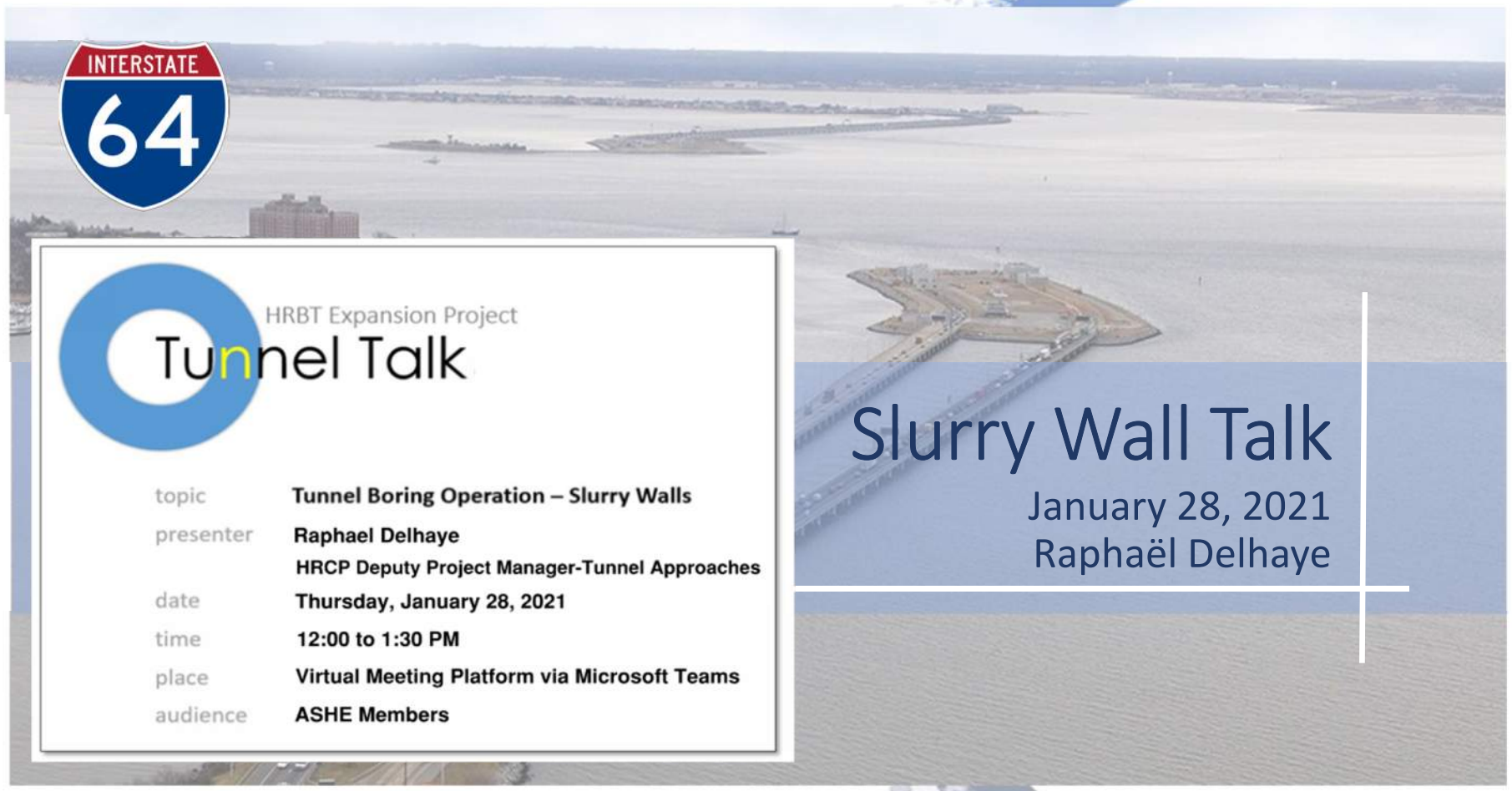

Slurry Wall Talk

January 28, 2021

Raphaël Delhaye

Introduction

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3. **Guide walls**
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Why do we have slurry walls on the project ?

What ?

A wall built using trenches excavation techniques under slurry fluid management

Why ?

Support of Excavations (SOE) for Tunnel Approach Structures South & North Island

- Launching pit
- Bore Proximity Walls
- Approaches

How ?

With a very specific technique involving giant excavating tools, cranes, etc.

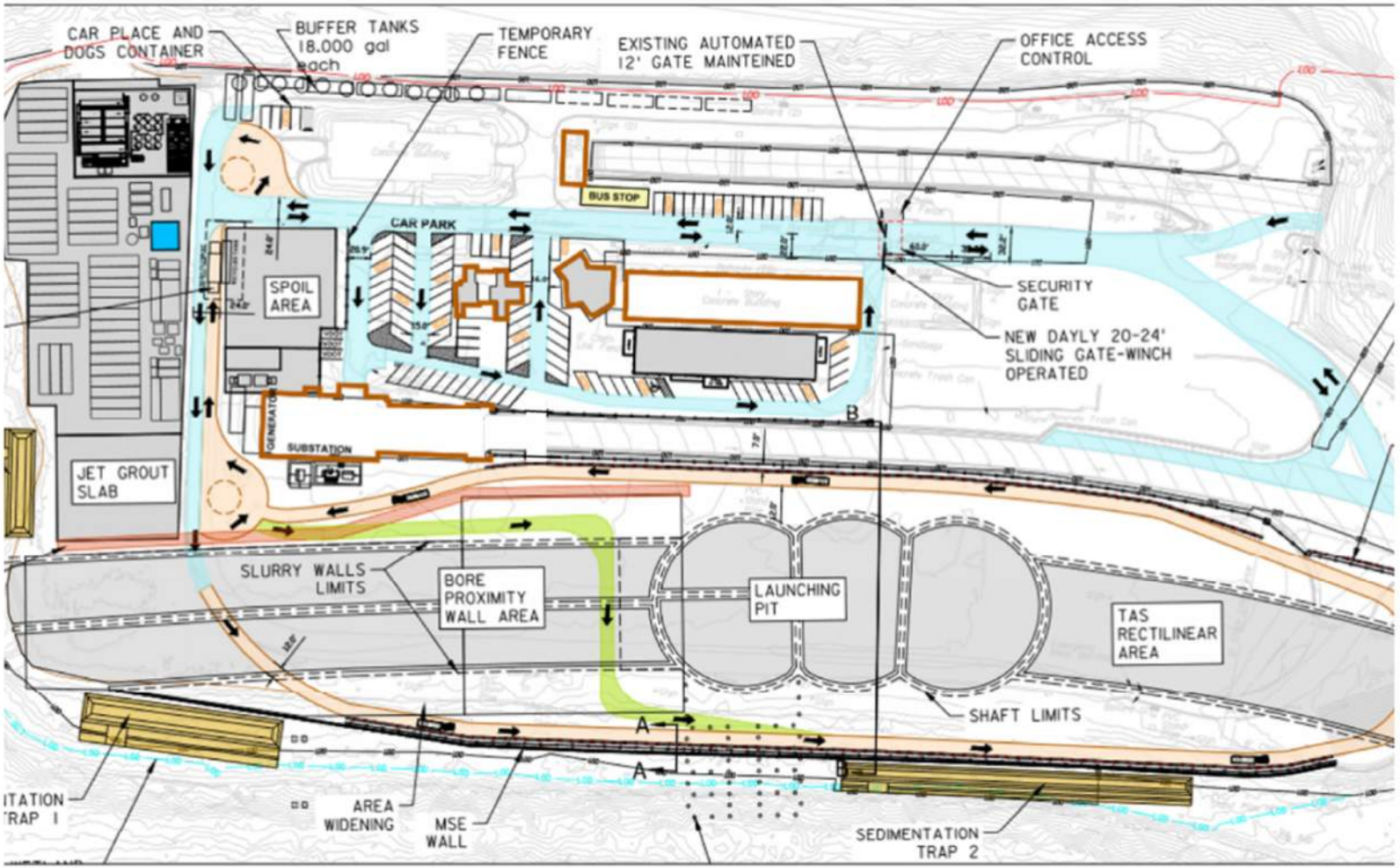
Who ?

