Chapter 13
Concrete Paving

Concrete paving is a broad subject that involves quality control (materials, concrete mix, finished slab); subbase preparation; form setting; materials; material handling; and concrete production, placing, and finishing. Much thought and planning go into setting up an efficient concrete-paving operation. The military engineer at the job site directs day-to-day operations; therefore, he must understand and be familiar with concrete theories and equipment.

SECTION I - MATERIAL MEASUREMENTS AND TRUCK REQUIREMENTS

CEMENT

13-1. Each sack of cement weighs 94 pounds. It is unnecessary to weigh sacked cement.

13-2. Bulk cement must be weighed for each batch. This is usually done at a bulk-cement plant, where the cement is stored in a bin that is equipped with a weighing hopper. If a central mix plant is used, the weighing hopper discharges through a canvas tremie directly into the charging hopper on the mixer. If a central mix plant is not used, the cement is dropped into batch trucks via a flexible hose that is attached to the batcher.

WATER

13-3. Water must be accurately measured for each batch of concrete. Water tanks on machine mixers are equipped with measuring devices, and the amount of water going to the mixer is controlled by a predetermined setting. Continual maintenance and periodic checks assure proper operation of the measuring device.

13-4. If the automatic measuring device is not functioning correctly, use a galvanized pail to measure the water. Paint 1/4-, 1/2-, and 1-gallon marks on the inside of the pail. Keep the pail near the mixer, and use it only for measuring water.

NOTE: Never add unmeasured water to concrete. The amount of water required for mixing includes the surface water (see FM 5-428).
AGGREGATE

13-5. Aggregate must be accurately measured for each batch of concrete. Measure aggregate by weight, if possible, and by volume if scales are unavailable. The accuracy of volume measurement depends on estimating the amount of hulking present in the aggregate, and the amount of hulking varies depending on the sand’s moisture content.

WEIGHT MEASUREMENT

13-6. Measuring aggregate by weight is the most accurate and efficient method. An aggregate batching plant should be used if possible, but truck scales can be used as an expedient measuring device. The weight will be accurate to within 20 pounds if the scales are in good condition. The following example shows the procedures for measuring materials with truck scales:

Step 1. Total weight of truck = 20,810 pounds
Step 2. Desired weight of gravel = 3,000 pounds
Step 3. Gross weight of truck and gravel (Step 1 + Step 2) = 23,810 pounds
Step 4. Desired weight of cement (for example, 7.5 sacks x 94 pounds/bag) = 705 pounds
Step 5. Gross weight of truck, gravel, and cement (Step 3 + Step 4) = 24,515 pounds
Step 6. Desired weight of sand = 1,500 pounds
Step 7. Gross weight of truck and all materials (Step 5 + Step 6) = 26,015 pounds

13-7. In this example, place gravel in the truck until the scales indicate a gross weight of 23,810 pounds, add cement until the weight reaches 24,515 pounds, and add sand until the total is 26,015 pounds.

13-8. Weigh each truck before each load. The greatest source of error in this method is weight changes caused by men getting on and off the scales during weighing. One man stepping on the scales during the addition of cement can cause a shortage of about two bags of cement in the batch.

VOLUME MEASUREMENT

13-9. Measuring aggregate by volume is usually an expedient method because of its low efficiency and accuracy. To weigh aggregate by volume, place known weights of materials in a wheelbarrow, a bucket, or a box. Level the surface and mark the weight on the inside of the container. Repeat until all desired weights are marked. The major error in this method is caused by the differences in the amount of voids in each batch. The weight of each mix component is different, so separate measuring containers are required.

TRUCK REQUIREMENTS

13-10. The haul road’s condition and the truck’s capacity affect the number of batches that can be hauled per truck. For round trips of 4 to 10 miles on roads in fair condition, trucks can average 10 mph (including loading and dumping).
if sacked cement is used and 12 mph if bulk cement is used. Use the following formula to determine truck requirements for round-trip distances of >4 miles:

\[
N = \frac{BD}{bs}
\]

where—
N = number of batch trucks required
B = number of batches mixed per hour
D = round-trip distance, in miles, from batch plant to paver (4 miles minimum)
b = number of batches per truck
s = speed, in mph (10 for sacked cement, 12 for bulk cement [increase if D is more than 10 miles])

SECTION II - PROCEDURES

SEQUENCE OF OPERATIONS

13-11. The recommended sequence for concrete paving is as follows:

- Prepare the subgrade.
- Mix the concrete.
- Transport the concrete.
- Prepare expansion joints.
- Place the concrete.
- Vibrate the concrete.
- Finish the surface.
- Prepare contraction joints.
- Finish the edges.
- Cure the concrete.
- Seal joints and cracks.
- Remove forms.
- Test the surface.
- Test the strength.

NOTE: Appendix B contains an inspection checklist that can be used as a guide, and Section III of this chapter discusses specific procedures for paving during hot and cold weather.

PREPARE THE SUBGRADE

13-12. Compact the subgrade and bring it 3 to 4 inches above grade. Use a motor grader to shape and cut the surface 2 inches above grade. Set the forms to line and grade (see Chapter 10). Check the forms and then conduct the final grading with a form-riding subgrader. Carefully set the cutting blades so that they will cut to the correct depth (within 1/4 to 1 inch above the finished grade). Use the subgrade planer to cut the subgrade to the required section.
and elevation. Ensure that the subgrade conforms to the required section within specified tolerances (usually 1/8 inch).

13-13. Check the contour of the finished subgrade with a scratch template. Operate the template on the side forms, with the adjustable steel rods projecting downward to the subgrade at not less than 1-foot intervals. Adjust the rods to the required contour of the subgrade. Add or remove material to bring all portions of the subgrade to the correct elevation. Thoroughly recompact the subgrade and retest it with the template. The equipment should be strong and rigid so that it will not show a deflection of more than 1/8 inch at the center. If a template is unavailable, check the subgrade with piano wire or another strong line to mark the grade. Hold the wire taut at the top of the form that has been set to grade, and measure from the wire to the subgrade at 1-foot intervals.

13-14. To minimize the subgrade's absorption of moisture from the concrete, thoroughly wet the subgrade before placing the concrete. Ensure that the subgrade is damp but not muddy. In dry, hot weather, sprinkle the subgrade with water immediately before placing and spreading the concrete. The required degree of saturation depends on the character of the material in the subgrade. Correct soft or spongy places in the subgrade by removing poor material, replacing it with good material, and recompacting the subgrade.

13-15. Compact the subgrade based on its abrasiveness. Some types of soil, such as loess, absorb water like a sponge. Loess is soft when it is wet; but when it is dry, it causes plastic shrinkage due to water loss from the concrete. To circumvent this problem, place a layer of tar paper on the subgrade. If a bituminous treatment is used, check the water loss in a test section.

