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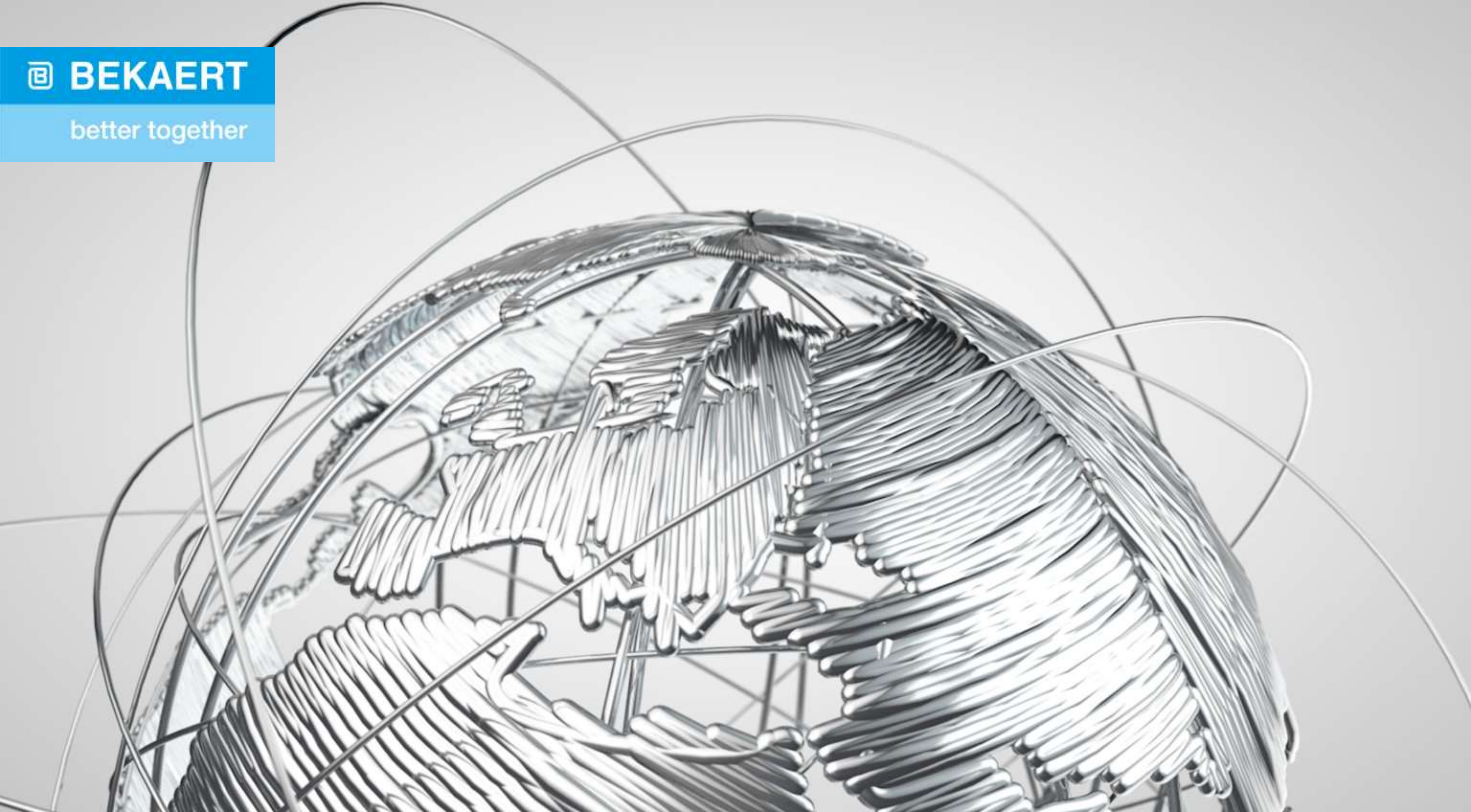
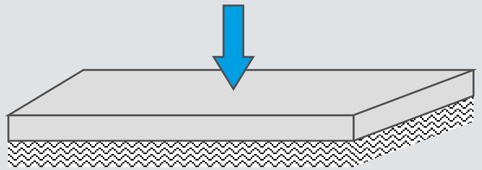


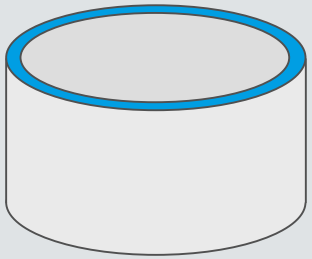
1

Technical Aspects of SFRC

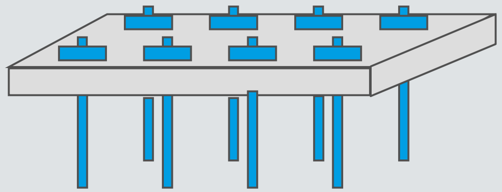
Statically indeterminate systems with multiple load redistribution possibility



