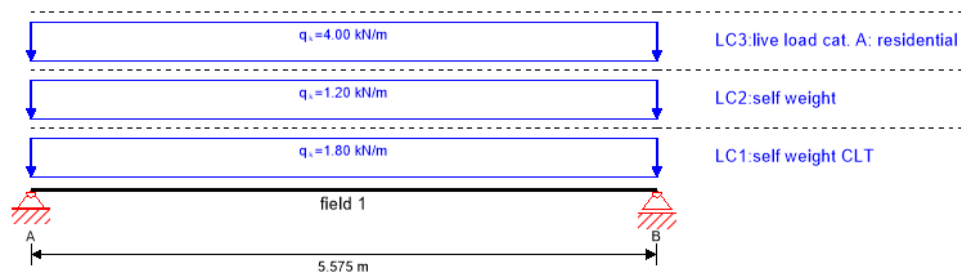


system

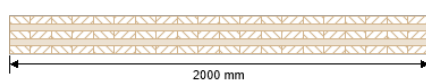


global utilization ratio

88 %

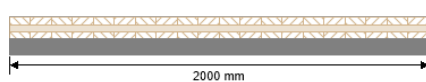
ULS	25 %	ULS fire	16 %	SLS	54 %	SLS vibration	88 %	support	-1 %
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section: CLT 180 L5s



layer	thickness	orientation	material
1	40.0 mm	0°	C24 spruce ETA (2019)
2	30.0 mm	90°	C24 spruce ETA (2019)
3	40.0 mm	0°	C24 spruce ETA (2019)
4	30.0 mm	90°	C24 spruce ETA (2019)
5	40.0 mm	0°	C24 spruce ETA (2019)
t _{CLT}	180.0 mm		

section fire: CLT 180 L5s



layer	thickness	orientation	material
1	40.0 mm	0°	C24 spruce ETA (2019)
2	30.0 mm	90°	C24 spruce ETA (2019)
3	34.0 mm	0°	C24 spruce ETA (2019)
t _{CLT}	104.0 mm		
time	90 min		

t _{ch,h}	t _{f,h}	t _{a,h}	d _{ta,h}	k ₀	d ₀	d _{char,0,h}	d _{ef,h}
[min]	[min]	[min]	[mm]	[-]	[mm]	[mm]	[mm]
21	24	42	25	1	7	69.0	76.0

material values

material	f _{m,k}	f _{t,0,k}	f _{t,90,k}	f _{c,0,k}	f _{c,90,k}	f _{v,k}	f _{r,k min}	E _{0,mean}	G _{mean}	G _{r,mean}
	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]	[N/mm ²]
C24 spruce ETA (2019) C24 spruce ETA (2019)	24.00	14.00	0.12	21.00	2.50	4.00	1.25	12,000.00	690.00	50.00

load

load case groups

	load case category	Typ	duration	Kmod	γ _{inf}	γ _{sup}	Ψ ₀	Ψ ₁	Ψ ₂
LC1	self weight CLT	G	permanent	0.6	1	1.35	1	1	1
LC1	self weight CLT	G	permanent						
LC2	self weight	G	permanent	0.6	1	1.35	1	1	1
LC2	self weight	G	permanent						

load case groups									
	load case category	Typ	duration	Kmod	γ_{inf}	γ_{sup}	ψ_0	ψ_1	ψ_2
LC3	live load cat. A: residential	Q	medium	0.8	0	1.5	0.7	0.5	0.3
LC3	live load cat. A: residential	Q	term medium term						

LC1:self weight CLT									
continuous load									
field	load at start								
	[kN/m]								
1	1.80								
1									

LC2:self weight									
continuous load									
field	load at start								
	[kN/m]								
1	1.20								
1									

LC3:live load cat. A: residential									
continuous load									
field	load at start								
	[kN/m]								
1	4.00								
1									

