Design LIGNATUR element   Pos.110.0. 001

Decisive building regulations   EN 1991, EN 1995

Object:	Example School
Component:	Floor above ground floor
Description	-
Project-No.	2021'0017

Content:

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Responsible: Dipl. Bauingenieur ETH/SIA Ralph Schläpfer

Date: 2021-06-29

Object:	Example School
Component:	Floor above ground floor
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Load hypothesis Pos.110.0. 001

Decisive building regulations EN 1991, EN 1995

Permanent actions

			0.00 kN/m^2
Floor structure	Cement screed 60mm (22kN/m³ * 0.060m)		1.32 kN/m^2
Noise insulation board	Trittschalldämmung Mineralfaser 40mm (s' ≤ 7 MN/m³)		0.04 kN/m^2
Weight	Elastisch gebundene Schüttung 80mm (15kN/m³ * 0.080m)		1.20 kN/m^2
	-		0.00 kN/m^2
LIGNATUR surface element LFE t=40	g + 0.00		0.62 kN/m^2
	-		0.00 kN/m^2
		g_k=	3.18 kN/m^2

Variable actions

C1 - Areas with tables		3.00 kN/m^2
Lightweight separating walls (< 3 kN/m)		0.80 kN/m^2
	q_k=	3.80 kN/m^2

Partial safety factors for actions in different design situations

Partial safety factor			
- permanent actions		Y_g=	1.35 ()
- permanent actions	Accidential design situation	$Y_{g,A}$=	1.00 ()
- variable actions		Y_q=	1.50 ()
Factor for combination value			
- rare		Ψ_0=	0.70 ()
- frequent		Ψ_1=	0.70 ()
- quasi permanent		Ψ_2=	0.60 ()
Deformation factor		k_{def}=	0.60 ()

Ultimate limit state

Permanent action	Y_g*g_k	=	**4.29** kN/m^2
Permanent + variable action	$Y_g*g_k+Y_q*q_k$	=	**9.99** kN/m^2

Ultimate limit state in fire

Permanent + variable action	$Y_{g,A}*g_k+\Psi_2*q_k$	=	**5.46** kN/m^2

Serviceability limit state

Permanent + variable action, inst	g_k+q_k	=	**6.98** kN/m^2
Permanent + variable action, fin	$g_k*(1+k_{def})+q_k(1+\Psi_2*k_{def})$	=	**10.25** kN/m^2

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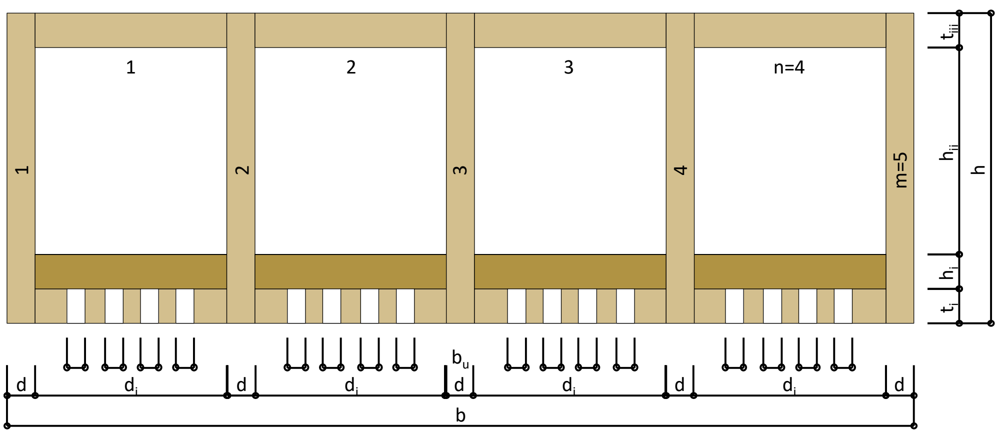
Cross section caracteristics Pos.110.0. 001

Decisive building regulations EN 1991, EN 1995



Cross section

Element type	LIGNATUR surface element LFE t=40	L40
Fire resistance	REI60	REI60
Sound insulation	-	0
Thermal insulation	-	
Absorption	Acoustics type 3.1	3.1

