203 EARTHWORK

203-2 General

An excellent description of construction equipment can be found in the Caterpillar Performance Handbook (available online).

The inspector should check the Special Provisions for pre-wetting requirements when cuts are deeper than three feet. The inspector should review subsection 206-3 of the Standard Specifications when the contractor decides to pre-wet pay items that will be measured and paid on the basis of weight.

203-2.01 Earthwork Adjustments

On projects large and small, earthwork quantities have been a major source of contractor claims for the Department. Since these quantities are based on calculations made during design and are not field measured, the process through which adjustments are made to the project’s bid quantity require a fair amount of engineering analysis and cannot be addressed in the field, utilizing conventional measurement methods. Additionally, earthwork claims will not be validated with haul truck load counts .

In these instances, earthwork adjustments will need to be substantiated and verified via construction survey or photogrammetric survey. Due to this, when the prospect of an adjustment to earthwork quantities is imminent, the Engineer should get ADOT Statewide Survey Services involved at the earliest possible opportunity. ADOT Statewide Survey is able to provide standard construction survey services, as well as aerial surveys via survey-grade drones to assist the Engineer in determining the merit of the quantity adjustment.

It should be noted that investigations into whether an earthwork adjustment is warranted may be initiated by either the contractor or the Engineer. Investigations ordered by the Engineer can be utilized to verify finished elevations on large excavations, or they can be carried out as verification of anticipated earthwork quantities on the project.

When an earthwork adjustment is substantiated, the resulting change in quantity will be based on the project’s plan’s quantity, minus five percent, depending on the nature of the change. In instances where the earthwork quantity is decreased, said decrease will be made to the plans quantity, minus five of the plans quantity. When the earthwork quantity is increased, the revised quantity will be minus five percent of the plan's quantity as well. In essence, when earthwork quantities are decreased, the Department will bear the cost for the five percent variation of the plans quantity, and when earthwork quantities are increased, the contractor will bear the costs for the five percent variation of the plans quantity. The following tables offer further clarification as to how bid quantity adjustments are to be administered:

Example Calculation when Quantity Increases

Item Description	Plans Qty	Measured Qty	Change in Qty	± 5% of Plans Qty	CY Increase	Quantity to Pay
Roadway Excavation	35,140.00	51,911.00	16,771	-1,757.00	15,014.00	**50,154.00**

Change Order quantity will increase quantity by 15,014.00 CY's

Example Calculation when Quantity Decreases

Item Description	Plans Qty	Measured Qty	Change in Qty	± 5% of Plans Qty	CY Decrease	Quantity to Pay
Drainage Excavation	15,400.00	12,500.00	-2,900	770.00	-2,130.00	**13,270.00**

Change Order quantity will decrease quantity by 2,130.00 CY's

203-2.02 Contractor Quality Control

When the Special Provisions require that the contractor perform quality control, the contractor will be responsible for quality control measures necessary to provide acceptable quality in the production, hauling, and placement of materials.

203-3 Roadway Excavation

Roadway excavation involves loosening, digging, loading, hauling, placing, compacting, finishing, and disposal of the excess materials in the roadway cut sections as specifically described in the Standard Specifications and Special Provisions. Before beginning this operation, the Resident Engineer should have a discussion with the contractor on the removal and disposition of material excavated from specific areas within the project. There should be an agreement as to the placement of excavated materials.

203-3.03 Construction Requirements

(A) General

The Standard Specifications do not allow payment for materials excavated beyond the limits of the roadway, except in certain instances. If at any time the contractor excavates outside the slope stake limits, excavates below finished subgrade elevation, gouges, or over excavated slopes (except as required by the Project Plans), then the contractor needs to be notified in writing that this material will not be paid for. When the contractor excavates outside the Project Plans limits, the material will be replaced with a material of equal or better quality and compacted to an acceptable density at the contractor's expense.

Over Excavation below subgrade elevation might be ordered for the purpose of correcting an unstable condition, diverting water, or providing a more gradual change from cut to fill. Observation of numerous fill settlements in areas of abrupt changes indicates a need for over excavation at these locations. Other problems at grade cut points are caused by topsoil being an inferior subgrade material.

Any over excavation which the Resident Engineer has authorized should be measured for payment as roadway excavation unless there are extenuating conditions that warrant performance of the work as extra work. (See Subsection 109.04). However, if the over excavation was the result of the contractor's operation, no additional payment should be made.

Before the work is accepted, the roadway section affected by such over excavation shall be inspected to be corrected to true plans grade and section.

In cut sections, cut ditches may be constructed to prevent the pooling of water. The outlet ends of these ditches should be constructed so that the water will be discharged onto natural ground and not against the embankment slope. Cut ditch sections are staked in conjunction with the roadway excavation.

(B) Slopes

The contractor's selection of the type of equipment for finishing of slopes is predicated upon steepness, access, and type of material.

Rounding of slopes at the top and ends of cut sections is normally done as the excavation progresses, because of more ready access to those areas. Slopes should be trimmed and shaped as much as possible during the progress of the excavation operation.

Slope rounding is not always shown on the typical roadway section in the Project Plans since the typical section refers to Standard Drawings that do specify slope rounding.

