

# Shaft Base Grouting

Perching Deep Foundations in Specific Soil Layers



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# Acknowledgements



# Presentation Overview

- Principles of Base Grouting
- Project Location & Purpose of Base Grouting
- Shaft & Base Grouting Construction
- Lessons Learned

# Principles of Base Grouting

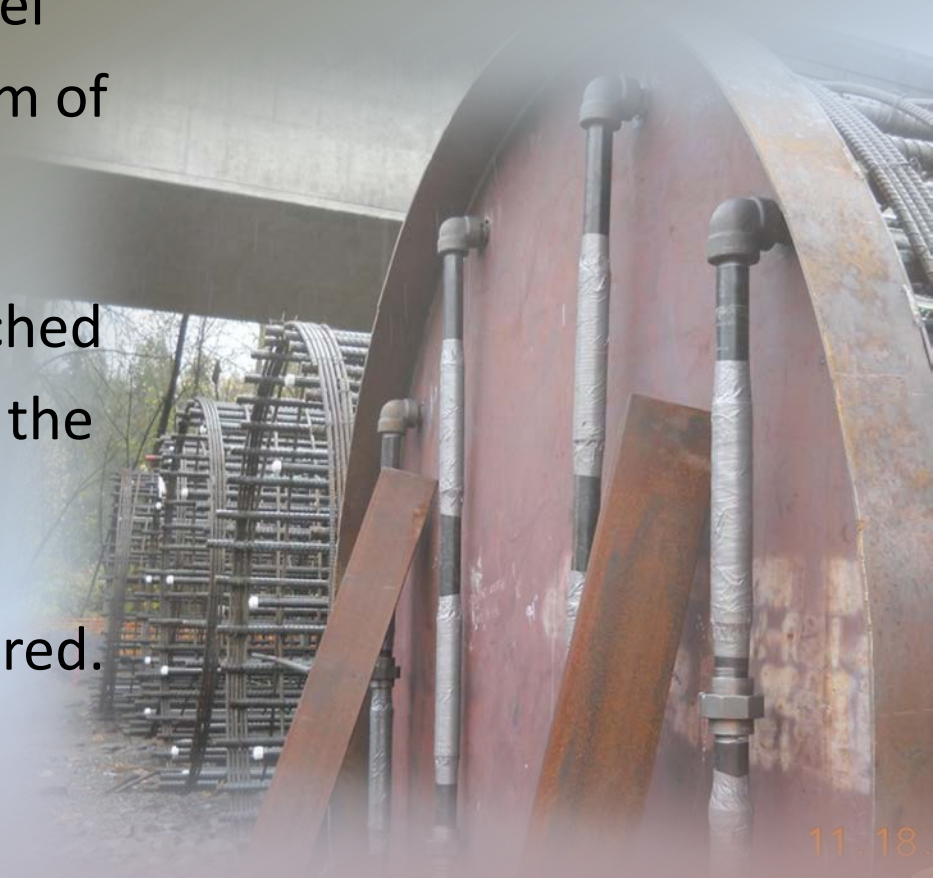
- Process of Preloading & Improving Soil Conditions
- Benefits of Base Grouting
- Risks & Potential Problems



# Principles of Base Grouting

Process of preloading and improve bearing materials at the base of the shaft...

- Once the shaft is drilled, a gravel medium is placed in the bottom of the hole for several feet.
- A grout delivery system is attached to the shaft cage and placed in the shaft.
- Shaft concrete is placed and cured.
- The grouting process begins ...

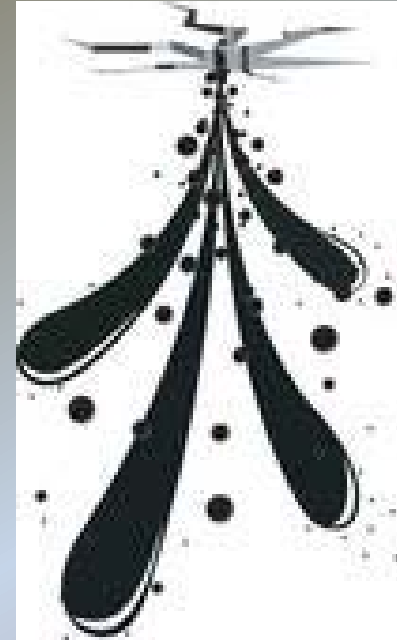


# Principles of Base Grouting Continued...

## Process Continued...

- Grout is pressurized to displace water, break the seals at the gravel medium, and fill the voids.

Note: all grout up to this point is considered incidental, part of the preparation, before actually improving the soils.