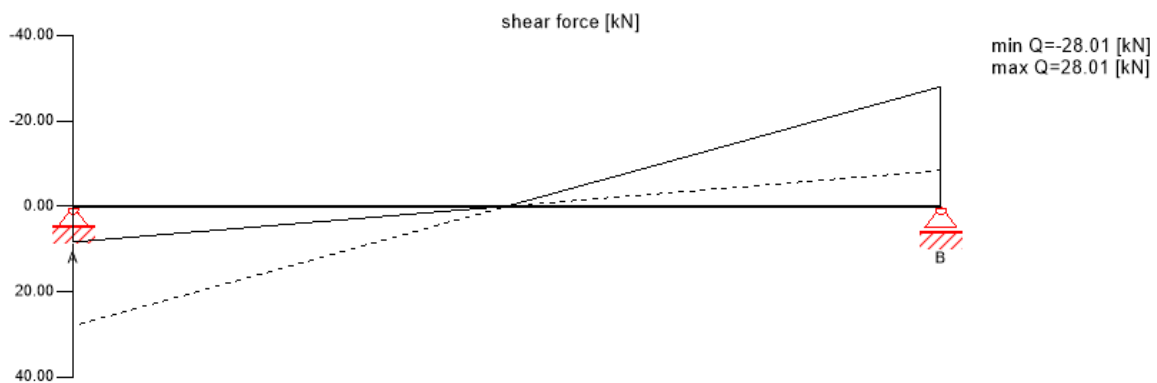
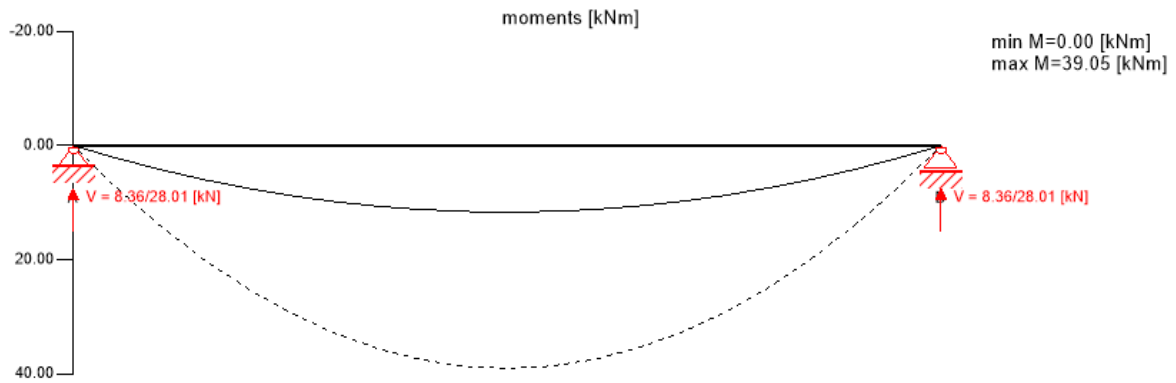
ULS combinations									
	combination rule								
LCO1	$1.35/1.00 * LC1 + 1.35/1.00 * LC2$								
LCO1	$1.35/1.00 * LC1 + 1.35/1.00 * LC2$								
LCO2	$1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3$								
LCO2	$1.35/1.00 * LC1 + 1.35/1.00 * LC2 + 1.50/0.00 * LC3$								

ULS combinations fire									
	combination rule								
LCO3	$1.00/1.00 * LC1 + 1.00/1.00 * LC2$								
LCO3	$1.00/1.00 * LC1 + 1.00/1.00 * LC2$								
LCO4	$1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3$								
LCO4	$1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3$								

SLS characteristic combination									
	combination rule								
LCO5	$1.00/1.00 * LC1 + 1.00/1.00 * LC2$								
LCO5	$1.00/1.00 * LC1 + 1.00/1.00 * LC2$								
LCO6	$1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3$								
LCO6	$1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * LC3$								

SLS quasi-permanent combination									
	combination rule								
LCO7	$1.00/1.00 * LC1 + 1.00/1.00 * LC2$								
LCO7	$1.00/1.00 * LC1 + 1.00/1.00 * LC2$								
LCO8	$1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3$								
LCO8	$1.00/1.00 * LC1 + 1.00/1.00 * LC2 + 1.00/0.00 * 0.30 * LC3$								

