King County
Department of Transportation

HNTB

Sunken Caisson Foundations for South Park Bascule Bridge

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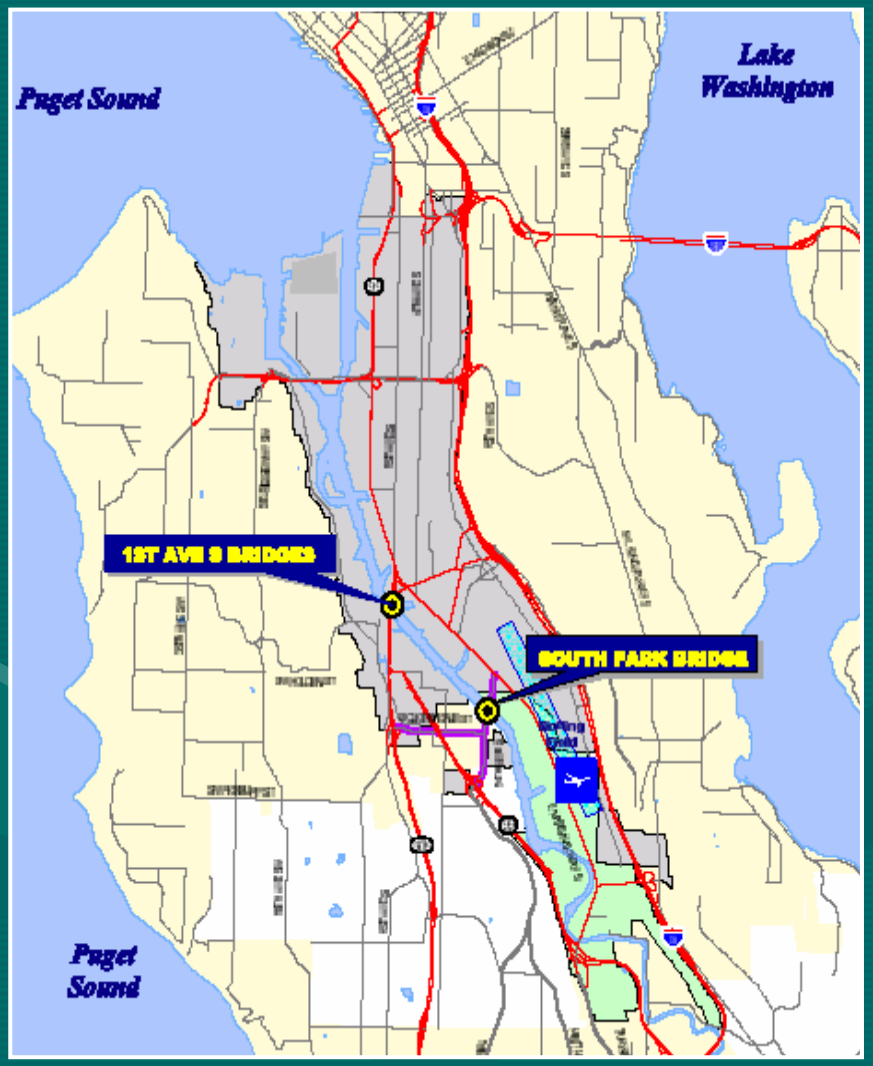
Outline

1. Existing Bridge
2. Replacement Bridge
3. Seismicity and Seismic Design Criteria
4. Drilled Shaft vs. Sunken Caisson
5. Factors Affected the Decision
6. Caisson Construction Sequence
7. Design Status
8. Questions/Answers

Bridge Location



- Located in South Seattle across Duwamish Waterway.
- Subsurface consists of silty sand fill in upper regions and underlain by very soft to medium stiff clay.
- Soils are contaminated.
- The area has been subjected to numerous earthquakes of magnitude up to 6.8 in the Richter Scale (2001 Nisqually Earthquake)

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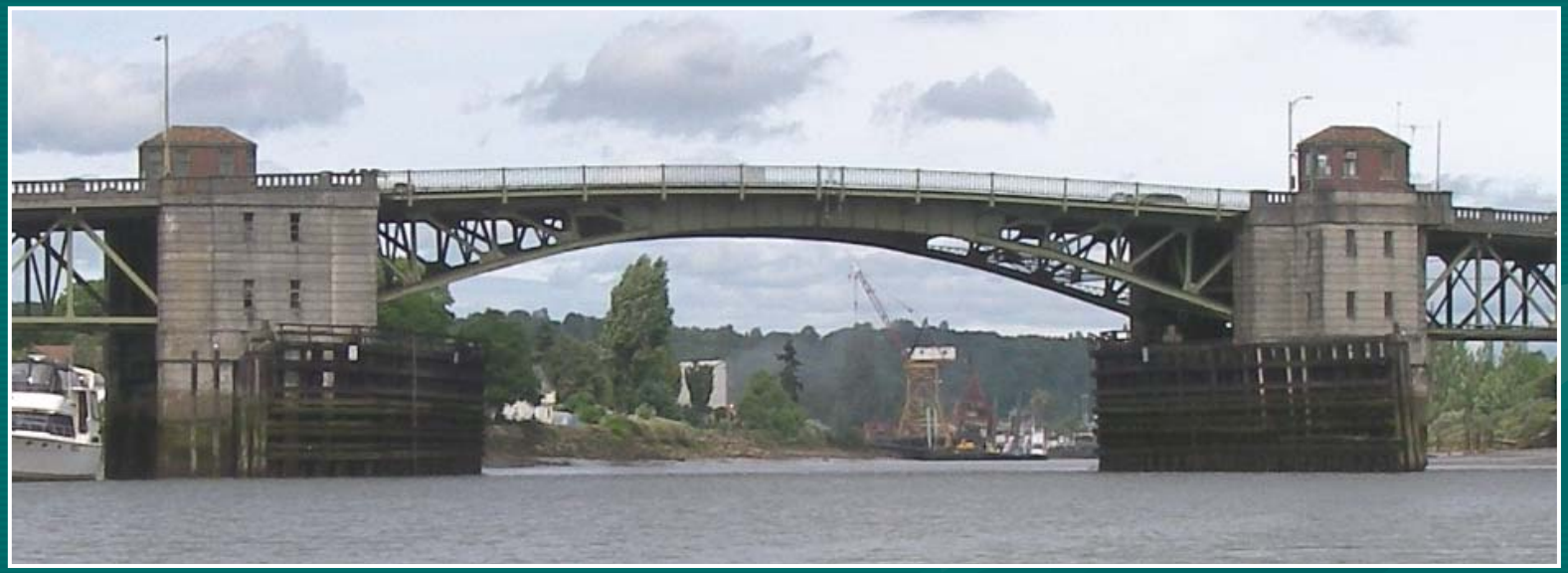
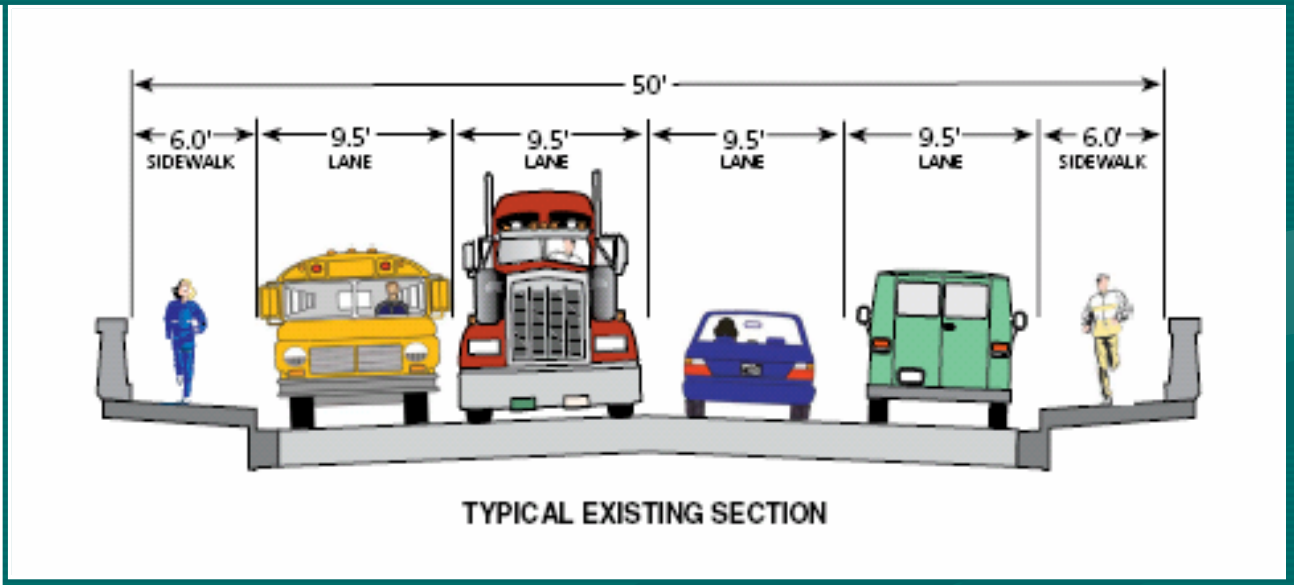
Existing Bridge



- Double-leaf bascule bridge with truss deck approaches
- Scherzer rolling-lift bridge
- Constructed in 1929-1931
- The bridge was constructed for $482,000

Existing Bridge Configuration



TYPICAL EXISTING SECTION

- Four-lane road with two lanes in each direction
- Substandard 9.5-foot lane width
- Open-grate deck on moveable span

Historic Features

National Register of Historic Places (1982)

