structural practices

Basics of Ground Anchors

Applications, Considerations and Specifications...

By Lawrence F. Johnsen, P.E.

Ground anchors hold down basements subjected to hydrostatic pressure, increase the sliding resistance of concrete dams, provide lateral resistance to structures via guy lines, and restrain temporary as well as permanent walls. Typically, they consist of inclined drill holes that are grouted and reinforced with steel tendons or bars, but they may also consist of steel helixes affixed to steel shafts, or anchors formed by jet grouting or compaction grouting methods. Soil nails differ fundamentally from ground anchors in that they have no stressing zone, and mobilize lateral resistance in a different manner.

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Ground anchors require both a stressing zone and a bond zone. The purposes of the stressing zone are to allow the tensioning of the anchor after installation, and in the case of wall restraint, to develop anchor resistance behind the active zone of the backfill. Typically, stressing zones are a minimum of 10 feet when the anchor is bonded in bedrock and 15 feet when the anchor is bonded in soil, although both values may increase for deep walls. Stressing lengths for strands are typically longer than for bars because of the movement required for the wedges to engage the tendons. In a helical anchor, the extension shaft serves as the stressing zone.

Applications

The first prestressed rock anchor was installed in 1934 during the raising of the Cheurfas Dam in Algeria. Although typical capacities are in the range of 40 to 200 kips, rock anchors were successfully tested to 3705 kips for the Warragamba Dam in Australia. The first soil anchor was installed for the Munich Olympics construction in the late 1960's.

The most common application of a ground anchor for permanent construction in a building is as a tie-down anchor for a structural mat subjected to hydrostatic pressures. In detailing the anchor connection, the waterproofing is generally placed at the bottom of the mat. The mat is made in two pours with the anchor being locked off against the lower slab, which is structural. The upper slab serves to cover the anchor head. Since the anchor passes through the waterproofing, it must be assumed that seepage will occur at this point. If seepage into the basement is not acceptable, a layer of gravel should be placed between the slabs to collect the seepage.

One of the most important considerations in determining the applicability of ground anchors, which is too often overlooked, is easements and the lead time required to obtain easements. Sometimes only temporary easements are granted. In such cases, the designer must be aware of the varying "definitions" of removable anchors. Most contractors see the process as installing a specially fabricated bar or tendon that can be removed at the end of the project. In this case, the grout will remain in the ground. Unfortunately, some contractors install conventional anchors and then "try" to pull them at the end of a project. When penalty clauses are lax, these contractors will profit from their unsuccessful "attempts". If removable anchors are required, the designer must specify either specially fabricated bars or tendons, or helical anchors. If grout remnants are not allowed, helical anchors must be specified.

Design and Construction Considerations

Corrosion protection is often a point of confusion. The selection of the appropriate level of corrosion protection will depend on the design life of the anchor, the aggressiveness of the environment, consequences of failure, and relative costs. The Post Tensioning Institute's Class I and II corrosion protections are commonly referred to as double corrosion protection and single corrosion protection, respectively. Single corrosion protection can be obtained with a helical anchor by galvanizing the anchor. Kendorski[1], reviewed the performance of rock reinforcements installed primarily in mines and tunnels, and found that the few reported observations of corrosion were due to exposed steel, such as ungrouted mechanical anchors, loss of resin at water bearing joints and poor grout installation techniques.

Materials for drilled and grouted anchors include cement based grout and either high-strength strands or bars. Water/cement ratios are typically 0.4 to 0.5 to ensure high strengths and to reduce bleed. The reduction of bleed is important in ground anchors since bleeding could result in voids or a reduced pullout capacity. In one case, a foreman had reduced the cement content to improve workability in an anchor that included full-length corrugated tubing for double corrosion protection. The excess water outside of the tubing was able to bleed into the surrounding soil with no ill effects. However, the excess water inside the tubing concentrated at the grout-bar interface, resulting in numerous anchor failures during testing.

"The reduction of bleed is important in ground anchors..."

Common cement admixtures include accelerators, retarders, fluidifiers, expanders and anti-bleed agents. The 3- and 7-day grout strengths are most important on projects where the delay between anchor installation and testing impacts the construction schedule. In cases of extremely tight schedules, helical anchors are used since they can be tested immediately after installation. Typically, anchors are not rejected for low grout strengths if they pass proof testing, since the structural capacity of the anchor is provided entirely by the steel bar or tendons.

Tendons typically meet ASTM A-416 Specification for 7-wire strand, with an ultimate stress of 270 ksi. A 0.6 inch diameter strand has an ultimate load of 58.6 kips and a design load of 35.2 kips. Sheathed assemblies of up to 60 strands are commercially available, with design capacities of 2112 kips.