**MIX THE CONCRETE**

13-16. Mixing is one of the most important steps in producing high-quality concrete that meets design specifications. For efficient production of concrete, use the correct type of mixer, locate the mixer and ingredients near the paving operation, and properly operate the mixer. Mixing can be done in stationary mixers in a central plant, which combines the batching and mixing operations, or it can be done in pavers at the work site. Regardless of the type of mixer used, blend the materials into a uniform mix throughout the batch. Ensure that all aggregate particles are coated with the paste and that the mixed concrete discharges without segregation or loss.

13-17. Ensure that all concrete mixing units are clean and in good operating condition. Replace mixing blades that are worn down ≥3/4 inch. It is especially important that the water-batching mechanism not leak when the valve is closed. Check all control devices for proper operation. If applicable, ensure proper operation of automatic equipment for batching and dispensing admixtures.

13-18. Pavers are normally used for large-scale paving operations. Aggregate and bulk cement are weighed at the batching plant and hauled to the paver in batch trucks. The situation determines where and when sacked cement is added, but it is normally added just before the concrete is mixed. Sacked cement can be added to aggregate in the trucks after they arrive on the job or
after the aggregate is unloaded into the mixer’s skip pan. Add water to the batch during charging of the aggregate and cement into the mixer.

13-19. Pavers are equipped with a boom and a bottom dump bucket to distribute the mixed concrete between the forms. Ensure that this equipment is in good operating condition. The discharge gate on the bucket should close tightly so that there is no leakage of mortar or concrete. When using dual-drum pavers, concrete is partially mixed in the first drum where the materials are charged. Mixing is completed in the second drum where the partially mixed concrete is transferred during the operating cycle.

13-20. Central-plant mixing allows closer coordination of batching and mixing operations, and it provides the best conditions for inspection and control of the mix. This method is less flexible than using pavers, and it requires additional equipment and labor for transporting and distributing the concrete in the forms. When a central plant is used, all materials are batched by weight.

**TRANSPORT THE CONCRETE**

13-21. After concrete leaves the mixer, it must be handled and transported so that segregation does not occur. Improper handling and transporting can spoil the most carefully designed and properly mixed concrete. Segregation occurs because concrete is composed of materials that have different particle sizes and specific gravities. Honeycomb concrete (rock pockets) is caused by CA particles settling to the bottom and liquids rising to the top.

13-22. Dump trucks (central mix plants) are commonly used to transport plastic concrete for large projects in TOs. Keep hauling distances as short as possible because segregation occurs rapidly enroute. Minimize segregation by preparing the mix as stiff as possible and adding an air-entraining agent to the mix.

13-23. A 34E paver can transport concrete from the mixer drum to the grade where it is being distributed. This is accomplished by a bucket that is suspended from the boom on four rollers and pulled back and forth on the boom with two ropes. The bucket doors are opened by a lever movement from the operator’s platform, and they close automatically when the bucket returns to its position under the discharge trough. The bucket has a spreading radius of 32 feet 6 inches.

13-24. A belt conveyor can be used to transport concrete short distances. It can also transport concrete up slopes that do not incline >1/2 inch per foot and down slopes that do not incline >1 inch per foot. Ensure that the man-hours required to set up a belt conveyor is justified by the volume of concrete to be moved. A belt conveyor is frequently used to move aggregate or cement (sacked or bulk). The belt can be 12 to 60 inches wide and several hundred feet long. It is supported at 4- to 5-feet intervals by V-type idler pulleys and operates at speeds up to 400 linear feet per minute. The belt can handle a continuous flow of concrete (hopper) or intermittent output (batch mixer). Clean or wet the belt during its return trip to avoid an accumulation of dried mortar.

**NOTE:** Transit mixers and agitator trucks are also designed to transport concrete, but they are not standard Army equipment.
PREPARE EXPANSION JOINTS

13-25. Before the mix is placed, construct expansion joints on the finished subgrade. These procedures are discussed in Chapter 12.

PLACE THE CONCRETE

13-26. Deposit the concrete as close to the placement site as possible so that it will require minimum rehandling in the forms. To avoid segregation, ensure that concrete does not free fall more than 5 feet. Bottom dump buckets are the most satisfactory means of handling concrete in the forms. The buckets should be large enough to handle the complete batch of concrete from the mixer. Spread the concrete and strike it off slightly above the finished grade so that when the slab is consolidated and finished, it will be at the proper grade and have the required thickness. Concrete can be spread by concrete spreaders or by hand as follows:

- Use concrete spreaders on large jobs because they are very efficient and save labor. Set the spreader so that it strikes off the concrete to the desired elevation for placing welded wire fabric or finishing the surface.
- Spread concrete by hand with a square-edge shovel. Do not use rakes (they will cause the mix to segregate), dig into the subgrade, or walk on the concrete with mud or dirt on your feet. Strike off the concrete at the proper elevation.

13-27. Do not dump concrete directly on or against B-joints. Hand emplace it to avoid displacing the joint filler or load-transfer assembly. Deposit concrete near the joint, and then shovel it against both sides simultaneously to maintain equal pressure on both sides. Continuously check for displacement of the joint and dowels.

13-28. Spread concrete in even layers from 6 to 24 inches deep, depending on the type of construction. When placing concrete in two or more layers, avoid exposing any layer for more than 30 minutes because it may cause a plane of weakness between layers. If the placing operation consists of two layers, place welded-wire fabric between them. To prevent honeycombing or voids, vibrate the concrete after placement as described below in paragraphs 13-29 to 13-31. Do not overvibrate the concrete because it can cause void segregation and a weak surface.

VIBRATE THE CONCRETE

13-29. Vibrate the concrete adjacent to all forms and joints regardless of the slab's thickness. Apply vibration only long enough to consolidate the concrete; avoid excessive vibration. Withdraw vibrators from the concrete during movement between points of vibration; do not drag them over the concrete. Vibrate concrete adjacent to joints very carefully, and do not allow the vibrator to come in contact with the joint or load-transfer material. Operate vibrators only when necessary for consolidation of concrete; do not operate them during slack periods. Ensure that additional vibrators, motors, and repair parts for vibratory equipment are available on the job at all times to avoid a delay or shutdown of the paving operation due to equipment failure.
13-30. If pavement is <12 inches thick, internal vibration is normally not necessary. Consolidation and compaction depend on the action of finishing operations, and surface vibration may be required. The finishing machine is equipped with a vibrator to apply high-frequency vibration to the surface of the concrete. The vibrator is mounted between the two screeds on the finisher, but it will not normally be used if the vibrator on the concrete spreader is being used. Use surface vibration for very dry mixes only and check it carefully. Vibration of more-plastic mixes and overfinishing cause accumulation of an excessive layer of mortar with high water content at the surface and reduces the quality of the concrete. Excessive scaling and deterioration of pavement are caused by overmanipulation of the surface.

