

# Construction Specification 29—Soil-Cement

## 1. Scope

The work consists of furnishing, placing, compacting, and curing a mixture of soil material, portland cement, and water. The mixture shall be uniformly mixed, blended, compacted, finished, and cured as specified. It shall conform to the lines, grades, thicknesses, and cross section(s) shown on the drawings.

## 2. Material

**Soil** material shall be obtained from the required excavations or designated borrow locations and shall meet the requirements outlined in this section.

Deleterious material, such as sod, brush, or roots, shall be separated from soil material during the selection, blending, and routing operations. Rock particles larger than 2 inches in any dimension shall be removed before mixing.

Soil material, cement content, and moisture content other than those specified in section 15 may be used as approved by the engineer. Proposed alternatives must meet one of the following requirements to be considered:

- a. If the soil material to be used has gradation and Atterberg limits similar to the soils specified, the same cement content and water content shall be used. The contractor shall provide gradation and Atterberg limit test data from a qualified soil testing laboratory verifying gradation and Atterberg limits.
- b. If the soil material does not have gradation and Atterberg limits similar to the soils specified, the contractor shall provide soil-cement durability tests, moisture-density relations data, Atterberg limits, and gradation tests from a qualified soil testing laboratory. The soil-cement mix ratio and water content shall also be provided by the laboratory. As a minimum, the following durability tests shall be provided: ASTM D 559 and ASTM D 560. The moisture-density relations are to be in accordance with ASTM D 558. The tests must indicate a soil-cement of a quality equal to or exceeding the quality specified.

**Portland cement** shall conform to the requirements of Material Specification 531, Portland Cement, for the specified type. Mixing of different brands or types of cement is not permitted.

Portland cement shall be furnished in bags, barrels, or bulk. Bagged cement that is stored at the job site shall be used in the same order as the deliveries arrived on the site. Each shipment of bagged cement shall be handled and stored so that it may be readily distinguished from other shipments. Emptied cement bags shall be disposed of by the contractor at offsite locations selected by the contractor. Burning of emptied cement bags is permitted if identified on the burning permit as an allowable activity.

**Water** used in mixing or curing soil-cement shall be clean and free from injurious amounts of oil, acid, alkali, organic matter, or other deleterious substances, and shall meet the requirements for water as specified in ASTM C 94.

**Pozzolanic material**, when used, shall comply with the requirements of ASTM C 618 Class C or F, Specifications for Fly Ash, and Raw or Calcined Natural Pozzolan, except the loss on ignition shall not exceed 3 percent.

**Curing compounds**, when used, shall conform to the requirements of Material Specification 534, Concrete Curing Compound, for the type of curing compound specified. Application of the curing compound shall be in accordance with section 12 of this specification and the manufacturer's recommendations.

### **3. Operations of pits or stockpiles of soil material**

All work required in the opening and operation of borrow areas or stockpiles shall be performed by the contractor. The borrow areas or stockpiles shall be opened in a manner to expose a near vertical face of the soil material for a suitable working depth. Exposed cut faces shall not exceed 5 feet in height without benching back if it poses a threat to construction personnel or others. The contractor shall conform to OSHA Construction Industry Standards (29 CFR Part 1926) Subpart P, Excavations, Trenching, and Shoring, during all excavation operations.

Material shall be excavated in successive vertical cuts extending across the pit or stockpile. When approved by the engineer, successive horizontal cuts on a horizontal oriented working face may be permitted in homogeneous soils. All pockets or strata of unsuitable material not meeting the quality requirements specified in Section 2, Material, shall be wasted. The method of operating the pit or stockpile and the blending of material shall be adjusted as necessary to obtain material conforming to the specifications. Upon completion of the work, the pits shall be graded and dressed to minimize erosion and to provide free drainage.

### **4. Foundation preparation**

Before soil-cement processing commences, the subgrade placement area shall be graded, shaped, and compacted in conformance with the lines and grades shown on the drawings. The subgrade shall firmly support the construction equipment. Immediately before placement of the soil-cement, the compacted subgrade surface shall be moistened to approximately the same moisture content as specified for the soil-cement, and shall be kept moist until the soil-cement is placed.

### **5. Design of soil-cement mixture**

The materials and proportions of the soil-cement mixture shall constitute the job-mix. After a job-mix has been approved, the source, character, or grading of the soil and the type, brand, or quantity of cement or pozzolanic material shall not be changed without prior approval of the engineer. A change in material or proportions requires the establishment of a new job-mix supported by evidence, as required for the initial job-mix, that the proposed new material and mix proportions will produce soil-cement of the strength specified.