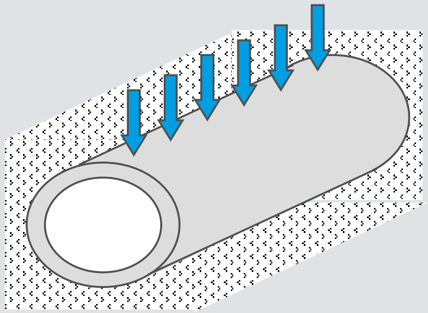
Slab on grade



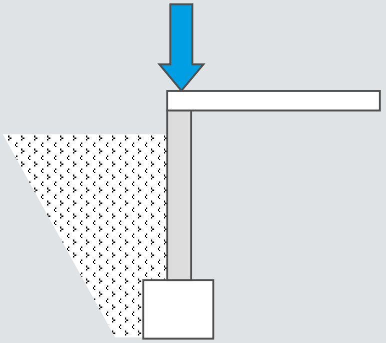
Tunnel linings



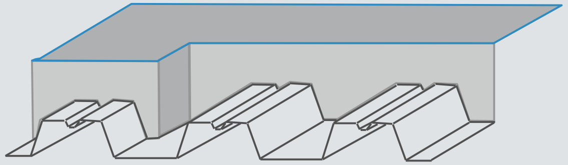
Floors on piles



Precast structures



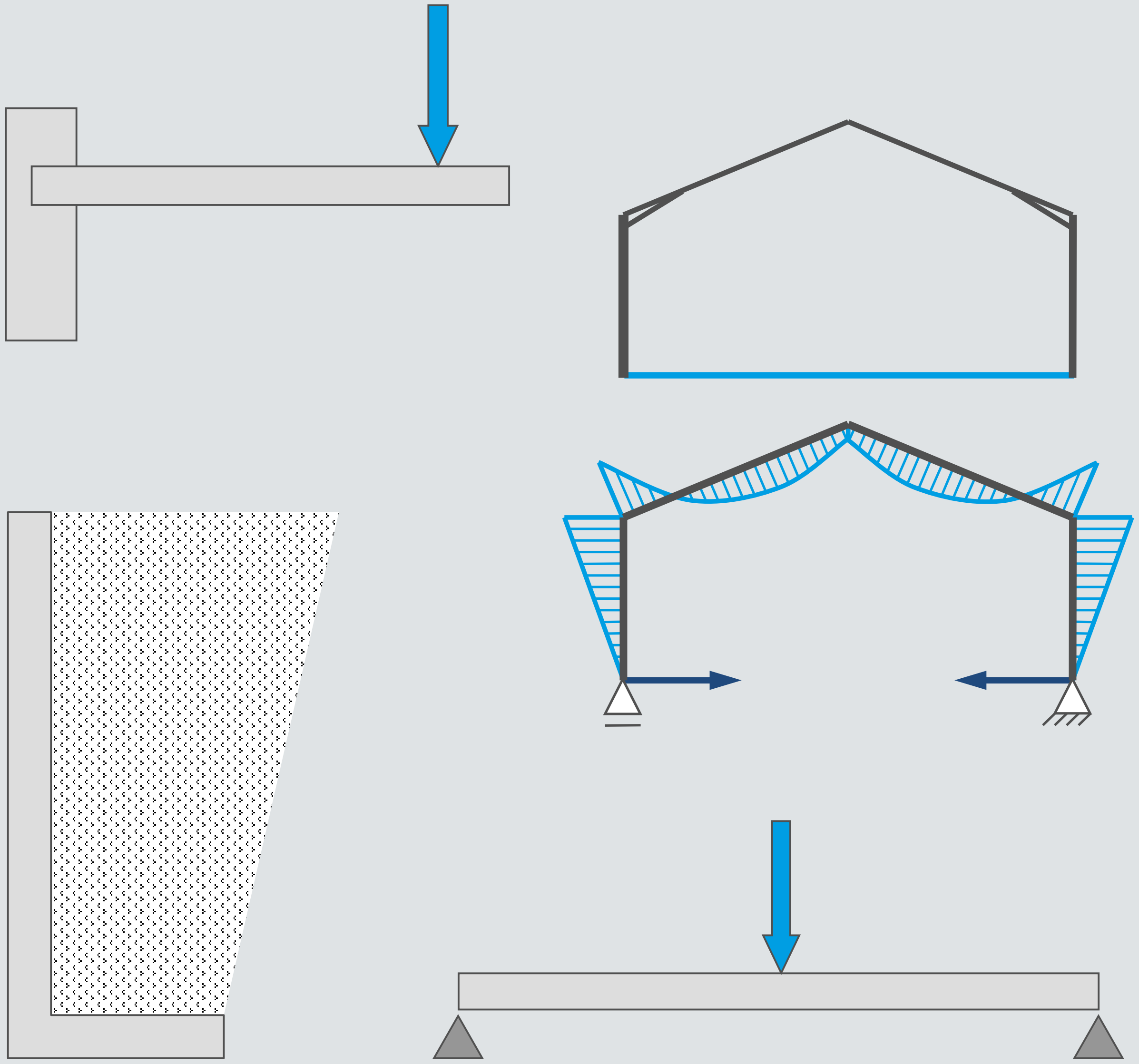
Foundations



Slab on metal deck

Suitable applications where steel fibers can be used without additional reinforcement

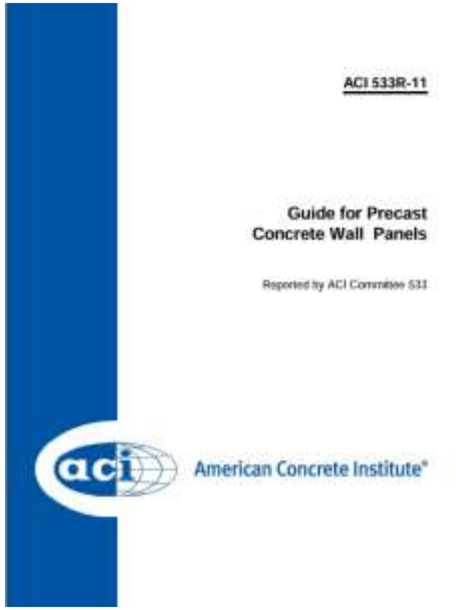
Not suitable for statically determinate systems where the first crack becomes the last crack with no possibility of load redistribution

