CHAPTER 5

MISCELLANEOUS SURFACES

5-1. Maintenance and repair

This section covers maintenance and repair of various surfaces not specifically previously discussed. At military installations, light service roads to isolated facilities, range roads, patrol roads, emergency storage areas, areas under repair, stage construction, and stabilized airfield infield areas may be maintained as nonpaved surfaces. These surfaces may be untreated soil and aggregate (processed and unprocessed) or stabilized with chemical additives or by mechanical means. Methods for controlling dust on traffic areas are also discussed. Stabilized areas may have bituminous surfaces and seals that require maintenance in accordance with chapter 3.

a. *Surface defects*. Surface defects can usually be attributed to poor subbase or subgrade conditions, inadequate compaction strength of surface, erosion, inadequate drainage, or lack of routine maintenance operations. Overloading of a light traffic surface will also cause surface defects. An inspection for surface defects will include a careful investigation of the causes. Repair of these defects will be ineffective unless the cause is first corrected.

b. Drainage inspection. Drainage maintenance is particularly important in earth surface maintenance because the surface is generally not waterproofed, and the ground may be saturated and softened by water. If water is carried away promptly and surfaces are kept relatively dry, earth surface failures will be kept to a minimum. Those areas where runoff is slow or where water is ponded will be noted during the maintenance inspection following a heavy rain. These areas will be marked for prompt corrective measures. Earth surfaces will be graded regularly to maintain horizontal and vertical gradients and to keep cross-section crowns in an even and smooth condition.

5-2. Types of Surfaces and Materials

There are many types of surfaces and materials. Several types are discussed in this manual.

a. Earth surfaces. Earth surfaces include properly graded natural soil and may include occasional areas of other material such as gravel and crushed stone. Their anticipated life can be extended by proper maintenance. Three basic operations are involved in this maintenance: adequate repair and shaping to promote good drainage and a smooth surface, compaction as required to provide surface stability, and adequate dust control or replenishment of other surface treatments used to stabilize or seal the surface. The grading and shaping operations imply proper repair of potholes, ruts, and other surface irregularities. Earth surface maintenance involves blading to maintain adequate crown and roadway elevation so water drains rapidly and does not flow within the roadway. Blading should produce a smooth surface. Blading consists mainly of light scraping with a motorized blade grader of a drag. In remote areas where a motorized blade grader may not be readily available, consideration will be given to constructing multiple blade drags. They are normally pulled by a medium-size truck. Multiple bladed drags can be built of iron and heavy timbers and are useful for floating mud and water off a road surface. Blading will be done when moisture conditions are suitable for blading and compaction. Hand tools are necessary for work around manholes and other places inaccessible to machinery.

b. *Soil aggregate surfaces*. Untreated soils and aggregates used for low use surfaces and for flexible bases under pavements include a wide variety of natural and processed materials. All are generally similar in manner of use, flexibility, and methods of maintenance of repair. However, materials vary widely with respect to particle size, resistance to wear, and stability under wet or dry conditions. The more common types included in this category are gravel, crushed stone, slag, mine tailings, coral, shell, iron ore gravel, shale, caliche, disintegrated rock or granite, limerock, volcanic cinders, sand clay, and sand-clay gravel. In a given locality, the selection of types is usually limited to two or three of these materials or to combinations which are most economical.

(1) *Materials.* Soil-aggregate stability is provided by mechanical interlocking of particles and, to some extent, by the cementing action of fine soil particles developed by compaction. The particles of the material used for surface courses will be hard, in order to resist wear and crumbling when subjected to traffic. Maximum size of coarse particles should be limited to 1 to 1V2 inches in the case of surface courses to ensure ease in working and to prevent raveling and displacement of aggregate by traffic. Shell, used only in coastal localities, needs a binder material to achieve compaction and will normally break down under heavy traffic. Limerock, caliche, shale, disintegrated granite, and similar types of materials will make a dense base course containing many fine particles. Compacted coral, limerock, iron ore gravel, and hard caliche develop stability from cementing action. Crushed stone develops stability from mechanical interlocking produced

by compaction. A good base material requires the complete drainage of all free water.

(2) *Gravel roads*. Maintenance procedures for gravel roads are the same as those for other earth surface roads. Continual shaping is needed to maintain a smooth riding surface and a uniform crown, and the drainage system will be kept functioning at full capacity. Gravel roads subject to heavy traffic require constant attention by maintenance patrols. Intensive maintenance is required when the surface is first opened to travel, since any irregularities that are compacted at this time will remain in the surface and can only be corrected by scarifying, reshaping, or adding more material and compacting. The surface should be bladed or dragged until all ruts and holes are filled; however, one should not work on a dry or saturated surface. A crown of not less than 1/2 inch per foot will be maintained. Graders will be used for both routine maintenance and for heavy reshaping work, and multiple blade drags or sled drags will be used for routine maintenance. A slight excess of gravel will be kept available at edges of the roadway and bladed uniformly over the surface in wet weather. Additional material may be stockpiled for use in fall and winter and during prolonged wet periods. Material added or spread on the surface during warm dry weather is of little value unless water is used during spreading and shaping.

(3) *Coral roads*. The maintenance of well-built coral roads is a relatively simple operation. Fresh unweathered coral of the proper moisture content is the only required repair material. Maintenance is best accomplished while the coral is still moist. Low spots, ruts, and potholes will be filled by shoveling or dumping coral material directly from the truck into the low spots. Such patches, if rolled while moist, will bond onto the original material. If maintenance must be performed when the surface is dry, salt water will be sprinkled on the surface before the start of maintenance operations. Salt water seems to develop a better bond with coral materials than does fresh water. Occasional blading and rolling are necessary to maintain a proper crown and a smooth surface. In dry seasons, sprinkling, preferably with salt water, is necessary to minimize dust nuisance and maintain high stability. In wet seasons, the road will hold up more satisfactorily. If, in prolonged dry seasons, dust and raveling become too serious, the application of an asphalt surfacing may be justified.