Ultimate limit state (ULS) - design results



ULS flexural design

field	dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	ratio	
	[m]	[N/mm ²]	[-]	[-]	[-]	[N/mm ²]	[kNm]	[N/mm ²]		
1	2.79	24.00	1.25	0.80	1.10	16.90	39.05	-4.31	25 %	LCO2 LCO2

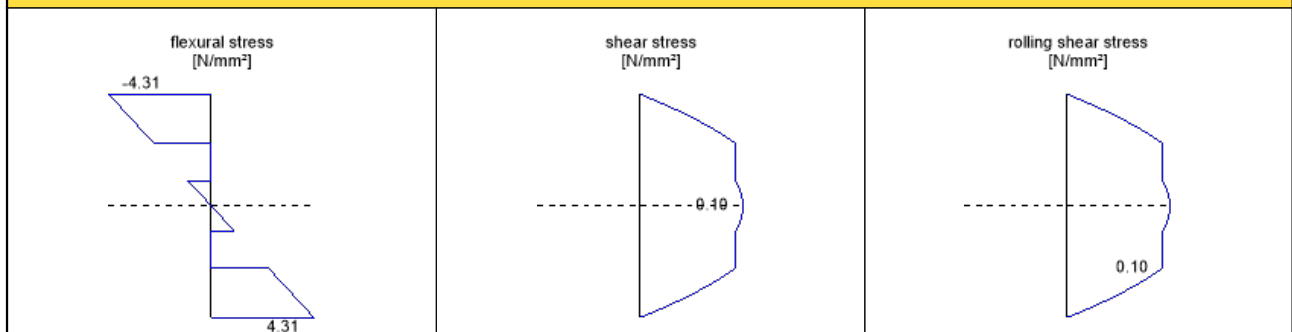
ULS shear analysis

field	dist.	$f_{v,k}$	γ_m	k_{mod}	$f_{v,d}$	V_d	$\tau_{v,d}$	ratio	
	[m]	[N/mm ²]	[-]	[-]	[N/mm ²]	[kN]	[N/mm ²]		
1	5.58	4.00	1.25	0.80	2.56	-28.01	0.10	4 %	LCO2 LCO2

ULS rolling shear

field	dist.	$f_{r,k}$	γ_m	k_{mod}	$f_{r,d}$	V_d	$\tau_{r,d}$	ratio	
	[m]	[N/mm ²]	[-]	[-]	[N/mm ²]	[kN]	[N/mm ²]		
1	5.58	1.15	1.25	0.80	0.74	-28.01	0.10	13 %	LCO2 LCO2

stress diagram



flexural stress analysis

$M_{y,d} =$	39.05	kNm	$f_{m,k} =$	24.00	N/mm ²
$N_{t,d} =$	0.00	kN	$\gamma_m =$	1.25	-
			$k_{mod} =$	0.80	-
			$k_{sys,y} =$	1.10	-
			$k_{hm} =$	1.00	-
			$k_l =$	1.00	-
$\sigma_{t,d} =$	0.00	N/mm ²	$f_{t,d} =$	8.96	N/mm ²
$\sigma_{m,y,d} =$	-4.31	N/mm ²	$f_{m,y,d} =$	16.90	N/mm ²

utilization ratio

25 %

shear stress analysis

$V_d =$	-	kN	$f_{v,k} =$	4.00	N/mm ²
	28.01		$\gamma_m =$	1.25	
			$k_{mod} =$	0.80	
$T_{v,d} =$	0.10	N/mm ²	$f_{v,d} =$	2.56	N/mm ²

