Golder Associates Innovative Applications (GAIA) Inc.

Environmental and Geotechnical Applications of Cutter Soil Mixing

RemTech October, 2007

Presented by: Brian Wilson

Building a better world

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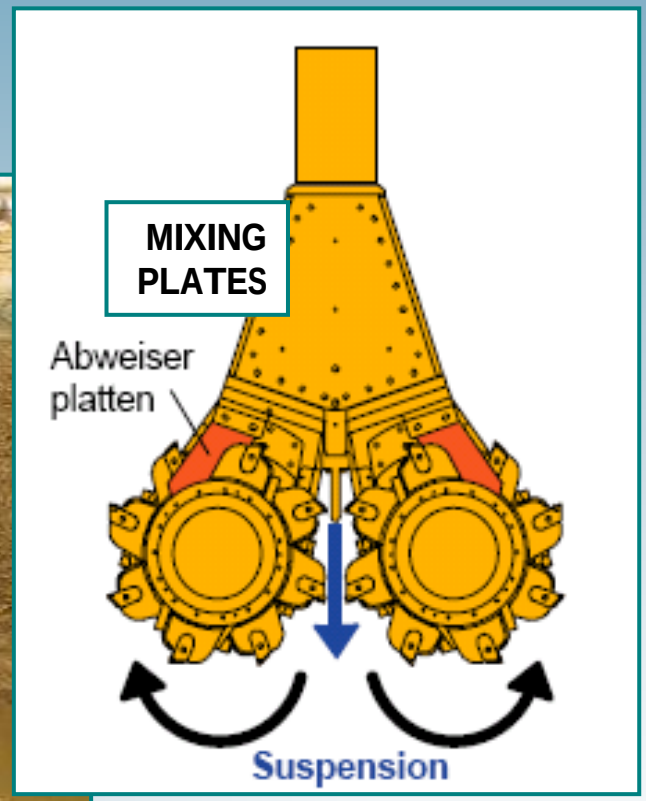
What is Cutter Soil Mixing (CSM)?



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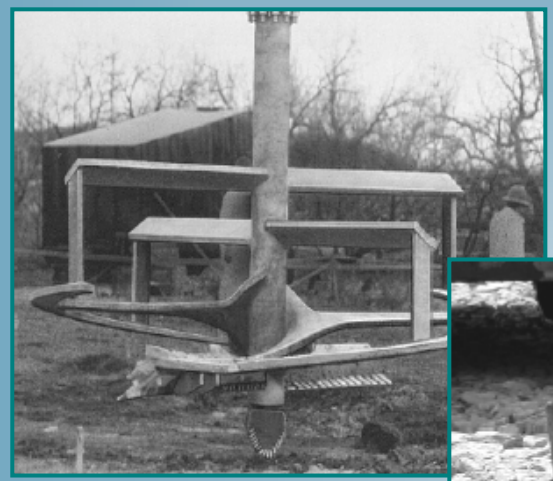
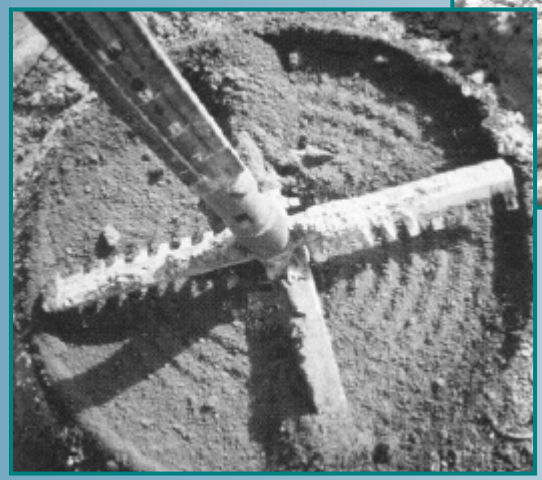
Traditional Deep Soil Mixing Methods

Utilizes a variety of cutting tools and mixing devices rotating about vertical axes





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Traditional Methods often utilize Multiple Vertical Shafts

Five-shaft Mixing Paddles

Three-shaft CFA

Three-shaft Mixing Paddles

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Triple Shaft with Cutting Shoes

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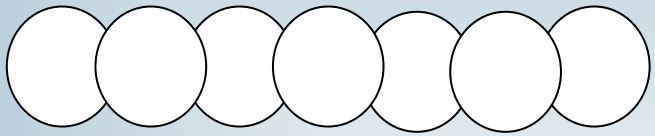
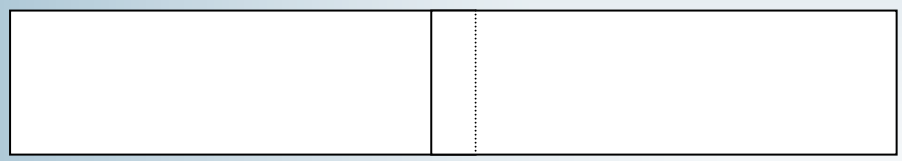
Development of the CSM method

The CSM method, developed from cutter technology, differs from traditional Deep Soil Mixing methods in so far as it makes use of two sets of cutting wheels that rotate about a horizontal axis to produce rectangular panels of treated soil rather than one or more vertical rotating shafts that produce circular columns of treated soil. Key attributes include its ability to penetrate dense strata, and the ability to "steer" the cutting tool at depth to maintain the designed position.

Traditional method



CSM method



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CSM Kelly Mounted System (up to 30m depth)

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CSM Cable Mounted System 20m+

Quattro Cutter

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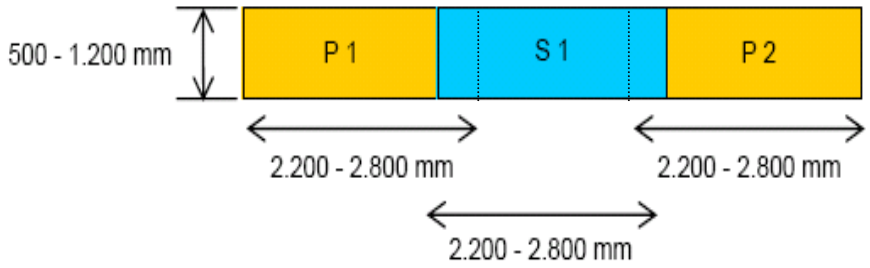
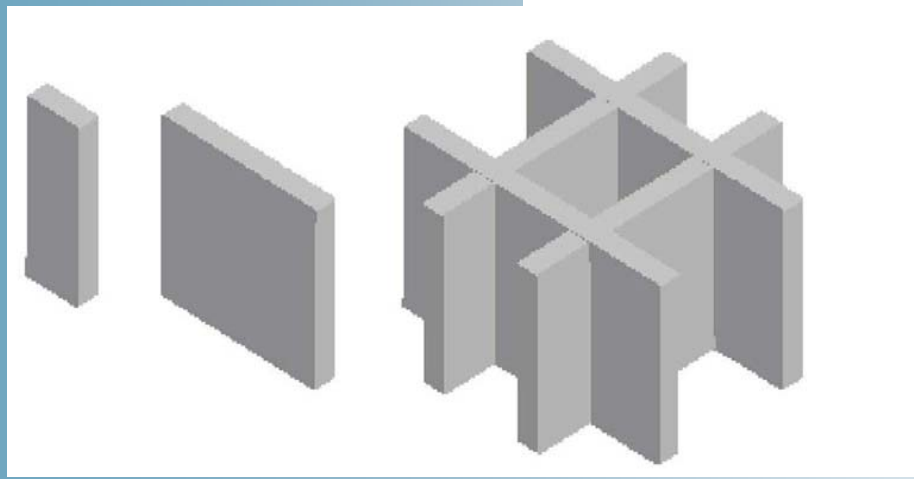
Typical Construction Sequence