(4) *Crushed stone roads*. The maintenance of roads surfaced with crushed stone or other processed materials is similar to that of gravel roads with one exception, the blading and grading operations will not be required as often. The proper blending of the crushed material is essential for the durability of the mixture. Proper compaction provides the stability by the mechanical interlocking of the particles and, for some aggregates, a cementing of the particles. Surface failures are usually sharpedged depressions, generally caused by poor drainage. Surface repairs will consist of cleaning down to solid subgrades , replacing with aggregate of same gradation as the original surface, and compacting.

c. Stabilized surfaces. Soil stabilization is defined as the process by which soil properties are improved by chemical addition or by additional mechanical effort. Two methods are generally used. One method, mechanical stabilization, involves the controlling of soil gradation and the use of an externally applied force such as compaction to improve the engineering properties of a soil. The second method, chemical stabilization, involves the application of one or more chemicals to a soil to achieve a desired change in its characteristics. Chemical stabilization is generally the most expensive and should only be used if the soil cannot be stabilized mechanically. In most cases, the use of mechanical means, particularly compaction, will be required to supplement chemical stabilization. A wide selection of specific soil stabilization processes and materials are available. In its broadest sense, soil stabilization implies improvement of soil so that it can be used for subbases, bases, and in some instances, surface courses. Stabilization is usually considered when available material is of marginal quality or nonacceptable for use as a base of subbase. The material, by stabilization, is upgraded by increase in strength properties or change in material characteristics. Stabilized wearing surfaces can be used successfully in nontraveled areas such as shoulders where the surface is not subject to abrasion by traffic. Cement- and lime-stabilized materials will be surfaced with a bituminous wearing surface to keep down dust and abrasion of the surface. In the interest of economy, commercial additives will not be used when natural materials can be utilized as stabilizing agents. Thus, the methods of stabilizing used in maintenance and repair will be governed by the characteristics of the soils and available stabilizing materials. The most economical method of stabilization that will produce the desired properties in the available materials will be selected.

(1) *Mechanical*. Mechanical stabilization is accomplished by utilizing rollers to apply force to compact the soil at an established optimum water content. This water content will be established in the laboratory using MILSTD-621A, Method 100.

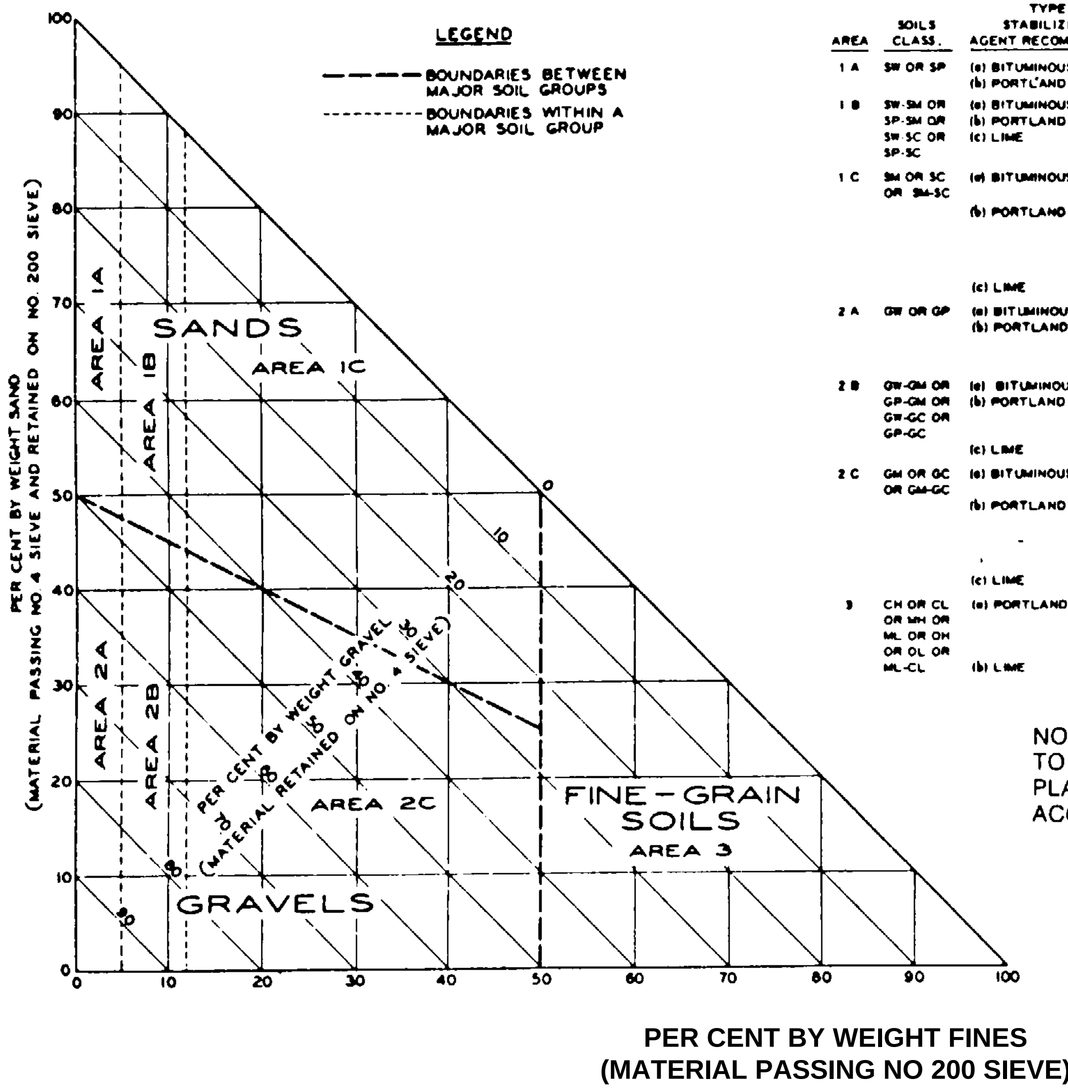
(2) *Chemical*..Chemicalstabilizers accomplish stabilization in two ways: by cementing the soil into a hardened mass and by changing the charac-

teristics of the soil to make it more suitable construction material. The first method generally requires a greater percentage of stabilizing agent and also produces a higher type construction material. In the use of stabilizers to change the characteristics of the soil, the primary objective is to reduce the plasticity index of the soil and make it less susceptible to the action of water.

(a) *Types of commercial stabilizers*. There are a number of types of admixtures, varying in behavior, that can be used in stabilization; each has its particular use and, conversely, its own limitation. Cementing materials that may be used include Portland cement, lime, asphalt, and mixtures of lime and fly ash or sodium silicate. Many times the use of a cementing material is restricted because of cost. Therefore, low quantities of the material may be added to the soil merely to modify it. Only the more common commercial materials in use today (i.e., bitumen, lime, and Portland cement) will be discussed further in this manual. Additional information can be obtained from TM 5-822-14/AFJMAN 32-1019 and NAVFAC DM-5.