HRCP/KELLER North America

When ?

August 2020 – June 2022

Why do we have slurry walls on the project?



Why do we have slurry walls on the project?

A total of :

25 millions lbs of steel

128,300cy of concrete

16,000 trucks hauling spoils

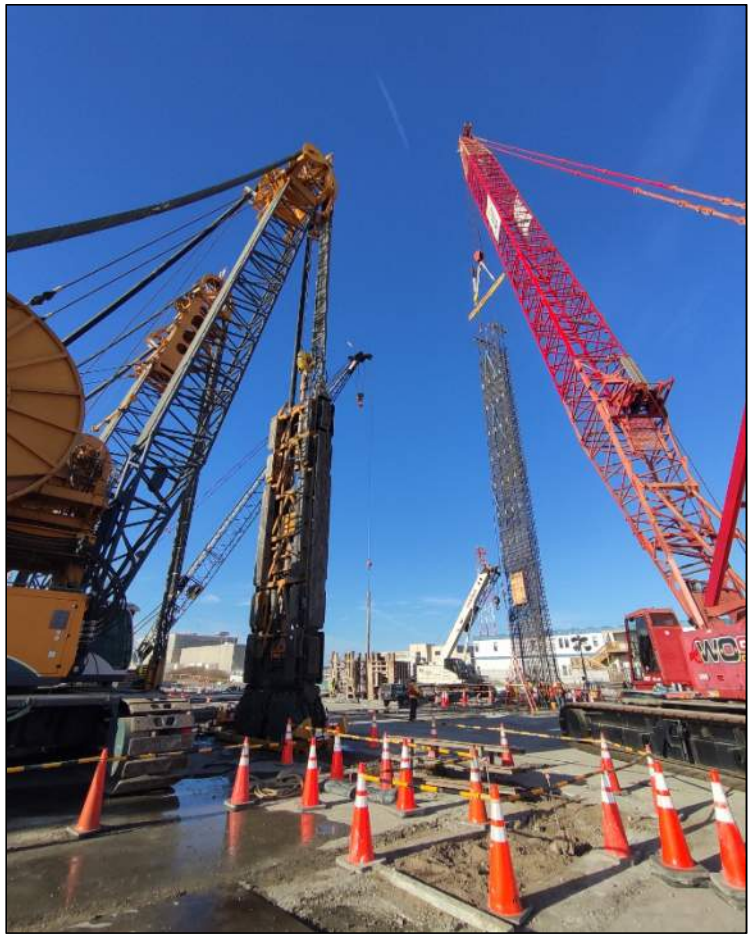
22 Months of activity

Diaphragm Wall: Definitions and Uses

Part 1

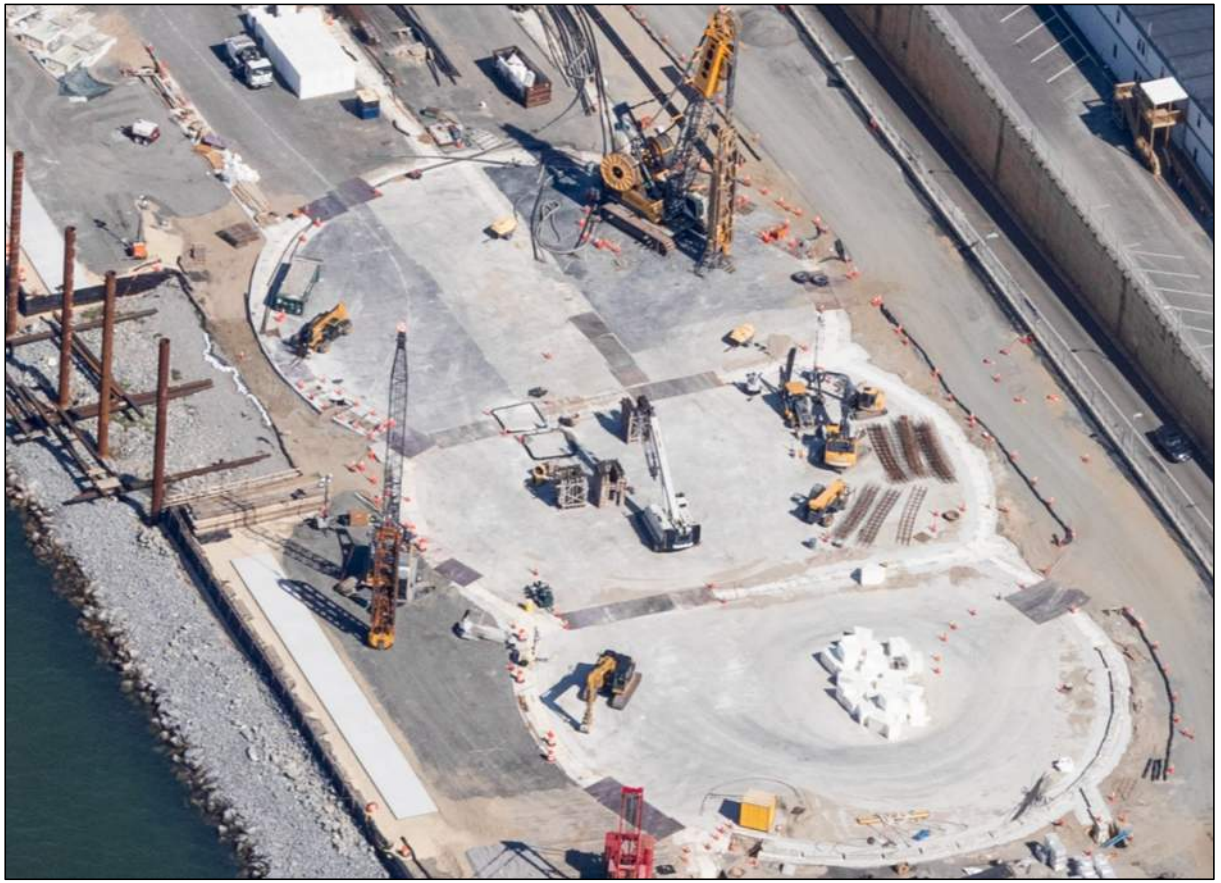
“Slurry Wall”

A term widely used to describe the construction of a **concrete wall** using slurry fluid to support the excavated trench before replacing it by tremie concrete



“Diaphragm Wall”

A diaphragm wall is a reinforced concrete wall excavated under a slurry fluid using the panel method.



