SOIL-CEMENT STABILIZATION

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Cement stabilization refers to stabilizing soils with Portland cement. The primary reaction is with the water in the soil that leads to the formation of a cementitious material. These reactions occur almost independently of the nature of the soil and for this reason Portland cement can be used to stabilize a wide range of materials.

Although there are several types of cement stabilized soils, there are two types associated with highway construction:

1. Soil-cement—it contains enough cement (usually > 3%) to pass standard durability tests and achieves significant strength increase.

2. Cement-modified soil—an unhardened or semi hardened mixture of soil, water, and small quantities of cement.

In general, there are three types of soil-and-cement mixtures as follows:

1. *Plastic soil-cement* is a hardened mixture of soil and cement that contains, at the time of placing, enough water to produce a consistency similar to plastering mortar. It is used to line or pave ditches, slopes, and other areas that are subject to erosion. It also may be used for emergency road repair by mixing high-early-strength cement into the natural material in mudholes.
2. *Cement-modified soil* is an unhardened or semihardened mixture of soil and cement. When relatively small quantities of Portland cement are added to granular soil or silt-clay soil, the chemical and physical properties of that soil are changed. Cement reduces the plasticity and

water-holding capacity of the soil and increases its bearing value. The degree of improvement depends upon the quantity of the cement used and the type of soil. In cement-modified soil, only enough cement is used to change the physical properties of the soil to the degree desired. Cement-modified soils may be used for base courses, sub-bases, treated sub- grades, highway fills, and as trench backfill material. .

3. *Compacted soil-cement*, often referred to as simply soil-cement, is a mixture of pulverized soil and calculated amounts of Portland cement and water that is compacted to a high density. The result is a rigid slab having moderate compressive strength and resistance to the disintegrating effects of wetting and drying and freezing and thawing. The remainder of our discussion of soil-cement is directed towards this type of soil-and-cement mixture.

MATERIALS FOR SOIL-CEMENT

Soil, Portland cement, and water are the three basic materials needed to produce soil-cement. Low cost is achieved mainly by using inexpensive local materials. The soil that makes up the bulk of soil-cement is either in place or obtained nearby, and the water is usually hauled only short distances.

The word soil, as used in soil-cement, means almost any combination of gravel, sand, silt, and clay, and includes such materials as cinder, caliche, shale, laterite, and many waste materials including dirty and poorly graded sands from gravel pits.

The quantities of Portland cement and water to be added and the density to which the mixture must be compacted are determined from tests. The water serves two purposes:

- It helps to obtain maximum compaction (density) by lubricating the soil grains.

- It is necessary for hydration of the cement that hardens and binds the soil into a solid mass. Properly produced soil-cement contains enough water for both purposes.

Table (1) below show's the Cement Requirements for Various Soils :-

AASHTO Soil Classification	Unified Soil Classification*	Usual Range in Cement Requirement		Estimated Cement Content and That Used in Moisture-Density Test	Cement Contents for Wet-Dry and Freeze-Thaw Tests
		Percent by Volume	Percent by Weight	Percent by Weight	Percent by Weight
A-1-a	GW, GP, GM, SW, SP, SM	5–7	3–5	5	3–5–7
A-1-b	GM, GP, SM, SP	7–9	5–8	6	4–6–8
A-2	GM, GC, SM, SC	7–10	5–9	7	5–7–9
A-3	SP	8–12	7–11	9	7–9–11
A-4	CL, ML	8–12	7–12	10	8–10–12
A-5	ML, MH, CH	8–12	8–13	10	8–10–12
A-6	CL, CH	10–14	9–15	12	10–12–14
A-7	OH, MH, CH	10–14	10–16	13	11–13–15

*Based on correlation presented by Air Force.

Table (1) Cement Requirements for Various Soils

The cement could be almost any type of Portland cement that complies with the requirements of the latest ASTM (American Safety for testing and Materials), AASHTO(American Association of State Highway and Transportation Officials), or federal specifications. Types I (normal) and IA (air entrained) Portland cements are the most commonly used.

