Less piles with PileCore – Smart Grouper

Existing pile foundation design software does not include tools to optimize your pile foundation. Conventional software lacks the ability to deal with the variation of the subsurface, which is an important factor that influences the design and amount of construction material (piles) used. Smart grouping of CPTs can lead to a lower ξ factor and thus higher pile load capacity and an optimal design.

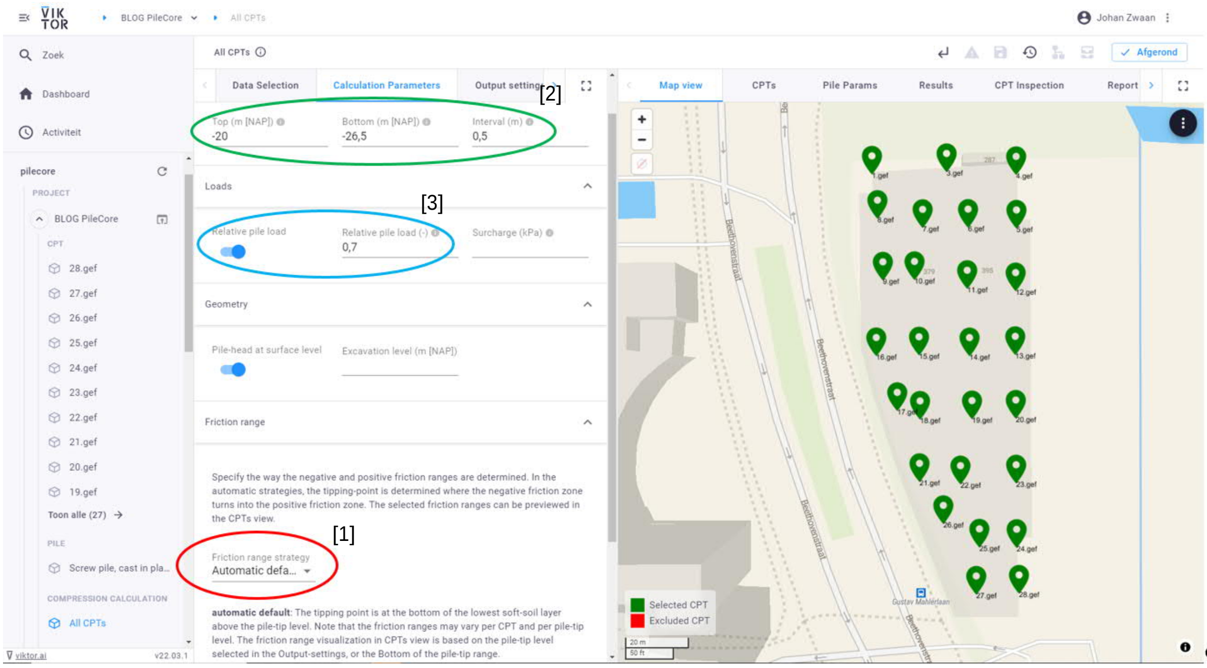
With a large group of CPTs the number of potential subgroups that can be formed quickly increases, making it time consuming and easy to lose overview. This task is better left to the calculating power of computers. We have utilized this computing power by developing the python library PileCore API, available in the cloud. PileCore is pile foundation design software that groups CPTs in a convenient way. By using PileCore, foundation contractors can optimize existing designs so that they can offer lower prices in tenders.

The PileCore API can be easily integrated into an engineering pipeline of, for example, a tunnel section. To make this possible we came up with some smart solutions for automatic interpretation of CPTs. Together with VIKTOR we made a graphical user interface that communicates with the PileCore API. In this blog we briefly explain how you can quickly and easily get started with PileCore yourself on the VIKTOR platform. Based on a case we will show u how this works. We will cover the following main subjects:

- Automatic determining of positive and negative skin friction.
- Grouper function to optimize foundation design, in a smart way.
- Clear overview of the results and used parameters on the VIKTOR platform and a detailed report

