Case Study Swiss Grid

Electrical Transmission Towers

Racquel Nottingham | June 2023

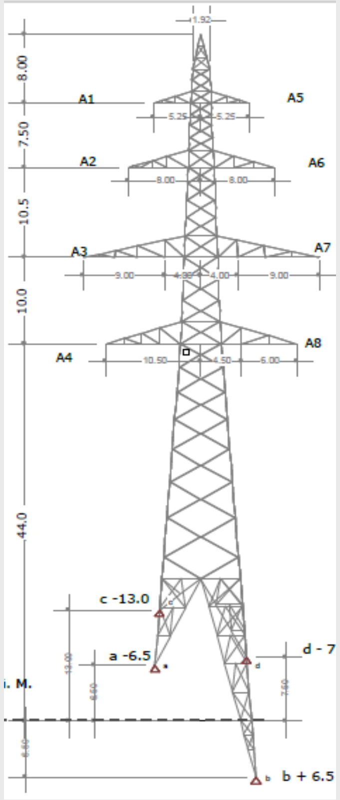
Agenda

1. Project Overview
2. Corrosion Consideration
3. Site Constraints
4. Micropile Solution
5. Conclusions

- Installation of new high voltage powerlines between Mörel and Ernen.
- To replace existing lines which deliver 220kV and 65kV with a line that transmits approximately 380kV from Valais hydropower plant.

- The current line passes through the village which restricts any further development in those areas
- The line is to be constructed on the southern slope further away from the settlement areas.

- Part of the Swiss Energy strategy 2050 which aims to reduce the country’s dependency on fossil fuels, by developing the renewable energy supply
- The strategy Was revised in May 2017 identifying the following major actions:
  - ❑Reduce energy consumption,
  - ❑Increase energy efficiency,
  - ❑Promote renewables,
  - ❑Prohibit the construction of new nuclear power plants,
  - ❑Upgrade the electricity grids.



Timeline

2009
- Start of planning

Dec. 2016
- Construction of the line Mörel to Ernen legally binding

Aug. 2020
- First contact with micropile designer

Dec. 2020
- Submit design of 16 mast foundations

Aug. 2022

Corrosion Considerations

Acc. to Swiss society of engineers and architects

Standard and Regulations in Switzerland

- Swiss Standard (SIA – Swiss Society of Engineers and Architects) - Regulations created by the Swiss
  Cannot be compared to EN Standards

- Eurocode (EN) - Design Norm for Europe
  - Introduced in Switzerland

Officially the authorities require the SIA standards for designs

Eurocodes		SIA - Structural Standards
EN 1990	Basics of structural design	SIA 260
EN 1991	Action on structures	SIA 261
EN 1992	Design of concrete structures	SIA 262
EN 1993	Design of steel structures	SIA 263
EN 1994	Design of composite steel and concrete structures	SIA 264
EN 1995	Design of timber structures	SIA 265
EN 1996	Design of masonry structures	SIA 266
EN 1997	Geotechnical Design	SIA 267
EN 1998	Design of structures for earthquake resistance	
EN 1999	Design of aluminum structures	

Risk Evaluation

- Initially the Risk has to be evaluated according to the Swiss Norm based on the construction class.

11.6.2.1.2 Four levels of protection are applicable. Table 6 applies for their specification.

Table 6: Protection levels for passive anchors

Planned service life		Short (≤ 5 years)			Long (>5 years)		
Construction class (Norm SIA 261)		I	II	III	I	II	III
Corrosion Risk	Low Corrosion Risk	0	1	1	1	1	2
	Medium corrosion risk	1	1	2	2	2	3
	High corrosion risk	2[1)]	2[1)]	x[2)]	2[1)]	3[1)]	x[2)]

1) See clause 11.6.3.2.1

2) Not recommended for passive anchors

SIA 267 - Geotech

Level 0	Level 1	Level 2a	Level 2b	Level 3a	Level 3b
No special measures required	Between steel member and borehole wall at least 20mm cement grout cover required	Ribbed plastic tube; closed on one end.	Stainless steel acc. To corrosion class 1 and up.	acc. to 2a	Stainless steel acc. to corrosion resistance class 3 and up.
		Min. 20mm grout cover between tube and edge of borehole	20mm grout cover between reinforcing steel and borehole wall.	Including 40mm minimum cover between plastic tube and borehole wall	20mm grout cover between steel and borehole wall.
		Min 5mm cover to prefabricated anchors 20mm cover to anchors formed on site			

SIA 267

Stainless Steel

- Possible sulphate attack.
- Pre-injected grout body and plastic sheeting can be damaged during transportation.

