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# Chapter 22
# CONSTRUCTION

## 22.1 GENERAL

### 22.1.1 Overview

The Geotechnical Section provides construction support to the District Construction personnel and the Construction Engineering Services Bureau for the geotechnical portions of projects. The geotechnical support is used to resolve urgent and emergency situations resulting from soils and foundation problems during construction, and to address more routine questions that arise from site condition changes, issues related to construction material acceptability or requirements for construction quality control and testing. This support includes advising Construction personnel in executing change orders, resolving claims and assessing Value Engineering (VE) proposals. The Geotechnical Section also supports construction personnel when specialty geotechnical construction elements are required (e.g., prefabricated vertical drains, ground improvement, soil nails, MSE walls).

### 22.1.2 Responsibilities

Geotechnical support is provided when requested by the Construction Project Manager (PM) or as agreed to during preconstruction. Responsibilities for providing geotechnical support depend on whether the project design was performed by the MDT Geotechnical Section or a consultant.

#### 22.1.2.1 Projects Designed by Geotechnical Section

During construction, the Geotechnical Section may be responsible for the following:

1. Advisor. For geotechnical problems during construction, the Project Manager contacts the Geotechnical Section for guidance. Unexpected issues may require conducting additional drilling, testing and developing alternative recommendations. Alternatively, the Geotechnical Section can recommend to the PM that specific field construction monitoring activities occur to support the Geotechnical Section design work. Typically, contract documents identify specific field construction monitoring activities. However, the Geotechnical Section will likely need to remind the PM of the importance and expected role of the project geotechnical specialist.

2. Instrumentation Monitoring. For MDT-designed projects, the Geotechnical Section or designated representative is responsible for installing, monitoring and interpreting results from geotechnical instrumentation during construction. This includes preparing all necessary reports and documentation of the results. Depending upon the specific project requirements, the instrumentation could be installed before construction begins or the contract could require the prime contractor to subcontract this work out as part of the contract. For additional guidance on instrumentation, see Chapter 11. For consultant-designed projects, the consultant is responsible for all the geotechnical instrumentation. However, the Geotechnical Section may be asked to review the

consultant's plans to determine if the monitoring methods are sufficient and if conclusions being made by the consultant are consistent with those reached by the Geotechnical Section.

3. Contract Changes. If there are contractor claims, change order requests or value engineering proposals, the Project Manager may contact the Geotechnical Section for guidance. The Geotechnical Section support to Construction is always technical in nature, leaving construction administration issues to Construction Engineering Services Bureau. Because the technical support provided by the Geotechnical Section could affect the construction contract, it is extremely important that the Geotechnical Section contact the Project Manager and District Construction Engineer as soon as possible to let them know of potential technical issues related to the contract.

   Avoid direct communications and directions to the contractor. All communications and recommendations must be through the Project Manager and District Construction Engineer. Any written communication, including e-mail correspondence, should communicate only technical issues and not compromise MDT's ability to administer the contract effectively. This is especially important if potential contractor claims are involved.

   If potential contractor claims are involved, the Geotechnical Section's role is to assist the Project Manager. For example, with changed conditions claims, the Geotechnical Section's professional evaluation of the situation should focus on determining and describing the geotechnical conditions observed during construction in comparison to what was expected based on the data available at time of bidding. The Geotechnical Section does not determine or even imply the merits of the contractor's claim. The Construction Engineering Services Bureau is responsible for contract administration.

4. Verification Drilling. Occasionally, the Project Manager and/or contractor may suspect a difference between geotechnical conditions summarized in the contract documents versus those conditions encountered in the field. For these situations, the Geotechnical Section may recommend or be requested to conduct additional drilling to verify the subsurface conditions.

### 22.1.2.2 Projects Designed by Consultants

The consultant who originally performed the design work should normally handle questions or issues that develop during construction. The responsibility for addressing construction-related design questions rests with the preconstruction consultant because the consultant is more familiar with the assumptions and approaches used in design and, therefore, is in a better position to identify the appropriate response to the question. The project geotechnical specialist may need to initiate or coordinate discussions with the design consultant and/or construction.

Project liability is another reason for requiring the consultant to address the construction-related questions and design issues. By having the consultant address the issue, a clear line of responsibility will occur. As MDT assumes more responsibility for addressing design-related construction issues, liability shifts from the consultant to MDT. In some situations, this change in liability is appropriate and in the best interest of MDT. However, in situations where the consultant could be deficient in design recommendations, it may not be to MDT's advantage to assume this responsibility.

In emergency cases where the Geotechnical Section becomes involved in addressing construction issues for schedule reasons, the original design consultant should be advised of the support provided by the Geotechnical Section, as soon as practical, to confirm that the direction provided by the Geotechnical Section is consistent with the consultant's design intent. Occasionally, for contractual reasons, a request is made for the Geotechnical Section to provide support to the Construction Engineering Services Bureau rather than the consultant. The Geotechnical Section should carefully review and understand to the extent practical, the consultant's assumptions, approaches and recommendations.