Parameter

Height		h=	360	mm
Width		b=	1000	mm
Number of webs		m=	5	()
Thickness of web		d=	31	mm
Number of cavities	m-1	n=	4	()
Width of hollow space	(b-m*d)/n	d_i=	211	mm
Thickness upper lamella		t_{iii}=	40	mm
Thickness middle lamella		t_{ii}=	0	mm
Thickness lower lamella		t_i=	40	mm
Filling opening		b_o=	0	mm
Ø Filling opening		$b_{o,w}$=	0	mm
Perforation acoustics type 3.1 in lower lamella	n*4*20	b_u=	320	mm
Ø Perforation acoustics type 3.1 in lower lamella	n*4*20	$b_{u,w}$=	320	mm
Height of hollow space	$h-t_{iii}-t_{ii}-h_i-t_i$	h_{ii}=	240	mm
Wood fibre absorber thickness		h_i=	40	mm

Densities

Spruce wood		ρ_{Holz}=	4.70	kN/m^3
Insulation in the hollow space	Air=0kg/m3	$\rho_{Isolation}$=	0.00	kN/m^3
Wood fibre absorber	Air=0kg/m3	$\rho_{Absorber}$=	1.10	kN/m^3

Cross section areas						
Wood gross (self-weight)	$b*h-(n*d_i)*(h_{ii}+h_i)$			A_b=	123400	mm^2
Wood net (ultimate limit state)	$b*h-(n*d_i)*(h_{ii}+h_i)-b_o*t_{iii}-b_u*t_i$			A_n=	110'600	mm^2
Wood Ø (serviceability limit state)	$b*h-(n*d_i)*(h_{ii}+h_i)-b_{o,w}*t_{iii}-b_{u,w}*t_i$			$A_Ø$=	110'600	mm^2
Holow space	$(b-m*d)*h_{ii}$			A_K=	202'800	mm^2
Wood fibre absorber	$(b-m*d)*h_i$			A_A=	33'800	mm^2
Self-weight						
LIGNATUR element	$(A_b*\rho_{Holz}+A_K*\rho_{Isolation}+A_A*\rho_{Absorber})/1000^2/b*1000$			g=	0.62	kN/m^2
Center of gravity Z coordinates in Y direction						
Wood net	$(m*d*h^2/2+(n*d_i-b_u)*t_i^2/2+n*d_i*t_{ii}*(t_i+h_i+t_{ii}/2)$ $+(n*d_i-b_o)*t_{iii}*(h-t_{iii}/2))/A_n$			s_y=	199	mm
Wood Ø	$(m*d*h^2/2+(n*d_i-b_{u,w})*t_i^2/2+n*d_i*t_{ii}*(t_i+h_i+t_{ii}/2)$ $+(n*d_i-b_{o,w})*t_{iii}*(h-t_{iii}/2))/A_Ø$			$s_{y,Ø}$=	199	mm
Moments of inertia in case of fire						
