

Full scale ISS/ISCO soil mixing

Søllerød Gasværk

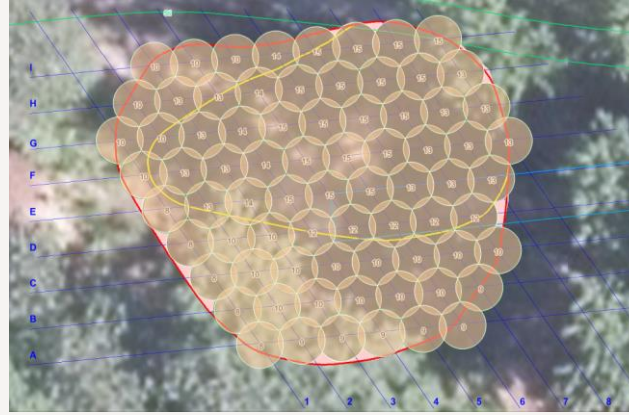
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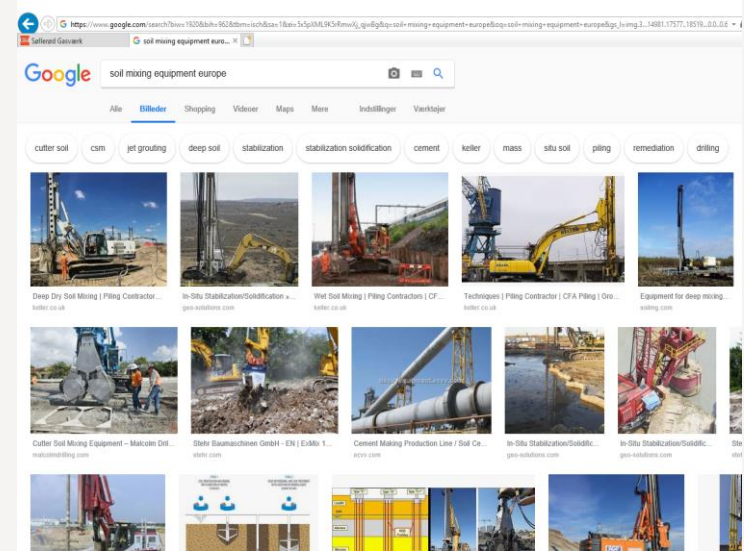


Full scale soil mixing project

- 1.800 m³ of tar contaminated soil to be mixed.
- Mixing depth 10-15 m bss.
- Removal of 1.500 m² of poplars.
- 700 m³ of overlaying peat to be removed.
- Columns with overlap.
- Handling of 30% excess slurry.
- One step mixing approach.

Finding contractor?

- Market research via network and Internet.
- Contractors situated in DK and across borders.
- Phone-interview with a checklist designed for the project.
- Discussing technical challenges in phone meetings.
- Documentation for adequate equipment (primary machine size).
- Project was bid out to Keller Fundering, Aarsleff A/S og Arkil A/S.
- Won by **Arkil A/S**.



Planning of full scale work

Arkil prepared a workplan for the full scale project:

- Handling of challenges from pilot project.
- Datahandling from machines, pumps etc.
- Mixing equipment functioned, but tank for persulfate corroded after few days.
- The kellybar was leaking causing excess water to go into the columns.
- Manual labour was to extensive.
- Progress of work was slower than expected due to planning of the work.

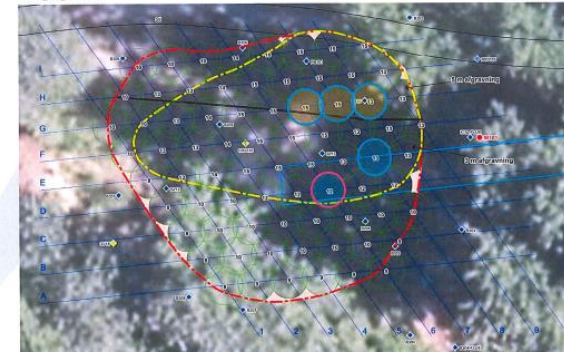
ISS/ISCO SØLLERØD GASVÆRK, ØVERØDVEJ 8

ARKIL MILJØ-
TEKNIK

Fuldscale oprensning vha. Soilmix.

