Regional Geotechnics II

INSIDE: 2013 GeoCongress

ALSO
Ten Practical Employee Engagement Steps That Drive Results
Piedmont Residual Soils and Rocks

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The Piedmont region of eastern North America lies between the Appalachian Mountains and the Coastal Plains (Figure 1), extending from Alabama to New Jersey and covering large portions of Georgia, the Carolinas and Virginia. The name comes from Latin, meaning “foot (pied) of the mountains (mont).” The eastern boundary of the Piedmont is commonly called the “fall line,” in reference to the location at which upstream navigation became difficult for colonial settlers. The elevation change promoted grist mills, sawmills, and subsequently textile mills, and cities grew in locations such as Columbus, Macon, and Augusta, GA, Columbia, SC, and Richmond, VA. Major metropolitan cities within the Piedmont include Atlanta, Charlotte, Washington, D.C., Baltimore, and Philadelphia.

Figure 1. Piedmont Region.

The Piedmont is composed of residual soils, saprolites, and decomposed rocks formed by the in-place disintegration of very old metamorphic and igneous bedrocks. Ancient metamorphic mountain chains of Precambrian Z-age gneiss and schist with later igneous intrusions of Paleozoic age granites form the original parent materials. As the mountains are long gone, the remnant topography is now reflected by rolling hillsides. The rocks have been subjected to eons of weathering, which have now broken down to form residuum that appears as fine sandy silts to silty fine sands and other soil-like geomaterials with trace mica that commonly have a reddish to orange-tan color due to iron oxides.

Characteristics of Piedmont Soils and Rock

The thickness of residual overburden soils varies from zero, as with rock outcrops, to depths of 45 m or more. Some prominent rock exposures include Kennesaw Mountain, Stone Mountain, King’s Mountain, and Great Falls at the Potomac River. Rock quality designations (RQD) can vary from 0 to 90 percent with corresponding rock mass ratings (0 < RMR < 80 percent). The granitic inclusions are often used as an excellent source of aggregates, frequently shipped to Florida and other coastal regions where such materials are scarce or non-existent.

Because the soils are formed from slow disintegration of the parent rock, there is typically a transition from soil-like, through a zone of progressively less intensely weathered materials, to solid rock. This zone of decomposed rock, often called “partially weathered rock” or “PWR” in the southern Piedmont, is often characterized as an intermediate geomaterial (IGM), transitional between soil and rock. The partially weathered rock zone presents a challenge when determining engineering properties because sampling is difficult. Standard penetration tests are commonly used to delineate the decomposed rock zone from the residual soil, with PWR characterized as those materials with SPT N-values exceeding 100 blows/30 cm.

Towards a better understanding of Piedmont residual soils, Auburn University and the Alabama Department of Transportation established a national geotechnical experimentation site (NGES) with the Piedmont geology at a 150-hectare property just south of Opelika, AL. The extensive laboratory and field test data from this site provide a useful cross-reference for comparison of geotechnical site characterization in the Piedmont and for understanding the behavior of this unique soil. The subsurface conditions were explored with many series of soil test borings for sampling and a wide array of laboratory testing, including index, consolidation, resonant column, triaxial, and direct shear testing. The in situ test methods used included:

- standard penetration testing (SPT),
- cone penetration and piezocone (CPT and CPTu),
- flat dilatometer (DMT),
The partially weathered rock zone presents a challenge when determining engineering properties because sampling is difficult.

Figure 2. Profiles of SPT, DMT, PMT, CPTu1, and CHT at Opelika NGES.

- pressuremeter (PMT),
- borehole shear tests (BST),
- field permeability tests,
- crosshole tests (CHT),
- downhole tests (DHT), and
- surface wave methods (SASW).

Figure 2 shows a sampling of these in situ test results. In addition, a number of specialty tests on a wide range of deep foundations have been conducted at the Opelika NGES.

The Unified Soils Classification System (USCS) was developed on the basis of sedimentary soil deposits, and therefore the residual soils of the Piedmont geology often do not fare well within this system. For instance, at the Opelika NGES, the grain size distributions show approximately 50 percent fines with a mean grain size $D_{50} = 0.08$ mm. Thus, small differences in percent fines content can show fluctuations in depth intervals of boring logs between ML and SM soil types when no such variations actually occur.

The notion of “layers” and “strata” are misleading too, as the formations result from in-place differential weathering of metamorphic rock strata, which may be folded, faulted, and contorted so that spatial variation is quite unpredictable. More clayey soils are common within the upper few meters due to the more advanced chemical weathering and leaching of surficial soils. Desiccation of surficial layers having higher clay content often produces a strong surface crust.

As a result of training via textbook problems in university classes, geotechnical engineers often come to think of soils as composed of either “sand” (drained) or “clay” (undrained). The Piedmont soils do not conveniently fit into these two boxes. In some cases, the silty soils appear to behave drained as in a loose sand behavior, and in others the silts behave as stiff clays. A summary of triaxial test data from the Opelika NGES is shown in Figure 3, exhibiting a relatively low drained friction with small amount of cohesion. However, pore water pressures can control effective stress conditions for many short-duration loading conditions, with the result that soil response is difficult to predict, being somewhere between drained and undrained triaxial loading conditions.