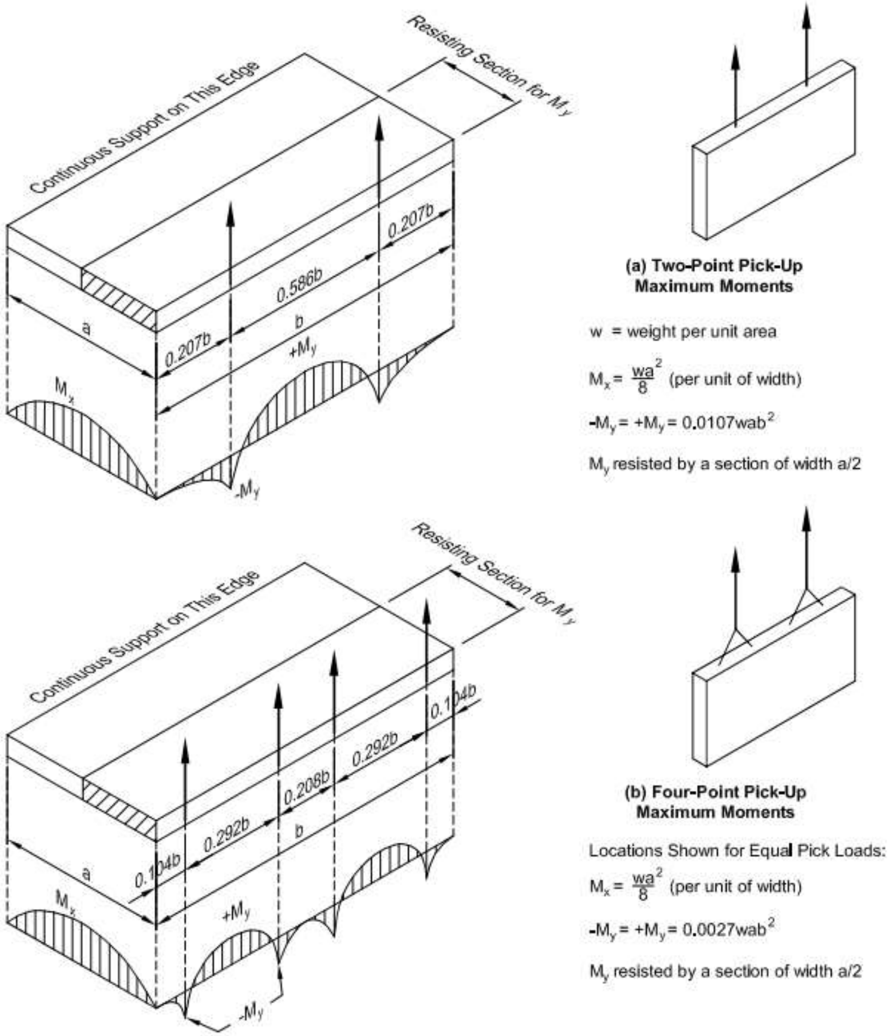


Those systems are only suitable for combined reinforcement

Dramix® in Precast

Design start from Guideline





Design start from Guideline

Figure 5.2.2.1 Positive drafts and breakaway forms

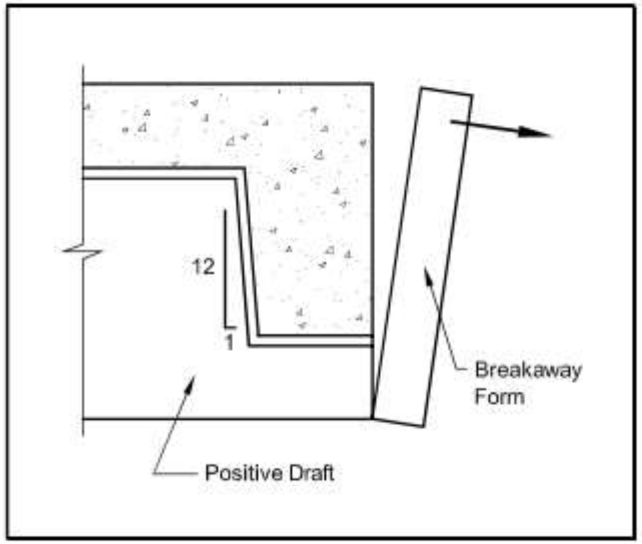
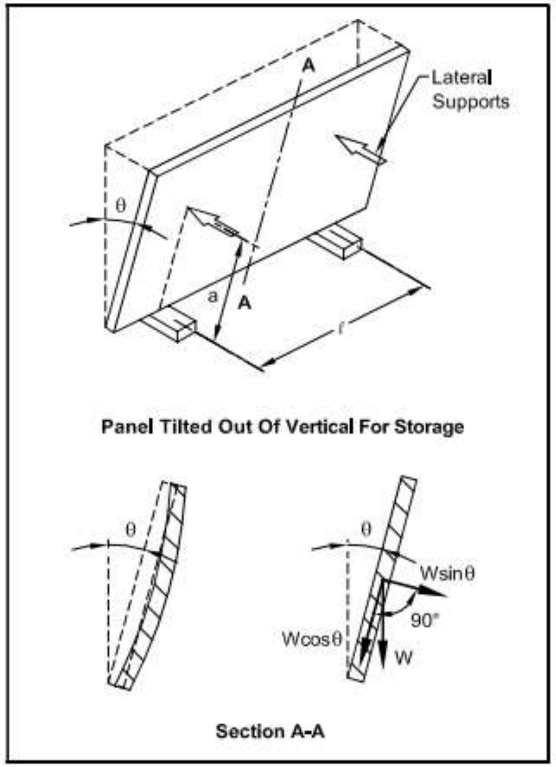


Figure 5.4.2.1 Panel warpage in storage



Design start from Guideline

Figure 5.5.1 Transporting single-story panels

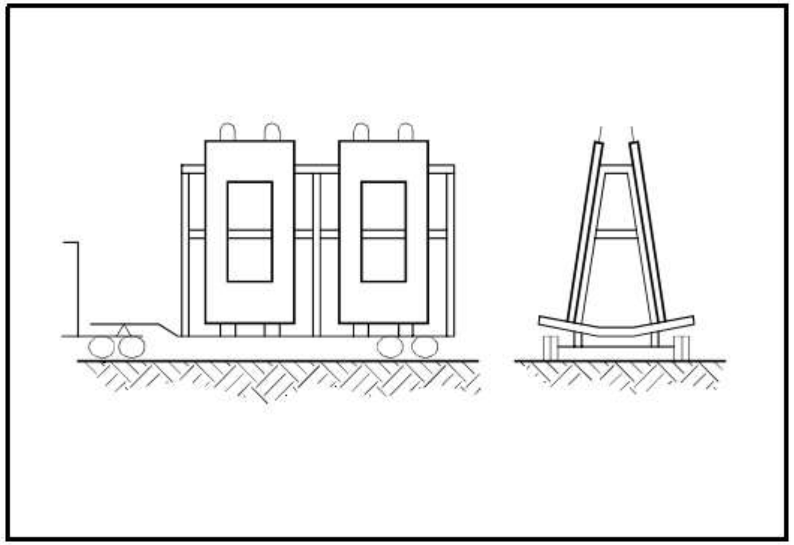
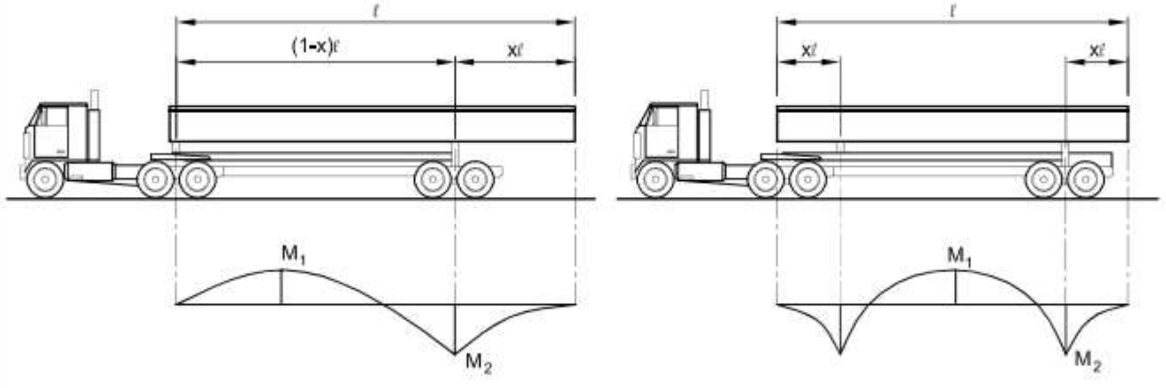


Figure 5.5.3 Equations for equal tensile stresses at top and bottom of member



(a) One End Cantilevered

(b) Both Ends Cantilevered

$$x = \frac{1}{2}\left[1 + \sqrt{\frac{y_b}{y_t}} - \sqrt{1 + \frac{y_b}{y_t}}\right]$$

$$x = \frac{1}{2\left[1 + \sqrt{1 + \frac{y_t}{y_b}}\right]}$$

Where:

y_b = distance from the bending axis to the bottom fiber

y_t = distance from the bending axis to the top fiber

Design start from Guideline

(b) Panel with openings

Analyzing as a continuous beam with rigid supports:

$$f_t = \frac{(6.8)(1.4)(12)}{1280} = 0.089 \text{ ksi}$$

$$\text{or } f_t = \frac{(5.9)(1.4)(12)}{640} = 0.155 \text{ ksi}$$

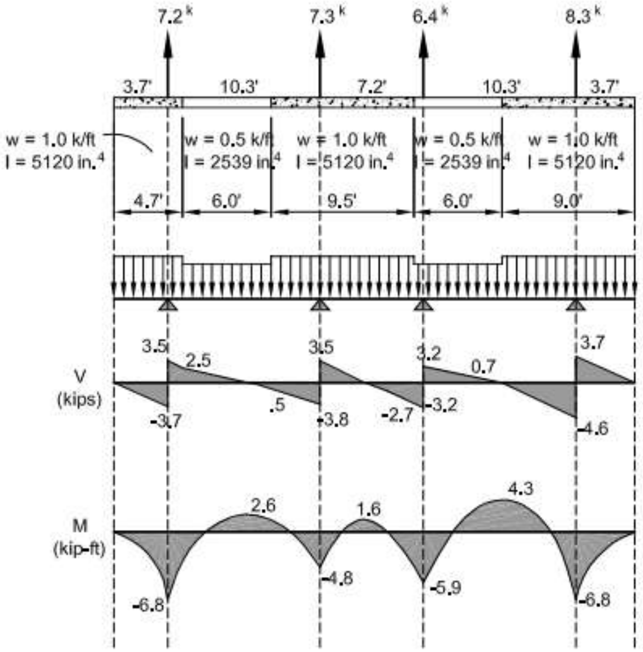
0.155 ksi < 0.274 ksi OK

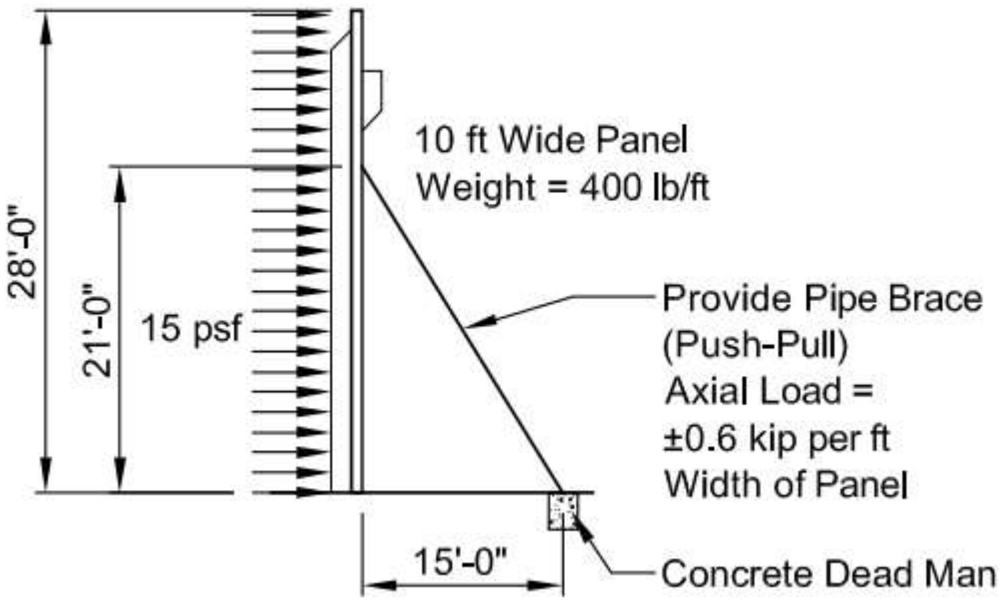
Because there is a false joint near the point of maximum stress, recalculate stress using reduced cross section.

S_t at false joint:

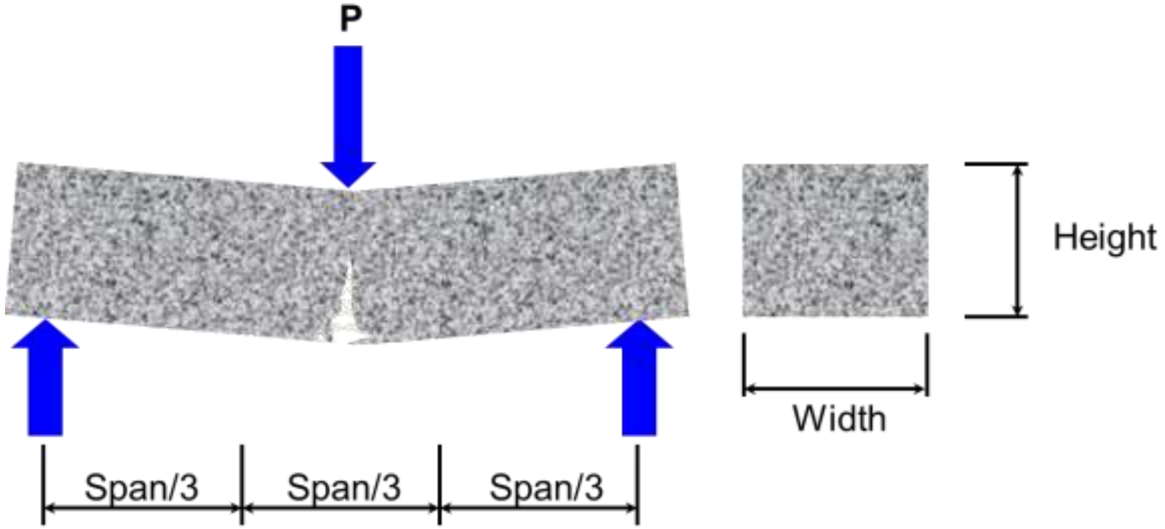
$$= \frac{(120-60)\left(8-\frac{3}{4}\right)^2}{6} = 526 \text{ in.}^3$$

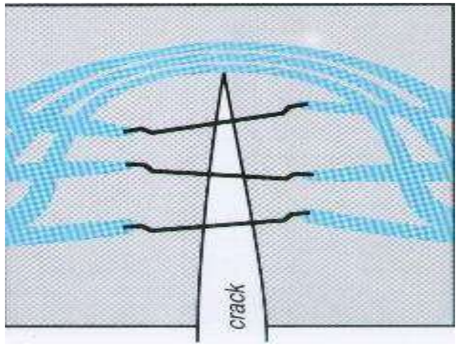
$$f_t = 0.155\left(\frac{640}{526}\right) = 0.189 \text{ ksi} < 0.274 \text{ ksi} \quad \text{OK}$$

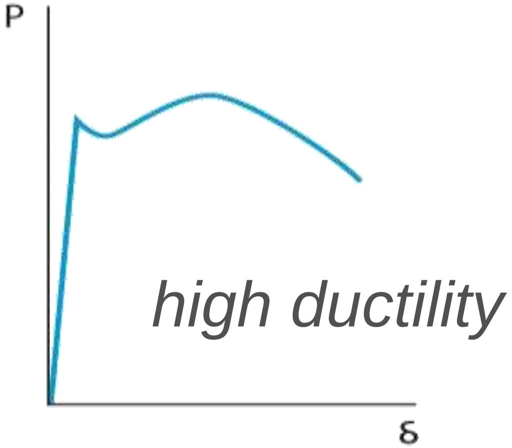




Resisting Force







From material characterization to design rules → international standards

- ASTM 820 - C 1018 (USA)
- JSCE - SF 4 (Japan)
- Efnarc/Rilem/CEN (Europe)

- Model Code 2010 (global)
- DAfStb guideline (Germany)
- ACI 360 - ACI 544 (USA)
- TR 34, 4th edition (UK)
- DBV, fibre approvals (Germany)
- CUR 111 and BRL 5060 (BE/N/LUX)
- SIA 162/6 (Switzerland, Tunnelling)
- SS 812310 (Sweden, Yield line)
- GB 50037 (China)
- SOG chapter of < SFRC structure design code >

Many others …

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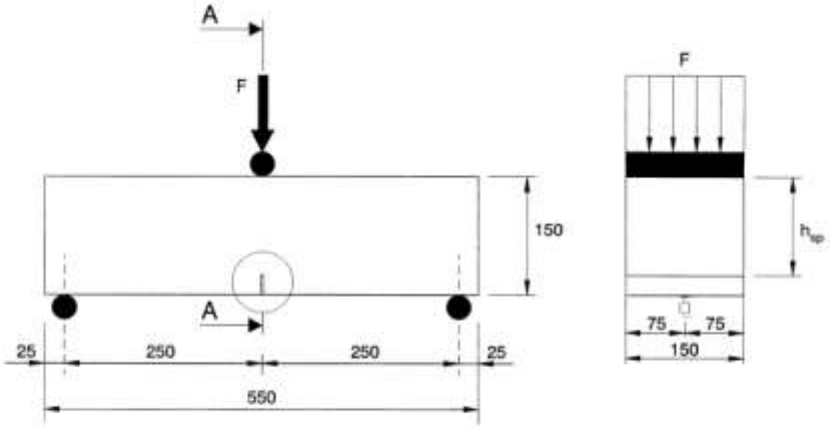
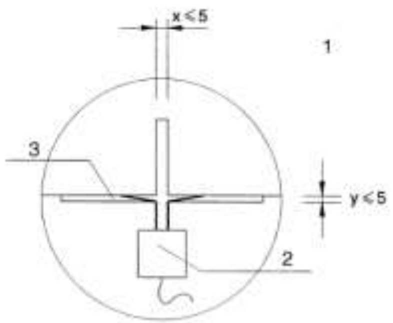
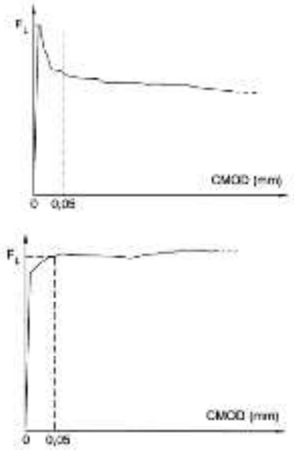
Flexural Strength – EN 14651 Beam Test