Wood net	$m*d*h^3/12+m*d*h*(h/2-s_y)^2+(n*d_i-b_u)*t_i^3/12$ $+(n*d_i-b_u)*t_i*(s_y-t_i/2)^2+n*d_i*t_{ii}^3/12$ $+n*d_i*t_{ii}*(s_y-t_i-h_i-t_{ii}/2)^2+(n*d_i-b_o)*t_{iii}^3/12$ $+(n*d_i-b_o)*t_{iii}*(h-s_y-t_{iii}/2)^2$			I_y=	1'974'903'484	mm^4
Wood Ø	$m*d*h^3/12+m*d*h*(h/2-s_y)^2+(n*d_i-b_{u,w})*t_i^3/12$ $+(n*d_i-b_{u,w})*t_i*(s_y-t_i/2)^2+n*d_i*t_{ii}^3/12$ $+n*d_i*t_{ii}*(s_y-t_i-h_i-t_{ii}/2)^2+(n*d_i-b_{o,w})*t_{iii}^3/12$ $+(n*d_i-b_{o,w})*t_{iii}*(h-s_y-t_{iii}/2)^2$			$I_{y,Ø}$=	1'974'903'484	mm^4
Resistance moment						
Wood net	I_y/s_y			W_y=	9'948'275	mm^3
Bending stiffness						
Wood Ø	$E_{0,mean}*I_{y,Ø}$			$EI_Ø$=	$21.724 * 10^{12}$	Nmm^2
Static moment of area						
Wood net						
$t_i+h_i+t_{ii}<s_y\leq h-t_{iii}$	$m*d*(h-s_y)^2/2+(n*d_i-b_o)*t_{iii}*(h-s_y-t_{iii}/2)$			S_y=	6'803'064	mm^3
Shear surface						
Wood net	$m*d*I_y/S_y$			A_w=	44'996	mm^2
Characteristic properties						
Strength class					C24	
Bending	$f_{m,k}*k_{mod}/Y_m$	$f_{m,k}$=	24 N/mm²	$f_{m,d}$=	16.6	N/mm^2
Tension parallel to the grain	$f_{t,0,k}*k_{mod}/Y_m$ 20	$f_{t,0,k}$=	14 N/mm²	$f_{t,0,d}$=	9.7	N/mm^2
Tension perpendicular to the grain	$f_{t,90,k}*k_{mod}/Y_m$	$f_{t,90,k}$=	0.4 N/mm²	$f_{t,90,d}$=	0.3	N/mm^2
Compression parallel to the grain	$f_{c,0,k}*k_{mod}/Y_m$	$f_{c,0,k}$=	21 N/mm²	$f_{c,0,d}$=	14.5	N/mm^2
Compression perpendicular to the grain	$f_{c,90,k}*k_{mod}/Y_m$	$f_{c,90,k}$=	2.5 N/mm²	$f_{c,90,d}$=	1.7	N/mm^2
Shear	$f_{v,k}*k_{mod}/Y_m$	$f_{v,k}$=	2.0 N/mm²	$f_{v,d}$=	1.4	N/mm^2
Modulus of elasticity parallel				$E_{0,mean}$=	11'000	N/mm^2
Modification factor				k_{mod}=	0.9	()
Partial safety factor				Y_m=	1.3	()