The water used in soil-cement should be relatively clean and free from harmful amounts of alkalies, acid, or organic matter. Water fit to drink is satisfactory. Sometimes seawater has been used satisfactorily when fresh water has been unobtainable.

Practically all soils and soil combinations can be hardened with Portland cement. They do not need to be well-graded aggregates since stability is attained primarily through hydration of cement and not by cohesion and internal friction of the materials. The general suitability of soils for soil-cement can be judged before they are tested on the basis of their gradation and their position in the soil profile. On the basis of gradation, soils for soil-cement construction can be divided into three broad groups as follows:

1. Sandy and gravelly soils with about 10- to 35-percent silt and clay combined have the most favorable characteristics and generally require the least amount of cement for adequate hardening. Glacial-and water-deposited sands and gravels, crusher-run limestone, caliche, lime rock and almost all granular materials work well if they contain 55 percent or more material passing the No. 4 sieve and 37 percent passing the No. 10 sieve. Stones over an inch or two in diameter are undesirable. Exceptionally well-graded materials may contain up to 65-percent gravel retained on the No. 4 sieve and have sufficient fine material for adequate binding. These soils are readily pulverized, easily mixed and can be used under a wide range of weather conditions.
2. Sandy soils deficient in fines, such as some beach sands, glacial sands, and windblown sands, make good soil-cement although the amount of cement needed for adequate hardening is usually slightly greater than with the soil in Group 1 above. Because of poor gradation and absence of fines

in these sands, construction equipment may have difficulty in obtaining traction. Traction can be vastly improved by keeping the sand wet and by using track-type equipment. These soils are likely to be “tender” and to require care during final packing and finishing so that a smooth, dense surface may be obtained.

3. Silty and clayey soils make satisfactory soil- cement but those containing high clay contents are harder to pulverize. Generally the more clayey the soil, the higher the cement content required to harden it adequately. Construction with these soils is more dependent on weather conditions. If the soil can be pulverized it is not too heavy textured for use in soil- cement.

SOIL-CEMENT TESTS

Laboratory tests determine three fundamental control factors for soil-cement. These factors are as follows:

1. Proper cement content
2. Proper moisture content
3. Proper density

An adequate cement content is the first requisite for quality soil-cement. Well before construction, the soils at a project site should be identified, the limits of each soil defined, and a representative sample of each soil type should be forwarded to the laboratory to determine the quantity of cement required to harden it. A soil survey of the construction area should be made.

Proper soil surveying, identification, and sampling are important. For instance, if one soil type was sampled and tested while actual construction involved a different soil type, the tests would be worthless and, in fact, detrimental since they would mislead the engineers. Obviously, it is important to sample and test the soils that will actually be used in soil-cement construction. A 75-pound sample of each type of soil is adequate for laboratory testing.

Soil samples are usually taken from a graded roadway by digging a trench from the center line to the edge of the proposed pavement and to the depth of processing. Soil samples for proposed roadways not yet graded are taken with an auger from the various soil horizons of each soil type from the "dressed-down" face of exposed cuts or from the surface. Samples should be taken so that only one horizon of each soil type is represented by each sample. Similarly, it is not good practice to take a composite sample from various locations. Data obtained from a composite sample does not apply to soil in any single location and may be misleading. There are exceptions. For instance, in sampling pit material that is to be loaded during construction by a shovel operating over the vertical face of the pit, the sample is taken from the bottom to the top of the vertical face after the overburden is removed. On small projects, it is not uncommon to sample only the poorest soil on the job, and the cement content for this sample is used throughout the job. Be sure that complete identification is supplied with each sample.

The purpose of laboratory testing is to determine the minimum cement content needed to harden the material adequately and the optimum moisture content (OMC) and density values to be used for construction. The OMC and maximum density are determined by the moisture-density test and the required cement content is determined by either the wet-dry test for pavements located in nonfrost areas or the freeze-thaw test for pavements located in frost areas. A brief description of each test is provided below.