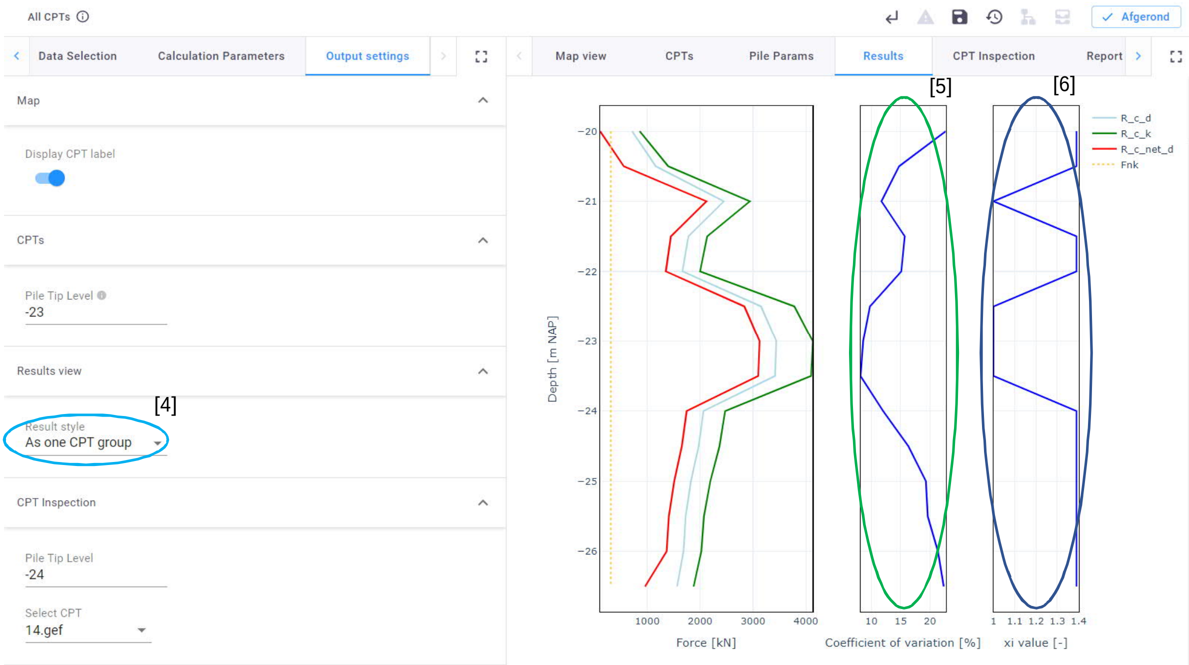
Getting started

We have already configured 6 pile types for you according to table 7.c of NEN9997-1, so you can choose one. After uploading your CPTs you can have the positive and negative skin friction determined automatically [1] for each CPT individually. PileCore takes the lowest compressible soil layer above a pile tip and calculates all the upper soil layers as negative skin friction. When you calculate a relatively large range of pile tip levels that include compressible layers, the negative and positive adhesion zones change automatically with each pile tip level. Based on the CPTs, we have chosen a calculation range from NAP -20 m to NAP -26.5 m with a bearing capacity every 0.5 m [2]. We chose to calculate the settlement of the pile at 70% of the characteristic value of the bearing capacity of the pile [3]. Of course you can also use a SLS load specified by the structural engineer.



