Chapter 7
Maintaining and Repairing Bituminous Wearing Surfaces

The maintenance and repair of roads and airfields are particularly important because of increased mobility in modern warfare. Damage caused by the weight of heavy loads, the abrasive action of military traffic, and combat conditions must be repaired as quickly as possible. The repairs are often made under adverse conditions, such as shortages of manpower, material, equipment, and time and the possibility of an attack. Continuous maintenance cannot be overemphasized; small repairs made immediately are much cheaper than major repairs made at a later date.

PRINCIPLES

7-1. For effective results, the cause of a failure must be corrected. If surface repairs are made without correcting a defective subgrade or base, the damage will reappear and repairs can be more extensive. Also, a minor maintenance job that is postponed can develop into a major repair job involving the subgrade, the base, and the wearing surface. Repairing the surface without correcting the base is justifiable only as a temporary measure to meet immediate needs under combat or other urgent conditions.

7-2. Ensure that the maintenance and repair of a surface conform as closely as possible to the original specifications for strength, appearance, texture, and design. Ignoring the original specifications can mean recurring maintenance on areas that are below standard, and differences in wear and traffic impact may result from spot strengthening.

7-3. The priority for maintenance and repair depends on tactical requirements, traffic volume, and hazards that can result from failure of the paved area. For example, roads used to support tactical operations should have priority over less essential facilities. A single pothole in a heavily used road that is in excellent condition otherwise should have priority over a less used road that is in poor condition.

MATERIALS

7-4. Use any stable material for temporary repairs in combat areas or in areas where suitable material is unavailable and the area must be patched to keep traffic moving. Use good-quality soils and masonry or concrete rubble for this purpose. Ensure that patches are thoroughly compacted and constantly maintained. Permanently patch the area as soon as possible.

7-5. Blade the shoulders to facilitate rainwater drainage from the surface, and fill in ruts and washouts. Grade the shoulder material flush against the
pavement edges to restrict water seepage to the subgrade and to prevent the pavement edge from breaking under traffic. Replace material that is displaced from the shoulders with new material as required.

7-6. Successful repair with bituminous materials is more likely in warm, dry weather. When breaks occur during cold weather, repair them on a temporary, expedient basis to prevent progressive failures until the weather conditions allow more permanent repairs. Eliminate frost and moisture from the area with surface heaters or blowtorches.

INSPECTIONS

7-7. Maintenance inspections detect early evidence of defects before failure occurs. Frequent inspections and follow-up procedures prevent minor defects from becoming serious and developing into major defects. Inspections are particularly important during rainy seasons and spring thaws and after heavy storms. When inspecting surface defects, look for the causes of the defects. Inspect the drainage systems to ensure that debris is not obstructing drainage channels and structures.

7-8. Inspect dams for debris and excessive erosion, and investigate water remaining on surface areas or adjacent to surface areas. Conduct drainage inspections during every storm or immediately afterward. Inspect surface areas in late fall to prepare for winter, and inspect them again in the spring. In most cases, adequate inspections result in repairs being made only to the surface.

CAUSES OF FAILURE

7-9. A bituminous wearing surface depends on the base for its load-carrying capacity. If the subgrade or base course fails, the wearing surface that lies directly above the weakened area will also fail. Inadequate drainage, frost action, unsatisfactory compaction, unsatisfactory materials, or overloading may cause a base to fail. Disintegration or decomposition of the surface may be the result of a hardened bituminous film, insufficient bitumen, or bitumen stripping:

• **Hardened bituminous film.** Continuous exposure to the weather slowly hardens bitumen, causing it to lose resilience and become brittle. The asphalt film starts to harden when the bitumen is applied, and the process continues during the entire life of the surface. This process is usually referred to as oxidation. To anticipate failure from oxidation, estimate the yearly decrease in penetration residue (oxidation rate) and check the surface periodically. For example, material with an initial penetration residue of 60 is expected to harden in a temperate climate as shown in Table 7-1. If the oxidation rate remains above 30, failure from oxidation is unlikely to occur. A rate of less than 20 indicates that the pavement is brittle and will crack, ravel, and disintegrate.
• **Insufficient bitumen.** Insufficient bitumen can cause a surface to disintegrate. A poorly designed mix, unsatisfactory proportioning of aggregate and bitumen, or inadequate mixing results in insufficient bitumen.