Control Tower

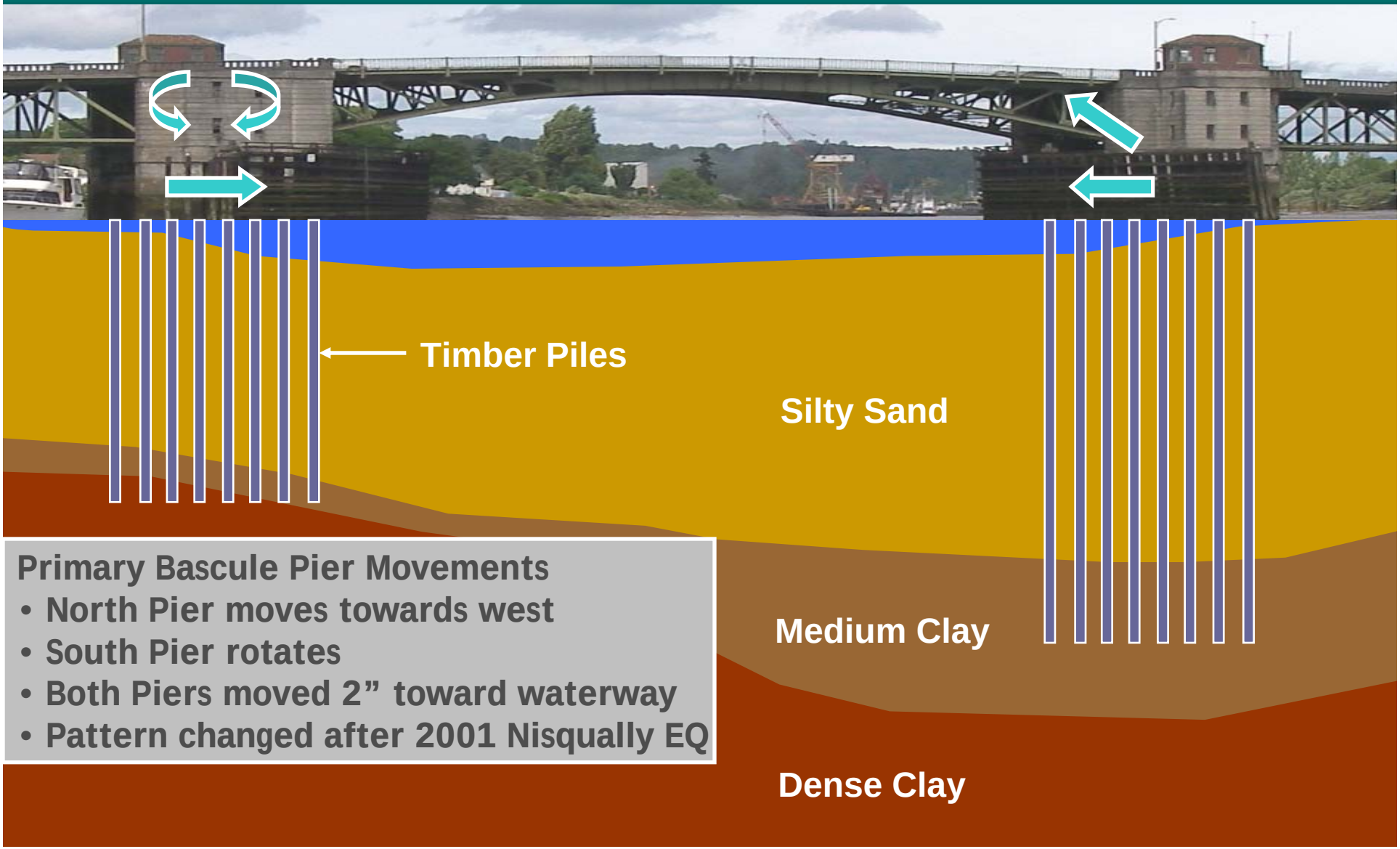
Guide Track & Rocker

Red-Brick Road

Existing Bridge Foundation

South Bascule Pier

North Bascule Pier

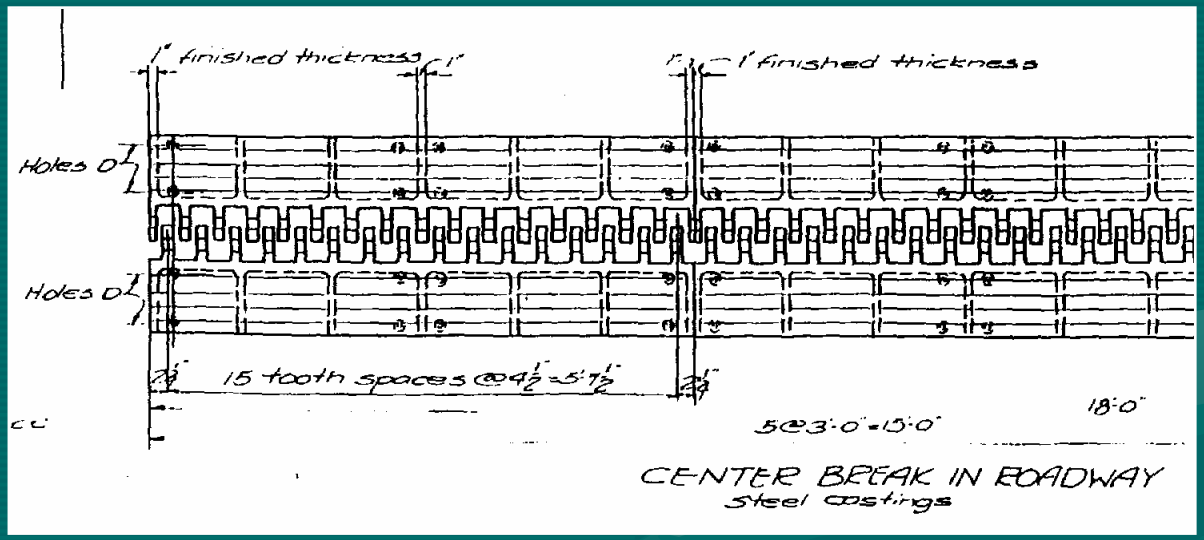


Primary Bascule Pier Movements

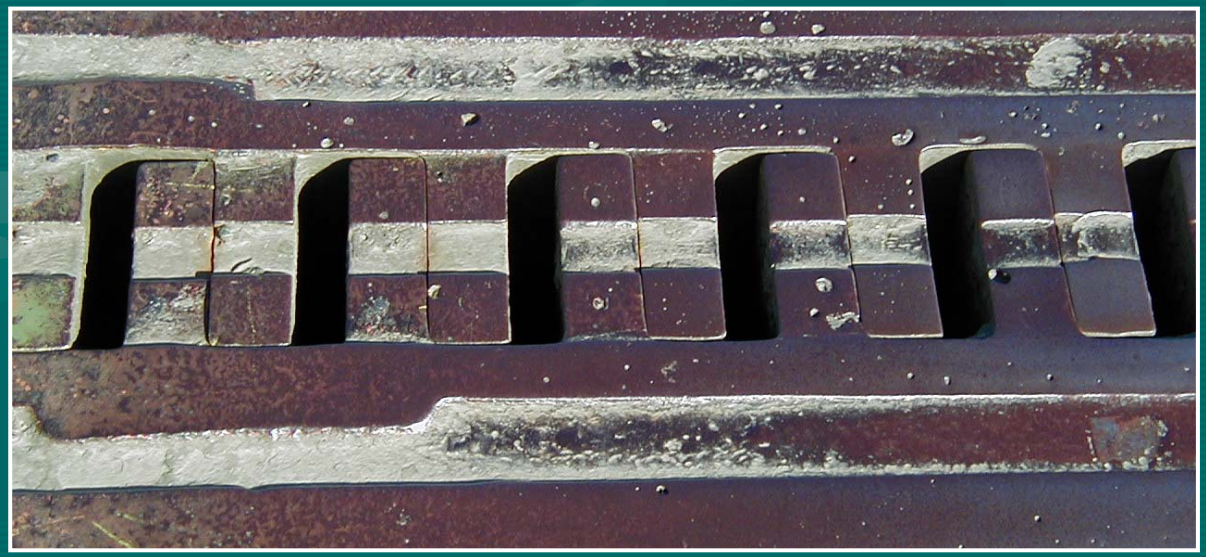
- North Pier moves towards west
- South Pier rotates
- Both Piers moved 2” toward waterway
- Pattern changed after 2001 Nisqually EQ

Leaf Misalignment

Teeth as designed



Teeth after Nisqually Earthquake



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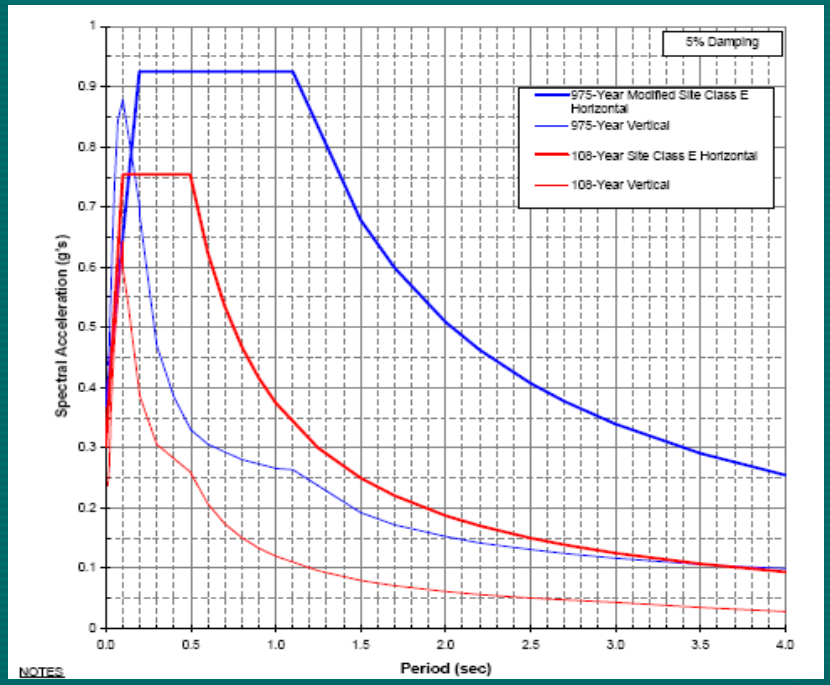
Replacement Bridge

- A double-leaf bascule movable bridge
- Wider four 11-foot traffic lanes
- A pedestrian / bicycle pathway on each side
- Architectural features of existing bridge
- State-of-the-art electrical control and mechanical drive
- Solid deck for a better driving surface and drainage treatment
- Minimum disruption after earthquakes

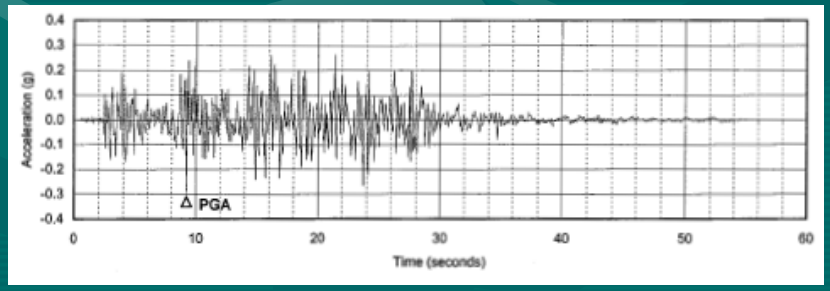
Seismic Parameters

- Two-Level Earthquake Design
  - Operational Earthquake - 108 Year Event
  - Design Earthquake - 975 Year Event
- Bridge Importance “Essential”
- Seismic Performance Zone 4
- Site Class “E”

Ground Motions



- Site-specific response spectra for two levels of earthquakes were developed by Shannon & Wilson, Inc.



- Spectrum-compatible time histories were developed by Earth Mechanics, Inc.

Governing Seismic Criteria

- AASHTO "LRFD Movable Highway Bridge Design Specifications," 2nd Edition, 2007 with 2008 Interims.
- AASHTO "AASHTO LRFD Bridge Design Specifications," customary U.S. units, 4th Edition, 2007 with 2008 Interims.
- WSDOT "Bridge Design Manual LRFD," May 2008.

Choice of Foundation Type

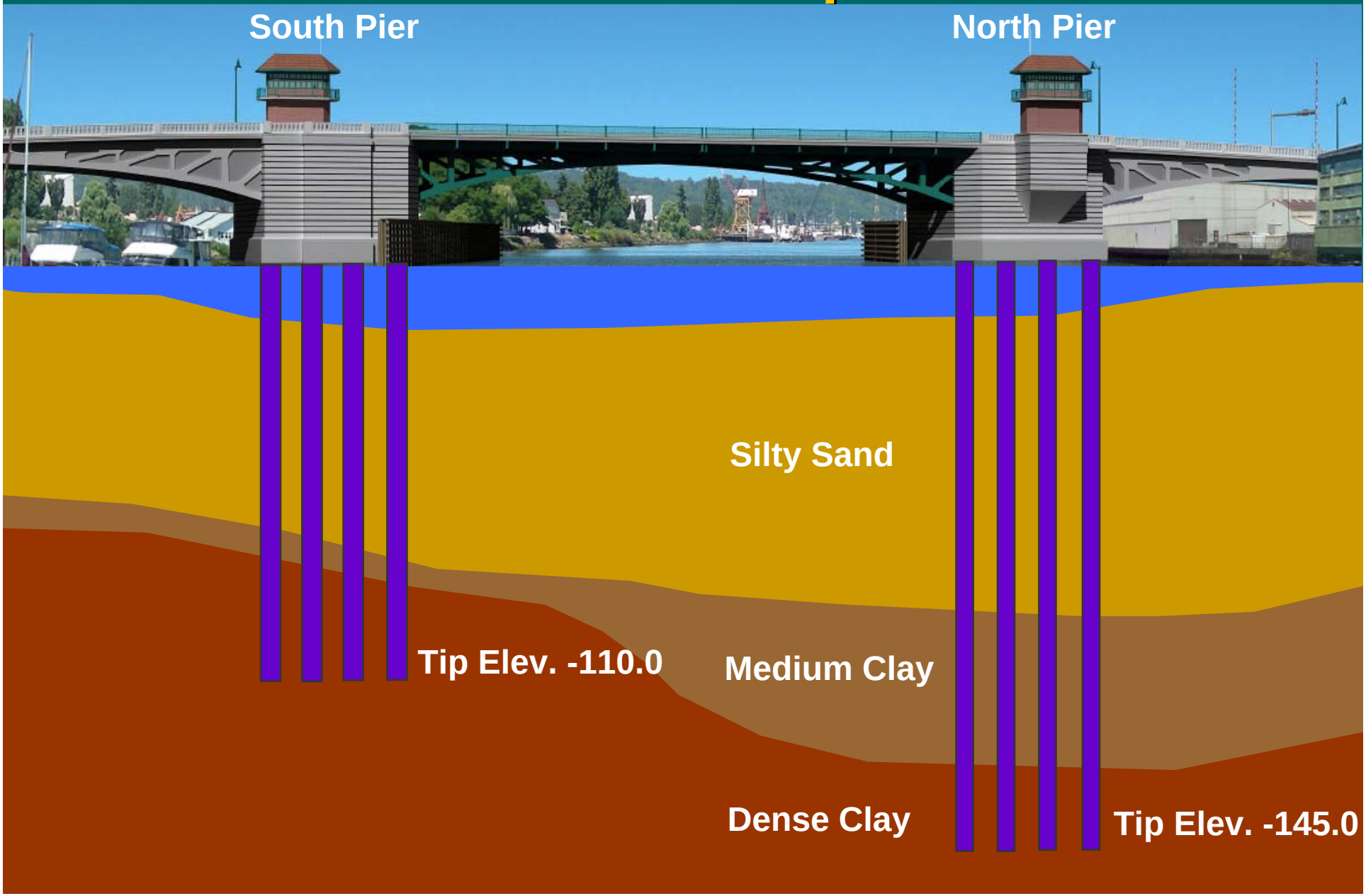
Courtesy of Malcolm

Drilled Shaft or Sunken Caisson

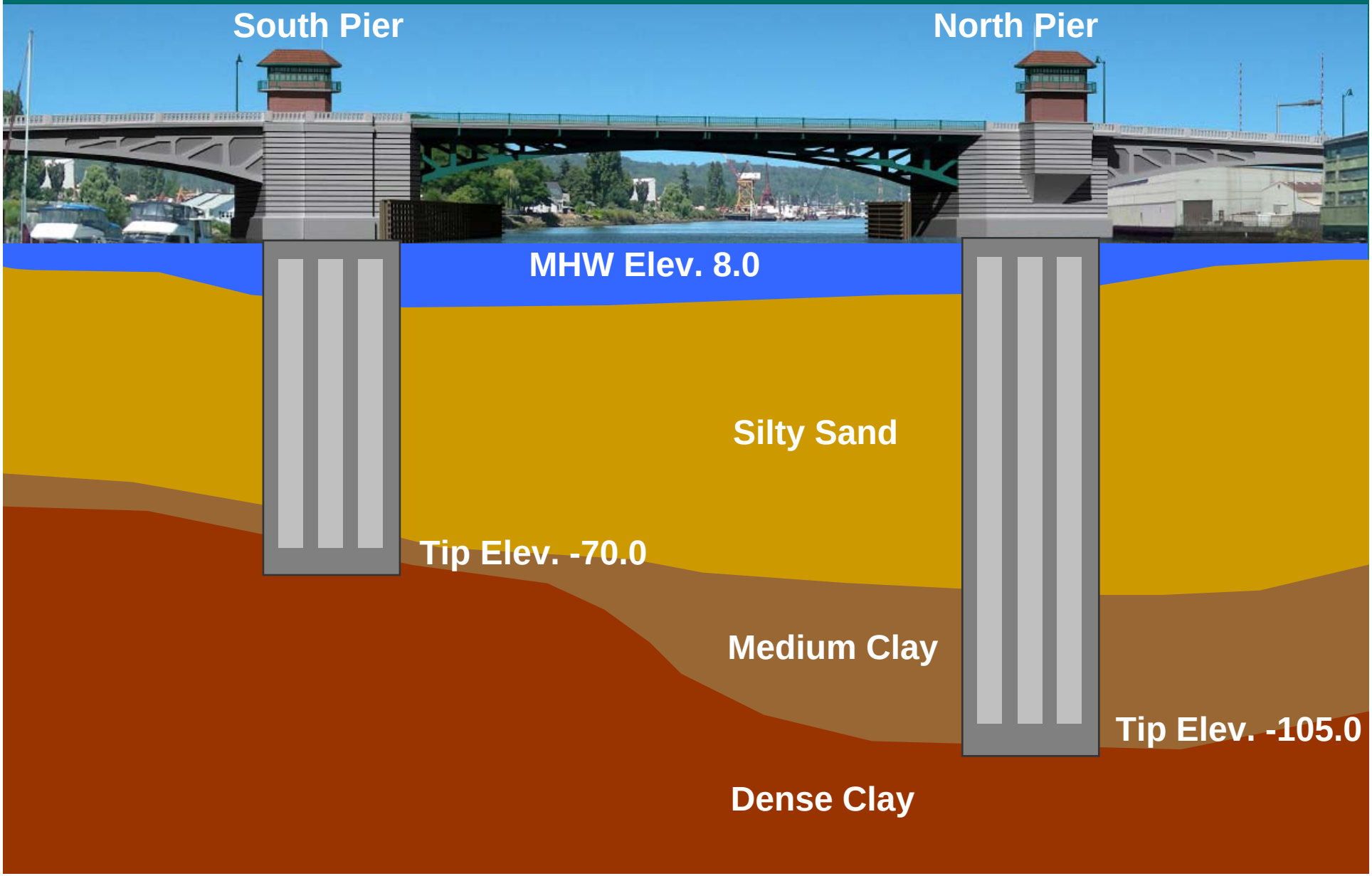
Caisson Foundation

- Improves seismic performance
- Reduces construction schedule
- Minimizes environmental impacts
- Reduces cost

