SIKAFIBER® Product Proposal

FOR FIBER REINFORCED CONCRETE SLABS ON GROUND

PROJECT INFORMATION	
Project reference	ABC / 246810
Project name	New Multi-Purpose Warehouse
Customer	Your Customer Ltd
Date	20/02/2020
Calculation title	Warehouse A - Zone 1
Calculation by	DTI
Approved by	
Remarks	General loading + forklift + racking 1,2 and 3 + UDL
Country	Switzerland

PRODUCT INFORMATION	
Product	SikaFiber® Force-50
Dosage	3.0 kg/m³

DESIGN SUMMARY	
Design method	Concrete Society Technical Report 34 - Concrete Industrial Ground Floors, 4th Edition
Regulations	EN 1992-1-1. Eurocode 2: Design of structures - Part 1-1: General rules and rules for buildings
Concrete class	C40/50
Slab thickness	h = 300 mm
Joint spacing	x = 5000 mm; y = 5000 mm
Modulus of subgrade reaction	k = 0.020 N/mm³

LOADING SUMMARY

CHECKING TYPE	LOAD CASE	VALUE
Bending	Mezzanine 1	0.9721
Bending (MHE)	MHE 1	0.9160
Punching	Mezzanine 1	0.6868
Uniformly distributed loads	Uniform load 1	0.7331
Linearly distributed loads	Linear load 1	0.1167

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NOTES

Joints are placed in the slab to minimize the risk of cracking

- In fiber reinforced floors use square panels or limit the length-to-width (aspect ratio) to 1:1.5
- Limit the longest dimension between to sawn joints <6 m
- Avoid re-entrant corners
- Avoid slabs with acute angles at corners
- Avoid restrained shrinkage of the slab, isolate the slab around fixed points
- Avoid point loads in corners

Shrinkage and curling shall be evaluated on a project basis. There are several factors including, but not limited to.

- Internal concrete stresses occur greatly depending on the aggregate size, type and quality; the water content, cement paste content, admixture usage, concrete temperature and generally the mix design.
- Placement conditions due to the sub-grade moisture and preparation, sub-grade restraint and protection from environmental and ambient conditions (temperature variations, wind and humidity)
- Location and timeliness of jointing and proper joint activation.
- Proper curing is vital to all concrete construction. The standard rules of good concreting practice, concerning production and placing, shall be followed.

INDEX

1.- DESIGN DATA

Regulations

Concrete Society Technical Report No. 34 (TR 34): Concrete industrial ground floors. A guide to design and construction.
EN 1992-1-1. Eurocode 2: Design of structures - Part 1-1: General rules and rules for buildings

Partial safety factors for materials

Material	γ_m
Concrete / Fibre reinforced concrete	1.50
Steel	1.15

Partial safety factors for loads

Loads	γ_F
Racking loads	1.20
Permanent loads	1.35
Variable loads	1.50
Dynamic loads	1.60
Uniformly distributed loads	1.00
Linearly distributed loads	1.00

Soil parameters

k: modulus of subgrade reaction — k : *0.020* N/mm³

Concrete data

Concrete class: C40/50

f_{ck}: Characteristic cylinder compressive strength of concrete — f_{ck} : *40.00* MPa

E_{cm}: secant modulus of elasticity of concrete — E_{cm} : *35220.46* MPa

f_{ctm}: Mean axial tensile strength — f_{ctm} : *3.51* MPa

v: Poisson's ratio — v : *0.20*

Slab panel data

Panel dimensions: 5000 x 5000 mm

Load transfer at the edge: 15.0%

Load transfer at the corner: 15.0%

Reinforncement information

Reinforcement for bending: Not considered

Local reinforcement for punching: Not considered

2.- RESULTS

2.1.- Summary of results

Checking	Load case	Type	Usage ratio
Bending	Mezzanine 1	Single point load	0.9721
Bending (MHE)	MHE 1	Single point load	0.9160
Punching	Mezzanine 1	Single point load	0.6868
Uniformly distributed loads	Uniform load 1	Uniformly distributed load	0.7331
Linearly distributed loads	Linear load 1	Line loads	0.1167

