Tiebacks/Anchors & Soil Nails

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Anchors & Nails

- Design Intro
- Materials
- Construction
- Testing
Anchor Basics

• Tieback = Anchor

• An anchor is a tension support, which limits movement from subsequent excavation by providing a pre-loaded condition to the supported ground.

• Tensile load is transmitted by a steel tendon made of individual strands or bars. The tendon is bonded to competent rock or soil by cement grout.
Applications for Anchors

- retaining walls
- temporary excavation support (replace struts or rakers for improved working space)
- anchored marine bulkheads
- landslide control
- rock cuts
- dam stabilization
Sales Pitch for Anchors

- Using comprehensive corrosion protection systems, rock and soil anchors achieve reliability, longevity, and economy.
- In both temporary and permanent retaining applications, ground anchor systems have proven to be a viable economic alternative to conventional retaining walls -- especially in instances where excavation is undesirable.
- Stressing tests every anchor to greater than design load
- High capacities in rocks and soils
Versatility of Anchors

• Can be permanent if installed with appropriate corrosion protection
• Can be installed at any inclination through all types of overburden and rock
• Can be hundreds of feet deep.
• Compatible with the construction of all types of wall systems including sheet piles, soldier piles and laggings, drilled shafts, soil mixed walls and diaphragm walls.
Nicholson Anchor Experience

- In 1969 Nicholson constructed the 1st permanent anchored wall installed in the U.S.
- In 1990 we installed the longest (318 ft.) and largest (58-strand) dam anchors installed to date in the U.S. and tested over 2700 kips.
- In 1992 we installed ~4,000 anchors to support the largest anchored retaining wall in North America in Steubenville, OH.
- In 1997 we installed 55-strand double corrosion protected anchors using 10-in. ID corrugated sheathing – 1st application of this process in the U.S.
- In 2002, installed 61 strand anchors in corrugated sheath at 45 degree angle = largest in US
Anchors and Anchored Wall Design
Traditional Braced Cut Pressure Diagrams

Figure 23. Terzaghi and Peck apparent pressure envelopes (after Terzaghi and Peck, 1967, Soil Mechanics in Engineering Practice, Reprinted by permission of John Wiley & Sons, Inc.).
Updated Pressure Diagram for Granular Soil = 33% more load than active wedge

(a) Walls with one level of ground anchors
(b) Walls with multiple levels of ground anchors

\[ p = \frac{\text{TOTAL LOAD}}{2/3 \, H} \approx K_A \gamma H \]

\[ p = \frac{\text{TOTAL LOAD}}{H - 1/3 \, H_1 - 1/3 \, H_{n+1}} \]

- \( H_1 \) = Distance from ground surface to uppermost ground anchor
- \( H_{n+1} \) = Distance from base of excavation to lowermost ground anchor
- \( T_{hi} \) = Horizontal load in ground anchor \( i \)
- \( R \) = Reaction force to be resisted by subgrade (i.e., below base of excavation)
- \( p \) = Maximum ordinate of diagram

\[ \text{TOTAL LOAD} = 0.65 \, K_A \, \gamma H^2 \]

Figure 24. Recommended apparent earth pressure diagram for sands.
Updated Pressure Diagram for Stiff Clay

(a) Walls with one level of ground anchors
(b) Walls with multiple levels of ground anchors

\[ p = 0.2\gamma H - 0.4\gamma H \]

\[ H_1 = \text{Distance from ground surface to uppermost ground anchor} \]
\[ H_{n+1} = \text{Distance from base of excavation to lowermost ground anchor} \]
\[ T_{hi} = \text{Horizontal load in ground anchor } i \]
\[ R = \text{Reaction force to be resisted by subgrade (i.e., below base of excavation)} \]
\[ p = \text{Maximum ordinate of diagram} \]

TOTAL LOAD (kN/m/meter of wall) = \(3H^2 - 6H^2\) (H in meters)

Figure 27. Recommended apparent earth pressure envelope for stiff to hard clays.
Free Length Determination

Minimum unbonded length = 3m (bar) or 4.5m (strand)

$\chi = 1.5m$ or $0.2H$, whichever is greater

(a) Wall cross section
(b) Wall plan view

Figure 37. Vertical and horizontal spacing requirements for ground anchors.
Typical Anchor Design Loads in Soil
Assumes 30’ to 40’ Bond Length

- Soft clay - 60-150 kips*
- Hard clay - 100-250 kips *
- Sandy Silt/Silty Sand - 125-250 kips
- Clean Granular - 175-420 kips
- Till - 200-420 kips

* With Post-Grouting
Typical Anchor Design Loads in Rock

- 150-2000 kips
- See PTI Values
- Limited by claystones and/or practical structural limitations
Recommended Ultimate Bond Values for Rock in psi per PTI

- Granite and Basalt: 250-450
- Dolomitic Limestone: 200-300
- Soft Limestone: 150-200
- Slates and Hard Shales: 120-200
- Soft Shales: 30-120
- Sandstone: 120-250
- Concrete: 200-400
RECOMMENDATIONS FOR PRESTRESSED ROCK AND SOIL ANCHORS

Anchor Design, Materials, Fabrication, and Testing
Benefits of Polystrand

- Assured Corrosion Prevention
  - Corrosion-inhibitor-encased strand
  - Seamless-inert-polymer-sheath
- Guaranteed Force Transmission
  - Coefficient of friction of 0.05 or less
  - Longer or curved tendons
  - Consistency of elongation and testing
Multistrand anchor