• **Bitumen stripping.** Water can cause the asphalt film to separate from the surface of the aggregate, resulting in surface failure. If the aggregate absorbs too much water, the aggregate and the bitumen may separate. Other causes of bitumen stripping are unsuitable or insufficient bitumen and/or inadequate mixing. Bitumen may also be stripped by dirty aggregate or be cut away by a petroleum distillate.

7-10. An unstable wearing surface cannot withstand deformation under the impact of traffic. Some causes of instability are—

- Excess or soft bitumen.
- Smooth aggregate.
- Low density (insufficient compaction).
- Unsuitable mix design.
- Poor gradation of aggregates.
- Unsatisfactory placement.
- Uncured prime.
- Excess tack coat or overpriming.
- Dirt between the surface and the base.

7-11. Bombing, shelling, or other enemy combat action may cause surface failure. A nuclear airburst may harden or disintegrate a bituminous wearing surface. Continuous use of bituminous-paved airfields by jet aircraft is likely to burn or scorch the surface, causing pavement failure.

### TYPES OF FAILURE

7-12. There are several types of surface failure. They are discussed in the following paragraphs:

#### POTHHOLES

7-13. Potholes are the most frequent type of failure found in bituminous wearing surfaces. They may be caused by defective drainage, frost action in the base, settlement of the base, or heavy traffic. A small pothole may be surrounded by a large area that is progressively failing. Repair a pothole with a hot or cold premix patch or a penetration patch. If a large area has several

---

Table 7-1. Example of Oxidation Rate

<table>
<thead>
<tr>
<th>Period</th>
<th>Percent of Loss</th>
<th>Rate of Oxidation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement</td>
<td>20</td>
<td>48</td>
</tr>
<tr>
<td>End of first year</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>End of second year</td>
<td>10</td>
<td>36</td>
</tr>
<tr>
<td>End of third year</td>
<td>5</td>
<td>33</td>
</tr>
</tbody>
</table>

---
potholes, rework or replace the entire paving system with the same type of bituminous material that was used in the original pavement.

RAVELING

7-14. Raveling occurs when the bond breaks down between the aggregate and the bitumen. The damage starts at the top and disintegrates the surface. Raveling is frequently caused by brittle bitumen that can no longer bind the aggregate together. Repair raveling by applying a skin patch or a seal coat.

CRACKING

7-15. Surface cracking first appears as minute hairline cracks that are visible only under careful scrutiny. The cracks run lengthwise and appear to be more numerous toward the edge of the traveled area. Surface water may seep through the cracks to the base, causing base failure and potholes. Perform the following procedures when repairing cracks:

- Clean cracks with compressed air.
- Fill cracks that are wider than 1/8 inch with a lean sand-asphalt mix of 2 to 3 percent MC-250, RC-250, or RT-2 and fine-graded sand. Fill infrequent, small cracks with RC-70, RC-250, RT-6, RS-1, or RS-2.
- Place sand-asphalt mix into the cracks until they are full, and tamp the mix with a spading tool.
- Seal filled cracks with RC-70, RC-250, or RT-6 and cover them with sand.
- Apply a sand seal when surface cracks and checks are so extensive that water seeps through them into the base course and endangers the pavement. Clean the pavement thoroughly, and apply bituminous material (maximum 3 gallons per square yard). Apply an even coat of clean, dry sand over the bitumen and roll the surface until the sand is well set. Do not open the area to traffic until the bituminous seal has set and will not pick up under traffic.

RUTTING AND SHOVING

7-16. Instability may cause rutting and shoving of a wearing surface. Correct defects caused by too much cutter stock in the bitumen by blading the material from one side of the strip to the other until the volatile substances evaporate. If a cold mix has excess bitumen, add new aggregate and mix it until the bitumen is evenly distributed. Then, reshape and reroll the mix and apply a seal coat. If excess bitumen is present in a hot mix, remove and replace the affected area. Correct weaknesses of the base by reworking the subbase.

CORRUGATION

7-17. Corrugation frequently occurs when the bond between the surface and the underlying course has been broken. The causes of corrugation are the same as discussed in paragraph 7-16, so correcting the problem is also the same. Repair a corrugated surface by removing the surface, reconditioning and priming the base, and applying a new surface treatment.
BURNED AREAS

7-18. Bituminous materials become brittle and lifeless if they are burned or overheated during the mix process. Remove and replace the full depth of the pavement course that was constructed from such material.