# Principles of Base Grouting Continued...

## Process Continued...

- Grout is placed until one of the following is reached:
  1. *A specific pressure is attained.*
  2. *A specific volume of grout is placed.*
  3. *The shaft displaces vertically a specified amount.*
- Depending on the outcome above, the Contractor may:
  1. *Grout other placement systems in the same shaft, until they all get to the prescribed pressure.*
  2. *Wait for the grout to start setting below the shaft.*
  3. *Flush the lines and wait for the grout to set,*
  4. *Change the grout mix properties.*
  5. *Repair the shaft skin friction.*

# Principles of Base Grouting Continued...

## Benefits of Base Grouting

- Increase bearing resistance to:
  1. *Improve a soil layer that is good, but not quite adequate,*
  2. *Perch the shaft base above a questionable soil layer,*
  3. *Repair improperly constructed shaft,*
- Quantify costs and time requirements *by avoiding* construction hazards, below the perching limit, such as:
  1. *Large obstructions or changed conditions,*
  2. *Artesian well effects,*
  3. *Deep compressible soils (clays, peats, etc.),*



# Principles of Base Grouting Continued...

## Risks & Potential Problems

- Issues with the tube-a-manchette delivery system:
  1. *Valves do not open or plug prematurely,*
  2. *Flushing process washes away grout below shaft,*
  3. *Pump or batch plant failures,*
  4. *Grout with too much water that washes out the existing substrate,*
  5. *Grout too dry and lines plug over time,*
- Improper grout placement in gravel medium,
- Excessive displacement of shaft vertically and expensive repairs to restore skin friction,

# Principles of Base Grouting Continued...

## Risks & Potential Problems Continued...

- Excess grout placement from:
  1. *Over-excavation of original shaft foundation,*
  2. *A soil layer (vein) transferring grout to a void, compressible soil layer, or water source,*
  3. *Blowout to adjacent shaft,*

... it is all below ground!



# Project Location & Purpose of Base Grouting

- Snohomish River Bridge
- Soil Conditions
- Design Considerations
- Contract Requirements

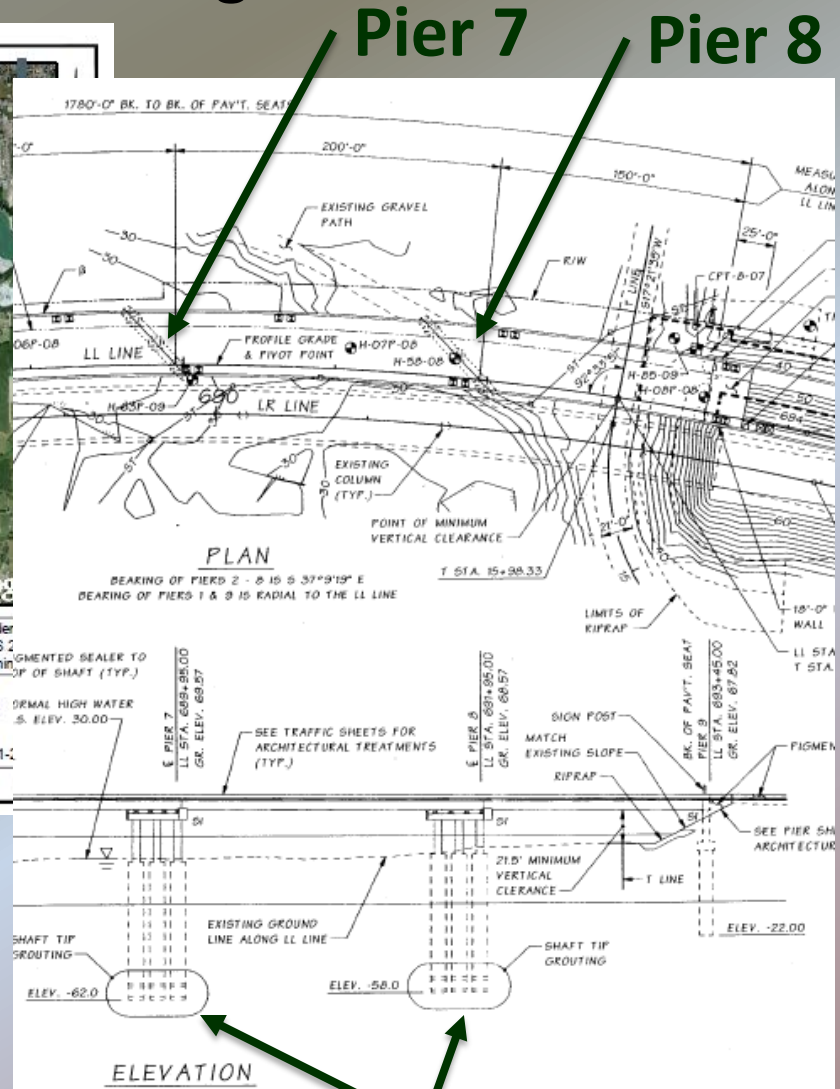


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# Project Location & Purpose of Base Grouting

## Snohomish River Bridge



XL-2042, Safety and Wider  
Snohomish River Bridge to US 2  
Snohomish County, Washin