- Steel cap
- Wedge plate
- Anchor plate
- Anti-corrosion compound
- Spacer
- Seal
- Greased & sheathed strand
- Cement grout
- Anchor head
- Bond length
- Loaded structure
- Free length
- Retained strata
- Load carrying strata
- Retained strata
- Spacer
- Cement grout
- Free length
- Bond length
- Loaded structure
Double Corrosion Protected Strand  DCP
Completed Tendons

photo courtesy of Lang Tendons
Dywidag THREADBAR

- ASTM 615 & ASTM 722
- Sizes #6 through #20 Grade 60 & 75
Double Corrosion Protected Bar  DCP
Anchor Installation

1. Drill hole
2. Set tendon
3. Grout via Tremie Tube (may be before tendon)
4. After grout cures; stress, test, and lock-off anchor
Anchor Testing
Anchor Testing
Local Anchor Projects
Rockcliff Bikeway Slide, Rocky River, OH

• In 2002 Cleveland Metroparks noticed that its existing Rockcliff Bikeway retaining wall was failing at a rate of 1-inch outward every 10 days over a three-month period.

• Nicholson designed and installed a semi-continuous reinforced drilled shaft soldier pile retaining wall with tieback anchors, which relieved pressure on the existing wall and stabilized the slope.
Angles were installed between the caisson/anchor constructs and the existing soldier pile retaining wall to provide support.
**U.S. 22/S.R. 7 Interchange**  
Steubenville, Ohio

- Worked for ODOT District 11
- Anchoring 3 retaining walls with 4,000 permanent soil and rock anchors ranging from 40 ft. to 120 ft. in length.
- One of the walls, over 130 ft. high, is the largest anchored wall in North America.
Garrett Morgan Waste Water Treatment Plant, Cleveland, Ohio

- Worked for the City of Cleveland
- Installing 400 temporary tieback anchors
- 100 to 220 kip working load = 3 to 7 strands
- Bonded in lacustrine clay
- Postgrouting
- Lengths ranging from 60 ft. to 120 ft.
- 250 to 300 bags of cement routinely mixed per shift.
Postgrout Tubes
Soil Nails
MANUAL FOR DESIGN & CONSTRUCTION MONITORING OF SOIL NAIL WALLS

Revised October 1998

Innovation Through Partnerships
Soil Nail Process

Ref: FHWA-SA-96-069R
Soil Nail Wall for Temporary Shoring

Ref: FHWA-SA-96-069R
Soil Nail Wall as Permanent Wall

Figure 2.2 Permanent and Temporary Cut Slopes
Soil Nail Wall for Roadway Widening under Bridge

Figure 2.3 Widening Under Existing Bridge

Ref: FHWA-SA-96-069R
CITY OF PITTSBURGH
PARKING GARAGE

ELEV. 741
EXISTING GRADE

ELEV 727
GROUT COLUMNS

4 INCHES

PPG BUILDING "C"
AND THREE LEVEL
PARKING GARAGE

ELEV 750

20°

ELEV 720
BATTERED 1:12

ELEV 710

SOIL NAILS

ELEV 700

H-PILING FOR NEW
BUILDING

NICHOLSON
Soil Nail Wall – Failure Modes

Ref: FHWA-SA-96-069R
Sliding is normally covered by internal wedge analysis methods.

**Soil Nail Wall – External Failure Modes**

- (A) Sliding
- (B) Tilt/Bearing Failure
- (C) Slip Failure

Fig. 10. External Analysis.
(A) ADHESION FAILURE
Soil Nail Wall

Reinforced Soil Wall (MSE)
Soil nails (threadbar)

Levels of protection
- Plain bar (grouted)
- Epoxy coated
- Galvanized
- Double corrosion protection (DCP)
Photo Courtesy of Con-Tech Systems, Vancouver, BC
Self Drilling, Hollow Injection Grouted Micro Piles
complying with DIN 4128, EAU E 28 and draft CEN/TC 288/WG 8
with ultimate loads from 220 kN to 3460 kN (50 to 778 Kips)
Soil Nail Tests

Very Important
Real Proof Test Setup
CENTRALIZER 10' D.C. MAX.
(SHAPE SUBJECT TO CHANGE.)

EDGE OF DRILL HOLE

GROUT

INSERT
Fig. 11. Wall Section.
Shotcrete

Gunite
Facing Reinforcement
Shotcrete
Shotcrete – “Nicholson” Method
Finishing Shotcrete as final face
Soil Nail Case Study

Tunica Riverfront Park
Tunica County, Mississippi
Installed 964 soil nails & 42 tiebacks for riverboat facility.
Tunica Soil Nail Specifications

- Soil Nail Design Load = 24 kips
- Design Bond = 0.86 kips/ft = 24 k/28 feet
- Nail Length 60 ft
- Proof Test (1.5 D.L.) - 32 required
- Verification Test (2.0 D.L.)- 10 required
Installing Test Nails
Flushing Grout from Test Anchor
Setting up Verification Test
Testing Soil Nail
Drilling Nails on “D” Row
Flooding of Site
a) Soil Nailing

b) Reticulated Micro Piles

c) Soil Dowelling
Fig. 6. Nicholson "INSERT Wall"™ L.R. 69.