### 22.1.3 References

When addressing construction-related geotechnical issues, the project geotechnical specialist should review the project files, appropriate chapters in the *MDT Geotechnical Manual* and other references as necessary. This review step is performed to obtain important background regarding the method to evaluate and resolve the construction issue. As appropriate, consult the references in each chapter, which often provide important guidance on addressing construction issues. Also consult with others within the Geotechnical Section to obtain their experience relative to the particular construction issue. The same construction issue or question may have been addressed on other projects, and alternative methods of resolving the issue or question may be available.

Other references to use during the evaluation of construction questions or issues include the following:

- *MDT Construction Administration Manual*,
- *MDT Standard Specifications for Road and Bridges*, and
- special provisions and general plans pertaining to earthwork and related geotechnical and foundation issues.

## 22.2 EXCAVATION AND EMBANKMENTS

### 22.2.1 General

The Construction Project Manager determines whether to contact the Geotechnical Section based on the type of problem or the construction issue encountered. Most of the support provided for embankments and excavations involves review of change orders and value engineering proposals or providing assistance when problems occur.

When providing support during construction of a project, it is important that the project geotechnical specialist review the design files for project background. This review includes methods used in the design of excavations and embankments. Chapter 15 discusses these methods. If support is provided to the Project Manager, document the observations or recommendations in the field report.

It is essential that the Project Manager and the project geotechnical specialist develop and maintain good dialogue whenever a request to provide field support is made. In most cases construction will be on-going when the Geotechnical Section hears from the Construction staff; therefore, it is critical to provide timely responses to the Construction staff so that construction work is not affected. To the extent practical, the Geotechnical Section should always maintain good communications with the Construction staff before and during construction so that the Construction staff will consider the project geotechnical specialist a valuable resource for any earthwork-related question or problem. If the Geotechnical Section does not respond in a timely manner to requests from the Construction staff, the Construction staff may be less likely to contact the Geotechnical Section in the future.

While the project geotechnical specialist has limited participation in many construction projects, the following Sections summarize activities and considerations that may require support during the construction of excavations and embankments.

### 22.2.2 Borrow and Excavation Materials

A common construction request to the Geotechnical Section involves guidance to the Project Manager as to the suitability of borrow and excavation material. Questions on material suitability require the project geotechnical specialist to review how the material will be used in construction and whether the proposed material meets engineering design requirements. These requirements range from changes in the friction angle or the compressibility of the material to changes in permeability or frost susceptibility. These requests will need to be determined on a case-by-case basis.

For cases involving the suitability of existing materials for foundation support or for re-use at another location, the type of support will depend on the specific construction plans for the location and the design requirements. Good practice in these situations is for the project geotechnical specialist to visit the project site and specifically examine the material and discuss the conditions with the Project Manager. In cases where strength, compressibility or permeability is in question, the project geotechnical specialist may require laboratory tests of the material.

### 22.2.3 Benching Decisions and Inspections

The *MDT Standard Specifications* and *MDT Construction Administration Manual* provide guidance to the contractor for benching of existing slopes prior to fill placement. Normally, the Construction inspectors confirm that these requirements are met. If there are concerns that the benching will not achieve its function or if the need for benching is not apparent, the Geotechnical Section will be requested to review the benching requirements and possibly visit the site.

### 22.2.4 Compaction and Density Testing

Occasionally, the Project Manager contacts the Geotechnical Section regarding difficulties related to compaction control. In this case, the contractor's method of compaction may not meet minimum density requirements regardless of the compactive effort. The project geotechnical specialist may be requested to evaluate the situation and then identify alternative compaction criteria or alternative compaction testing methods.

In most cases, the compaction issue will involve a difference between the material used to develop the Proctor curves and the material placed by the contractor. It may be difficult to resolve this issue without conducting additional Proctor and grain-size analyses to understand the cause of the problem. With some materials, the limitations in the method of developing the Proctor curves or performing the field density measurement might be the source of the problem. This type of problem occurs when dealing with oversized materials.

The compaction problem may be related to the type of equipment being used by the contractor. If the Project Manager or Construction Engineering Services Bureau is not able to identify a suitable solution, one option is to work with the Project Manager or Construction Engineering Services Bureau to develop a test program for the contractor to demonstrate the success of alternative compaction methods.

### 22.2.5 Embankment Fill Placement and Testing

#### 22.2.5.1 General

In most cases, the project geotechnical specialist will not be involved in the routine placement of embankment fill. Observations and testing of the embankment fill will normally be the responsibility of the District Construction Inspector. The exception to this would be in special cases where there are unusual fills used, such as fills with geosynthetic base reinforcement, lightweight fills (e.g., pumice, shredded tires, extruded polystyrene) or construction of mechanically stabilized earth (MSE) walls. These types of fills and walls involve unique placement requirements and benefit from inspection by the project geotechnical specialist.

#### 22.2.5.2 Instrumentation

During construction, an important function of the Geotechnical Section is the installation, monitoring and interpretation of geotechnical instrumentation for embankment construction and, occasionally, for excavations where side slope stability or excavation heave is potentially a design concern. Requirements for instrumentation will typically be defined by the Geotechnical Section as part of the design process and will be called out on the construction plans and discussed in the special provisions.