BLEEDING

7-19. During hot weather, bituminous surfaces frequently bleed (secrete bitumen). Bleeding causes a slippery condition that is hazardous to traffic, and it can also cause the surface to become rutted and grooved. Remedy this condition as quickly as possible. If bleeding is caused by excess bitumen or inadequate curing, replace or rework the wearing surface. As an expedient method for light bleeding, apply a light, uniform coat of FA or coarse sand. Use a light drag to uniformly spread the aggregate (several applications may be necessary). Roll the pavement, if possible, or allow traffic to compact the aggregate. For expedient repair of heavy bleeding, perform the same procedures but use CA.

SETTLEMENTS AND DEPRESSIONS

7-20. If a settlement is caused by failure of a pipe, a culvert, or a supporting wall, repair the structure before repairing the pavement. A minor settlement or depression can be repaired with a surface treatment. Mark the edge of the failure with chalk or paint. Thoroughly clean the surface of the pavement within the marked area, and apply a tack coat of not more than 0.1 gallon per square yard. Use patching material that is similar in character and texture to that in the adjacent pavement. Place, rake, and roll the patching material. Repair a large settled area with one or more applications of bituminous material on top of the existing surface, or remove the surface course and bring the base up to proper grade. Under suitable weather conditions, blade the bituminous surface to one side of the affected area, readjust the base, and repave the area.

PATCHES

7-21. The types of patches used to repair bituminous wearing surfaces are premixed patches, penetration patches, skin patches, and seal coats (surface treatment). If the damage is extensive, rework and replace the entire paving system.

PREMIXED PATCH

7-22. A hot or cold mix can be used for a premixed bituminous patch. If small quantities cannot be obtained locally, prepare the mix on the job. Hot mixes prepared at a central plant are normally used for extensive repair. Hot mixes can be used with less delay from inclement weather, and hot patches can be opened to traffic in a shorter time. New cold patches displace easily under traffic before the volatile substances have evaporated. Hot patches have a longer life and less tendency to ravel at the edges. Prepare hot patching material according to the instructions in Chapter 4.
7-23. Cold-mix patches can be made with minimum equipment if materials are carefully selected and the mix is properly processed and stored. Cold mixes can be premixed and stockpiled. Many cold mixes are adapted to use local materials. Where tar is available, mixes using aggregate gradation II-1 and 14 to 16 gallons of RTCB-5 or RTCB-6 for each loose cubic yard of aggregate are satisfactory. These mixes remain usable after several months of storage.

7-24. For most cold patches, dry aggregate is needed for a satisfactory mix. Damp aggregate frequently reduces the life of the patch unless emulsions are used. With some emulsions, too much moisture in the aggregate may still be detrimental. During the summer months, sun-dried aggregate is usually satisfactory. In unfavorable weather, dry the aggregate with small, portable dryers. A small quantity of aggregate can be dried by heating it in a pan over an open fire and turning it frequently to hasten drying. Covered storage is desirable for small quantities of dry aggregate.

7-25. Table 7-2 lists aggregate gradations for the following types of bituminous patching mixes:

- **Dense-graded plant mixes.**
  - Long storage. These mixes are made with SC-800 or MC-250 at a rate of 3.5 to 7 percent by weight of dry aggregate. They can be stored for many months and are satisfactory for temporary roads and temporary patching of heavily traveled surfaces.
  - Short storage. These mixes are made with MC-800 or MC-3,000 and RT-7 to RT-12 at the rate of 3.5 to 7 percent by weight of dry aggregate. They stiffen rapidly but can be stored for several weeks during hot weather.

- **Open-graded plant mixes.** These mixes are made with RC-800, RC-3,000, RS-1, MC-250, and RT-7 to RT-12 at the rate of 3 to 5 percent by weight of dry aggregate. They cure within 6 to 20 hours under average weather conditions and cannot be stored very long.