High strength bars are available in Grades 70, 80, 95, 140, 150 and 160. The Grade 150 bar is commonly available up to 1.875 inch diameter, which provide an ultimate capacity of 409 kips and a design capacity of 245 kips.

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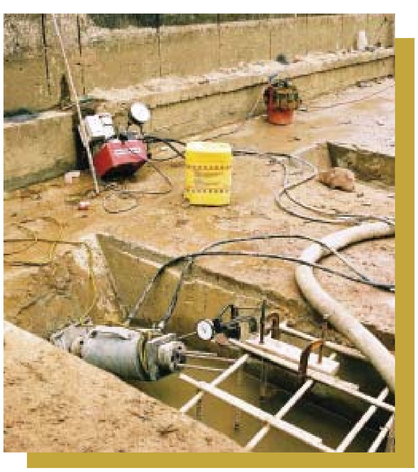
Commonly, every anchor is subjected to proof testing, and a few are performance tested. A proof test consists of loading the anchor incrementally to 120 to 150% of design load and holding the maximum load for a period of at least 10 minutes to observe its creep behavior. Performance testing consists of loading and unloading the anchor incrementally to similar maximum test loads. In addition to verifying the capacity and creep characteristics of the anchor, an evaluation of the anchor elongations from the proof test will verify the length of the stressing zone and give an indication of the length of the bond zone that has been activated. The performance test allows a more accurate evaluation of the activation of the bond zone. Test loads in excess of 133% may increase the steel requirements, since tendons and bars are typically designed for 60% of the guaranteed ultimate tensile strength (GUTS).



Specifying Ground Anchors

The specification must identify the responsibilities of the Owner's engineer and the contractor. Typically, the Owner and/or his engineer will conduct necessary investigations, decide on the appropriateness of anchors, determine anchor loads, corrosion protection and testing requirements, monitor the work and evaluate the test results. In some cases, the engineer may also prohibit certain drilling methods that may damage the soil or nearby structures. The owner is usually responsible for maintenance and any required long-term monitoring.

The contractor will select the materials necessary to satisfy the structural and corrosion requirements, detail the anchor head, select the drilling method and take responsibility for achieving the required anchor load. The primary reason for the contractor taking responsibility for achieving test loads is that the contractor's installation methods and workmanship can greatly influence load capacity. In many cases, when the contractor is less certain of the bond capacity, he will install a re-grout tube, tube-a-machete. If the initial anchor test fails, a fluid cement-water grout will be injected under high pressure through the sleeve ports of the tube-a-machete. The grouting pressure will be sufficient to fracture the initial grout cover and penetrate into the surrounding soils. The combined effects of grouting pressure and grout penetration can improve capacities significantly.

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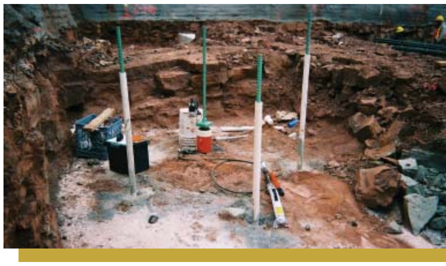
No lateral earth support design is complete without evaluations of external stability, and the possible detrimental effects of the proposed construction methods on nearby structures or utilities. External stability, also called global stability, is an evaluation of potential modes of failure that are located beyond the active soil zone and do not involve the structural and geotechnical capacities of the anchor. External stability usually considers slope stability types of failures. In fine-grained soils, base stability must also be considered.

For sensitive projects, the specifications should clearly state that the contractor is responsible for damage caused to nearby properties, and require the contractor to engage a licensed engineer to design the earth support



system and to evaluate its potential for causing damage. Nearby buildings can be monitored in a variety of methods for settlement, tilt and vibration. Clear action limits and procedures must be provided.

Most designers and contractors follow the Post-Tensioning Institute's ***Recommendations for Prestressed Rock and Soil*** Anchors[2] which provides guidance on specifications, materials, corrosion protection, design, construction and testing.▪

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Product information on high strength tendons can be obtained from Lang Tendons, Inc. Toughkenamon, New Jersey and Tehachapi, California. Product information on high strength bars is available from Dywidag-Systems International, Bolingbrook, Illinois or SAS Stressteel, Inc., Fairfield, New Jersey.

References

1) Kendorski, Francis S., (2003): "Rock Reinforcement Longevity", Geo-Strata, October 2003, ASCE, Reston, Virginia.

2) Post-Tensioning Institute (1996): "Recommendations for Prestressed Rock and Soil Anchors", Post-Tensioning Institute, Phoenix, Arizona.

Also see:

Littlejohn, G. S. and Bruce, D. A. (1977): "Rock Anchors – State-of-the-Art", Foundations Publications Ltd., Brentwood, Essex, England.

Littlejohn, G. S., editor (1997): "Ground Anchorages and Anchored Structures", Thomas Telford Publishing, London, England.