Engineering Behavior of Piedmont Soil and Rock

The characteristics of Piedmont soils present a number of geotechnical challenges and opportunities. The silty nature of the soil makes it particularly prone to erosion. The high mica content results in greater compressibility than might be expected for otherwise similar siliceous soils. The transition zone of decomposed rocks provides a stratum which is quite strong but difficult to characterize and quantify and may contain large inclusions of relatively unweathered rock.

The intact rock provides a very strong bearing layer, but may include seams of highly fractured or decomposed material. Variability in the rock surface and the potential for large rock inclusions within the transition zone presents a challenge in predicting the quantity of rock excavation in cut areas and the difficulty in removal of rock. This challenge has led to fre-

![Figure 3. Summary of triaxial test data from Opelika NGES.](image)
quent construction claims and lawsuits related to expectations and responsibility for this aspect of construction.

Erosion of the fine-grained soils can be a significant problem for drainage features, and is a constant concern on large earth-moving projects, as is dust control. The silty soils also tend to absorb rainwater in the relatively wet climate of this area, and the clay content is often just sufficient that the soils may be slow to dry out to suitable moisture content for compaction. Earthwork requires careful planning and attention to details to stay on schedule. This soil's susceptibility to seepage erosion also requires careful attention to design of earth dams and flood control structures.

The combination of compressibility related to mica content and erosion-susceptibility affects the design and performance of pavement structures. Good drainage is especially important because when saturated the silty soils can be very much affected by pore water pressures from cyclic loading and prone to pumping. Deflections at pavement joints combined with pumping and erosion of silty subgrade soils can lead to potholes and premature failures of concrete pavements.

The clay content of the soil and small amount of cohesion intercept can be beneficial for excavation support. Cut slopes will often stand for periods of many days or weeks, and construction of excavation support using techniques such as soldier beams and lagging or soil nailing are generally well suited to these soils. However, the partial drainage conditions which may exist can provide apparent cohesion (i.e., undrained shear strength) and lead to a false sense of security. Trench excavations will often stand for short periods and tempt workers to place pipelines without suitable shoring, as evidenced by the reports of disastrous consequences from news broadcasts in the Piedmont region.

**Foundation Engineering in Piedmont Soil and Rock**

Shallow foundations are suitable for routine construction of light commercial structures up to several stories in height for most urban areas of the Piedmont. Soil bearing capacity is often sufficient for high foundation bearing pressures, but settlements of the micaceous silty soils typically control design of these structures. A careful consideration of the localized soil conditions is paramount, as evidenced by one case study in Atlanta where the geotechnical firm estimated 35 mm of maximum settlement for a 14-story dormitory on a large structural mat only to discover the building actually settled 250 mm after completion.

A broad range of deep foundation options, from steel H piles driven to rock to auger cast-in-place (ACIP) piles to drilled shafts, is employed in the Piedmont. The optimum deep foundation type depends upon the specific ground conditions and project requirements. ACIP piles, also known as continuous flight auger piles, in the range of 40 to 60 cm diameter are quite popular for commercial buildings where the speed and economy of these piles can be used to great advantage. Because of the small cohesion typical in Piedmont soils, construction of these piles into or through the PWR is relatively simple. Where deep residual soils are present, drilled displacement piles (Figure 4) can be used to actually densify the soil around the pile and install a cast-in-place pile with a minimum of spoil.

Drilled shafts are commonly used for very heavy structures to transfer loads into the strong bedrock formation within the Piedmont. Because the capacity of drilled shafts on rock may be limited only by the structural capacity of the shaft itself, these foundations are often used to support individual

Figure 4. Installation of drilled displacement piles for the Georgia Aquarium, Atlanta, GA.

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The partial drainage conditions which may exist can provide apparent cohesion... and lead to a false sense of security.

columns without the need for a footing. Besides tall buildings, bridges and transmission structures in the Piedmont often employ drilled shaft foundations for support. For example, the new elevated rail line project extending the Washington, D.C. Metrorail to Dulles Airport includes single-column hammerhead piers located within existing highway right-of-way and founded on drilled shafts up to 3 m in diameter.

Recent research provides useful information on the performance of drilled shafts in the Piedmont, including some of the challenges with design and construction of drilled shafts in this unique geology, as well as load test results from a site in Lawrenceville, GA. The load tests performed at this site demonstrate the extremely high potential side and end bearing resistance which can be mobilized in the Piedmont bedrock. As shown in Figure 5, the values of $E$ represent the computed displacement of a circular plate bearing on an elastic half space with an equivalent elastic modulus equal to $E$. The research also summarizes the consensus approach to design of drilled shaft foundations in the Atlanta area developed by a working committee of local practicing engineers.

Experience Is Everything

Like geological and geotechnical challenges in other regions, the soils and rocks in the Piedmont region pose their own unique challenges that may not be immediately apparent to a geoprofessional who has not encountered them before, yet they cover a significant portion of the southeastern and mid-Atlantic region of the U.S. The residual soils and decomposed rocks often behave quite differently than the usual types of sands and clays, and thus can present some unique geotechnical challenges. Geotechnical engineers and constructors practicing in this area must understand and consider the particular characteristics of the Piedmont geology; experience in the area is a strong component of a geotechnical skill set. This rapidly growing region of the country promises to present many future opportunities for geotechnical engineers to gain valuable practical experience.

![Figure 5. Measured base resistance from Lawrenceville, GA load tests.](image)

**AUTHORS**

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