Chapter 11 provides a summary of instrumentation used by the Geotechnical Section during projects.

## 22.3 ROCK EXCAVATION

### 22.3.1 General

Many roadway construction projects in Montana require the contractor to perform rock excavations. The contractor normally determines the rock excavation method. Depending on the logistics for the site and the type of rock, the excavation methods can range from ripping with a dozer to blasting. If the rock requires blasting, the contractor will need to meet minimum blasting requirements described in the *MDT Standard Specifications* and special provisions for blasting operations.

The role of the project geotechnical specialist during the construction phase ranges from review of blast plans to inspection of new rock slopes for stability. The intent of the review and inspection activities provided by the Geotechnical Section is to confirm that:

- rock excavation will be accomplished in a manner that meets the intent of the geotechnical design while avoiding risk to nearby structures, and
- the excavated slope meets long-term stability requirements while minimizing long-term maintenance problems from rock instabilities.

A significant amount of practical experience is required when providing support to the Construction staff for typical rock excavation projects. Guidelines for providing this geotechnical support are summarized in Section 22.3.2. In most cases, personnel with significant experience in this type of work from the Geotechnical Section should be involved in this review and inspection work.

### 22.3.2 Review and Inspection Activities

The specific review and inspection activities will depend on the amount of excavation (e.g., volume, height) and type of rock structure at the site. These conditions vary for each site; therefore, before providing any review and inspection services, carefully review the Geotechnical Report to develop a clear understanding of the site geology and any special issues associated with the rock excavation.

In general, the review and inspection services will be more involved if blasting is required because of the potential for over-break of the rock during blasting, damage to nearby structures and safety risks. Typical review and inspection services are summarized below:

1. Pre-Blast Survey. Special provisions require the contractor to conduct a pre-blast survey of both on-site and off-site conditions. The project geotechnical specialist may be requested to participate in this survey. The on-site survey involves a review of the contractor's proposed blasting plan and an evaluation of any potential concerns or problems relative to the blasting operations. An off-site survey should be conducted of nearby structures to assess any existing damage (i.e., damage that existed prior to any blasting activities on the project). The role of the project geotechnical specialist in the on-site survey is to identify rock characteristics that could be important for developing an excavation plan and geologic conditions that could be affected by vibrations from

blasting (e.g., location of potential rock falls on steep slopes, loose sands that could densify).

2. Blasting Plan. The contractor will submit to the Project Manager a Blasting Plan before drilling and blasting operations begin and whenever there is a change in the proposed drilling and blasting methods. The Blasting Plan should be in accordance with the *MDT Standard Specifications* and special provisions. The project geotechnical specialist will review, but not approve, the contractor's blasting plan and may require, through the Project Manager, that the contractor clarify and then revise the drilling and blasting methods. As part of this review, the lift heights should be checked to confirm that the heights will allow scaling with track hoes and other similar equipment or will allow for installation of rock bolts if required.

3. Testing Blast. Prior to conducting full-scale operations, the blasting contractor is required to conduct test blasts to determine the adequacy of the proposed blasting plan. The Geotechnical Section will likely be asked to attend the test blast to observe the effects of the blast on the geologic formations and, in particular, the amount of over-break for the proposed program.

4. Production Blasting. The Geotechnical Section may be requested to observe blasting activities during full-scale operations to ensure satisfactory results are obtained. Of particular importance is the over-break that occurs during the blast and whether long-term stability issues could result. As part of the blasting operations, the contractor is required to submit a plan to establish vibration control and monitoring.

5. Post-Blast Survey. If blasting methods are used to excavate the rock and there are nearby structures, the contractor may be asked to support a post-blast survey if complaints of damage or annoyance are made. The intent of this survey should be to determine whether the blasting methods resulted in any damage to nearby structures. This damage could include cracks in plaster and settlement of structures.

6. Inspection and Support After Blasting or Mechanical Excavation. Support may include the following:

   a. Scaling Inspection. The Project Manager may request the project geotechnical specialist to travel to the project site and inspect the face of the excavated rock, either during blasting/mechanical excavation or afterwards. The objective of this inspection is to evaluate the stability of the excavated face. This inspection identifies fractures in the rock that could result in sliding or topping of rock blocks or fractures that could collect water in the winter and freeze, potentially resulting in future failures. Document the field survey in the field report and photograph all features that may fail. The project geotechnical specialist may also be requested to participate with the Project Manager and contractor in deciding whether reshooting of the excavation slope is required.

   b. Mitigation Methods: If the inspection identifies rock features that could pose a future risk to vehicular traffic, buildings or other structures, the project geotechnical specialist should document these risks and recommend methods for stabilizing the rock surface. The stabilization procedures could range from use of stabilization berms to rock bolts. If the unstable features are relatively small, the project geotechnical specialist could recommend further rock scaling to remove the loose or unstable features. If rock bolts are required, the project geotechnical specialist should observe rock bolt or rock anchor testing and determine whether test requirements are satisfied.

Whenever field inspections of rock excavations are performed, the project geotechnical specialist should use the inspection opportunity to confirm that the original design assumptions and approaches are still valid based on the exposed rock conditions. If the characteristics of the exposed rock suggest a potential for long-term stability issues, it is critical that the issue be brought to the attention of the Project Manager and the Geotechnical Engineer and that a consensus be reached on how to handle the issue.