Test Method for metallic fibered concrete – Measuring the flexural tensile strength (limit of proportionality (LOP), residual).



section A-A





- The entire beam geometry is standardized
- Known crack location
- Reflective of true engineering properties

(CMOD → flexural strain → axial strain)

(Load → beam geometry → stress)

→ **σ-ε**

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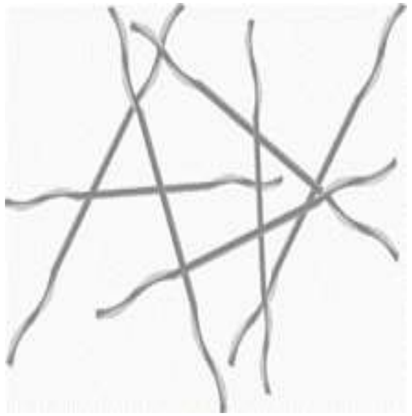

. . .

There are fibers of every size and every shape…

But Fiber ≠ Fiber

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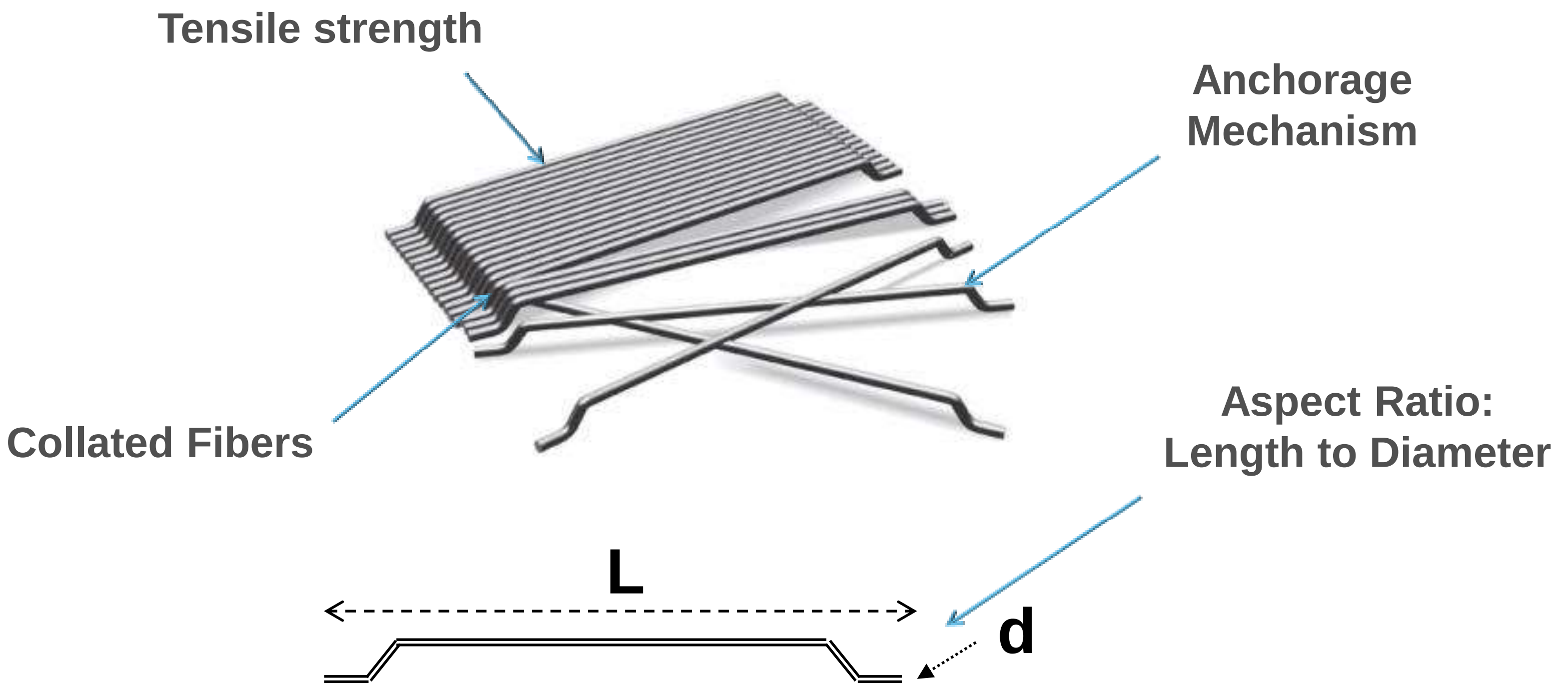
4 Important Factors Influence the Performance of Steel Fibers in SFRC



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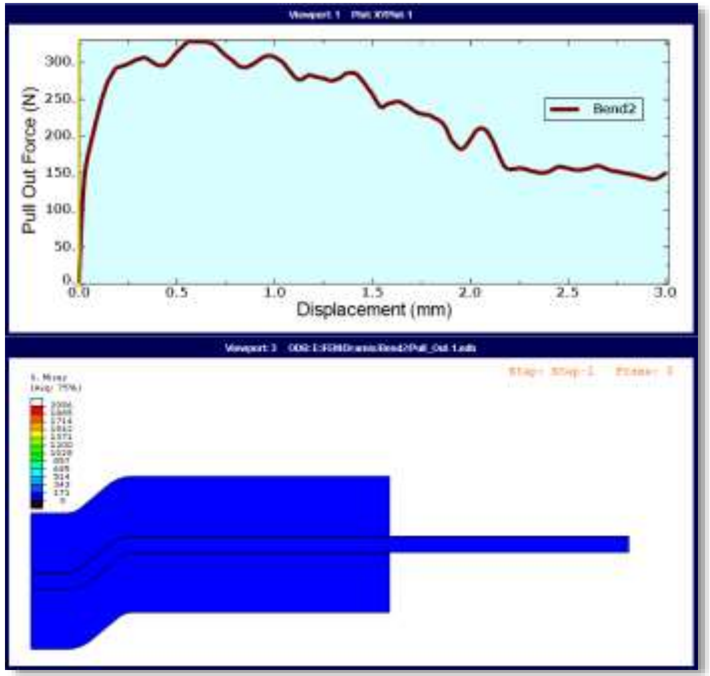
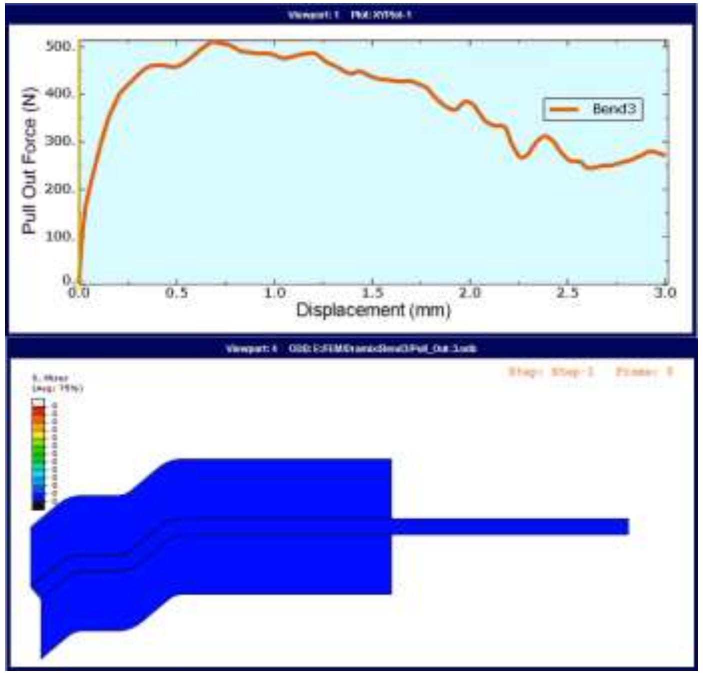
The performance of steel fibers depends on the Anchorage