13-31. If slabs are ≥12 inches thick, vibrate them with internal vibrators. However, internal vibrators tend to produce some concrete segregation in the area of operation. Avoid overvibration, and do not operate a vibrator in one location >20 seconds. The following types of vibrating machines are used for internal vibration:

- **Multiple-unit vibrator.** A multiple-unit vibrator consists of a group of internal vibrating units that are mounted in a single line on a frame. Each unit is capable of perpendicular and radial movement. Vibrating units should be mounted ≤30 inches apart. A multiple-unit vibrator is normally attached to the rear of a concrete spreader, and the concrete is vibrated immediately after spreading. The vibrators are inserted into the concrete to within 2 inches of the subgrade and dragged through the concrete as the spreading machine advances. However, the preferred method is to mount the vibrating machine on a separate carriage and withdraw the vibrating units from the concrete while advancing the machine in 2-foot increments.

- **Tube vibrator.** A tube vibrator has vibrating elements embodying two closely spaced parallel tubes. A submersible vibratory motor and the tube assemblies are mounted on each element. The vibrating elements are mounted on a frame that can be attached to a spreader or a finishing machine. The tubes should be readily adjustable to operate at any desired depth within the concrete, but they are normally operated at the midpoint of the slab's thickness.

**FINISH THE SURFACE**

13-32. Begin finishing operations immediately after placing the concrete. Use machines to finish concrete, if possible; finish concrete by hand only if it is inaccessible to machine finishers. Ensure that finishing equipment and tools are clean and free of hardened concrete or grout. Strike off concrete as soon as it is placed, and screed it to the crown. Cross-section the concrete to the proper elevation so that when the surface of the pavement is properly consolidated and finished, it is at the correct grade and free of porous places.

**SPREADING**

13-33. A concrete spreader follows immediately behind the paver and works intermittent batches of concrete into a continuous, uniform slab of concrete between the forms. The trolley blade, which is the first part of the spreader to
come in contact with the wet concrete, moves transversely between the forms while the spreader advances forward on the forms. The trolley blade can be set at, below, or above the elevation of the top of the forms to facilitate the laying of two lifts of concrete for reinforcing material. The strike-off plate strikes off the concrete at the desired elevation at, below, or above the forms' elevation. The strike-off plate can be set to give the pavement a crown, a warp, or a straight cross section. The spreader works just ahead of the finishing machine.

13-34. The spreader operator, aside from the purely mechanical handling of the machine, must carefully watch the operation of the paver. Through experience, he learns the best way for the paver operator to deposit successive batches of concrete in front of the spreader.

13-35. The spreader operator must carefully watch the action of the concrete in front of the screed to ensure that excessive concrete is not going through the finishing machine. He must not strike off the concrete so low that the finishing machine screens are starved.

**HAND FINISHING AND FLOATING**

13-36. Areas that are inaccessible to the finishing machine are floated by hand with wooden hand floats or trowels. Floating by hand is accomplished from bridges that rest on the side forms and span the concrete.

**STRAIGHTEDGE FINISHING**

13-37. While the concrete is plastic, eliminate minor irregularities and score marks in the pavement with long-handled wooden floats and straightedges. Use a long-handed float to smooth and fill in open-textured areas in the pavement's surface; use a straightedge to do the final finishing. A 12-foot straightedge can be operated from a bridge or from the side of the pavement. A straightedge operated from the side of the pavement should be equipped with a handle that is 3 feet longer than one-half the width of the pavement. Test the surface for trueness with a 12-foot straightedge held in successive positions parallel with and at right angles to the centerline of the pavement. Check the entire surface to detect any variations from the desired cross section. Immediately fill depressions with freshly mixed concrete that is struck off, consolidated, and refinished.

**BURLAP DRAG FINISHING**

13-38. Drag the surface of the pavement with burlap after most of the water glaze or sheen has disappeared and before the concrete becomes nonplastic. Drag longitudinally in the direction of placement with multiple burlap drags at least 3 feet wide and equal in length to the width of the slab. Securely fasten the leading transverse edge of the drag to a traveling bridge, leaving at least 1 foot of the burlap adjacent to the rear edge in contact with the pavement. Ensure that the burlap is moist; clean and change it as required. Burlap drag finishing produces a surface that has a fine, granular or sandy texture without disfiguring marks. Drag joint edges, as necessary, with a small, hand-operated drag. Ensure that tool marks are not present on the finished surface.
PREPARE CONTRACTION JOINTS

13-39. Construct contraction joints on the finished surface. These joints provide a weakened plane that controls cracking from construction. See Chapter 12 for more information on contraction joints.

FINISH THE EDGES

13-40. Remove soupy mortar along the edges. Fill areas of insufficient mortar with the proper amount of concrete at the right consistency. Eliminate tool marks and ensure that the edges are smooth and true to line. Carefully finish the edges of the slab along the forms and at the joints with an edging tool to form a smooth, rounded surface of the required radius. Patch honeycombed or damaged areas after removing the forms.

CURE THE CONCRETE

13-41. Cure concrete by preventing the loss of moisture and rapid temperature changes for at least 7 days from the beginning of the curing operation. In addition, protect unhardened concrete from rain and flowing water. Ensure that equipment needed for adequate curing and protection is on hand and ready to install before placement begins. When the curing medium requires the use of water, procure rights to water supplies before placement.

13-42. Provide protection, as necessary, to prevent cracking of the pavement caused by temperature changes during the curing period. Protect the sides of concrete slabs for 1 hour after removing the forms. This provides continuous curing treatment to exposed surfaces and also prevents damage to pavement edges and the underlying subgrade. Do not use covering material that contains or is contaminated with sugar (in any form), tannic acid, or any other substance detrimental to portland cement concrete. Remove covering material as necessary to test the surface, correct deficiencies, and saw joints. Keep the concrete surface wet with a water spray until you replace the covering material. If membrane curing is used, respray damaged areas with curing compound immediately after testing and surface correction.

13-43. After the concrete has set sufficiently to prevent marring the surface, cover the forms and the entire surface with wet burlap or cotton mats. Continue the initial moist curing for at least 24 hours. Keep the surface of the newly laid concrete moist until the cover is in place. Continue curing the concrete by any of the following methods:

BURLAP OR COTTON MAT

13-44. Burlap cover consists of two or more layers of burlap with a combined weight of ≥14 ounces per square yard when it is dry. Ensure that burlap is new or has only been used for curing concrete. After shrinkage, cotton mats and burlap strips should be at least 1 foot longer than the entire width of the pavement, including edges. Cotton mats should overlap each other at least 6 inches. Thoroughly wet mats or burlap before placement; keep them wet and in contact with the pavement surface and the edges during the entire curing period.
WATERPROOF-PAPER BLANKET OR IMPERMEABLE SHEET

13-45. Wet the entire surface with a fine water spray, and then cover the surface with waterproof-paper blankets. Polyethylene-coated burlap blankets or polyethylene sheets can also be used. If using burlap, thoroughly saturate it with water before emplacement. Waterproof-paper blankets, polyethylene-coated burlap blankets, or polyethylene sheets should be large enough to cover the entire surface and the edges of the slab.