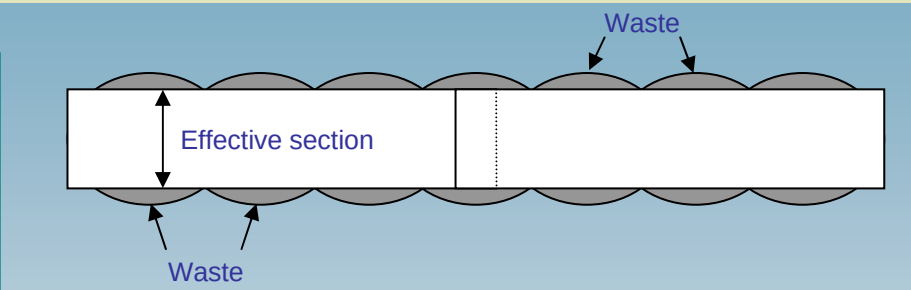


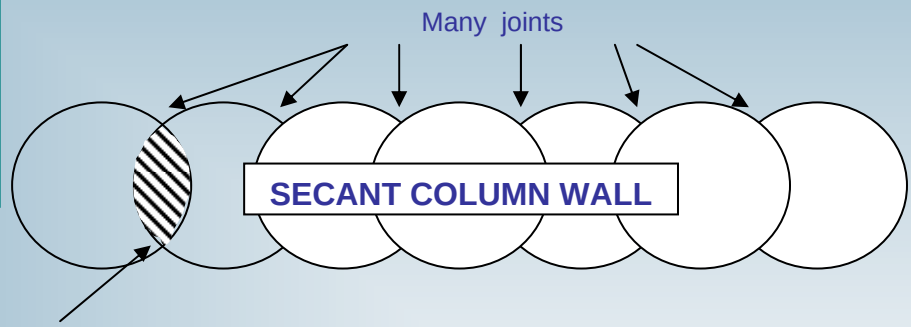


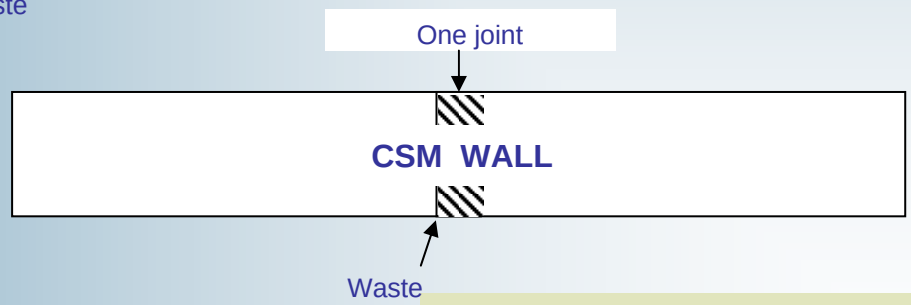
Comparison between CSM & traditional DSM methods

CSM Wall

Traditional DSM Wall







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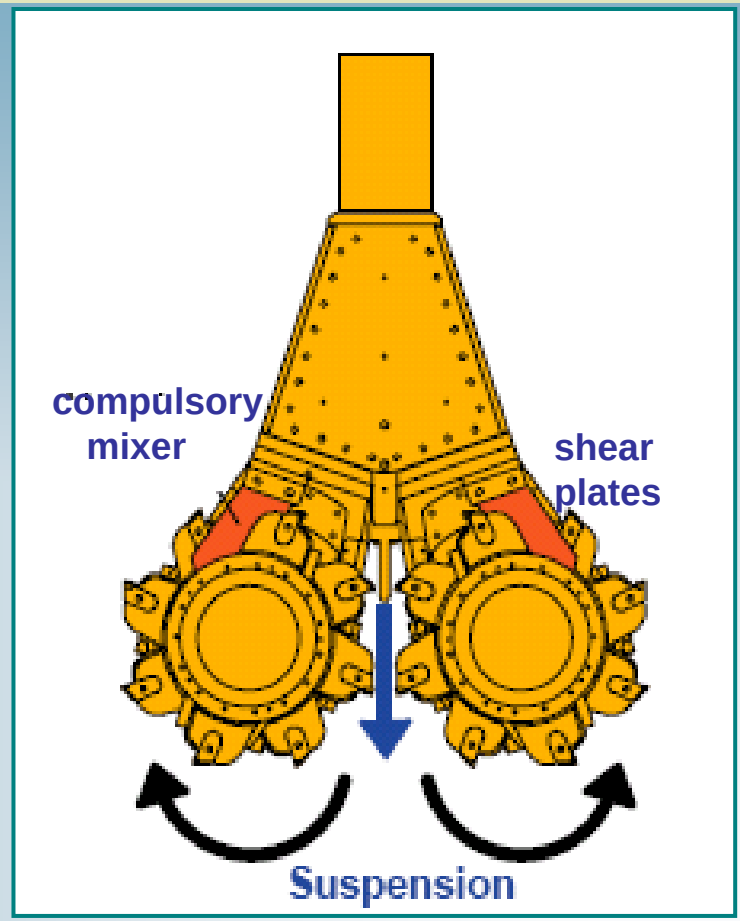
CSM – Cutter Head

- The slurry is added through nozzles between the wheels
- About ½ to 3/4 of the necessary quantity on the way down
- Balance on the way back to the surface
- Preferred rotary direction for cutting as shown



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Materials Handling

Automated batch plant and radio controlled slurry delivery system is used to create and deliver a consistent mix at specified water cement ratios and cement concentrations

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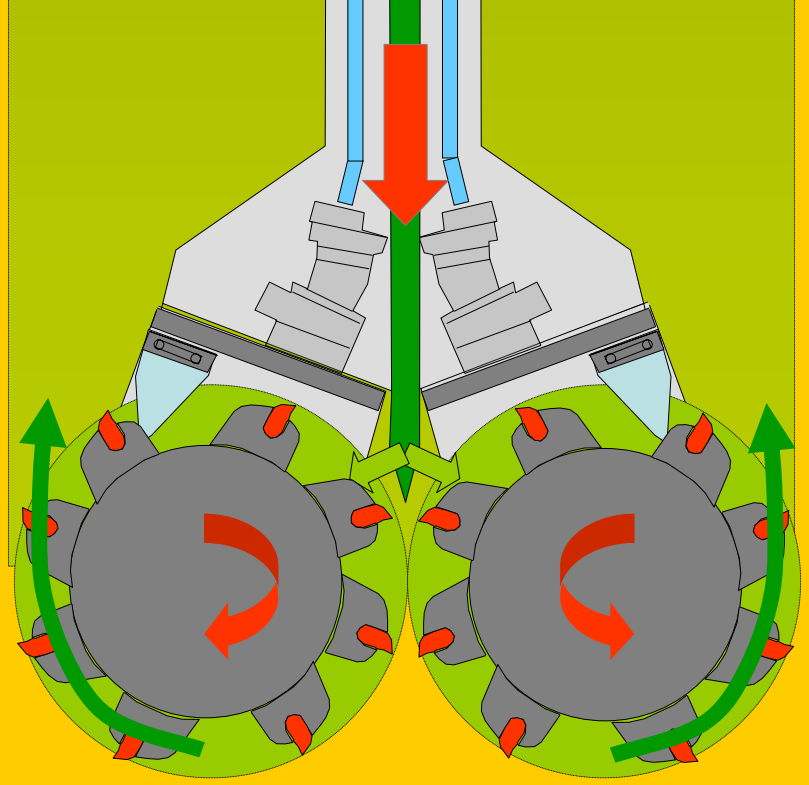
CSM Procedure

Cutting & mixing on downward stroke with the injection of a binder or fluidifier that can be:

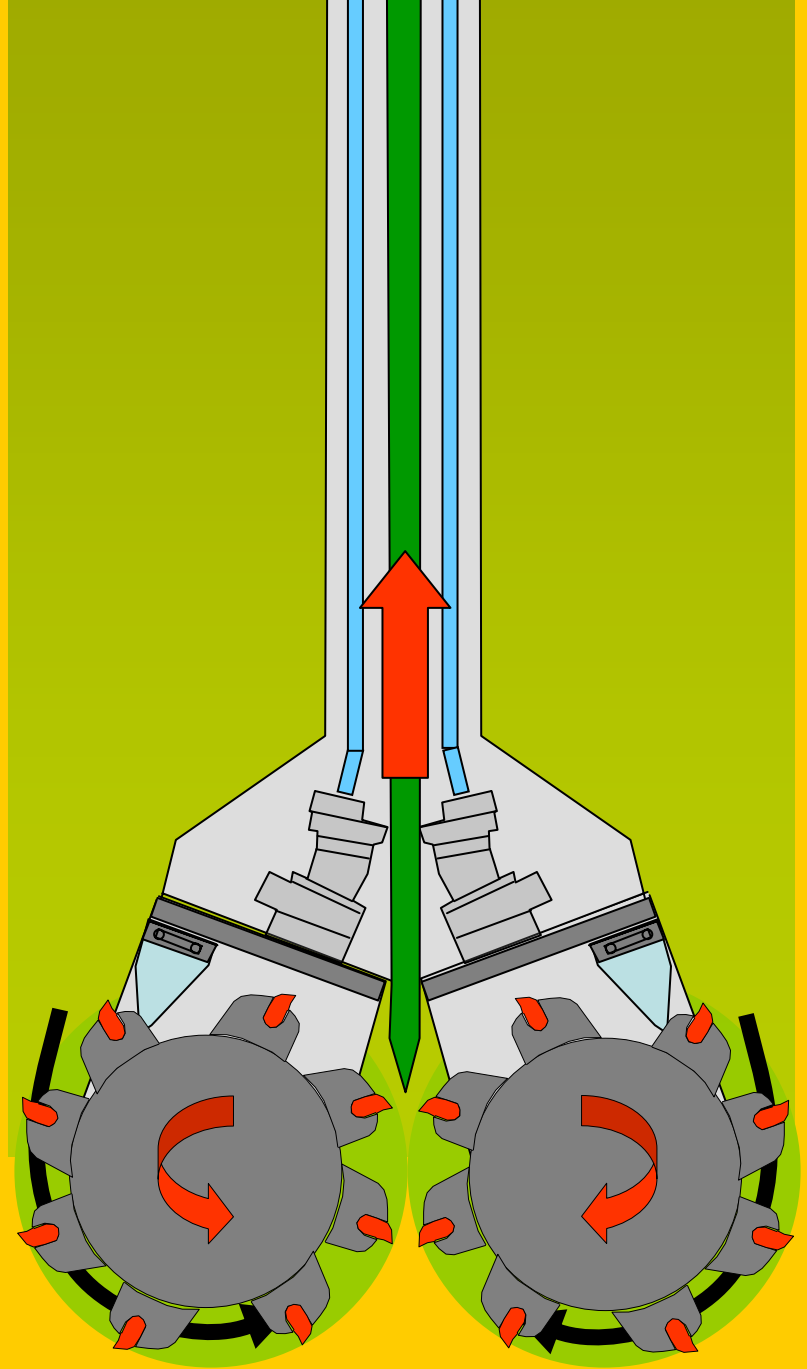
- **Water.**
- **Bentonite.**
- **Polymers**
- **Cement**
- **Other**