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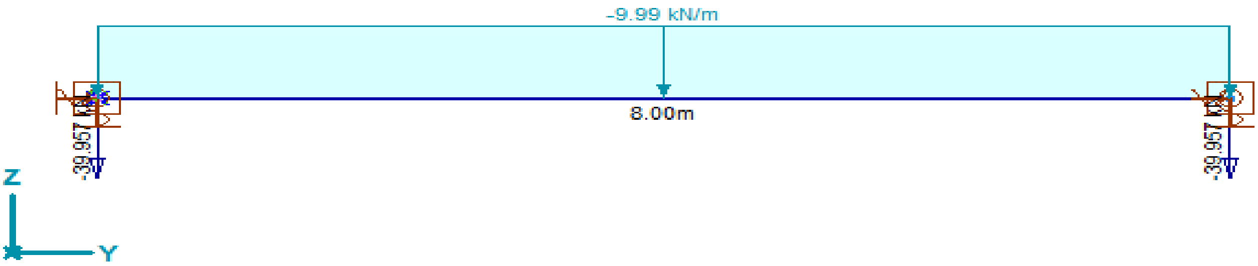
Ultimate limit state, serviceability limit state Pos.110.0. 001

Decisive building regulations EN 1991, EN 1995

Calculation with AxisVM

Structural system in ultimate limit state

1-span beam

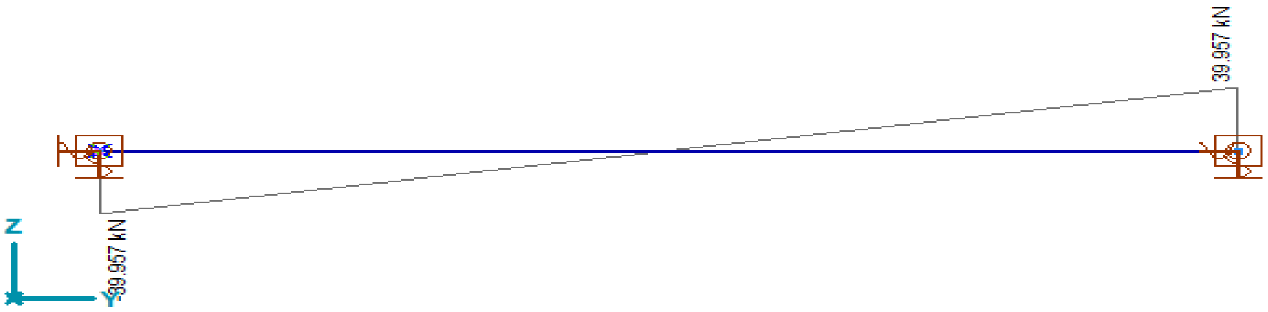


Span length S1 l_{S1}= 8'000 mm

Moment diagram

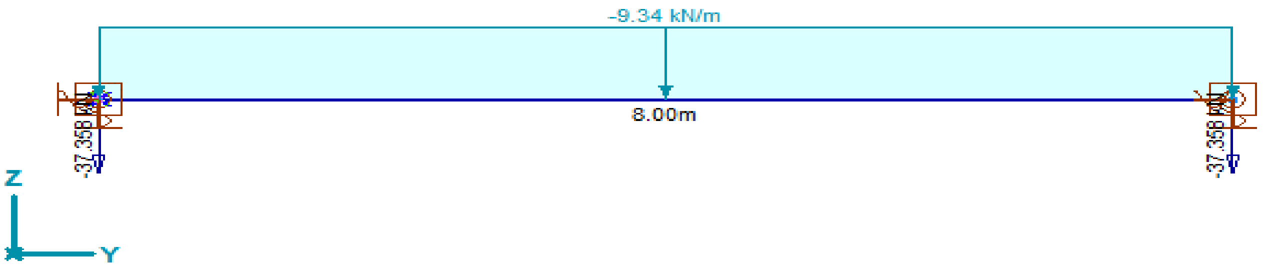
Maximum moment		$M_{y,d}$=	79.9 kNm
Maximum bending stress	$M_{y,d}$*1000000/(I_y/(h-s_y))/1000*b	$\sigma_{o,d}$=	6.5 N/mm^2
	$M_{y,d}$*1000000/(I_y/s_y)/1000*b	$\sigma_{u,d}$=	8.0 N/mm^2
	MAX($\sigma_{o,d}$;$\sigma_{u,d}$)/$f_{m,d}$		**0.48 ≤1**

Shear diagram

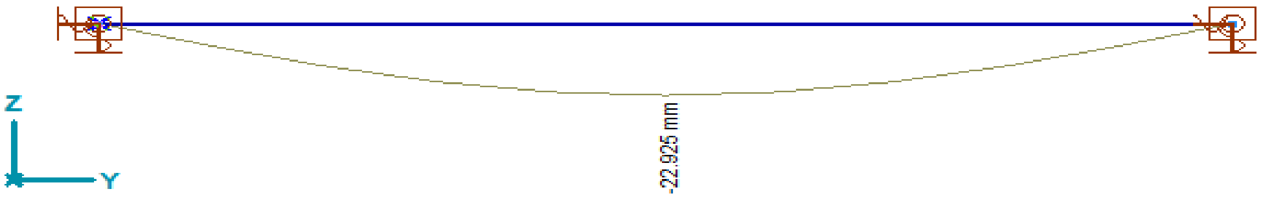


Maximum shear force		$V_{z,d}$=	40.0 kN
Maximum shear stress	$V_{z,d}$*1000/A_w/1000*b	τ_d=	0.9 N/mm^2
	$\tau_d/f_{v,d}$		**0.64 ≤1**

Structural system in serviceability limit state for frequent combination



Deflection



Maximum deflections

$w_{z,inst,S1}$=		17.1 mm
	$l_{S1}/w_{z,inst,S1}$	**467 ≥400**
$w_{z,fin,S1}$=		25.2 mm
	$l_{S1}/w_{z,fin,S1}$	**318 ≥300**