Level 2b	Level 3a	Level 3b
Stainless steel acc. To corrosion class 1 and up.	acc. to 2a	Stainless steel acc. to corrosion resistance class 3 and up.
20mm grout cover between reinforcing steel and borehole wall.	Including 40mm minimum cover between plastic tube and borehole wall	20mm grout cover between steel and borehole wall.

Site Constraints

Equipment access, material delivery

Restricted Access

- The high-voltage line should travel along the valley and then over the Alps towards Italy
- In the valley, the rock formations overlain by highly weathered material
- In the Alps mostly healthy rock formations.

Restricted Access

- Terrain was generally hilly.
- Slopes varied in inclination angles and heights

Restricted Access

- Material was mostly flown in by helicopter
- Site workers access:
  - Narrow Paths
  - Hiking Trails
  - Dirt bikes
  - ATVs

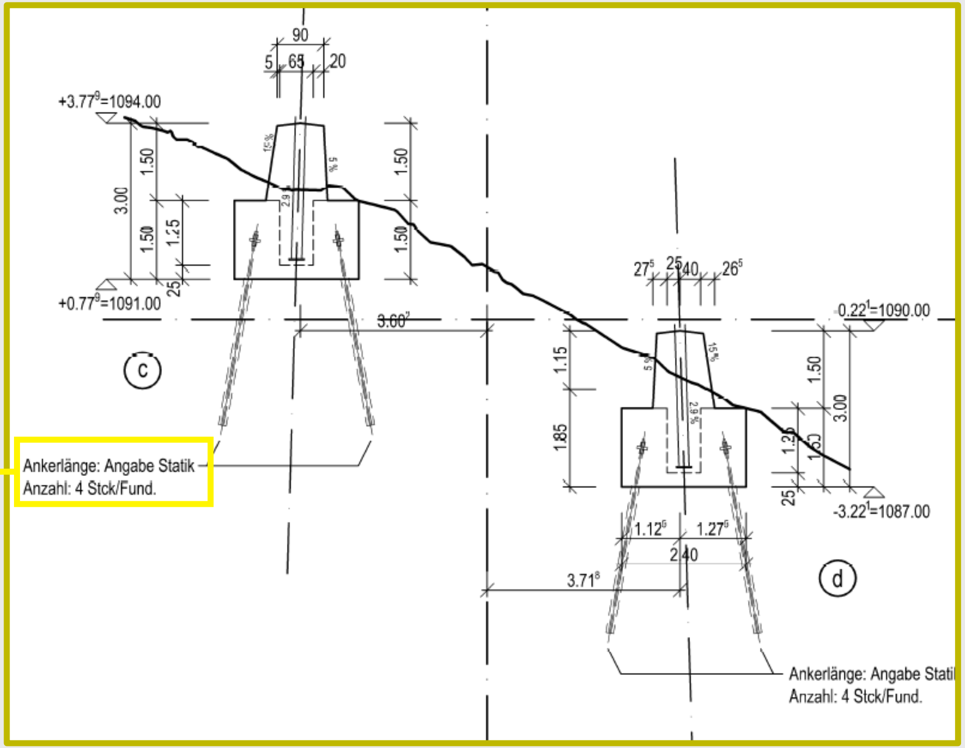
Micropile Solution

Conceptualized, Designed, Checked and Installed

Original Design

- 4 slightly inclined micropiles per footing
- Loads included axial loads, lateral loads and moments
- Ground conditions pre-defined

Solid Bar ϕ, 2in [50mm]
F_{yk} = 220.8 kips [982kN]
4No. per leg



Design Constraints

- Stainless steel is available in a limited range.
- TITAN 40/16 – 119.2 kips [530kN] is the largest possible in INOX.
- The loads were considerably high and more than 4 micropiles would be required.
- Limitations regarding the spacing of the micropiles so the full capacity of the micropile can be considered.