### Table 7-2. Aggregate Gradation for Bituminous Patching Mixes

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Percentage Passing</th>
<th>Dense-Graded (Long Storage)</th>
<th>Dense-Graded (Short Storage)</th>
<th>Open-Graded Gradation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-1</td>
<td>I-2</td>
<td>I-3</td>
<td>II-1</td>
</tr>
<tr>
<td>1 inch</td>
<td>100</td>
<td></td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3/4 inch</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1/2 inch</td>
<td>85-95</td>
<td>85-95</td>
<td>100</td>
<td>80-85</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>75-85</td>
<td>75-90</td>
<td>85-90</td>
<td>85-95</td>
</tr>
<tr>
<td>No. 4</td>
<td>50-70</td>
<td>55-75</td>
<td>60-80</td>
<td>85-95</td>
</tr>
<tr>
<td>No. 8</td>
<td>40-60</td>
<td>45-65</td>
<td>50-70</td>
<td>40-55</td>
</tr>
<tr>
<td>No. 16</td>
<td>35-60</td>
<td>35-60</td>
<td>40-55</td>
<td>50-70</td>
</tr>
<tr>
<td>No. 200</td>
<td>5-10</td>
<td>5-12</td>
<td>5-12</td>
<td>2-7</td>
</tr>
</tbody>
</table>
Preparing Cold Mix

7-26. The gradation of aggregates and the amount of bitumen used when preparing a patching mix are very important. If the ingredients are not accurately proportioned, the patch may shove or ravel and break down in a short time. Because aggregates vary greatly in quality and grading, the quantity of bitumen used in the mix fluctuates. FA or dense gradation requires more bitumen to coat the increased surface area in a given volume. Use about 2 quarts of bituminous material per 1 cubic foot of most crushed stone; more bitumen is needed for fine sand. For any gradation, a dull black color with all particles coated indicates the correct bitumen content for the mix. When the mix is thrown into a pile, the particles should slowly roll over each other or creep.

7-27. An asphalt kettle or a bituminous distributor is normally used to heat, transport, and apply bituminous material. Ensure that the thermometer on the kettle is accurate, and heat the bitumen to the mixing or spraying temperature listed in Table 2-1, page 2-2. Observe all safety precautions for heating bituminous materials. Constantly agitate the bituminous material during the heating process by using a pump attached to the equipment or by stirring it. For surface patching, bituminous material can be accurately distributed with a hand sprayer. Distribute bitumen from pouring pots only when filling cracks. If the use of pouring pots for surface patching is necessary, broom the tile application for uniform coverage.

7-28. A pug mill or a similar mixer provides the best results for cold mixes. If a pug mill is unavailable, blend a workable mix with open-graded aggregates in a mortar mixer. Another method is to spread aggregate on an abandoned section of pavement, apply bitumen with a distributor, and mix the materials with a motor grader. Use or stockpile the mix immediately. For small quantities of open-graded mix, use a shovel to blend the materials.

Repairing a Pothole

7-29. For best results, patches should have the same density and shed water as effectively as the surrounding area. The area below the surface normally requires hand-tamping. Ensure that successive layers of patching material are not more than 3 inches deep. To repair a pothole or a burned area, follow the instructions below:

- Prepare a cold mix as directed in paragraphs 7-26 through 7-28.
- Mark off the pothole area, including all the surrounding weak material (see Figure 7-1, page 7-8).
- Remove the damaged area (Figure 7-2, page 7-8), including base material that may be weak. Cut a rectangular hole with vertical edges to hold the patching material against the flow of traffic. Remove all loose and defective material. When placing a patch adjacent to the shoulder of a road or airfield, key the patch to the shoulder.
Figure 7-1. Removal of Material From a Failed Area

**Step 1.** Clean and trim pothole to rectangular lines and vertical faces.

**Step 2.** Replace the base material and compact it thoroughly by tamping.

**Step 3.** Prime the bottom and paint the sides of the hole with light-grade bituminous material. Allow it to dry until it becomes tacky.

**Step 4.** Fill the hole with 3 inches or smaller lifts of compacted, premixed bituminous material.

Figure 7-2. Pothole Repair
• Replace the base by refilling the bottom of the hole with thin layers of new base material (3/4-inch crushed stone); thoroughly tamp each layer. If the wearing surface is more than 2 inches thick, fill the pothole even with the bottom of the wearing surface. If the wearing surface is less than 2 inches thick, fill the pothole to within 2 inches of the top.

• Apply a light tack coat (RC-2, RC-3, or RC-4) on the new base material, on the sides of the hole, and around the edges of the hole. The tack coat provides a bond between the new base material and the patching mix. Ensure that the tack coat is sticky before placing the patching mix.