Nærværende dokument beskriver den planlagte/forventede procedure i fhm. fuldscale oprensning af område E på Søllerød Gasværk ved hjælp af teknikken Soilmix.

I juni 2018 blev der udført hhv. pre-test samt pilottest, begge med hensyn til at afprøve effekt af den kemiske oxidation, effekt af cementstabiliseringen samt ikke mindst afprøve/teste eventuelle svagheder ved materiel og fremgangsmåde.



Figur 1 : Område E med i alt 75 kolonner til soilmixing, heraf 5 (som markeret) som blev udført ved pilottesten.

Erfaringer fra pilotforsøg.

Nærværende beskrivelse omhandler kun de praktiske udfordringer, som pilottesten kastede af sig, altså vurderinger eller data på hvorvidt "performancekriterierne" blev opnået, forventes afprøvet af COWI/Geosyntec.

Områder/arbejdsgange som skal optimeres til fuldscaleoprensningen er :

- Elektronisk dataindsamling. Der mangler troværdige data over maskindata fra Bauer, korrekt logning af data på tilsat kloruropløsning samt endelig registrering af borestammens omdrejninger.

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Performance criteria – re-evaluation

Visual criteria

- > No clods >6 cm
- > No free phase
- > Appear well mixed

Unconfined Compressive Strength

- > The ISS+ISCO treated soil is expected to achieve at least 0.35 MPa UCS after 28-day curing period in 90% or more of the confirmation samples as performance criteria, and no samples with results less than 0.15 MPa after a 28-day curing period.

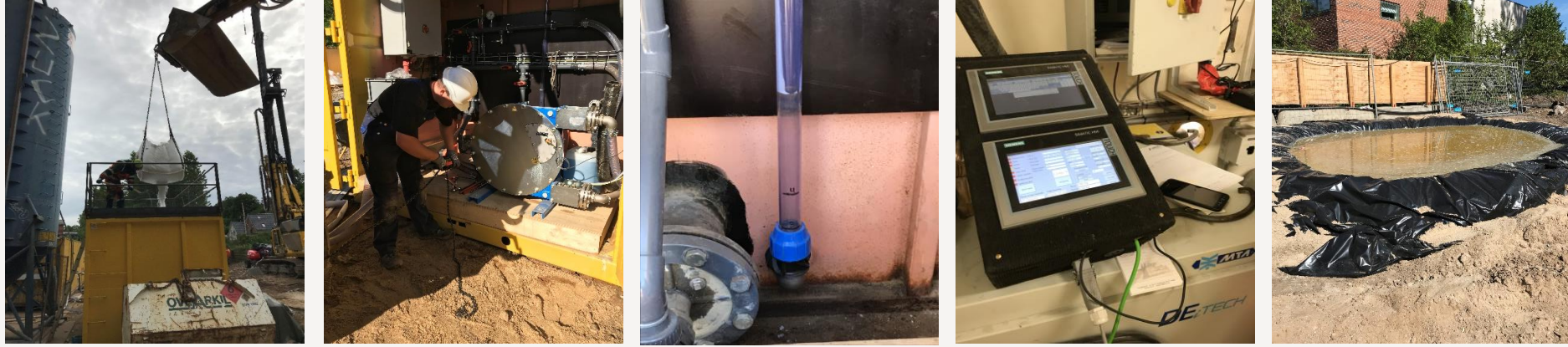
Hydraulic Conductivity

- > The ISS+ISCO treated soil is expected to achieve a hydraulic conductivity less than or equal to 1×10^{-8} m/sec.



Setup equipment – ISS/ISCO

- › Drill rig 100 ton RTG machine RS20.
- › Mixing head with one level of flights designed to mix the soil in situ.
- › Discharge capability along the auger flights to convey grout to mixing zone.



Setup equipment – ISS/ISCO

- › Mixing unit persulfate, peristaltic pump.
- › Mixing unit cement slurry, cement silo, conveyer pump, high pressure mixing cyclone, grout pump.
- › Lagune excess water.