There are some instances where slope rounding is not required. These areas are usually described in the Project Plans or Special Provisions.

(C) Blasting

(1) General

Overshooting, or blasting which loosens solid rock formations outside the limits of the planned slopes, may cause slides and overbreakage. The contractor can avoid overshooting by plotting the depth and direction of the drill holes and determining their relation to the slope line to ascertain that they are not beyond the slope line. The contractor should evaluate the amount and type of explosive and the spacing of the holes. The Resident Engineer should closely observe the drilling and shooting operations. If the method used results in overshooting or damage to the adjacent property, the contractor should modify the blasting plan. The Resident Engineer will not assume responsibility for the contractor's methods or procedures, but should become familiar with the properties, uses, and action of explosives and detonators used by the contractor. ADOT Geotechnical Services may be contacted for technical assistance. Each project office located on a job where blasting will be done should obtain information pertaining to the use and safety of commercial explosive material. Refer to the Reference and Additional Information section at the end of this chapter for publications available.

The Resident Engineer should see that good records are kept of blast hole patterns, loading rates, types of blasting agents used, and comments on the results of the blast. Did it throw a lot of rock outside the slopes, was there overbreakage, etc.? Good records of the blasting operations are often useful in resolving disputes about overbreakage and alleged changed conditions.

If blasting is near a developed area, a joint inspection should be made of the surrounding properties prior to blasting to assist in verifying any damage which may occur from the blasting. Photographs or a video recording of the area during this inspection should be made.

It is very important that the Resident Engineer review the blasting plan to ensure that the contractor has followed all requirements for a blasting permit. All required permits must be obtained prior to any blasting.

(2) Controlled Blasting

The contractor shall provide a written blasting plan prior to beginning any blasting work. This plan must be reviewed by the Resident Engineer to verify it contains the following minimum requirements:

- Method for transporting the blasting agent to the site
- Type of blasting agent used

- Size and depth of holes
- Size and loads of blast pattern
- Type of stemming material
- Ignition source
- Method of storage on site
- Procedures in case of a misfire
- Type of firing device (electrical, etc.)
- Type of security that will be used
- Name of blasting company or person doing the blasting, and copies of their certifications or license with the issuing agency

The Inspector should review all requirements for transporting and storage of the blasting agent and review the contractor's operation for compliance.

In an attempt to control the fracture of the rock along the slope line, presplitting is often required on many rock cuts. Presplitting or preshearing can be defined as the establishment of a free surface or shear plane by the controlled use of explosives and blasting accessories in appropriately aligned and spaced drill holes. Preshearing involves a single row of holes drilled along the neat excavation slope line. Presplitting involves a series of charges fired simultaneously in adjoining holes. Collision of the shock waves between holes places the web between the holes in tension and shears the rock between the holes. With proper hole spacing and charge to suit the type of material being blasted, the fracture zone between the holes will be a narrow sheared area through which the subsequent primary blasts can break.

The pre sheared plane reflects some of the shock waves from the primary blasts that follow, which prevents them from being transmitted into the finished wall and minimizes shattering and overbreak.

(3) Radio Frequency Hazards

Radio Frequency (RF) transmitters, which include AM and FM radio, cellular phones, television, and radar, create powerful electromagnetic fields, decreasing in intensity with distance from the transmitter antenna. If the electric detonator wires are in a strong RF field (near a transmitter that is radiating RF power) the unshielded leg wires or circuit wires, whether connected to a blasting machine or not, will act as an antenna similar to that on a radio or TV set. The RF field will induce electric current in the circuit wiring that will flow through the electric detonator connected to it and sufficient RF energy may be induced in the wires to fire the electric detonator. Tests have demonstrated that electric detonator wires, under certain circumstances, may pick up enough electric energy from such fields to cause them to explode.

Commercial Amplitude Modulated (AM) transmitters are potentially the most dangerous. They combine high power and low frequencies so that there is little loss of RF. Low frequencies induce more current than high frequencies so the potential to induce a current in the blasting wire is high.

Frequency-Modulated (FM) and TV transmitters are unlikely to create a hazardous situation. Although their power is extremely high and antennas are horizontally polarized, the high frequency currents are rapidly attenuated in detonators or lead wires. Also, these RF sources usually employ antennas on top of high towers and this has an additional effect of reducing the electromagnetic field at ground level.

Mobile radio transmitter units must be rated as a potential hazard because they enter directly into the blasting area. The Citizen Band radio is an unusual problem for several reasons.

- There are millions of units being used by the general public

- The operating frequency of these units is in the range that is considered to be the worst case for typical electric blasting circuits
- Some irresponsible operators use illegal linear amplifiers to increase their power output

Federal regulations require the posting of signs within 1000 feet of construction sites warning that two-way radios should be turned off because of blasting. Observance of the posted signs will provide the necessary degree of safety if the units are operating within the legal power output. Exhibit 203-3.03-1 shows tables of distances designed for the convenience of the commercial blaster. The selected groupings include all the obvious types of RF transmitters that may be encountered around blasting areas.

The safe distances recommended are for the FCC approved units; it is not possible to specify safe distances for the illegal units because they do not operate within any limits. When planning to blast electrically at a new location, the Resident Engineer should inspect the area for RF transmitters before blasting is started and follow the recommendations of Exhibit 203-3.03-1.