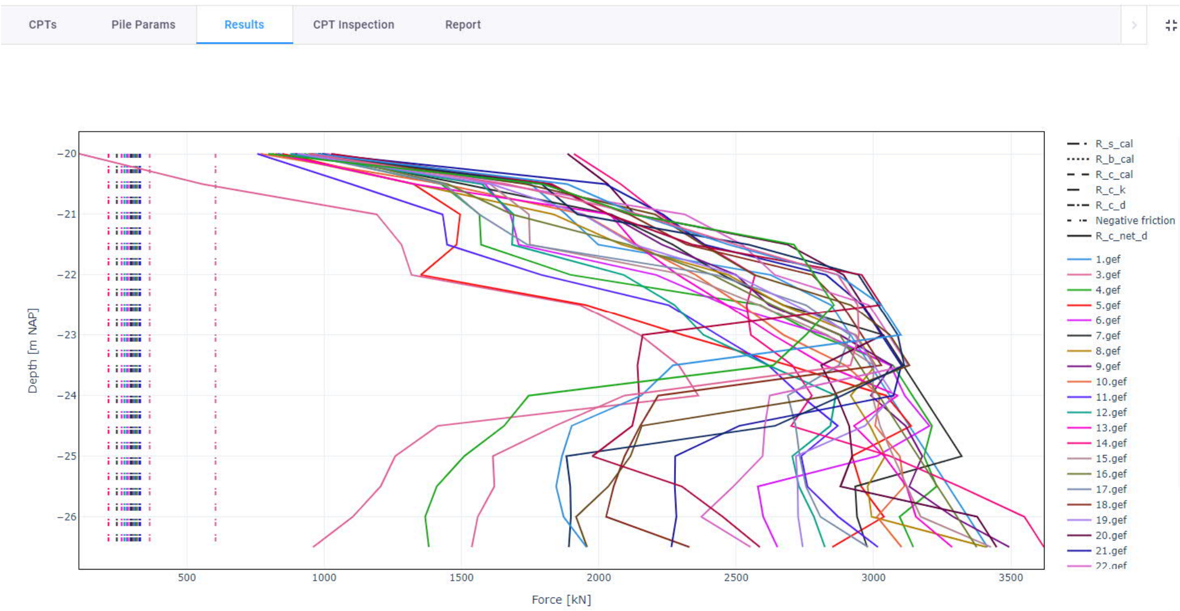
PileCore presents all CPTs side by side, so if you don’t agree with the automatically determined friction ranges, you can easily adjust them manually.

We perform the calculations for all CPTs and present the bearing capacity result as 1 pile group [4]. PileCore checks if the variation coefficient [5] meets a maximum of 12% to determine the ξ value (Xi) for each pile tip level. The bearing capacity of the group is clearly shown in one figure. As you can see the ξ varies between 1,0 and 1,39 [6].