“Slurry Cutoff Wall” or “Slurry Trenches”

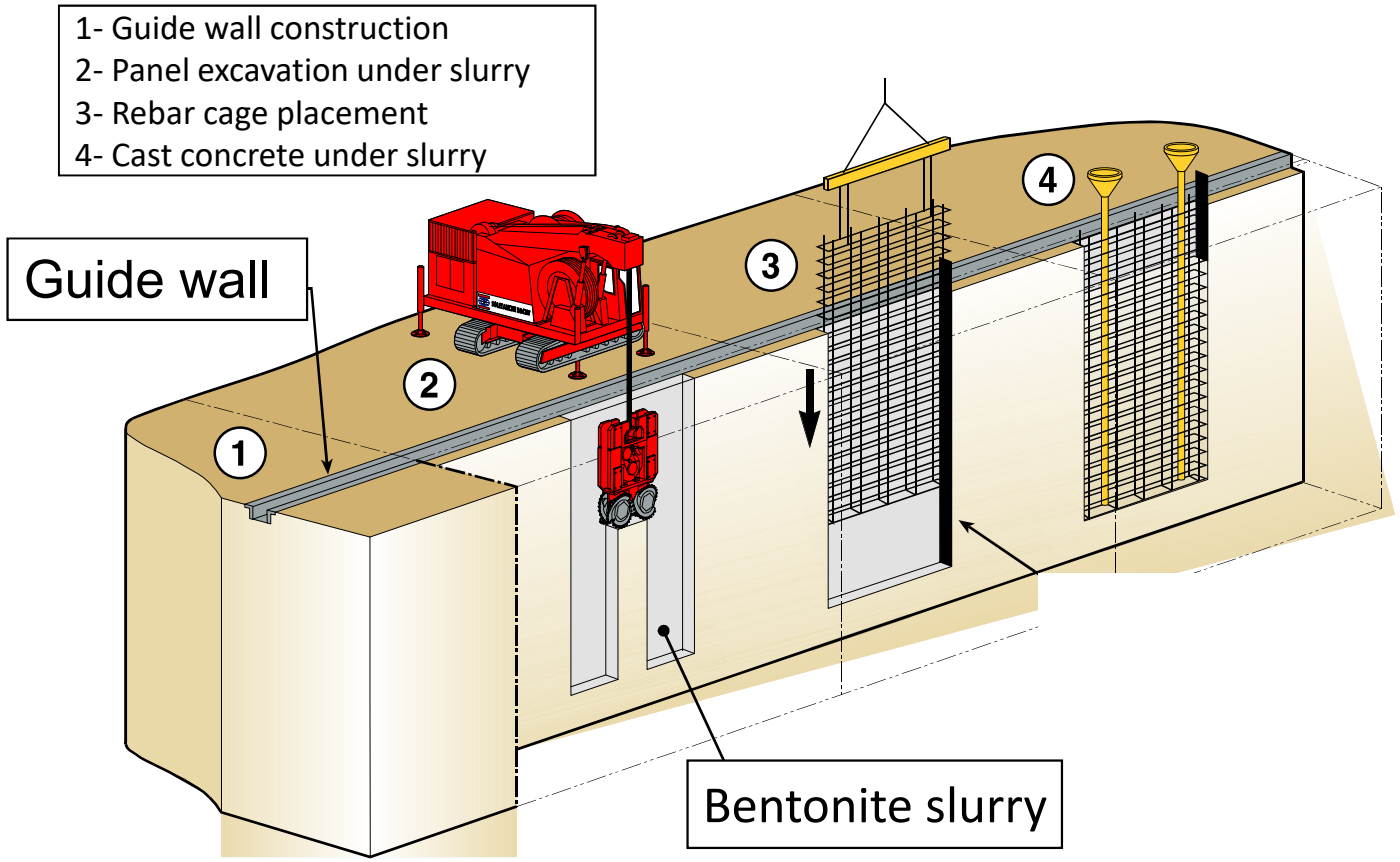
Describes a wall excavated under slurry to install water cutoff barrier or environmental barrier.

Diaphragm wall Advantages:

- Either a temporary or permanent structure
- Great stiffness
- This is a very important consideration when working in an urban environment.
- In addition to its retaining role, a diaphragm wall can have other functions:
  - Load bearing foundations - Barrettes
  - Hydraulic cut-off

Diaphragm Wall Installation

Part 2


1- Guide wall construction
2- Panel excavation under slurry
3- Rebar cage placement
4- Cast concrete under slurry
Guide wall
1
2
3
4
Bentonite slurry

1 – Guide walls

2 – Panel excavation

3 – Rebar cage placement

4 – Cast concrete under slurry

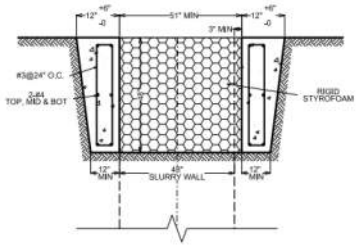
Guide Walls

Part 3

Guide Walls:
Temporary structure constructed in advance and consisting of two reinforced concrete sections.

Functions:

- Confirms the location of the wall (layout)
- Guide the excavation tool and ensure verticality
- Support for suspension of t reinforcement cages



GUIDE WALLS
TYPICAL SECTION
FOR 48" STYROFOAM
SCALE 1/2"=1'

Excavations

Part 4

Excavating Tools:

Hydraulic Clamshell Bucket

- Equipped with real time monitoring device
- Great productivity, monitoring and correction of the verticality if necessary.

Currently, HRCP/Keller has one clamshell working on the South Island.

Excavating Tools:

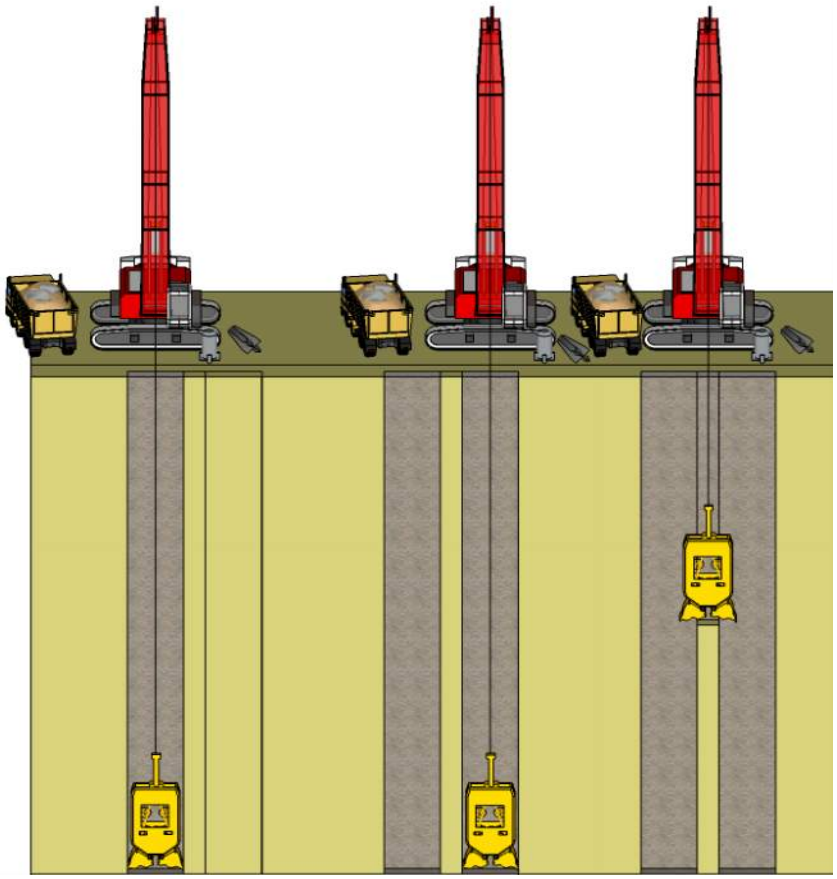
Hydrofraise

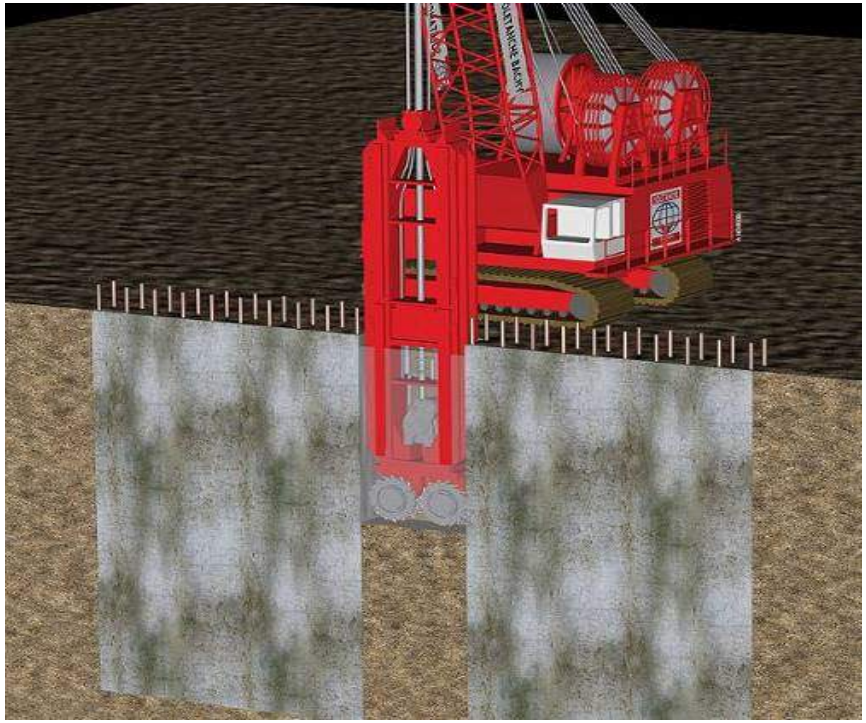
- A Hydrofraise consists of two counter-rotating drums on horizontal axes fitted with cutting teeth.
- Continuous excavation under engineered slurry
- Cut soil and rock into particles which are pumped to the desanding plant
- Particles from slurry will be separated and cleaned slurry is returned to excavation location
- Excavation progress verticality is monitored in real time

2 hydrofraises are currently working for HRCP
We call them: the Queen and the King

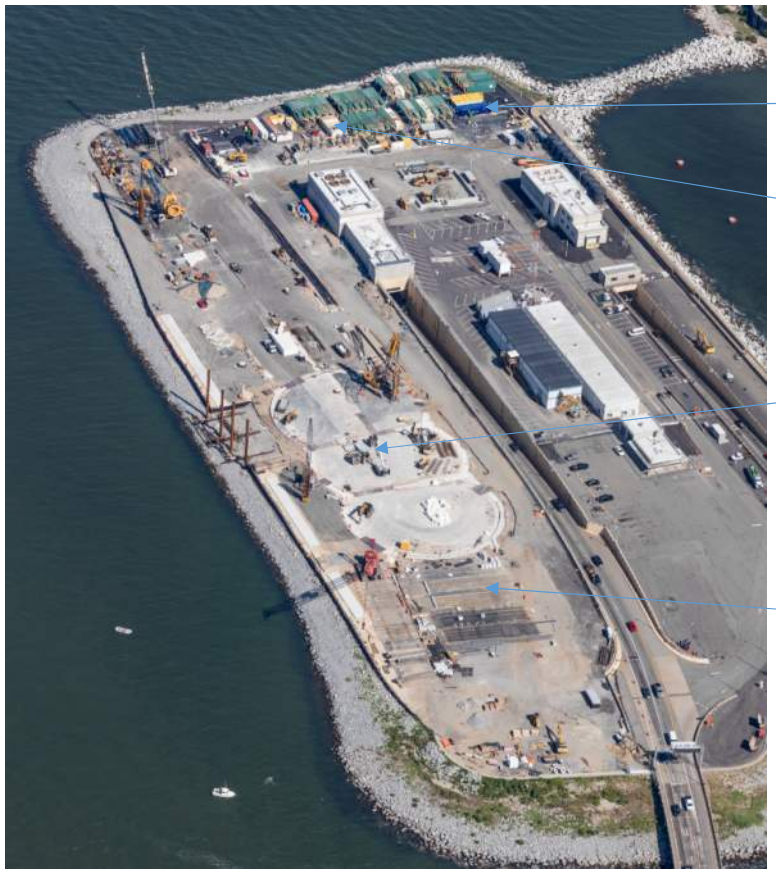
Paneling Method

Primaries and Secondaries





Diaphragm wall installation



Water plant : 15 tanks

Slurry plant : 43 tanks

Current work zone
- **2 hydromills**
- **1 clamshell**
- **4 cranes**

Cages fabrication area

100% of the island surface is mobilized to achieve the Dwall activities.

Slurry Fluid Management

Part 5

5. Slurry Fluid Management

What do you know about Mud drilling ?

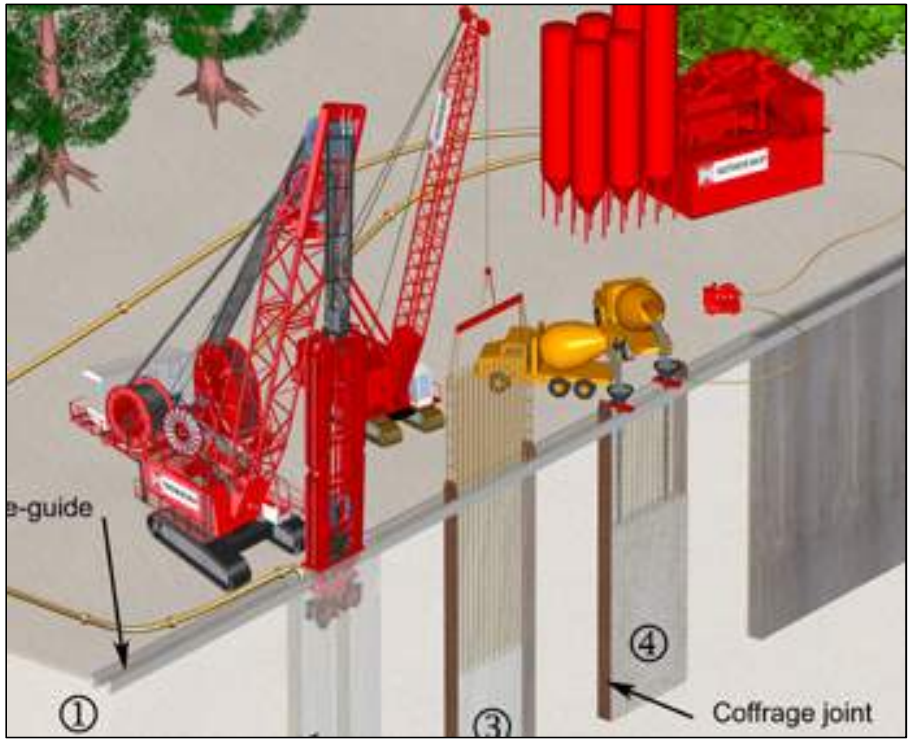
5. Slurry Fluid Management

Slurry Treatment plant

Main function

Maintain borehole / panel stability

- Prevent collapses
- Prevent water inlets into excavation
- Remove cuttings for reverse circulation technique
- Lubricate drilling tool