(b) Selection of stabilizing agents. Selection of proper stabilizing agents for a specific project is most important and involves a number of factors; some of the more critical are soil type, desired strength of stabilized courses, cost, weather, water table, and size and location of project. All of these factors will be considered. But the most important single factor to be considered is generally the type of soil. Since, in stabilization work, it is necessary to obtain a uniform distribution of the stabilizing agent in the soil, it is obvious that the pulverization characteristics of the soil are very important. Generally speaking, when a bituminous material or Portland cement is used as a stabilizer, it is imperative that good distribution in the soil be obtained. Therefore, Portland cement and bitumen are more suitable for the stabilization of the granular and less cohesive soils. Since the pulverization characteristics of the soil are of primary consideration in selecting the type of chemical to be used, a gradation triangle has been developed (fig 5-1) to aid engineers in making the selection. It will be noted that the triangle has been divided into three major areas to group the soils. The soil grouping is based on ASTM D 3282 which classifies soil according to the predominant particle size into gravels (retained on No. 4 sieve), sand (passing No. 4 sieve and retained on No. 200 sieve), and fines (passing No. 200 sieve). In this gradation chart, the sand and gravel areas have each been subdivided into three areas. In addition to gradation, this chart takes into account the Atterberg limits of the soil and places certain restrictions on the amount of fine material passing the No. 200 sieve. This chart is, at best, a general guide and cannot cover all possible conditions. It should be used only to provide knowledge on what types of chemical stabilizers should generally be considered for a specific job. In areas where a particular type of soil has been successfully stabilized, it is recommended that such experience be taken into account in the selection of the stabilizing agent. After the type of stabilizing agent is selected, it is necessary to determine by laboratory tests the optimum additive content. Chemically stabilized soil layers abrade readily under traffic. Thus, it is necessary to provide a wearing surface over the stabilized soil layer.

(c) Cement. Soil-cement and cement-treated bases are uniformly blended mixtures of soil or coarse aggregates and measure amounts of Portland cement and water that have been compacted and cured. Cement stabilization is most beneficial when used with inferior granular materials. Cement content depends upon the kind of soil or material being stabilized and the characteristics desired in the base course. Laboratory test procedures given in ASTM Standard Methods of Test D 558, D 559, and D 560 have been developed to provide guidance in selection of optimum cement content. However, other factors such as weather conditions, desired durability, and strength have to be considered and may govern the cement content. Cement stabilization requires the use of granular materials or soils that can be thoroughly pulverized. Soils and aggregates which have a high silt and clay content, as shown in the soil triangle (fig 5-1), cannot be used. Suitability of a particular aggregate is predetermined by trial mixtures. Standard Portland cement is the usual stabilizing agent, although high-early strength cement can also be used. As a general rule, the cement requirement of soils increases as the silt and clay content increase; gravelly and sandy soils require less cement content for adequate strength than silt and clay. An exception to this rule is poorly graded one-size sand materials devoid of silt and clay require more cement than do sandy soils containing some silt and clay. In general, a well-graded mixture of gravel and sand will require 5 percent or less cement by weight. Poorly graded one-size sands such as beach sands or desert-blown sands will require about 9 percent cement by weight. The remaining sandy soils will generally require about 7 percent cement. The nonplastic or moderately plastic silty soils generally require about 10 percent cement by weight and soils having high plasticity require about 13 percent or more. The water required should be free from excess amounts of organic matter. Any water satisfactory for human consumption is suitable for cement stabilization. Base



AREA	SOILS CLASS.	TYPE STABILIZING AGENT RECOMMENDED	RESTRICTION ON LL, PL & PI OF SOIL	RESTRICTION ON (-200 MATL)	REMARKS
1 A	SW OR SP	(a) BITUMINOUS (b) PORTLAND CEMENT			SEE NOTE (A)
1 B	SW-SM OR SP-SM OR SW-SC OR SP-SC	(a) BITUMINOUS (b) PORTLAND CEMENT (c) LIME	PI NOT TO EXCEED 10 PI NOT TO EXCEED 30 PI NOT LESS THAN 12		
1 C	SM OR SC OR SM-SC	(a) BITUMINOUS	PI NOT TO EXCEED 10	NOT TO EXCEED 30% BY WT	
		(b) PORTLAND CEMENT	PI NOT TO EXCEED NO. IND. BY EQ: $20 + \frac{50 - \text{FINES CONT.}}{4}$		
		(c) LIME	PI NOT LESS THAN 12		
2 A	GW OR GP	(a) BITUMINOUS (b) PORTLAND CEMENT			WELL-GRADED MATL ONLY MATL SHOULD CONTAIN AT LEAST 45% BY WT OF MATL PASSING NO. 4 SIEVE
2 B	GW-GM OR GP-GM OR GW-GC OR GP-GC	(a) BITUMINOUS (b) PORTLAND CEMENT	PI NOT TO EXCEED 10 PI NOT TO EXCEED 30		WELL-GRADED MATL ONLY MATL SHOULD CONTAIN AT LEAST 45% BY WT OF MATL PASSING NO. 4 SIEVE
		(c) LIME	PI NOT LESS THAN 12		
2 C	GM OR GC OR GM-GC	(a) BITUMINOUS	PI NOT TO EXCEED 10	NOT TO EXCEED 30% BY WT	WELL-GRADED MATL ONLY
		(b) PORTLAND CEMENT	PI NOT TO EXCEED NO. IND. BY EQ: $20 + \frac{50 - \text{FINES CONT.}}{4}$		MATL SHOULD CONTAIN AT LEAST 45% BY WT OF MATL PASSING NO. 4 SIEVE
		(c) LIME	PI NOT LESS THAN 12		
3	CH OR CL OR MH OR ML OR OH OR OL OR ML-CL	(a) PORTLAND CEMENT	LIQUID LIMIT LESS THAN 40 AND PI LESS THAN 20		ORGANIC AND STRONGLY ACID SOILS FALLING WITHIN THIS AREA ARE NOT SUSCEPTIBLE OF STABILIZATION BY ORDINARY MEANS
		(b) LIME			

NOTE: (A) SOIL CLASSIFICATION CORRESPONDS TO MIL-STD-619B. RESTRICTION ON LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX IS IN ACCORDANCE WITH METHOD 103 IN MIL-STD-621A.

Figure 5-1. Gradation triangle for aid in selecting a commercial stabilizing agent.

courses stabilized with cement are more rigid than those constructed without cement, but they ravel quickly if subjected to traffic abrasions and suffer extensive cracking patterns in their surface during the hydration process if high cement contents are used. If cracks are not sealed, water infiltrates into the underlying materials, causing instability. Careful control of proportions, moisture content, and compaction are essential. Thickness of stabilized layers should not be less than 4 inches. A bituminous surface treatment or surface course is generally required to resist the abrasive action of traffic. A curing period is required, but emergency use during the curing period is possible. Soil-cement and cement-treated bases are quickly built with proper equipment in dry weather. However, work is restricted during wet or freezing weather.