13-46. Using carefully lapped polyethylene sheets eliminates the need for two curing treatments. This material is also lighter, cheaper, and more easily handled than polyethylene-coated burlap. Place the sheets with the light-colored side up. Ensure that sheets overlap at least 12 inches, with the lapped edges securely weighted down and cemented or taped to form a continuous cover and a completely closed joint. To prevent displacement or billowing from winds, fold the cover over the pavement edges and secure it with earth or other available material. Patch tears and holes immediately, and keep the cover in place during the entire curing period.

MEMBRANE

13-47. Coat the entire exposed surface of the concrete with a pigmented membrane curing compound. Curing compounds are wax- or resin-base. Do not allow the concrete to dry out before applying the membrane. If drying has occurred, moisten the surface with a water spray.

13-48. When the free water has disappeared, apply the curing compound to the finished surface with an approved automatic spraying machine, if available. A spraying machine is self-propelled and rides on the side forms or on previously constructed pavement, straddling the newly paved lane. The machine is equipped with a spraying nozzle(s) that covers the pavement surface with curing compound.

13-49. Mechanically agitate the curing compound in the storage drum during the application. Air agitation can be used to supplement mechanical agitation. Ensure that pressure is sufficient to produce a fine spray, and cover the surface thoroughly and completely with a uniform film. Maintain spraying equipment in excellent mechanical condition, and provide an adequate wind guard for the spray nozzle. Overlap the curing compound so that it gives a two-coat application of ≤200 square feet per gallon.

13-50. Apply curing compound with a hand-operated pressure sprayer on odd widths or shapes of slabs and on concrete surfaces that are exposed by removing forms. Apply the second coat at a right angle from the direction of the first coat. The compound should form a uniform, continuous, cohesive film that will not check, crack, or peel. It should also be free of pinholes and other imperfections. If discontinuities, pinholes, or abrasions exist, apply a third coat of compound to the affected area within 30 minutes of the second coat. Respray concrete surfaces that are subjected to heavy rainfall within 3 hours after the curing compound has been applied.

13-51. Ensure that the concrete is properly cured at the joints and that curing compound does not enter the joints to be sealed with joint-sealing compound. Tightly seal the top of the joint opening and the joint groove at exposed edges.
immediately after joint-sawing operations. Spray the concrete around the joint with curing compound to prevent moisture loss from the joint during the curing period.

13-52. Provide an approved standby facility for curing concrete pavement at a location that is readily accessible from the work site. This facility is used if mechanical failure of the spraying equipment or any other conditions prevent correct application of the membrane-curing compound at the proper time. Protect concrete surfaces from pedestrian and vehicular traffic during the curing period except as required for joint-sawing operations, surface tests, and repairs. Respray areas that are damaged by subsequent construction operations.

SEAL JOINTS AND CRACKS

13-53. Use a mechanical grooving machine to groove all cracks 1 inch deep and 1/4 to 5/8 inch wide. Widen the top of the crack without spalling or otherwise damaging the concrete. Remove loose, fractured concrete and thoroughly clean the groove. Completely fill the groove with joint-sealing compound. Joint sealing is discussed in Chapter 12.

REMOVE FORMS

13-54. Remove the forms as soon as the concrete can support itself, unless they are used to promote curing. Forms can usually be removed 12 hours after placement; but in cold weather, leave them for 7 days.

TEST THE SURFACE

13-55. After curing is complete, use a 10-foot straightedge to test the finished surface of the pavement for trueness. Operate the straightedge in different positions to reveal irregularities. Correct deviations from specification requirements or remove and replace the pavement. Minor irregularities can usually be corrected by grinding the surface.

TEST THE STRENGTH

13-56. Test the flexural strength of the pavement to ensure conformance with design criteria. Conduct tests at 7 and 28 days or more frequently if necessary. If the required strength is not obtained, adjust the mix or increase the pavement's thickness (see FM 5-428).

SECTION III - COLD- AND HOT-WEATHER TECHNIQUES

COLD-WEATHER CONSTRUCTION

13-57. Concrete construction at temperatures <30°F normally requires additional equipment and protective material. At temperatures >30°F, emplace concrete using standard equipment and methods. Use the following techniques when constructing pavement during cold weather:
• Prepare, treat, and protect the subgrade.
• Produce and deliver concrete at temperatures that will compensate for heat loss during placement so that the concrete will harden at a normal or accelerated rate.
• Place and finish the slab with minimal heat loss from the concrete.
• Protect the slab to maintain satisfactory hardening temperatures.

**FROZEN SUBGRADE**

13-58. Heat is withdrawn from concrete placed on frozen subgrade, causing a retarded rate of hardening. If frost extends a considerable depth in the subgrade, it may withdraw sufficient heat to freeze at least the lower part of the slab. It is important, therefore, that the subgrade be almost or completely free of frost. Whenever possible, prevent the freezing of the subgrade.

**Preparation**

13-59. Except in unusually protracted cold spells, freezing can be prevented by covering the grade with straw. Before freezing temperatures occur, cover the area with 12 to 24 inches of straw. The thickness required depends on the expected temperature. Dry straw has better insulating properties than wet straw, so cover the straw with tarpaulins or waterproof paper if necessary.

13-60. Uncover the subgrade during form setting and fine grading, and recover it with straw to protect it until concrete placement. If the finished subgrade becomes soft and muddy, remove free water and mud. Add sand, screening, gravel, cinders, or unfrozen earth (tamped or rolled) to produce a firm grade and bring the subgrade to the proper elevation. Heating the added material further protects the subgrade from freezing, and the heat can be retained by covering the subgrade with straw until concrete placement.

**Treatment**

13-61. Thaw the surface layer of frozen subgrade by burning straw on it, using torches or steam or, where permitted, covering the subgrade with hot sand, screening, or cinders. Burning straw covered with sand removes frost ≥8 inches deep. Spread the straw loosely on the subgrade, about 4 feet deep (50 to 70 pounds per square yard). Flax straw is preferred, but any dry straw can be used; loose straw is better than baled straw. Spread sand on top of the straw at the rate of about 4 cubic yards per 100 square yards (100 to 150 pounds per square yard) of subgrade. Use pit-run sand, blow sand, or any other inexpensive sand that is available. The sand ordinarily weighs the straw down to about half of its original depth. Ignite the straw at the edges. It will smolder for hours under the sand, holding in heat to thaw the subgrade. Cover the thawed subgrade with fresh straw to hold the heat and prevent refreezing. There will be a layer of granular material on the subgrade. It can be left in place or, if necessary, removed during fine grading or before concrete placement. When the frost to be removed is only about 2 inches deep, reduce the thickness of the straw to about 3 feet (30 to 50 pounds per square yard) and apply sand at the rate of about 3 cubic yards per 100 square yards (50 to 100 pounds per square yard) of subgrade.
13-62. Surface layers of frozen subgrade can be thawed with surface heaters, such as those used for patching and resurfacing asphalt pavements. A layer of hot sand or screening can remove frost from subgrade that is frozen to a shallow depth. If the grade permits, the layer of material can be left in place to provide insulation between the concrete and frost that may be left in the subgrade. The amount of heated material required depends on the depth of the frost. A 1-inch layer of heated material may be sufficient when the frost has slightly penetrated the subgrade; however, greater frost depths may require a 3- or 4-inch layer of material. A large volume of material is needed for very thick frost, and this method of thawing is not practical unless suitable material is locally available at a low cost.