The use of calcium chloride or other accelerants or antifreeze compounds is not permitted unless approved by the engineer.

**Method 1**—The contractor shall determine the mix proportions and submit the job-mix design along with the supporting test results to the engineer for approval before incorporating any of the material into the work. The brand of cement and the location of the soil material source shall be included with the job-mix design data. The mix design shall be such that the soil-cement meets or exceeds the minimum compressive strength specified. A new mix design shall be submitted for approval any time the contractor requests a change in material or a proportioning of material from that given in the approved mix design. In no case will the engineer's review and approval of a mix design relieve the contractor of responsibility to provide soil-cement meeting the contract specifications.

A maximum of 15 percent of the total weight of cement may be replaced with fly ash at a rate of 1.2 pounds of fly ash per pound of cement replaced.

**Method 2**—The contractor shall furnish the soil, fly ash, cement, and moisture content as specified in section 15 of this specification. During the course of the work, the engineer may adjust the job-mix proportions as needed to achieve the specified compressive strength.

**All methods**—The percent of cement to be used in the mix is determined by dividing the weight of cement by the oven-dry weight of the soil material.

## **6. Mixing**

The mixing plant shall produce a mixture of soil, cement, and water that is uniform in color and at the required moisture and cement content throughout. The plant shall be equipped with measurement devices that proportion the mix in the specified quantities. Before all measurement devices are used, they shall be calibrated and certified by a qualified technician approved by the engineer. The actual quantities of the mix shall not vary more than 2 percent from the approved job-mix quantities unless otherwise approved. The moisture content shall be the percentage of moisture in the mixture at the time of compaction.

The engineer shall have full and free access to the mixing plant at all times for inspection of the plant's operation and for sampling the soil-cement mixture and its components.

**Method 1**—Mixing of the soil, cement (including fly ash), and water shall be accomplished in a stationary mixing plant. The plant may be either a batch type or a continuous flow type design. The plant may use either weight or volume proportioning. The scale or metering devices shall be sensitive to 1 percent of the maximum load that may be required or imposed. The mixer shall be a pugmill, revolving-blade, or rotary-drum system.

Facilities for efficiently storing, handling, and proportioning unmixed materials shall be provided at the plant.

**Method 2**—Mixing of the soil, cement (including fly ash), and water shall be accomplished in a truck mixer. The mixer shall meet the requirements for truck mixers contained in ASTM C 94.

**Method 3**—Mixing of the soil-cement shall be accomplished in place. Mixing of the soil, cement (including fly ash), and water shall be accomplished by a single or multiple transverse shaft mixer, a traveling pugmill, or similar equipment approved by the engineer. A motor grader or similar equipment is not acceptable in lieu of the mixing equipment specified.

Soil material to be mixed in place shall be formed into windrows or divided into known grid areas. If windrows are used, they shall be prepared to a known size with a sizing device. The tops of the windrows shall be flattened or slightly trenched to receive the cement.

The cement quantity necessary to meet the specified cement-to-soil ratio shall be distributed uniformly on the windrowed soil or over the prepared grid areas. After spreading, cement that has been displaced or is found to be less than that specified shall be properly adjusted or replaced before starting mixing operations.

The mixing operation shall be accomplished so that no unmixed seams of soil are between layers. Excessive streaking of the soil cement below the layer being mixed is not allowed.

**All methods**—The following provisions apply to all methods of mixing. The mixing time shall be controlled so that all ingredients are mixed as long as necessary to ensure a thorough, uniform, homogeneous mixture of soil, cement, pozzolanic material (if used), and water. Mixing time shall be adjusted based on tests and field determinations. Mixing time is considered as the interval between the time the cement contacts the soil and water and the time the mixture leaves the mixing unit or when the mixer speed is reduced to the agitating speed. The soil and cement shall be mixed sufficiently to prevent cement balls from forming before the water is added. The water may be applied through the mixing machine or separately by approved pressure distributing equipment.

Soil that has plastic silt or clay lumps larger than 1 inch shall be pulverized or screened out of the raw soil before mixing.

## **7. Transporting**

The soil-cement mixture shall be transported from the mixing plant to the site of placement in vehicles having tight, clean, smooth beds or mixer trucks. Haul time shall not exceed 30 minutes.

The contractor shall protect the soil-cement mixture if transported during unfavorable weather. Any material excessively wet by precipitation is subject to rejection.

Equipment shall not be operated on a finished and compacted layer of soil-cement except where specifically permitted. Any damage resulting to the finished surface of the soil-cement from such an operation shall be repaired by the contractor at no cost to the owner.