# 22.4 SUBGRADES

## 22.4.1 General

The construction inspector is responsible for monitoring subgrade preparation during construction. However, the Geotechnical Section may receive calls from the Project Manager if site conditions are causing construction difficulties. The most common type of difficulty is soft subgrade conditions, where compaction criteria cannot be met or where construction equipment cannot operate due to wet weather conditions. Chapters 14 and 15 provide discussions of the required foundation conditions for roadway embankments and pavements. Section 22.4.2 identifies types of subgrade issues that the project geotechnical specialist may be required to address.

## 22.4.2 Subgrade Stabilization

A common construction problem is that the soils are softer than expected, based on the available geotechnical information. If the amount of soft subgrade material is limited, the Construction personnel will often determine the type of mitigation that is required, and the Geotechnical Section may not be contacted. However, if the depth or extent of the unsuitable material is of such extent that a significant change in the contract may be required, the Geotechnical Section may be contacted to provide recommendations.

A variety of options are available for mitigating the extent of soft material. In most cases, these mitigation measures are site specific and are based on the following:

- types of soil involved;
- quantity of material that needs to be mitigated;
- availability of specialized contractors, if required;
- availability of materials and/or equipment;
- time requirements; and
- costs of potential mitigation measures.

The project geotechnical specialist will usually need to travel to the site and inspect conditions to fully understand the conditions and mitigation requirements. If the depth or extent of mitigation cannot be identified by visual means, it may be necessary to mobilize exploration equipment to quantify the extent of soft materials.

Subgrade areas requiring mitigation may be identified during the geotechnical investigation phase of a project. In this circumstance, the project plans will specifically indicate the location and depth of required mitigation, and the specifications will describe the requirements for mitigation. A number of potential options exist to establish a more suitable subgrade when unexpected poor quality subgrade material is encountered during construction. Often, the most economical and expedient solution, when deemed suitable, is to expand the mitigation of nearby areas that were identified during design.

The following mitigation options are available to address soft soils:

1. Dig-outs. At locations where unsuitable soils or soft ground conditions are encountered, soils can be overexcavated (also called dig-out situations or subexcavation) at the

direction of the Project Manager. Dig-outs generally extend to a maximum depth of 2 ft to 5 ft (0.6 m to 1.5 m) below top of subgrade (bottom of base course elevation), depending on the thickness and consistency of the soft material. The decision on the amount of dig-out is usually made in the field by the MDT field inspector in consultation with the project geotechnical specialist. Dig-outs are typically backfilled in compacted lifts using A-1-a soils or imported granular fill. A stabilization geotextile is often placed prior to placing the backfill.

2. Bridging of Soft Soils. A common approach traditionally used by MDT when soft subgrade soils are encountered has been to "bridge" over the soft ground by placing fill in thick uncompacted lifts until enough fill has been placed to adequately support equipment. Often a heavy stabilization geotextile will be placed before adding the fill. This method can be successful where proposed embankment fill depths are generally on the order of 5 ft (1.5 m) or greater. This method has limitations, especially where proposed fill heights are low and the "bridging" material is at or near the design subgrade elevation and is unsuitable to support the pavement section. The possibility of creating a mud wave also exists and, in some cases, the additional ground disturbance caused by the mud wave may not be acceptable.

3. Geosynthetics. Stabilization geosynthetics in conjunction with imported granular fill are often used for soft, very moist to wet subgrade conditions. Geosynthetics for this application must function as a separator, a filtration layer and, to a minor extent, as a reinforcement layer. Do not use woven, slit-film geotextiles (i.e., geotextiles made from yarns of a flat, tape-like character) for this application. Further recommendations for stabilization with geosynthetics are provided in Chapter 20. This technique is attractive in that this method:

   - is not dependent upon potential chemical reactions with admixtures,
   - usually is economical in that geosynthetics are often already being used elsewhere on the project and/or are readily available from local sources, and
   - does not require extensive experience by the contractor for successful implementation.

4. Subgrade Admixtures. Subgrade stabilization admixtures (e.g., soil-cement, lime, fly-ash stabilizations) are generally limited to treatment of the upper 1 ft to 2 ft (0.3 m to 0.6 m) of the subgrade and, therefore, may not be adequate for treating deeper deposits. These methods are often not suitable or, at a minimum, need to be evaluated very carefully including performing sufficient laboratory tests to evaluate the potential for sulfate/calcium reactions between the soil and stabilizing agent (e.g., cement, lime). Sulfate bearing soils are especially common in the Great Falls, Billings and Glendive Districts and could be present in the Butte and Missoula Districts as well. These methods may also require special equipment, specialized knowledge and experience by the contractor, and require additional time to allow the chemical reactions to occur.

5. Other Ground Improvement Methods. Other alternatives include recommending a ground improvement program that may involve the use of preloads and surcharges. These methods are usually determined during design and may be difficult to implement

during construction. As discussed in Chapter 15, it may be appropriate to use prefabricated vertical drains (PVD) to accelerate the rate of improvement in locations where deep compressible soils occur. Other methods of ground improvement include the use of stone columns and in-place soil cement mixing amongst other methods.