CSM Procedure

Thorough mixing takes place on upward stroke with the ongoing injection of binder

Moving the cutter up and down will mix layered soils and achieve greater uniformity



Cutting and Mixing

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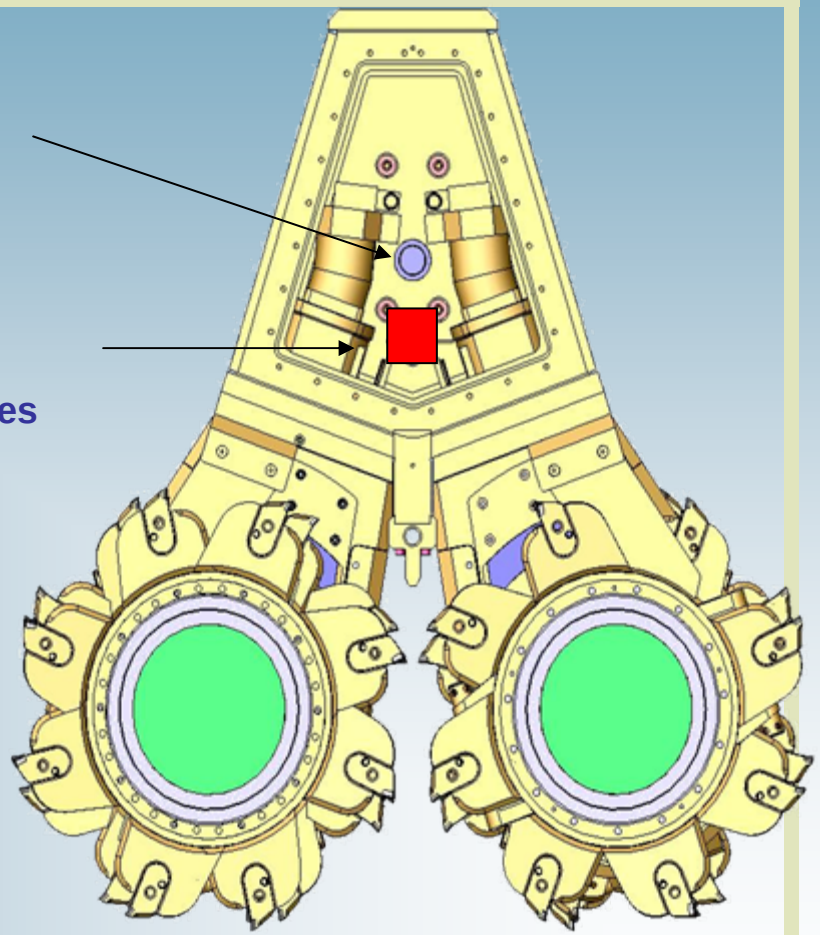
CSM Instrumentation

External pressure sensor

Instruments that read:

- **Verticality on “X” and “Y” axes**
- **Torque on cutting wheels**
- **Wheel speeds**



The CSM machine is fitted with a complete set of instruments that convey to the operator, in real time, all the information that is needed to monitor and control the quality of the work.

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CSM - Operator Instrumentation

B-TRONIC touch screen in operators cabin

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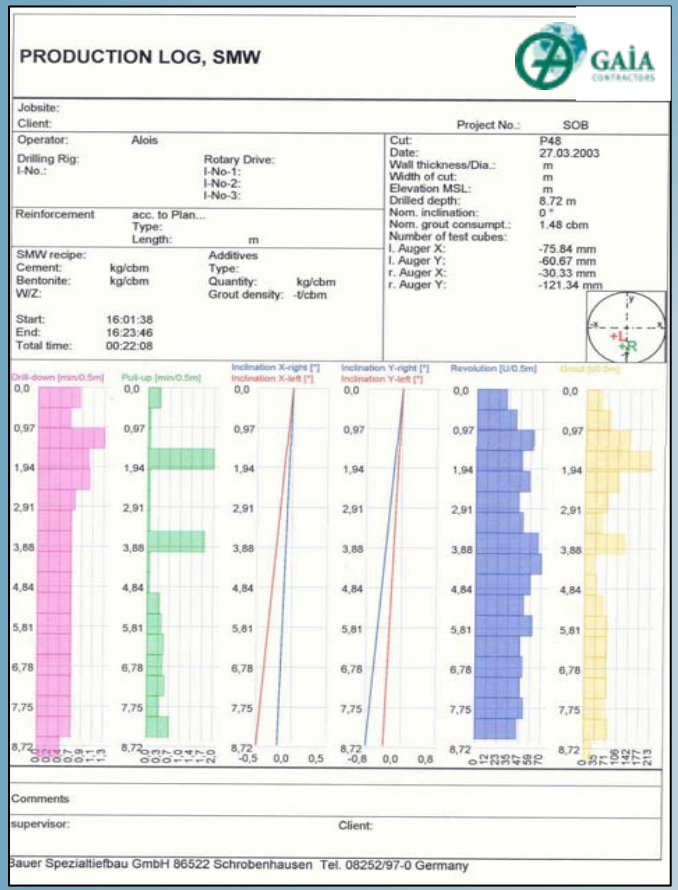
DOCUMENTATION



PRODUCTION LOG, SMW

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Jobsite:
Client:
Project No.: SOB

Operator: Alois
Drilling Rig:
I-No.:
Rotary Drive:
I-No-1:
I-No-2:
I-No-3:

Reinforcement: acc. to Plan...
Type:
Length: m

SMW recipe:
Cement: kg/cbm
Bentonite: kg/cbm
W/Z:
Additives
Type:
Quantity: kg/cbm
Grout density: -t/cbm

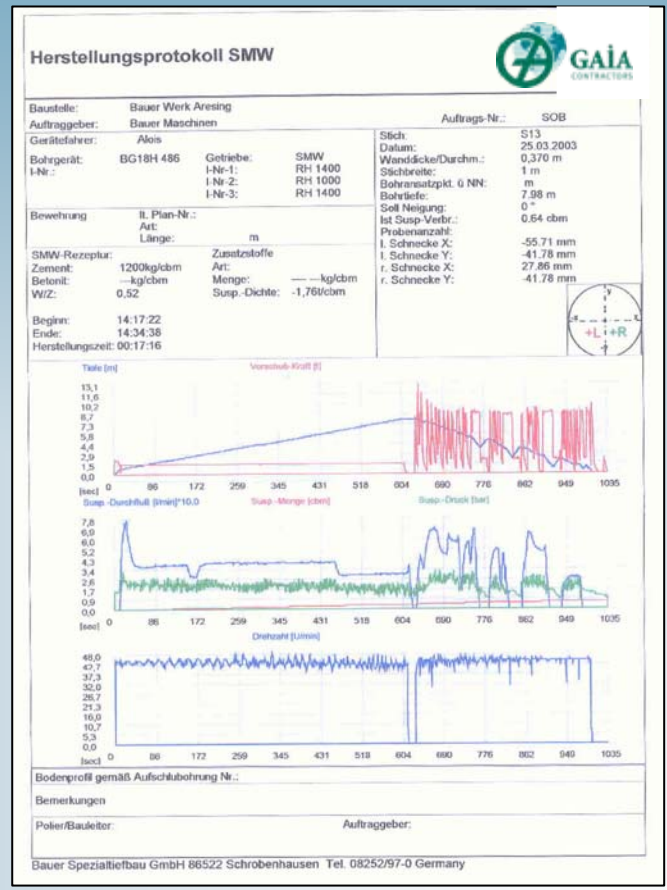
Start: 16:01:38
End: 16:23:46
Total time: 00:22:08

Cut: P48
Date: 27.03.2003
Wall thickness/Dia.: m
Width of cut: m
Elevation MSL: m
Drilled depth: 8.72 m
Norm. inclination: 0 °
Norm. grout consumpt.: 1.48 cbm
Number of test cubes:
l. Auger X: -75.84 mm
l. Auger Y: -60.67 mm
r. Auger X: -30.33 mm
r. Auger Y: -121.34 mm

Drill-down [min/0.5m] | Pull-up [min/0.5m] | Inclination X-right [°] / Inclination X-left [°] | Inclination Y-right [°] / Inclination Y-left [°] | Revolution [U/0.5m] | Grout [l/0.5m]

Comments
supervisor: Client:

Bauer Spezialtiefbau GmbH 86522 Schrobenhausen Tel. 08252/97-0 Germany



Herstellungsprotokoll SMW

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Baustelle: Bauer Werk Aresing
Auftraggeber: Bauer Maschinen
Auftrags-Nr.: SOB