5. Slurry Fluid Management

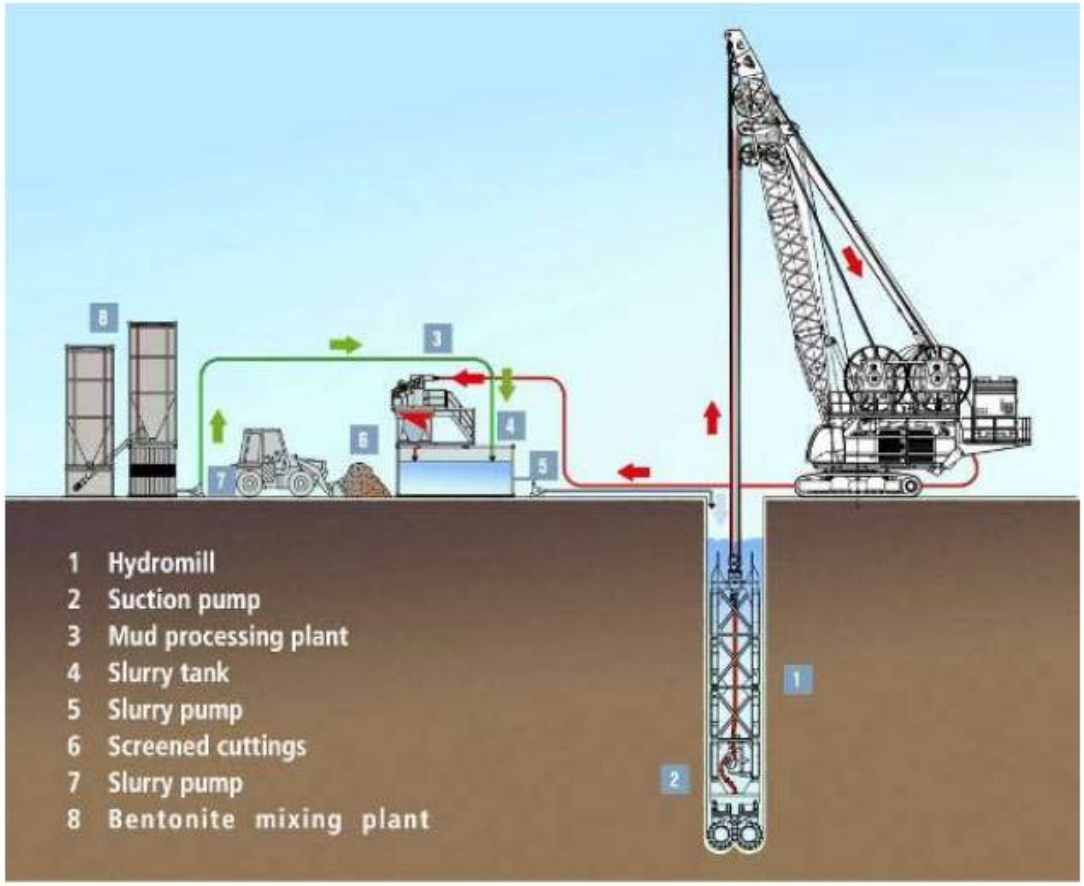
Slurry Treatment plant

- Slurry: water and bentonite powder mixed with high shear mixer.
- The development of a thin impervious filter cake on the panel sidewalls controls the transfer of slurry in the soil and maintains the positive hydrostatic head.
- Relatively coarse and heavy particles are suspended in the viscous slurry.
- Sufficient viscosity and gel strength are important to transport the excavated material to the desanding plant (Hydromill operation)
- Prior to concrete placement, slurry will be desanded and cleaned

43 tanks are on South Island for bentonite slurry

5. Slurry Fluid Management

Slurry Treatment plant



Hydrofraise schematic of working principles

5. Slurry Fluid Management

Slurry Treatment plant

5. Slurry Fluid Management

Slurry Treatment plant

5. Slurry Fluid Management

Type of Contamination

Cement

Creeping clay

Reinforcement Fabrication

Part 6

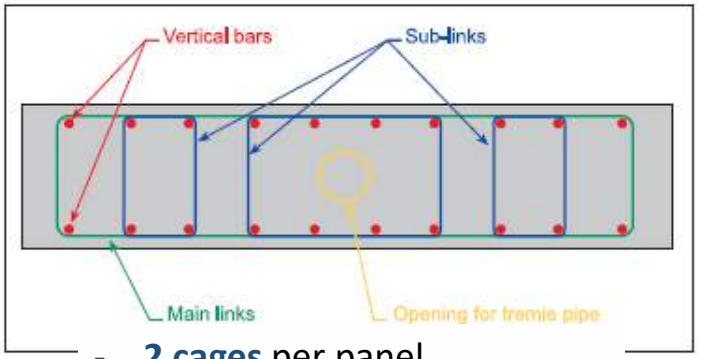
Reinforcement and buildability considerations

A diaphragm wall reinforcement cage includes the following:

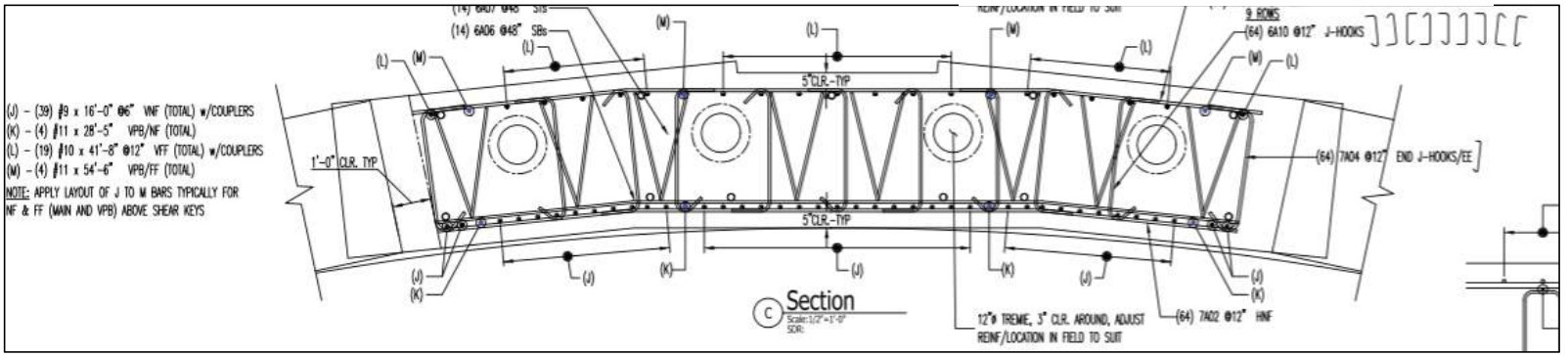
- Structural bars:
  - main vertical bars to resist bending moments,
  - horizontal bars to resist shear force.

