NGF Geosyntetkomiteen
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Geogrid reinforced LTP

An alternative to soft soil replacement

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Constructing connections.
Consciously.

On-shore wind mill farms in Denmark

Efficiency

- Flat landscape in Denmark and stable wind from west gives a respectable output

Installation

- On-shore installation is far cheaper than off-shore – the same goes for maintenance costs
- Majority of foundation in Denmark is on soil, hence foundation issues are generally soil related
  - Only hard bed rock (granite) on Bornholm
  - Soft bed rock (limestone) in the northern part of Jutland and on east/south east part of Zealand
- In Denmark occurrences of soft soil layers is fairly common.
- If project progress allows for general settlements (to some extend) then geogrid aids to an even settlement

On-shore wind mill farms in Denmark

Elements benefitting from geosynthetic use

- Construction/service roads
  - Heavy loads during construction but minimal loads during service
  - Relatively limited requirements to differential settlements, but strict requirements to have a sturdy road. Can be established based on relatively pragmatic and quick geotechnical assessments

- LTP/crane hardstands
  - Heavy loads during construction but minimal loads during service
  - Strict requirements to differential settlements, require a more thorough geotechnical assessment and design

Overgaard Wind Mill Farms

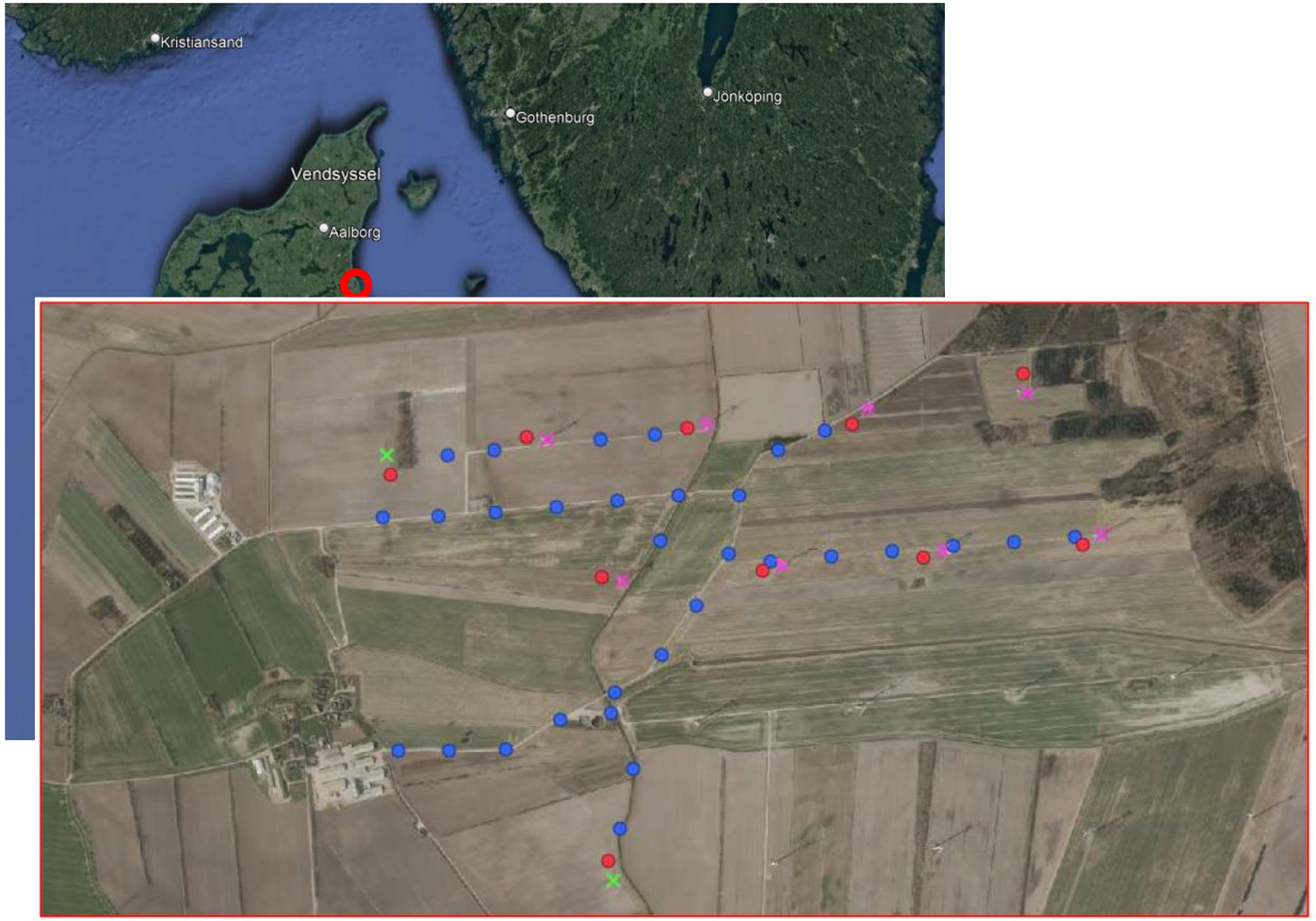


Figure 1: Overview of the site. Dots show positon of boreholes for roads (blue) and crane pads (red). Green crosses show position for new WTG and purple crosses position of existing WTG.

Location: Overgaard Gods near Hobro

Magnitude: ca. 8 km of construction/service road (22t axle load)

10 x LTP/crane hardstands (200 kN/m^2 on 6m x 2,4m)