Recommended Distances of Mobile Transmitters
Including Amateur and Citizens' Band

Minimum Distance (feet)

Transmitter (1) Power	MF 1.6 to 3.4 MHz Industrial	HF 28 to 29.7 MHz Amateur	VHF 35 to 36 MHz Public Use 42 to 44 MHz Public Use 50 to 54 MHz Amateur	VHF 144 to 148 MHz Amateur 150.8 to 161.6 MHz Public Use	UHF 450 to 470 MHz Public Use Cellular Automobile Telephones Above 800 MHz
(Watts)	(Feet)	(Feet)	(Feet)	(Feet)	(Feet)
5	30	70	60	20	10
10	40	100	80	30	20
50	90	230	180	70	40
100	120	320	260	100	60
180 (2)	170	430	350	130	80
250	200	500	410	160	90
500 (3)	280	710	480	220	120
600 (4)	300	780	640	240	140
1000 (5)	400	1,010	820	310	180
1000 (6)	1,240	3,200	2,600	990	560

Citizens Band, Class D Transmitters, 26.96-27.41 MHz

Recommended Minimum Distance

	Type	Hand-Held	Vehicle-Mounted
Double Sideband -	4 watts maximum transmitter power	5 ft.	65 ft.
Single Sideband -	12 watts peak envelope power	20 ft.	110 ft.

(1) Power delivered to the antenna.

(2) Maximum power for two-way mobile units in VHF (150.8 to 161.6 MHz range) and for two-way mobile and fixed station units in UHF (450 to 460 MHz range).

(3) Maximum power for major VHF two-way mobile and fixed station units in the 35 to 44 MHz range.

(4) Maximum power for two-way fixed station units in VHF (150.8 to 161.6 MHz range).

(5) Maximum power for amateur radio mobile units.

(6) Maximum power for some base stations in the 42 to 44 MHz band and 1.6 to 1.8 MHz band.

Exhibit 203-3.03-1. Recommended Distances For Transmitters

There may be instances where the use of two-way radios will increase the overall safety of a blasting operation by providing instant communication. When radios are used for this purpose, the minimum separations specified, in Exhibit 203-3.03-1 for a particular transceiver, should be maintained.

Due to static electricity, firing of explosives should not be carried out during a thunderstorm or when one is approaching. During such a period, leading wires should be short-circuited and all persons should move to a safe distance. Short-circuiting is a safeguard; however, it may not prevent the firing of a charge if the wires are struck by lightning.

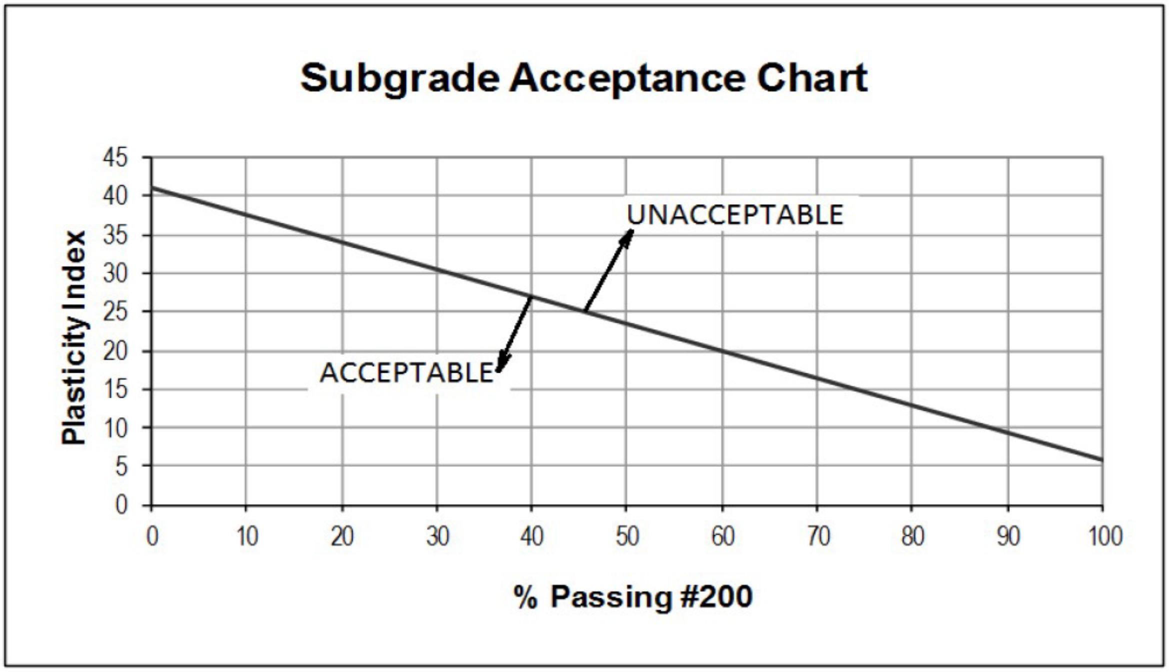
Safety should be the concern of all individuals in the blasting area. Shattered windows, flying boulders, moved railroad tracks, damaged forest and highways, and injured people could be the result of a poor blasting operation. Blasting is an extremely dangerous activity, and the contractor must have the proper respect for the havoc that negligence or errors can cause. Before blasting, the contractor should inform the local law enforcement agencies, inform neighbors in the area, post "Blasting Ahead - Turn Off 2-Way Radio" signs, purchase necessary permits, and use necessary personnel to cordon off the area.