(d) Lime. The addition of lime to soils will change the plasticity properties and increase the soil strength. Either hydrated lime or quicklime may be used as the stabilizing agent, depending on availability of the type of lime and construction equipment. The reaction of quicklime with soils is similar to that of hydrated lime. But hydrated lime is easier and safer to handle. Quicklime can cause burns and irritations to workmen and should be used with caution. Lime is generally used in the stabilization of clay soils or gravels with clay binder material. The effectiveness of the lime treatment will vary depending on the relative amount of the component minerals. Lime in small quantities (2 to 4 percent by weight) is very effective with clay gravel mixes. In base course construction, much more lime is required for moist fine-grained clay soils than for gravelly clay binder mixes. If used in sufficient quantities, lime will improve fine-grained silty soils; however, it usually will not be as effective with these materials as with clays. The use of lime alone is not recommended for sandy soils. A certain amount of water in the soil is used in hydrating, which in turn gives off heat that produces a drying effect. The percentage of loss of water in a soil has been found to be approximately one-half the percentage by weight of the lime added to the soil. Hence, the application of lime to areas that are unstable due to excessive moisture may actually dry the soil and allow construction work to proceed at an earlier date. Lime stabilized soils must be cured at a minimum of 50 degrees F.

(e) Fly ash. Fly ash will act as a pozzolan and/or a filler to reduce air voids in naturally occurring or blended aggregate systems. Fly ash is not normally necessary in fine-grained soils. It can be difficult to thoroughly mix fly ash with fine-grained soils. Coarse silts are generally considered the most suitable soil type for treatment with fly ash. However, most types of coarse-grained soils can be successfully treated and compared to fine-grained soils. They can be more economical and have a greater resistance to frost action. While pozzolan action is desirable, the amount of calcium oxide in fly ash will vary both from the same source and from other various sources. Fly ash should normally be used as a filler, and additional pozzolans action is employed but not planned for in the design scheme.

(f) Bitumen. Only those soils that can readily be pulverized by mixed-in-place construction equipment is satisfactory for bituminous stabilization. Thus, the use of bitumen is limited mostly to the coarse-grained or sandy soils. Soils containing clay and silt having more than 30 percent by weight of minus No. 200 sieve material or a plasticity index greater than 10 are generally not adaptable to bituminous stabilization. The addition of a small percentage of lime may facilitate mixing of the bitumens. Friable soils which possess inherent stability and whose stability cannot be improved by admixing other soils economically are best suited for stabilization with bituminous materials. For stabilization work in which the bituminous material is to be mixed with the soil, such materials as asphalt cements (central plant applications only), cutback asphalts, emulsified asphalts, and tars perform quite satisfactorily. Asphalt cements are usually used for base courses but not for subgrades. The harder grades of asphalt cements (penetration 40-50) (AC-40 or stiffer) will be used in hot climate areas.
The cutback asphalts (grades 70-3, 000) are used in all phases of stabilization. The quantity of cutback material necessary can be approximated by the following surface area formula:

$$p = 0.02a + 0.07b + 0.15c + 0.20d$$

where

p = percent residual asphalt by weight of dry aggregates
a = percent of mineral aggregate retained on the No. 50 sieve
b = percent of mineral aggregate passing No. 50 and retained on No. 100 sieve
c = percent of mineral aggregate passing No. 100 and retained on No. 200 sieve
d = percent of mineral aggregate passing No. 200 sieve

The design amount of bitumen and its workability will be determined by laboratory tests or small scale field tests before the project starts. Emulsified asphalt is also utilized in all phases of stabilization. The grade SS-lh is usually used with soils having less than 5 percent material passing the No. 200 sieve; grades SS-1 or CMS-2 are used for soils having greater than 5 percent passing the No. 200 sieve. Tars conforming to ASTM Specification D 490, grade RT-1 to RT-6, have also been used for soil stabilization.

(g) *Combinations*. The use of various stabilizing agents in combination is often advantageous. The main advantages of using combinations are to reduce plasticity and increase workability so the soil can be intimately mixed and effectively stabilized. Portland cement is an agent used in many combinations. However, lime normally used as a pretreatment is the agent most widely used in combination with others. Lime is usually used to reduce plasticity and increase workability. Although some strength increase is usually noted, Portland cement can now be added to the altered soil for a larger strength gain. Cement fly ash or lime fly ash mixtures are combinations that can be used for most silts. Both of these agents have been used in bituminous emulsion stabilization operations to help control emulsion break and the cure time.

d. Dust palliatives. Treatment or processes used to control dust are called palliatives. The primary function of palliatives is to prevent soil particles from becoming airborne. Secondary function includes preventing erosion from the action of wind and other air blast, and from the action of rain and running water. Some palliatives also protect the soil ground surface against penetration of water, acting as waterproofing. Palliatives should reduce the migration of the fine-grained particles which provide stability for the larger particles. Thus, rutting is delayed, and the need for blading the unsurfaced roadway is greatly reduced. Before any large dust prevention project begins with a palliative, small test sections are recommended to assure the palliative performs as desired.

(1) *Water*. Water is the most commonly used palliative. Water must be applied whenever dust occurs which is usually during construction or maneuver activities. Whenever these activities are conducted at night, the amount of water needed is reduced because there is less evaporation. The time, equipment, and manpower required limit the use of this method to that of a temporary expediency.

(2) *Salts*. Salts include both calcium chloride and magnesium chloride. They can be used in flakes, pellet form, or dissolved in water and are shipped in waterproof bags or in bulk. These materials absorb moisture from the air if the humidity is not too low. They are not effective as a palliative under arid or semiarid conditions. They are successful on all types of soil in regions where the relative humidity averages 30 percent or more. When spread on or incorporated into the surface of traveled areas, they attract moisture which helps hold soil particles in place. Since salts are soluble in water, they are carried away by rain and must be reapplied periodically. Application should be made during periods of light traffic and when rain is not expected for at least 24 hours. Salts should not be applied to dry washed gravel or to dry shifting sands without binder soils (soils passing the No. 200 sieve). They should not be used on plastic clays because the moisture generated will make the clay surface slick. Surface material must be granular with some fines and as smooth as possible to receive treatment. When there is loose aggregate on the surface, it can be mixed with the binder; however, the preferred method is to remove all loose material. If the surface is covered with a heavy cushion of finely powdered dust, this undesirable material should be removed.