VICINITY MAP

number 2010 21-1-1

NON & WILSON, INC.  
and Environmental Consultants



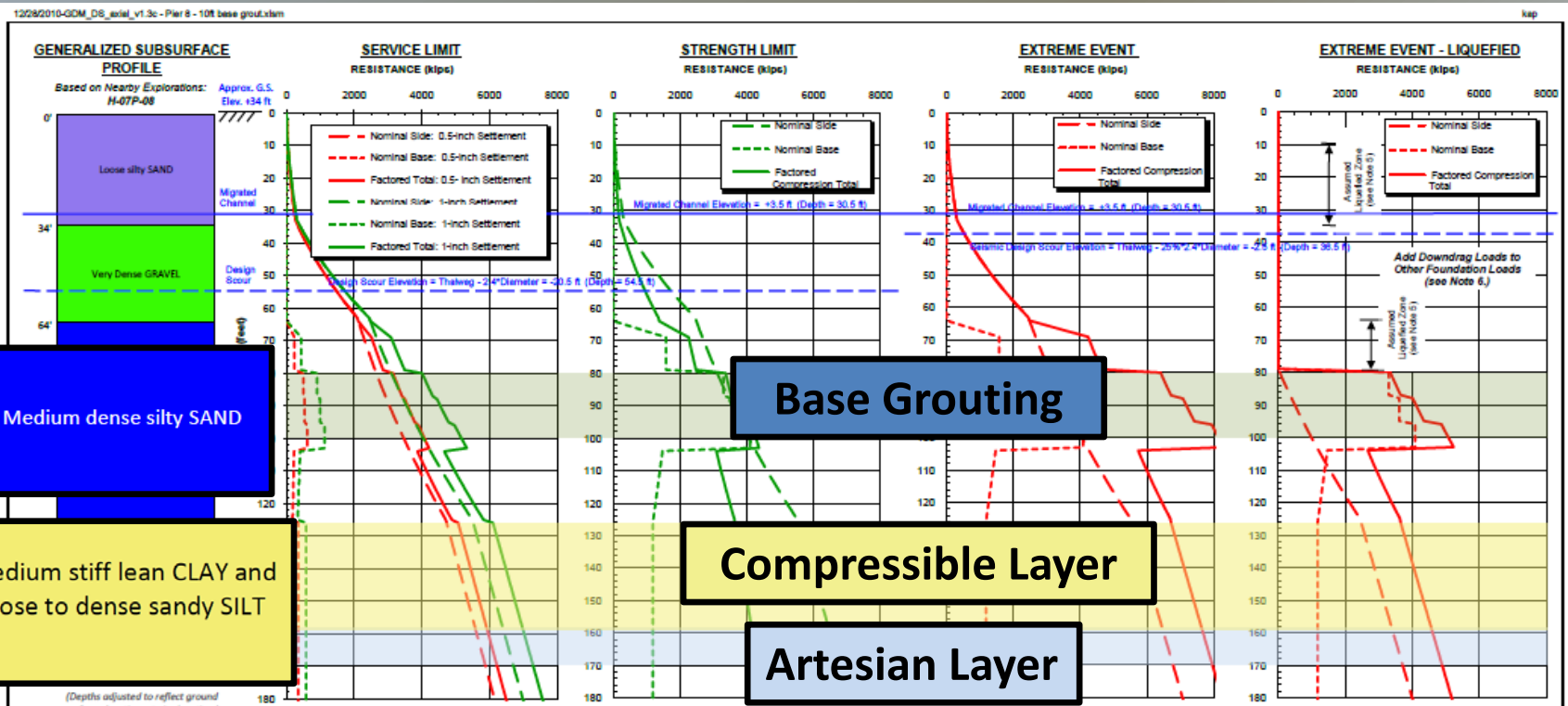
(3) ~ 10' Dia. Shafts  
w/ 5'-6" Dia. Columns

Shaft Base Grouting

FIG. 1

Map adapt:  
Google Ear  
Survive rep  
Google Ear

# Project Location & Purpose of Base Grouting Soil Conditions



Medium dense silty SAND

Medium stiff lean CLAY and loose to dense sandy SILT

Base Grouting

Compressible Layer

Artesian Layer

### AXIAL RESISTANCE NOTES

- The analyses were performed based on guidelines included in the WSDOT Geotechnical Design Manual (GDM) and local experience. The analyses are based on a single shaft and do not consider group action of shafts spaced closer than 3 diameters, center to center.
- Factored total shaft compression resistance shown on plots is determined by adding nominal side and base resistances multiplied by the corresponding resistance factor.
 

	Service	Strength	Extreme	Extreme - Liquefied
Side Resistance	1.0	0.55	1.0	1.0
Base Resistance	1.0	0.50	1.0	1.0
- Shaft uplift resistance can be estimated by using the nominal side resistance shown above and recommended resistance factor of 0.45 and 0.8 for Strength and Extreme Event conditions, respectively.
- Axial drilled shaft resistance for Migrated Channel and Design Scour conditions may be determined by subtracting the following values from factored total compression resistance determined in the above plots:
 

	Service	Strength	Extreme	Extreme - Liquefied
Migrated Channel	250	140	250	0
Design Scour	1650	920	450	0
- Per the WSDOT GDM, potential liquefaction below a depth of 80 feet was not considered.
- Unfactored downdrag force is estimated to be 2620 kips. Downdrag force is recommended to be applied with post-earthquake loading.
- Estimated shaft resistance assumes that if casing is used, it will be removed after shaft installation.