13-63. Sand can be heated to about 400°F in a sand-dryer unit similar to that used by a portable or stationary asphalt plant. The unit will produce enough heated sand to cover the subgrade ahead of one concrete paving mixer. Do not place concrete on the sand immediately. Spread the heated sand and cover it with straw the day before concrete is to be placed, allowing the subgrade to thaw. The temperature of the subgrade should not exceed 90°F when the concrete is placed.

13-64. It is unnecessary to remove frost to its full depth from subgrade that does not have appreciable volume change under frost action, provided there is a layer of frost-free material insulating the concrete from the frozen subgrade soil. This is particularly applicable where granular subbases are being used. The required thickness of the unfrozen, insulating layer depends on the depth of the frost that underlies it. Use the methods discussed in FM 5-428 to determine the required thickness.

**EFFECT OF TEMPERATURE**

13-65. The rate that concrete hardens and gains strength is retarded by low temperatures and accelerated by high temperatures. Near the freezing point, the rate is very slow; and at temperatures below freezing, there is almost no increase in strength. Concrete that has been kept at a low temperature will later gain strength rapidly when more favorable conditions are provided. Ensure that the concrete's temperature is high enough for it to harden, and keep the concrete at a suitable temperature until it has gained ample strength. It may be necessary to heat concrete ingredients and protect the concrete against low temperatures.

**Heating Materials**

13-66. If the aggregate is above 50°F, it is only necessary to heat the mixing water. Do not heat the mixing water above 175°F because there is danger of flash setting. If the aggregate is below 47°F, heat the aggregate and the mixing water to bring the concrete's temperature to 70°F. Add heated mixing water to the aggregate to distribute the heat before adding the cement; never place heated mixing water directly in cement.

13-67. Aggregates are more difficult to heat than water, and special equipment is required to heat them in the quantity needed. It is usually possible to produce concrete of the required temperature by heating only the sand; but if the CA contains frozen lumps, it must also be heated.
13-68. Using steam is a practicable method of heating aggregate. Closed steam coils are preferable to open jets due to the moisture-control problem in the aggregate. However, closed steam coils require larger storage piles or bins than those needed when live steam is used because the transfer of heat is slower. Live steam can be fed into the base of stockpiles that have been covered with tarpaulins. Further increases in temperature can be attained by discharging steam through the aggregates in the bins above the weighing hoppers. Best results are obtained when the bins are full and the batches are loaded out at a uniform rate. When using live steam, it is better to use steam under considerable pressure because low pressure is more likely to result in the accumulation of condensed moisture. Variable moisture content in the aggregate can cause undesirable variations in concrete consistency, so watch it carefully.

13-69. Oil-burning heaters can be used to heat concrete by injecting a hot flame into the mixer drum. In mild weather and on small jobs, they can be the sole means for heating concrete. Other heating methods are required in cold weather and on large jobs because oil-burning heaters will only produce a boost in temperature.

**Heating Requirements**

13-70. Determine the amount of heating necessary to bring the mix to the specified temperature. Assuming that no ice is present in the water or the aggregate, use Figure 13-1 and the following formula to determine the amount of heat required. Increase temperatures until the concrete temperature is at the desired point.

\[
X = \frac{(W_g \times T_g) + (W_s \times T_s) + (W_c \times T_c)}{W_g + W_s + W_c}
\]

where—
- \(X\) = weighted average temperature of aggregates and cement
- \(T\) = temperature of heated gravel, sand, or cement
- \(W\) = weight of gravel, sand, or cement
- \(g\) = gravel
- \(s\) = sand
- \(c\) = cement

**Example:** Determine the amount of heat necessary to make the concrete 55°F using the conditions outlined in Table 13-1.
Solution: Heat the aggregate >32°F (preferably 35°F) to avoid contact freezing between the aggregate and the water. Heat the water to 137°F (from Figure 13-1).

\[
X = \frac{(2,000 \times 35) + (1,200 \times 35) + (600 \times 40)}{2,000 + 1,200 + 600}
\]

\[
X = \frac{(70,000 + 42,000 + 24,000)}{3,800}
\]

\[
X = \frac{136,000}{3,800} = 35.8 \text{ or } 36°F
\]
HEATING EQUIPMENT

13-72. Operate heating equipment several hours before paving starts. A sand dryer should be started early so that an ample supply of heated sand is available when the mixer starts. Make provisions for heating or store aggregates in insulated bins overnight and during shutdowns to keep them from freezing. If steam heating is used, discharge live steam constantly into the covered stockpile throughout the entire 24 hours to ensure an adequate supply of aggregate at the required temperature.

HEAT PRESERVATION

13-73. During the construction of large areas of pavement a comparatively short distance from the plant, such as an airport, a central mixing plant is advantageous. The mix can be transported to the subgrade in dump trucks covered with tarpaulins. In a short haul from the mixer to the subgrade, heat loss is not great. With experience, the temperature at the mixer can be adjusted to obtain the desired temperature of concrete on the subgrade in cold, windy weather. A piece of sheet metal can also be placed over the mixer drum opening (opposite the burner) to reduce heat loss.

PLACING AND FINISHING

13-74. Place and finish the concrete quickly to minimize heat loss. To accelerate finishing, add the minimal amount of mixing water needed. Keep bleeding to a minimum by paying special attention to the mix design. For example, increase the amount of fine material in the sand, make adjustments in the gradation, or use a different type of aggregate.

13-75. When mixing concrete, add calcium chloride to accelerate hardening. If flake-type calcium chloride (78 percent anhydrous calcium chloride) is used, do not exceed 2 pounds per sack of cement. If pellet-type calcium chloride (96 percent anhydrous calcium chloride) is used, do not exceed 1 3/5 pounds per sack of cement. Adding calcium chloride permits quicker finishing and also allows the insulating layer of straw to be placed on the pavement sooner. Concrete >90°F and containing calcium chloride hardens too quickly to permit good finishing results. Finishing can be done in the open if the outside temperature is >15°F and straw, paper, or a cloth cover is applied quickly. If the temperature is <10°F, especially with a strong wind, some form of shelter is required. The shelter may be covered framework that is mounted on wheels and rolled forward as work progresses. Remember to provide enough room for men to work. Use portable space heaters if the shelter alone does not sufficiently reduce heat loss. At very low temperatures, it may be necessary to heat steel side forms before the concrete is placed.

