HL-LHC

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Tunnel heat transfer estimate

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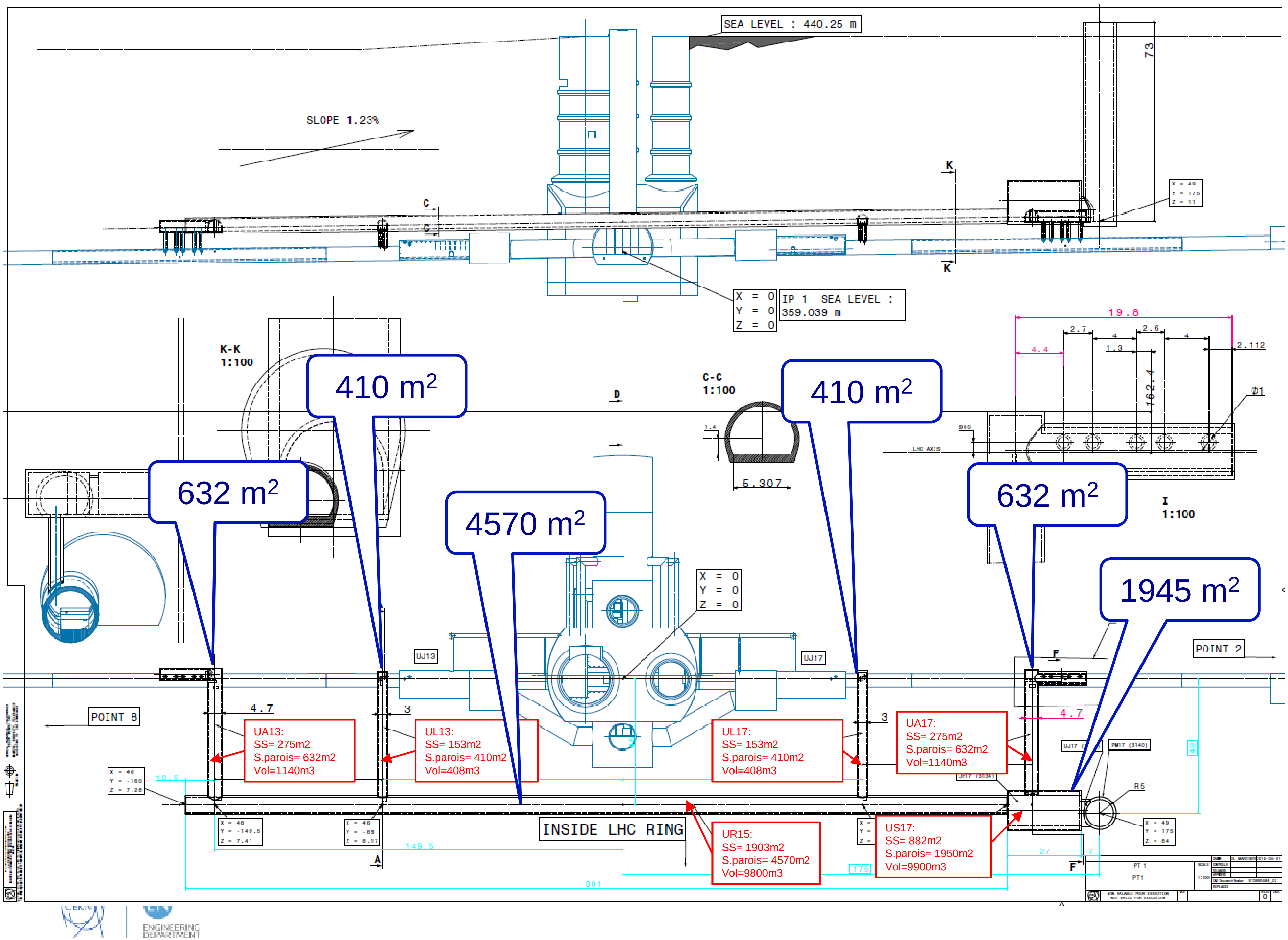
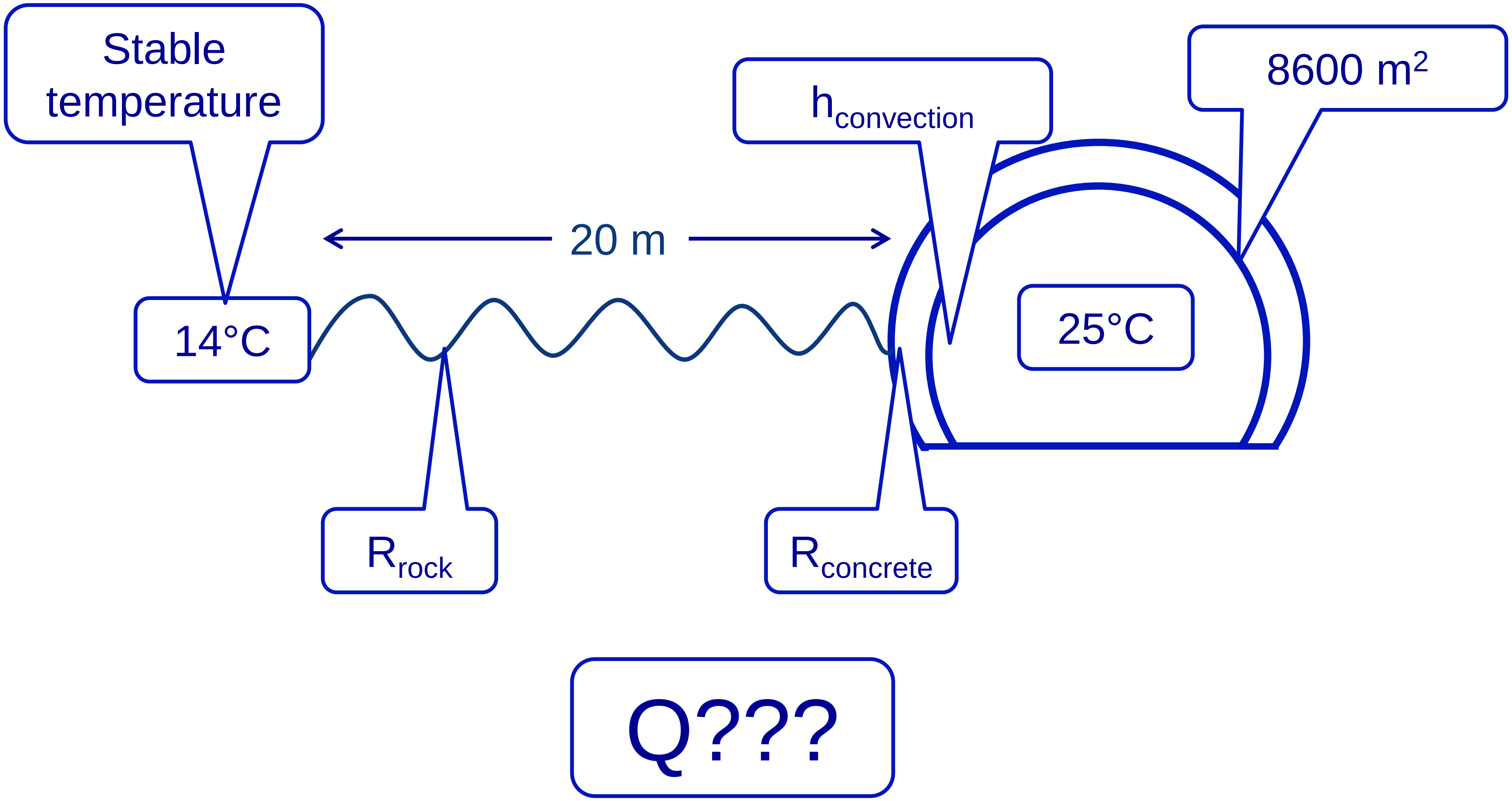
Agenda