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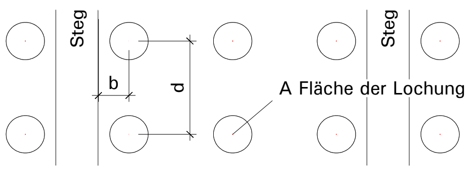
Cross section caracteristics in fire — Pos.110.0. 001

Decisive building regulations	EN 1991, EN 1995
	ETA-11/0137 for LIGNATUR elements

Effective charring depth in fire				
Duration of fire exposure		t=	60	min.
- charring time in slat ti	$t_i/\beta_1 \leq t$	t_1=	46	min.
- charring time in wood fibre absorber hi	$h_i/\beta_2 \leq t-t_1$	t_2=	14	min.
- charring time in slat tii	$t_{ii}/\beta_3 \leq t-t_1-t_2$	t_3=	0	min.
- charring time in thermal insulation hii	$h_{ii}/\beta_4 \leq t-t_1-t_2-t_2-t_3$	t_4=	0	min.
Charring rate in slat ti	Acoustics 0.22*k+0.72	β_1=	0.86	mm/min.
Factor (IBK report no. 283 ETH Zurich)	$A_{Akustik}/d_{Akustik}*1000/(b_{Akustik}^{1.5}*t_i)$	k=	0.65	()
Surface of holes or slits		$A_{Akustik}$=	314	mm^2
Distance between holes or between slits		$d_{Akustik}$=	40	mm
Distance between holes or slits and web		$b_{Akustik}$=	45	mm



Charring rate in wood fibre absorber hi	$0.9*(450/\rho_{Absorber})^{½}$	β_2=	1.82	mm/min.
Charring rate in slat tii		β_3=	0.00	mm/min.
Charring rate in thermal insulation hii		β_4=	0.00	mm/min.
Charred layer	$t_1*\beta_1+t_2*\beta_2+t_3*\beta_3+t_4*\beta_4$	d_{char}=	65	mm
Condiseration of loss of strength		d_{red}=	7	mm
Effective charring depth	$d_{char}+d_{red}$	d_{ef}=	72	mm
Parameters in fire				
Height	$h-d_{ef}$	h_{fi}=	288	mm
Width	b	b_{fi}=	1'000	mm
Number of webs	m	m_{fi}=	5	()
Thickness of web	d	d_{fi}=	31	mm
Number of cavities	n-1	n_{fi}=	4	()
Width of hollow space	$(b_{fi}-m_{fi}*d_{fi})/n_{fi}$	$d_{i,fi}$=	211	mm
Thickness upper lamella	$t_{iii} \geq t_i+h_i+t_{ii}+h_{ii}+t_{iii}-d_{ef} \geq 0$	$t_{iii,fi}$=	40	mm
Thickness middle lamella	$t_{ii} \geq t_i+h_i+t_{ii}-d_{ef} \geq 0$	$t_{ii,fi}$=	0	mm
Thickness lower lamella	$t_i-d_{ef} \geq 0$	$t_{i,fi}$=	0	mm
Filling opening	b_o	$b_{o,fi}$=	0	mm
Perforation acoustics type 3.1 in lower lamella	b_u	$b_{u,fi}$=	320	mm
Height of hollow space	$h_{ii} \geq t_i+h_i+t_{ii}+h_{ii}-d_{ef} \geq 0$	$h_{ii,fi}$=	240	mm
Wood fibre absorber thickness	$h_i \geq t_i+h_i-d_{ef} \geq 0$	$h_{i,fi}$=	8	mm

Cross sectional area in fire

Wood net (ultimate limit state)	$b_{fi}*h_{fi}-(n_{fi}*d_{i,fi})*(h_{ii,fi}+h_{i,fi})-b_{o,fi}*t_{iii,fi}-b_{u,fi}*t_{i,fi}$	$A_{n,fi}=$	78'462 mm^2