Occasionally unsuitable soils (e.g., peat, ash, highly expansive soils) may be unexpectedly encountered during construction. Addressing these cases when they occur is highly site specific and often includes removing the unsuitable soils unless the vertical and lateral extent is extensive in which case mitigation will require other options.

### 22.4.3 Shallow Footing Inspection

Special provisions generally require that a representative of the Geotechnical Section observe the completed excavation of a proposed shallow foundation. The project geotechnical specialist will need to observe the excavation and determine if the soil/rock at the bearing elevation is what was expected during the design phase of the project.

This inspection may require that additional excavation be performed if the inspection indicates that the soils/rock are not compatible with design elements. When performing these inspections, it is often helpful to use a probe to determine the depth to which the soft soils occur.

# 22.5 DEEP FOUNDATION CAPACITY VERIFICATION

## 22.5.1 General

The Geotechnical Section provides construction support to the Project Manager during the installation of driven piles or drilled shafts. This support ranges from evaluating the driving resistance of piles to conducting static pile load tests. The following Sections discuss the role of the project geotechnical specialist in the construction of driven piles and drilled shafts. Chapter 16 summarizes the methods used in the design of these deep foundations.

## 22.5.2 Driven Piles

MDT projects commonly use driven piles for the support of bridge structures. The types of driven piles are generally steel H-Piles or steel pipe piles (either open or closed ended), which are filled with concrete after driving. Chapter 16 summarizes the methods for designing these piles. Contract documents for the driven piles will identify the size, planned toe elevation and required capacity. The contractor will propose a hammer to use for installing the piles. The contractor will submit the proposed hammer and driving system details to the Project Manger, who will forward it to the Geotechnical Section. The Geotechnical Section has 14 days to review and approve the contractor’s hammer and driving system details. The Geotechnical Section will perform a wave equation analysis to evaluate if the proposed hammer is capable to drive the piles to the required capacities without overstressing the piles. When wave equation analyses indicate that the proposed hammer cannot drive the piles, the contractor will be required to propose a different hammer system to satisfy drivability requirements. If the wave equation analyses indicate that the pile will be overstressed, the contractor will be required to limit the hammer stroke, propose a different hammer or demonstrate through pile driving analyzer (PDA) testing that the drive system does not overstress the pile. If a different hammer system is used, additional wave equation analyses will be conducted by the Geotechnical Section to evaluate drivability or pile stress.

### 22.5.2.1 Evaluation of Pile Driving

MDT’s Geotechnical Section will participate in the confirmation that piles are meeting capacity through evaluation of driving records, review of the Pile Driving Analyzer (PDA) results, and oversight of pile-load testing, if required. MDT Construction will provide field inspectors to monitor the installation of driven piles for MDT projects. For each pile, the Construction Inspector records the number of blows required to drive the pile per foot or per inch (per meter or per mm) at termination. The inspector also records hammer information, including the blow rate and hammer stroke.

The project geotechnical specialist will support the construction effort by reviewing the driving results. This review involves confirmation that the pile has been driven to the minimum required pile toe elevation, and that the blowcount based upon a given stroke height at the termination depth meets the capacity requirements. There are two methods to determine whether the capacity requirements are met when a PDA test is not performed:

1. Wave Equation Analyses. As part of the hammer approval, the Geotechnical Section will provide an inspector's chart for the required ultimate capacity during driving. This chart provides the hammer stroke height versus blow count (per foot (0.3 m)) for the approved hammer. In those instances where a PDA test is performed, a hammer approval is still performed, but the results of the PDA and CAPWAP analyses are used to evaluate pile acceptance.

2. Dynamic Formula. The Geotechnical Section does not determine ultimate pile capacity during construction solely based on the dynamic formula. The dynamic formula is used as a check against wave equation analyses. The dynamic formula is also used as a preliminary means of evaluating alternative hammers if piles cannot be driven to capacity; however, the preliminary assessment should be supplemented with wave equation analyses. The dynamic formula is provided in the *MDT Standard Specifications*.

The wave equation analysis provides a better representation of the contractor's driving system. The results of the wave equation analysis are used to assess whether driving stresses exceed allowable levels. Wave equation analyses are conducted before the start of driving based on information contained in the contractor's submittal, which describes the proposed driving system.

The Project Manager contacts the Geotechnical Section if the final toe elevation of the pile at termination is greater than 1 ft (0.3 m) from the toe elevation shown on the contract documents, or if the required capacity during driving is not achieved at the design tip elevation. The purpose of this contact is to confirm that the pile is acceptable. This is an important consideration for piles that do not reach the planned toe elevation at refusal driving. In this case, the axial capacity may be met, but the depth to achieve fixity for lateral loading may not be satisfied. The project geotechnical specialist needs to review the original design to evaluate the effects of changing the toe elevation.