Geology

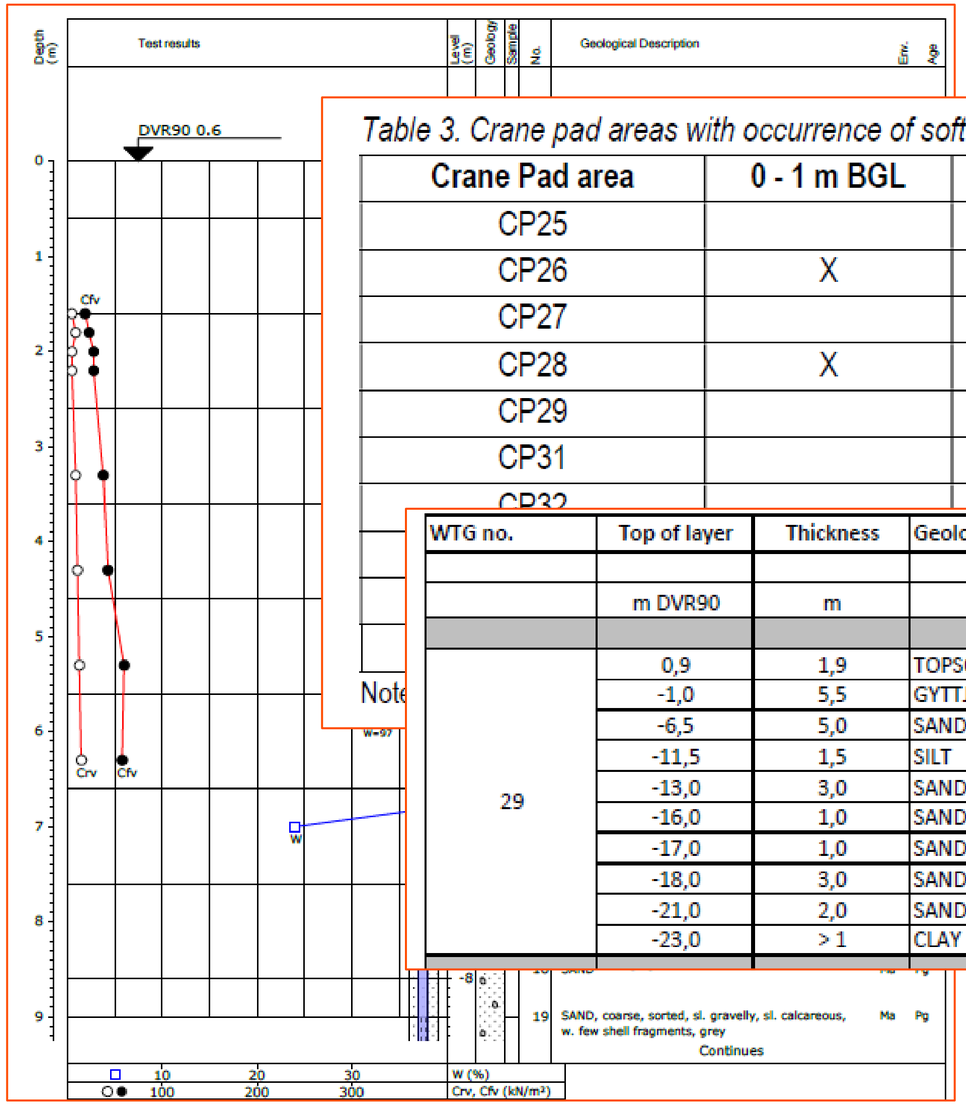


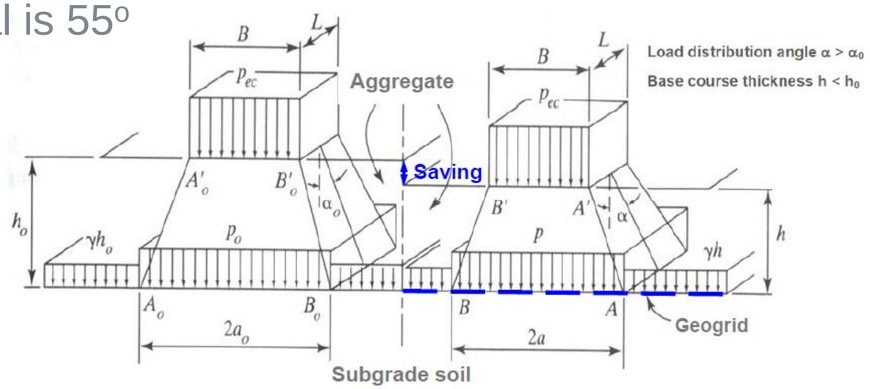
Table 3. Crane pad areas with occurrence of soft soil

Crane Pad area	0 - 1 m BGL	1 – 2 m BGL	>2 m BGL
CP25		X	
CP26	X	X	
CP27		X	X
CP28	X	X	X
CP29			X
CP31		X	X
CP32		X	X

WTG no.	Top of layer	Thickness	Geological Description	γ	γ'	φ	c'	cu	E'	E_{oed}	Q	E_0
									(SAND)	(CLAY)	(GYTTJA)	SAND/CLAY
	m DVR90	m		kN/m³	kN/m³	°	kPa	kPa	MPa	MPa	%	MPa
29	0,9	1,9	TOPSOIL	17	9							
	-1,0	5,5	GYTTJA	15	5	15	0	20			32	
	-6,5	5,0	SAND	17	9	39	0		40			210
	-11,5	1,5	SILT	19	9	30	0		20			-
	-13,0	3,0	SAND	17	9	35	0		35			170
	-16,0	1,0	SAND / SILT	17	9	36 / 30	0	80	40			200 / -
	-17,0	1,0	SAND / CLAY	17	9	40 / 25	0 / 12	125	60	-		325 / 140
	-18,0	3,0	SAND	17	9	37	0		50			290
	-21,0	2,0	SAND / CLAY	17	9	40 / 25	0 / 18	175	65	-		365 / 200
	-23,0	> 1	CLAY	18	8	25	18	175		-		200

Design basis

- Assumptions, general
  - Fill material is well graded gravel or crushed material with φ =37°
    Based on tests the equivalent friction angle for the friction material is 55°