(3) *Oils*. *Oils include any type of petroleum derived substance of varying viscosity cush as crankcase waste, bunker oils, crude oil, marine oils, motor oil, or residue from storage of asphalt base crude oils. The heavy grades of oil such as Bunker C or waste oils will require heating for transfer of materials and application. The higher viscosity oils will be used for soils containing a high percentage of sand or gravel or where the surface is loosely bonded. Oil will be applied only on dust-free, moist surfaces. The low viscosity materials are applied to bind the surface and prevent displacement of the fine particles. Oils are absorbed by soil to form a shallow treated area. In all cases, excess oil standing on the surface must be blotted by spreading on sandy soil; otherwise, a hazardous condition will exist. Use of oils as dust palliatives must meet all local environmental standards; precautions will be taken that the soils do not percolate into the water table or streams. Oils can be washed off the road surface by rains if it has not had time to penetrate into the soil. Treatments will be repeated each year, or as often as necessary, to keep dust in place.

(4) *Asphalt emulsions*. Asphalt emulsion is a blend of asphalt cement, water, and an emulsifying agent, and is available as either a cationic or anionic type. For dust control, the slow-setting anionic types SS-1 and SS-1 are preferred, although the slow-setting cationic types CSS-1 and CSS-1 also can be used. It is preferable to use the asphalt emulsions undiluted. The emulsion breaks upon contact with the soil, separating into the water and asphalt phases. On a porous soil, the asphalt phase penetrates and cures in several hours under favorable conditions. On an impervious or tight soil surface, an asphalt film will remain on the surface and

*Oils have been condemned for use by the Environmental Protection Agency (EPA) in areas subjected to their surveillance.

must be blotted with a thin coating of sand before traffic is applied.

(5) *Proprietary products*. Commercial dust palliatives are on the market under various trade names. These proprietary products are usually based on either chloride materials, asphalts, or some other material. Concerning any proprietary products, the buyer should beware of any extravagant claims made by commercial companies and require a small scale test section.

5-3. Causes of distress

Any of the following causes can lead to distress. Care must be exercised to assure that a stabilized surface will not be excessively loaded before it has achieved its full strength, or distress will result.

a. Weathering (erosion). Weathering or raveling of the surface particles is a major cause of distress on nonpaved surfaces. The severity of this distress is related to the drainage conditions present. When the surface drainage is controlled to provide smooth flow at low velocity, this distress is minimized.

b. Water intrusion. Stabilized surfaces often develop cracks or faults which can result in water intrusion. This water will weaken the area around the crack and will eventually lead to greater distress.

c. Construction deficiencies. Construction deficiencies are listed below.

(1) *Poor grade and surface smoothness*. Poor grade control during construction will adversely affect the drainage of the surface and will cause problems. Roughness caused by poor blading (or any other cause) will cause corrugations and/or potholes to be formed.

(2) *Improper mixing*. Improper mixing will cause weak or deficient areas within the stabilized surface. This type of distress is often caused by inadequate or improper use of mixing equipment.

(3) *Poor proportioning*. An inadequate quantity of stabilizer can lead to difficulties similar to improper mixing. Without proper proportioning the stabilized surface will not perform as designed.

(4) *Improper compaction*. An improperly compacted surface will be less durable and more subject to failure. The proper density will help ensure a more water tight surface that is stable and durable.

(5) *Material deficiencies*. The use of inadequate or inadequately prepared materials will cause distress in the stabilized surface.

5-4. Types of distress

The most common types of distresses on miscellaneous surfaces are included in this section.

a. Potholes, ruts, and surface irregularities. These distresses should be corrected as soon as possible before they develop into larger problems. These distresses are common to most types of surfaces.

b. Corrugations or washboarding. All gravel roads tend to develop transverse or nearly transverse waves commonly called corrugations or washboarding. These corrugations may develop into ruts as deep as 4 inches ranging 1Y2 to 3 feet apart. This problem will continue to spread and disrupt traffic until it is repaired. Traffic impact tends to make corrugations progressively more pronounced once they are started.

c. Soft spots. Soft spots indicated by rutting or shoving of the surface are generally caused by an excess of moisture or the use of an unstable material. These areas require improved drainage to eliminate excess water and removal of such unstable materials as peat, muck, or plastic clays, and replacement with suitable selected material. When adequate repair of soft spots cannot be accomplished immediately, the deficiency can be temporarily corrected by adding crushed rock or gravel to the affected area.

d. Cracking. Cracking is a normal characteristic of certain soils (usually those with a high percentage of clay) and also for some stabilized soils. The cracks in many soils are due to moisture loss, and they will tend to knead together with traffic. When these soils are used as a base course, they cause no problems if water is kept from them. The cracking in soil cement is due to shrinkage and does not impair its performance as a base course. These shrinkage cracks normally reflect through a bituminous surface and will require sealing when cracks are greater than 1/8 inch wide.

e. Dust. During dry weather, dust is not only a nuisance, but it is dangerous and wasteful (fig 5-2). If not kept in check, dust is detrimental to aircraft as well as vehicles. Earth and soil-aggregate surfaces give satisfactory service at low maintenance cost when dust is prevented. Blowing dust represents loss of binder material leading to potholes and raveling of surfaces which then require maintenance and repair.

5-5. Methods for maintenance and repair

A general description of the equipment and methods used in the maintenance and repair of unpaved surface areas are discussed.

a. Equipment. Certain equipment are needed for maintenance and repair of unpaved surface areas.

(1) *Application of material*. Materials are normally either applied by spray application or mechanically spread on the surface.

(a) Water truck. The water truck will be equipped with a spray bar and an adequate pumping

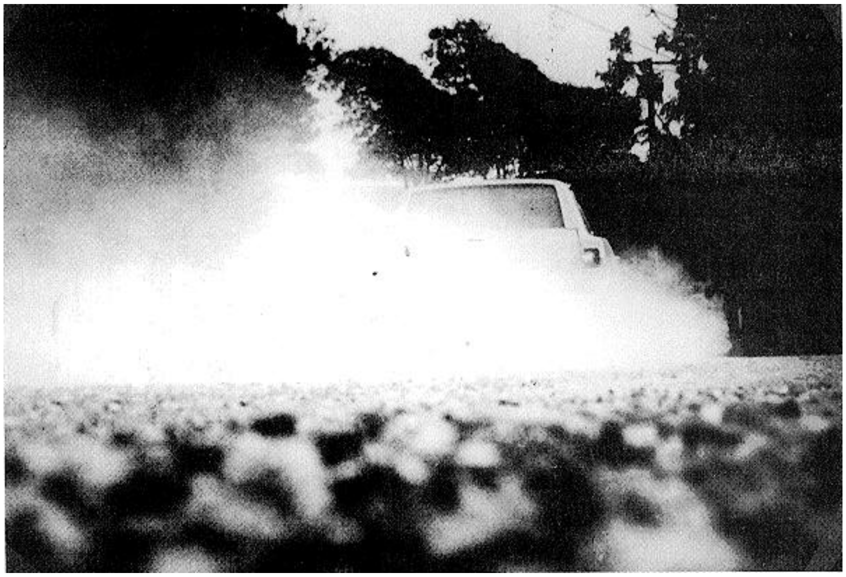


Figure 5-2. Dust created by a passing vehicle

system. It will be capable of accurately metering water at various rates. A conventional asphalt distributor can be used as a water truck.