XL-2042, Snohomish River Bridge to US2 Vicinity Safety and Widening Snohomish County, Washington

PIER 8  
ESTIMATED AXIAL RESISTANCE  
10-FT-DIA. DRILLED SHAFT W/BASE GROUT

December 2010 21-1-21270-005

SHANNON & WILSON, INC.  
Geotechnical and Environmental Consultants

FIG. 13B



# Project Location & Purpose of Base Grouting

## Design Considerations

- More piers with shorter spans:
    1. *Increase number of shafts means increase potential for change conditions,*
    2. *Base grouting was still a likely requirement on more shafts,*
  - Longer shafts that would penetrate through the compressible layer:
    1. *Significant increase in cost and subsurface risks,*
    2. *Artesian effects create difficult drilling conditions,*
- ... Base grouting was the best solution.

# Project Location & Purpose of Base Grouting

## Contract Requirements

### ***Grouting Procedure***

The base grouting process shall be performed in accordance with the grouting criteria set by the Engineer and the following:

1. The Contractor shall survey and record the shaft top elevation.
2. Using the grout pump, fill pump reservoir with water and flush pump lines. Prior to grouting, all u-tube circuits will be flushed with water until clear water is returned, have all air bled out of lines, and valves closed. Valves shall remain closed at all times except during grouting of the u-tube circuit.
4. The contractor shall mix a sufficient amount of neat cement grout. The grout shall be mixed thoroughly with the high efficiency mixer in accordance with manufacturer recommendations.
5. The Contractor shall connect the grout pump to one u-tube and pump cementitious grout with open return side access line until competent grout is returned in return line. Close return line and steadily pump grout into the toe of the shaft until the design grout pressure is sustained for a period of two minutes. This pressure shall be recorded as the maximum sustained shaft base grouting pressure. Fluctuating peak pressures observed at the pump shall not be interpreted as sufficient. Upon completion of grouting a u-tube circuit, the grout pressure shall be released and the valves closed. At this time, the grout source shall be moved to the next grout circuit and the process repeated. The grouting process shall be continuous from the time of commencing.

# Project Location & Purpose of Base Grouting

## Contract Requirements Continued ...

6. A minimum net volume of 5 cubic feet shall be pumped to the toe by the time the design shaft base grouting pressure is achieved to ensure that an artificial pressure is not induced by access line blockage.

### Definitions:

#### **Net Volume**

Total grout volume minus initial grout return during flushing of grout lines, volume in grout lines, and estimated grout volume to fill voids in gravel layer in consideration of drilling fluid and bottom cleanout methods.

7. It may be necessary to perform a second stage grouting operation to meet the design shaft base grouting pressures specified. The second stage of grouting, if needed, shall be performed as stated above and shall be performed sequentially using all of the available u-tubes.

# Project Location & Purpose of Base Grouting

## Contract Requirements Continued ...

The unit contract price per each for “Shaft Base Grouting – Stage 1” shall be full pay for performing the work as specified, including all cost arising from the use of patented devices, materials, or processes used on or incorporated in the Work including costs in association with license agreements and/or royalties, if any, pursuant to standard specification 1-07.20.

### ***Design Base Grout Pressure***

Design shaft base grouting pressures are as follows:

Pier 7 Shafts	350 psi
Pier 8 Shafts	325 psi

# Project Location & Purpose of Base Grouting

## Contract Requirements Continued ...

### ***Termination and Acceptance Criteria***

Grouting operations shall continue until one of the following criteria is achieved, or as specified by the Engineer:

1. The design shaft base grouting pressure is achieved while pumping a minimum net volume of 5 cubic feet to the base of the shaft for a sustained period of two minutes. The intent is to demonstrate that the grout pressure is delivered to the bottom of the shaft, and not an artifact of a blocked grout injection line. If the minimum volume is not met, de-pressurize the system, open the return line, and pump grout through the U-tube circuit to demonstrate that the line is not blocked.
2. The average upward surveyed displacements exceed 0.25 inches. The corresponding pressure shall be recorded as the achieved shaft base grouting pressure. If the design pressure has not been attained when the limiting displacement has been reached, the grout lines shall be fully flushed with clear water, and remedial side shear improvement and/or additional upward reaction steps must be taken. Remedial side shear improvement may consist of jet grouting or compaction grouting around the shaft perimeter. Such remedial steps shall be approved by the Engineer, and base grouting shall resume once these remedial steps have been taken wherein the displacement criteria shall restart