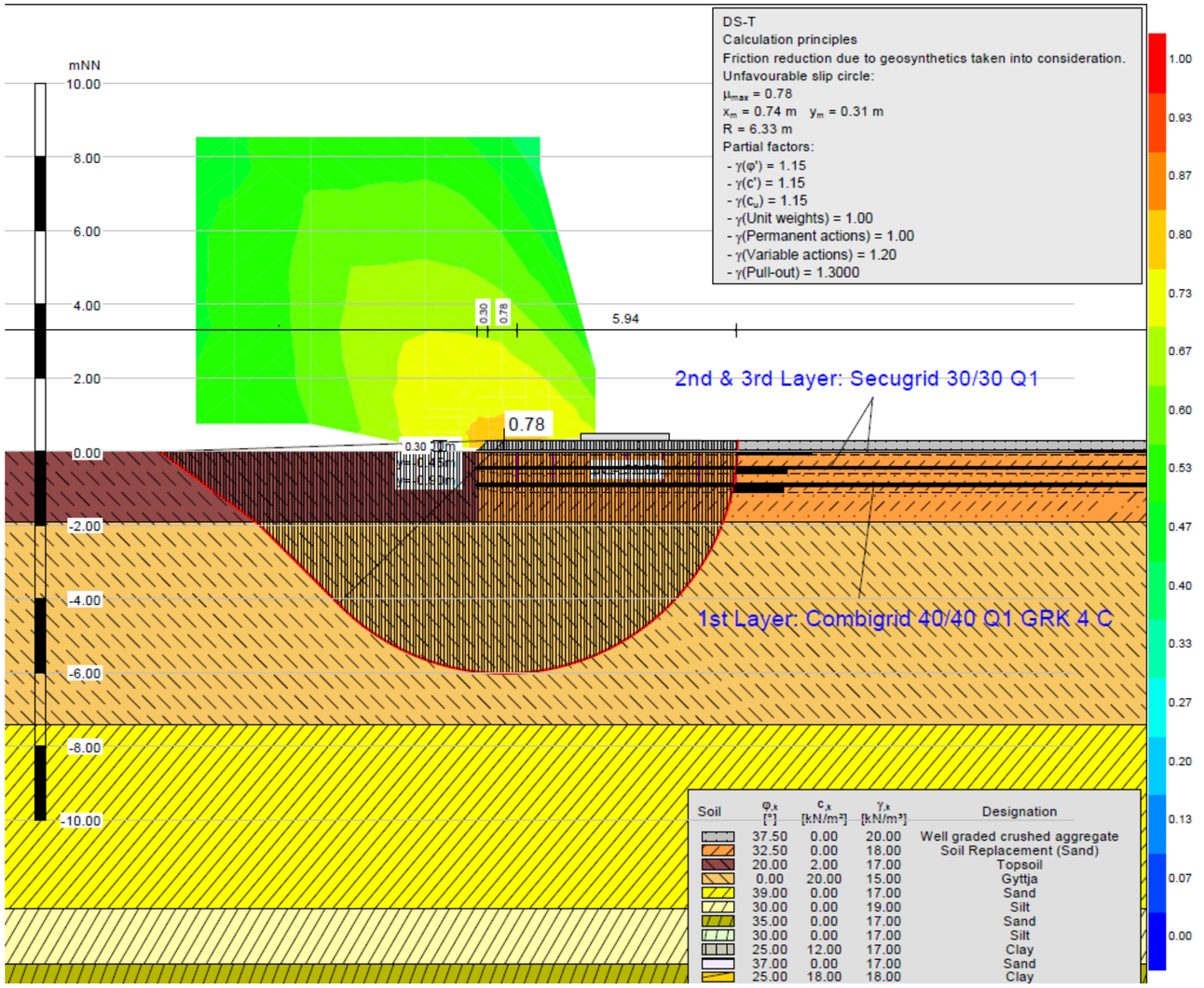
- Assumptions, roads
  - Max. rut depth of 75 mm at 10.000 axel paases
    - Reality: 0-25mm
  - Target E_{V2} ≥ 80 kN/m²