Gerätefahrer: Alois
Bohrgerät: BG18H 486
I-Nr.:
Getriebe: SMW
I-Nr-1: RH 1400
I-Nr-2: RH 1000
I-Nr-3: RH 1400

Bewehrung: lt. Plan-Nr.:
Art:
Länge: m

SMW-Rezeptur:
Zement: 1200kg/cbm
Betonit: —kg/cbm
W/Z: 0,52
Zusatzstoffe
Art:
Menge: — —kg/cbm
Susp.-Dichte: -1,76t/cbm

Beginn: 14:17:22
Ende: 14:34:38
Herstellungszeit: 00:17:16

Stich: S13
Datum: 25.03.2003
Wanddicke/Durchm.: 0,370 m
Stichbreite: 1 m
Bohrmeißelpkt. ü NN: m
Bohrtiefe: 7.98 m
Soll Neigung: 0 °
Ist Susp-Verbr.: 0.64 cbm
Probenanzahl:
l. Schnecke X: -55.71 mm
l. Schnecke Y: -41.78 mm
r. Schnecke X: 27.86 mm
r. Schnecke Y: -41.78 mm

Teufe [m] | Vorschub-Kraft [t]
Susp.-Durchfluß [l/min]*10.0 | Susp.-Menge [cbm] | Susp.-Druck [bar]
Drehzahl [U/min]

Bodenprofil gemäß Aufschlußbohrung Nr.:
Bemerkungen
Polier/Bauleiter: Auftraggeber:

Bauer Spezialtiefbau GmbH 86522 Schrobenhausen Tel. 08252/97-0 Germany

Printed reports for analysis

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Why Do It?

Poor Ground Conditions

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Why Do It?

Environmental Clean-up

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Does it work in all types of soil?

So far we have used it in:

- Organic Soils
- Clays
- Silts
- Sands
- Gravels
- Cobbles

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How do you design DSM?

How much cement do you need?

What is the long term performance?

Strength and permeability are generally the main focus of design.
The final composition and characteristics of the wall depend on:

- Cement content
- Bentonite content
- Water/Cement ratio
- Silt and clay fraction of soil
- Homogeneity of the soil
- Original Moisture content of the soil
- Depth of water table
- Degree of mixing
- Uniformity of the slurry

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Quality Assurance/ Quality Control

Is preliminary mix design reliable?

What should you test?

What should you specify?

What factor of safety should be used?

How do you get representative samples?

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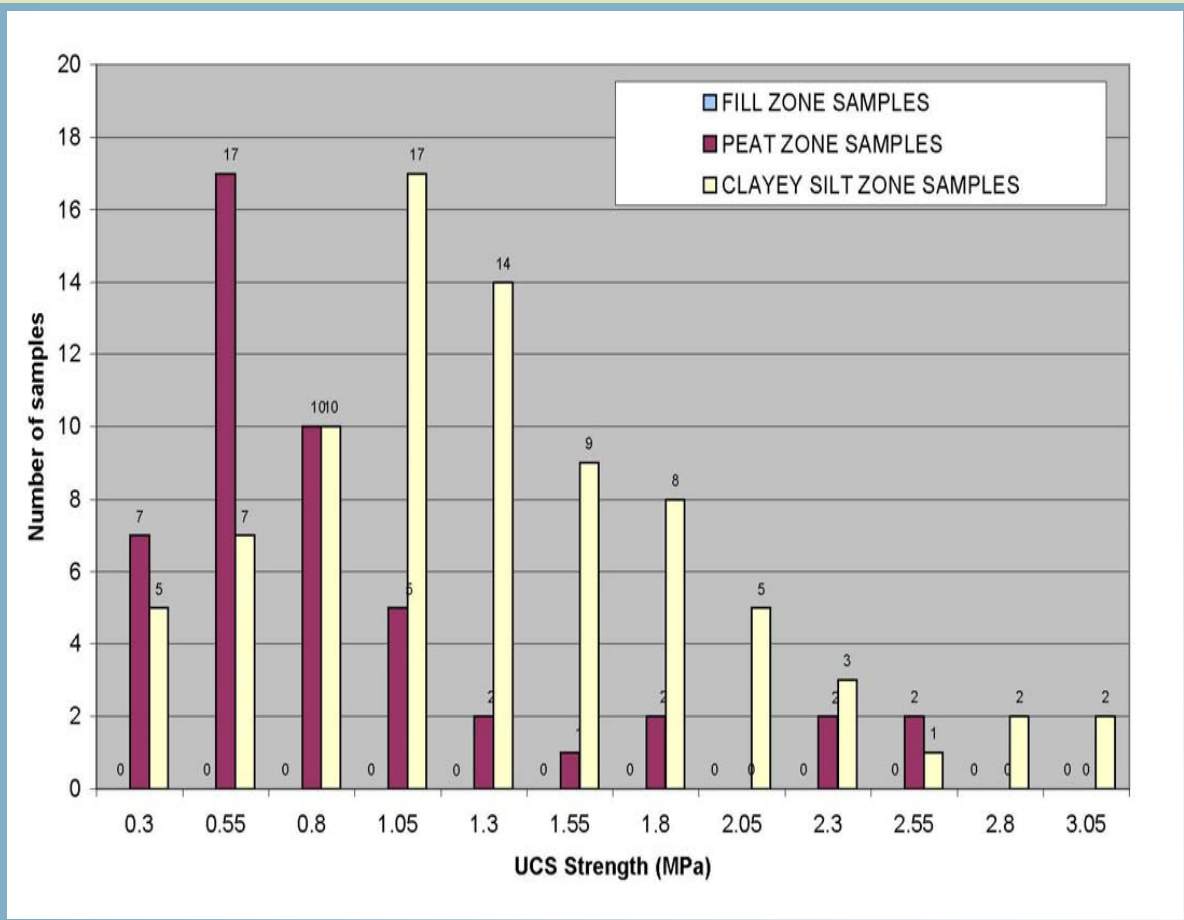
Laboratory Test Data - Strength



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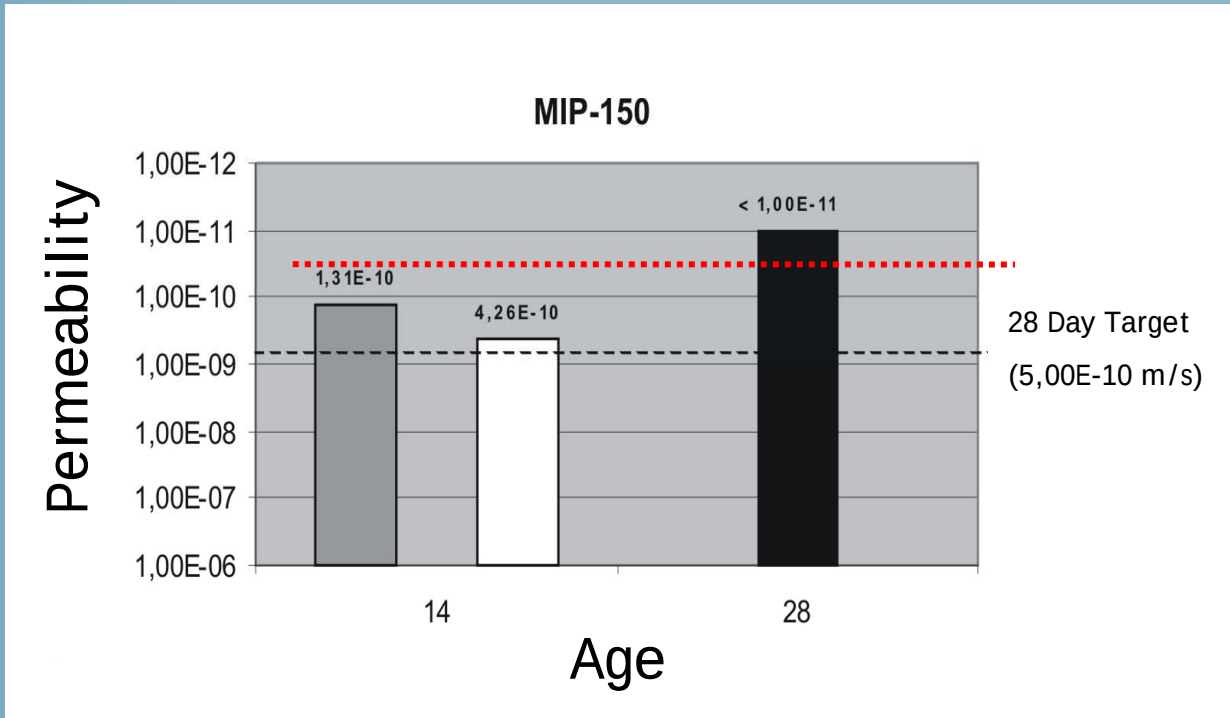
CSM – Permeability



Test results: Permeability

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Applications

Geotechnical

- Seismic Site Stabilization
- Foundation Support
- Shoring
- Cut-off Walls
- Slope Stabilization
- Underpinning
- Scour Protection
- Dyke Upgrading
- Anchoring (up-lift)
- Other ?