Center of gravity Z coordinates in Y direction in fire

Wood net	$(m_{fi}*d_{fi}*h_{fi}^2/2+(n_{fi}*d_{i,fi}-b_{u,fi})*t_{i,fi}^2/2$ $+n_{fi}*d_{i,fi}*t_{ii,fi}*(t_{i,fi}+h_{i,fi}+t_{ii,fi}/2)$ $+(n_{fi}*d_{i,fi}-b_{o,fi})*t_{iii,fi}*(h_{fi}-t_{iii,fi}/2))/A_{n,fi}$	$s_{y,fi}=$	198 mm

Moment of inertia in case of fire

Wood net	$m_{fi}*d_{fi}*h_{fi}^3/12+m_{fi}*d_{fi}*h_{fi}*(h_{fi}/2-s_{y,fi})^2$ $+(n_{fi}*d_{i,fi}-b_{u,fi})*t_{i,fi}^3/12+(n_{fi}*d_{i,fi}-b_{u,fi})*t_{i,fi}*(s_{y,fi}-t_{i,fi}/2)^2$ $+n_{fi}*d_{i,fi}*t_{ii,fi}^3/12+n_{fi}*d_{i,fi}*t_{ii,fi}*(s_{y,fi}-t_{i,fi}-h_{i,fi}-t_{ii,fi}/2)^2$ $+(n_{fi}*d_{i,fi}-b_{o,fi})*t_{iii,fi}^3/12$ $+(n_{fi}*d_{i,fi}-b_{o,fi})*t_{iii,fi}*(h_{fi}-s_{y,fi}-t_{iii,fi}/2)^2$	$I_{y,fi}=$	609'685'643 mm^4

Static moment of area in fire

Wood net			
		$S_{y,fi}=$	3'023'564 mm^3
$t_{i,fi}+h_{i,fi}+t_{ii,fi}<s_{y,fi}\leq h_{fi}-t_{iii,fi}$	$m_{fi}*d_{fi}*(h_{fi}-s_{y,fi})^2/2$ $+(n_{fi}*d_{i,fi}-b_{o,fi})*t_{iii,fi}*(h_{fi}-s_{y,fi}-t_{iii,fi}/2)$	$S_{y,fi}=$	3'023'564 mm^3

Shear surface in fire

Wood net	$m_{fi}*d_{fi}*I_{y,fi}/S_{y,fi}$	$A_{w,fi}=$	31'255 mm^2

Characteristic properties in fire

Strength class			C24
Bending	$f_{m,k}*k_{fi}/\gamma_{m,fi}$	$f_{m,d,fi}=$	30.0 N/mm^2
Tension parallel to the grain	$f_{t,0,k}*k_{fi}/\gamma_{m,fi}$	$f_{t,0,d,fi}=$	17.5 N/mm^2
Compression parallel to the grain	$f_{c,0,k}*k_{fi}/\gamma_{m,fi}$	$f_{c,0,d,fi}=$	26.3 N/mm^2
Shear	$f_{v,k}*k_{fi}/\gamma_{m,fi}$	$f_{v,d,fi}=$	2.5 N/mm^2
Factor for the determination of the 20th percentile		$k_{fi}=$	1.25 ()
Partial safety factor		$Y_{m,fi}=$	1.0 ()

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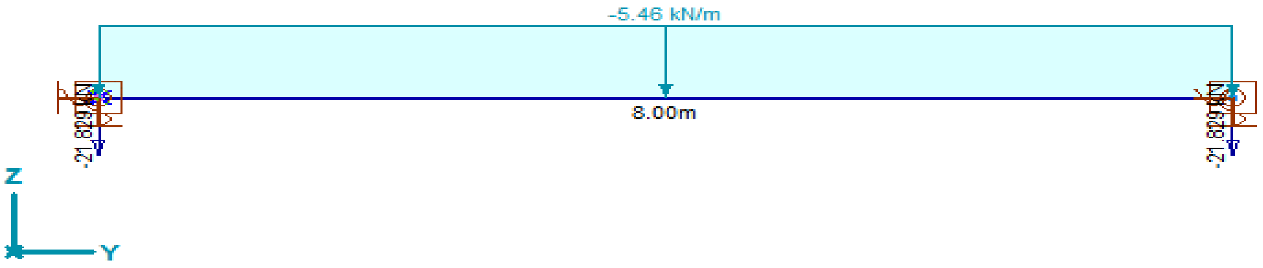
Ultimate limit state in case of fire **Pos.110.0. 001**