#### 22.5.2.2 Pile Driving Analyzer (PDA) Testing and Evaluation

During the design phase, the project geotechnical specialist determines whether PDA tests are necessary at the beginning of pile installation. This determination is a function of numerous factors, some of which include:

- variability in subsurface,
- the number of spans and/or piles,
- previous experience or records of driven piles in similar conditions,
- uncertainty in soil parameters, and
- economics.

PDA tests provide a measurement of pile capacity at the end of initial driving (EOID) and, if required, at the beginning of restrike (BOR). The PDA test also provides a measurement of tension and compressive stresses during driving and the energy developed by the contractor's hammer system. Results of the PDA tests can be used to modify the cushions within the hammer system. In some cases, the PDA results may indicate that a different hammer system should be used. The requirement for PDA testing is specified in the contract documents;

however, a decision to conduct PDAs could be made during construction if the contractor is not meeting required pile capacities. In most cases, a PDA testing agency is hired by the contractor; however, for special situations, MDT could contract this service. The PDA testing agency must be certified by MDT to provide PDA testing results.

Typically, the PDA testing is conducted on the first pile within a group during production pile driving. After the PDA data are collected and a CAPWAP analysis is performed, Construction personnel will forward the data and results from the dynamic testing program to the Geotechnical Section. The project geotechnical specialist reviews these records to confirm that minimum required capacities are met and that driving stresses are not exceeding allowable values.

If the capacity at the EOID is less than required, the field inspector will contact the project geotechnical specialist to determine whether the pile driving should continue. The geotechnical specialist’s evaluation should consider the potential of capacity gain that occurs over time in some soil types (i.e., pile setup), without further driving. Most of the capacity increase results from dissipation of porewater pressures developed during driving. In the case of cohesionless soils, the increase occurs relatively rapidly, in 1 to 3 days. However, for cohesive soils, setup may require a week or more to develop. Where soils are very soft, it may be desirable to measure setup after different periods of time to establish the rate of setup with time. Piles used for setup measurements should be protected from the effects of driving adjacent piles, because interference from adjacent pile driving could alter soil conditions and negate or reduce setup. Setup does not occur in all soil types. For example, dense to very dense soils that have a tendency to dilate during loading may generate negative excess porewater pressures during pile driving. In this case, setup will not occur, and the potential for a reduction in capacity over time (relaxation) may occur as the negative pore pressures dissipate back to an equilibrium condition.

Sometimes PDA testing is performed after the start of production pile driving. This decision is usually based upon one of the following conditions:

- pile capacities are not reached at the design tip elevation,
- pile damage from the driving operation is suspected, or
- evaluation of a different drive system is necessary because of equipment changes by the contractor.

When conducting the PDA after the start of production pile driving, it is usually desirable to have CAPWAP analyses conducted on the PDA measurements. The CAPWAP analysis procedure gives the distribution of toe versus side resistance and the amount of displacement that occurred during the hammer blow. Additional costs and time are associated with obtaining data that can be used in a CAPWAP analysis; however, this additional information is often valuable when trying to diagnose construction problems or difficulties.

#### 22.5.2.3 Static Pile Load Testing

The Geotechnical Section occasionally specifies pile load tests and supports Construction by coordinating pile-load tests. This type of testing is performed to obtain a more reliable estimate of pile capacity. As with the PDA testing, Section 10 of the AASHTO *LRFD Bridge Design Specifications* allows the use of a higher resistance factor if a static load test is conducted.

The following are general types of static load tests:

1. Proof Test. The proof test involves loading the pile to two times the design load to confirm that the displacement (often called settlement) of the pile is less than a predetermined level, for the applied load. During the proof test, the pile head load and displacement are monitored and recorded. The maximum applied load often is not sufficient to cause plunging failure of the pile. The limited amount of loading, the relatively rapid rate of loading if the ASTM D1143 quick test protocol is followed, and the absence of instrumentation make this a relatively inexpensive test.

2. Fully Instrumented Pile Load Test. Fully instrumented tests generally include enough instrumentation to determine the distribution of loads and displacement within the pile during the loading sequence. Strain gauges and displacement tell tales are used to monitor load and displacement within the pile. Load and pile-head displacement are recorded, similar to the proof test. The fully instrumented test is normally loaded to failure. Various sequences of loading and unloading can be included with the pile load test.

Whichever test method is used, it is imperative that redundant load and pile-head displacement measurements are made during data collection.

The load test is most often conducted as part of the construction contract. Contract documents define the type of loading, instrumentation and monitoring required. The project geotechnical specialist develops this plan for the contract documents and then provides oversight during the testing to confirm that the load test is meeting the intent of the contract documents. At the conclusion of the load test, the project geotechnical specialist interprets the test results. This interpretation involves comparisons to design capacities that were calculated using typical empirical and analytical equations (see Chapter 16) and, depending on the type of test, the interpretation could involve evaluation of side resistance and toe bearing capacity.

Chapter 11 discusses some of the instrumentation considered during the load. The textbook by J. Dunnicliff, *Geotechnical Instrumentation for Monitoring Field Performance* covers details of the instrumentation. ASTM D-1143 Quick Load Test Method provides provisions for static load tests.