- Block-outs for ground anchors, slab, etc.

- Bars required for installation such as lifting bars

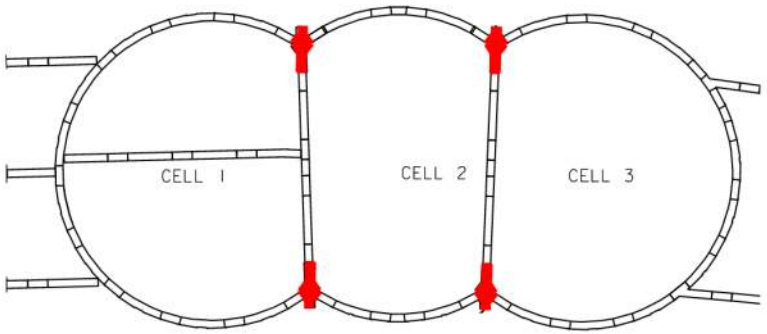


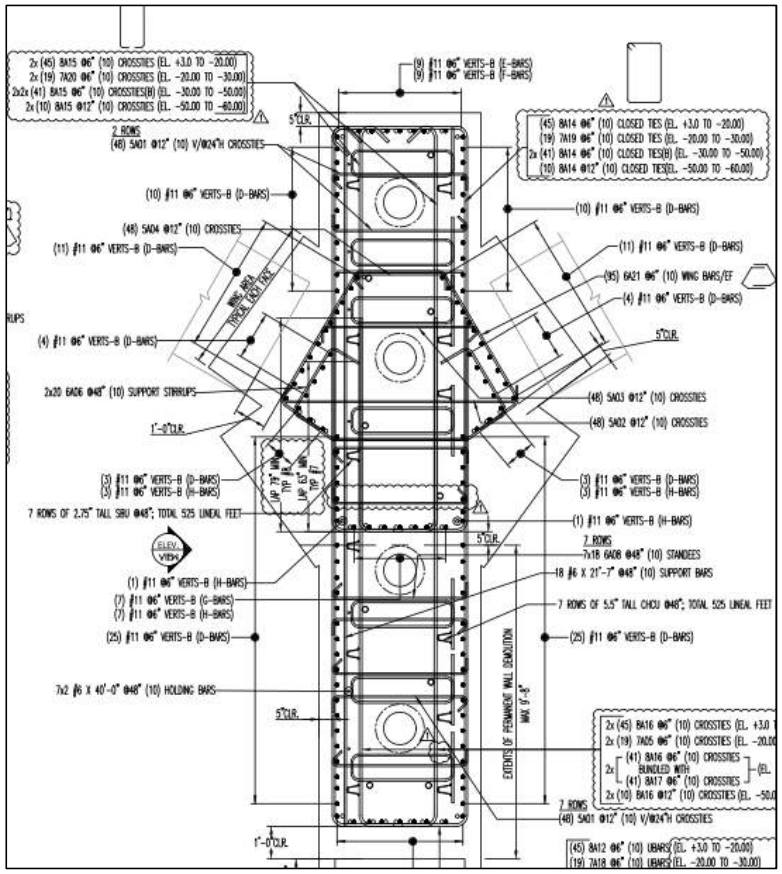
- **2 cages** per panel
- Total weight of **120,000lbs**
- **800 CY** of concrete



Y panels: 4 major critical points on the slurry walls construction

- **3 cages** per panel
- Total weight of **400,000lbs**
- One special crane (750t) to install the cages
- **1,200cy** of concrete



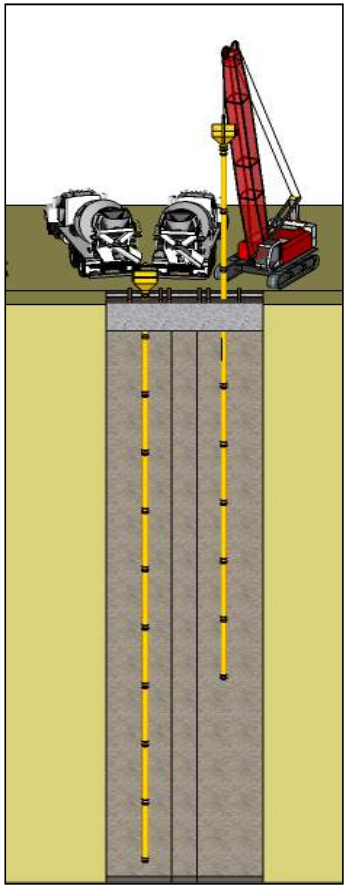


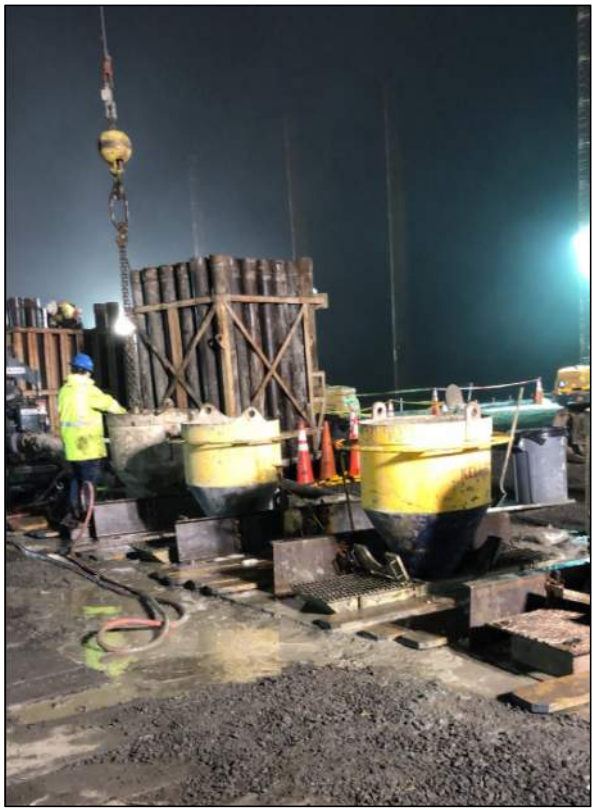
- Reinforcement cages are built horizontally on the ground
- Shear keys / blockouts are installed inside the cages
- Reinforcement is typically made of two 90-ft cages
- Cage will be suspended and anchored on top of the guide-walls

Concrete Placement

Part 7

- Tremie pipes are assembled and lowered and placed in designated location
- Concrete is placed from the bottom to the top
- The slurry displaced is pumped back to the treatment plant.