1. The moisture-density test determines the OMC and maximum density for molding laboratory specimens and, in the field, to determine the quantity of water to be added and the density to which the soil-cement mixture should be compacted. Before you start this test, select the cement contents that will be used in the wet-dry or freeze-thaw test. The cement contents are usually selected in 2-percent increments to encompass values given in table (2)

Soil classification*	Cement required (percent by weight)
GW, GP, SW, SP, GM, or SM . . .	3-5
SP, GM, SM, or GP	5-8
SM, SC, some GM, or GC	5-9
SP	7-11
CL or ML	7-12
ML, MH, or OH	8-13
CL or CH	9-15
OH, MH, or some CH	10-16

Table (2) Basic Range of Cement Requirements

Since maximum density varies only slightly with variations in the cement content, only the median value is used in preparing specimens for the test.

The procedures for determining the OMC are described with the following exceptions:

a. Compaction is performed on five layers of approximately equal thickness to result in a total compacted depth of 5 inches.
b. Each layer is compacted by 25 uniformly spaced blows using a 10-pound tamper dropped from a height of 18 inches.

2. The wet-dry test (ASTM D 559) determines the cement content for soil-cement mixtures used in nonfrost areas. The objective is to determine the minimum amount of cement that will enable the soil-cement mixture to pass the test. For the test, specimens are molded using the OMC and the cement contents described above for different soil classifications. Use the procedure for the OMC determination to mold the specimens, and take a 750-gram sample from the second layer for a moisture determination. Cure the specimens for 7 days in high humidity. After curing, the specimens are weighed and submerged in tap water at room temperature for 5 hours. They are then oven-dried for 42 hours at 160°F. Material loosened by wetting and drying is then removed using two firm strokes of a wire brush. After this, you then reweigh the specimens and subtract the new weight from the old weight to determine the amount of disintegration (soil-cement loss) that occurred during the cycle. The process is repeated for a total of 12 cycles. A passing grade ranges from 14-percent loss for sandy or gravelly soils down to 7 percent for clayey soil. Additional information about the wet-dry test and an example of determining the soil-cement loss can be found in NAVFAC MO-330.

3. The freeze-thaw test (ASTM D 560) determines the cement content for soil-cement mixtures used in areas subject to frost action due to repeated freezing and thawing. As in the wet-dry test, the objective of the freeze-thaw test is to determine the minimum amount of cement that enables the mixture to pass the test. For the test, specimens are molded and cured in the same manner as the wet-dry test. After 7 days of curing, the specimens are placed on moist blotters and are refrigerated for 24 hours at -10°F. They are then thawed in a moist atmosphere at 70°F for 23 hours. Then you brush the specimens as described above and, if necessary, remove any half-loose scales using a sharp-pointed instrument. After 12 cycles, the specimens are oven-dried and weighed. The soil- cement loss is determined the same way as in the wet-dry test. Again, passing grades range from 14-percent loss for sandy or gravelly soils down to 7 percent for clayey soil. as shown in table (3):-

AASHTO Soil Group	Unified Soil Group	Maximum Allowable Weight Loss, Percent
A-1-a	GW, GPP, GM, SW, SP, SM	14
A-1-b	GM, GP, SM, SP	14
A-2	GM, GC, SM, SC	14
A-3	SP	14*
A-4	CL, ML	10
A-5	ML, MH, CH	10
A-6	CL, CH	7
A-7	OH, MH, CH	7

*The maximum allowable weight loss for A-2-6 and A-2-7 is 10%.