2.2.- Fibre reinforcement proposal

Fibre-reinforced concrete data

Fibre type: Synthetic Macro-fibres

Sika product: SikaFiber® Force-50

Fibre dosage: 3.0kg/m³

f_{ck}: Characteristic cylinder compressive strength of concrete	f_{ck} :	40.00	MPa
f_{R1}: Residual flexural strength at CMOD 0.5	f_{R1} :	1.32	MPa
f_{R2}: Residual flexural strength at CMOD 1.5	f_{R2} :	1.33	MPa
f_{R3}: Residual flexural strength at CMOD 2.5	f_{R3} :	1.23	MPa
f_{R4}: Residual flexural strength at CMOD 3.5	f_{R4} :	1.13	MPa
h: Thickness of the slab	h :	300	mm

Joint spacing (X-direction): 5000mm

Joint spacing (Y-direction): 5000mm

2.3.- Capacity of fibre reinforced section

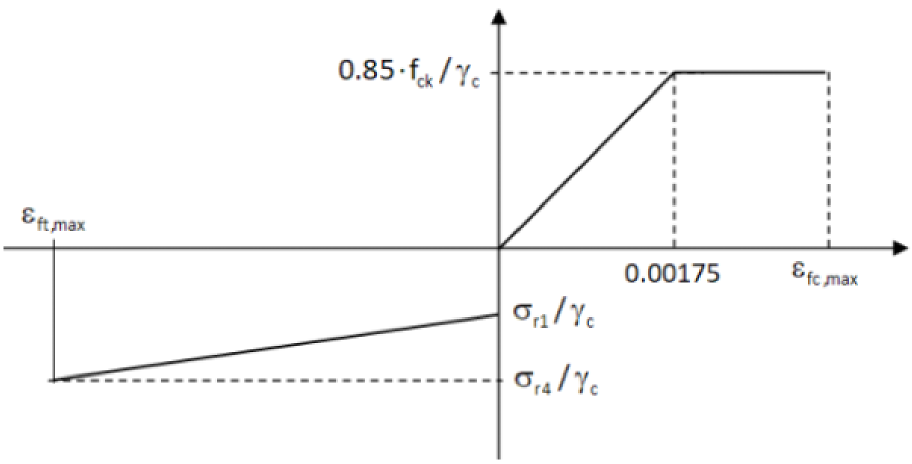
The ultimate moment capacity is dependent on the strain at the extremity of the section. On the compression face, the strain is limited to 0.0035, as is the case for conventional reinforced concrete sections. On the tension face, the strain is limited to 0.025.

The moment - crack width (M-w) response of the section is derived in terms of the residual strengths fR1 and fR4 obtained from the EN 14651 beam test. fR1 and fR4 represent the flexural tensile stresses at a Crack Mouth Opening Displacement (CMOD) of 0.5mm and 3.5mm respectively in the 150mm deep test beam. Although in sections deeper than 150mm, the strain at a CMOD of 3.5mm will be lower than in the test beam, the maximum tensile strain is set at the value resulting from a CMOD of 3.5mm, subject to a limiting maximum strain of 0.025.

For a slab with a low (cracked) flexural tensile capacity, the compressive strain in the concrete may remain in the elastic range, below 0.00175, in which case the concrete stress block is triangular. As the flexural tensile capacity increases, the compressive strain in the concrete increases and the compressive stress block becomes bi-linear.

Stress and strain diagram for bi-linear stress block for strain softening $|\sigma_{r1}| \geq |\sigma_{r4}|$

Stress and strain diagram for bi-linear stress block for strain hardening $|\sigma_{r1}| < |\sigma_{r4}|$



$e_{ft,max}$: Maximum tensile strain in fibre reinforced concrete — $e_{ft,max}$: *25.00* ‰

$e_{fc,max}$: Maximum compressive strain concrete — $e_{fc,max}$: *3.50* ‰

s_{r1}: Mean axial tensile strength derived from beam test EN 14651 at CMOD 0.5 — s_{r1} : *0.60* MPa

$$\sigma_{r1} = 0.45 \cdot f_{r1}$$

f_{r1}: Residual flexural strength at CMOD 0.5 — f_{r1} : *1.32* MPa

s_{r4}: Mean axial tensile strength derived from beam test EN 14651 at CMOD 3.5 — s_{r4} : *0.42* MPa