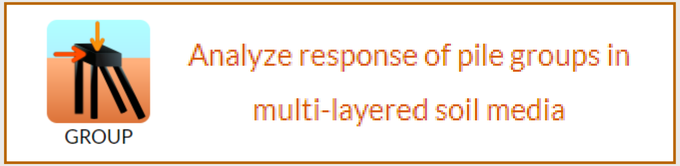
Ground Conditions

- Skin friction analyses were carried out by the site engineer and the values were given directly

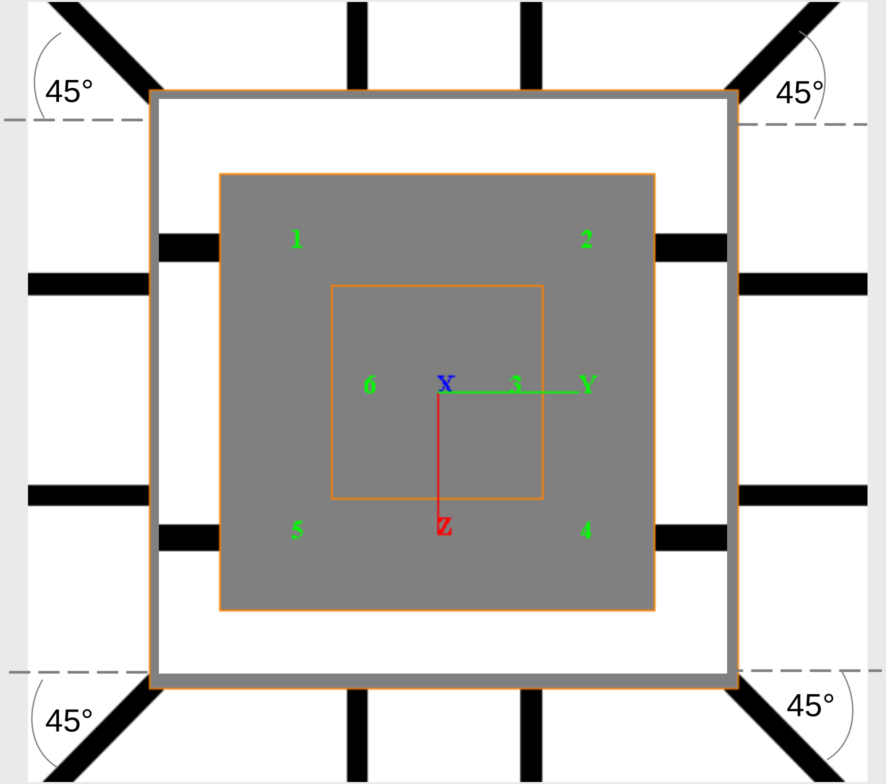
Material type	Skin Friction, kips/ft^2 [kN/m^2]
Moraine	3.76 [180]
Slope debris	3.13 [150]
Gneiss	5.22 [250]
Calcareous Slate	5.22 [250]
Rock	3.76 [180]

Foundation Design

- Model using Ensoft Group

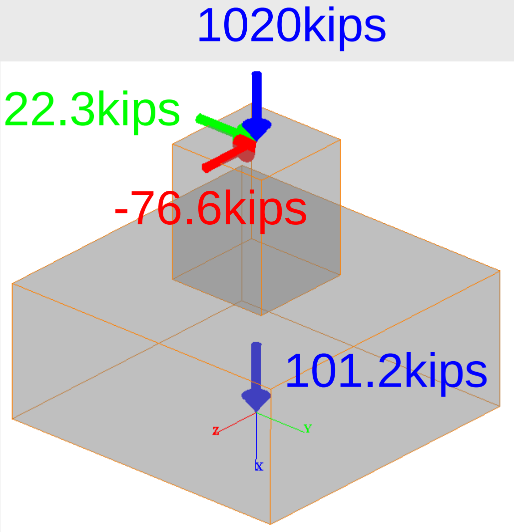


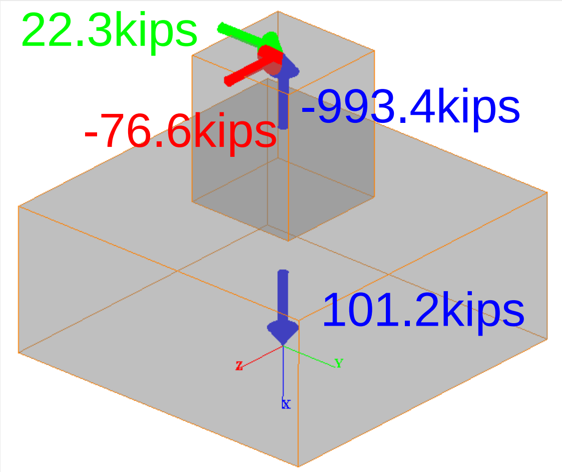
- Iterative calculation to obtain best possible solution
- Smallest foundation - 6 micropiles per leg
- Largest foundation – 22 micropiles per leg

