

Environmental and economic optimization of a conventional concrete building foundation: selecting the best of 28 alternatives by applying the Pareto Front

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Supplementary Material 1 – Characteristics of the foundation of the reference project.

Characteristics	Driven Precast Concrete Pile	Precast concrete beams
Concrete strength	C35/45	C40/50
Environmental class	XC4	XC3
Concrete cover (width)	30 mm	30 mm
Reinforcement	B500B	B500A
	Prestressed steel: Y1860	

Supplementary Material 2 - Materials/processes and quantities introduced in SimaPro.

1	C30/37 beams (cast-in-situ)	m ³	Tap water {RER} market group for Cut-off, U	164.85	kg
			Gravel, round {RoW} market for gravel, round Cut-off, U	884.10	kg
			Idemat2020 Sand	850.50	kg
			Idemat2020 Concrete aggregate	217.35	
			Cement, Portland {Europe without Switzerland} production Cut-off, U	33.60	kg
			Cement, blast furnace slag, 66-80%, non-US {Europe without Switzerland} cement production, blast furnace slag 66-80%, non-US Cut-off, U	298.20	kg
			Idemat2020 Plasticizers for concrete	0.53	kg
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry	156.16	tkm

			>32 metric ton, EURO6 Cut-off, U		
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	49.77	tkm
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	0.11	tkm
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	146.95	tkm
2	(375 kg/m ³ cement) piles (cast-in-situ)	m ³	Tap water {RER} market group for Cut-off, U	170.10	kg
			Gravel, round {RoW} market for gravel, round Cut-off, U	1055.25	kg
			Idemat2020 Sand	836.85	kg
			Cement, Portland {Europe without Switzerland} production Cut-off, U	118.65	kg
			Cement, blast furnace slag, 66-80%, non-US {Europe without Switzerland} cement production, blast furnace slag 66-80%, non-US Cut-off, U	278.25	kg
			Idemat2020 Plasticizers for concrete	1.10	kg
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	151.37	tkm
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	41.74	tkm

			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	0.22	tkm
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	147.55	tkm
3	C12/15 blinding (cast-in-situ)	m ²	Tap water {RER} market group for Cut-off, U	17.64	kg
			Gravel, round {RoW} market for gravel, round Cut-off, U	77.39	kg
			Idemat2020 Sand	86.94	kg
			Idemat2020 Concrete aggregate	32.03	kg
			Lime, hydrated, packed {RER} market for lime, hydrated, packed Cut-off, U	1.58	kg
			Cement, blast furnace slag, 66-80%, non-US {Europe without Switzerland} cement production, blast furnace slag 66-80%, non-US Cut-off, U	27.30	kg
			Idemat2020 Plasticizers for concrete	0.00	kg
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	15.83	tkm
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	4.10	tkm
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry	0.00	tkm

			>32 metric ton, EURO6 Cut-off, U		
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	14.57	tkm
4	Transport of waste	t	Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	60.00	tkm
5	Steel reinforcement	kg	Reinforcing steel {RER} production Alloc Rec, U	1.00	kg
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	0.26	tkm
6	Precast transport	t	Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	300.00	tkm
7	Diesel	l	Idemat2020 Diesel low- sulphur including combustion	0.83	kg
8	Formwork	m	Idemat2020 Spruce, European FSC/PEFC 460 (kg/m3)	2.20	kg
			Transport, freight, lorry >32 metric ton, euro6 {RER} market for transport, freight, lorry >32 metric ton, EURO6 Cut-off, U	0.22	tkm

The dosages of precast concrete are missing because the precast company does not want to make this information public.

Supplementary Material 3 - Structural results

Foundation alternatives (piles and beams)

	prefab				in situ				
	P4.300	P4.350	p4.450	p3.400	i4.500	i4.550	i3.500	i3.550	i3.650
Prefab	250x250 350x350	510 760	C35/45 C35/45						
Avegaar	Ø500 Ø600	510 760	C20/25 C20/25	Avegaar not in combination with prefab beams, that's not logical					
Fundex	Ø380/450 Ø380/450 Ø460/560	510 760 760	C20/25 C20/25 C20/25	not logical with prefab beams not logical with prefab beams					
Vibro	Ø273/310 Ø273/310 Ø273/310 Ø305/350 Ø305/350 Ø305/350 Ø305/350 Ø356/400 Ø356/400	510 510 510 510 760 760 760 760 760	C20/25 C30/37 C40/50 C20/25 C30/37 C20/25 C30/37 C40/50 C20/25 C25/30	not possible with reinforcement					

Prefab, CPI, Fundex and Vibro piles.