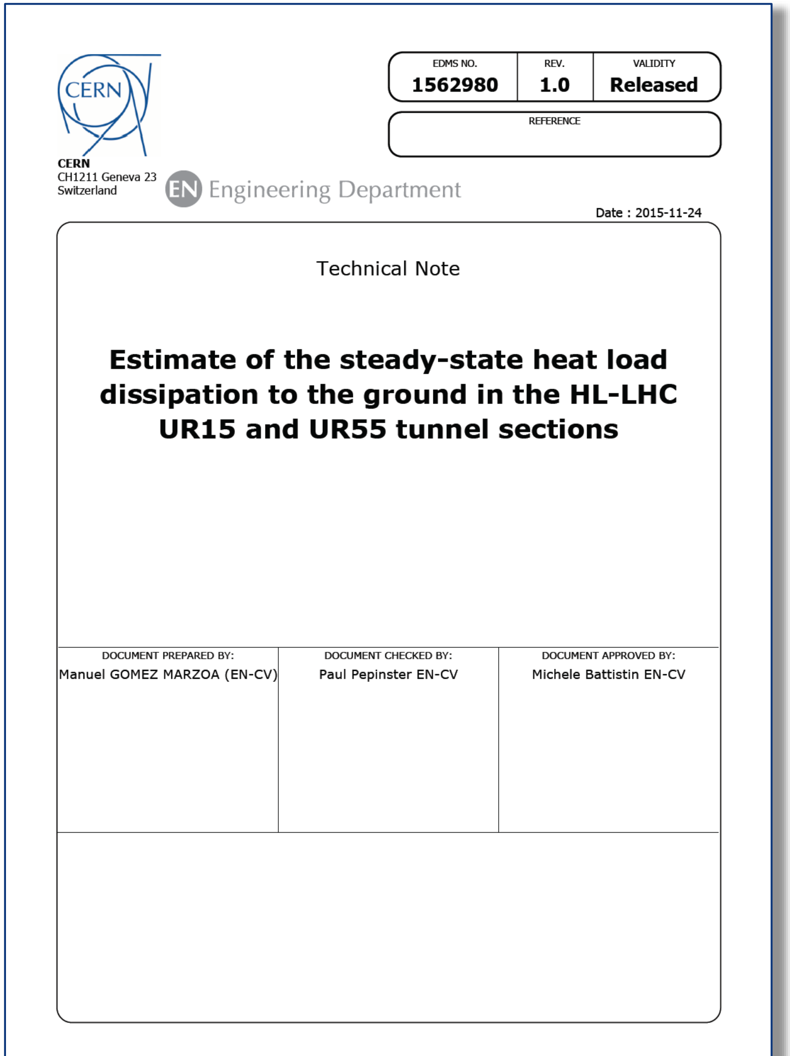
- Surface measurement
- Heat transfer problem
- Convective heat transfer estimate
- Radiation heat transfer estimate
- Conclusions