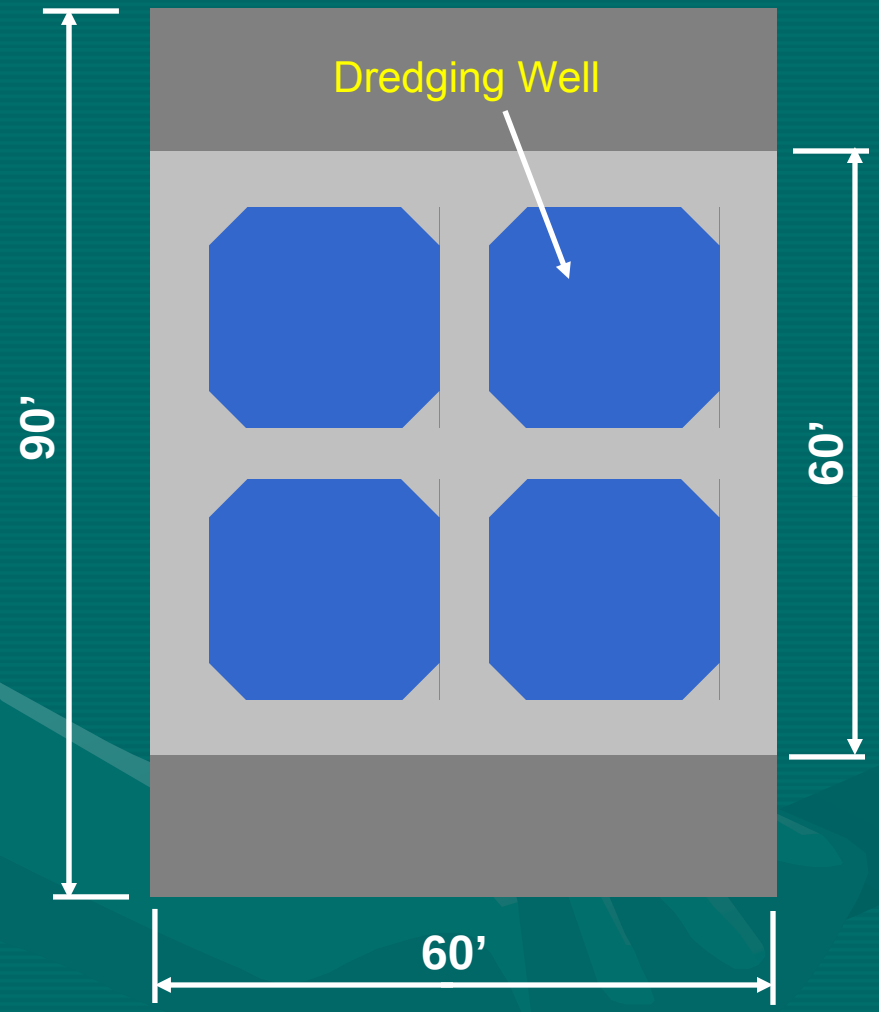
Drilled Shaft Option



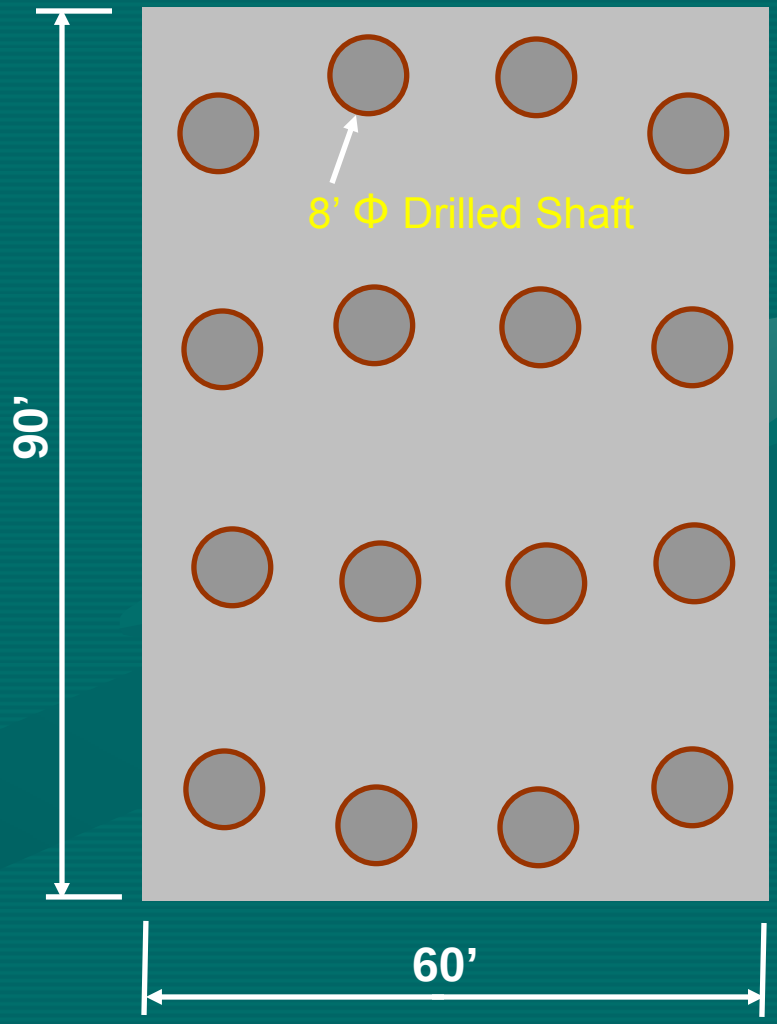
Caisson Option



Cross Sections

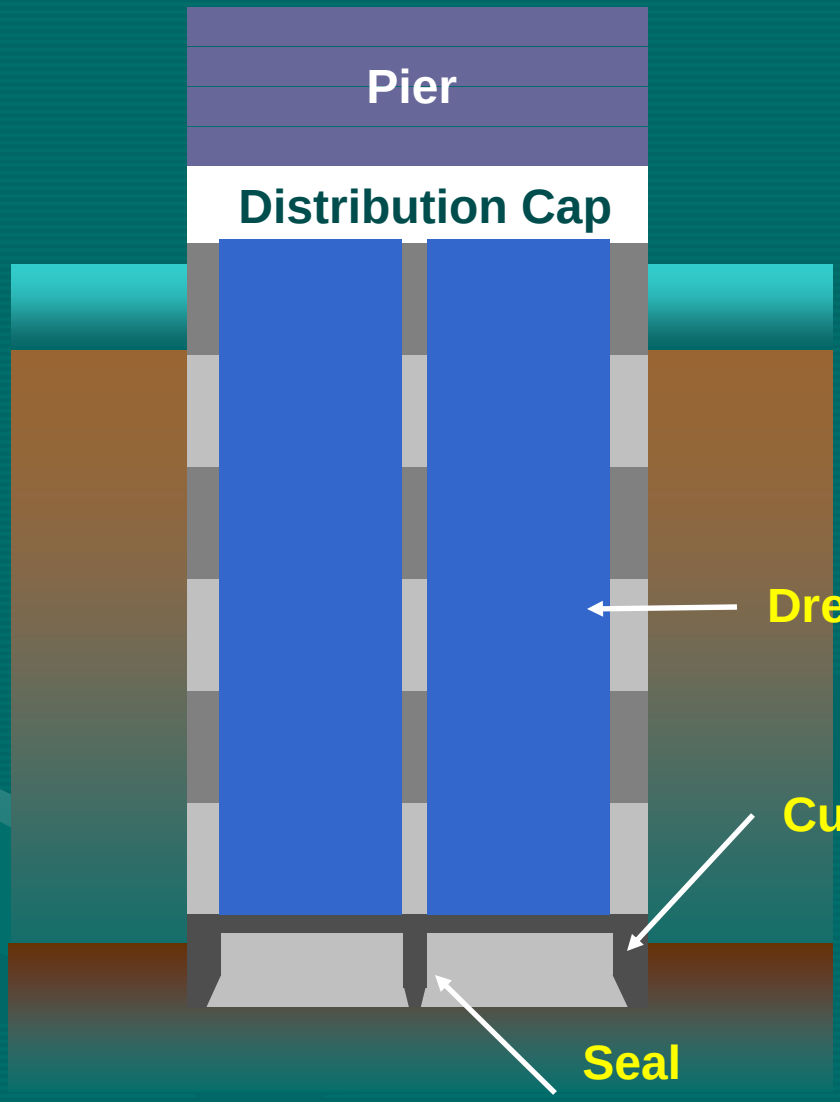


Caisson



Shaft

Caisson Elevation



Top of Cap Elev. 0.0’

Mudline Elev. -15.0

Dredging Well

Cutting Edge

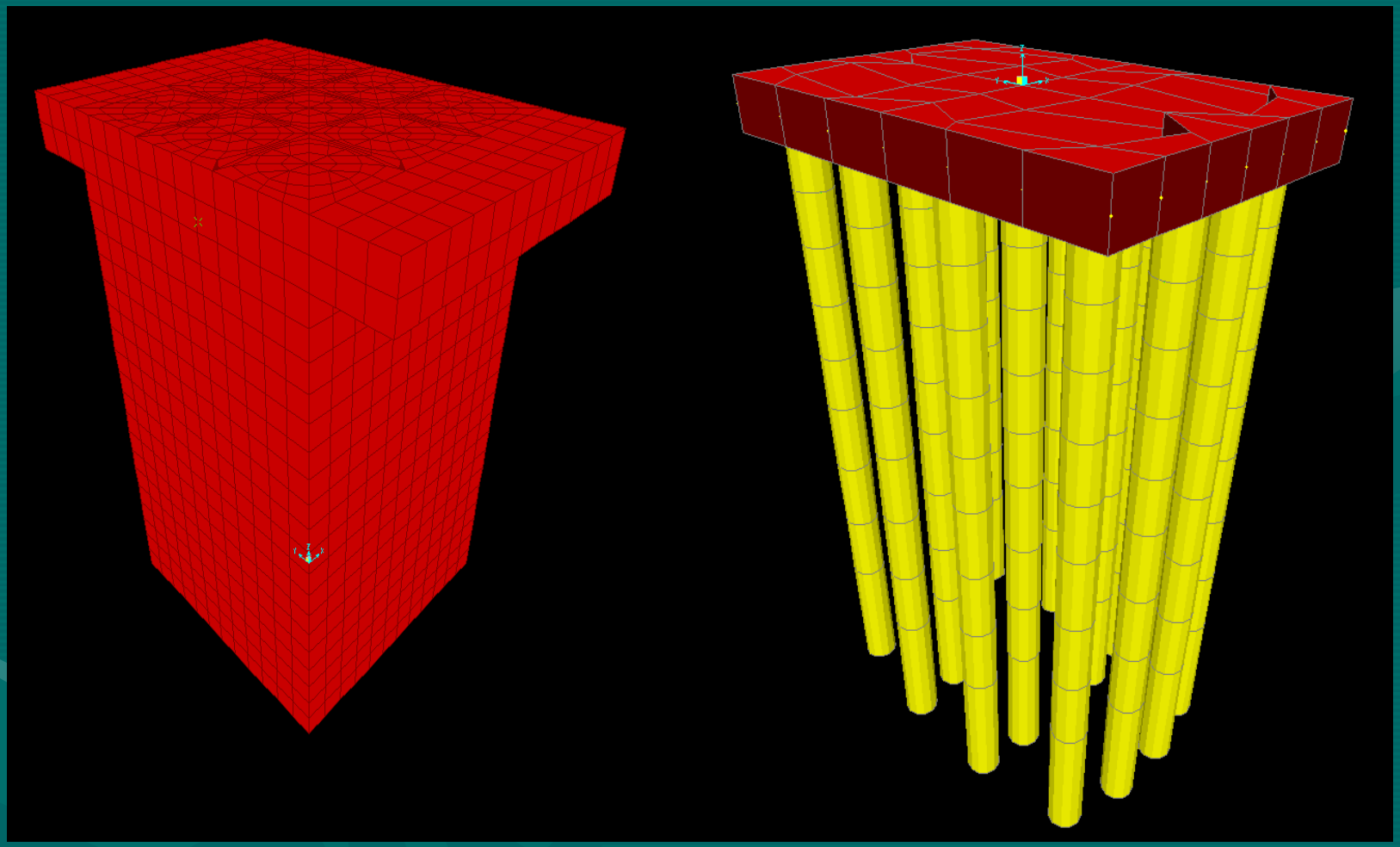
Tip of Caisson Elev. -105.0

Seal

Seismic Performance

- Created stand-alone models for both caisson and shaft foundations using SAP2000
- Used elasto-plastic springs for soil-structure interactions
- Applied static seismic loads and compare deflections
- Performed push-over analyses
- Compared the predicted seismic performances