Piles

Paaltype	Afmeting [mm]	Paalpuntniveau [m] tov NAP	F _{Rd} [kN]	F _{Ed} [kN]	M _{Ed} [kNm]	L _{buc} [mm]	Kwaliteit beton	D _{eff} [mm]	Dekking [mm]	#staven _{min} [-]	A _{s,min} [mm ²]	A _{s,req} [mm ²]	Toegepaste wapening
Prefab	250x250	-11,6	536	510	25,5	3000	C35/45	-	30	4			volgens leverancier
	350x350	-11,6	819	760	38,0	3500	C35/45	-	30	4			volgens leverancier
Avegaar	Ø500	-11,6	547	510	25,5	5000	C20/25	475	80	5	886	354	5Ø16 L=3m + centraalstaaf Ø25 L=10m
	Ø600	-11,6	752	760	38,0	6000	C20/25	570	80	7	1276	510	7Ø16 L=3m + centraalstaaf Ø25 L=10m
Fundex	Ø380/450	-10,1	741	510	25,5	3800	C20/25	350	75	5	481	192	5Ø12
	Ø380/450	-10,1	741	760	38,0	3800	C20/25	350	75	5	481	930	5Ø16
	Ø460/560	-10,1	1092	760	38,0	4600	C20/25	430	75	5	726	290	7Ø12
Vibro	Ø273/310	-11,1	642	510	25,5	3000	C20/25	243	50	4	232	2499	NVT; te hoog wapeningspercentage
	Ø273/310	-11,1	642	510	25,5	3000	C30/37	243	50	4	232	1777	6Ø20 (op de grens van toegestaan wapeningspercentage)
	Ø273/310	-11,1	642	510	25,5	3000	C40/50	243	50	4	232	1001	5Ø16
	Ø305/350	-11,1	768	510	25,5	3100	C20/25	275	50	4	297	1014	6Ø16
	Ø305/350	-11,1	768	510	25,5	3100	C30/37	275	50	4	297	354	4Ø12
	Ø305/350	-11,1	768	760	38,0	3100	C20/25	275	50	4	297	2492	8Ø20 (op de grens van toegestaan wapeningspercentage)
	Ø305/350	-11,1	768	760	38,0	3100	C30/37	275	50	4	297	1661	6Ø20
	Ø305/350	-11,1	768	760	38,0	3100	C40/50	275	50	4	297	813	5Ø16
	Ø356/400	-11,1	>768	760	38,0	3650	C20/25	326	50	5	417	936	5Ø16
	Ø356/400	-11,1	>768	760	38,0	3650	C25/30	326	50	5	417	474	5Ø12

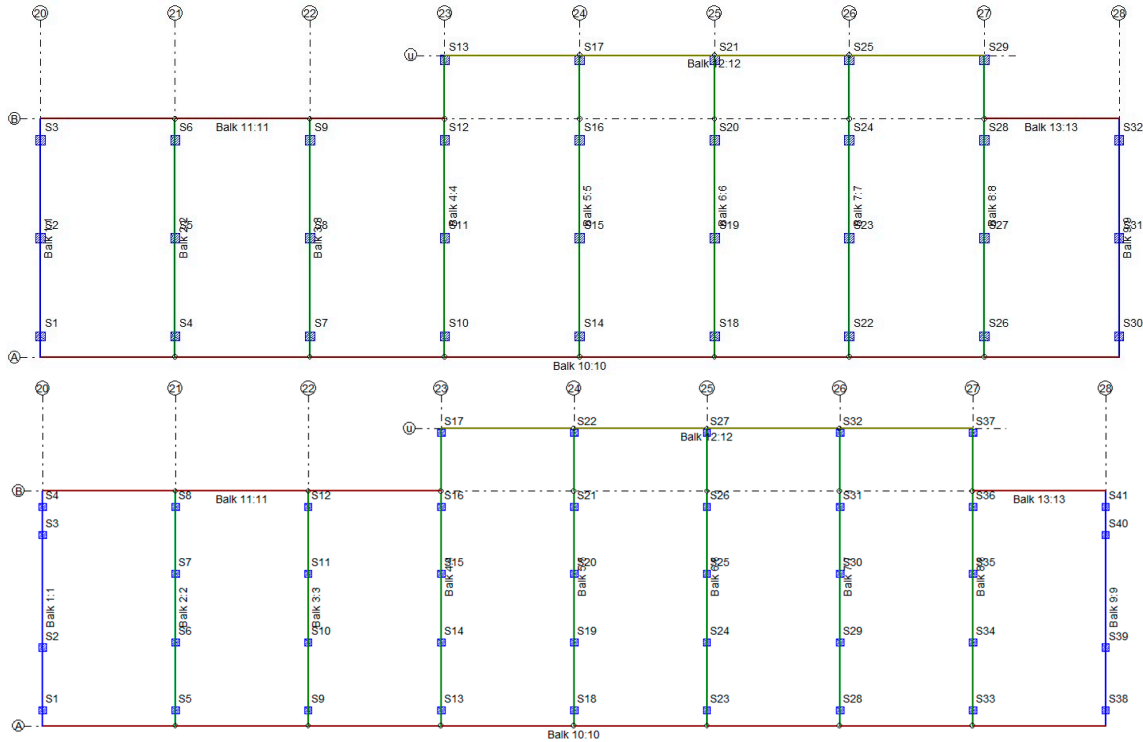
Type of pile, size, pile point level, concrete quality, concrete cover, reinforcing bars, appropriate reinforcement.