PROTECTION AFTER FINISHING

13-76. Ordinary curing specifications, which are aimed at supplying or retaining sufficient water within the concrete to ensure continuing hydration, can be disregarded during cold weather. Water evaporates very slowly at low temperatures, and the covering applied to protect the pavement from cold sufficiently reduces evaporation and retains plenty of moisture in the concrete.
13-77. Apply a layer of dry straw as soon as possible. If the pavement has not hardened enough to prevent marring from footprints, use light, movable bridges to apply the protective covering. Dry straw has better insulating properties than wet straw, so cover it with waterproof paper or canvas to keep it dry. This also keeps wind from blowing the straw away and exposing portions of the pavement. In extreme weather conditions, use steam pipes under the covering to provide additional heat. Hand forks or adapted mechanical equipment can be used to handle straw. For example, baled and loose straw can be handled with a clamshell that is equipped with long teeth to convert it into a grappling fork.

13-78. The heat of hydration increases the temperature of concrete after it is covered. This increase in temperature cannot be relied on as a substitute for heating materials, but it will offset heat loss during finishing. The temperature of the subgrade rises substantially after the warm concrete is spread. During early hardening of the concrete, this quick rise in temperature causes an appreciable volume change in frozen subgrade when it thaws. Protect concrete until it has attained a flexural strength of at least 400 psi. The length of time protection is required depends on the temperatures maintained and the corresponding rate of hardening. It can range from 72 hours for high-early strength concrete mixtures to 7 to 10 days for normal concrete.

HOT-WEATHER CONSTRUCTION

13-79. High temperatures of concrete or air require adjustments in construction procedures. An increase in the temperature of freshly mixed concrete increases the amount of mixing water needed to maintain the same slump. An increase in temperature from 73 to 120°F would result in an additional 3.3 gallons of mixing water per cubic yard to maintain the same slump in a 5.5-sack mix. The additional 3.3 gallons of water would lower the 28-day strength by approximately 10 percent. If possible, keep the mix temperature below 85°F.

13-80. Protect the water supply from the sun’s heat by painting storage tanks with white or aluminum paint. On small projects, water containers can be wrapped with wet burlap, and the evaporation of moisture will produce natural cooling. Other measures that can be taken to keep water cool during extremely hot weather include using underground storage (wells) and burying pipelines. Adding flaked ice to the mix water works well, but necessary quantities of ice are normally unavailable for TO construction. If necessary, lower the temperature of aggregates by sprinkling stockpiles with water. This also satisfies the absorptive qualities of the aggregate, so take this into consideration when designing the concrete mix.

13-81. Under normal summer conditions, moist burlap or paper covering maintains sufficient moisture during the concrete’s curing period. Maintaining moisture is very important, because the rapid loss of it during hardening results in crazing (temperature cracking). Crazing causes rapid deterioration of the concrete, especially if the pavement is subjected to freezing and thawing cycles.
13-82. Under extreme drying conditions, counteract moisture loss by replacing some of the evaporated water with a fog spray. Sprayers can be hand-operated or attached to the screed carriage of a concrete finisher. Make the use of fog sprays the exception rather than the rule.

13-83. Normal procedures, such as wetting the subgrade and using curing compound immediately after finishing, become more important during hot weather. If experimenting with expedient hot-weather measures, first try them on small test areas and then expand their use over the entire project.

SECTION IV - REINFORCED AND PRESTRESSED CONCRETE

REINFORCED CONCRETE

13-84. The use of reinforcing steel to increase flexural strength is not normally recommended for pavement construction. Additional load-carrying capacity can be obtained more economically by increasing the slab's thickness. Although welded-wire fabric is sometimes called reinforcing mesh, it does not increase the strength of a slab.

13-85. Welded-wire fabric (Figure 13-2) holds together fractured faces of slabs after cracks have formed. Adequate load transfer across a crack is assured by the interlocking action of the rough faces of the crack. Seal cracks with bituminous material to prevent ice damage during cold weather. When welded-wire fabric is used in economical quantities, it does not increase the flexural strength of a slab. It does, however, prevent intermediate cracks from developing in the central portion of a slab when joint spacings are excessive.

![Figure 13-2. Welded-Wire Fabric](image)
13-86. Welded-wire fabric is available in sheets and in rolls. Unroll the fabric counterclockwise (Figure 13-3). This is more difficult than unrolling it clockwise, but it counteracts the tendency of the placed end to curl up. After unrolling the fabric, inspect it for irregularities and rust. Remove rust with wire brushes to ensure a good bond with the concrete. Do not oil the fabric because this will prevent bonding.

Figure 13-3. Placement of Welded-Wire Fabric

13-87. The exact location of the fabric within the slab is unimportant. Ensure that it is at least 2 inches from any edge or the top and that it is more than 1/2 the slab thickness above the bottom. The usual procedure is to use two spreaders in the paving train. Set the first spreader to level the concrete about 1/2 inch above the desired level for placing the mesh. Place the mesh on the surface and force it into the concrete to the desired depth. Add additional concrete and strike the surface off at the desired grade with the second spreader.
13-88. Common steel, garden fencing with wires spaced 4 to 6 inches apart can be used as expedient welded-wire fabric, but the results are marginal. Do not use aluminum fencing because aluminum combines with chemicals found in some concrete mixes, forming a compound that has a much greater volume and causing the concrete to crack.

PRESTRESSED CONCRETE

13-89. Using prestressed concrete for pavement construction increases the strength of a slab without increasing its thickness, greatly increasing the economy of slabs with high load capacities. Initial compression is usually gained through tension applied to steel wires and rods in the concrete. Because prestressed concrete is elastic, it recovers its original shape after deformation when the load is removed. The actual design and construction of prestressed slabs is beyond the scope of this manual, but the various types of prestressing are discussed below:

- **Internal and external prestressing.** A prestressed concrete structure may be stressed externally or internally. In most cases, the loading is internally applied because many problems affect external prestressing, such as shrinkage and creep.
- **Linear prestressing.** Linear prestressing is used on beams and slabs. The prestressing tendons in linear-prestressed structures are not necessarily straight; they can be bent or curved.
- **Pretensioning and posttensioning.** Pretensioning describes any method of prestressing where the tendons are tensioned before the concrete is placed. Posttensioning is the method of prestressing where the tendon is tensioned after the concrete is hardened. The tendons are anchored against the hardened concrete immediately after prestressing.
- **End-anchored or non-end-anchored tendons.** In pretensioning, tendons transmit prestress to the concrete simply by their bond action near the ends. In posttensioning, tendons are anchored at their ends with mechanical devices to transmit prestress to the concrete.
- **Bonded or unbonded tendons.** Bonded tendons are bonded throughout their length to the surrounding concrete. Non-end-anchored tendons are bonded tendons; end-anchored tendons can be bonded or unbonded to the concrete. In general, the bonding of posttensioned tendons is accomplished by subsequent grouting. When the tendons are unbonded, provide protection from corrosion by galvanizing or greasing.
- **Full or partial prestressing.** Concrete is fully prestressed when there are no tensile stresses under the working load. When tensile stresses are reduced under the working load, the concrete is partially prestressed.
SECTION V - MAINTENANCE AND REPAIR

INTRODUCTION

13-90. Prompt and adequate maintenance—care of joints, repair of cracks, replacement of broken areas, and correction of settlement and drainage faults—greatly extends the life of concrete pavements. Essentially, maintenance involves retaining a smooth surface and keeping the subgrade as dry as possible. A smooth surface protects the pavement from the destructive effects of traffic, and it reduces wear and tear on vehicles.