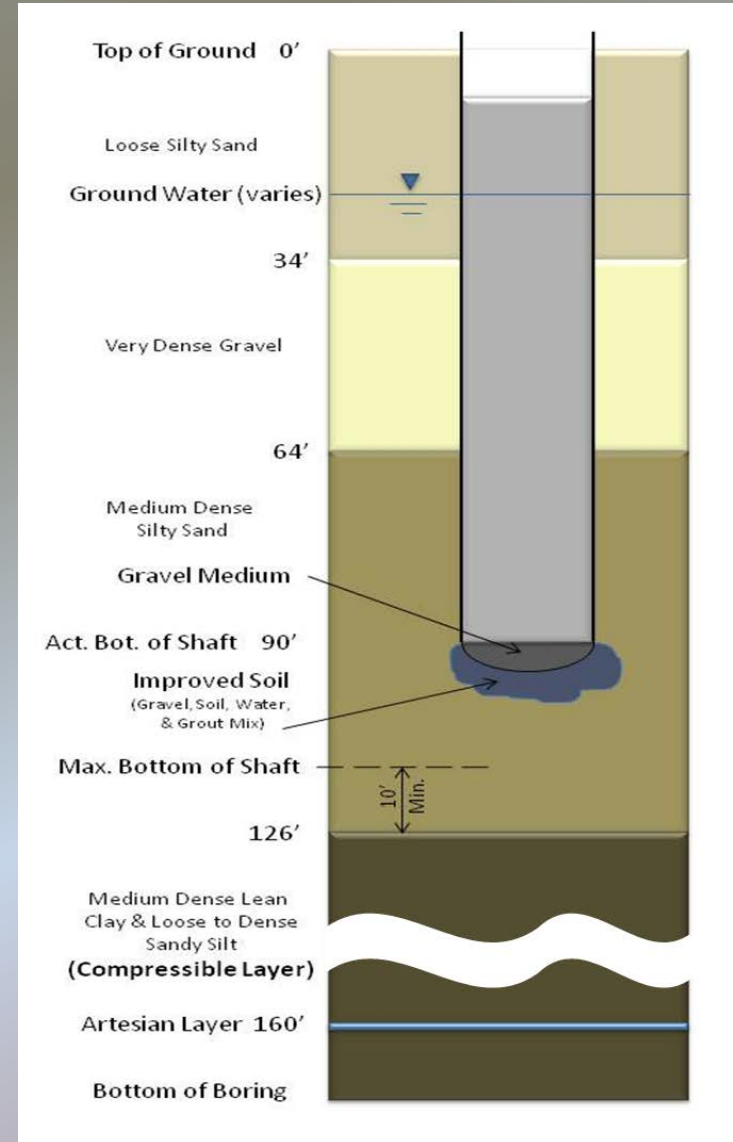
# Project Location & Purpose of Base Grouting

## Contract Requirements Continued ...

3. Should the grout pressure not be achieved by an upper limit net volume of 30 cubic feet while the shaft has not exceeded the upward displacement criterion, one or more of the following approaches shall be taken:
  - a. The grouting can be continued until the design shaft base grouting pressure is achieved. Observations that the pressure is still generally increasing with additional grout volume tend to indicate that this approach is progressing to the design pressure criteria.
  - b. The water to cement ratio can be reduced systematically (increments no greater than 0.04) to the lower end of the specified range, and grouting continued until the design shaft base grouting pressure is achieved.
  - c. A second stage of grouting can be performed by opening the return line, and circulating fresh grout through the u-tube currently being grouted to keep it open (free of set grout) while grout from the first stage injected below the shaft base attains an initial set sufficient to build pressure with the subsequent stage (30 minutes minimum after completion of stage 1 grouting). The return line can then be closed, and further grouting may continue until the design shaft base grouting pressure is achieved.
  - d. The grout lines can be fully flushed with clear water before initial set of the grout from the first stage of grouting. A second stage of grouting can then be performed using all of the available u-tubes after initial set of the grout from the first stage of grouting (4 hours minimum after completion of stage 1 grouting). Each of the U-tubes shall be grouted in sequence in an attempt to achieve the design shaft base grouting pressure in each of the grout circuits.

# Shaft & Base Grouting Construction

- Contractor's Selected Method
- Construction Challenges
- Final Product & Monitoring



# Shaft & Base Grouting Construction

## Contractor's Selected Method

The tube-a-manchette, also referred to as a sleeve-port method, was a contract requirement.





