ROCK ANCHOR DESIGN AND CONSTRUCTION
The Dalles Dam Spillwalls

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• Design load at 1,050 kcfs river flow
  – Assumed spill on one side of wall, not on the other
• Overturn Moment – 1,084 ft-kips/ft of wall
• Shear – 62.1 kips/ft of wall
Spillwall:
Height 43 ft
Length 193 ft
Width 10 ft

Fishwall:
Height 43 ft
Length 47 ft
Width 8 ft
Rock Bolt Design

- Construct Walls First
  - Tremie placed concrete
- Construct Foundation Last
  - Post-tension wall to rock using rock bolts
- Requires 3 rock bolts evenly spaced across the width (2.5 ft o.c.) every 3 ft o.c. the entire length
- Each rock bolt post-tensioned to 545 kips
Fishwall Drilling
Fishwall Drilling

Flying lead supported down the hole hammer
Upstream Spillwall Drilling

Rail supported down the hole hammer
Downstream Spillwall Drilling

Flying lead supported down the hole hammer
Rock Bolts
Lessons Learned

- Ducts Through Concrete Wall
- Complications During Anchor Drilling
- Penetration and Anchor Grouting
- Rock Bolt Installation
**Problem:** Tie-downs not stout enough for tremie concrete placement or workers using them as ladders during forming. Duct alignment not maintained and results in problems during drilling.

**Lesson:**
Locate tie-downs in lower portion of form where lateral load from tremie pour is highest.
Prohibit workers from stepping on tie-downs.
Ducts – Material Selection

**Problem:** Duct material bowed during tremie concrete placement, then tore and shredded during drilling of bowed ducts.

**Lesson:** Select duct material stiff enough for tremie concrete lateral load and won’t shred during drilling.
Ducts – Material Selection

Duct material on face of button bit.

Air vents blocked and prevented proper circulation of cuttings from the bottom of the hole.
Drilling – Anchor Spacing, Staggering, and Vertical Alignment

**Problem:** Vertical alignment tolerances very difficult to monitor and achieve.

**Lesson:**
Typical vertical alignment tolerance of 1 in 100. Improved tolerance results in additional drilling and inspection costs.

Require specific alignment inspection process that is repeatable and meets alignment tolerance requirements.

Stagger anchors if elect not to inspect. Stagger interval is dependent on the depth of the anchor but not less than 5 feet.
Problem: Very tight anchor spacing, over-drilling, short bond zone (15 feet), and difficult vertical alignment tolerances result in the contractor suggesting a 3 part stagger system.

Lesson:
Tight anchor spacing requires staggered depths.

- Use 7 -10 foot stagger due to over-drilling and alignment concerns.
- Prefer 4 part stagger because all adjacent anchors at same depth.
Drilling – Damage to Adjacent Holes

**Problem**: Tight anchor spacing resulted in damage to adjacent anchors during drilling - loss of sidewall material and grout infilling.

**Lesson**: Assume damage to adjacent drill holes during drilling and penetration grouting will require additional drilling and grouting efforts.
Drilling – Damage to Adjacent Holes

Problem: Drill cuttings run into uncapped adjacent completed drill holes requiring additional cleanup effort.

Lesson: Require caps on prepped drill holes.
**Problem:** Drilling and grouting can damage existing features – foundation drain system and concrete slab foundation.
Drilling – Existing Features

**Lesson:**

Evaluate proximity of existing features to drill hole locations. Select drilling method that will not cause degradation to existing features.

Monitor drilling for indications that degradation is occurring.

Contract documents should have language that indicates that drilling operations may be modified if degradation is occurring.
Grouting – Penetration Mix Design

**Problem:** Several different types of grout mixes were required but many did not work well during application.

**Lesson:**

Require specific grout mix designs that account for:

- Small or large voids
- Proximity to existing underground drains
- Long and short travel distances
- Use of slick lines
- Distance between concrete pump and grout plant

Use of fibers and anti-wash additives work, but may not be needed with proper placement method or when have 100’s of feet of slick line.
Grouting – Placement Method
Grouting – Placement Method

**Problem:** Contractor used poor placement methods resulting in inadequate grouting in lower 5 - 10 feet of drill hole.

**Lesson:**

Require submittal information that includes:

- How grout flow maintained between batches
- How tremie pipe charged at start of every hole
- How grout delivered from grout plant
- How segregation will be prevented
**Problem:** Grout flows into adjacent drill holes during penetration grouting reducing the effectiveness of the grouting.

**Lesson:**

Require caps on already drilled holes prior to and after grouting.
Lesson: Design over-water structures to contain water, cuttings, and grout.
**Problem:** Bolts damaged during installation/removal, indicating areas susceptible to damage.

**Lesson:** Prevent damage to corrosion protection and expansion sleeves.
Bolt Installation – Jacking Pad Construction

**Problem:**
Grout pads cracked during bolt stressing.

**Lesson:**
Grout pads should be several inches larger than bearing plates or not used. Concrete surface could be ground down for pads.
**Problem:** Lift-off test procedures modified during construction. Observed 50% of lift-off tests failed in anchors with more than 12 hours between initial lock-off and lift-off tests.

**Lesson:**

24-hour lift-off tests are state of practice for high capacity rock bolts. Critical that tensioning one bolt doesn’t reduce load of adjacent bolt.

Increasing initial lock-off load then lowering to final lock-off load reduces number of lift-off failures.
Questions??