Post-tensioned rock anchors used for retrofitting Canadian dams, 1999 - 2013

Jim Bruce, P. Eng.
GEO-FOUNDATIONS CONTRACTORS INC.
1968

22 October: Justice Minister Ralph Hanan fires the final shot in the tailrace tunnel. It is packed with a little more dynamite than necessary, and blows off everyone's safety helmets!
Rock anchors – why and how

- Many existing structures constructed in early 20th century
- Dam safety codes are ever evolving
- Overturning, sliding, PMF

- By installing post-tensioned rock anchors, the centre of gravity can be lowered below the underside of existing structure
Rock anchors – the challenge for designers

- Must find a safe way “through” the structure
- Must find an appropriate staging point on top of the dam
- Might have to strengthen the structure beneath the anchorage
- Often times must grout the contact under flowing conditions
- Often times must grout the rock mass under flowing conditions
The resource for designers:


 Particularly:
• Chapter 5 – corrosion protection
• Chapter 6 – design
• Chapter 7 – installation (incl. water tightness testing)
• Chapter 8 – stressing and acceptance criteria
But what does a typical job at a Canadian dam look like?
Find a structure that could benefit from increased resistance to sliding and overturning
Pick a top-notch crew
(or the B team, if the A team is not available)
Make sure you don’t start in winter ...
... but if you have to, make sure you’re protected!
Plan for safety – and walk the walk!
Install special access measures if required... like personnel access
... or drill rig access (suspended version) ...
.... or drill rig access (barge version) ...
.... or, as often as not, both ...
... or be prepared to modify equipment as required in order to access existing conditions.
Drill some holes through the structure, deep into bedrock.
Install environmental containment measures to ensure drill cuttings do not enter water course.
Or plan ahead if the work is part of an addition
Thoroughly clean the hole
Pre-condition the rock mass, if necessary
Make a pocket for the bearing plate – usually by diamond coring ....
.... or sometimes by cast-in-place method
Order some anchors from a PTI-certified manufacturer and ship them to site.
Inspect the corrosion protection system for defects prior to installation down the hole.
“Dress up” your tendon with centralizers and grout tube(s)
Hoist your tendon over and into the hole ...
... or use an off-coiler for ease of installation ...
... or install it with old-fashioned elbow grease
Suspend the anchor in position and grout it
Install the bearing plate and bedding mortar
Fine tune the corrosion protection prior to stressing
Allow enough time for all grout to gain sufficient strength
Set up your jack and chair
Submit and double check the jack calibration.
Perform mono-strand jacking to ensure harmonious tendon elongation when it really counts
Carefully post-tension the anchor using qualified personnel
Perform lift-off testing of select anchors
Submit stressing records

CARLINGVIEW
239001
STRAND ANCHORS PROOF TEST
3rd Row

ANCHOR ID: A
DATE: April 29, 2014
Jack Time: B21 AM
Time: B22 AM

JACK LSU:
Tendon: 6-strand
P: 500 kN
Test Load: 1043 kN
Lock-off Load: 571 kN
Jack Ram area: 38.5 sq in

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Lock-off Load at Conclusion of Proof Test:
Gauge Pressure (PSI): 6500

LOAD VS ELONGATION

Date: ____________________________
Report: __________________________
Inject final grout after tensioning to fill the trumpet.
Cut down excess tendon projection and encase in PT grease
Install permanent grease cap (filled with PT grease)
Don’t forget to invoice your client!
Some exceptions to these rules:
“Special” drilling for difficult access
Light weight drilling where required
Externally threaded anchor heads
Load cells for long term monitoring of permanent pre-stress
Class 1 corrosion protection via wax extruded strand
Two-stage grouting (classic post-tensioning)
Some interesting case studies
Island Falls GS, Sandy Bay, SK

- Site is a 3 hour drive north of Flin Flon, MB
- 107 PT anchors (up to 19-strand) + 228 passive anchors
- Constructed over 2 seasons
OPG – Smoky Falls GS, Smooth Rock Falls, ON

- Deepest anchors 52 m deep
- Test load 7700 kN
- 18 no. anchors – contract value > $2M
McArthur Falls GS, Lac du Bonnet, MB

- #1 world ranking in generating capacity vs. fall
- 92 no. anchors, 1700 lineal metres of drilling
- Largest anchors are 15-strand / 3118 kN test load
Laurie River GS #2 – Thompson, MB
SaskPower – Boundary Dam, Estevan, SK
Big Eddy Dam – Nairn Centre, ON
Okikendawt Hydroelectric, Dokis F. N., ON
Blind Slough Dam, Mission, BC
### 3.0 Definitions

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<tr>
<td>&quot;Post Tensioning Institute&quot;</td>
<td>The worldwide authority on post tensioning</td>
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<tr>
<td>&quot;Post-Tensioning&quot;</td>
<td>A method of strengthening concrete or soil using tensioned anchors, where the tensioning is completed after the concrete is cured.</td>
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<td>&quot;Lift-Off&quot;</td>
<td>The tension when the anchor head lifts off of the plate</td>
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<td>&quot;Lock-Off&quot;</td>
<td>The tension target during tensioning</td>
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<tr>
<td>&quot;Pre-Load&quot;</td>
<td>The tension on the anchor, with no tower loads</td>
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Perspective ... the good ...

NHI Course No. 132078
Micropile Design and Construction
Reference Manual

National Highway Institute
... the in-between ...

ROCK ANCHOR NOTES:

1. ROCK ANCHORS ARE TO BE GROUTED INTO SOUND ROCK. INSTALL GROUT FOLLOWING MANUFACTURER RECOMMENDATIONS, 50 MPa.

2. PROOF TEST TWO ANCHORS TO ULTIMATE DESIGN LOAD DURING 15 MIN.; ULTIMATE DESIGN LOAD PER ANCHOR, RA1 = 1400 kN & RA2 = 2500 kN.

3. ANCHORS TO BE DOUBLE PROTECTION WILLIAMS ANCHORS (1080 MPa) ALL-THREAD BAR.

4. INSTALL AFTER PILES HAVE BEEN DRIVEN. PILES ADJACENT TO ROCK SHALL BE RESTRIKED AFTER INSTALLATION OF ROCK ANCHORS.

5. SEE DETAIL ON S1.1 FOR ADDITIONAL INFORMATION.
G. Others:


3. Federal Highway Administration Publication No. FHWA NHI–05-039: Micropile Design and Construction


E. Except as specified herein, the reaction piles/ground anchors shall be designed in accordance with the design recommendations of the Post Tensioning Institute Recommendations for Prestressed Rock and Soil Anchors
.... and the worse ....  

(applying PTI water-tightness rationale where no gradient exists)
“Proof test every anchor to 1.33 DL” ......

but anchors are FULLY bonded (not post-tensioned)
Thank you!

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