TYPES OF CEMENT

13-91. Standard portland cement is normally used in concrete construction, but high-early strength portland cement is preferred for repair work because repaired surfaces may be opened to traffic quicker. The supply of high-early strength portland cement in the TO is normally limited; however, some of its characteristics can be obtained by using standard portland cement mixes with low water-cement ratios. In addition, calcium chloride (up to 2 percent) can be used as an admixture with standard portland cement to accelerate the initial set. The mixture will harden quickly and must be placed and finished promptly after mixing.

REPAIR OF JOINTS AND CRACKS

13-92. Seepage causes subgrade failure and allows earth and debris to plug joints and cracks, preventing their closure during hot weather. Inspect concrete pavement periodically for cracks and open joints that need to be cleaned, filled, and sealed to prevent water seepage into the subgrade. Repairing joints and cracks is particularly important in the fall when the pavement is slightly contracted and weather conditions are still favorable for repair. The sealing compound used should stick to the concrete and remain plastic at all temperatures. If the sealing compound becomes brittle and hard, it will crack at low temperatures; if it becomes soft, it will flow from the joint.

13-93. Remove dirt, dead sealing material, and concrete chips from the joint. Removal is more efficient when temperatures are <50°F and joints are opened by the pavement's contraction. Do not remove the existing sealer if it is in good condition. Some trimming of edges may be required to remove overhanging sections of concrete that can break off under traffic. If an expansion joint is filled with an extruding filler, trim it to the level of the surrounding pavement but do not pull it out of the joint. Ensure that joint and crack faces are dry. If a blow torch or other heating device is used to dry surfaces, do not burn live filler in the joint or crack.

13-94. Before resealing an expansion joint, prime it with a thin mixture of 3 or 4 parts gasoline to 1 part asphalt. (If tar is being used to seal a joint, use benzol in place of gasoline.) Flammable materials must be used with caution.
Primer can be applied more successfully by brooming rather than spraying, but brooming is not required if joints or cracks have been dried by the application of heat.

13-95. The following equipment is used to repair joints and cracks:

- Straight or hooked, hand-operated bars are used to clean joints and cracks. Their chisel ends are shaped to fit into crevices.
- Sharp-edged shovels, spades, or straightened hoes are used to cut off extruded joint filler.
- Special-made hooks or plows are pulled along joints with a tractor or a winch line to remove old sealing material in large quantities. The plow tooth is shaped to fit the joint and remove old material to the desired depth.
- Stiff, fiber or wire brooms are used to clean joints and cracks. A power sweeper saves time on extended operations.
- Air compressors are used to blow debris out of cracks and joints. The compressor should deliver at least 100 cubic feet of air per minute at 100 psi.
- Hand-pouring cones are used to pour small quantities of sealer. Large jobs require a distributor that delivers sealing material through a nozzle.
- Conventional kettles are used to heat bituminous materials, asphalt, and tar compounds. Indirect heating is required to heat sealing compounds that contain rubber or latex.

REPAIR OF AREAS

13-96. Areas that show extensive spalling, scaling, or map cracking can be repaired with a bituminous patch or cement mortar. Spalling is the chipping or splintering of sound pavement, and it usually occurs along the joints or cracks in the pavement. Scaling is normally caused by the deterioration or disintegration of concrete and can occur anywhere on the pavement surface. Map cracking is characterized by irregular cracks over the pavement surface.

13-97. When bituminous materials are used, clean loose and foreign material from the damaged area. Scale the area with one or more applications of RC cutback asphalt, fast-setting asphalt emulsion, or light road tar. Immediately cover the area with coarse sand, fine gravel, or fine stone chips. When excessive spalling or scaling has occurred 1 1/2 to 3 inches deep, place a base course of penetration macadam or bituminous premix on the area and follow with a surface treatment. Bituminous patches are the preferred method of repair when closing the area for more than 24 hours would cause great inconvenience to traffic.

13-98. Spalling at joints, deep surface scaling, and deep depressions can be satisfactorily patched with cement mortar. Chip the area to a vertical edge, remove all loose particles, and thoroughly clean the area with a stiff broom or compressed air. Use a 25 percent solution of muriatic (hydrochloric) acid to remove the cement coating from exposed aggregate. Wash the solution away with water and allow the surface to dry.
13-99. Make the cement mortar by thoroughly mixing 1 part cement and 2 parts sand. Add enough water for the mortar to stick lightly together when squeezed by hand. Brush the surface with a thin coat of freshly mixed portland cement paste, and fill the depression with thoroughly compacted cement mortar. Strike off the surface and finish it to match the surrounding slab.

REPAIR OF BREAKS

13-100. Breaks are caused by excessive expansion, unusual loads, inadequate subgrade support, washouts, and war damage. Replacing portions of concrete pavement is necessary when broken areas have become displaced or when the broken pieces are too small to distribute the load to the subgrade without settling or rocking.

13-101. Improve defective subgrades by draining, removing and replacing subgrade material, reconstructing subbases, or using other means as indicated by the cause. Thoroughly tamp the new material in place and bring the damaged portion of the subgrade up to the standard of the surrounding material. Correct poor drainage by installing subdrains or lowering the groundwater level as required.

13-102. In small areas being repaired, use rectangular patches wherever possible. Trim the upper 2 inches of the edge of the old concrete to a vertical face, thus preventing thin edges in the pavement or the patch. The remaining edge depth should be rough and free of loose fragments, dust, and dirt to ensure a good bond with the patch.

CONCRETE PATCHES

13-103. Concrete patches preserve uniformity and are not readily distinguishable from the rest of the pavement. Patches at pavement joints and edges should be about 2 inches thicker than the original pavement, but interior patches should be the same thickness as the existing slab. The concrete mix used for patching depends on the length of time the pavement can be closed to traffic. Normally, the use of the pavement is required as soon as possible. For this reason, use high-early strength portland cement for patching because it permits traffic on the patch in 24 to 72 hours. If high-early strength portland cement is unavailable, use a low water-cement ratio, high cement-factor mixture (dry, rich mix) made with standard portland cement.