Environmental

- Containment
- In-situ stabilization
- Funnel and Gate
- Hydraulic Cut-off
- In-situ treatment
- Leachate control
- Other ?

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Excavation Support

BEFORE (during mobilization)

AFTER (excavation completed)

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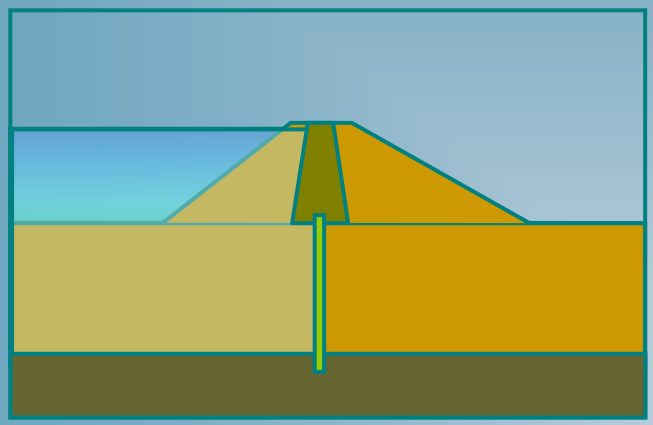
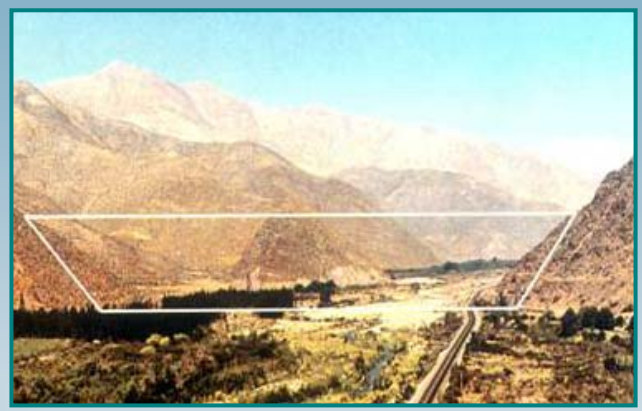
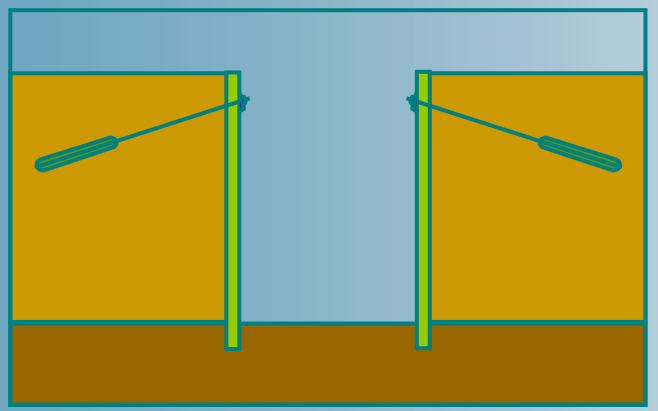
Cut-off Walls & Shoring







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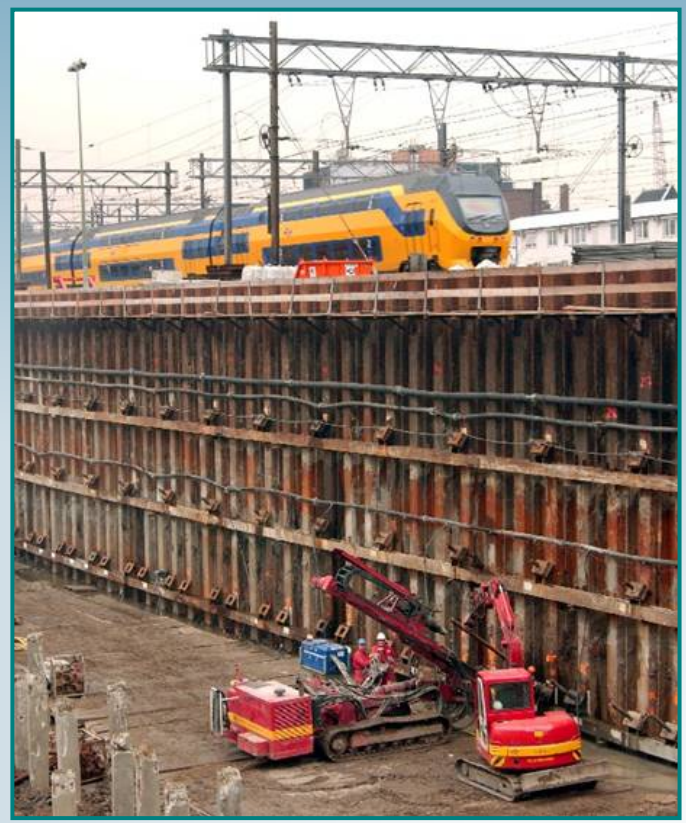
As a Substitution for Conventional Methods to create retaining walls

- **Soldier/King/Berlin pile walls**
- **Sheet pile walls**
- **Secant/Contiguous pile walls**
- **Diaphragm walls**



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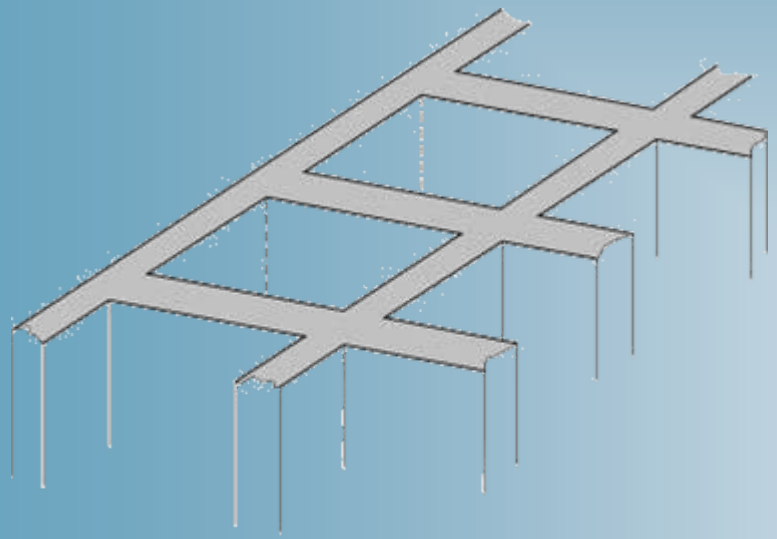
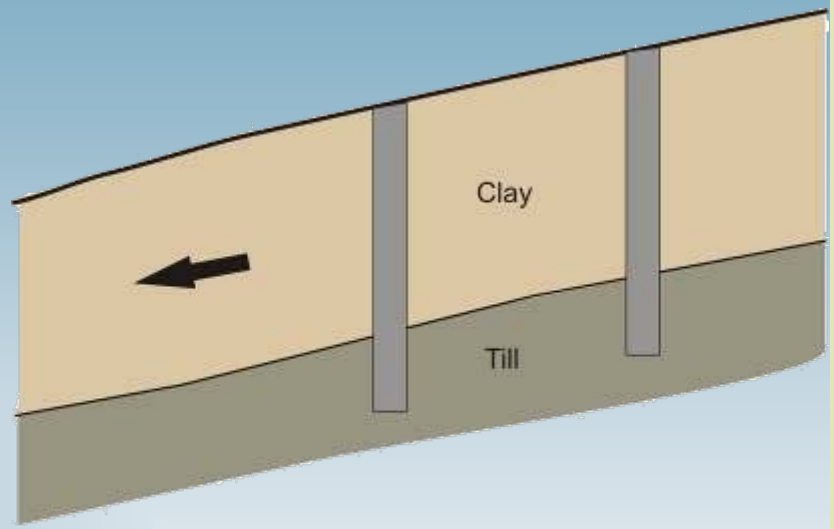
Other Applications



STABILIZATION GRILLAGE



BLOCK SLIDING

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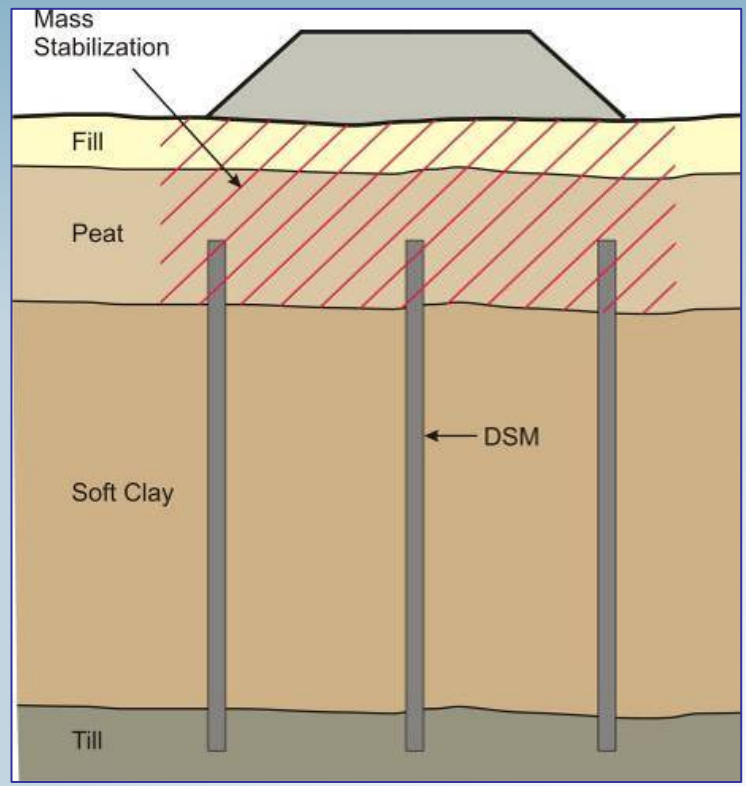
Other Applications