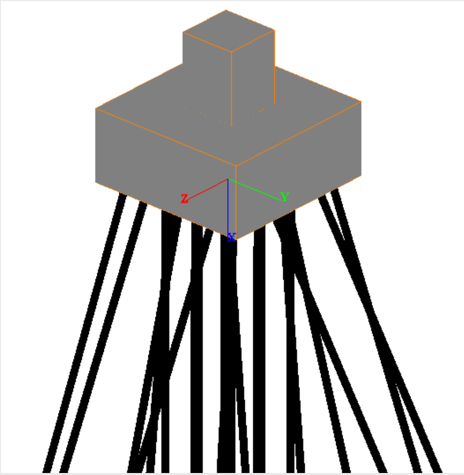


Deep Foundation Design

Largest Foundation – 22 Micropiles





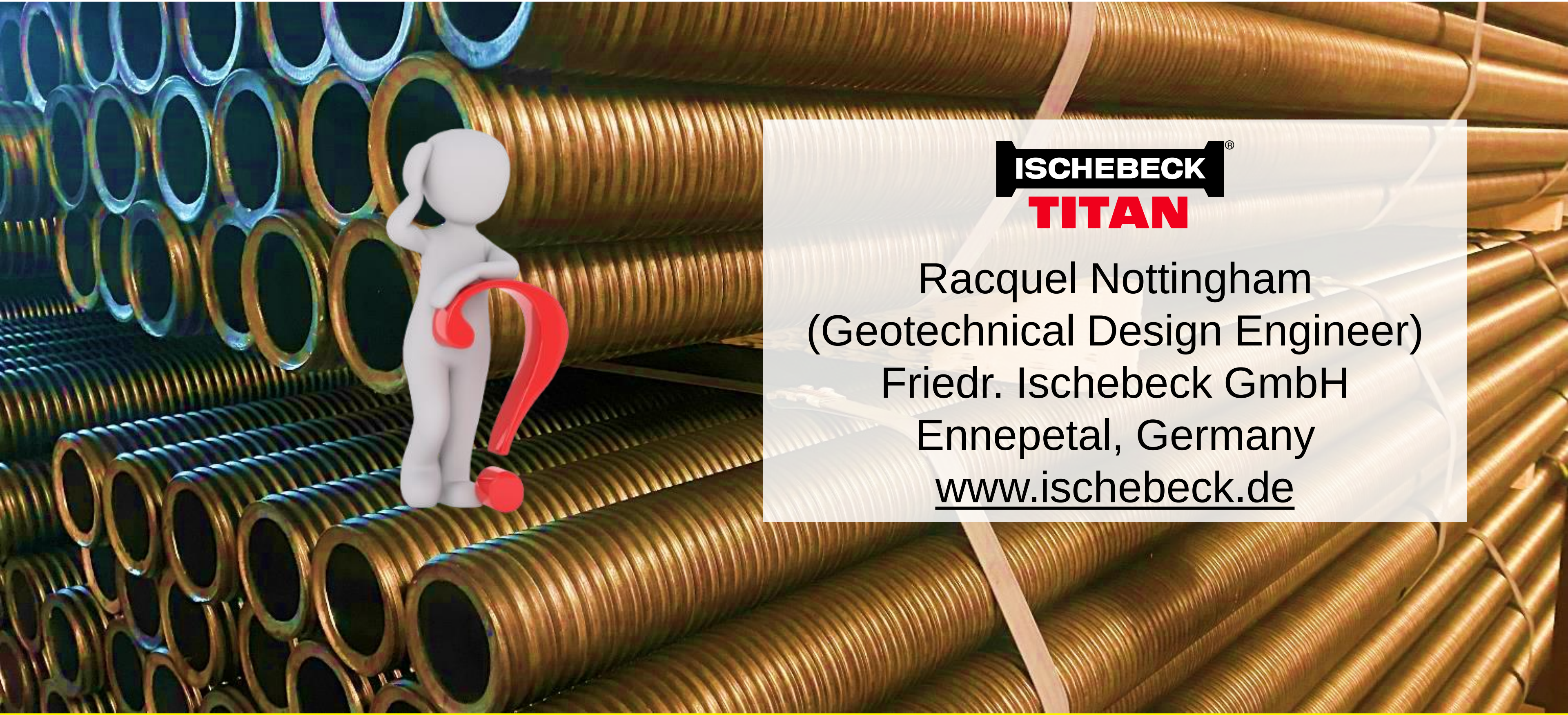


Challenges during Installation

The Mast foundation overlain on the contour map of the terrain showed that some of micropiles will protrude from the slope face.

Conclusions

- Most importantly the design had to be carried according out to the highest possible corrosion protection standards according to the Swiss Norm.
- Increasing the number of micropiles and varying the inclinations can produce favourable results where significant lateral moments are present



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