Earth ramps crossing over completed soil-cement must have a minimum compacted thickness of 2 feet. Where ramps are constructed over soil-cement that is not to finished grade, all foreign material and the uppermost inch of the top layer of soil-cement must be removed before the soil-cement installation is continued.

## **8. Placement**

Soil-cement shall not be placed until the required excavations and preparation of the foundation are completed and the foundation has been inspected and approved by the engineer.

Equipment for spreading the soil-cement mixture shall be suitable for the purpose and shall be operated to produce a reasonably smooth, uniform surface. The equipment shall be controllable so as to produce uniform layers not more than the specified maximum thickness. The layer of soil-cement, or each successive lift when layering is required, shall be spread and compacted as soon as possible after the preceding layer is completed and approved. Soil-cement shall be placed in horizontal layers or layers conforming to the plane of the subgrade.

When the time between completion of compaction on a layer and start of placement of the next layer is more than 2 hours, the contractor shall scarify the surface to a depth of 1 inch at a maximum spacing of 12 inches unless specified otherwise in section 15 or approved by the engineer. The contractor shall clean off the scarified surface thoroughly by power brooming or other approved methods before proceeding. The entire broomed surface shall then be thoroughly moistened before the next layer of soil-cement is placed.

Soil-cement placement operations may commence when the air temperature is not less 40 degrees Fahrenheit and a rising temperature is expected for the work period. Soil-cement shall not be placed on a frozen foundation or if the soil to be processed is frozen or if weather conditions are such that the material being processed cannot be completely compacted and protected before the onset of damaging weather (overnight lows below 40 degrees Fahrenheit, cold fronts, rainstorms). The use of accelerators or antifreeze compounds is not allowed unless otherwise specified. The temperature of fresh soil-cement shall not be allowed to drop below 32 degrees Fahrenheit for 7 days after placement. If temperatures are expected to be below 45 degrees Fahrenheit, the contractor's method for protection shall be approved by the engineer before placement of any soil-cement.

When the mean air temperature does not exceed 90 degrees Fahrenheit, the moisture content at the time of compaction shall be within the range specified. When the mean air temperature exceeds 90 degrees Fahrenheit or conditions promoting rapid drying of the soil-cement mixture exist, the moisture content of the mixture may be increased up to 2 percentage points above optimum unless otherwise specified. Any increase in moisture content shall be less than the quantity that causes the soil-cement to become unstable during the compaction and finishing operations.

## **9. Compaction**

**Equipment**—Compaction equipment used shall be capable of uniformly compacting the soil-cement mixture to the specified density. It shall not have tamping feet or projections that penetrate to previously compacted layers. Compaction with only the wheels of the hauling equipment is not an acceptable method of compaction.

**Compaction requirements**—Soil-cement shall be uniformly compacted to a density not less than the minimum density specified. Optimum moisture and maximum density shall be determined by ASTM D 558. Natural Resources Conservation Service Test No. S-6 (USBR Test E-25), Rapid Compaction Control Method as referenced in NEH-19, may be used as equivalent to ASTM D 558.

Compaction shall start as soon as possible after spreading. Elapsed time between the addition of water to the soil-cement mixture and the start of compaction shall not exceed 60 minutes. The elapsed time between addition of water to the soil-cement mixture and completion of compaction shall not exceed 90 minutes.

**Other requirements**—If the surface of a layer of soil-cement has been rutted or compacted unduly by hauling or other equipment, the contractor shall scarify and recompact such surfaces within 2 hours of the addition of water to the cement. When required to maintain uniformity of the layer surface, blading in connection with compaction operations shall be employed. If blading is required, raw unmixed soil shall not be bladed onto the mixed soil-cement. When more than 2 hours has occurred from the time water was added to the cement, the damaged soil-cement shall be removed in a manner and to the extent approved by the engineer.

## **10. Construction joints**

At the end of each workday, or when the adjacent placing operation is terminated for more than 2 hours, a vertical construction joint shall be made along all unfinished edges of the thoroughly compacted soil-cement. Just before placing operations are resumed, the construction joint shall be shaved to remove all dry soil-cement and all curing compound from the joint face.

## **11. Removal and replacement**

The soil-cement installation shall be considered defective and shall be removed and replaced in accordance with these specifications when any one of the following conditions occur:

- a. Compaction operations are interrupted for any reason before the completion of compaction and the soil-cement mixture is left undisturbed for more than 30 minutes.
- b. The soil-cement mixture becomes excessively wet before completion of compaction so that the moisture content exceeds the specified limits.
- c. The compacted soil-cement does not meet the density and moisture requirements except that when the moisture is lower than required, the soil-cement mixture may be reworked, thoroughly mixed, and compacted within the time limits stated in section 9, Compaction requirements.
- The finished surface is rough or below grade such that a thin "scab" section would be required to smooth the surface or bring the surface to grade.