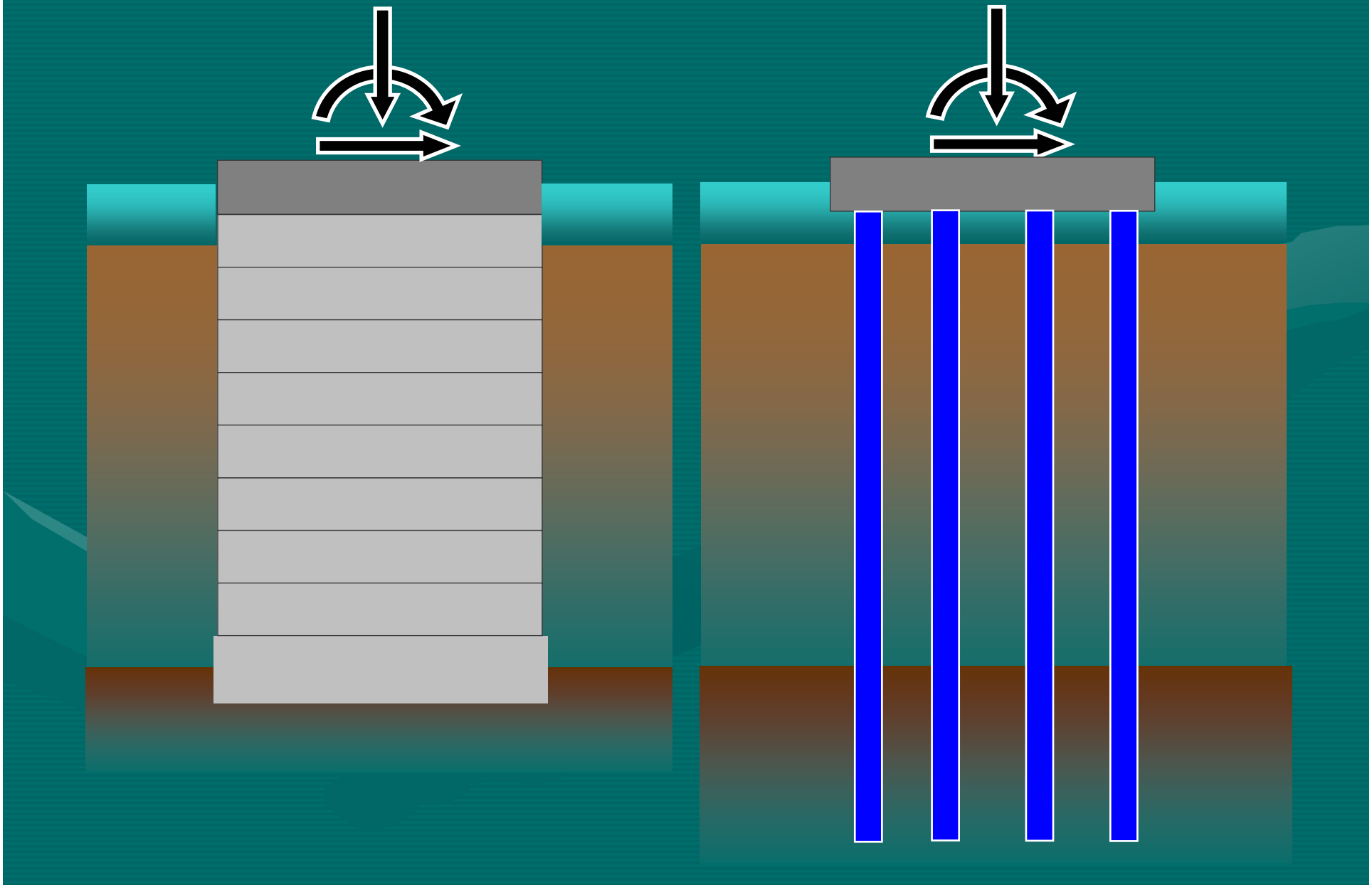
SAP 2000 Models



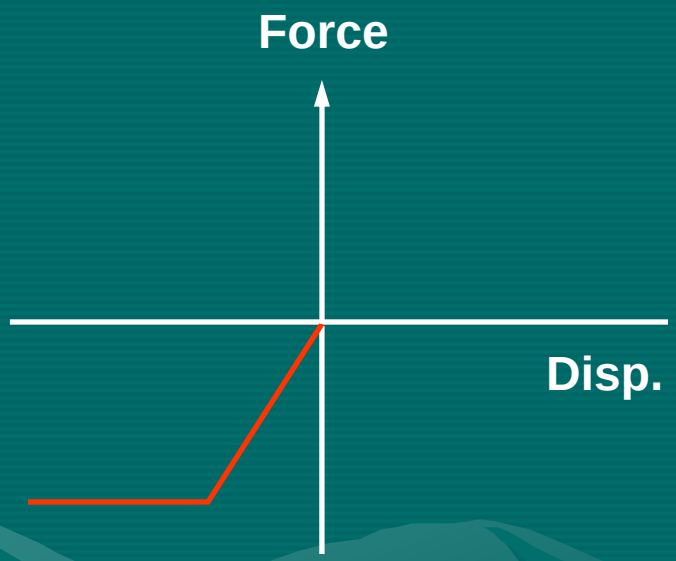
Caisson

Shaft

Applied Loads

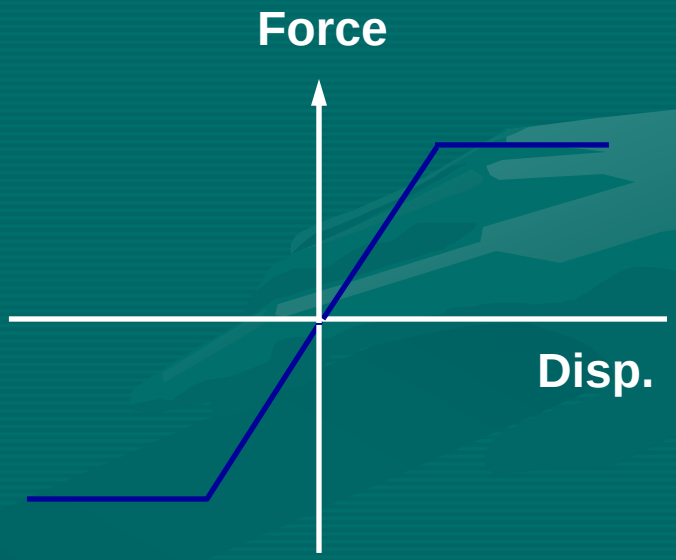


Elasto-Plastic Springs



Bearing Spring

Passive Pressure Spring

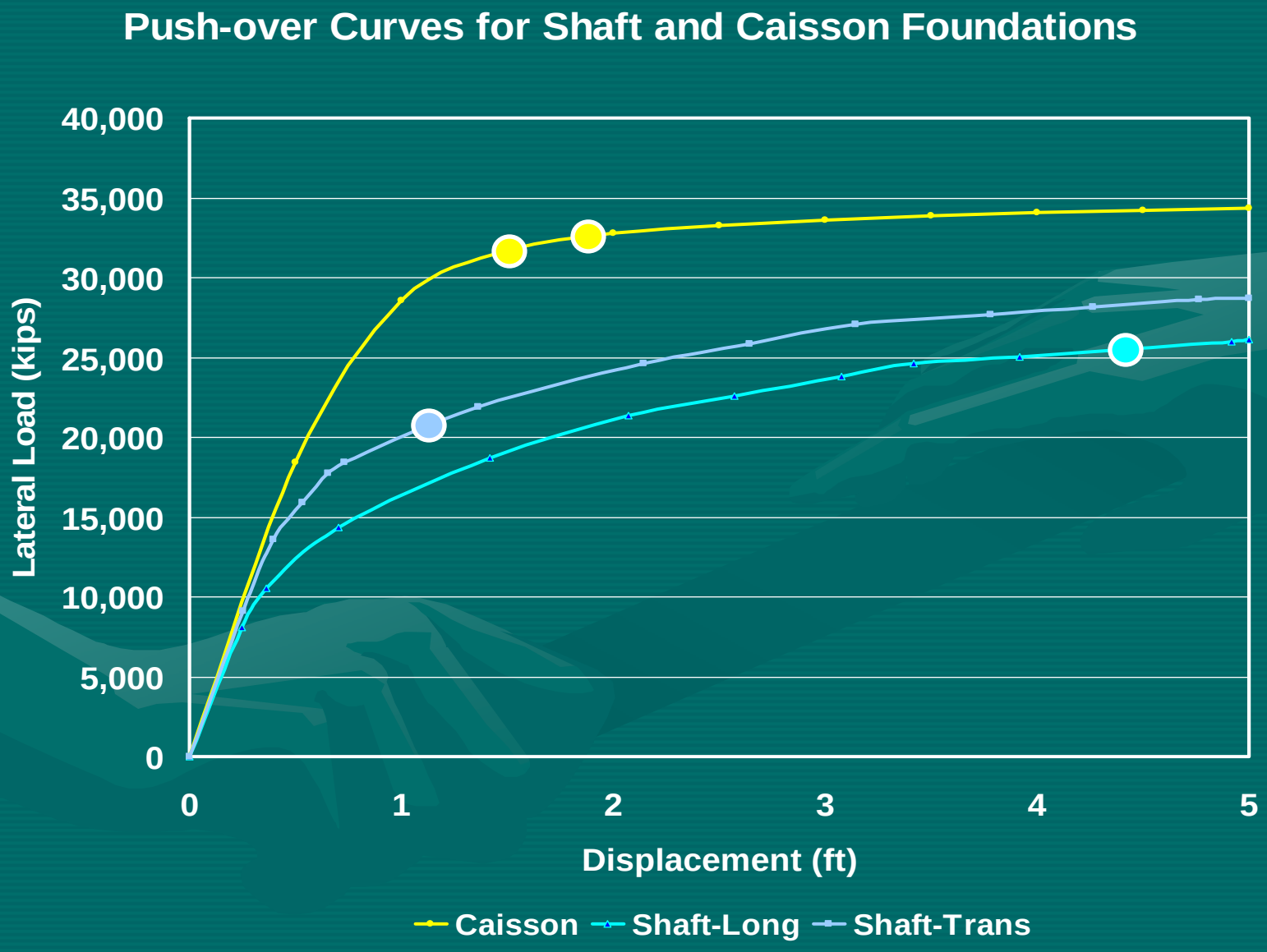


Friction Spring

Analysis Results

	Load Case	Long Disp	Trans Disp	Long Rotation	Trans Rotation
Caisson	Max Long	1.92’	0.27”	1.06°	0.16°
	Max Trans	0.27’	1.54’	0.15°	0.86°
Shaft	Max Long	4.48’	0.42’	2.37°	0.25°
	Max Trans	0.33	1.14’	0.13°	0.23°

Analysis Results



Seismic Performance

- Caisson option exhibits a stiffer behavior for lateral loading and results in smaller displacements
- Caisson option provides a more balanced behavior in longitudinal and transverse directions
- Caisson option is less likely to have a residual displacement after an earthquake
- Small displacement is better for the machinery during an earthquake and easier for repair after an earthquake

Other Considerations

- Environmental impact
- Economy
- Constructability
- Construction schedule
- Construction risk

Environmental Impact

- Volume of contaminated soils
- Volume of disturbed soils
- Noise during construction
- Vibration during construction
- Footprint of work bridge
- Daily construction equipment usage
- Number of workers commuting to site per day
- Fish considerations
- Endangered species

Economy

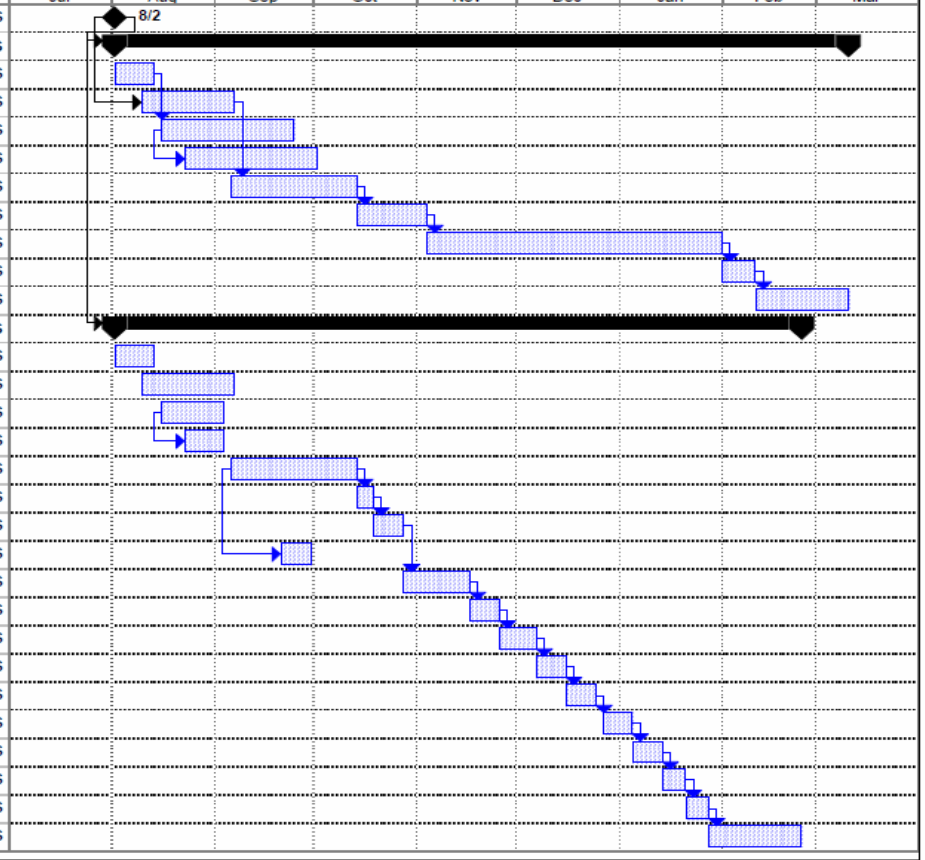
South Park Bridge - Gross Relative Quantities for North Bascule Foundation

	Item	Unit	Unit Price	Caisson Option		Shaft Option	
				Quantity	Cost	Quantity	Cost
1	Cofferdam	SF	$ 35	28,520	$998,000	23,100	$809,000
2	Caisson Cap / Pile Cap	CY	$ 450	1,987	$894,000	1,987	$894,000
3	Concrete Seal	CY	$ 225	2,136	$481,000	613	$138,000
4	Caisson Concrete	CY	$ 500	6,303	$3,151,000		$0
5	Shafts Concrete	CY	$ 300		$0	3,593	$1,078,000
6	Shaft Excavation	CY	$ 450		$0	3,721	$1,675,000
7	Caisson Excavation	CY	$ 100	13,600	$1,360,000		$0
8	Placing Permanent Casing for Shaft	EA	$ 2,500		$0	16	$40,000
9	Shaft Casing	LB	$ 1.25		$0	4,088,562	$5,111,000
10	Caisson Cutting Edge Steel	LB	$ 2.00	266,000	$532,000		$0
11	Dredge Well Backfill	CY	$ 30	5,359	$161,000		$0
12	Temporary Trestle and Drill Platform	LS	$ 937,500			1	$938,000
13	Temporary Trestle	LS	$ 525,000	1	$525,000		$0
14	Sand Island	CY	$ 50	5,281	$264,000		$0
15	Barge Usage	DAY	$ 10,000	50	$500,000		$0
16	Removal of Contaminated soils	CY	$ 50	2,136	$107,000	447	$22,000
17	Steel Reinforcement	LB	$ 1.25	1,243,484	$1,554,000	837,035	$1,046,000
	Total				$10,500,000		$11,800,000

Construction Schedule

South Park Bridge - Estimated Construction Schedule of North Bascule Foundation

ID	Task Name	Duration
1	1st Year In Water Construction	0 days
2	**Drilled Shafts**	**159 days**
3	Partially Remove Fender	10 days
4	Compaction Grout - North Pier	20 days
5	Drive Steel Piles for Trestle & Platform	30 days
6	Construct Trestle and Plat form Deck	30 days
7	Construct Cofferdam	28 days
8	Foundation Excav.	15 days
9	Const. 8 ft Diam. Shafts	63 days
10	Pour Seal	8 days
11	Construct Footing	20 days
12	**Sunken Caisson**	**149 days**
13	Partially Remove Fender	10 days
14	Compaction Grout -North Pier	20 days
15	Drive Steel Piles for Trestle	15 days
16	Construct Trestle form Deck	10 days
17	Construct Cofferdam	28 days
18	Backfill Cofferdam w/ Sand	3 days
19	Install Cutting Edge	7 days
20	Set Dredge Equipment	7 days
21	Cast & Dredge Seg 1 &2	14 days
22	Cast & Dredge Seg 3	7 days
23	Cast & Dredge Seg 4	7 days
24	Cast & Dredge Seg 5	7 days
25	Cast & Dredge Seg 6	7 days
26	Cast & Dredge Seg 7	7 days
27	Cast & Dredge Seg 8	7 days
28	Clean and Install Seal	5 days
29	Backfill Dredge Wells	5 days
30	Cast Distribution Cap	20 days



Project: VE -Caisson-Trestle .mpp
Date: Sat 10/11/08

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

Note: Schedule for drilled shaft option was obtained from PB preliminary design.