$$\sigma_{r4} = 0.37 \cdot f_{r4}$$

f_{r4}: Residual flexural strength at CMOD 3.5 — f_{r4} : *1.13* MPa

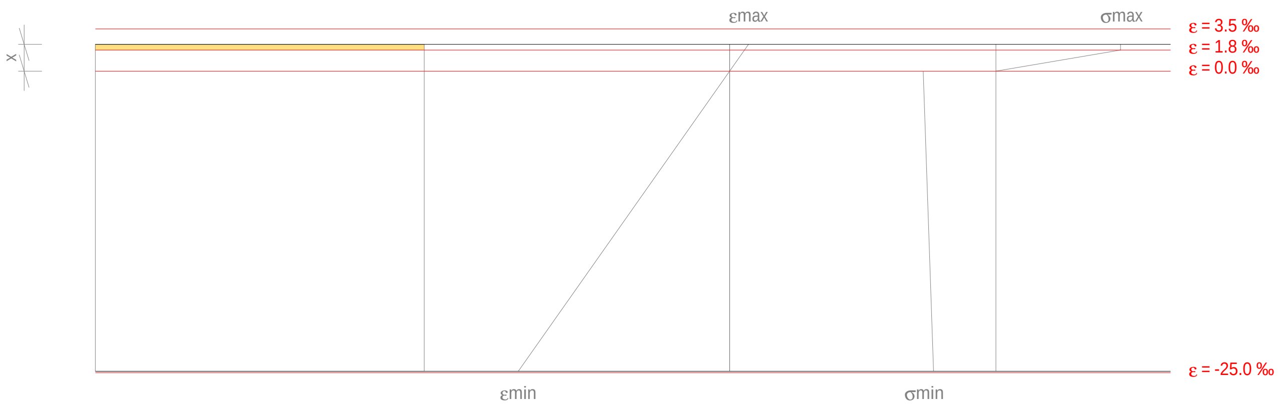
f_{ck}: Characteristic cylinder compressive strength of concrete — f_{ck} : *40.00* MPa

g_c: Partial safety factor for concrete — g_c : *1.50*

The stresses in the steel reinforcement are derived from the stress-strain curves in the section 3.2 of EN 1992-1-1:

M_p: Ultimate positive resistance moment per unit width of slab — M_p : *50.83* kN·m/m

Balance for section failure



e_{max}: Maximum strain — e_{max} : *2.22* ‰

e_{min}: Minimum strain — e_{min} : *-24.88* ‰

s_{max}: Maximum stress — s_{max} : *22.67* MPa

s_{min}: Minimum stress — s_{min} : *-1.13* MPa

x: Distance from extreme compression fiber to neutral axis — x : *25* mm

M_n: Negative resistance moment per unit width of slab — M_n : *45.61* kN·m/m

The negative moment of the slab is taken to be that of the plain unreinforced concrete.

$$M_n = f_{ctd,fl}\left(h^2/6\right)$$

h: Slab thickness — h : *300* mm

$f_{ctd,fl}$: Design concrete flexural tensile strength — $f_{ctd,fl}$: *3.04* MPa

$$f_{ctd,fl} = f_{ctm} \times (1.6 - h/1000)/\gamma_c \geq f_{ctm}/\gamma_c$$

f_{ctm}: Mean axial tensile strength — f_{ctm} : *3.51* MPa

g_c: Partial safety factor for material — g_c : *1.50*

2.4.- Bending checking

Single point load

Corner location

$P_d / P_u \le 1.0$	P_d / P_u :	0.9721	✓
P_d: required ultimate load	P_d :	109.650	kN
$P_d = \sum \gamma_{Fi} \cdot P_i \cdot (1-\alpha/100)$			
g_{F1}: Partial safety factor for load	g_{F1} :	1.35	
g_{F2}: Partial safety factor for load	g_{F2} :	1.50	
P1: Point load	*P1* :	40.000	kN
P2: Point load	*P2* :	50.000	kN
a: Load transfer at the corner	*a* :	15.0	%
P_u: Total failure load	P_u :	112.801	kN
Failure load obtained by linear interpolation between values of a/l between 0 and 0.2			
$P_{u,0}$: total failure load with a/l = 0	$P_{u,0}$:	91.229	kN
$P_{u,0} = 2M_n$			
$P_{u,0.2}$: total failure load with a/l = 0.2	$P_{u,0.2}$:	190.729	kN
$P_{u,0.2} = 4M_n / [1-(a/l)]$			
a / l: radius of contact area-radius of relative stiffness ratio	*a / l* :	0.04	
a: equivalent radius of contact area of the load	*a* :	62	mm
$a = \sqrt{A/\pi}$			
A_p: baseplate area	A_p :	12000	mm²
l: radius of relative stiffness	*l* :	1425	mm
$l = [(E_{cm}h^3)/(12(1-v^2)k)]^{0.25}$			
E_{cm}: secant modulus of elasticity of concrete	E_{cm} :	35220.46	MPa
v: Poisson's ratio	*v* :	0.20	
h: Slab thickness	*h* :	300	mm
k: modulus of subgrade reaction	*k* :	0.020	N/mm³
M_n: negative resistance moment per unit width of slab	M_n :	45.61	kN·m/m