The ADOT Safety and Health Section can assist in resolving safety issues related to blasting. In addition, each project office should have a current copy of the OSHA Safety and Health Standards for the Construction Industry.

(D) Unsuitable Materials

Unsuitable materials are defined as those materials that may adversely affect the stability of the roadbed. Any soils that may cause instability or have some other detrimental effect should not be used unless adequately treated to make them satisfactory. If unsuitable materials are encountered, they should be removed and replaced with acceptable material, or should be processed and placed in a manner that will make the material acceptable. Asphaltic concrete millings may be included in accordance with subsection 203-10.02(D).

The design of a pavement structure is influenced by many variables. One of the most important variables is the strength of the subgrade soils. Our present design method characterizes the subgrade soils by use of the "R" value test, or Resilient Modulus. In the AASHTO Test Manual, the "R" value test method is described as a "procedure for testing both treated and untreated laboratory compacted soils or aggregates with the stabilometer and expansion pressure devices to obtain results indicative of performance when placed in the base, subbase, or subgrade of a road subjected to traffic loads." The "R" value test takes three days to complete and requires specialized equipment. For that reason, all the "R" value tests are performed by the Materials Group. For design purposes, the design "R" value is determined from calculated "R" values, using the Plasticity Index (PI) and the percent passing the #200 sieve (PC) of the subgrade materials as well as from actual "R" value tests. Using this PI and material passing the #200 sieve (PC) information, a subgrade acceptance chart is developed (an example is shown Exhibit 203-3.03-2). This chart is used to determine whether the subgrade is suitable for the proposed design. The subgrade acceptance chart is included in the Final Materials Design Report distributed to the District and the project. When borrow is required to construct subgrade, the project Special Provisions will include the equation, “PC+(2.83xPI) shall not exceed XXX”, to determine its acceptability based on the PI and PC. If the chart or formula is not available at the District, a copy may be obtained by contacting Pavement Design Section.



Subgrade Construction Control R-value:	20
Design R-value:	20

Exhibit 203-3.03-2. Subgrade Acceptance Chart

Borrow placed within three feet of the finished subgrade elevation shall conform to the following requirement:

Value = PC + (2.83 x PI), and shall not exceed XXXX as stated in the project special provisions.

where:

PC = Percent of material passing the No. 200 sieve (determined in accordance with Arizona Test Method 201), and

PI = Plasticity Index (determined in accordance with AASHTO T 90).

Example of the Special Provision:

If during subgrade acceptance testing (other than borrow), the PI and materials passing a #200 sieve of the sample fall within the unacceptable region of the subgrade acceptance chart, Pavement Design Section should be contacted. The design may be affected by these results, necessitating a redesign of the pavement structural section. Meanwhile, efforts should be made to isolate the area of unacceptable material.

Isolating the area of unacceptable material is normally done by sampling on each side of the unacceptable material in increments of 100 feet until acceptable samples are obtained. Using this information, Geotechnical Service Section or Materials Group will determine the best method of dealing with the unacceptable subgrade material which may include chemical or bituminous stabilization, installation of geogrid, removal or replacement with more suitable material.

If borrow material fails to meet the requirements of the formula, the contractor will be required to locate another source of borrow.

Subgrade acceptance samples will normally be taken from the upper 3 feet of subgrade. In certain circumstances the sampling will extend to a greater depth if the conditions could affect the structural design.

(E) Surplus Material

Some projects may have an excess of excavated material after the required embankment work is completed. If this is known beforehand, a designated disposal site may be provided on the Project Plans. If no designated disposal site is provided, then it becomes the responsibility of the contractor to provide an acceptable means of disposing of this material. The Resident Engineer may approve of disposing of this excess material within the project limits. If the contractor intends to provide a disposal site, an Environmental Analysis may be required.

When left to remain on the project, surplus material should be used in widening embankments, constructing berms, emergency turnouts, view points, and dikes. If a large amount of waste appears to be developing due to errors in estimating shrinkage and swell factors or for any other cause, the District Engineer should be notified as soon as possible so that necessary steps may be taken for proper disposal of the surplus material. Unsightly waste piles of surplus material should not be allowed.

Waste material that is used for roadway items such as widening embankments, widening berms, turnouts, viewpoints, dikes, etc., will be placed in accordance with Specification 203-10. End dumping over the side of a fill will not be allowed. Widening of fills from the top will cause the fill to be unbalanced—a condition that can cause the fill to slide or crack from the unequal loading. This type of failure becomes more severe on steep side slopes.

Material shall not be wasted without the permission and direction of the Resident Engineer. When working within US Forest Service lands, US Forest Service officials must approve waste sites.

203-4 Drainage Excavation

It is important that much consideration be given to adequate drainage around and through the roadway prism. Expenditure for drainage control may prove to be well justified due to potential maintenance savings and protection of adjacent properties.