Quality Control

Part 8

Phases of controls

During excavation

- Test of trench geometry
- Slurry parameters

During cage fabrication

- Steel conformity
- Compliance with shop drawings

During concreting the panel

- Test of concrete
- Record of concrete curve placement

After panel completion

- Test of panel integrity
- Test of concrete strenght

Quality Control Steps

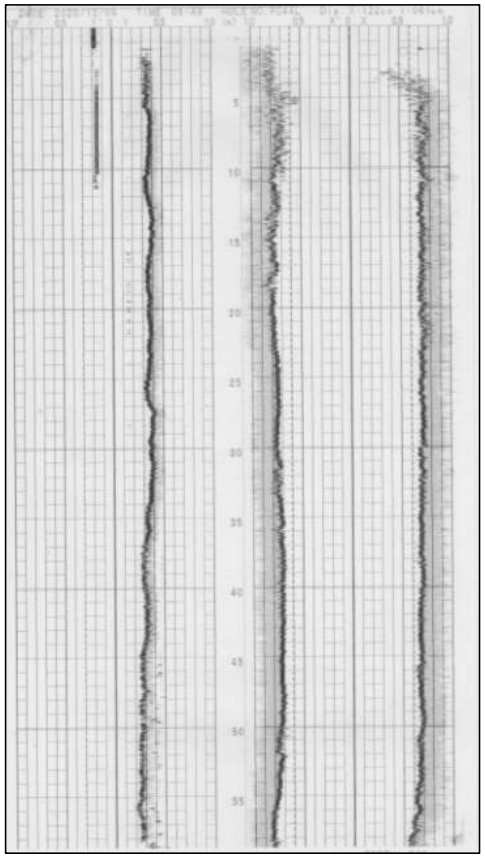
- Example of Hydromill on-board Instrumentation to ensure verticality control

On board inclinometers

Quality Control Steps

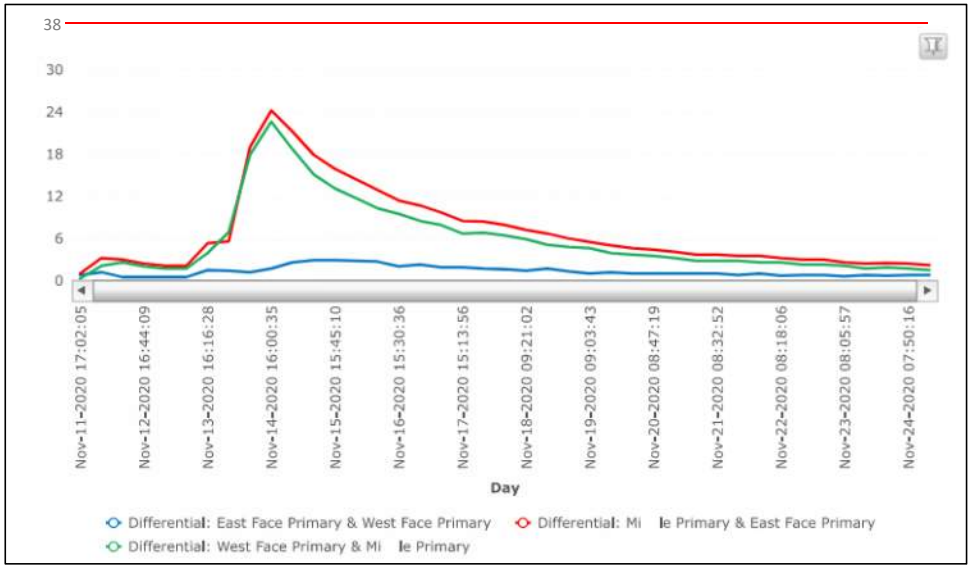
- Example of using immerged sonar to ensure excavation verticality during and after excavation

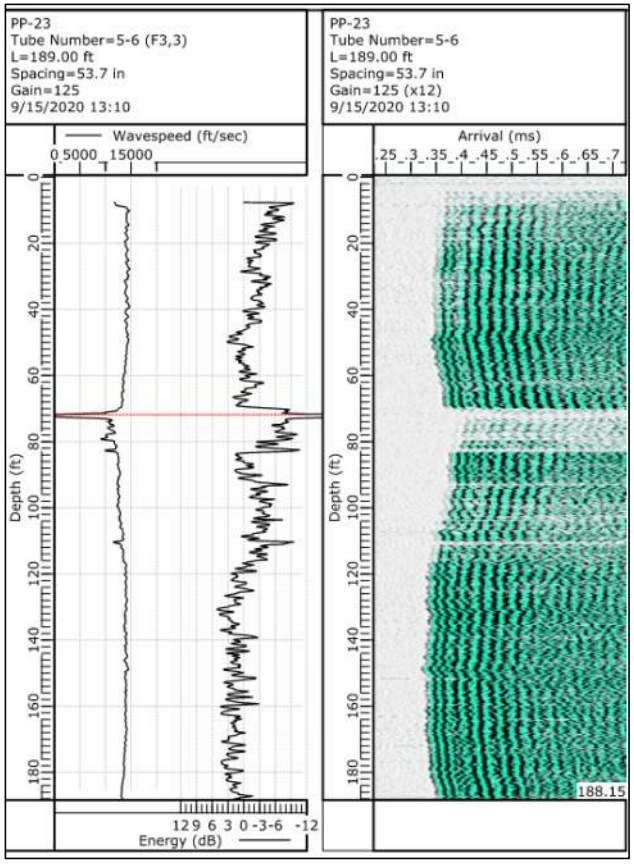
- **HF: 0.75%**
- **KS:1%**



Thermal & Sonic Analysis

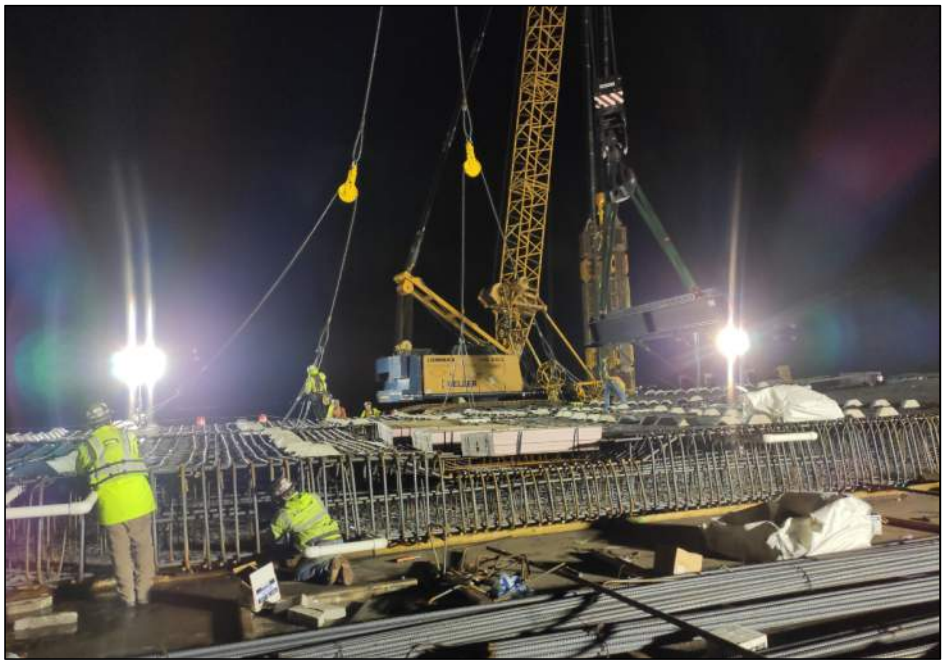
- Confirm panel integrity
- Anticipate defects and repairs