Setup equipment – ISS/ISCO

- › Persulfate and cement transferred to kellybar.
- › Drill rig 40 tons with auger and casings.
- › Covering of mixed columns
- › Mixer head cutting through clay till.
- › Mixed column

Materials

MATERIALS	VENDOR	TONS/M3
Klozur Persulfat	PeroxyChem	104
Slag cement CEM III/B 42,5 N, LH/SR	Deuna Zement GmbH	266
Tap water	Novafos	Ca. 300



Soil mixing - full scale work

> 8% slag cement and 3% persulfate

13		Miafm			
Mixing total meter / volu		5	21,7	15,708	
Cykles nr.	Penetrering i meter/min	Samlet minut	Rotation a	Bemærkning	BRM
1-D0/WN	0,2	25	10	+ Tilset cement/slorry	50
1-UP	0,3	17	32	Kun mixing	107
2-D0/WN	0,3	17	32	+ Tilset 50% klozur	107
2-UP	0,3	17	32	+ Tilset 50% klozur	107
3-D0/WN	0,3	17	32	Kun mixing	107
3-UP	0,3	17	32	Kun mixing	107
Mixing Time:		108	Total BRM:		543

Count	Date	Column ID	Row	Column	Start Time	Stop Time	Total Minutes	min/m	Auger Diameter (m)	Treatment Volume (m³/m)	In situ Dry Density (g/cm³)	CEM III/B	Persulfate	Top El. (m El.)	Bench Depth (mbs)	Actual Top of ISS/SCO El. (m)	Actual Bottom of ISS/SCO El. (m)	Total Depth (m)	Treatment Thickness (m)
1	24-08-2018	A1	A	1	08:16				2	3,14	1,84	0,08	0,03	23	3	20	15	8	5
2	29-08-2018	A2	A	2	08:02				2	3,14	1,84	0,08	0,03	22,9	3	19,9	13,9	9	6
3	03-09-2018	A3	A	3	09:08	11:14	126	42	2	3,14	1,84	0,08	0,03	22,7	3	19,7	13,7	9	6
4	11-09-2018	A4	A	4	14:00	15:35	95	32	2	3,14	1,84	0,08	0,03	22,6	3	19,6	13,6	9	6
5	17-09-2018	A5	A	5	13:27	15:54	147	49	2	3,14	1,84	0,08	0,03	22,4	3	19,4	13,4	9	6
6	18-09-2018	A6	A	6	14:37	16:30	113	38	2	3,14	1,84	0,08	0,03	22,4	3	19,4	13,4	9	6
7	27-08-2018	B1	B	1	15:26	16:29	63	21	2	3,14	1,84	0,08	0,03	22,9	3	19,9	14,9	8	5
8	05-09-2018	B2	B	2	10:10	12:34	144	36	2	3,14	1,84	0,08	0,03	22,9	3	19,9	12,9	10	7
9	06-09-2018	B3	B	3	09:07	11:07	120	17	2	3,14	1,84	0,08	0,03	22,7	3	19,7	12,7	10	7
10	17-09-2018	B4	B	4	08:12	10:10	118	17	2	3,14	1,84	0,08	0,03	22,5	3	19,5	12,5	10	7

Swell Elevation	Swell Percentage	Number of Passes	Number of Overlaps	Effective V Treated (m³)	Total Mass Treated (kg)	Total Cement Required (kg)	Total Cement Added (kg)	Total percent cement	Total NaS2O8 [Klozur® SP] Required (kg)	Vand Required For Persulfate Solution (L)	Total NaS2O8 [Klozur® SP] Required (L)	Actual Liters Injected	Total Persulfate Required (kg)	Total Persulfate Injected (kg)	Total percent Persulfate
NM	#VALUE!	4	0	15,7	28902,7	2313,37	2351	8,13%	1074,82	2477,37	2892,37	2777	867,1	832,812266	2,9%
21,8	32%	3	1	17,8	32702,8	2617,54	2555	7,81%	1013,19	2337,69	2727,23	2752	981,1	825,3	2,52%
21	22%	3	1	17,8	32702,8	2617,54	2628	8,04%	1013,19	2337,69	2727,23	2733	981,1	819,616825	2,5%
21,4	30%	3	2	16,7	30722,4	2459,02	2462	8,01%	951,83	2196,13	2562,08	2568	921,7	770,1	2,5%
20,2	13%	3	1	17,8	32702,8	2617,54	2634	8,05%	1013,19	2337,69	2727,23	2737	981,1	820,81641	2,5%
22	43%	3	2	16,7	30722,4	2459,02	2463	8,02%	951,83	2196,13	2562,08	2566	921,7	769,5	2,5%
21,6	34%	4	2	13,9	25602,0	2049,19	2057	8,03%	952,07	2194,45	2562,06	2534	768,1	759,937444	3,0%
21,88	28%	4	4	17,0	31221,8	2499,00	2551	8,17%	1161,06	2676,15	3124,45	3137	936,7	940,8	3,0%
22,32	37%	3	3	18,2	33532,3	2683,93	2692	8,03%	1246,98	2874,20	3355,67	3363	1006,0	1008,55155	3,0%
20,75	18%	3	4	17,0	31221,8	2499,00	2498	8,00%	967,31	2231,83	2603,73	2604	936,7	780,9	2,5%