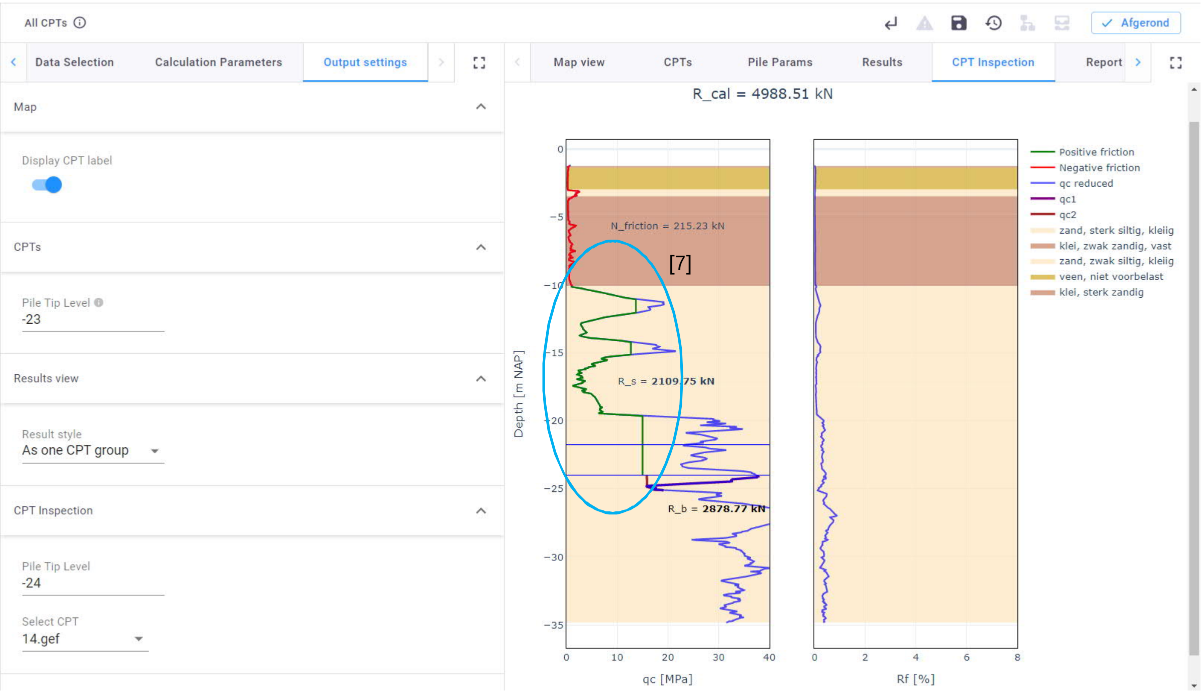


Let’s say we are looking for a bearing capacity of 3000 kN. At NAP -23 m the variation coefficient results in a ξ value of 1,0 (Xi4). This means that we have found a foundation level for this project at NAP -23 m that satisfies the NEN9997-1 requirements based on the least favourable CPT. Let's keep that in mind and see further on if we can optimize this by finding CPT subgroups using the PileCore Grouper.

The results of all individual CPTs can also be made visible in one figure, a bit less clearly though ;-).



In addition, an individual CPT can be inspected in detail. For instance the green line [7] shows how the positive skin friction is determined, cutting off values at 12 or 15 MPa.



What about the new Grouper feature?

After performing the pile calculation, we can put the grouper to work to see what gains can be made by making smaller groups. This new feature is unique for projects with multiple CPTs (>4) and leads to shorter or less piles in most cases.

Here we assume a flexible foundation where load redistribution is not possible.

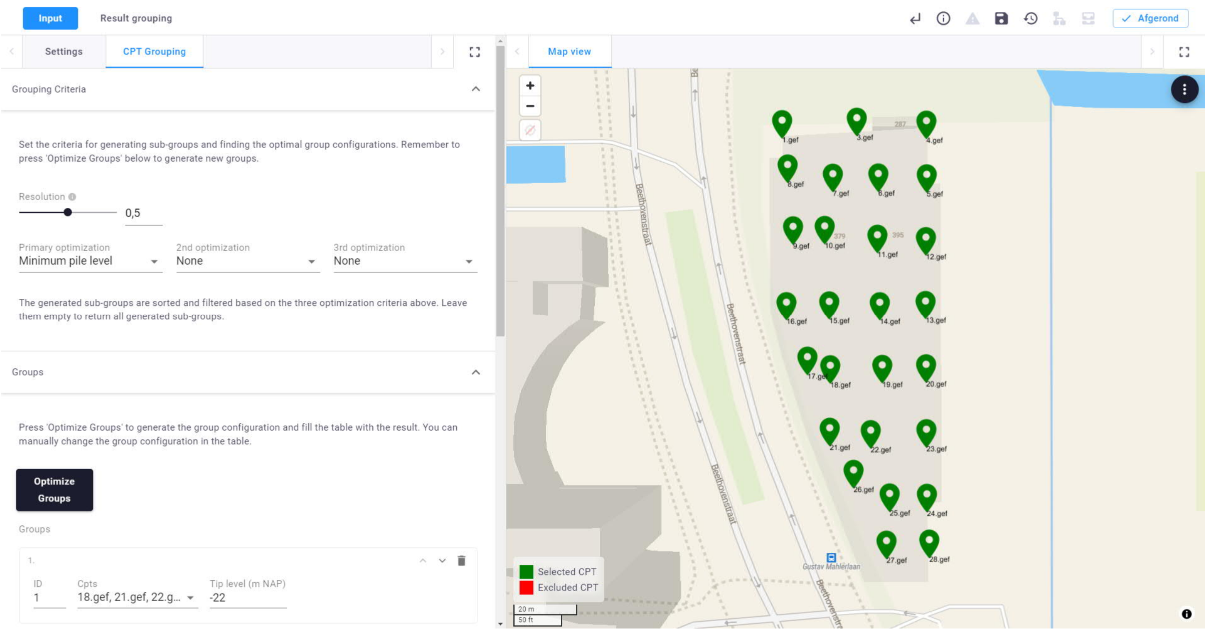
The grouper uses pile bearing capacity results calculated by PileCore to form subgroups of CPTs. Valid subgroups have three characteristics:

1. a coefficient of variation of maximally 12% at one or more pile-tip levels. (Variation check);
2. a minimum design pile bearing capacity based on the given pile load ULS at one or more pile-tip levels. (Bearing capacity check);
3. is spatially coherent, which means there are no other CPTs in between the members of the subgroup. (Spatial check).