Evaluate not only what condition exists, but also what might occur during the life of the project. Bank protection is often overlooked when evaluating drainage channels, as is nearby urban development. Urban development reduces natural ground surface area, which dramatically increases precipitation runoff. Possible scour or erosion of streambeds is very important in determining proper grades for construction of bank protection. Always try to plan drainage so that no abrupt directional changes are made, but rather gradual changes that will allow the water to run its course with minimal erosion.

Occasionally, properly engineered drainage will require work outside of the established right-of-way. In such cases, additional drainage easement areas or construction easements will have to be secured from the ADOT Right-of-way Group.

Detailed staking of drainage work is required to ensure "puddling" does not occur on abutting private property. This is especially important in developed areas.

Channel changes that will direct the flow into a drainage structure should be completed by the time the structure is completed. To minimize embankment damage during construction, channel changes for the purpose of directing the water flow away from the roadway section should be constructed before completion of embankment. Adequate protection should be provided to prevent erosion due to diversion of water through new channels.

When failure to complete the needed channels and dikes endangers the work or other property, the contractor should be notified in writing. The condition should be well documented and photographed when the contractor does not take timely action to correct the situation.

Inlet or outlet channels to culverts should present a neat appearance upon completion and should be open and ready for use upon completion of the structure. The contractor is responsible for any damage and repair necessary due to inlets and outlets at structures not working properly.

Inspection of Drainage Facilities

After completion of all drainage structures, drainage ditches, and channels, the Resident Engineer should make an inspection of the entire project for the purpose of locating any areas where water might collect. If such areas are encountered, the necessary corrections should be made. Rainstorms during construction afford an excellent means of checking the adequacy of constructed drainage. Take advantage of them.

203-5 Structural Excavation and Structure Backfill

203-5.03 Construction Requirements

(A) Excavation

In most types of soil it is necessary to provide shoring, or slope the ground beyond the neat lines shown in the Project Plans or Standard Drawings in order to avoid caving. The contractor’s slope, shoring and trenching plan must be approved by the Resident Engineer. Side slopes must conform to the Occupational Safety and Health Administration (OSHA) standards. Therefore, all excavations will automatically be referred to the OSHA Standards for excavation. It is very important that the Inspector have a copy of the latest OSHA Standards for excavation when working in these areas.

When plans indicate the structure is to rest on rock, then excavate to a depth sufficient to expose sound material. The rock surface shall be rough, and approximately level, or stepped. Rock seams should be pressure grouted.

It is essential that the subgrade foundation under a structure be uniform and firm under the entire bearing surface. When unsuitable material is at the excavation planned grade then it must be removed and replaced with structure backfill material. When a portion of the structure is on yielding material and the other portion is on unyielding material, or rock then remove the rock to a minimum depth of 2 feet below grade, and replace with structure backfill material in accordance with Specification 203-5.03(B). If it can be avoided, culverts should not be placed partly on filled ground and partly on undisturbed natural ground because of the probability of unequal settlement. If any portion of a culvert must be placed on filled material, the filled material should be placed in accordance with Specification 203-10 Embankment Requirements.

When concrete is to be placed on material other than rock, special care must be taken not to disturb the bottom of the excavation. When suitable material in the bottom of the excavation is disturbed or over excavated, that portion of the foundation shall be restored by the contractor in accordance with Specification 203-5.03 (B) to a firm foundation without payment.

(B) Backfill

Specification 203 permits the contractor some latitude in selecting the material while still requiring a material that is free of frozen lumps, chunks of clay, or other objectionable material, and conforms to gradation, plastic index, and resistivity requirements.

The material should be placed in layers not to exceed 8 inches in depth before compaction. It is advisable to mark the wall or area being compacted in 8 inch increments as each lift is placed in order to assure proper lift thickness. Care should be taken to extend the compacted area as far as necessary in order to notch into firm material.

The Standard Specifications require cutting into compacted material both laterally and longitudinally, with all material to be compacted.

The minimum frequency of density testing should be in accordance with the Sampling Guide in the Materials Testing Manual. At the start of operations on a project, it is advisable to perform more frequent tests to evaluate the effectiveness of compaction methods, material, and moisture content, as well as the variability of the entire backfill and compaction process. The tests should be timely so that there is a minimum of delay to the contractor's operations.

Backfill material should not be placed adjacent to a concrete structure until the concrete has developed the minimum strength specified for that structure. Standard requirement is a minimum compressive strength of 2,000 PSI and in no case backfill before 72 hours after casting. Field cured cylinders and strength history are the basis for determining compressive strength. When placing backfill material around concrete structures care must be taken to bring the backfill material up uniformly on both sides of the structure. Backfill placement on one side must never be more than 2 feet above backfill placed on any other side.

Geocomposite Wall Drains conforming to Specification 1014-6 shall be installed on the soil side of abutment walls, wing walls, retaining walls, and culvert side walls. Care must be exercised to ensure Geocomposite Wall Drains are installed properly in accordance with Specification 203-5.03(C). If the drain fails to function properly it could cause the structure to fail. There will be no measurement for payment of Geocomposite Wall Drains, unless specified otherwise.

