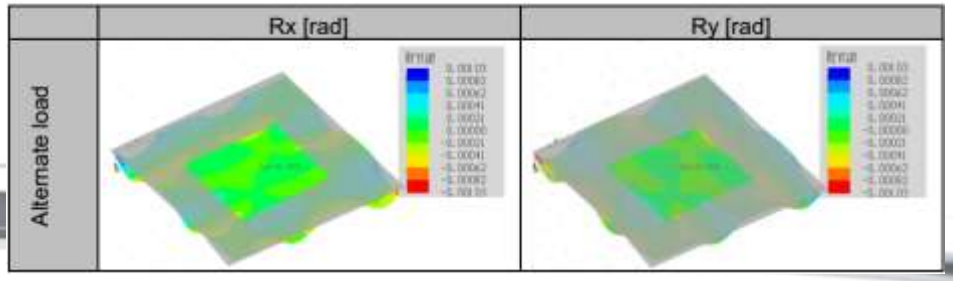
PepsiCo Thailand

Project info

Date: April 2017
Location: Saraburi Thailand
Contractor: Thai Takenaka
Owner: PepsiCo

Technical solution

Slab rotation consideration
Dramix® 4D 65/60BG 32 kg/m3
DB10@150 conti top reinforcement
350mm thickness
C30/37
some additional bars in the corners



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Many thanks for your attention

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