Construction Quality Assurance (CQA) – I

- > Samples for documentation of performance criterias.
- > Different depths.
- > Sieved to check mixing.

- > Visual inspection.
- > Temperature, pH, water content.
- > Put into molds and tampered.

Construction Quality Assurance (CQA) – II

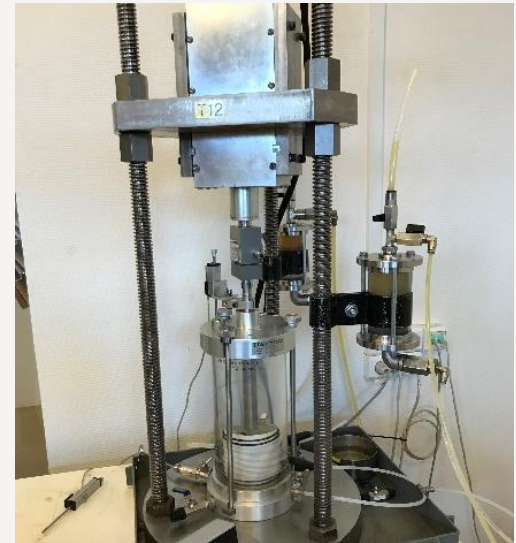
- › Pocket Penetrometer (field)
- › UCS test (GEO)
- › Permeability (GEO)
- › Chemical analyzes (Højvang)



Results permeability – full scale ISS/ISCO

- > The results from both pilot test and full scale is very satisfying according to the performance criteria.
- > The permeability in all 26 samples is $\leq 1 \times 10^{-8}$ m/sec.
- > The average value is $2,1 \times 10^{-9}$ m/sec (both pilot- and full scale), corresponding to the same values created in the lab. study.

Mean coefficient of permeability, k_{10}		=	3.8E-10	m/s
Before test			After test	
Notes Testing is carried out in accordance with ASTM-5084-10				
Prepared : SPL	Date : 2018-09-27	Project : 202691 SoilMix		
Checked : CGL	Date : 2018-10-03	Report :	Encl. no.:	
Approved : NIT	Date : 2018-10-03	Subject : Permeability test		
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		Geo Aarhus	+45 8627 3111	Page 1/1



Results UCS – full scale ISS/ISCO

STANDARD	NUMBER OF SAMPLES	UCS-AVARAGE (MPa)	AVERAGE WATER CONTENT (%)	PROCENTAGE SAMPLES PASSED
UCS-samples total	36	0,46	29,80	83 %
UCS \geq 0.35 MPa	22	0,65	28,10	61 %
UCS \geq 0.15 MPa	29	0,24	31,75	83 %
UCS < 0.15 MPa	6	0,07	32,70	17 %
UCS < 0.05 MPa	3	0,02	36,33	14 %

- > A direct correlation was observed between UCS and moisture content. Samples that did not exceed 0,15 MPa averaged greater than 32% moisture content.
- > Of the six (6) samples that did not exceed 0.15 MPa, three (3) did not exceed 0.05 MPa. These samples averaged greater than 36% moisture content.