# Shaft & Base Grouting Construction

## Contractor's Selected Method





# Shaft & Base Grouting Construction

## Construction Issues ~ Monitoring

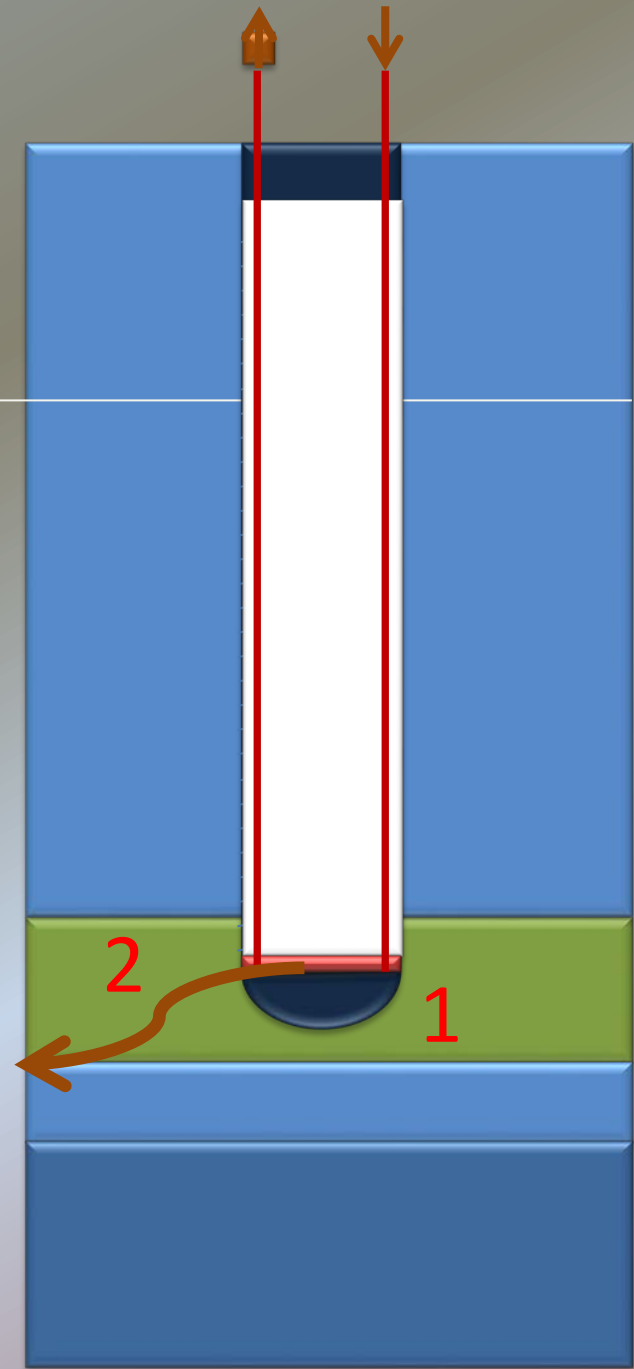




# Shaft & Base Grouting Construction

## Construction Challenges

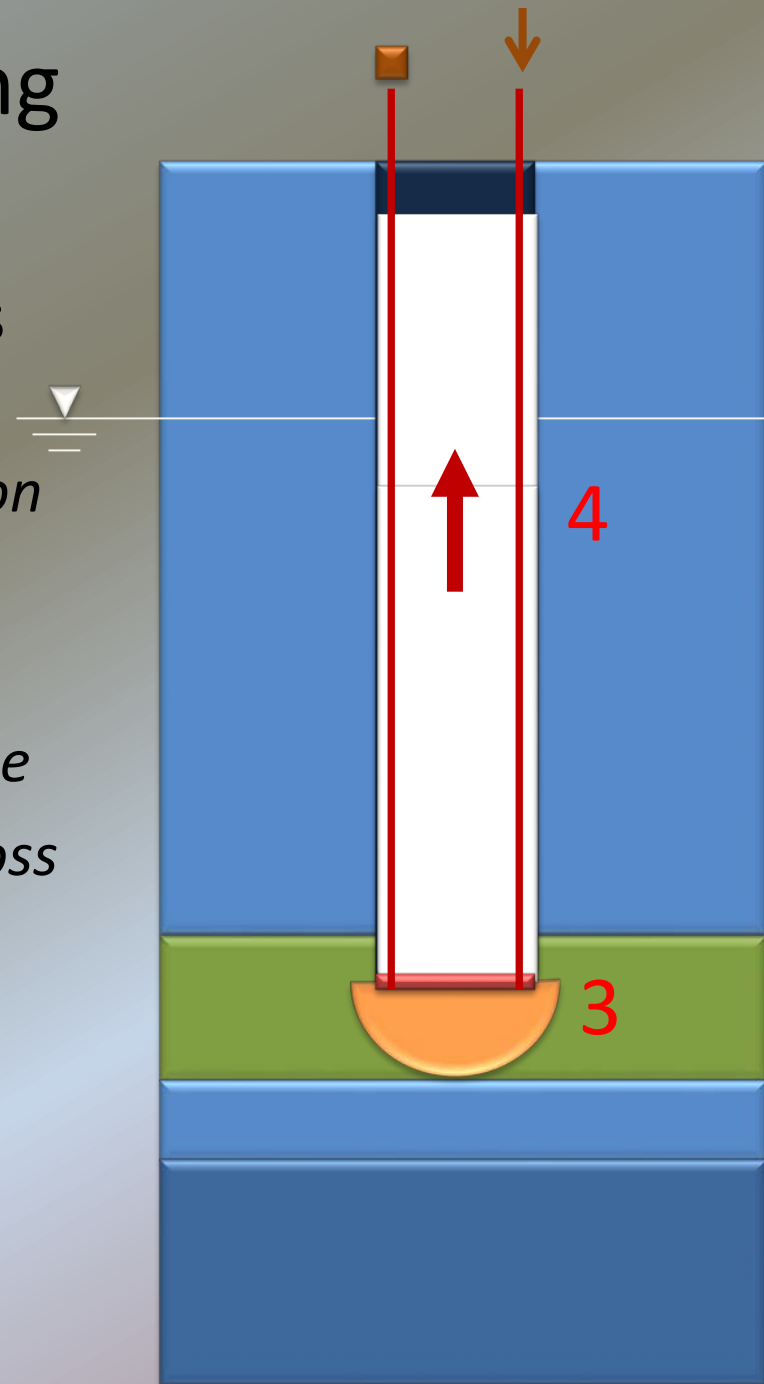
1. *Amount of base excavation*
2. *Hydro-Fracture; Loss of grout*