Decisive building regulations EN 1991, EN 1995
ETA-11/0137 for LIGNATUR elements

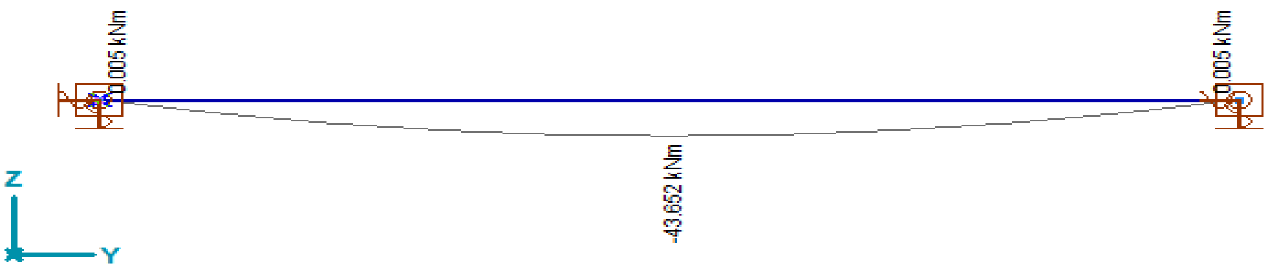
Calculation with AxisVM

Structural system in ultimate limit state in fire



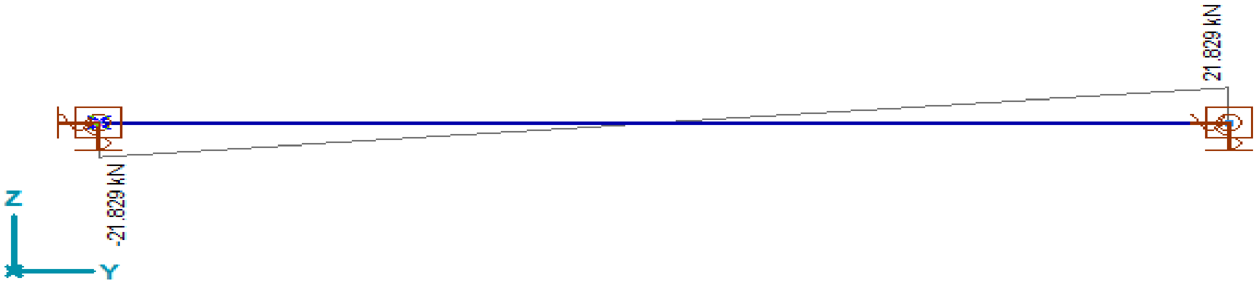
Span length S1		l_{S1}=	8'000 mm

Moment diagram in fire



Maximum moment		$M_{y,d,fi}$=	43.7 kNm
Maximum bending stress	$M_{y,d,fi}$*1000000/($I_{y,fi}$/(h_{fi}-$s_{y,fi}$))/1000*b_{fi}	$\sigma_{o,d,fi}$=	6.5 N/mm^2
	$M_{y,d,fi}$*1000000/($I_{y,fi}$/$s_{y,fi}$)/1000*b_{fi}	$\sigma_{u,d,fi}$=	14.1 N/mm^2
	MAX($\sigma_{o,d,fi}$,$\sigma_{u,d,fi}$)/$f_{m,d,fi}$		**0.47 ≤1**

Shear diagram in fire



Maximum shear force		$V_{z,d,fi}$=	21.8	kN
Maximum shear stress	$V_{z,d,fi}$*1000/$A_{w,fi}$/1000*b_{fi}	$\tau_{d,fi}$=	0.7	N/mm^2
	$\tau_{d,fi}/f_{v,d,fi}$		**0.28**	**≤1**