SEA LEVEL : 440.25 m
SLOPE 1.23%
X = 0
Y = 0
Z = 0
IP 1 SEA LEVEL :
359.039 m
K-K
1:100
C-C
1:100
5.307
19.8
I
1:100
410 m2
410 m2
632 m2
632 m2
4570 m2
1945 m2
UJ13
UJ17
POINT 8
POINT 2
UA13:
SS= 275m2
S.parois= 632m2
Vol=1140m3
UL13:
SS= 153m2
S.parois= 410m2
Vol=408m3
UL17:
SS= 153m2
S.parois= 410m2
Vol=408m3
UA17:
SS= 275m2
S.parois= 632m2
Vol=1140m3
UR15:
SS= 1903m2
S.parois= 4570m2
Vol=9800m3
US17:
SS= 882m2
S.parois= 1950m2
Vol=9900m3
INSIDE LHC RING
149.5
301
ENGINEERING
DEPARTMENT

Heat Transfer Problem



Technical note



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Technical Note

Estimate of the steady-state heat load dissipation to the ground in the HL-LHC UR15 and UR55 tunnel sections

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$$T_{GROUND} = (10.9 <> 11.7)^{o}C + \left(\frac{depth[m]}{100}\right) 3^{o}C$$

100 m depth -> ≈14°C

Thermal Resistance Parameters

SOIL

Type de roche	Conductivité type [W/(mK)]	Valeur recommandée [W/(mK)]
Argilite-marne	2.2 – 2.7	2.3
Marnes	2.3 – 2.8	2.4
Grès fins	2.4 - 2.8	2.5
Grès moyens	2.7 – 3.2	2.9
Grès grossier et conglomérats	2.2 – 3.1	2.4
Moyenne	**2.5**	**2.5**

SIA Standard Soil conductivity ≈ 2.5 W m^{-1} K^{-1}

Concrete

Material group or application		Density ρ kg/m³	Design thermal conductivity λ W/(m·K)	Specific heat capacity c_p J/(kg·K)	Water vapour resistance factor μ dry	wet
Asphalt		2 100	0,70	1 000	50 000	50 000
Bitumen	Pure	1 050	0,17	1 000	50 000	50 000
	Felt / sheet	1 100	0,23	1 000	50 000	50 000
Concrete a)						
	Medium density	1 800	1,15	1 000	100	60
		2 000	1,35	1 000	100	60
		2 200	1,65	1 000	120	70
	High density	2 400	2,00	1 000	130	80
	Reinforced (with 1 % of steel)	2 300	2,3	1 000	130	80
	Reinforced (with 2 % of steel)	2 400	2,5	1 000	130	80