(b) Mechanical spreader Mechanical spreaders can be truck-mounted, separate units, or self propelled. They are used to evenly spread material. The spreader will be capable of having a controllable rate of application. Self-propelled types are the most widely used and provide the best performance.

(2) *Mixing*. The type of mixing equipment used will depend on the type of materials being mixed and the amount to be mixed.

(a) Disk harrow and cultivator These pieces of equipment (normal agricultural equipment) are pulled through the soil to mix it (fig 5-3). These are relatively shallow mixers and must make several passes to achieve a good mix.

*(b) Pulvermixe*r The pulvermixer will be a size capable of thoroughly mixing the materials as required (fig 5-4). The pulvermixer will also be capable of breaking up the soil into its basic particle size.

(c) Grader The grader is used for shaping and to achieve the final grade and surface smoothness (fig-5).

(3) *Compaction*. The type of compaction equipment used will depend on the type of soil that is compacted.

(a) Sheepsfoot roller Sheepsfoot rollers (fig 5-6) used for compacting subgrade have metal projections for compaction, and these rollers are used for compaction until the roller "walks-out." Another roller, usually rubber-tired, will have to follow or finish roll after the sheepsfoot. The sheepsfoot roller is useful in compacting fine-grained cohesive soils.

(b) Rubber-tired roller. The rubber-tired roller (fig 5-7) is very versatile and effective at achieving the required density. These rollers can vary in size from 7 to 35 tons. To achieve maximum compactive effort, the tire pressure should be maintained at approximately 90 pounds per square inch or the maximum that the soil can support without excessive displacement.

(c) Vibratory roller Vibratory rollers (fig 5-8) are usually self-propelled with either all steel drums or a steel compaction drum and rubber-tire drive wheels. The rollers are very versatile and are effective at compacting most types of materials especially cohesionless soils.

(d) Steel-wheel (static). Steel-wheel rollers are used mainly as finished rollers to obtain a smooth final surface. For small repairs, this roller may provide adequate compaction by itself. Vibratory rollers run in the static mode may be used.

b. *Repair methods*. Methods needed to repair the road surface are listed below.

(1) *Regrading.* Regrading consists of scarifying the road surface, reshaping the road, including the shoulders and ditches, and thoroughly recompacting the reshaped material (fig 5-9). Gravel or crushed stone may be added to the reshaped roadway to assist in the elimination of distresses such as potholes and rutting. Care must be taken not to cut too deep with the grader blades. A deep cut often causes the blade equipment to "chatter." The cause of the chattering also develops corrugations or washboarding.

Figure 5-3. Cultivator mixing soil.

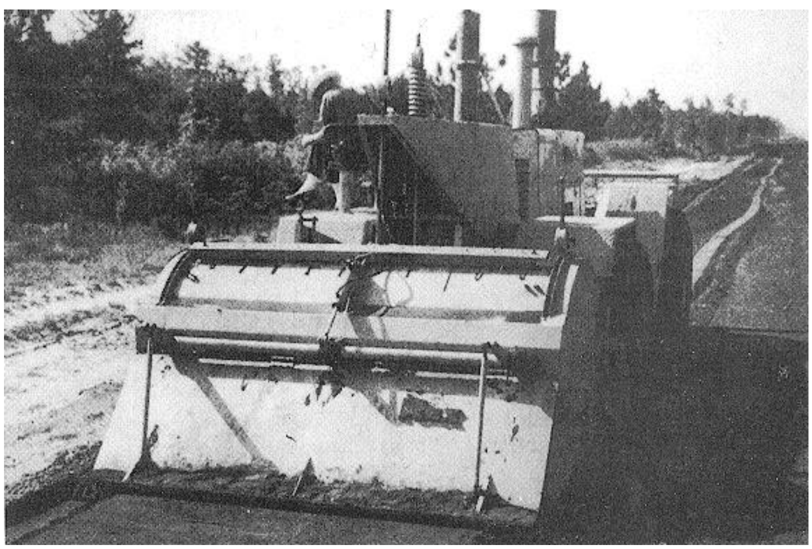


Figure 5-4. Pulvermixer.

(a) Adjustment of moisture content. Loosened, dry material will not compact properly; therefore, blading must be done soon after rains. When a very dry surface cannot be reworked, a scarifier can be used to bring moist material from beneath the surface. This moist material then will be blended with the surface material to make a workable mixture. Water may be added sparingly if needed.

(b) Sandy soil. Sandy soil roads should be bladed smoothly with a rather flat crown as this shape tends to retain moisture longer and is not as subject to erosion as is a high crown. In arid regions, loose materials should be bladed off the roadway.

(c) Clay and silt. Clay and silt soils should not be bladed while they are saturated. The crowns on such roads which inherently have a tendency to retain moisture will be somewhat higher than the edges in order to facilitate drainage.

(2) *Blade and sled drags*. Blade and sled drags

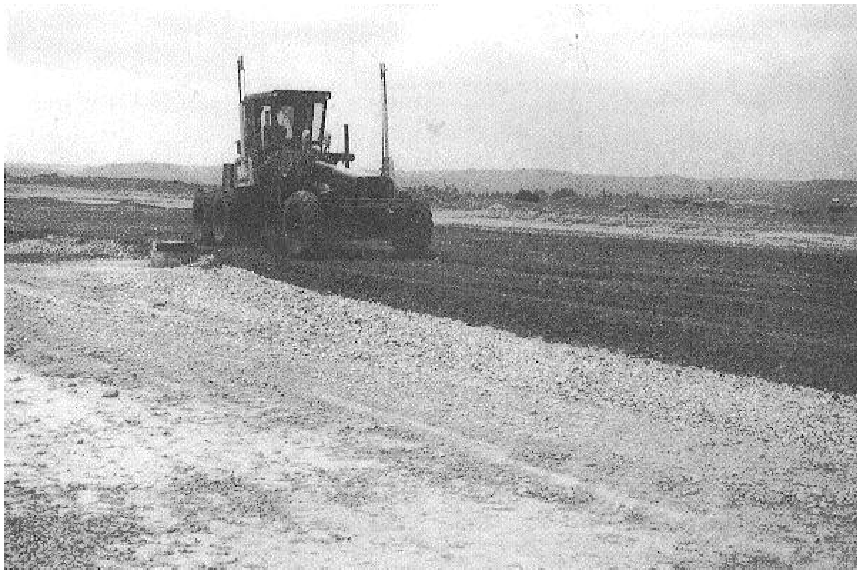


Figure 5-5. Grader leveling road surface.