3D Dramix®



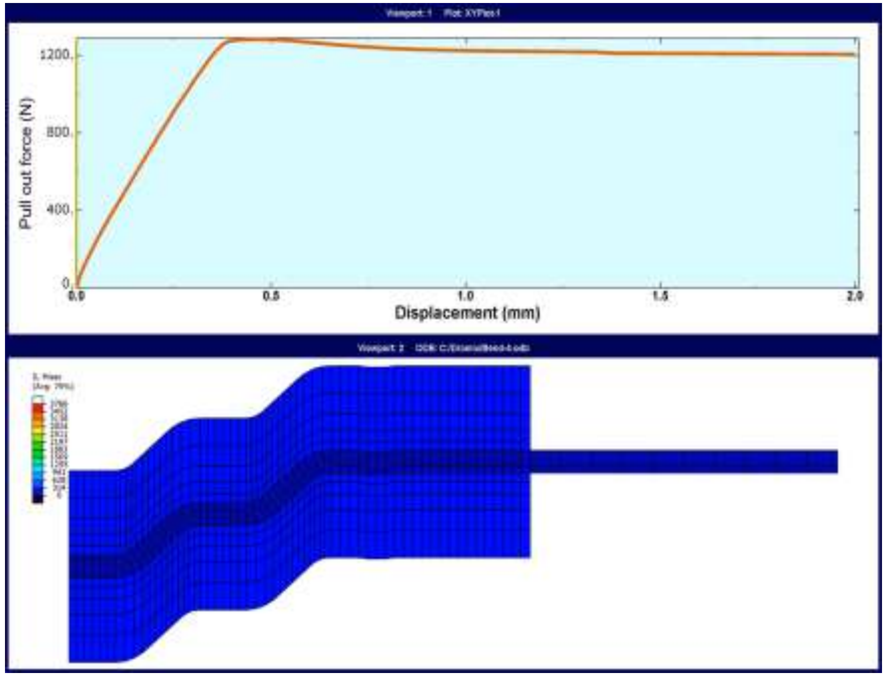
67 lbs

4D Dramix®



112 lbs

5D Dramix®



269 lbs

+67%

+140%

+300%

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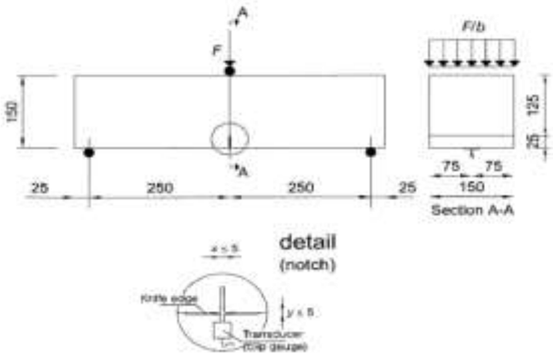
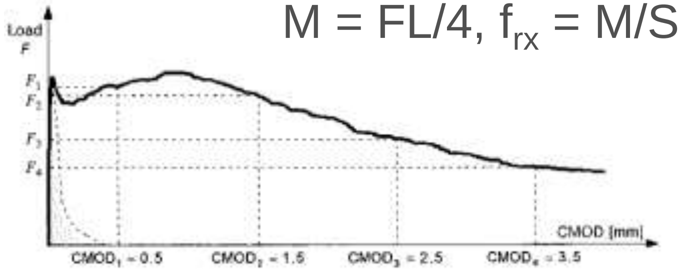
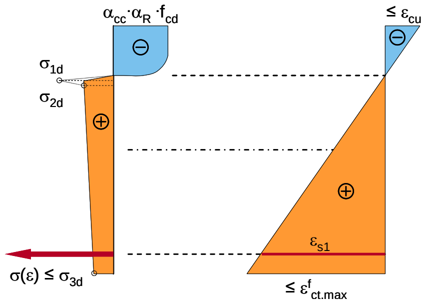
Determining the Section Moment Capacity:

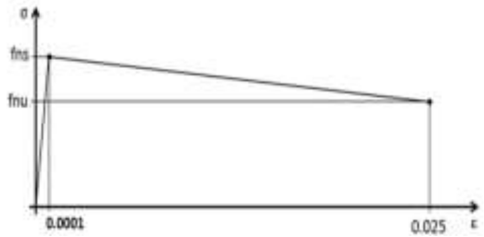


$M = FL/4,\ f_{rx} = M/S$

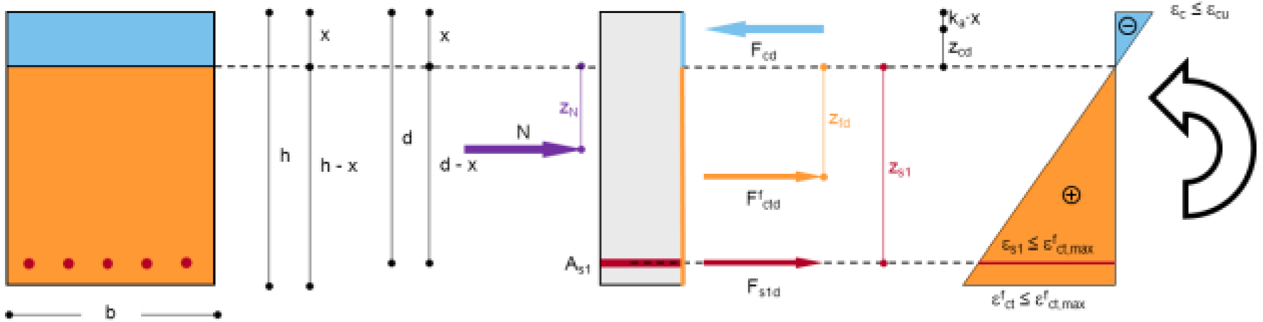




Constitutive model



Section moment capacity



Flexural Stress

Tension Stress

$f_{ns} = 0{,}45 f_{R1k}$ *fib* Model Code

$$f_{nu} = f_{ns} - \frac{w_u}{CMOD_3}(f_{ns} - 0{,}5 f_{R3k} + 0{,}2 f_{R1k}) \geq 0$$