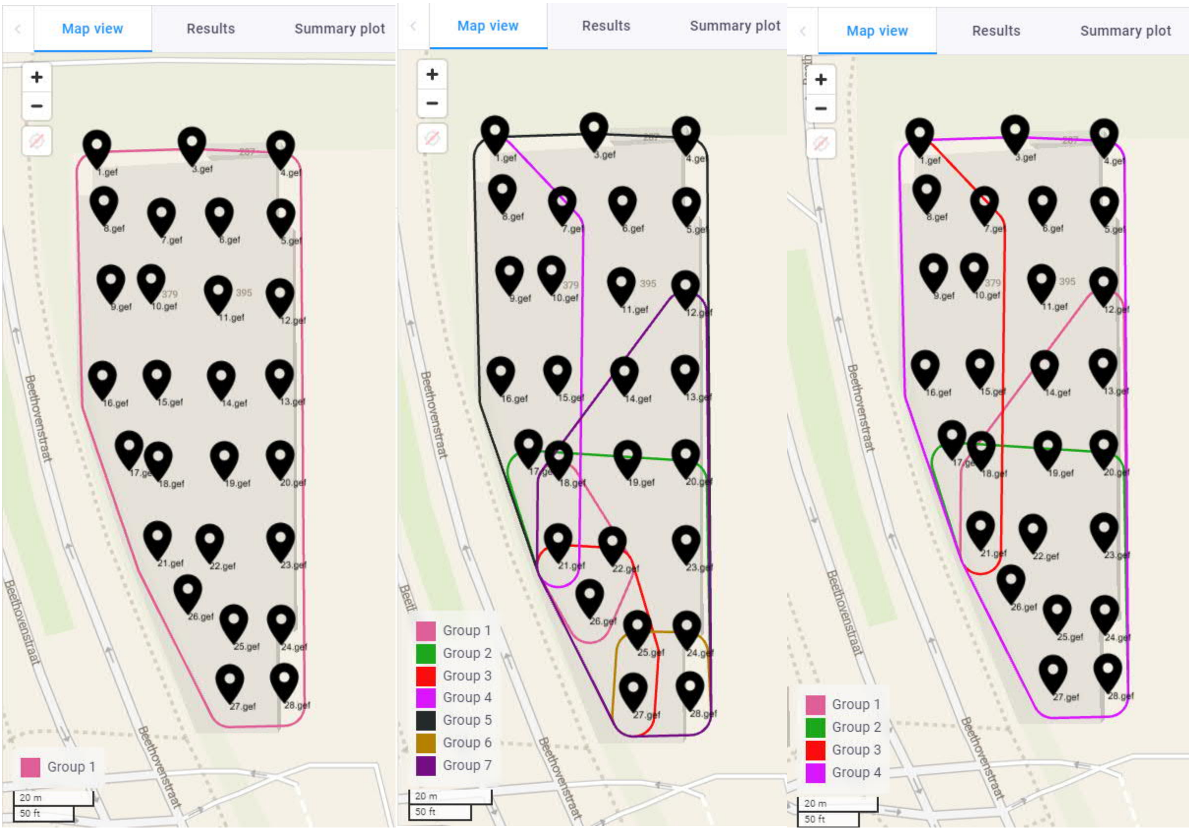
In case an individual CPT cannot be placed in a valid subgroup and does not pass the bearing capacity-check, it is placed in a residual subgroup. This residual subgroup is added to the report to provide a complete analysis of all CPTs.

The Grouper will try to generate a large number of potential configurations of valid CPT subgroups. It is not so easy to automatically determine the optimal configuration for our specific project requirements. That's why we are going to tell the Grouper what we find important, by selecting one or more of the following filter criteria:

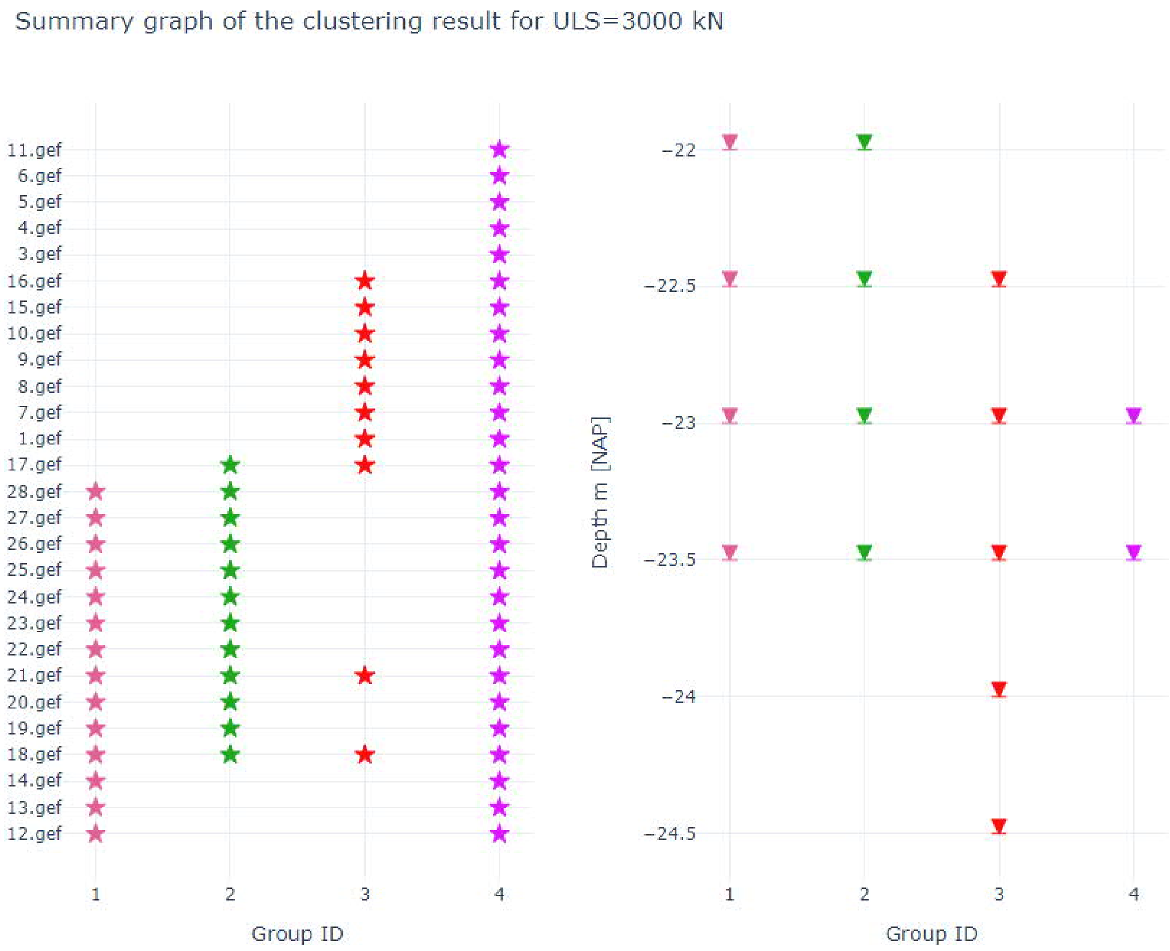
- Minimum pile level: to return groups that lead to the shortest piles, potentially leading to bigger pile tip variations between valid groups.
- Number of CPTs: to make the subgroup as big as possible to try and get a uniform pile tip level for most CPTs.
- Number of consecutive pile tip levels: to get groups that contain valid consecutive pile tip levels to ensure a consistent soil layer is used.