### 22.5.3 Drilled Shafts

The capacity of a drilled shaft often is more dependent on the contractor's construction method than driven piles. Because of the importance of construction methods on the shaft capacity, the project geotechnical specialist will normally observe construction of the drilled shaft. The Project Manager or Construction Engineering Services Bureau requests support from the Geotechnical Section in three areas, as summarized in the following Sections.

#### 22.5.3.1 Construction Inspection

A project geotechnical specialist is usually on-site during excavation of the hole for the drilled shaft. The project geotechnical specialist provides support in the following areas during the excavation work:

- Review soil types with respect to the site conditions established during the geotechnical exploration program and used in design. If the soil type differs from that shown on the exploratory boring, evaluate whether the capacity of the drilled shaft will be affected by the changed site condition.

- Observe conditions during drilling. These conditions include the type of equipment, progress of drilling, use of temporary and permanent casing, the depth to groundwater and the height of slurry in the hole if slurries are being used to maintain shaft hole stability. Check the conditions of the slurry. Contract documents provide the contractor with specific requirements for monitoring slurries and hole stability; the project geotechnical specialist provides an independent confirmation that these requirements are being met.

- Check the condition at the bottom of the drilled shaft excavation and confirm that slough accumulated at the bottom of the shaft excavation has been removed to the extent practical.

The project geotechnical specialist performs inspections from the surface of the ground. Procedures for inspecting the shaft excavation should conform to those identified in the *Drilled Shaft Inspector's Manual* published jointly by the Deep Foundation Institute (DFI) and the International Association of Foundation Drilling (ADSC). The FHWA Manual *Drilled Shafts: Construction Procedures and Design Methods* (FHWA-99-025) provides valuable construction inspection guidance. Further discussion of drilled shafts is provided in Chapter 16.

#### 22.5.3.2 Integrity and Sonic Cross-hole Testing

A minimum of one sonic cross-hole test per bent will be required following the concrete pour to meet MDT special provision for drilled shaft construction. For sites where subsurface conditions are variable or difficult shaft construction is anticipated, it may be desirable to test each shaft. The required testing is ultimately determined by the Project Manager.

The purpose of the testing is to confirm correct placement of the concrete or grout; to ensure that no voids, soil pockets or lenses are present; and that no zones of poor concrete exist. There are several methods of evaluating the integrity of drilled shafts; however, the cross-hole sonic logging (CSL) procedure is used by MDT. The MDT Bridge Bureau contracts a testing agency to provide the sonic logging service. The Bridge Bureau has a list of approved testing agencies that provide this service.

#### 22.5.3.3 Other Construction Support

The Geotechnical Section can provide support to the Project Manager or Construction Engineering Services Bureau in the following additional areas:

1. Drilled Shaft Coring. If the nature of the defect cannot be resolved through discussions with the contractor and the testing agency, it may be necessary to require the contractor to core the shaft to investigate the extent and nature of the discontinuity. Also consider the following:

   - Multiple holes may be required to establish the geometric limits of the discontinuity. It also may be necessary to test core sections from the zone of lower velocity to establish the amount of strength reduction, if any.

   - Diameter of coreholes typically range from less than 2 in to 4 in (50 mm to 100 mm) or more. An advantage of the larger size coreholes is that borehole cameras can be used to inspect the zone of lower velocity. However, the cost and rate of coring increase significantly with the large diameters.

   - If there is a defect, the project geotechnical specialist may assist in the assessment of effects of the defect on shaft capacity and methods of mitigating any deficiencies.

   - The Geotechnical Section will store cores from the inspection, if this work is required.

2. Shaft Load Testing. For bridge foundations involving special loading conditions or special soils, the Geotechnical Section could also develop and oversee static shaft load tests or the Osterberg load test method. However, these tests are rarely used by MDT because of the expense.

3. Mitigation Development. If it is determined that drilled shaft mitigation is necessary, one or more of the following methods may be used to increase shaft capacity at the contractor's expense:

   - high pressure jetting of the defect followed by pressure grouting,
   - grouting of high strength bars or H-Piles across defect,
   - shaft replacement, or
   - additional shafts.

## 22.6 RETAINING STRUCTURES

### 22.6.1 General

Construction support by the Geotechnical Section for retaining walls includes review and comment on submittals, and specifying and reviewing testing required for anchored and soil nail walls. In the case of anchored walls, each tieback anchor is tested. For soil nail walls, 5% to 10% of the soil nails are tested. The tieback or soil nail contractor is usually required to provide the testing service. The Geotechnical Section's role is to observe the testing, review the results of testing and to confirm that the design criteria are satisfied. The Geotechnical Section may support other types of wall construction when the Project Manager determines that the wall construction is not consistent with the contract documents.

### 22.6.2 Testing During Construction

The project geotechnical specialist provides the following construction inspection for retaining walls:

1. Mechanically Stabilized Earth (MSE) Walls. Inspect the subgrade before the first lift of MSE wall fill is placed. If any soft areas are identified, have the contractor overexcavate and replace the soft soils with compacted granular fill. Also, inspect any mud slab provided for the wall element. During lift placement, periodically review the contractor's placement methods to confirm that lift height, material and compaction meet project specifications. Inspect the facing for the wall to confirm that it is meeting alignment tolerances.