Table 1: Recommended thicknesses and reinforcement for several $E_{V2,SUB}$ values

$E_{V2,SUB}$	Required thickness	Required reinforcement
≥ 5 MN/m²	500 mm	1x Combigrid® 40/40 Q1 GRK 4 C 1x Secugrid® 30/30 Q1
≥ 7.5 MN/m²	420 mm	1x Combigrid® 40/40 Q1 GRK 4 C
≥ 10 MN/m²	350 mm	1x Combigrid® 40/40 Q1 GRK 4 C

Design basis

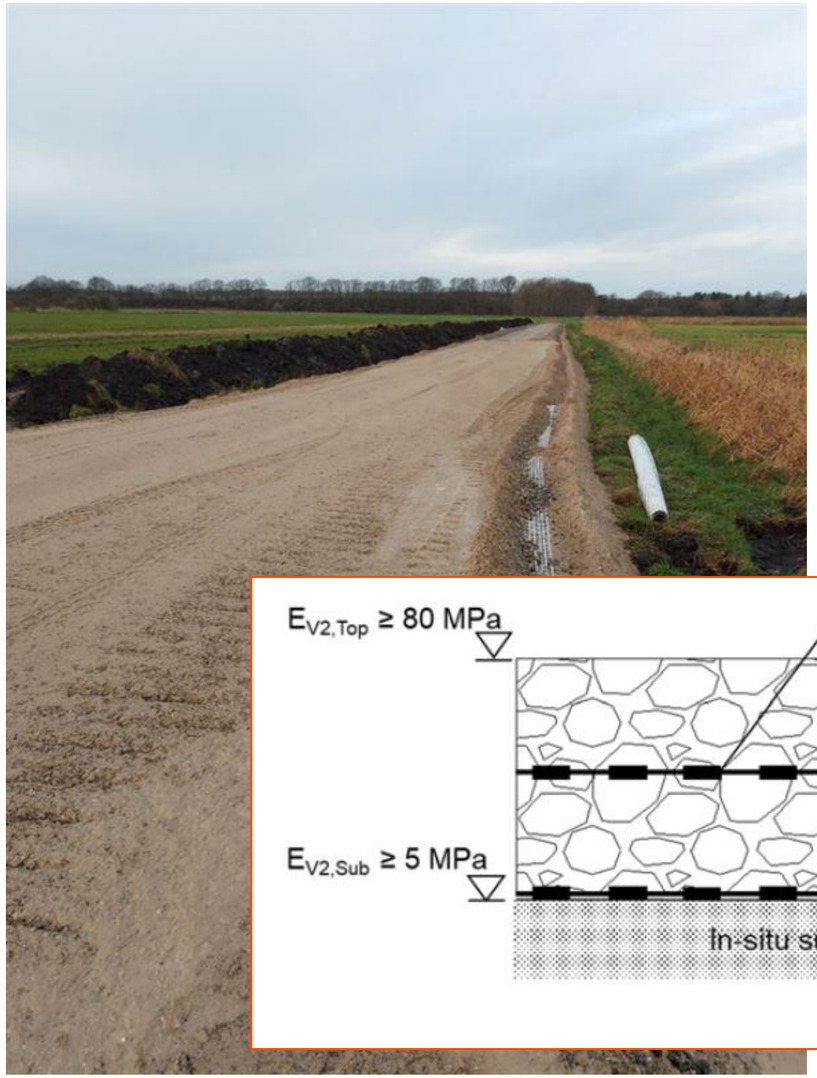
- Assumptions, LTP
  - Stability analysis
  - Target $E_{V2} \geq 100$ kN/m^2