utilization ratio

4 %

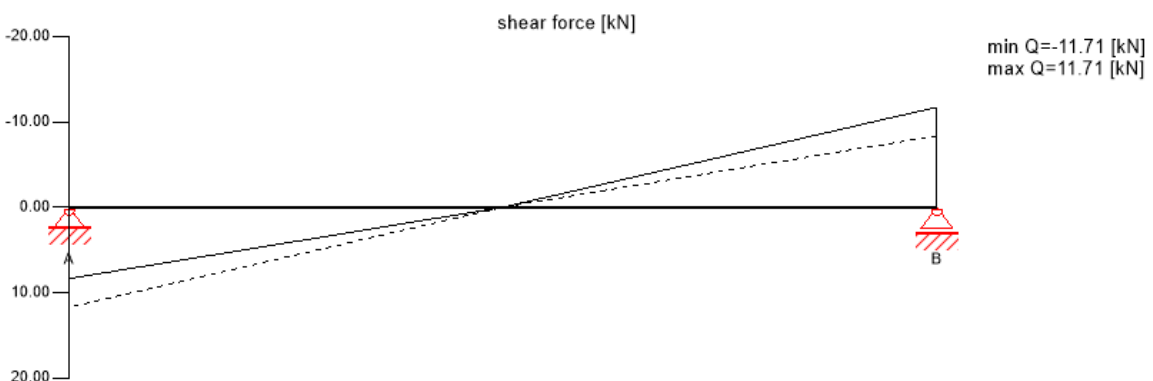
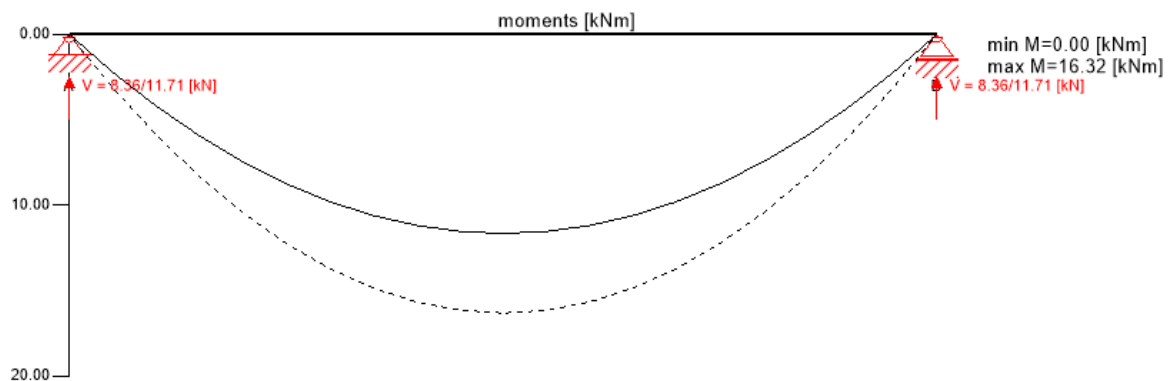
rolling shear analysis

$V_d =$	-28.01	kN	$f_{r,k} =$	1.15	N/mm ²
			$\gamma_m =$	1.25	-
			$k_{mod} =$	0.80	-
$T_{r,d} =$	0.10	N/mm ²	$f_{r,d} =$	0.74	N/mm ²