Sat 10/11/08

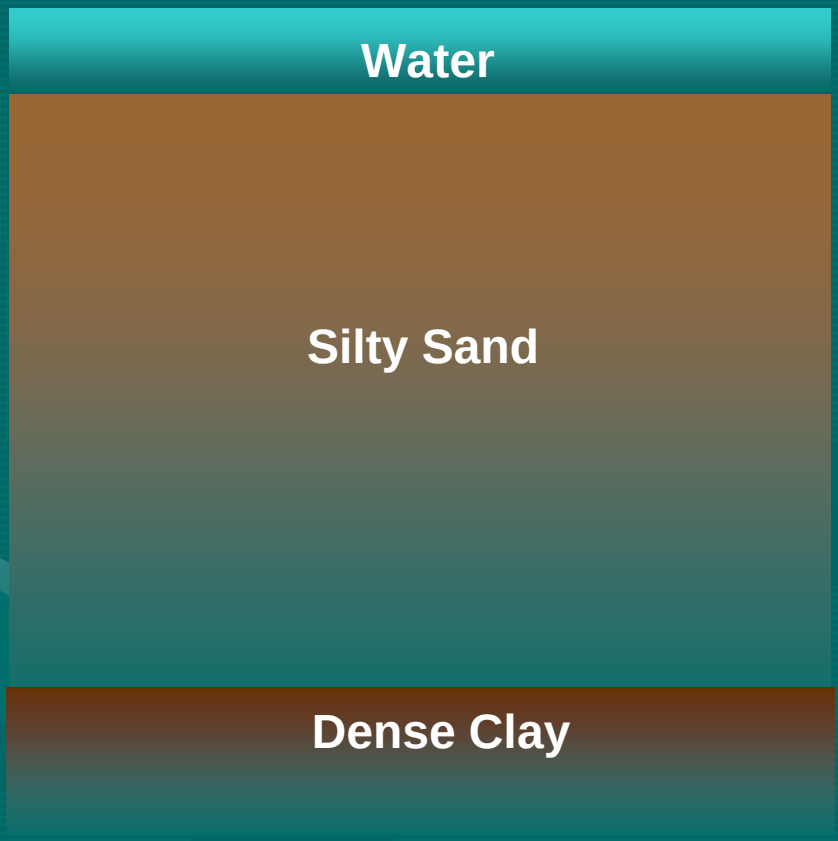
Construction Risks

- Steel prices for steel casing
- Effects of drill vibration on existing bridge
- Caisson may tilt during sinking
- Soil outside caisson may cave during excavation and thus impair existing bridge
- Driving deep cofferdams
- Obstacles during shaft drilling and caisson sinking
- Contractors experience with caisson and large drilled shafts
- Cost escalation for material and labor

Evaluation Matrix

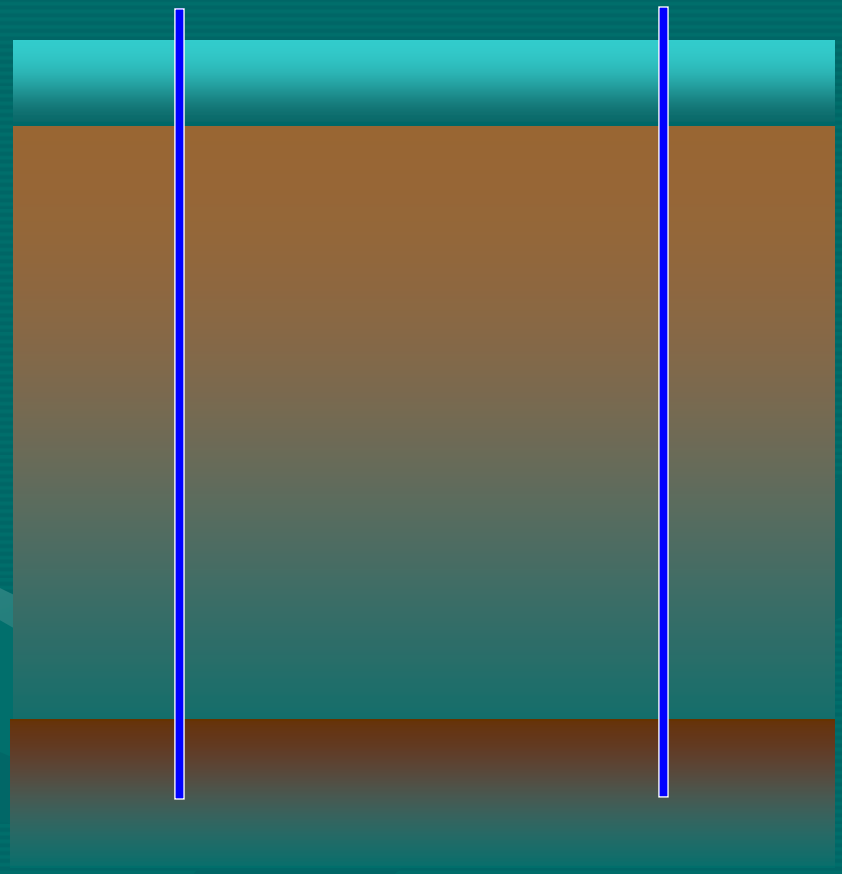
		Caisson		Shaft	
Considerations	Weight	No Weight	Weighted	No Weight	Weighted
1. Seismic Performance	30	9	2.6	5	1.6
2. Environmental Impact	20	7	1.4	6	1.1
3. Cost	20	8	1.5	6	1.1
4. Constructability	10	8	0.8	5	0.5
5. Construction Schedule	10	8	0.8	5	0.5
6. Risk	10	6	0.6	5	0.5
Total	100	45	7.7	33	5.5

Construction Sequence



Soil Profile

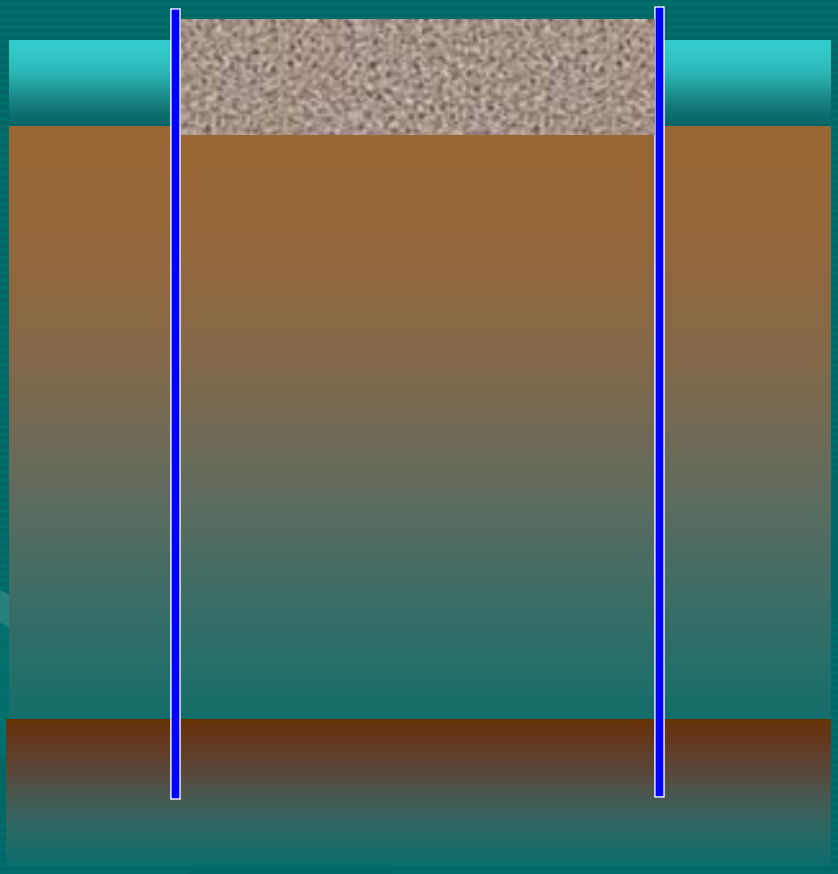
Construction Sequence



Stage 1:

Construct sheet pile cofferdam

Construction Sequence

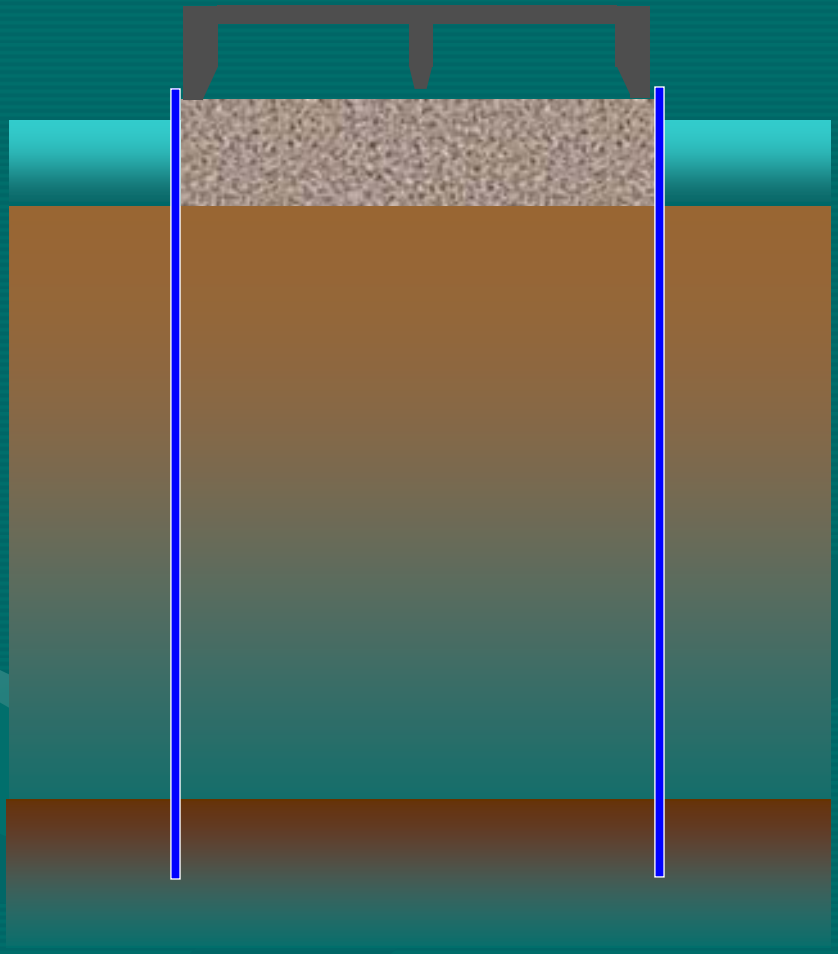


Stage 2:

Dredge the river

Place sand into cofferdam to create a sand island

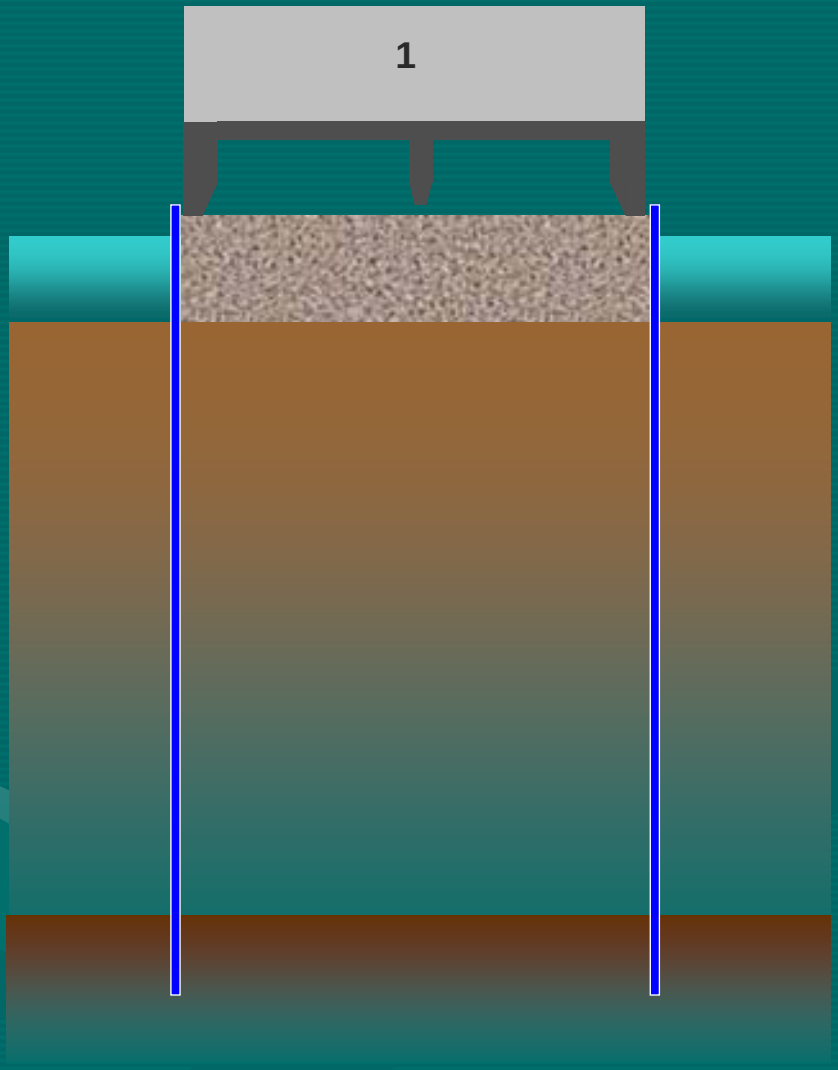
Construction Sequence



Stage 3:

Form and cast cutting edge on top of sand island

Construction Sequence

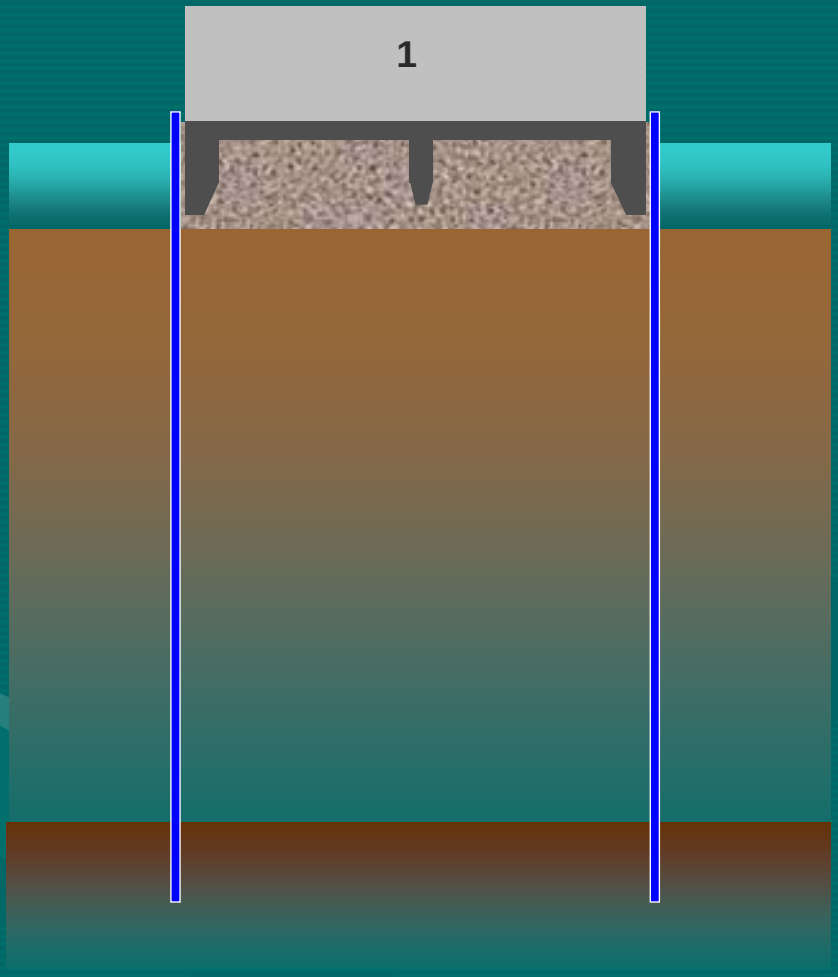


Stage 4:

Cast one 15-ft segment

Start dredging and sinking the caisson

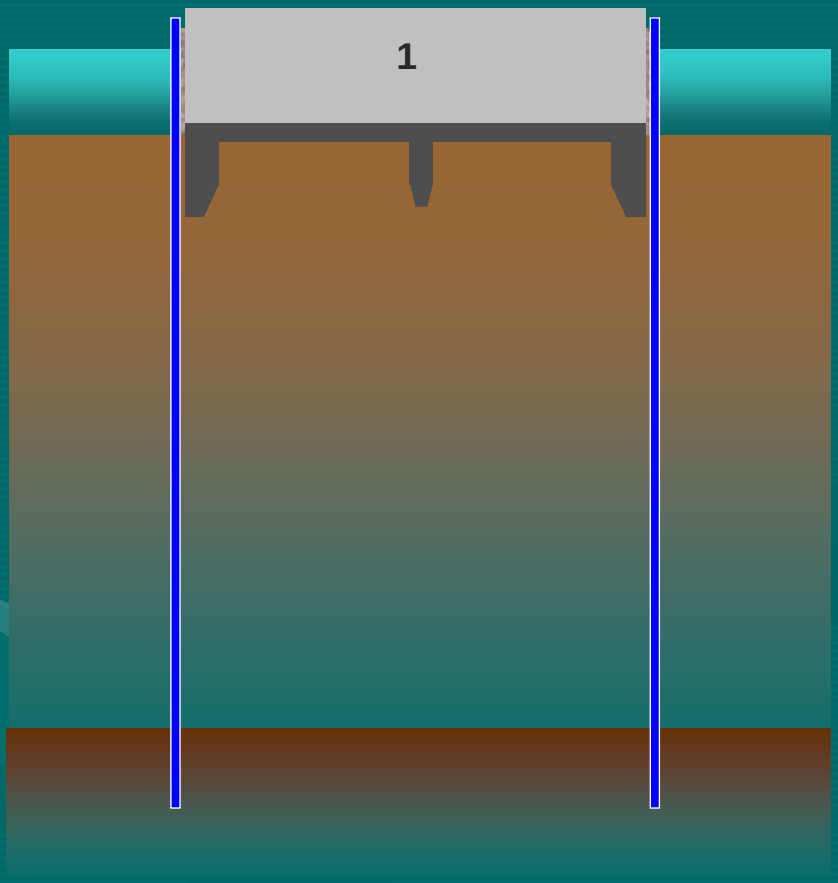
Construction Sequence



Stage 5:

Continue to dredge and sink the caisson

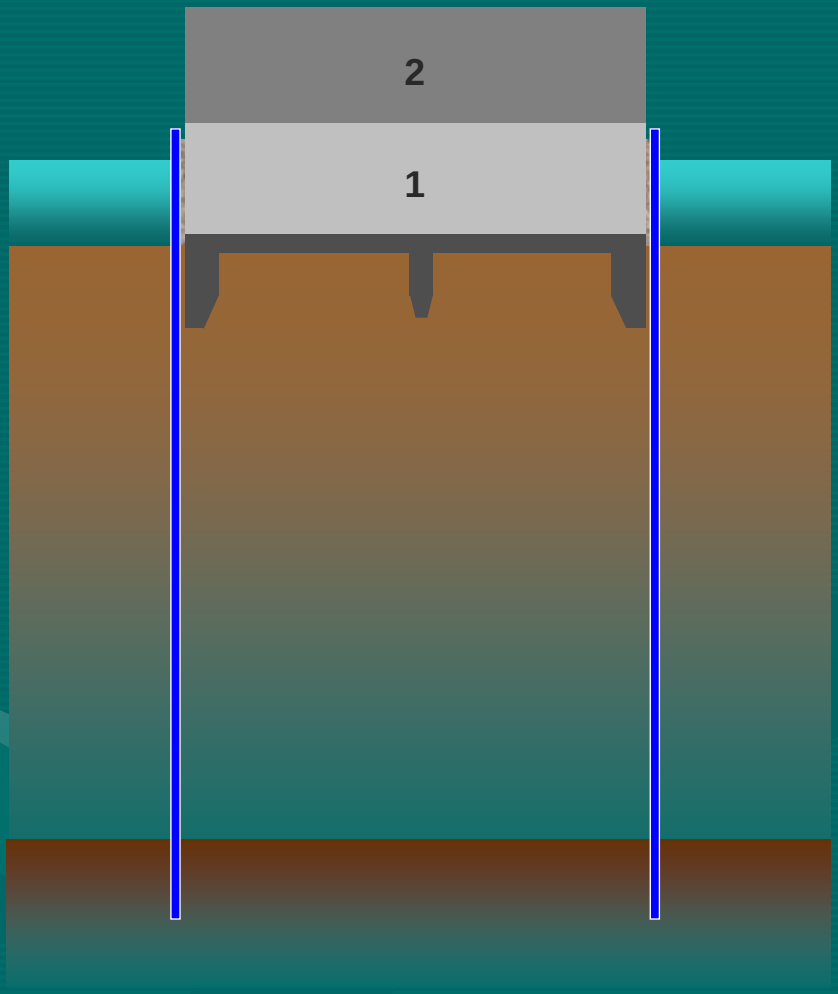
Construction Sequence



Stage 6:

Continue to dredge and sink the caisson

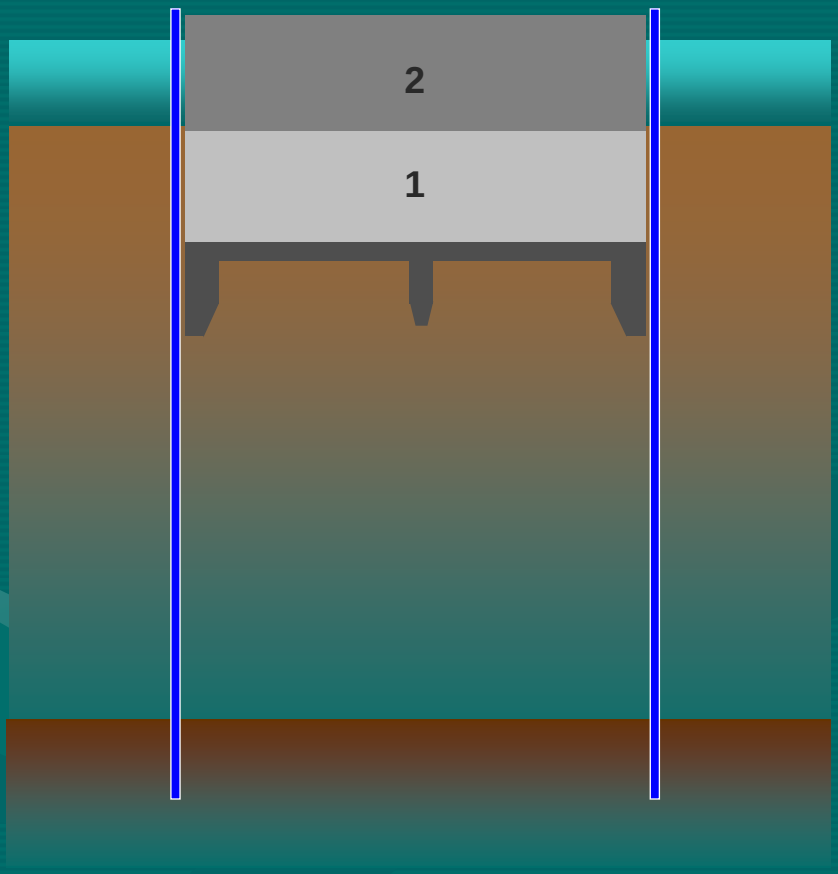
Construction Sequence



Stage 7:

Cast Segment 2

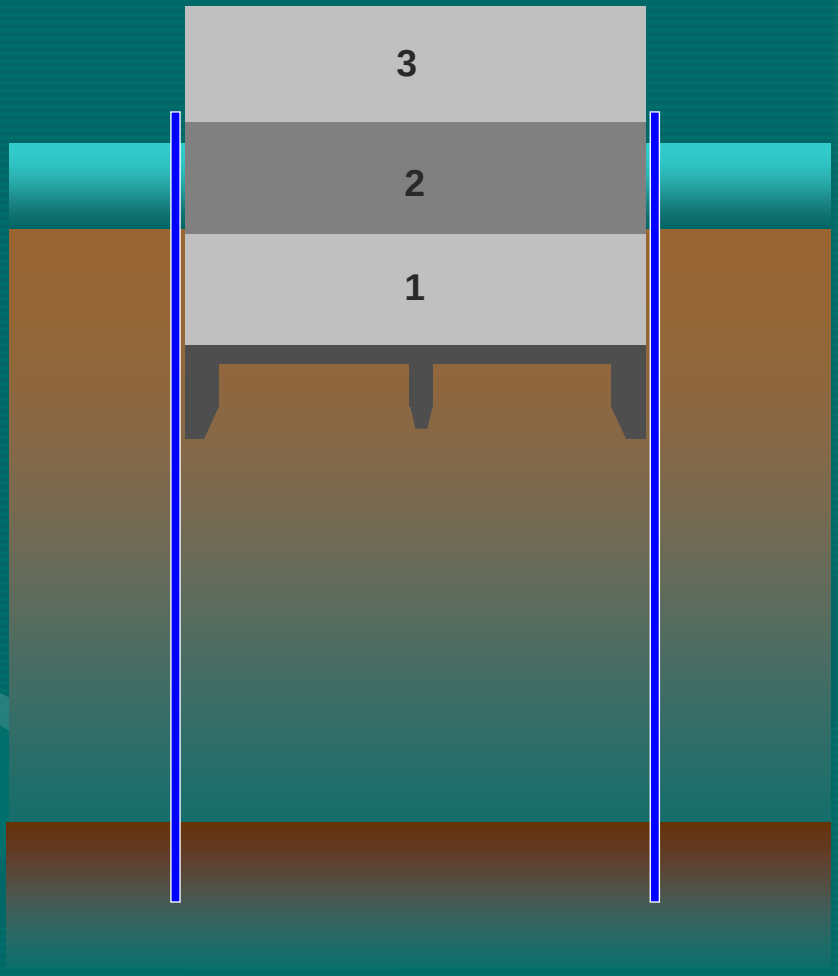
Construction Sequence



Stage 8:

Continue to dredge and sink the caisson

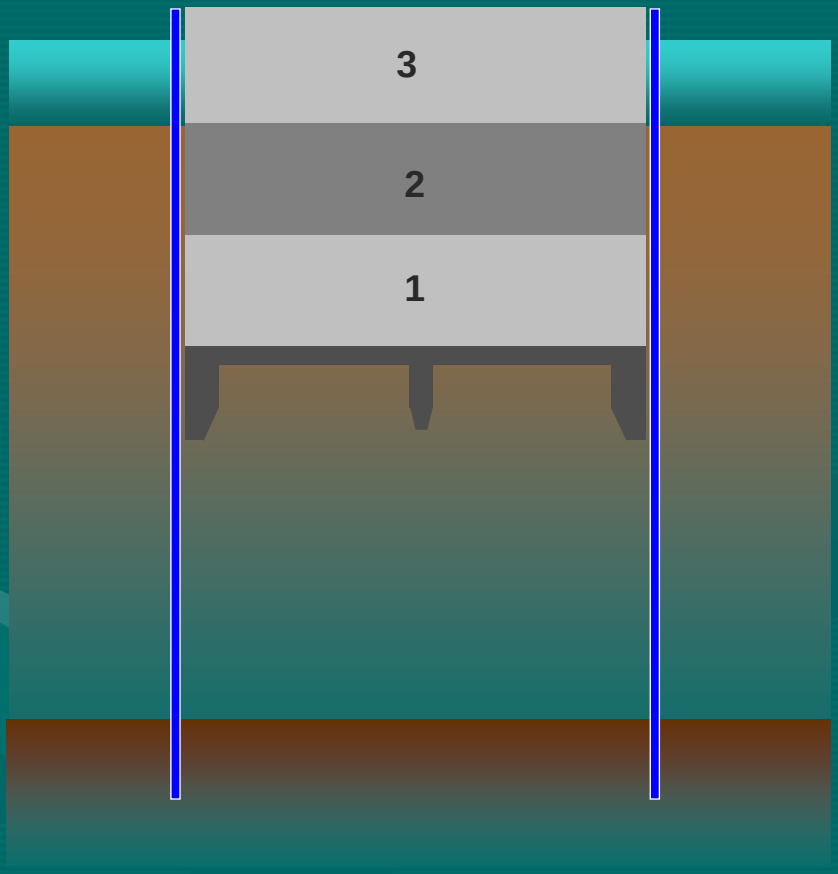
Construction Sequence



Stage 9:

Cast Segment 3

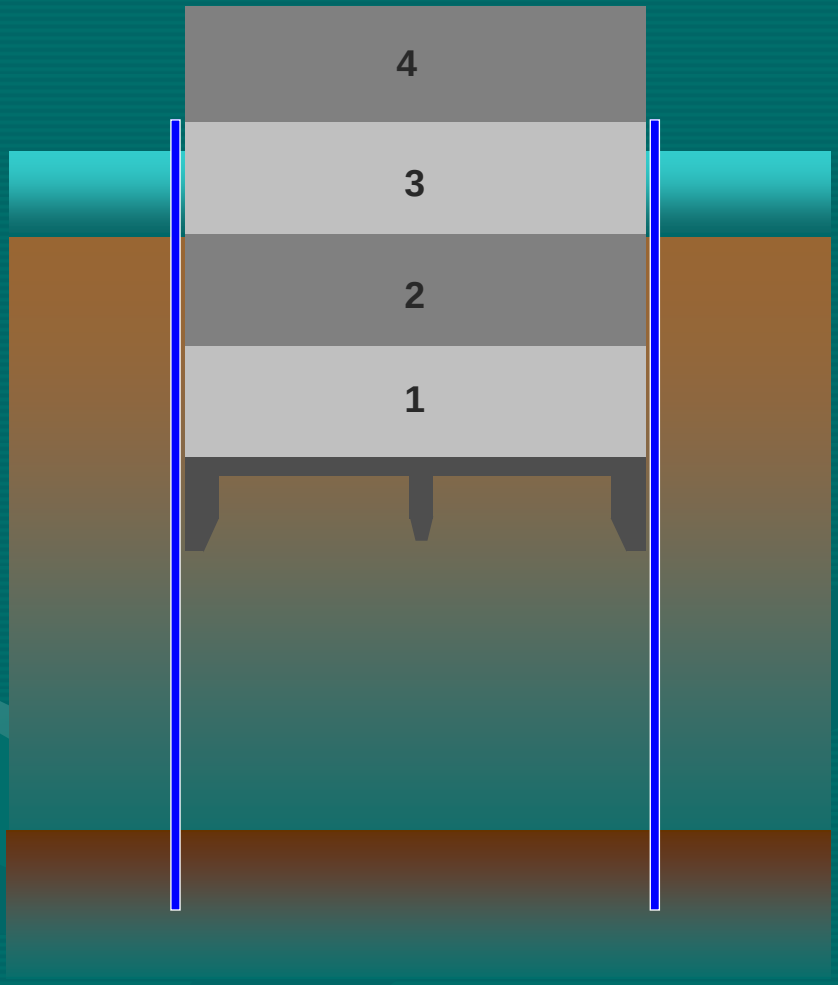
Construction Sequence



Stage 10:

Continue to dredge and sink the caisson

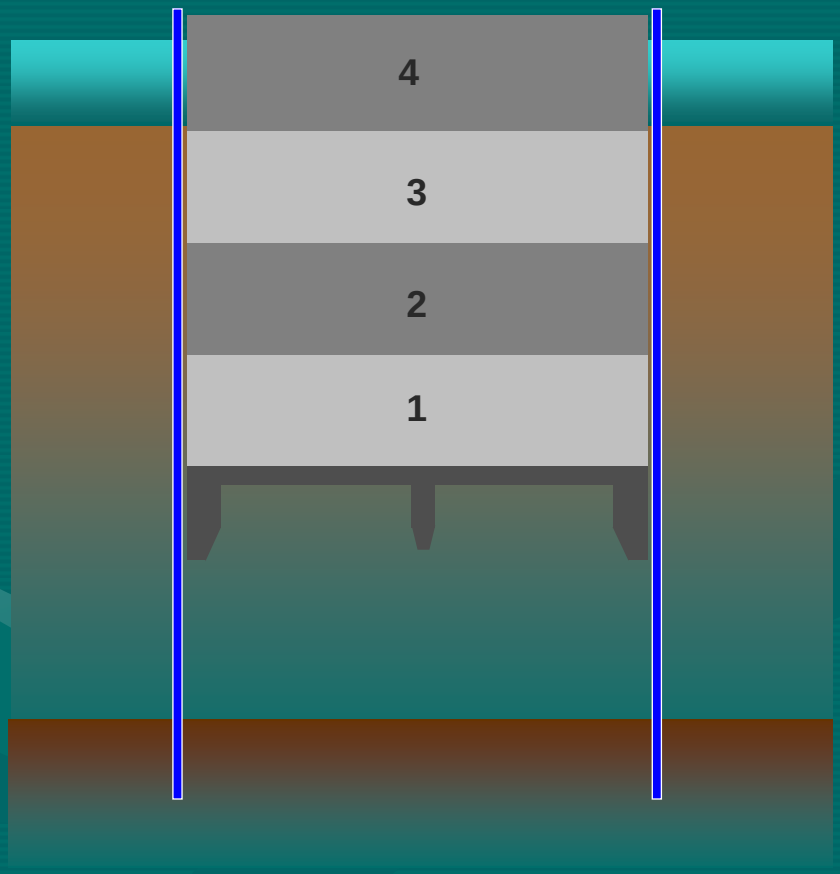
Construction Sequence



Stage 11:

Cast Segment 4

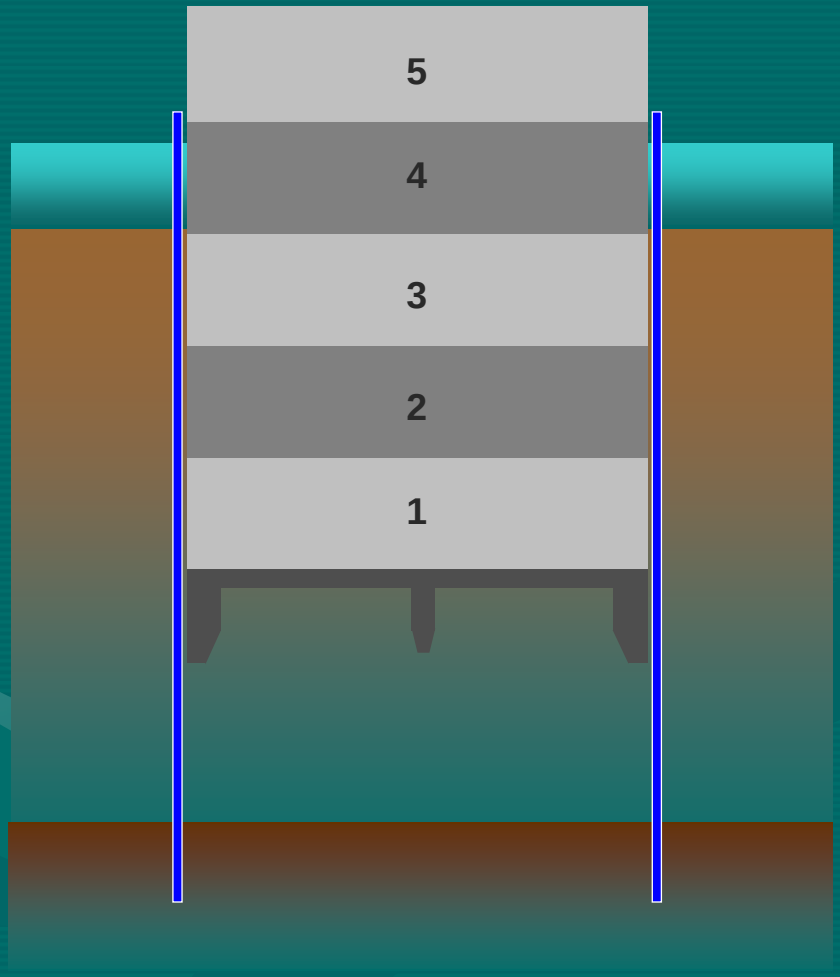
Construction Sequence



Stage 12:

Continue to dredge and sink the caisson

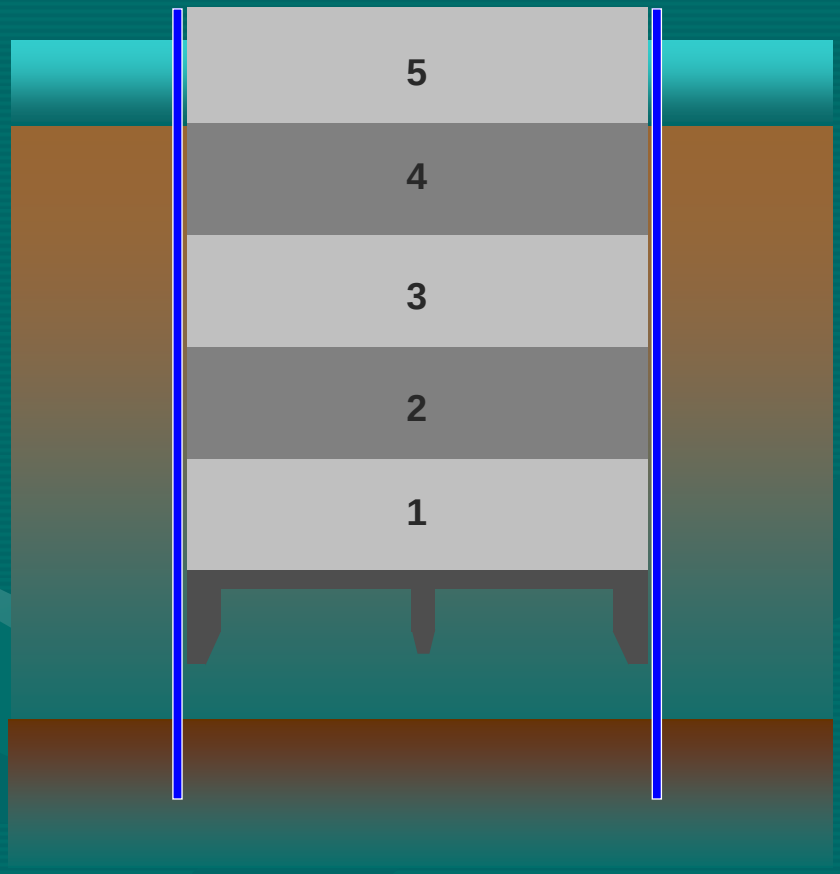
Construction Sequence



Stage 13:

Cast Segment 5

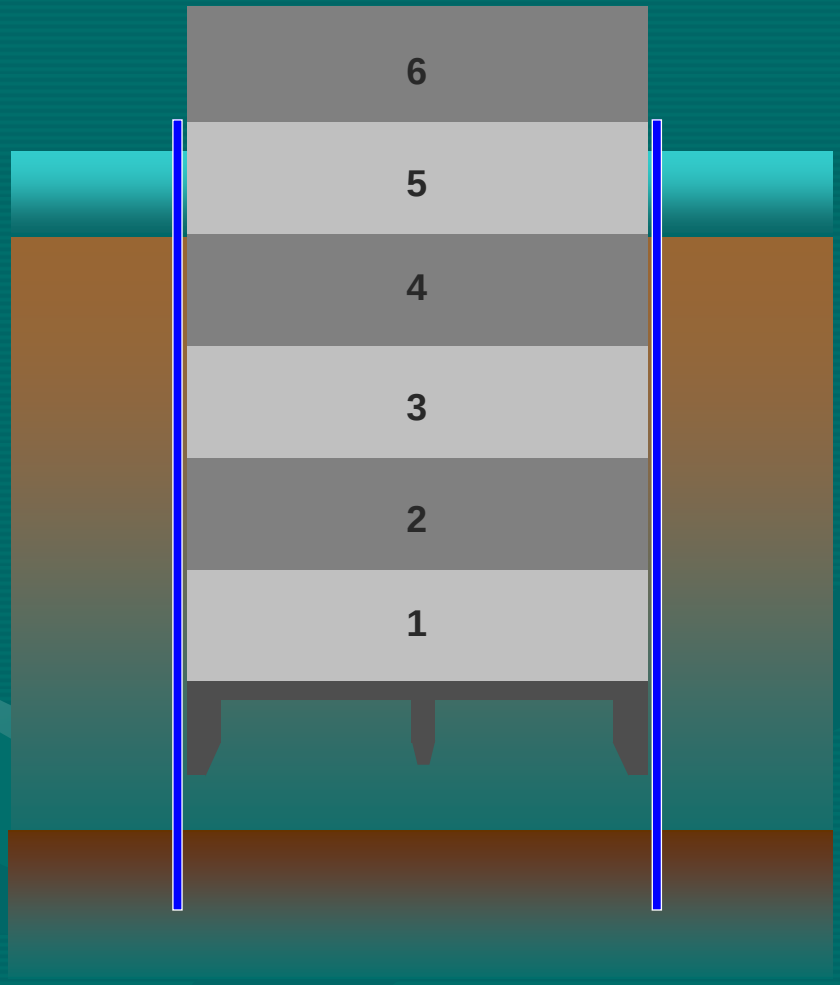
Construction Sequence



Stage 14:

Continue to dredge and sink caissons

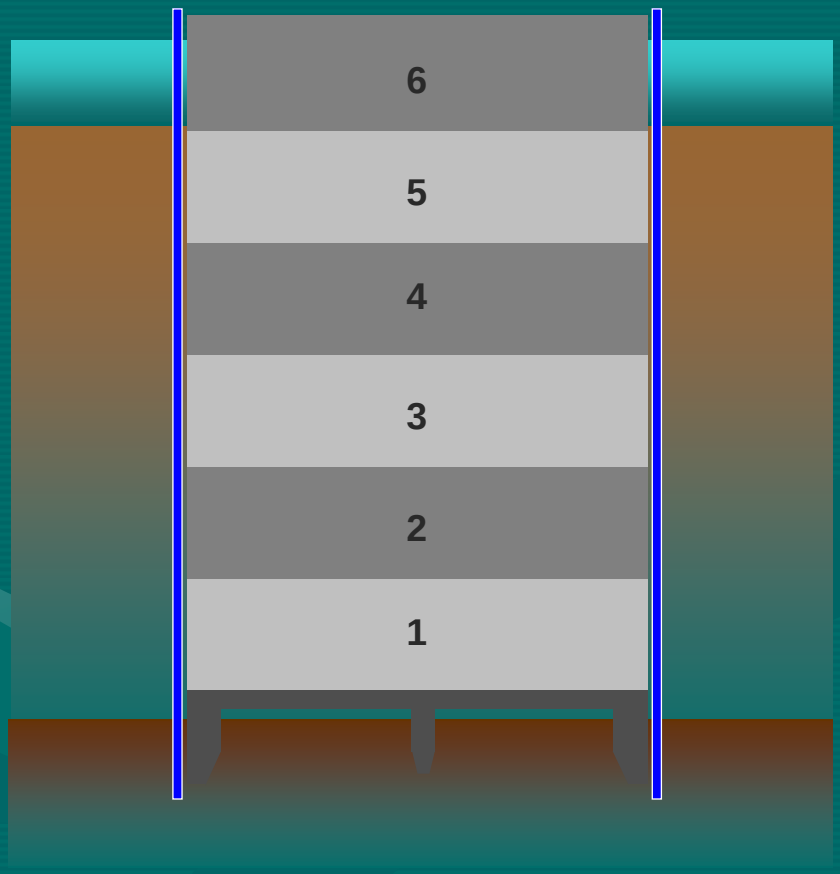
Construction Sequence



Stage 14:

Cast Segment 6

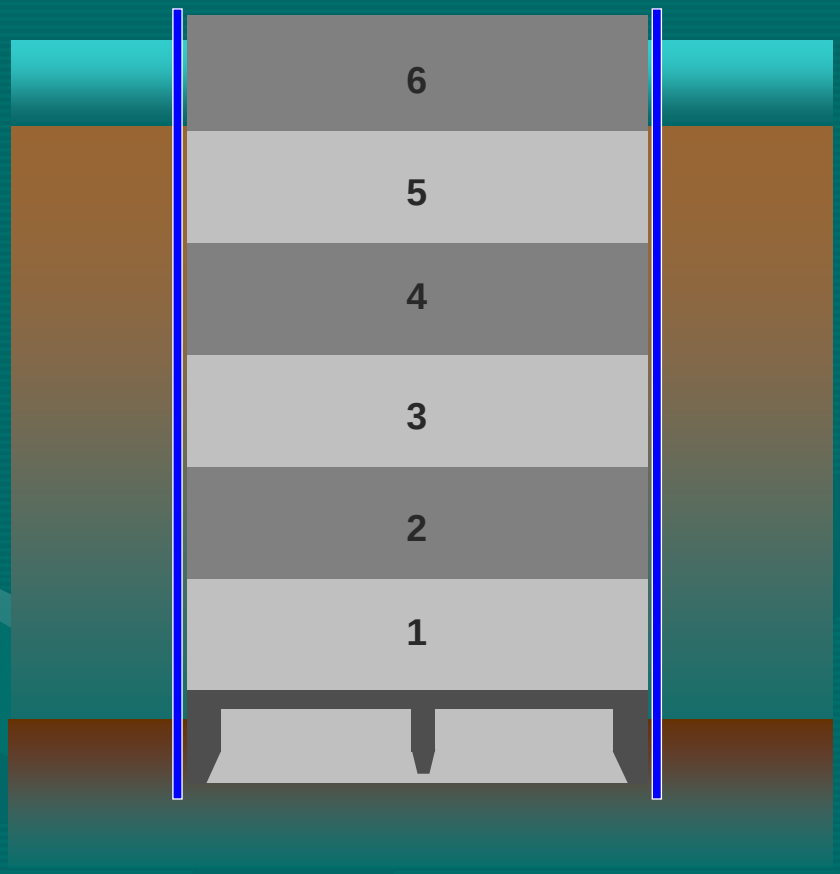
Construction Sequence



Stage 15:

Continue to dredge and sink caissons to the final elevation

Construction Sequence

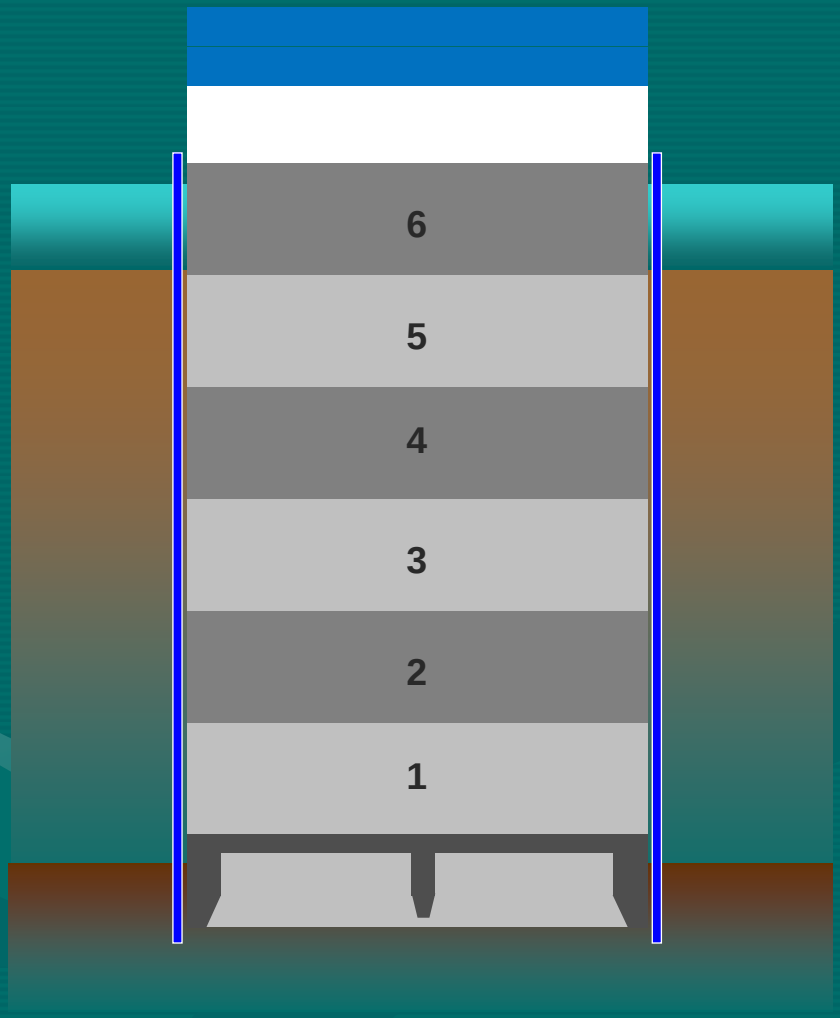


Stage 16:

Clean bottom and cast concrete seal

Fill dredging wells

Construction Sequence

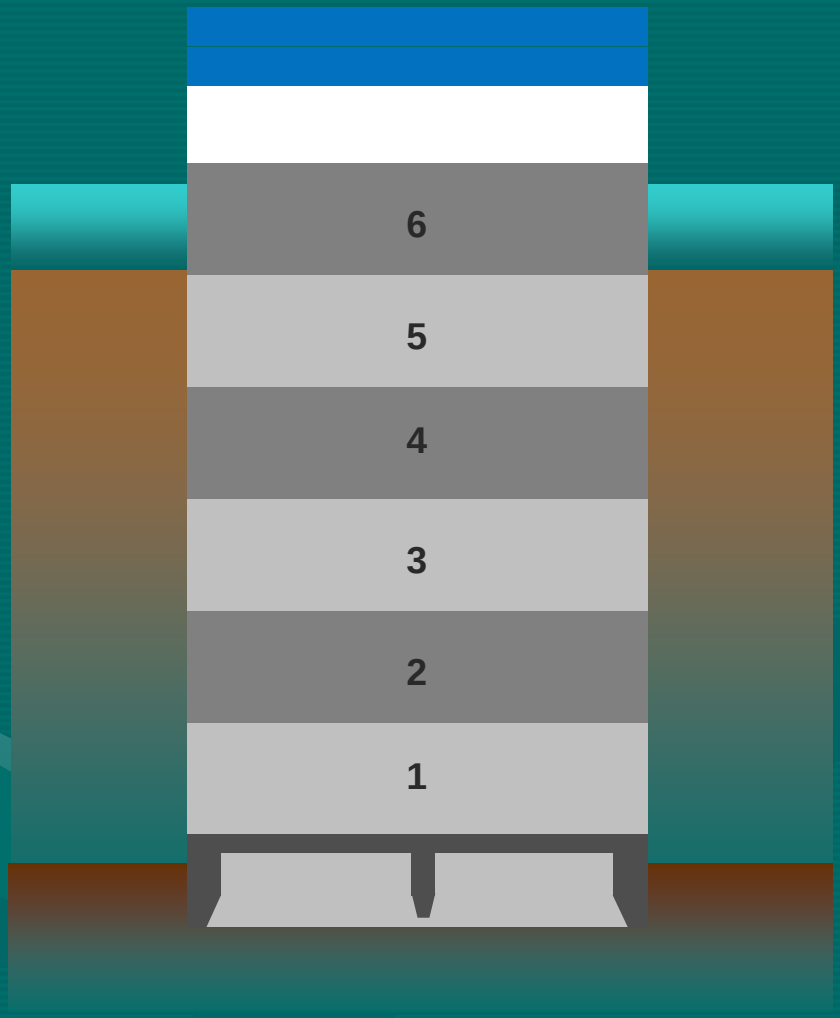


Stage 17:

Cast distribution cap

Start pier construction

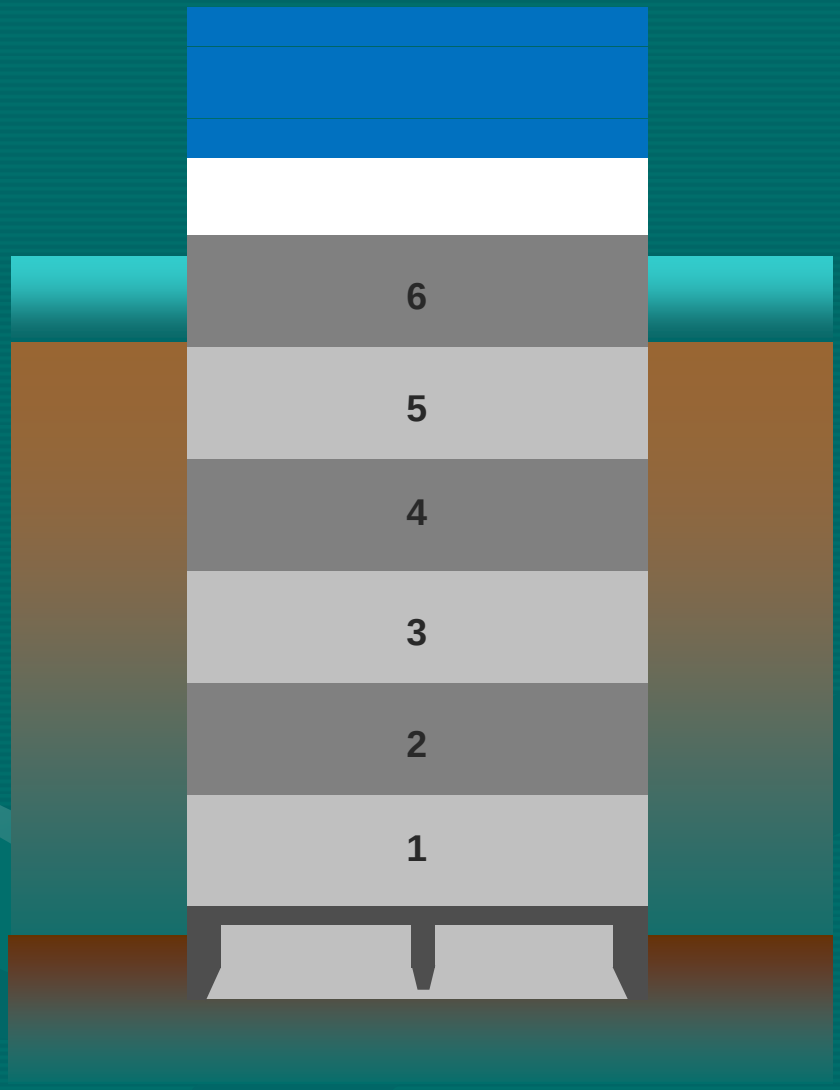
Construction Sequence



Stage 18:

Remove sheet piles

Construction Sequence



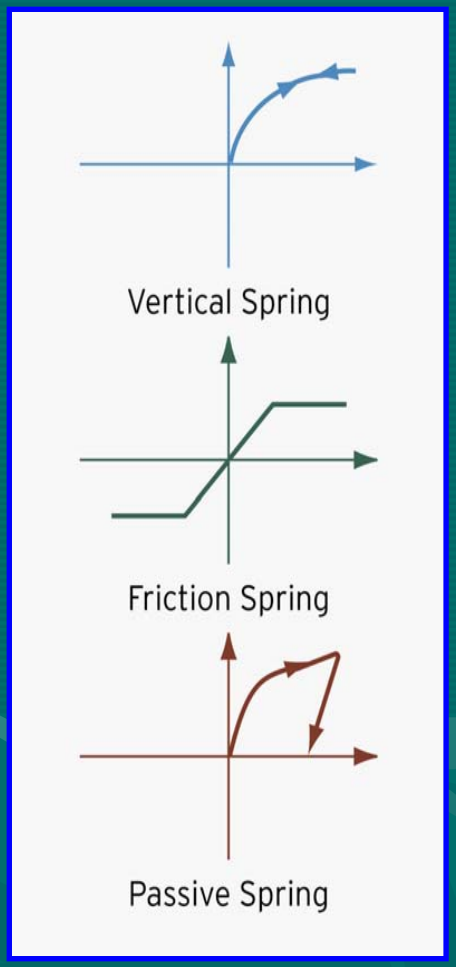
Stage 19:

Continue pier construction

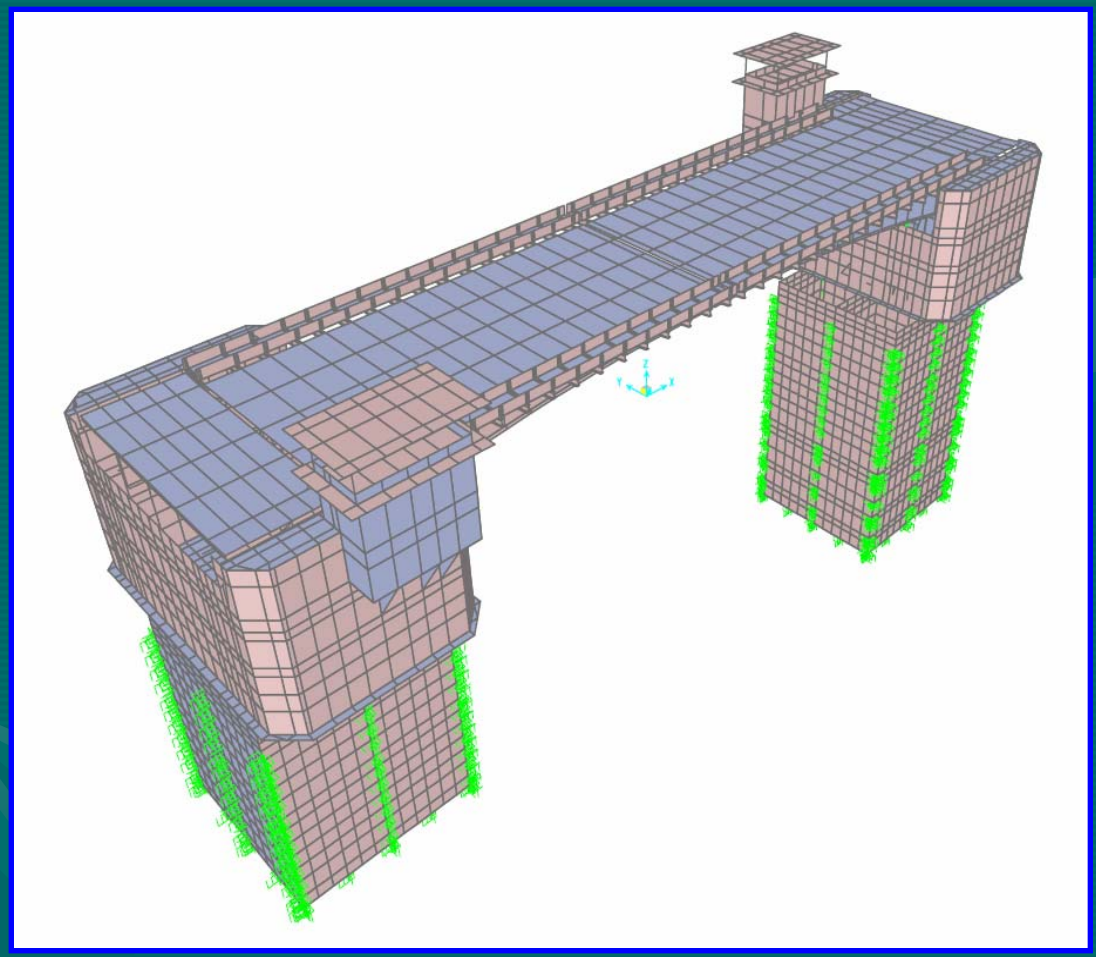
Design Status

- Completed 70% design
- Working on the final design
- Going to advertisement in January, 2010
- King County applied for TIGER Fund

Current Seismic Model



Springs



Global Model

Conclusion

- Caisson Foundation was selected for
  - ✓ Seismic Performance
  - ✓ Environmental impact
  - ✓ Economy
  - ✓ Construction Schedule
  - ✓ Construction Risk
- Supported by Value Engineering Team

Acknowledgements

- Time Lane of King County
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