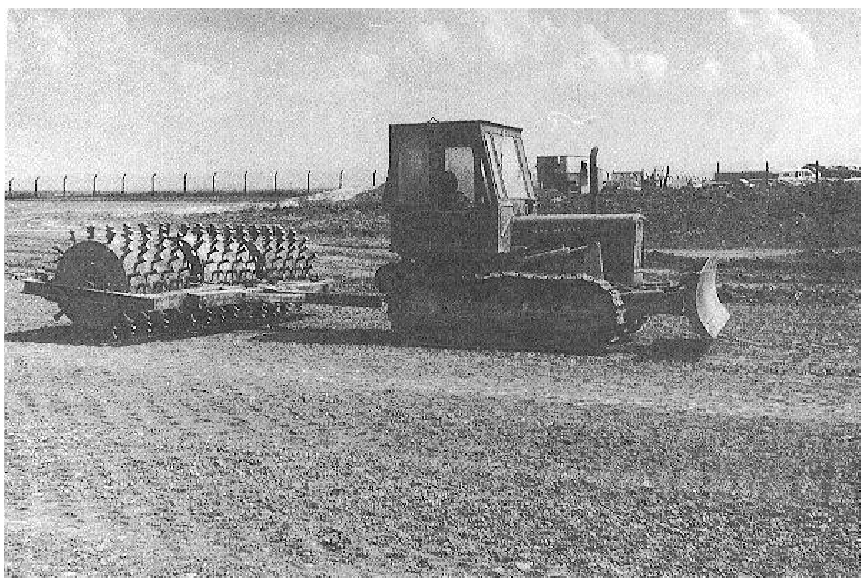


Figure 5-6. Sheepsfoot roller.

are used when minor repairs are required and the use of a grader is not required. This method can be used to repair potholes, ruts, and other surface irregularities.

(3) *Improve drainage*. To provide the surface drainage, the proper grade and surface smoothness must be provided. Drains and ditches should be provided for proper surface and subsurface drainage (see chap 7).

(4) *Pothole filling*. Most potholes caused by traffic displacement of material are shallow and readily filled by blading the surface when moist with a grader. Deeper holes require filling with more material than is normally available by blading. In filling deeper holes, greater care must be taken to ensure that adequate compaction is obtained in order to prevent the hole from reforming. The new material must contain sufficient moisture to allow satisfactory compaction.

(5) *Cement stabilization*. Cement requirements

Figure 5-7. Rubber-tired roller

Figure 5-8. Vibratory roller.

vary for each aggregate. The quantity actually required is based on laboratory tests of specimens subjected to freezing and thawing or wetting and drying. One bag of cement weighing 94 pounds is assumed to have a loose volume of 1 cubic foot. The amount of cement (bags) per square yard of a compacted base 6 inches deep for various proportions of cement is:

Cement Volume, Percent	*Bags/Square Yard*
8	0.36
10	0.45
12	0.54

Water requirements depend upon optimum demand of aggregate cement mixture, moisture contained in aggregate, and rate of evaporation during stabilization.

Figure 5-9. Regarding and rolling road surface.

The amount of water added should not exceed that required for workability and satisfactory compaction.

(a) Area treated. The area will be divided into sections of such size that necessary work from adding cement to final finishing is completed in one working period. This construction process will be continuous and completed as soon as possible after the cement is mixed into the soil.

(b) Preparation of area. All unsuitable material and soft areas will be removed and replaced with suitable materials. Placement of a stable subgrade beneath the area to be treated is important in soil-cement construction, and will be accomplished prior to commencement of operations. If any aggregate is to be added to the soil being treated, it will be spread evenly on top of it. The soil being stabilized will be loosened with a scarifier to a sufficient depth so that when the material is recompacted, it produces the required final thickness. The loosened soil is then pulverized with repeated trips of weighted disk, spring-tooth harrows, or preferably rotary tillers.

(c) Spreading cement. The cement will be spread in accordance with the proportions of soil to cement determined by laboratory tests. In maintenance and repair operations the method usually consists of spacing bags of cement horizontally and transversely at definite intervals to give required proportions (fig 5-10) and opening the sacks and distributing the cement by hand. This will be followed by light harrowing to give uniform distribution (fig 5-11). If suitable equipment is available, bulk cement can be spread from trucks by means of a mechanical spreader (fig 5-12).

(d) Dry mixing. Thorough mixing of the soil and cement is accomplished by means of the same equipment used to pulverize the soil (fig 5-13). The number of mixing operations is largely dependent on the type of equipment used and will vary to obtain the specified results. Special care will be taken to ensure a uniform mixture where fieldmixing methods are employed. If feasible, materials can be hauled to a central plant for mixing and returned to the site for distribution.

(e) Adding water. Water will be added by repeated sprinkling of /2 to 1 gallon per square yard (fig 5-14). Each sprinkling will be followed by harrowing or disking to facilitate absorption of water and minimize evaporation loss.

(f) Moist mixing. Moist mixing with cultivators, plows, and rotary tillers will start immediately. Meanwhile, water content will be equal to or slightly in excess of optimum water content. On large jobs, it is often more economical to use stationary or traveling mixing plants to conduct the operations of dry mixing, adding water, and moist mixing. If mixing requires an excessive amount of time, less durable mixtures will result.

(g) Compaction. The benefits derived from soil cement depend to a great extent upon the degree of compaction of the mixtures. Construction will be keyed to the initial set of the cement. A sheepsfoot roller is generally used for compaction, and proper cross section will be maintained with a motor grader. Moisture content will be kept at optimum content during this and succeeding operations.

Figure 5-10. Hand spreading bags of cement.