utilization ratio

13 %

Ultimate limit state (ULS) fire design - results

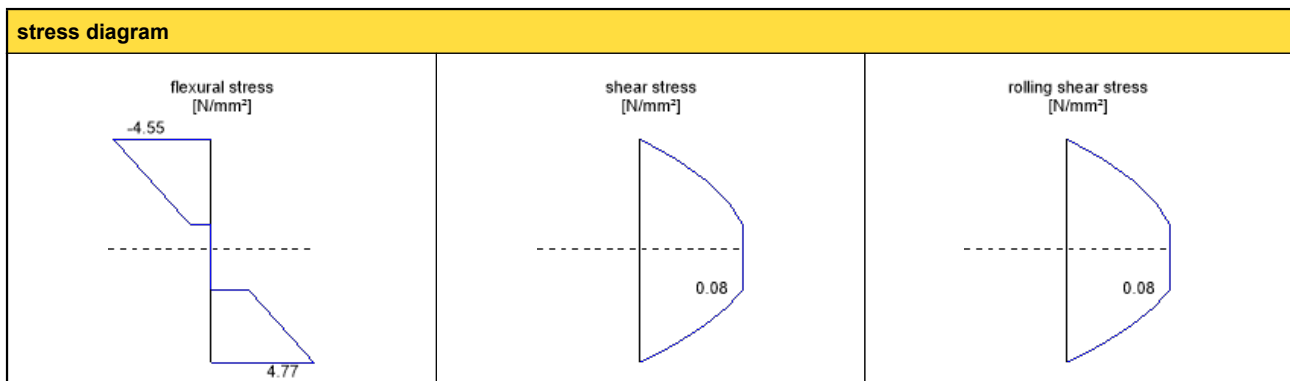


ULS fire flexural design

field	dist.	$f_{m,k}$	γ_m	k_{mod}	$k_{sys,y}$	k_{fi}	$f_{m,y,d}$	$M_{y,d}$	$\sigma_{m,y,d}$	ratio	
	[m]	[N/mm ²]	[-]	[-]	[-]	[-]	[N/mm ²]	[kNm]	[N/mm ²]		
1	2.79	24.00	1.00	1.00	1.10	1.15	30.36	16.32	4.77	16 %	LCO4 LCO4

ULS fire shear analysis										
field	dist.	$f_{v,k}$	γ_m	k_{mod}	k_{fi}	$f_{v,d}$	V_d	$T_{v,d}$	ratio	
	[m]	[N/mm ²]	[-]	[-]	[-]	[N/mm ²]	[kN]	[N/mm ²]		
1	5.58	4.00	1.00	1.00	1.15	4.60	-11.71	0.08	2 %	LCO4 LCO4

ULS fire rolling shear										
field	dist.	$f_{r,k}$	γ_m	k_{mod}	k_{fi}	$f_{r,d}$	V_d	$T_{r,d}$	ratio	
	[m]	[N/mm ²]	[-]	[-]	[-]	[N/mm ²]	[kN]	[N/mm ²]		
1	5.58	1.15	1.00	1.00	1.15	1.32	-11.71	0.08	6 %	LCO4 LCO4

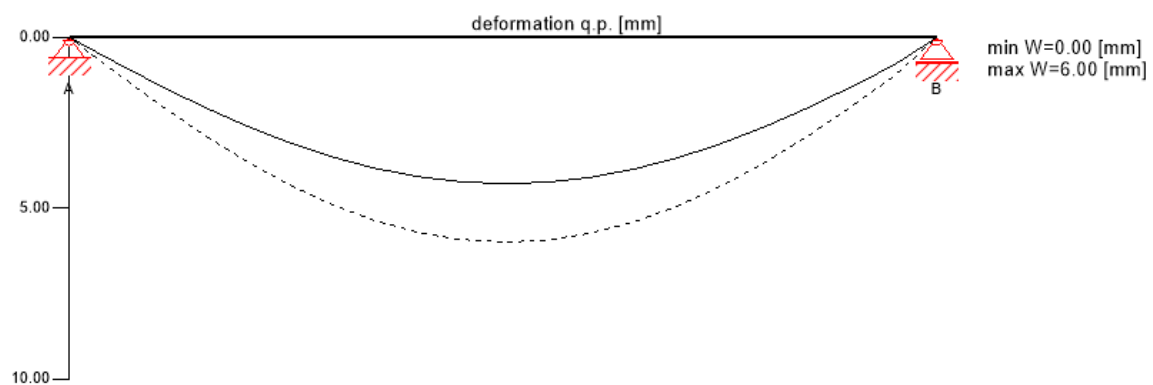
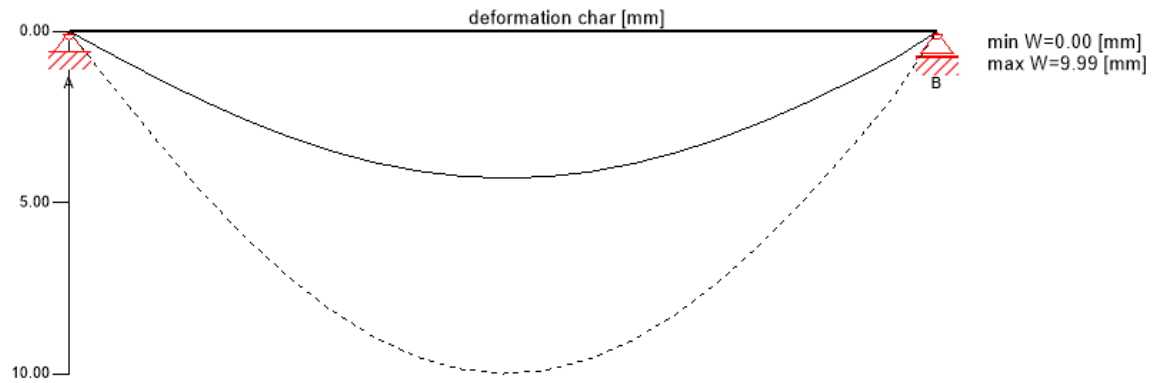