# Shaft & Base Grouting Construction

## Construction Challenges

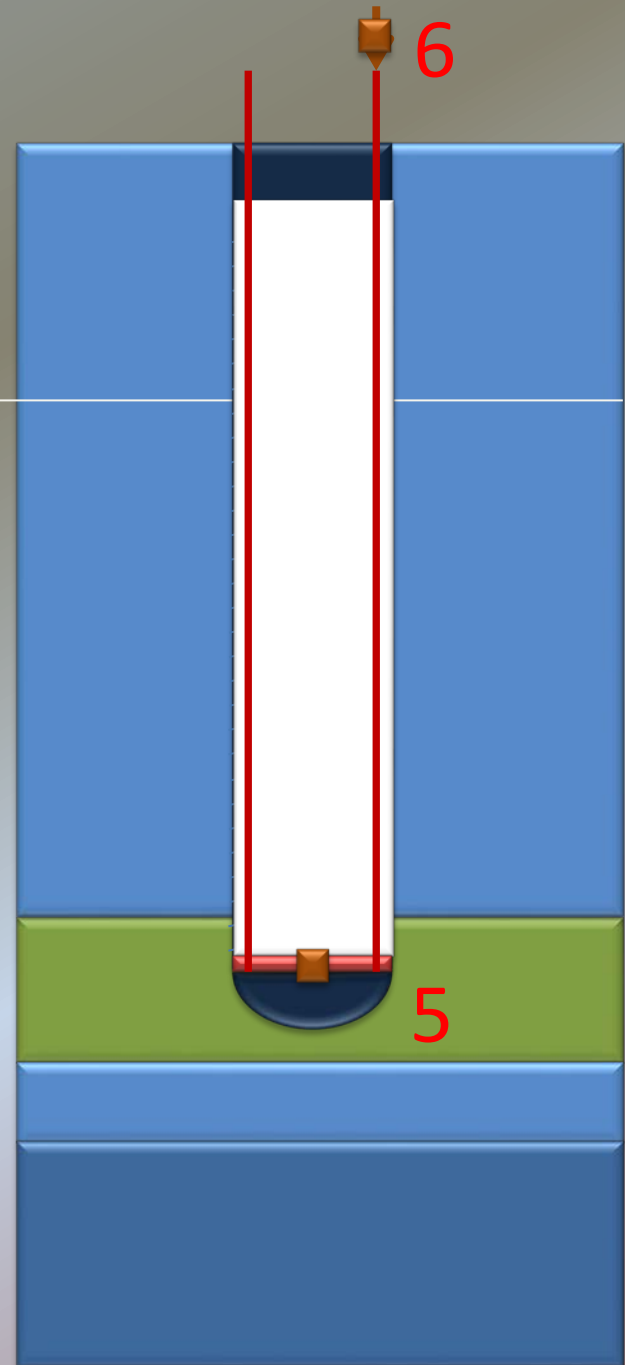
1. *Amount of base excavation*
2. *Hydro-Fracture; Loss of grout*
3. *Grout take; pre-net volume*
4. *Excessive Displacement; loss of skin friction*