Beams

Code	Inhoud balken m ³	Wapeningsgewicht kg	Gemiddeld kg/m ³
p4.300	29,6	1790,0	60,5
p4.350	31,8	1844,5	58,0
p4.400	34,1	1884,5	55,3
p4.450	36,4	1902,5	52,3
p3.400	34,1	2379,5	69,8
p3.450	36,4	2412,0	66,3
i4.500	38,9	1953,0	50,2
i4.550	41,2	2004,0	48,6
i3.500	38,9	2580,3	66,3
i3.550	41,2	2601,6	63,1
i3.650	45,7	2526,2	55,3

Code, concrete volume, reinforcement weight, ratio steel/concrete.

Supplementary Material 4 - Foundation options with three and four piles per beam



Supplementary Material 5 – Study value results: Total costs, Ecocosts, ReCiPe, GWP, CED and economic costs.

Total costs	Series	Name	Ecocosts	ReCiPe	GWP	CED	Costs
36296	9	9-P250-35/I3.500	6369	829	26770	258613	29927
35287	28	28-P250-35/P4.300	6543	842	28830	263175	28744
33498	21	21-V305-30/I4.500	7658	975	28306	297480	25840
33576	26	26-V305-30/P4.350	8029	1014	31257	309842	25547
33934	6	6-V356-25/I3.500	8125	1032	29588	310486	25809
44074	10	10-P350-35/I3.500	8414	1090	35330	334821	35660
34290	15	15-V356-25/P3.400	8572	1083	33163	326993	25718
35435	4	4-V305-40/I3.500	8850	1097	29855	325657	26585
44430	16	16-P350-35/P3.400	8861	1141	38905	351329	35569
35791	13	13-V305-40/P3.400	9297	1148	33430	342165	26494
37509	19	19-V273-40/I4.500	9306	1150	31213	342576	28204
36790	5	5-V356-20/I3.500	9385	1174	32597	348580	27405
37588	24	24-V273-40/P4.350	9677	1189	34165	354938	27911
37146	14	14-V356-20/P3.400	9832	1225	36172	365087	27314
42349	22	22-F380-20/I4.500	9999	1265	40950	453677	32350

40904	7	7-F380-20/I3.500	10258	1276	38721	434883	30647
39663	20	20-V305-20/I4.500	10423	1288	34911	381102	29240
44574	27	27-F380-20/P4.450	10733	1352	45651	481099	33841
39742	25	25-V305-20/P4.350	10794	1326	37863	393464	28948
50160	17	17-C500-20/I4.550	11137	1477	46141	449659	39022
40657	3	3-V305-30/I3.500	11369	1382	35873	401845	29287
45599	8	8-F460-20/I3.550	11509	1451	44651	486989	34090
41013	12	12-V305-30/P3.400	11816	1432	39448	418353	29197
54836	1	1-C600-20/I3.650	12243	1625	52593	472037	42594
44325	18	18-V273-30/I4.500	12534	1515	38924	440191	31790
43315	23	23-V273-30/P4.350	12708	1527	40983	444753	30607
44654	2	2-V305-20/I3.500	13168	1585	40169	456234	31486
45010	11	11-V305-20/P3.400	13615	1636	43744	472741	31395