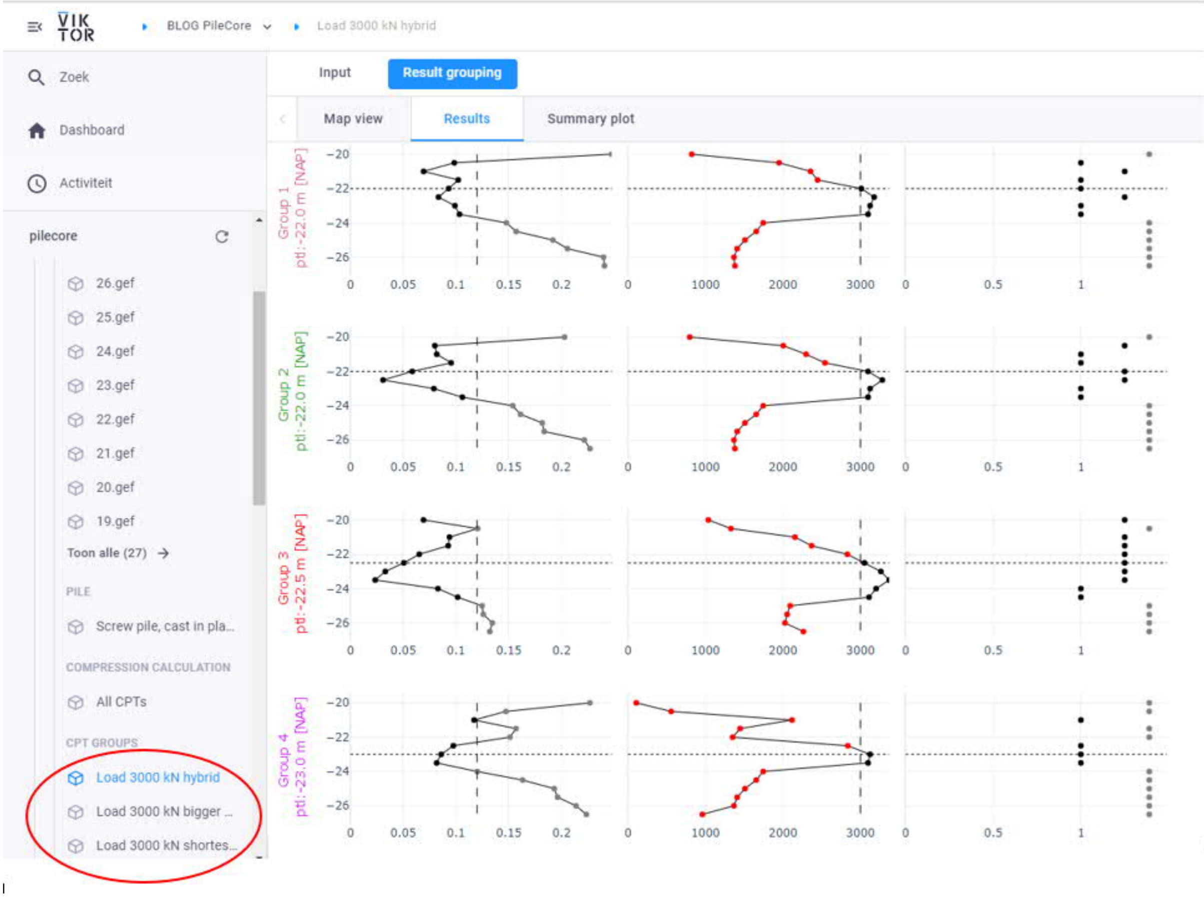
We can show the effect of these filters with some examples. We initially chose the filter "number of CPTs" and found one group in this case. This is the same group that was found earlier without the use of the Grouper. So we haven’t gained anything yet. When we choose "minimal pile length" we find 7 groups. This gives us the shortest piles, but leads to quite a large amount of groups for 28 CPTs. Therefore we make a 3rd calculation where we first filter on “minimal pile length” and then on “number of CPTs”. Now we find 4 groups which we think is a nice balance between number of groups and pile length.



So what did we gain by using the Grouper? That can be seen in the figure below. We can see which CPTs are part of a group and at which pile tip level a valid solution is found. Remember that we started with a single group requiring a pile tip level of NAP -23 m for all CPTs. By grouping the CPTs, the pile length is reduced by 1 meter at 15 of the 27 CPTs (groups 1 and 2) and another 7 by 0.5 m. At only 5 CPT locations the pile tip level remains NAP -23 m. Not bad for half an hours work! Ok to be fair, it will take you a bit longer at first but you will get the hang of it soon enough!



For each group you can check which variation coefficient and ξ value is used for each pile tip level. You can also always switch easily between the different results and grouper filters by using the side-bar on the left side of the screen. You don't see it in standard view but it is very useful!