As an option the contractor may use a slurry backfill material that conforms to the requirements of Specification 203-5.03(B). The slurry should be placed in uniform layers not to exceed 4 feet in depth before compaction. It is advisable to mark the wall or area being compacted in 4 foot increments as each lift is placed in order to assure proper lift thickness. The water content should not exceed 40 gallons per ton of backfill material. Internal vibrators should be used for compacting slurry in accordance with Standard 601-3.03(D). Have the contractor excavate holes in the slurry so compaction can be tested at random depths. Direct the contractor to refill and compact test holes. Subsection 501-3.04 of this manual and the Specifications have additional information on the applications and use of slurry backfill.

203-5.04 Method of Measurement

The pay limits for structural excavation and structure backfill are shown on the Standard Drawings (or in rare instances, the Project Plans). These quantities are not meant to represent the actual quantity necessary to complete the work. Over excavation may be permitted, but no payment will be made for excavation due to slides, cave-ins, silting, or filling due to lack of side support, the action of the elements, or contractor carelessness. No deduction will be made when the contractor elects not to excavate material within the pay limits, but excavation that does not extend to these limits should not be permitted if it interferes with the setting of forms and braces or the proper backfilling, compacting, and testing operations. Footings that must be over excavated deeper than plan depth shall be measured as structural excavation up to 3 feet deeper than the Standard pay limit.

203-6 & 203-7 Grader Ditch & Crown Ditches

Grader ditches should be constructed as shown on the Project Plans or as directed by the Resident Engineer. Care as to size and general appearance should be exercised in the cutting of grader ditches. Ditches constructed through rock formations should be shaped and trimmed to leave a reasonably pleasing appearance.

Grader ditches will be constructed to the length staked in the field, but it is often advisable to let an experienced blade operator determine the alignment between stakes in order to provide proper drainage.

A properly placed crown ditch or grader ditch may not ordinarily parallel the centerline of the roadway. All ditches should be constructed to approximate natural contour lines. When it becomes necessary to go beyond the limits of the right-of-way to provide proper drainage, no work shall be performed off the right-of-way until the Right-of-way Group has obtained an easement. This need would normally be coordinated through the District Engineer.

203-8 Crown Dikes

Crown dikes are usually formed from material obtained from roadway, structural, drainage excavation, or borrow. The same precautions described in Section 203-6 should be considered in constructing crown dikes.

Placing and finishing of crown dikes shall be as shown in the Project Plans or Standard Drawings.

203-9 Borrow

When the excavation does not develop enough material to complete the embankment, a borrow source may be provided to make up the difference. The need for borrow is usually evident during the design phase, but may develop from unforeseen conditions.

When borrow is required, it shall be obtained from approved sources in accordance with requirements of Specification 1001. One of the major factors affecting the acceptability of a borrow source is the requirements placed on the material by the structural design of the pavement. Requirements for borrow placed within the top 3 feet of subgrade will be specified in the Special Provisions.

Borrow is measured in the original, or final space it occupies depending upon the pay item description shown in the contract. Borrow (Pit) items are measured in the original space occupied, whereas Borrow (In Place) is measured in the final space occupied. All roadway, drainage, or structural excavation shall be incorporated into the roadway embankment prior to the importing of borrow unless the Resident Engineer has given written permission to the contractor to do otherwise.

There will normally be no payment for either roadway or structural excavation that is wasted when borrow has been used, unless specified in the contract documents.

On projects with Borrow (In-Place), or projects with over 5,000 cubic yards of earthwork, the Resident Engineer should consult with the Roadway Designer or Project Manager to determine if the existing ground line should be re-measured. The primary consideration should be reasonable accuracy and validity of the existing topographic information prior to beginning earthwork operations. The Resident Engineer can also contact the ADOT's Statewide Survey Services to complete measurements before and after earthwork operations.

If a question or disagreement regarding quantities arises, then additional measurements can be performed covering that appropriate stage of construction. If there are no problems with quantities in the earthwork operation, no measurement will be necessary beyond the initial work except for Borrow (In-Place). Arrangements to have aerial photography taken for the project should be made at least 30 days prior to beginning any earthwork operation. If a survey crew can make remeasurement, the request should be made with enough lead time to obtain the necessary crew. Borrow sources may need to be measured before and after excavation when borrow is used for miscellaneous purposes such as shoulder widening or flattening.

Changes in borrow placement that result in:

- Material with different properties being used
- Substitution for excavated material
- Changes from a specified source

Are all changes to the contract requiring a supplemental agreement. Always remember written approval is required to change the borrow placement from that shown in the Project Plans.

203-10 Embankment

203-10.02 Embankment Materials

It is very important for the Inspector to ensure that no large rocks, boulders, broken concrete, or other large debris are placed in areas where piling and drilled shafts are to be constructed, e.g. in embankment for a bridge abutment. Subsection 203-10.02, and Subsection 203-10.03 limit the size and type of material that can be placed in these areas. Subsection 203-10.03 includes all drilled shaft, metal pile, abutment, wing wall, and anchor slab locations. The same precautions should be taken at locations for guardrail, underground conduit, and light and signal pole foundations. Some projects build embankments for other projects, so the Inspector needs to be aware of the impacts the contractor's embankment work could have on a future project.