Section Moment Capacity

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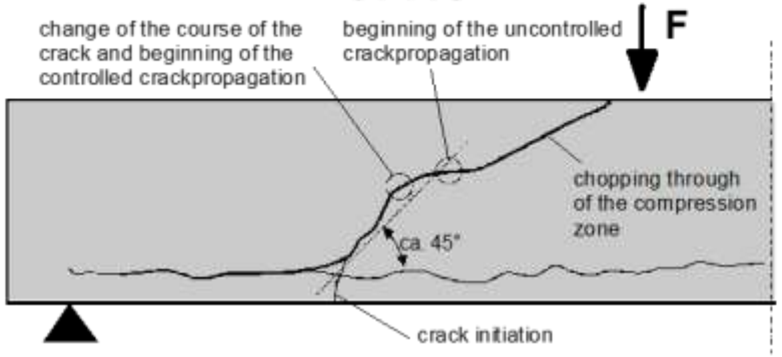
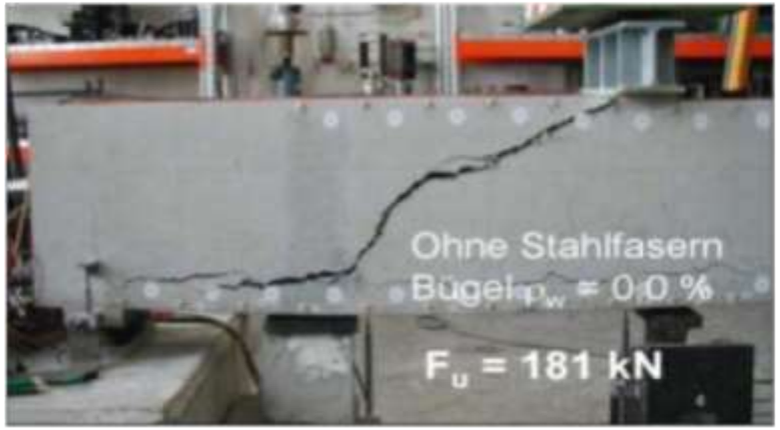
ULS: R_d – V_{Rd}

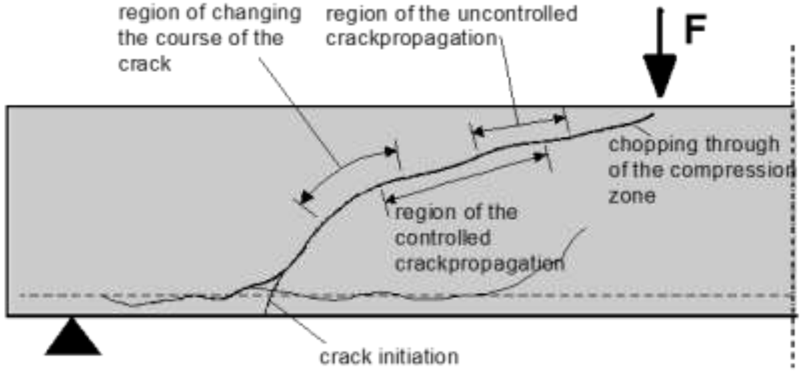
One Way Shear Capacity

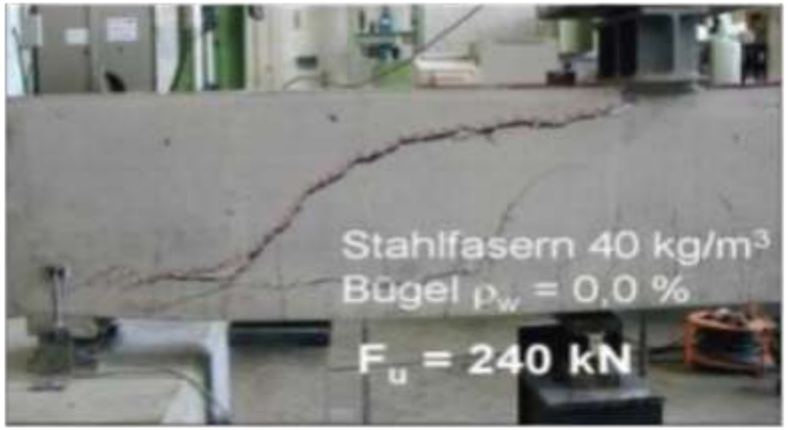
Shear Capacity without SFRC

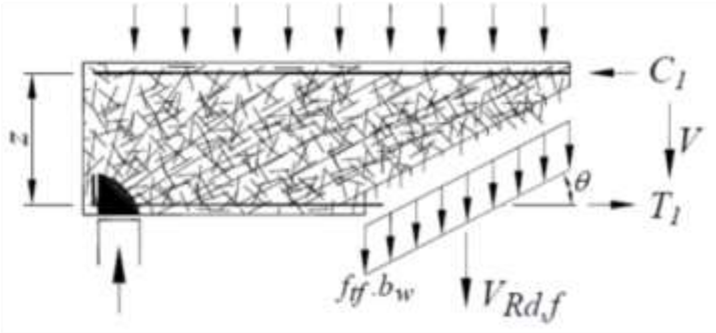


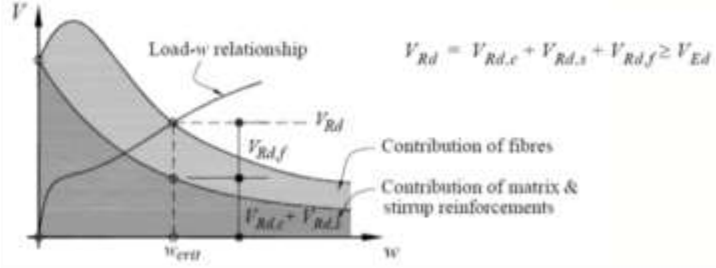


Shear Capacity with SFRC









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2

Dosing, Mixing and Finishing

Dosing of Steel Fibers

- Can be dosed at the job site and the batch plant
- Depends on the project
- Dramix® comes in 44 lb. bags
- Bekaert provides conveyers (if needed)
- Fibers should never be the first in the mixer
- Mix at 10-14 rpm for 70 revolutions

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Easy Placing of Dramix® Steel Fibers

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Easy Placing of Dramix® Steel Fibers

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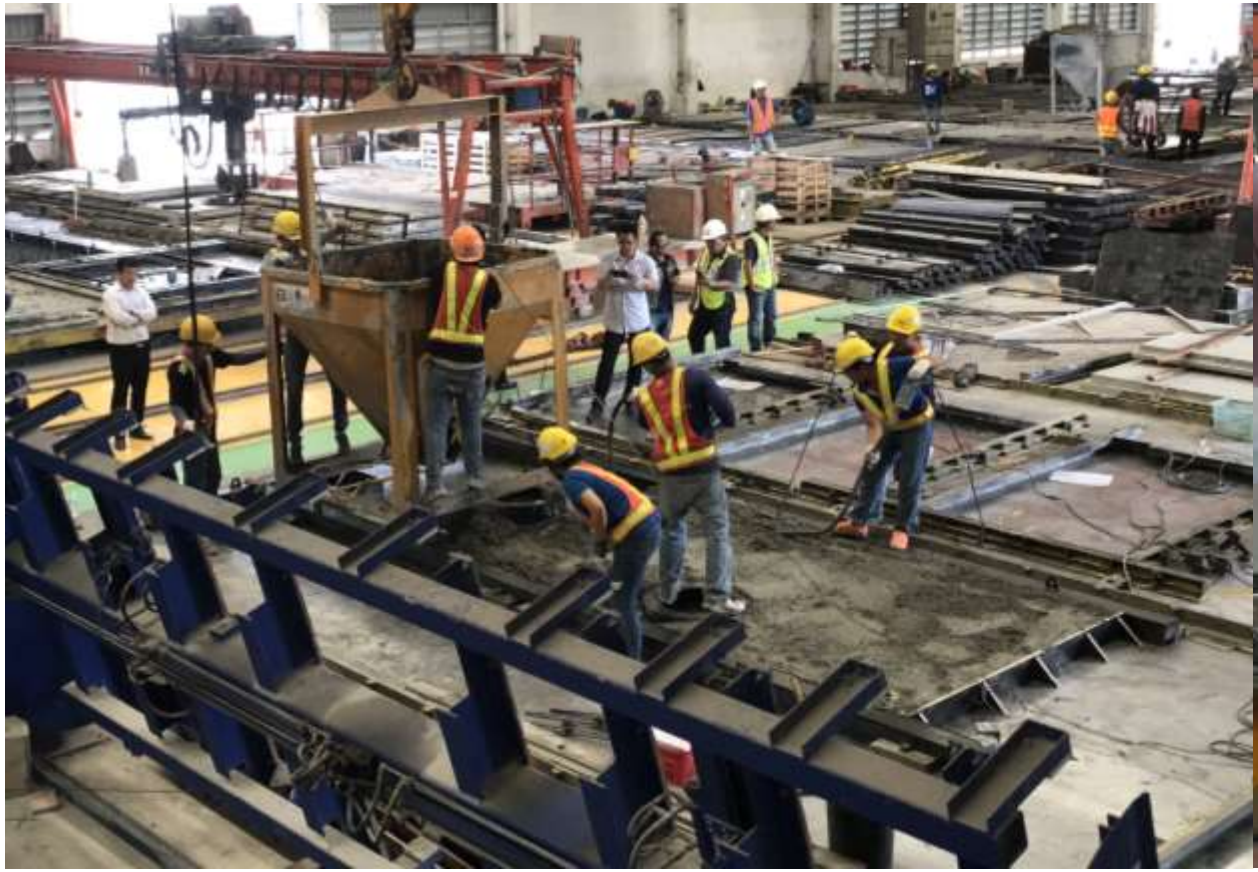
Vibrating and finishing