2.5.- Punching checking

Shear on the critical perimeter

Single point load

Corner location

$P_d / P_p \le 1.0$	P_d / P_p :	0.6868	✓
P_d: required ultimate load	P_d :	96.650	kN
$P_d = P'_d - R_{cp}$			
$P'_d = \sum \gamma_{Fi} \cdot P_i \cdot (1-\alpha/100)$			
g_{F1}: Partial safety factor for load	g_{F1} :	1.35	
g_{F2}: Partial safety factor for load	g_{F2} :	1.50	

$P1$: Point load | $P1$: 40.000 kN

$P2$: Point load | $P2$: 50.000 kN

a: Load transfer at the corner | a : 15.0 %

R_{cp}: sum of ground pressures within critical perimeter | R_{cp} : 13.000 kN

$$R_{cp} = 2.9\left(\frac{d}{l}\right)^2 P'_d + 1.9 \cdot u_0 \cdot \frac{dP'_d}{l^2}$$

$$u_0 = x + y$$

l: radius of relative stiffness | l : 1425 mm

P_p: Slab load capacity in punching | P_p : 140.719 kN

$$P_p = \left(v_{Rd,c} + v_f\right) u_1 d$$

v_{rdc}: concrete shear strength on the critical shear perimeter | v_{rdc} : 0.60 MPa

$$v_{Rd,c} = \frac{0.18 k_s}{\gamma_c}\left(100 \rho_1 f_{ck}\right)^{0.33} \geq 0.035 k_s^{1.5} f_{ck}^{0.5}$$

$$k_s = 1 + \left(200 / d\right)^{0.5} \leq 2$$

$$\rho_1 = \sqrt{\rho_x \rho_y}$$

r_l: Reinforcement ratio for punching | r_l : 0.000 %

v_f: Increase in shear strength given by fibres | v_f : 0.08 MPa

$$v_f = 0.015\left(f_{r1} + f_{r2} + f_{r3} + f_{r4}\right)$$

u_1: length of the perimeter at a distance 2·d from the loaded area | u_1 : 927 mm

$$u_1 = u_0 + \pi d$$

$$u_0 = x + y$$

x: effective dimensions of the bearing plate | x : 120 mm

y: effective dimensions of the bearing plate | y : 100 mm

d: effective depth | d : 225 mm

2.6.- Line load checking

$$P_{d,lin} / P_{u,lin} \leq 1.0$$

	$P_{d,lin}$ / $P_{u,lin}$:	0.1167 ✓	
$P_{d,lin}$: required ultimate line load per unit length	$P_{d,lin}$:	*8.00*	kN/m

$$P_{d,lin} = \gamma_F \cdot P_{lin}$$

g_F: Partial safety factor for load	g_F :	*1.00*	
P_{lin}: linear load per unit length	P_{lin} :	*8.00*	kN/m
$P_{u,lin}$: capacity of the slab under the action of a line load per unit length	$P_{u,lin}$:	*68.58*	kN/m

Where a line load is located adjacent to a free edge, the capacity is 3λM_{un} increasing to 4λM_{un} over a distance of 3/λ. For a joint with a minimum load transfer capacity of 15%, the capacity increases to 4λM_{un} at a distance of 1/λ.