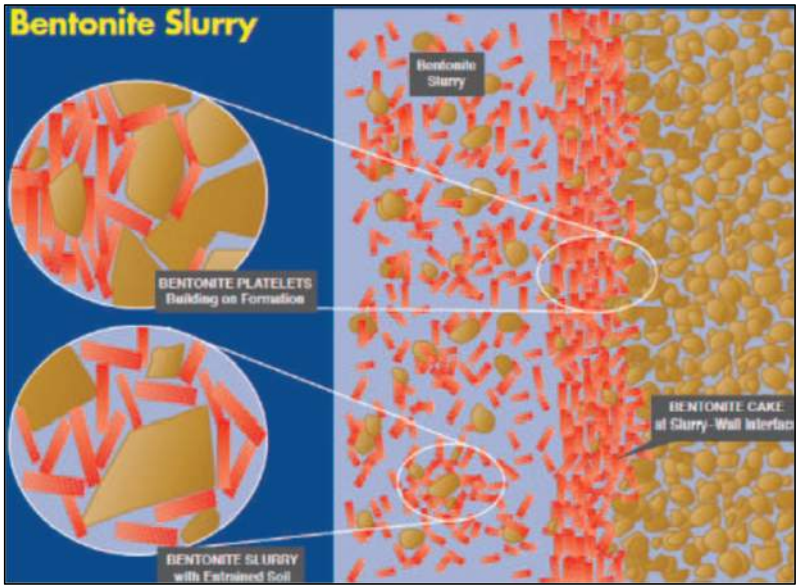
Quality control of rebar cages

- Confirm all the reinforcement is properly installed prior to lifting the cage
- Insure concrete coverage



WHAT MUD TESTS DO YOU KNOW?

- **Viscosity**
  - Stability of the excavation
  - Spoil in suspension *one question !!*
- **Density**
  - Verification of slurry dosage
  - Measurement of the mud's physical load
- **Filtrate/filter cake**
  - Waterproofing of the wall
  - Water retention capacity of the mud
- **pH**
  - Normally pH 7 (natural sodium) to 9 (activated)
  - Influence of the ground pH => interferes with mud performance
- **Sand content**
  - Physical load of the mud which can be only treated mechanically
  - Sand and/or silt remover (> 74µm)



SPECS 31 56 00 : CHARACTERISTICS OF THE MUD

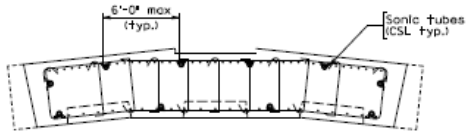
Measure	Fresh mud	Working mud	Before concreting
Marsh Viscosity (s)	> 36s	> 32s	> 32s
Density	65 pcf min 1.04	65 – 80 pcf 1.04 – 1.28	65 - 72 pcf 1.04 - 1.15
Filtrate (ml)	20ml in 30 min	< 30 mL	< 30mL
pH	N/A	7 - 12	7-12
Sand content (%)	N/A	< 5	< 4

- Every truck is tested prior to being allowed to pour
- Objective is to confirm the strength of the whole structure

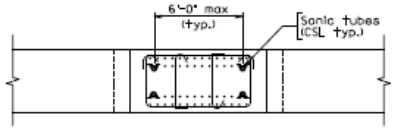
1. Slump flow: Each truck
2. Unit weight: Each batch or truck until a minimum of three consecutive batches meet the requirements and every 50 cy daily.
3. Temperature: Each batch or truck until a minimum of three consecutive batches meet the requirements and every 50 cy daily
4. Compressive strength: 7 cylinders / day or 150 cu yards. Out of 5 cylinders, 3 tested at specified age, 2 at 7 days and 2 at 28 days.
5. Durability tests: start every 200 cy for first, 2000 cy and every 500 cy thereafter.
6. Monitoring: Monitor placement and chart actual volume of concrete placed versus theoretical volume required.

8.4 CSL Testing:

1. Crosshole Sonic Logging (CSL) Testing is a slurry wall integrity test to detect concrete deficiencies.
2. Probes are inserted into vertical access tubes cast into the panels during construction.
3. 60200 LF CSL tubes (430 EA)
4. The 2 inch CSL tube will be steel pipe schedule 40. The 2 inch CSL tube will be PVC on the TBM breakthrough.
5. The CST Test is performed between 72 hours and 25 calendar days after concrete placement, and after the concrete f'c exceeds 3000 psi.
6. Concrete quality ratings from CSL Testing:



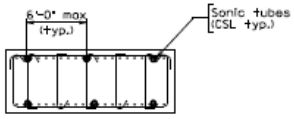
TYPICAL 3-BITE PRIMARY PANEL CSL LAYOUT
Scale: ¼" = 1'-0"



TYPICAL 1-BITE PRIMARY PANEL CSL LAYOUT
Scale: ¼" = 1'-0"

Table 31 56 00-4: Concrete Quality Ratings from CSL Testing

Category	First Pulse Arrival Time (FAT) Increase	AND / OR	Signal Reduction	Comment
G	Up to 10%	AND	< 6 db	Good
Q	10 to 20%	AND	< 9 db	Questionable
P/F	21 to 30%	OR	9 to 12 db	Poor/Flaw
P/D	> 30 %	OR	> 12 db	Poor/Defect



TYPICAL CLOSING PANEL CSL LAYOUT
Scale: ¼" = 1'-0"

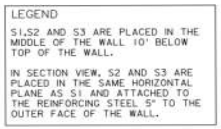
Thermal Testing:

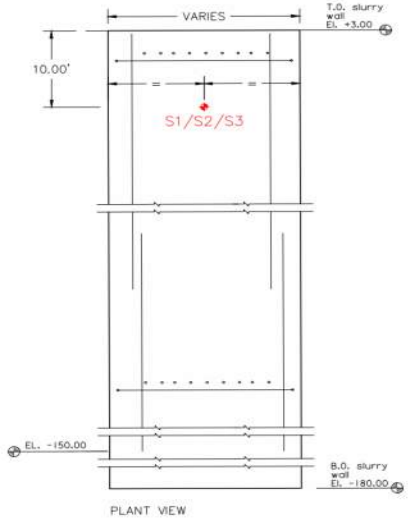
1. 1125 thermocouples EA
2. 3 pairs of thermocouples shall be placed at a minimum depth of 10 feet from top of panel

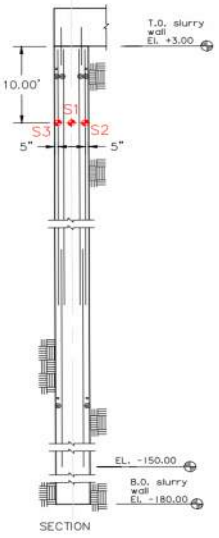
3. Max concrete temperature: 170 deg F

4. Record the temperature at each thermocouple at least once every hour for at least 2 hours prior to the anticipated start of placement until 3 days.
   Temperatures shall be reviewed by the tunnel QC manager every 12 hours to verify compliance with temperature limits.

5. Avoid shrinkage and thermal cracking







THANK YOU
FOR YOUR ATTENTION