Steel H-piles will corrode in disturbed soils that have a low resistivity or an extreme pH value. Subsection 203-10.02 places limits on embankment soil resistivity and pH for that reason. The key to understanding this specification is that embankment soils are disturbed soils. An undisturbed native soil, which the pile is driven through, may have a resistivity and pH value outside the specifications. As long as the soil is undisturbed, it is usually not a problem for the pile. It is only disturbed soils used for fill, embankment and structure backfill that threaten a pile with long-term corrosion (refer to Subsection 203-5.03[B]).

Two final points about piling and earthwork concern 1) the completion of all embankment work before piling driving begins (Subsection 603-3.04 [A]) and 2) the requirement of excavating to the top of the pile when the embankment has already been completed (203-5.03[A]). The first requirement is discussed further in Subsection 603-3.04 of this manual. The second requirement eliminates the risk of damaging or loosening of the piles as a result of exposing, cutting, and removing excessive lengths of piling.

Where millings are incorporated into embankment materials, it is important that the material consists of no more than 50% millings; it should be a mixture of soil or aggregate and millings. Difficulty compacting at ambient temperatures and long term consolidation may occur if it comprises more than 50% millings. This type of material must be thoroughly mixed to produce a homogeneous material; a pugmil type mixing apparatus is preferred.

203-10.03 Embankment Construction Requirements

(A) Placement

Embankment placed within top 3 feet of the finished subgrade elevation will have different requirements than embankment placed at greater depth. It is very important for the Inspector to ensure that material in the top layer meets all the standard requirements. Sampling and testing will be required in areas where embankment is covered by pavement or penetrated by bridge structures.

The contractor should not begin the removal and placement of borrow until all roadway, structural, and drainage excavation has been removed and incorporated into the embankment, unless otherwise authorized by the Resident Engineer.

The long-term smoothness of a road depends to a large degree on the proper preparation of the area upon which the embankment is to be placed (the embankment foundation). The presence of slippage planes, areas of unstable material, or water from irrigation, seepage, springs or just surface water retained in a clay basin, are some of the detrimental conditions that may be encountered. The presence of localized areas of heavier, lush vegetation is an indication of the presence of water. Such areas should be investigated with consultation of the Materials Group. If it is feasible, areas containing standing or running water should be removed, drained, or otherwise corrected before embankment is placed. In swamp areas where the subgrade is close to the ground line, it may be necessary to raise the grade. Corrective measures not included in the Project Plans or Special Provisions will require a supplemental agreement.

If the existing ground surface is highly irregular, the surface should be smoothed or otherwise restored to a reasonably regular surface.

When constructing embankments on steep slopes, attention should be given to preventing a slippage plane. Benching is required in such locations (see Subsection 2.03-10.03). Where embankments 5 feet or less in height are to be constructed. The top 6 inches of the ground on which the embankment is to be placed must be watered, processed, and compacted to 95% of maximum density in accordance with the Standard Specifications.

Earth embankments should be constructed in successive layers, not more than 8 inches thick before compaction. Thinner layers usually compact more readily. Roots and other unsuitable material should be removed before compaction. Layers of embankment on hillsides should be placed part width, beginning at the low side and decreasing in width as the embankment is raised. Earth embankments are generally built with scraper type equipment that haul, spread, and compact the embankment material.

Operators of large heavy equipment very rarely compact right to the outer edge of the embankment. They prefer to travel in a compacted area away from the edge. This leaves an uncompacted area several feet wide. The Inspector should watch for these areas and other areas where large equipment cannot maneuver, and require supplemental compaction. If supplemental compaction is not provided, the Resident Engineer should be informed and density tests should be taken in the uncompacted area.

When embankment slopes are to be seeded, surface cultivation to the specified depth is critical for minimizing erosion and achieving favorable seed germination. A minimum tillage of 6 inch depth is required on fill slopes and a minimum tillage of 12 inch depth is required on cut slopes. The seeding contractor generally doesn’t have the equipment to accomplish desired tillage. This is best achieved through the general contractor, who has access to larger equipment. The soil should be left in a loose, evenly roughened condition, free of dirt clods or large stones with the entire width of the tillage cultivated to the specified depth. This may require passing the equipment over the same area parallel to the contours several times to provide thorough soil cultivation. All tillage should result in furrows no more than 12 inches apart and directional along the contours.

Embankments should be constructed in such a manner that there will be no ponding of water that will soak into and soften the lower levels of the embankment.

Embankments can be constructed in cold weather, but the inspector must ensure no snow, or frozen chunks of earth are placed in the embankment. Snow and ice will eventually melt and cause the embankment to settle unevenly.

Changes in borrow placement that result in:

- Material with different properties
- Substitution for excavated material
- Change from a specified source

are all changes to the contract and may require a supplemental agreement. Written approval is required to change the borrow placement from that shown on the Project Plans.

Up to 50% milled asphaltic concrete may be included in embankment materials provided they are placed in accordance with subsection 203-10.02(D).