Foundation solutions

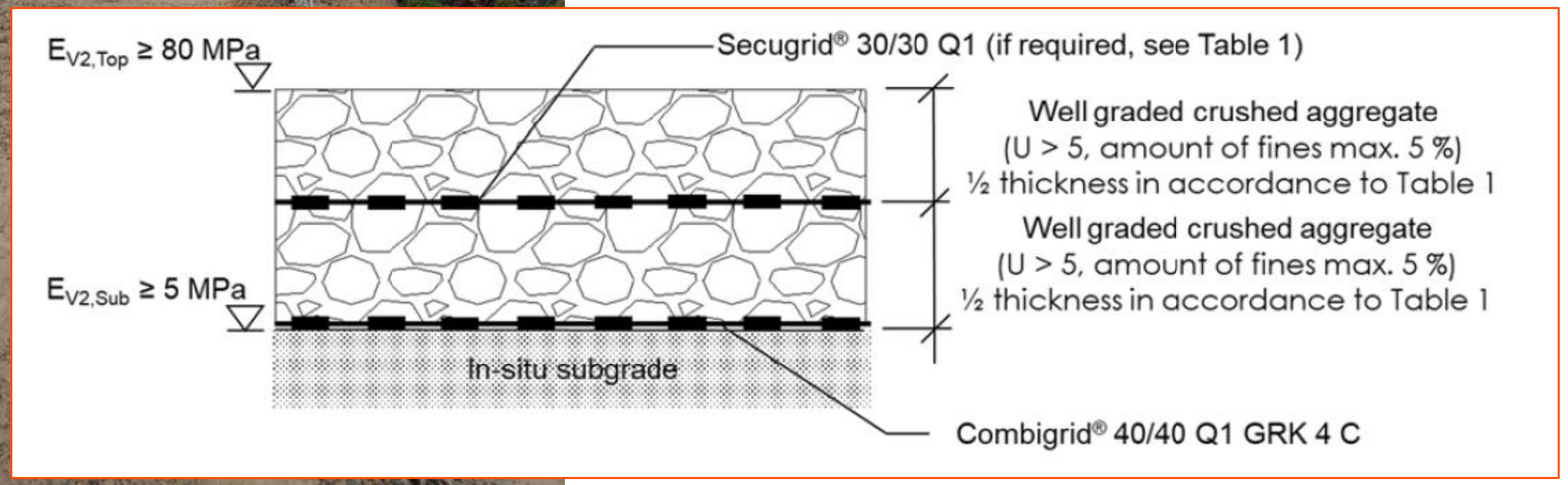
Wind mills: Concrete pile foundations

Foundation solutions



Wind mills: Concrete pile foundations

Roads: Combigrid 40/40 Q1 GRK4 directly on existing soil
Depending on the local conditions an additional layer of Secugrid 30/30 Q1 installed in the backfill layer



Foundation solutions

Table 2: Base course thickness and reinforcement for reinforced crane hardstands

WTG No.	Required thickness of soil replacement to remove Topsoil	Required thickness of well graded crushed aggregate	Reinforcement	Required distance of load to the upper edge of the crane pad
25 (E1.2)	1300 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
26 (E1.3)	900 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
27 (E1.4)	1000 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
28 (E1.5)	900 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
29 (E1.6)	1900 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
31 (E1.7)	900 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
32 (E1.8)	800 mm	400 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
33 (E1.9)	1000 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
34 (E1.10)	1900 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m
41 (E1.11)	1100 mm	300 mm	1x Combigrid® 40/40 Q1 GRK 4 C 2 x Secugrid® 30/30 Q1	2.5 m

Wind mills: Concrete pile foundations

Roads: Combigrid 40/40 Q1 GRK4 directly on existing soil
Depending on the local conditions an additional layer of Secugrid 30/30 Q1 installed in the backfill layer

LTP: Combigrid 40/40 Q1 GRK4 with of 0,8m-1,9m of top- and softsoil

2 layer of Secugrid 30/30 Q1 installed in the backfill layer

Limited soft soil replacement

Foundation solutions

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Limited soft soil replacement

Thanks for your attention