3

References

Stair Precast Element

- Thailand
- 200kg/m2 UDL
- Full Scale test to ensure structure

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Moment Capacity	**beam type section**		
design approach	DAfStb Technical rule on Steel Fibre Concrete		
safety factors	Structural Applications, Ultimate Limit State		
reinforcement layout	Combined		

Geometry: beam type section

h	120	[mm]
b_1	1000	[mm]

Fiber Concrete

concrete class	C28/35		
residual strength $f_{R1,m}$	2.70	[N/mm²]	(according to EN 14651
residual strength $f_{R4,m}$	3.00	[N/mm²]	(according to EN 14651

Steel Fibers

Dramix® fiber type	Dramix 4D 65/60BG	(EN 14889-1: System '1' - Structural Use
recommended dosage	20 kg/m³	(recommended dosage for testing according to EN 14561

Reinforcement

yield strength f_{yk}	390	[N/mm²]			
Reinforcement A_{s1}	(bottom)		**Reinforcement A_{s2}**	n/a	
bar diameter d_s	12	[mm]	bar diameter d_s	-	[mm]
number of bars	3	[-]	number of bars	-	[-]
rebar cross section	339	[mm²]	rebar cross section	-	[mm²]
concrete cover c_{nom}	30	[mm]	concrete cover c_{nom}	-	[mm]

Bending Moment Capacity

M_{Rd}	**13.31**	**[kNm]**	
N	0.0	[kN]	(compression force: negative sign

House Slab Precast Element

- Thailand
- 200kg/m2 UDL
- Fiber + PT
- Full scale test with varied PT to Optimum Design

Moment Capacity **slab type section**

design approach	DAfStb Technical rule on Steel Fibre Concrete		
safety factors	Structural Applications, Ultimate Limit State		
reinforcement layout	Fibers Only		

Geometry: slab type section

h	140	[mm]	
b_1	1000	[mm/m]	

Fiber Concrete

concrete class	C30/37		
residual strength $f_{R1,m}$	2.48	[N/mm²]	(according to EN 14651)
residual strength $f_{R4,m}$	2.12	[N/mm²]	(according to EN 14651)

Steel Fibers

Dramix® fiber type	Dramix 4D 65/60BG		(EN 14889-1: System '1' - Structural Use)
recommended dosage	20 kg/m³		(recommended dosage for testing according to EN 14561)

Reinforcement Fibers Only

yield strength f_{yk}	-	[N/mm²]

Reinforcement A_{s1}	n/a		Reinforcement A_{s2}	n/a	
bar diameter d_s	-	[mm]	bar diameter d_s	-	[mm]
bar distance s	-	[mm]	bar distance s	-	[mm]
rebar cross section / m	-	[mm²/m]	rebar cross section / m	-	[mm²/m]
concrete cover c_{nom}	-	[mm]	concrete cover c_{nom}	-	[mm]

Bending Moment Capacity

M_{Rd}	**5.26**	**[kNm/m]**	
N	0.0	[kN/m]	(compression force: negative sign)

Calculated moment direction: positive moment capacity

Data Base 1.1.1
Moment Capacity 3.1.6

- Capacity at 5% strain to match with PT requirement

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House Slab Precast Element (Wash area)

- Thailand
- 200kg/m2 UDL
- Fiber only application

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Moment Capacity	**slab type section**	
design approach	DAfStb Technical rule on Steel Fibre Concrete	
safety factors	Structural Applications, Ultimate Limit State	
reinforcement layout	Fibers Only	

Geometry: slab type section

h	140	[mm]
b_1	1000	[mm/m]

Fiber Concrete

concrete class	C28/35		
residual strength $f_{R1,m}$	2.70	[N/mm²]	(according to EN 14651)
residual strength $f_{R4,m}$	3.00	[N/mm²]	(according to EN 14651)

Steel Fibers

Dramix® fiber type	Dramix 4D 65/60BG	(EN 14889-1: System '1' - Structural Use)
recommended dosage	20 kg/m³	(recommended dosage for testing according to EN 14561)

Reinforcement	Fibers Only	
yield strength f_{yk}	-	[N/mm²]

Reinforcement A_{s1}	n/a		**Reinforcement A_{s2}**	n/a	
bar diameter d_s	-	[mm]	bar diameter d_s	-	[mm]
bar distance s	-	[mm]	bar distance s	-	[mm]
rebar cross section / m	-	[mm²/m]	rebar cross section / m	-	[mm²/m]
concrete cover c_{nom}	-	[mm]	concrete cover c_{nom}	-	[mm]

Bending Moment Capacity

M_{Rd}	**6.27**	**[kNm/m]**	
N	0.0	[kN/m]	(compression force: negative sign)

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Road Barrier Precast Element

- Thailand
- Lifting at 12 hours after cast

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House Wall Precast Element

- Thailand
- Lifting at 12 hours after cast
- Fiber + rebar (Lifting control)

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Dramix
INSIDE

SIMAT

- France
- Since 1995
- 3D 80/60GG

Pipes

Wall, India

EDF
CHANGER L'ENERGIE ENSEMBLE

- France

Electric cabins

Channel Tunnel Rail Link

- Tunnel (Ø: 7.5 m)
- UK
- 2003-2004

Segmental lining


PIPE
Pfeiffer
France
Colle SPB
Caraibes Island
Omag
Belgium
Vifesa
Spain
Schlosser Pfeiffer
Brazil
Vihy Supermatic
Spain
Colle SPB
Netherland
Vibration
Turkey
Vibration
Mexique
Croci
Italy
Vihy Mastermatic
Portugal

Drainage Element

Wall & Barrier

France

Italy

Pile Head

China & Indonesia

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4

Open up the possibility

Stadium Seat

BEKAERT
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Tetrapod

Waterbreak

Wall Panel Element

U-Ditch

BEKAERT
better together

Wall Panel

BEKAERT
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Thank you!

www.Bekaert.com/dramix