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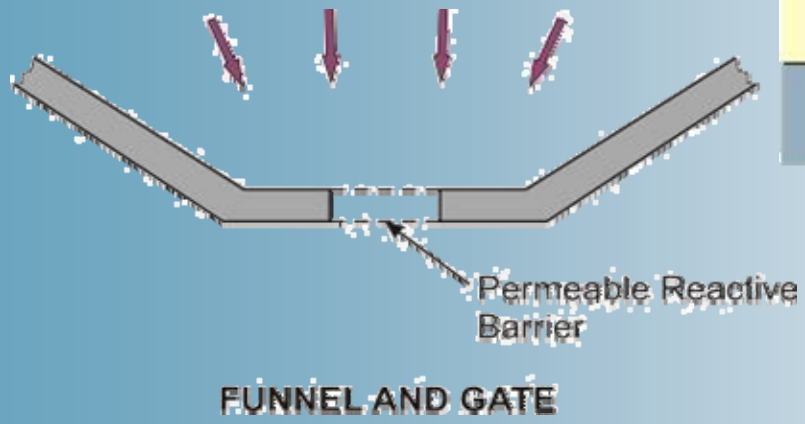
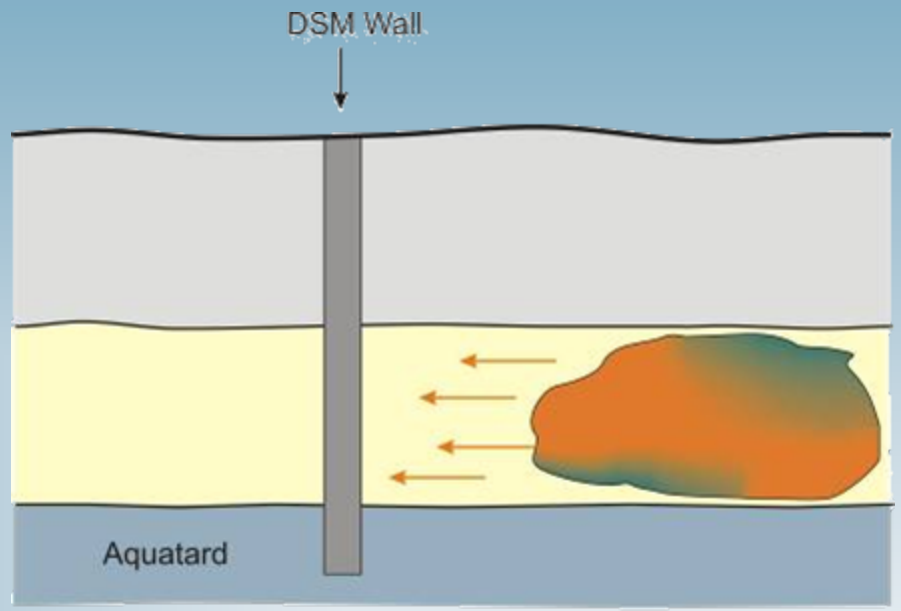
Other Applications



FUNNEL AND GATE



CONTAMINANT CONTAINMENT

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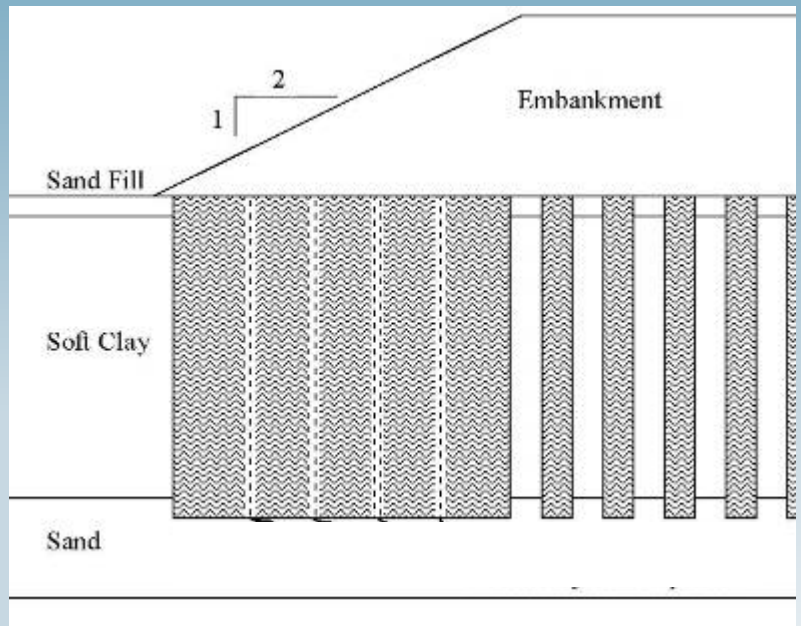
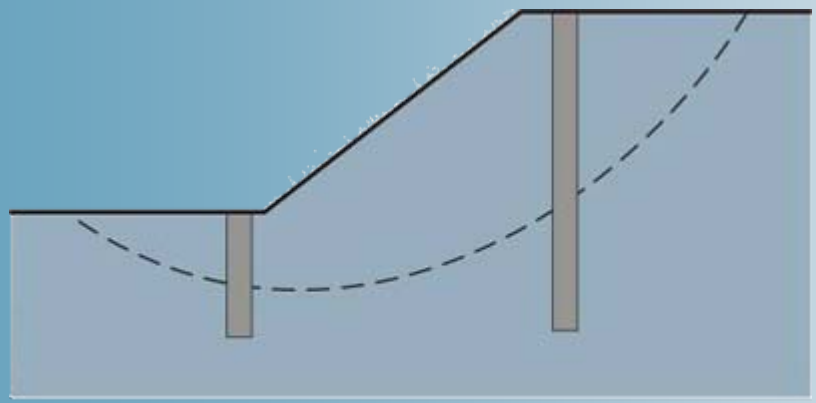
Other Applications

Support of embankments on soft soils





SLOPE STABILIZATION

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North America's First CSM Project

CITY OF NANAIMO
THE HARBOUR CITY

Vancouver Island Conference Centre

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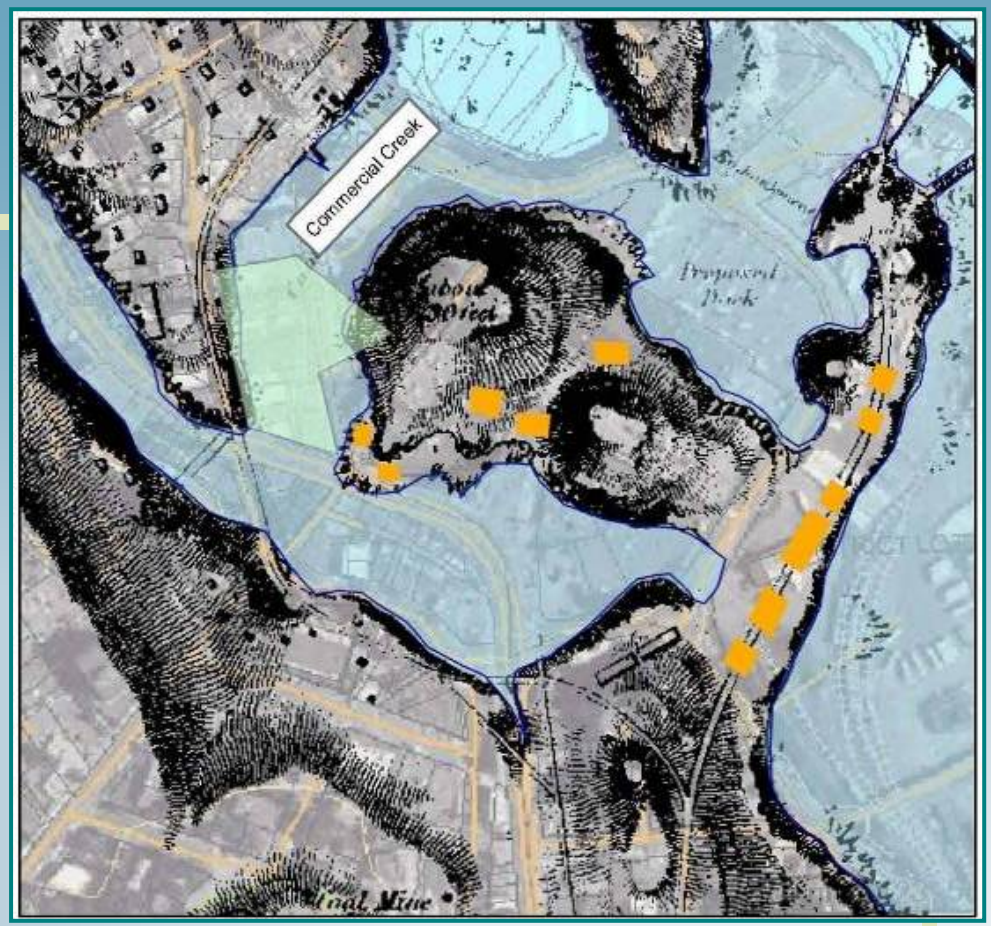
Location:

Commercial Inlet historically extended into Nanaimo City Centre, with Commercial Creek flowing into the harbour

Snuneymuxw First Nation winter settlement was located on Commercial Inlet, and their main settlement area was located south of the proposed VICC site



Nanaimo Harbour 1862

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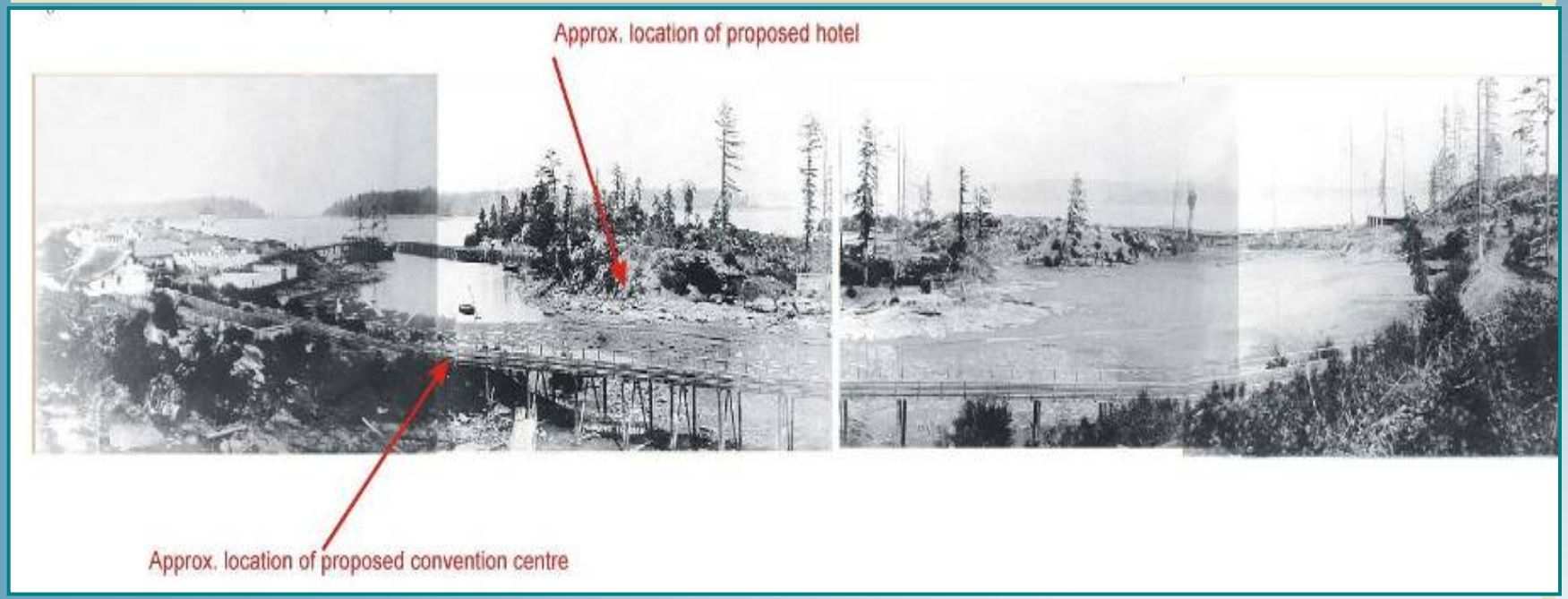
Original Site Condition (1858)



Nanaimo Harbour
(Nanaimo City Archives)

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Site History

In 1862 Vancouver Coal Milling and Land Company built a tramway and wharf into the present site, progressively backfilling the inlet with coal waste.

From 1882 onwards, land use was primarily commercial with some light industrial.

In the late 1950s/early 1960s the remaining portion of Commercial Inlet was landfilled with highly variable fill.

The VICC project spans the original shoreline lands and the reclaimed lands and hence has variable support conditions.

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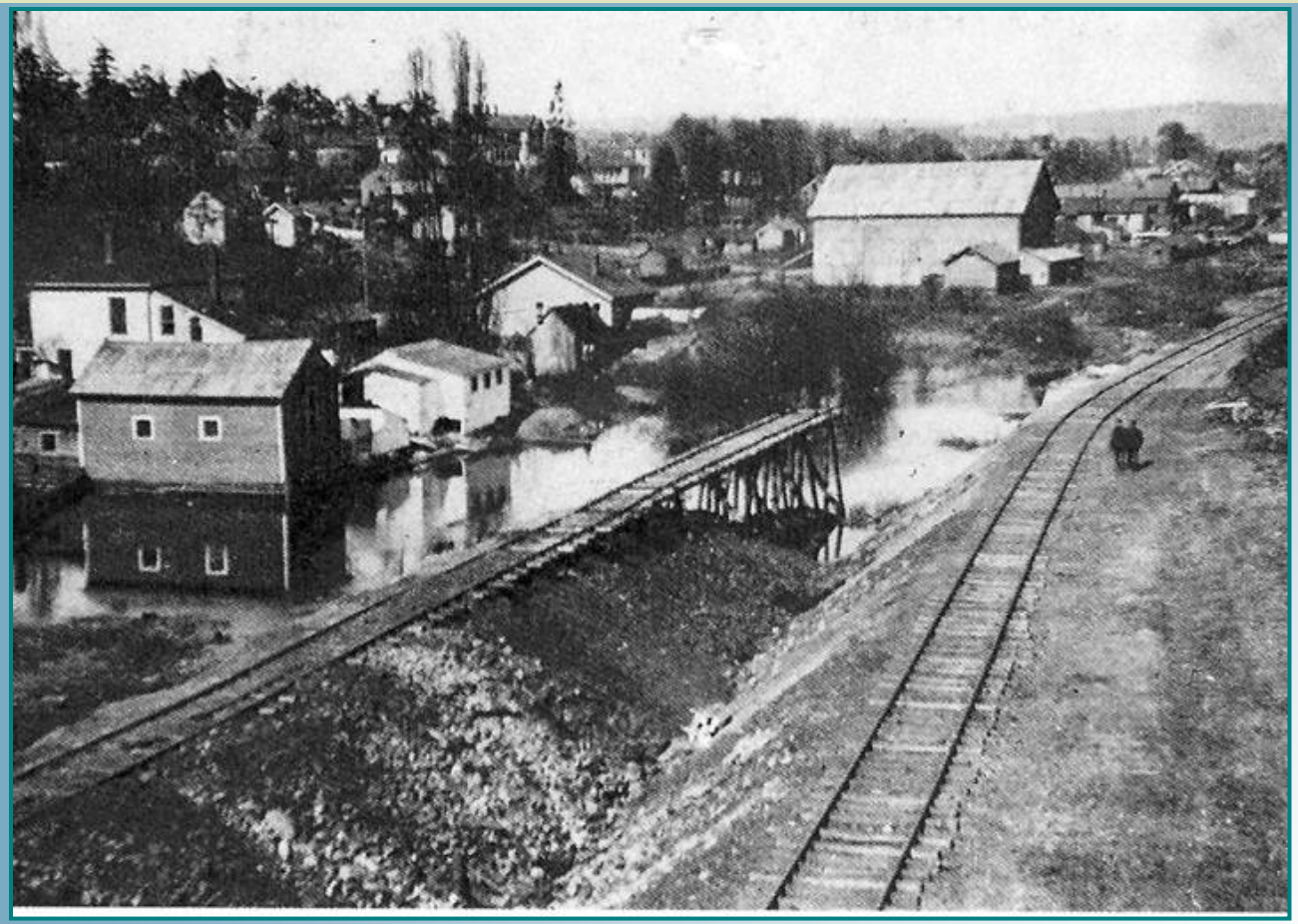
Site Partially Filled



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Geotechnical Challenges

Large building loads

Weak Soils

Deep excavations in relatively poor soils adjacent to the roadways (Highway located south of site)

High groundwater table

Potentially liquefiable materials in the eastern portion of the site

Potential for large lateral displacements of untreated ground during a 1 in 475 year return seismic event

Impacts on adjacent buildings and services

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Preliminary Environmental Options

Soil Excavation

$5M+ for excavation and disposal

Not including:

- Dewatering $$$$
- Shoring $$$$
- Place and compact imported fill $$$$
- Liability $$$....$$$....