flexural stress analysis fire										
$M_{y,d} =$	16.32	kNm	$f_{m,k} =$	24.00	N/mm ²	$\gamma_m =$	1.00	-		
$N_{t,d} =$	0.00	kN	$k_{mod} =$	1.00	-	$k_{sys,y} =$	1.10	-		
			$k_{nm} =$	1.00	-	$k_{fi} =$	1.00	-		
			$k_{fi} =$	1.15	-	$f_{t,d} =$	16.10	N/mm ²		
$\sigma_{t,d} =$	0.00	N/mm ²	$f_{m,y,d} =$	30.36	N/mm ²				✓	
$\sigma_{m,y,d} =$	4.77	N/mm ²								
utilization ratio									16 %	

shear stress analysis fire										
$V_d =$	-	kN	$f_{v,k} =$	4.00	N/mm ²	$\gamma_m =$	1.00			
	11.71		$k_{mod} =$	1.00		$k_{fi} =$	1.15			
$T_{v,d} =$	0.08	N/mm ²	$f_{v,d} =$	4.60	N/mm ²				✓	
utilization ratio									2 %	

rolling shear analysis fire										
$V_d =$	-11.71	kN	$f_{r,k} =$	1.15	N/mm ²	$\gamma_m =$	1.00	-		
			$k_{mod} =$	1.00	-	$k_{fi} =$	1.15	-		
$T_{r,d} =$	0.08	N/mm ²	$f_{r,d} =$	1.32	N/mm ²				✓	
utilization ratio									6 %	

Service limit state design (SLS) - design results



$$w_{inst} = w[char]$$

field	K_{def}	limit	W_{limit}	$W_{calc.}$	ratio
		[-]	[mm]	[mm]	
1	0.8	L/300	18.6	10.0	54 %

$$w_{fin} = w[char] + w[q.p.]*k_{def}$$

field	K_{def}	limit	W_{limit}	$W_{calc.}$	ratio
		[-]	[mm]	[mm]	
1	0.8	L/150	37.2	14.8	40 %

$$w_{net,fin} = w[q.p.] + w[q.p.]*k_{def}$$

field	K_{def}	limit	W_{limit}	$W_{calc.}$	ratio
		[-]	[mm]	[mm]	
1	0.8	L/250 L/250	22.3	10.8	48 %

vibration analysis

general

total mass	2.37	[t]
tributary width	2.8	[m]
stiffness longitudinal direction	9792.0	[kNm ²]
stiffness cross direction	1872.0	[kNm ²]
modal damping	1.0	[%]
α	0.0	[-]
man weight	700.0	[N]
modal mass	1183.7	[kg]

vibration analysis

analysis							
criterion	calc.	class I	class II	class I	class II	cl. I	cl. II
frequency criterion min	9.046 [Hz]	4.5 [Hz]	4.5 [Hz]	50 %	50 %	✓	✓
frequency criterion	9.046 [Hz]	8.0 [Hz]	6.0 [Hz]	88 %	66 %	✓	✓
acceleration criterion	0.317 [m/s ²]	0.05 [m/s ²]	0.1 [m/s ²]	635 %	317 %	✗	✗
stiffness criterion	0.133 [mm]	0.25 [mm]	0.5 [mm]	53 %	27 %	✓	✓

support reaction

load case category	k _{mod}	A _v	B _v
		[kN]	
self weight CLT	0.6	5.02	5.02
		5.02	5.02
self weight	0.6	3.35	3.34
		3.35	3.34
live load cat. A: residential	0.8	11.15	11.15
		0.00	0.00

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