# Shaft & Base Grouting Construction

## Construction Challenges

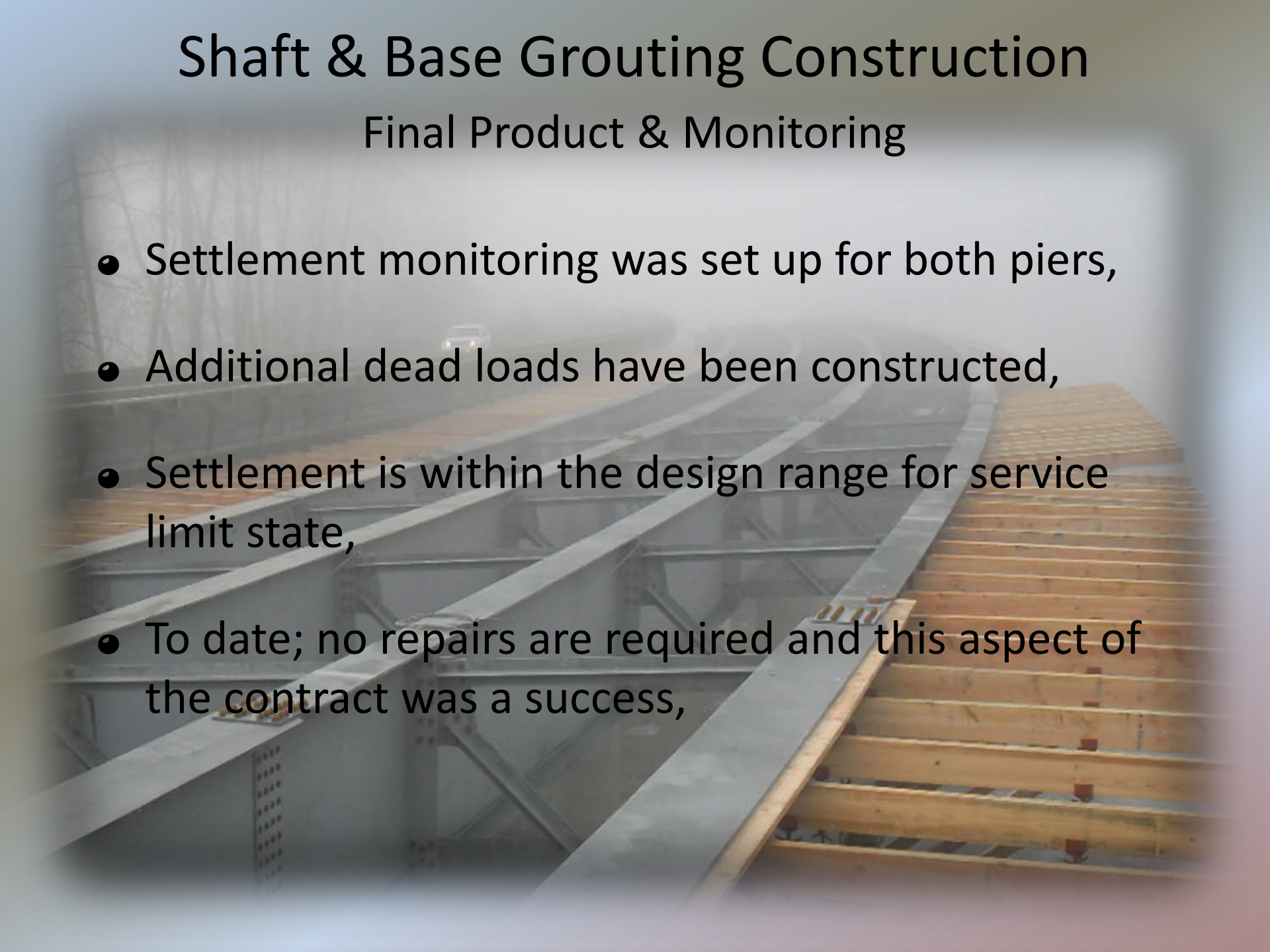
1. *Amount of base excavation*
2. *Hydro-fracture; Loss of grout*
3. *Grout take; pre-net volume*
4. *Excessive displacement; loss of skin friction*
5. *Plugged perforations or block in gravel medium*
6. *Grout mix, plugged lines, or grouting duration causing grout build-up*



# Shaft & Base Grouting Construction

## Final Product & Monitoring

- Settlement monitoring was set up for both piers,
- Additional dead loads have been constructed,
- Settlement is within the design range for service limit state,
- To date; no repairs are required and this aspect of the contract was a success,



# Lessons Learned

- Roles & Responsibilities
- Specification Requirements
- Base Grouting Submittal Requirements





# Lessons Learned

## Roles & Responsibilities

**Contractor** ~ wants to provide a quality product, reduce costs, and reduce risk whenever possible.

**Project Engineer** ~ wants to stay on time and budget, reduce impacts to the public, and ensure the contract is being followed.

**Designer** ~ wants product built as expected; without changes, issues, or repairs.

**Geotechnical Engineer** ~ wants to ensure proper techniques are followed, and validate that design assumptions are correct.

... follow established special provision protocol of assigned risk and requirements

# Lessons Learned

## Specification Requirements

- Delivery system:
  1. *Batch plant, tube-a-manchette system, and redundancy, including process description,*
  2. *Grout volumes to fill line, fill gravel medium, and fill to volume/pressure limit,*
  3. *Washout process of lines to protect base grouting,*
- *Displacement measuring system and what happens at specific movement limits,*
- Grout volume limits (Stage 1 & Stage 2) vs. grout pressure limits; these are dependent of each other and the construction process,

# Lessons Learned

## Base Grouting Submittal Requirements

- The Contractor's selected process is rarely what you think it is going to be. Even using the same contractor, the process will change over time as they learn from good and bad experiences.
- Detailed list of process, identifying each step, and discussions of various issues that may arise and how they will deal with them.
- Pre-construction conference to talk through process with all the participants. Have an open discussion, but keep responsibility for decision on the Contractor, to meet contract requirements.



# Questions?