Finally, a comprehensive report with results for each CPT and group is presented in detail. For each pile tip level, the spring stiffness, bearing capacity trajectories and pile settlements are shown.

Pile bearing capacity (ULS):

Pile tip level	Base resistance					Shaft resistance		Pile resistance			
	$q_{c;I;gem}$	$q_{c;II;gem}$	$q_{c;III;gem}$	$q_{b;max}$	$R_{b;cal;max}$	$q_{s;max;av}$ 2)	$R_{s;cal;max}$	$R_{c;k}$	$R_{c;d}$	$F_{nk;d}$	$R_{c;net;d}$
[m NAP]	[MPa]	[MPa]	[MPa]	[MPa]	[kN]	[kPa]	[kN]	[kN]	[kN]	[kN]	**[kN]**
-20.00	11.1	9.2	3.2	4.2	1036	70.12	1078	1521	1267	272	**996**
-20.50	26.2	26.2	4.3	9.6	2362	72.09	1170	2541	2118	272	**1846**
-21.00	31.7	25.5	6.9	11.2	2757	75.30	1291	2912	2427	272	**2155**
-21.50	29.6	28.3	9.5	12.1	2986	78.21	1409	3162	2635	272	**2363**
-22.00	35.5	32.9	12.6	14.7	3629	80.84	1528	3710	3092	272	**2820**
-22.50	37.9	35.7	16.1	15.0	3695	83.24	1646	3842	3202	272	**2930**
-23.00	42.4	34.1	19.6	15.0	3695	85.44	1764	3927	3273	272	**3001**
-23.50	40.8	23.2	18.3	15.0	3695	87.46	1883	4012	3344	272	**3072**
-24.00	34.9	7.5	7.4	9.0	2219	89.39	2003	3037	2531	272	**2259**
-24.50	28.1	8.4	7.4	8.1	1992	91.10	2121	2959	2466	272	**2194**
-25.00	22.5	8.5	7.4	7.2	1779	92.69	2240	2891	2409	272	**2137**
-25.50	17.6	8.6	7.4	6.5	1595	94.17	2358	2843	2370	272	**2098**
-26.00	13.5	8.5	7.4	5.8	1430	95.46	2476	2810	2342	272	**2070**

Pile settlement (SLS):

Pile tip level	SLS loads			Distributed capacity		Pile settlement/ spring stiffness				
	$F_{c;k}$	$F_{nk;k}$	$F_{c;k;tot}$	$R_{b;k}$	$R_{s;k}$	s_{el}	s_b	s_1	K_b	K_1
NÅP]	[kN]	[kN]	[kN]	[kN]	[kN]	[mm]	[mm]	[mm]	[kN/mm]	[kN/mm]
-20.00	2500	272	2772	745	776	9.5	1000.0	1009.5	3	3
-20.50	2500	272	2772	1699	842	9.7	1000.0	1009.7	3	3
-21.00	2500	272	2772	1983	929	9.9	40.3	50.2	69	55
-21.50	2500	272	2772	2148	1014	10.1	25.6	35.7	108	78
-22.00	2500	272	2772	2611	1099	10.3	12.4	22.7	224	122
-22.50	2500	272	2772	2658	1184	10.4	10.2	20.6	272	134
-23.00	2500	272	2772	2658	1269	10.6	9.2	19.8	300	140
-23.50	2500	272	2772	2658	1354	10.8	8.4	19.2	330	145
-24.00	2500	272	2772	1596	1441	10.9	27.1	38.0	102	73
-24.50	2500	272	2772	1433	1526	11.0	31.3	42.3	88	65
-25.00	2500	272	2772	1280	1611	11.1	36.6	47.7	76	58
-25.50	2500	272	2772	1147	1696	11.2	41.6	52.9	67	52
-26.00	2500	272	2772	1029	1781	11.3	46.5	57.9	60	48

Now it's clear, you can save on pile length and engineering costs by using the smart PileCore features. You can try PileCore for free for one month to discover the benefits yourself, we will gladly assist you on your journey!

In a follow up post we will show how you can make a call directly to our API and integrate PileCore into an engineering pipeline.

Contact j.zwaan@cemsbv.io and you will get access the same day.