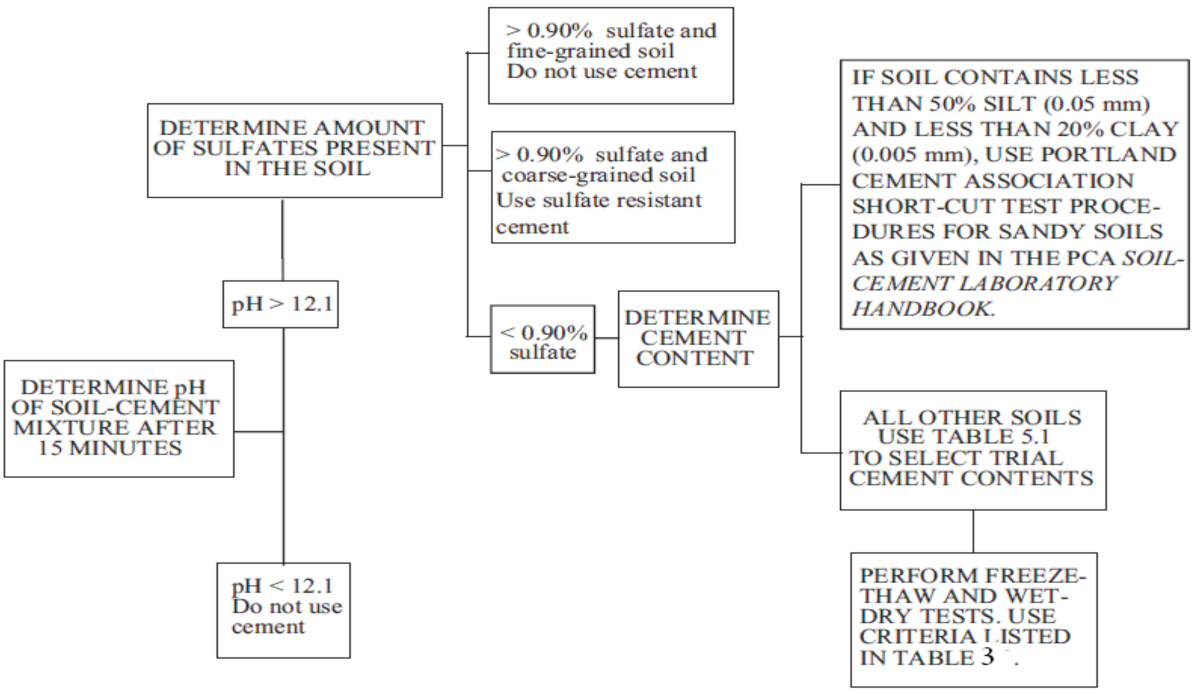
Table (3) Criteria for Soil-Cement as Indicated by Wet-Dry and Freeze-Thaw Durability Tests

The principal requirement of a hardened soil-cement mixture is to withstand exposure to the elements. Strength is a requirement also; however, most soil-cement mixtures that have adequate resistance to the elements also have adequate strength. In the ranges of cement contents producing results meeting the requirements above, the strength of soil-cement specimens tested in compression at various ages should increase with age and with increases in cement. A sample that has an unconfined compressive strength of approximately 300 pounds per square inch (psi) after curing 7 days and shows increasing strength with age can be considered adequately stabilized. NAVFAC MO-330 has the procedures that you should follow when performing unconfined compression tests.

For a discussion of modified mix design for sandy soils and for approximate and rapid test procedures that you can use when complete testing is impracticable, you should refer to NAVFAC MO-330. Construction methods using soil-cement can be found in Military, Soils Engineering, FM5-541, and in commercial publications, such as Moving the Earth, by Herbert L. Nichols, Jr., and various publications from the Portland Cement Association.

Stabilization Mechanisms:-

Portland cement is composed of calcium-silicates and calcium-aluminates that, when combined with water, hydrate to form the cementing compounds of calcium-silicate hydrate and calcium-aluminate-hydrate, as well as excess calcium hydroxide. Because of the cementitious material, as well as the calcium hydroxide (lime) formed, portland cement may be successful in stabilizing both granular and fine-grained soils, as well as aggregates and miscellaneous materials. A pozzolanic reaction between the calcium hydroxide released during hydration and soil alumina and soil silica occurs in fine-grained clay soils and is an important aspect of the stabilization of these soils. The permeability of cementstabilized material is greatly reduced. The result is a moisture-resistant material that is highly durable and resistant to leaching over the long term.



Subsystem for Base Course Stabilization with Cement

<u>REFRENCES</u> :-

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