13-104. To increase the bond between the patch and the concrete, thoroughly saturate the old concrete with water before placing the concrete patch. If an expansion or contraction joint intersects the patch, construct a joint of the same sort through the new concrete. This prevents concrete failure when rising temperatures subject the area to high compressive stresses.

13-105. Shovel the mix into the hole and thoroughly compact the mix. A surface vibrator provides the best results, but small patches can be compacted by hand-tamping. Use the tamp (a piece of 2- by 4-inch lumber is suitable) along the edges and force the concrete close against the slab. Repeat this procedure again, as late as possible before the concrete hardens so much that finishing cannot be accomplished. Cure the patch using the methods described.
earlier in this chapter for new concrete pavements. Keep the patch closed to traffic until it has developed sufficient strength to support the traffic without injuring the concrete. This period varies from one to several days depending on the type of cement and concrete mixture used and the temperature of the pavement.

CEMENT-BOUND MACADAM PATCHES

13-106. Satisfactory repairs can be accomplished quickly by using cement-bound macadam. Prepare the hole as for a concrete patch. Fill the hole with crushed rock, gravel, or broken concrete from the old pavement that is 1 1/2 to 2 1/2 inches in size. Thoroughly compact the material with a vibrator or a roller if available. Spread a thick cement-sand grout (1 part cement to 2 or 2 1/2 parts sand) over the compacted aggregate and thoroughly force it down until the voids are choked. Finish and cure cement-bound macadam patches the same as concrete patches.

13-107. When broken concrete is used to fill the hole, place large pieces first by hand and lay the flat sides down. Use small pieces to fill the voids. Ensure that the broken concrete is firm and free of dust and dirt. In an emergency, cement-bound macadam patches can be temporarily opened to traffic before applying grout.

BITUMINOUS PATCHES

13-108. Broken areas or craters in concrete can be successfully patched with bituminous materials. Penetration macadam or dense, fine-graded bituminous concrete is recommended for this purpose. A thoroughly consolidated base course that gives a patch thickness comparable in load-carrying capacity to the surrounding pavement is necessary. Such patches can be opened to traffic in a few hours if proper materials are used and the layers underneath the finished surface are constructed properly.

EMERGENCY PATCHES

13-109. Emergency patches can be made by using natural soil that is compacted at the proper moisture content. Pack the materials into place from the bottom to the top of the patch. Emergency patches are suitable in winter weather or when immediate, permanent repairs cannot be made. If the surface becomes sloppy under use, cover it lightly with FA.

SETTLEMENTS

13-110. Depressions in pavement caused by the settlement of the subgrade and the slab can be leveled with bituminous materials if settling has ceased and the slab is fully supported by the subgrade. Small broken pieces of pavement rocking under the load or the movement or displacement of the base course will be reflected in the bituminous patch and cause failure. Remove water and dirt from the surface with compressed air, and apply a thin coat of primer. Carefully apply bituminous material to ensure that the surface of the patch is flush with the surrounding pavement (after compaction). Correcting major settlements in concrete pavement may require the use of special methods and equipment to fill voids beneath the pavement by bituminous subsealing or mudjacking. These methods are discussed in TM 5-624.
PART THREE

Expedient Operations

The Army’s enhanced mobility allows soldiers and units to cover much larger areas of terrain, resulting in assets being dispersed. The need to protect these assets continues, yet the materials and methods for accomplishing this task have lagged behind other military technologies. Research and development have resulted in methods that are now catching up with doctrine; and military engineers have the expedient tools necessary to protect personnel, equipment, and supplies.

The Army is exploring the various techniques available for improving soil conditions. FMs 5-430-00-1 and 5-410 explain different methods and techniques where expedient paving and surfacing operations can be used in the TO.

In a TO, traffic routes are very important for moving troops and supplies. In a combat area, manpower, materials, equipment, and time are often unavailable for permanent construction so expedient pavements and surfaces are constructed. When determining the materials and methods to use, engineers consider the time available for construction, the required permanency, the type of terrain, and the anticipated type of traffic. Most prefabricated hasty surfaces have short lives and high maintenance outlays, but the ease and speed of construction greatly outweigh the disadvantages when the expedient surface is used as intended. When constructing an expedient pavement or surface—

- Use any method or material that provides a temporary road or airfield.
- Regard an expedient pavement or surface as an emergency measure, not as a permanent installation.
- Use a bituminous surface as an expedient if it meets the criteria for establishing a suitable base, because a bituminous surface’s life and capacity can easily be increased by stage construction in depth.

Chapter 14

Expedient Pavements and Surfaces

Throughout history, Army engineers have used expedient surfacing and paving methods. The methods used represent creative engineer responses to deficiencies of equipment, building materials, and trained manpower—circumstances that are typical of wartime field construction.

Although communication routes are vitally important in the TO, the overall need for personnel and equipment may greatly reduce the capability to construct these routes during combat operations. Expedient materials and methods have been developed to alleviate this problem. An
An engineer must choose the material and the method after considering the desired permanency, the time available for construction, the terrain type, the anticipated traffic volume and type, and the future use. As long as an engineer uses sound engineering judgment, he is limited only by his ingenuity in selecting expedient materials and methods. For information on paving and surfacing operations using membranes and mats, see FM 5-430-00-1.

MATERIALS

14-1. The word expedient is often misleading when used in the military sense. An expedient paving or surfacing operation is any procedure that must be completed quickly and whose end result is temporary. Expedient materials are often divided into the following groups:

- **Manufactured materials.** Manufactured materials are produced in a commercial factory. Landing mats are rigid or semirigid portable surfaces that interlock to form the surface of an expedient pavement. These structures contribute to the soil's bearing capacity, but they do not protect the soil from infiltration (water that works its way into the soil through the surface). Membranes do not contribute to the soil's bearing capacity, but they protect the soil from losing strength due to infiltrating water. These surfaces are extremely flexible and also control dust. Under certain conditions, some lower forms of bituminous surfaces are considered to be expedient surfaces.

- **Natural and nonstandard materials.** Natural expedient materials are materials found in nature at the site, such as rock, sand, timber, brush, and soil. Nonstandard expedient materials are materials that are produced for some purpose other than road construction, such as precut lumber, tar paper, sandbags, and bricks. Natural and nonstandard materials can be used to construct pavements and surfaces.

SPECIAL CONSIDERATIONS

14-2. Drainage in expedient operations is just as important as it is in standard paving operations. Since most expedient structures have a short design life, consider seasonal factors when examining the need for drainage. When designing drainage structures, consider the—

- Probability and intensity of precipitation.
- Anticipated storm duration and the use of alternate routes if the planned road is blocked.
- Ratio of time, personnel, and materials used in the original construction of adequate drainage facilities compared to those needed to repair and maintain the inadequately designed road or airfield.
- Cost of replacing or repairing the structure if it is damaged or destroyed by storms.
- Possibility of delays during construction.