## **12. Protecting and curing Moistening bonding surface**

Compacted surface of soil-cement that is to receive an overlay of soil-cement or concrete shall be kept moist until placement of the overlay or adjacent layer of soil-cement or concrete. The contractor is not required to keep such surfaces moistened for longer than 7 days unless the overlay of soil-cement or concrete is not accomplished within 7 days as a result of the contractor's operations.

### **Curing finished exposed surface**

**Method 1**—Concrete curing compound conforming to ASTM C 309 of the type specified shall be applied at a rate of not less than 1 gallon per 150 square feet of surface using constantly agitating, pressure spray equipment. This compound shall form a uniform, continuous, adherent film that does not check, crack, or peel.

The surface of each section of soil-cement to be treated with curing compound shall be moistened with a light spray of water immediately after the section has been compacted. As soon as the surface film of moisture disappears, but while the surface still has a damp appearance, the curing compound shall be applied. Special care shall be implemented to ensure ample coverage with the compound at edges, corners, and around rough spots. After application of the curing compound has been completed and the coating is dry to the touch, any required repair of the soil-cement surface shall be performed. To ensure a clean bonding surface, all curing compound or other foreign substances shall be removed from the area before additional soil-cement is applied. Each repair, after being finished, shall be moistened and coated with curing compound in accordance with the foregoing requirements.

**Method 2**—Curing moisture shall be maintained by sprinkling, flooding, fog spraying, or covering with continuously moistened canvas, cloth mats, straw, sand, or other approved material. Water or covering, or both, shall be applied so that the soil-cement surface is not eroded or otherwise damaged.

**Method 3**—Waterproof paper or plastic sheeting shall be used to completely cover the soil-cement and prevent moisture loss. Adjoining sheeting shall be overlapped at least 1 foot and weighted or taped to prevent moisture loss at joints. Sheeting shall be anchored sufficiently to prevent displacement by the wind.

**All methods**—The curing process shall be maintained for 7 days. Any curing compound that is removed from the surface or damaged within 7 days after application shall be repaired immediately. The contractor shall have all equipment and material required for curing at the site ready for use before starting soil-cement placement activities.

### **13. Inspection and testing**

During the course of the work, the engineer will perform quality assurance tests as required to identify materials and determine compaction characteristics, moisture content, and density of soil-cement in place. Tests performed by the engineer will be used to verify that the soil-cement placed conforms to contract requirements of the specifications and not as a replacement for the contractor's quality control program.

The contractor shall conduct all required quality control tests in accordance with the approved Contractor Quality Control Plan to assure that work performed meets contract requirements.

### **14. Measurement and payment**

For items of work for which specific unit prices are established in the contract, the quantity of soil-cement is measured within the specified limits and computed to the nearest cubic yard by the method of average cross-sectional end areas. The quantity of soil-cement required to fill voids resulting from overexcavation outside the neat lines or pay limits is included in the measurement for payment where such overexcavation is directed by the engineer to remove unsuitable foundation material, but only to the extent that the unsuitable condition is not a result of the contractor's improper construction operations, as determined by the engineer.

**Method 1**—Payment for soil-cement is made at the contract unit price per cubic yard. The payment will constitute full compensation for all labor, material, equipment, transportation, tools, and all other items necessary and incidental to completion of the work, but not including other items listed for payment elsewhere in the contract.

**Method 2**—Payment for soil-cement is made at the contract unit price per cubic yard. The payment will constitute full compensation for all labor, material, equipment, transportation, tools, and all other items necessary and incidental to completion of the work, but not including furnishing and handling cement or other items listed for payment elsewhere in the contract.

Measurement for payment of cement is made to the nearest 100 pounds by actual weight. For each load of cement delivered, the contractor shall furnish to the engineer a statement-of-delivery ticket showing the weight of the cement in the load. Payment for cement is made at the contract unit price for furnishing and handling the cement, and such payment will constitute full compensation for all material, labor, equipment, storage, transportation, and other items necessary and incidental to furnishing and handling the cement. No payment is made for cement used in wasted soil-cement, replacement of damaged or defective soil-cement, extra soil-cement required as a result of overexcavation, and excavations intentionally performed to facilitate operations.

**All methods**—The following provisions apply to all methods of measurement and payment. Compensation for any item of work described in the contract, but not listed in the bid schedule is included in the payment for items of work to which it is made subsidiary. Such payment and the items to which they are made subsidiary are identified in section 15 of this specification.

## **15. Items of work and construction details**