Risk Assessment

Requires more detailed investigation and delineation of contaminated soils

Some soil removal, but most soils remain in-situ

Cut-off walls required to prevent, or mitigate offsite migration of contaminated groundwater

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Preliminary Geotechnical Options

Piled Foundations (~ $7.2 M)

Stone Columns (used on the Library Building) (~ $4 M + disposal costs for water and spoil))

Bulk Excavation and Replacement with Structural Fill
(+ $10 M estimated)

Soil stabilization using a combination of deep and shallow mixing processes and shallow compaction methods (~ $3 M)

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CSM Solution for both Environmental and Geotechnical Issues

Uses proven and established technology

Provides axial support for the structural loads within the existing poor fill areas

Provides lateral stability of the fills during design seismic shaking

Provides containment of the contaminated groundwater and soil, thereby reducing offsite disposal requirements (estimated 85% reduction in off-site disposal)

Relatively fast

Generates low vibrations, in consideration of adjacent sensitive facilities

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North America's First CSM Project

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A complete ground engineering solution using Deep Soil Mixing, Rapid Impact Compaction (RIC) and ALLU shallow soil mixing

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North America's First CSM Project

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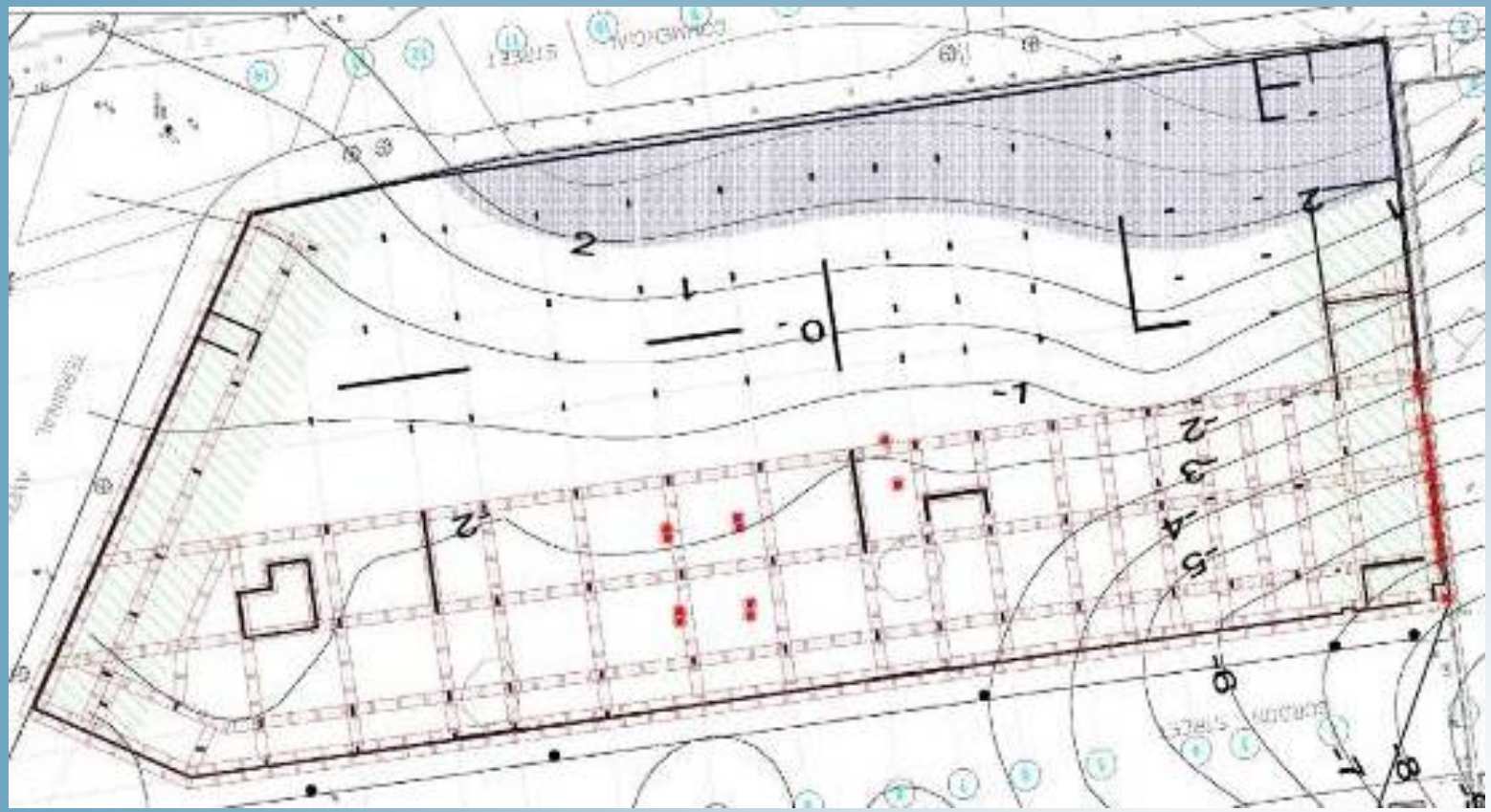

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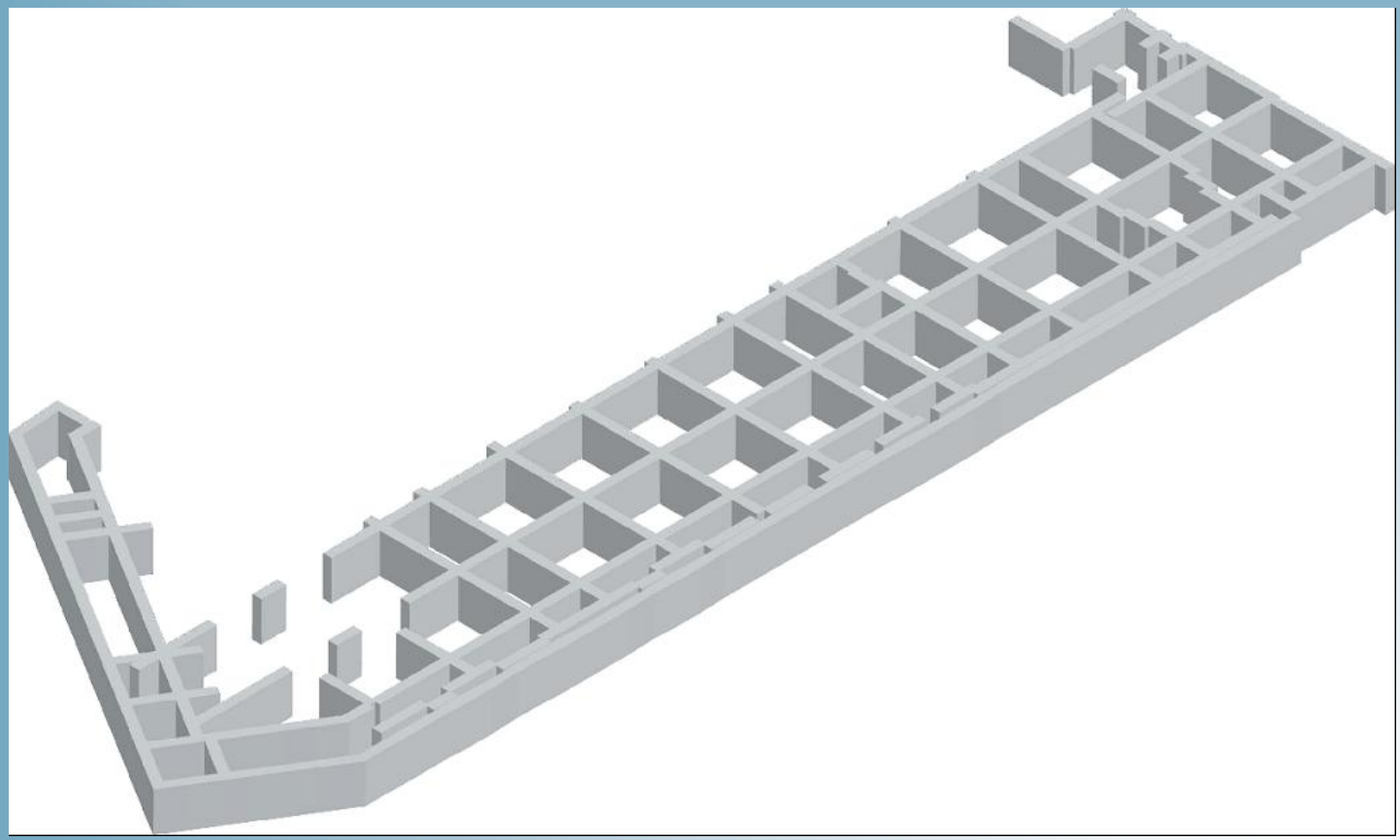
North America’s First CSM Project



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North America's First CSM Project

Vancouver Island Conference Centre

Acurate placement of CSM panels allows for optimized design layouts or the ability to work around obstructions (utilities, piles, or other structures)

Complete mixing of the in-situ soil with a cement slurry results in an intact soil cement column

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North America's First CSM Project

Vancouver Island Conference Centre

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North America's First CSM Project

Vancouver Island Conference Centre

BUILDING A BETTER WORLD:

YOUR WORLD.

By respecting your concerns, and those of the environment, in Canada and around the globe.

THANK YOU!

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