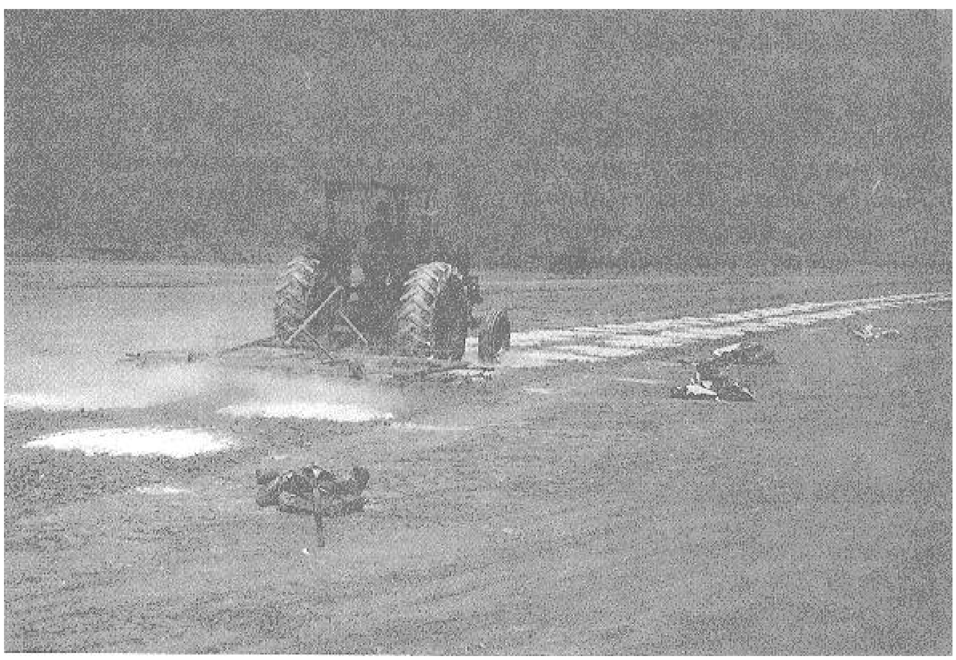


Figure 5-11. Spread lime with a harrow.

(h) Finishing. This process requires the use of motor grader, rubber-tired roller, and steel-wheel roller. The length of a section will be such that compaction and finishing are completed about 6 hours after beginning water application (fig 5-15).

(i) Curing. Soil-cement mixtures will generally require a curing period of 7 to 8 days, depending upon the amount of cement used. Since a bituminous surface is often added over this base, application of a bituminous prime or seal coat to facilitate curing is convenient. Curing can also be accomplished by covering with earth or with thoroughly wetted straw. If covered with 2 inches of earth or straw, the base may be used by rubber-tired vehicles after 1 day of curing. Application of bituminous surface should be deferred to allow any weak spots to develop under traffic, and these will be repaired as part of the surfacing operation.

Figure 5-12. Spreading cement directly from bulk carrier.

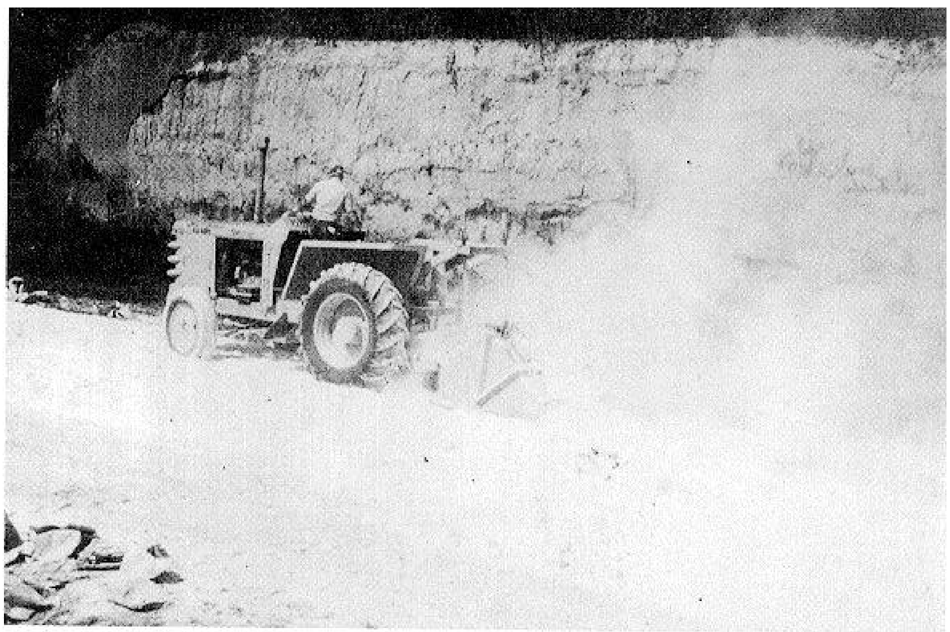


Figure 5-13. Dry mixing cement with pulverizer.

fore placing bituminous materials, soil cement will be cleaned by blading and brooming to remove unbound particles.

(6) *Lime stabilization.* Field equipment required and the steps employed in lime stabilization are similar to those used for soil-cement stabilization. When lime is applied in a dry state, the soil and the lime will be thoroughly blended at a moisture content below optimum. Water will then be blended into the dry mix in amounts necessary to bring the treated soil to the optimum moisture content for compaction as determined from laboratory tests of lime treated soil. The optimum moisture content from these tests includes additional water for hydration. Certain precautions are required when working with dry lime, including not allowing work on windy days and providing proper protective clothing. Quick lime can be slaked into a thin slurry in a large tank and then pumped into a distributor truck from which it can be sprayed on the road base (fig 5-16).

Figure 5-14. Adding water to the soil.

Figure 5-15. Finish rolling with a rubber-tired roller.

Lime-soil mixtures will be compacted to relatively high densities because the increased strength from cementing action is not apparent after compaction until a period of curing time. The compacted surface should be closed to traffic and kept covered and moist for a 5to 7-day curing period.

(7) *Fly ash stabilization*. The equipment and construction techniques used for fly ash stabilization are similar to those used for soil-cement stabilization. Fly ash can be applied in a dry state. However, due to dusting problems, it is normally distributed as a slurry when the job is large enough to be economical. The user time will vary with the climatic conditions, but it should be approximate 1 week to obtain sufficient strength for traffic.

(8) *Bituminous stabilization*. The type and quantity of bitumen to be used for stabilization must first be determined (see 5-2(3)(g)). The actual construction operation is similar to that discussed for lime and cement stabilization.

Figure 5-16. Spraying lime from a tank truck and immediately mixing treated soil.

However, control of a bitumen-stabilized course during construction is most difficult. There is not a set procedure or test that can be utilized to determine exactly when a mixture should be compacted. The best method of determining this is by trial and error. The mixture should be aerated until the moisture content is satisfactory for compaction. As soon as the mixture can be compacted without shoving and moving under the roller, compaction operations should be started. When using cutbacks in stabilization, the soil mass will be aerated before compaction so that some of the volatile material will be driven off and the soil mass allowed to partially harden. Curing time will be extended to ensure complete volatilization. It is possible to use the asphalt-stabilized material as a wearing surface.

(9) *Combination stabilization*. Combination stabilization will use the equipment and techniques employed for the particular material being used.