Subgrade Finishing

After all approved materials have been incorporated into the subgrade and compacted to the required density, "blue top" grade stakes, wire control line, or another method approved by the engineer shall be used to provide the finished subgrade elevation. Before the placement of any further materials, the Inspector shall verify that the roadway has been trimmed or slight fills made to bring the subgrade to desired grade and section. The final subgrade density tests must be performed and tests made on the subgrade materials (PI and materials passing a #200 sieve before any base material is placed on the roadway.

The subgrade is to be finished in conformity with the elevations called for in the Project Plans. When asphalt or concrete pavements are placed directly on the subgrade, without select or aggregate base, it is very important to construct the subgrade to the proper cross slope and grade. Subgrade tolerances are shown in the Standard Specifications.

(B) Compaction

(1) Earth

Ideal conditions for obtaining compaction with the least effort would be a material that contains uniform moisture content near optimum (-2% to +2%). Maintaining the moisture slightly below optimum often works better for some materials. With the use of heavy rolling equipment, moisture above may cause the material to pump and not compact properly.

In rare circumstances, fine, non-cohesive, silty soils found near river banks and alluvial fans may exhibit pumping behavior despite being at/slightly below optimum moisture content. Rather than reducing moisture further below optimum, testing to verify compaction may need to be delayed until compaction of a subsequent lift has occurred.

Fine, cohesive, clay soils may be more appropriately compacted at or slightly above optimum moisture content (-1% to +3%) to reduce the potential for further expansion. In most cases a vibratory padfoot compactor, known as a “sheepsfoot roller”, is the most efficient method of compaction.

Most soils compact more readily in thin layers. This is the reason for the maximum lift thickness requirement of 8 inches that appears in the Standard Specifications. In some cases it may be in the contractor's interest to further reduce the lift thickness.

Embankment placed near a bridge abutment must conform to special compaction requirements that will prevent settlement of approach slabs and anchor slabs.

Prewetting of roadway excavation and borrow pits is common practice among contractors: distribution of water is usually better, dust is controlled, loading of scrapers is aided, and compaction can be obtained easily with a minimum of loss by evaporation. (See Subsection 206-3 for the method of computing the weight of materials to which water has been added).

The amount of watering and rolling required in the construction of rock embankments depends on the amount and character of fine material contained between the rock fragments. Close observation of the placement of the material and good judgment will determine the amount of water and type of compaction needed. Normally, if the fine material does not fill the voids between the rocks, watering and rolling will not be effective. Since compaction tests can seldom be performed in rock embankments, the Inspector must give this type of work more attention than normally required for other embankments.

Stability and support of soils is directly affected by the degree of compaction. The lower the compaction, the lower the support, especially when moisture is present.

As mentioned in the discussion of embankment, the Inspector should keep the contractor advised of possible problem areas involving drainage and the roadway prism.

Saturated areas are to be drained, dried out, and compacted before being covered. Sometimes it is more efficient to just replace the material.

Filling in with dry material is usually not an acceptable method of stabilizing wet earth because complete mixing of the wet and dry material seldom occurs. The mixed area will look stable and may temporarily support construction equipment, but it will eventually fail under repeated loading.

Do not allow the contractor to bridge over a soft spot by covering the spot with dry, stable material. Soft, unstable areas do not meet specifications and must be corrected.

The removed material can be wasted in areas outside the roadway prism, or if sufficient embankment is available, it can be spread out to dry in thin lifts. Before being placed within 3 feet of finished subgrade elevation, the material is to be tested to be sure it meets subgrade acceptance requirements.

The Inspector needs to keep good records of the areas needing corrective work and how the work was accomplished.

Soils will vary widely as to the amount of effort necessary to achieve a uniform degree of compaction. It is the contractor's responsibility to provide the equipment needed to obtain the required density.

Compaction tests should be performed so that they represent any area where it is suspected that there may be inadequate compaction (such as near outside edges of roadway or near structures). The outside edges of fills should be given extra attention to assure density. Each lift of material placed must be tested and approved before placing additional lifts.

The contractor should be immediately advised of the results of the compaction tests.

Testing equipment, e.g. "Speedy" moisture testers, scales, molds, proctor hammers, nuclear gauges, and volume measuring devices, are to be checked or recalibrated before the start of each project and at suitable intervals during the life of the project.

(2) Rock

Rocky fill material should not be deposited in large piles and leveled off. Dumping the material on top of the layer being built and shoving it ahead with a dozer can obtain a more uniform arrangement of the different rock sizes. This method will provide a more effective placement of the material in the fill so that there will be a minimum of voids. When possible, rock should be placed, spread, and leveled in 24 inch thick layers. The ideal layer will cover the full width of embankment and contain sufficient earth or other fine material to fill the interstices between rocks. The top layer of the rock embankment should be built with the most care since this layer serves as the subgrade. Where suitable material is available within the cut area, it may be set aside for finishing the final layer. However, such material should be used only after tests have been performed to prove that its use is acceptable per Section 203-10. The use of material containing clay or frozen earth must be avoided for plating rocky subgrade. If satisfactory quality plating material is not available, it is better to use a greater thickness of subbase material for filling any irregularities in the surface of the subgrade.

In rocky material the Inspector should seek out areas that can be tested. There is a tendency to easily dismiss the need for compactive effort simply because the material is rocky. Vibratory compaction is best for rocky soil, but almost any type of compactive effort will be beneficial.