2. Standard CIP Walls. Standard CIP walls inspection should involve review of the exposed subgrade to confirm that it meets design requirements. If any soft areas are identified, have the contractor replace the soft soils with compacted granular fill. Inspect the granular fill and drainage systems to confirm that they comply with project requirements.

Anchored walls and soil nail walls require testing during design and construction of the wall. Testing programs are implemented to determine the capacity of grouted anchors and soil nails. Generally, testing involves monitoring the response of the anchor or nail to imposed load. The anchor or nail is accepted when the rate of movement of the anchor or nail under 1.5 to 2 times the design load is within acceptable limits.

Test anchors and nails during construction to confirm that nail or anchor capacities meet design requirements. FHWA manuals for *Ground Anchors and Anchored System* (GEC No. 4) and *Soil Nail Walls* (GEC No. 7) outline these testing requirements in detail.

The project geotechnical specialist should review the contractor's plans for testing, particularly the method of load application and the method of monitoring. During the testing program, the project geotechnical specialist observes initial phases of testing and ensures on-site Construction inspectors fully understand the requirements for testing and when to contact the Geotechnical Section to discuss changes in testing requirements or changes in anchor or soil nail design.

### 22.6.3 Other Support During Retaining Wall Construction

The Project Manager or Construction Engineering Services Bureau contacts the Geotechnical Section to help resolve other construction problems, particularly as they may affect the long-term function of the wall. This support ranges from evaluating the suitability of foundation support conditions to evaluations of wall backfill materials. In most cases, the project geotechnical specialist observes the conditions at the wall locations and may need to perform geotechnical analyses to develop revised bearing capacities, drainage methods or temporary shoring procedures.

Temporary shoring design is the responsibility of the contractor installing the shoring. In most cases, a licensed engineer should design the temporary shoring and submit the shoring computations to MDT to confirm use of appropriate methods in the design. At a minimum, the shoring design must meet OSHA and Montana State Department of Labor and Industry requirements. The project geotechnical specialist, however, may advise the Project Manager or the Construction Engineering Services Bureau on alternative shoring methods to consider and whether the contractor's proposed shoring design meets standard practices.

# 22.7 OTHER INSPECTION SERVICES

## 22.7.1 Backfill Around Structures

### 22.7.1.1 General

The Project Manager or Construction Engineering Services Bureau may request the Geotechnical Section to evaluate the acceptability of certain materials for use as backfill around structures. Evaluations of this type most often occur when the structure is unique or where atypical loading conditions are applied to the backfill. Geotechnical evaluations may involve a variety of situations, including:

- assessing the suitability of a material that does not meet specified gradations;
- inspections of an excavation adjacent to a structure, before the area is backfilled; and
- inspection of the subgrade for an MSE wall.

### 22.7.1.2 Inspection/Approval of Material Placement

The inspection and approval of material placement around structures is normally the Construction Inspector's responsibility. Inspectors observe placement and conduct density tests as needed. The Project Manager may sometimes request that the Geotechnical Section provide guidance on substitute materials (in place of those listed in the *MDT Standard Specifications* or special provisions) based on their judgment and experience. Because the decision will ultimately be made by the Project Manager, the project geotechnical specialist should advise the Project Manager on the implications of using alternative materials.

## 22.7.2 Cofferdams

Cofferdams are often used by contractors for constructing bridge pier foundations in a river. Contract documents generally assign the responsibility of cofferdam design to the contractor. The project geotechnical specialist reviews the contractor's submittal to confirm that the contractor's approach to design is reasonable. If the contractor has not adequately considered soil and water conditions, there can be a potential for cofferdam failure. These failures can pose a risk to workers, cause environmental damage and delay the construction contract.

The review of the contractor's submittal for cofferdam design should include the following:

- Determine whether the cofferdam has been designed for piping. Perform an independent set of calculations to confirm that these requirements are met.

- Review procedures for installing the sheetpiles and evaluate whether the contractor's method are likely to achieve the required toe elevations for the soil conditions at the site. Advise the Project Manager if the design or method of construction appear to be inadequate.

During construction, the Geotechnical Specialist may also be requested to observe the installation of the sheetpiles used in the cofferdam to confirm that the toe penetration is sufficient. As part of this inspection, the base of the excavation in the cofferdam should be inspected to confirm that soil or rock types are consistent with design information and the amount of water flowing into the cofferdam and the ability of the dewatering methods to handle the water should be observed.

### 22.7.3 Landslide Repairs

The project geotechnical specialist will often be requested to provide support during repair of landslides. This support is provided to confirm that the method of repair will not lead to additional failures or result in long-term maintenance requirements.

The field inspection should include the following activities:

- Review the method of excavation, the sequencing of work and the stockpile plans. If groundwater is expected, review plans for collection and disposal of groundwater. Assess whether any of these plans could result in further instabilities of the landslide.
- Confirm that the lines and grades for the excavation and backfill are being satisfied. Check backfill material to confirm that they meet repair requirements, particularly relative to any drainage collection layers or trenches.
- Oversee installation and monitoring of any instrumentation installed to monitor conditions. Review results of instrumentation immediately after installation to confirm that performance is acceptable.