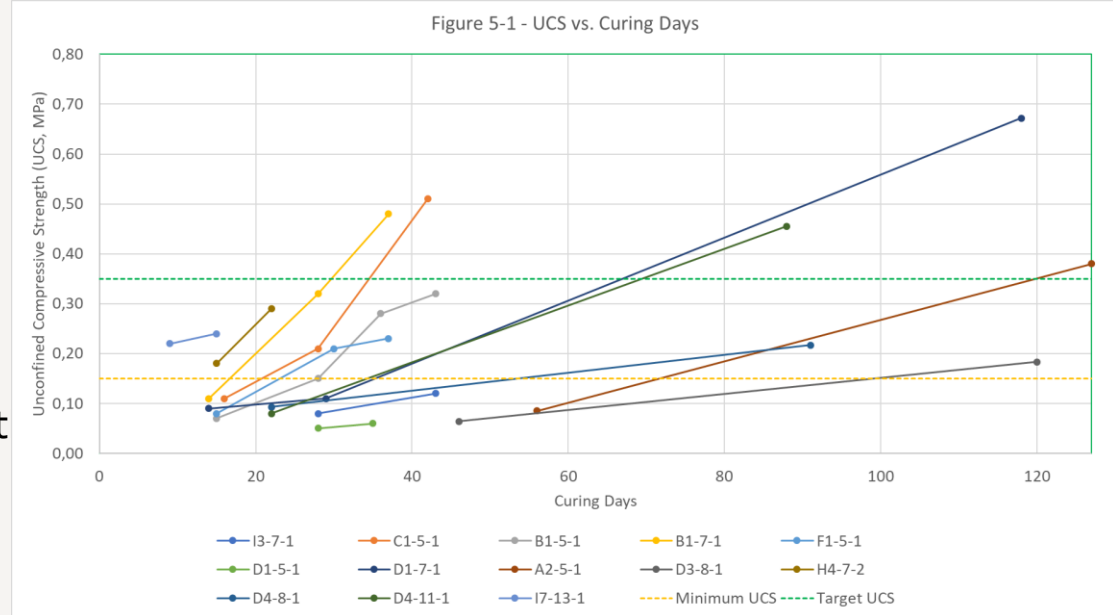
Results UCS – full scale ISS/ISCO

- Since the curing times to reach targeted UCS criteria were longer than expected, COWI A/S mobilized a cone pene-trometer testing (CPT) rig to further evaluate the strength of columns mixed in the field. A total of 10 columns were evaluated with a CPT rig.
- Four of the columns evaluated with the CPT rig were located in areas where the six UCS samples that did not meet the UCS criteria were collected. The results of the CPT rig demonstrated that adequate soil strength was achieved by the ISS/ISCO treatment in these areas.
- Since time for the drill rig was limited at the site, it was decided to re-treat the top elevation of some of the columns to make sure, that strength was adequate.




Results UCS – full scale ISS/ISCO

- Several samples required greater than 28-days of curing to reach the targeted UCS criteria.
- The samples (and columns) will most likely continue to gain strength.
- Long term evaluation of strength development.



Contaminant reduction

	UNIT	BENZENE	TOC	NAPHTALENE	PHENOLS
Treatment area	m ³	1865	1865	1865	1865
Treatment area	tons	3730	3730	3730	3730
Concentration after treatment	mg/kg	0	321	23	0,04
Contaminant mass after treatment	kg	0 	1200	85	0,15
Contaminant mass before treatment	kg	50-100	2000-3000	400-600	(ca. 10 kg)
Reduction after ISS/ISCO	%	ca. 100	40-60	80-85	Ca. 99

- > There has been a significant reduction with regard to benzene, phenols and naphthalene.
- > Analysing has been carried out as a soil sample on the molded samples and therefore we don't know if some benzene have evaporated before analysing. Therefore the effect may be overrated with regard to benzene.
- > For phenoles, naphthalene and higher TOC's we don't expect significant loss, due to sample preparation.
- > Monitoring in groundwater to evaluate if the desired flux reduction of 75% is achieved.



Challenges soil mixing

- › Mixing of persulfate
- › Minimizing water usage
- › Obstacles in ground
- › Corrosion
- › Solutions provided by the contractor as the project moves forward



Finishing of work

- › Membrane on top of soil mixed area.
- › Rainwater discharged to nearby stream.
- › Area finished with wood chips.

Thank you for listening