EN 12524 Concrete conductivity ≈ 2.5 W m^{-1} K^{-1}

Mixed Convective Heat Transfer

Table 4 : Mixed convection Nusselt number calculation

G_{AIR} [m^3 h^{-1}]	Nu_F [-]	h_F [W m^{-2} K^{-1}]	h_N [W m^{-2} K^{-1}]	Nu_N [-]	n	Nu [-]	h [W m^{-2} K^{-1}]
23000	154	0.62	3	742	3	745	3.00
50000	284	1.15	3	742	3	756	3.05
50000	284	1.15	3	742	4	746	3.02
50000	284	1.15	10	2475	4	2477	10.00
50000	284	1.15	15	3713	3	3714	15.00

$$Nu^n = \frac{h_{AIR-WALL} D_{TUNNEL}}{k_{AIR}} = Nu_F^n + Nu_N^n$$

$Nu \approx Nu_N$ -> the natural convection is dominating the heat transfer process

The expected heat tranfert coefficient at the wall is about **3÷15 W m^{-2} K^{-1}**

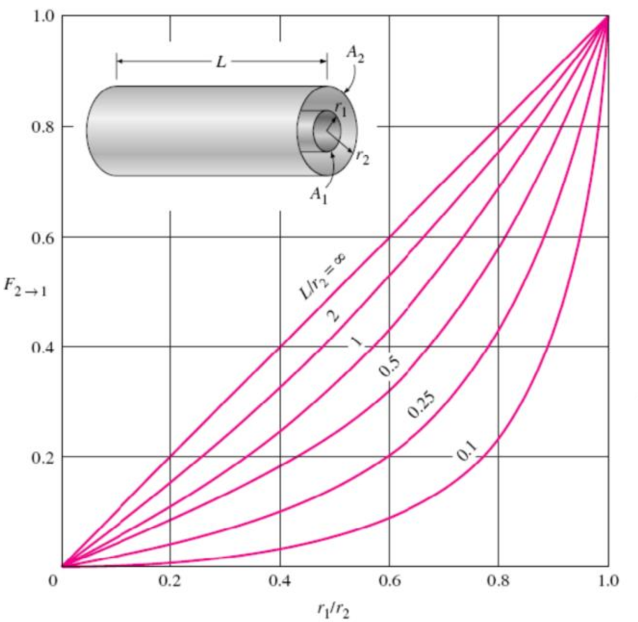
Convective Heat Load Estimate

$$Q_{AIR\text{-}GROUND} = \frac{T_{AIR} - T_{GROUND}}{\frac{1}{2\pi D_{TUNNEL} h L} + \frac{\ln\left(\frac{D_{TUNNEL} + 2t_{CONCRETE}}{D_{TUNNEL}}\right)}{2\pi k_{CONCRETE} L} + \frac{\ln\left(\frac{2r_{GROUND}}{D_{TUNNEL} + 2t_{CONCRETE}}\right)}{2\pi k_{GROUND} L}} \text{ [W]}$$

T_{AIR} [°C]	h [W m^{-2} K^{-1}]	$k_{CONCRETE}$ [W m^{-1} K^{-1}]	$t_{CONCRETE}$ [m]	T_{GROUND} [°C]	k_{GROUND} [W m^{-1} K^{-1}]	r_{GROUND} [m]	Q [kW]
25	5	2.5	0.5	14.0	2.5	20	63.4
25	3	2.5	0.5	14.0	2.5	20	55.4
25	15	2.5	0.5	14.0	2.5	20	74.0

The maximum expected convective heat load to the ground will be **74 kW**

Radiation Heat Load Estimate



D = 3.2 m; d = 1 m
D/d ≈ 0.31 -> View Factor = 0.31
Surface = 8600 m^2
T1 = 25 °C = 297 K
T2 = 14 °C = 286 K
S = 5.67×10^{-8} W m^2 K^{-4}
Emissivity both surfaces = 1.0

$$\dot{Q}_{1\to2} = A_1 F_{1\to2}\, \sigma (T_1^4 - T_2^4) \quad \text{(W)}$$

Q ≈ 80 kW

The radiation heat transfer is similar to the convective one

Conclusions

- The heat transfer between HL-LHC structure and the ground is mainly dominated by the natural convection and radiation
- Considering a tunnel air temperature of 25°C…
- ...the expected heat load is around **150 kW**

Any question?