$$P_{u,lin} = 4\lambda M_n \qquad d_e \geq 3/\lambda$$

$$P_{u,lin} = 3\lambda M_n \qquad d_e \leq 1/\lambda$$

l: Characteristic of the system	l :	*0.005012*	1/cm

$$\lambda = \left(\frac{3k}{E_{cm} h^3} \right)^{0.25}$$

k: Modulus of subgrade reaction	k :	*0.020*	N/mm³
E_{cm}: Modulus of elasticity of the concrete	E_{cm} :	*35220.46*	MPa
h: Slab thickness	h :	*300*	mm
M_n: negative resistance moment per unit width of slab	M_n :	*45.61*	kN·m/m

$$M_n = f_{ctd,fl} \left(h^2 / 6 \right)$$

$f_{ctd,fl}$: Design concrete flexural tensile strength	$f_{ctd,fl}$:	*3.04*	MPa
d_e: distance from edge or joint	d_e :	*300*	mm

2.7.- Uniform distributed load (UDL) checking

$q_d / q_u \leq 1.0$ | q_d / q_u : 0.7331 ✔

q_d: required ultimate uniformly distributed load | q_d : 50.0 kN/m²

$$q_d = \gamma_F \cdot q$$

g_F: Partial safety factor for load | g_F : 1.00

Partial safety factor for load (TR-34 4th Edition, clause 7.12). The elastic analysis is based on the work of Hentenyi. This analysis has traditionally used a global safety factor of 1.5. As a factor of 1.5 is already applied to the material properties, an additional factor should not be applied to the load.

q: Uniformly distributed load | q : 50.0 kN/m²

q_u: load capacity of the slab per unit area | q_u : 68.2 kN/m²

$$q_u = MIN\left(q_{u1}, q_{u2}\right)$$

$$q_u = 5.95\lambda^2 M_n$$

$$q_u = 6.20\lambda^2 (M_p + M_n)$$

l: Characteristic of the system | l : 0.005012 1/cm

$$\lambda = \left(\frac{3k}{E_{cm}h^3}\right)^{0.25}$$

k: Modulus of subgrade reaction | k : 0.020 N/mm³

E_{cm}: Modulus of elasticity of the concrete | E_{cm} : 35220.46 MPa

h: Slab thickness | h : 300 mm

M_n: negative resistance moment per unit width of slab | M_n : 45.61 kN·m/m

$$M_n = f_{ctd,fl}\left(h^2/6\right)$$

$f_{ctd,fl}$: Design concrete flexural tensile strength | $f_{ctd,fl}$: 3.04 MPa

M_p: ultimate positive resistance moment per unit width of slab | M_p : 50.83 kN·m/m

The maximum negative moment is induced between a pair of patch loads each of breadth π/λ spaced a distance π/λ apart. This spacing is commonly known as the critical aisle width. The maximum positive bending moment in the slab is caused by a load of breadth π/2λ

2.8.- Other verifications

The panel length to width ratio should not exceed 1:1.5.

$\frac{L_{max}}{L_{min}} \leq 1.5$ | L_{max} / L_{min}: 1.00 ✔

Limiting the longest dimension between sawn joints to typically 6000 mm.

$L_{max} \leq 600mm$ | L_{max}: 5000 mm ✔

$$L_{max} = MAX(X,Y)$$

$$L_{min} = MIN(X,Y)$$

X: X joint spacing | X : 5000 mm

Y: Y joint spacing | Y : 5000 mm

3.- ALSO AVAILABLE FROM SIKA

Concrete Admixtures	Optimising the fresh and/or hardened properties of concrete using plasticizers, water reducers, accelerators, retarders, air-entrainment, shrinkage reducers, antifreeze, corrosion inhibitors	Sika Viscoflow®, Viscocrete®, SikaControl®, FerroGard®, SikaRapid®
Pumping	For use with unfavourable aggregates and protecting equipment from excessive wear. Maintains internal cohesion.	SikaPump® Sika® Stabilizer
Curing	Liquid agents or sheets protecting the slab from premature drying.	Antisol®, Sika® Ultracure
Mould Release	Extend longevity of formwork by preventing concrete from sticking to the mould.	Sika® Separol®
Joints	Preventing dirt from filling the joint, accommodating movement and protecting the edges allowing smooth joint crossing.	Sikaflex®
Surface hardeners	Improve slab life span by impregnating the surface or by forming a monolithic layer.	Sika® CureHard, Sikafloor®
Surface coatings	Increase resistance against mechanical and chemical attack.	Sikafloor®, SikaScreed®

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