• Shovel premixed materials into place for hand-patching. Do not dump or drop the materials because doing so produces a compacted area that must be turned or moved to obtain a uniform texture. Slightly rake the patch to level it, and use heavy raking to featheredge the patch. Push coarse material toward the center of the patch with the back of a rake. For small surface applications, spread the aggregate with shovels as evenly as possible. Slightly sweep or rake the material for uniform application. Compact bituminous patches to obtain the required density, and seal the aggregate. For small repairs where using power rollers is impracticable or for large repairs that are inaccessible to power rollers, hand-tamp the patch and leave a slight crown for further compaction.

• Sprinkle the top of the patch with wet sand to prevent the roller and the traffic from picking up the mix while it is hardening. Compact the patch with tamps or rollers or by slowly driving a truck over it.

**PENETRATION PATCH**

7-30. A penetration patch is made with macadam aggregate and hot bitumen. It is essentially the same as the mix used for penetration-macadam pavement. To repair a pothole with a penetration patch—

• Cut out the failure according to the procedures for premixed patches (paragraph 7-29).

• Place, compact, and lightly tack layers of suitable base material into the hole. Tamp a layer of CA (broken stone or slag, 3-inch maximum size) into the hole over the base material. If using hot bitumen, ensure that the aggregate is uniform (not graded from coarse to fine). Use Table 2-2, page 2-4, as a guide for aggregate gradations.

• Use crushed aggregate because the strength of a penetration patch depends on the aggregate particles interlocking. The bonding qualities of the bitumen are secondary in importance. The preferred bitumen is RC-3,000, but AC (85 to 100 penetration) or RT-12 is acceptable. The bitumen application rate is 1 gallon per square yard for the first inch and 0.5 gallon per square yard for each additional inch. Heat and apply the bitumen according to the procedures for premixed patches (paragraph 7-27). Avoid using excess bituminous material in a penetration patch.
7-31. After applying bitumen, key and choke the voids in the first layer of macadam aggregate with the intermediate aggregates according to the procedures in Chapter 4. Fill the hole completely, and leave the final surface of the patch slightly mounded to allow for compaction by traffic.

7-32. An RS-1 emulsified asphalt can be used to make a modified penetration patch that is less than 2 inches thick. The procedures are similar to those for a penetration patch. Table 7-3 lists materials to use for successive operations. Do not open a modified penetration patch to traffic until it is thoroughly cured.

Table 7-3. Amount of Materials (Per Square Yard) for Penetration Patches

<table>
<thead>
<tr>
<th>Compacted, Finished Thickness (Inches)</th>
<th>RS-1 Prime Coat Application (Gallons)</th>
<th>CA</th>
<th>Intermediate Aggregate</th>
<th>RS-1 First Penetration Application (Gallons)</th>
<th>Intermediate Aggregate</th>
<th>RS-1 Second Penetration Application (Gallons)</th>
<th>Intermediate Aggregate</th>
<th>RS-1 Seal Coat Application (Gallons)</th>
<th>Intermediate Aggregate</th>
<th>Cover Aggregate No. 4 to No. 80 (Pounds)</th>
<th>Intermediate Aggregate</th>
<th>Minimum Total Aggregate (Pounds)</th>
<th>Minimum Total Emulsified Asphalt (Gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2</td>
<td>0.20-0.30</td>
<td>1 1/2 to 3/4 in</td>
<td>110-130</td>
<td>0.50-0.60</td>
<td>1 1/2 in to No. 8</td>
<td>20-30</td>
<td>0.60-0.70</td>
<td>15-25</td>
<td>0.25-0.35</td>
<td>8-12</td>
<td>150</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>1 1/4</td>
<td>0.20-0.30</td>
<td>1 to 3/8 in</td>
<td>75-90</td>
<td>0.40-0.50</td>
<td>3/8 in to No. 8</td>
<td>15-25</td>
<td>0.50-0.60</td>
<td>15-25</td>
<td>0.25-0.35</td>
<td>8-12</td>
<td>125</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.20-0.30</td>
<td>3/4 to 3/8 in</td>
<td>50-60</td>
<td>0.30-0.35</td>
<td>3/8 in to No. 8</td>
<td>15-25</td>
<td>0.45-0.50</td>
<td>15-25</td>
<td>0.25-0.35</td>
<td>8-12</td>
<td>100</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>3/4</td>
<td>0.20-0.30</td>
<td>3/4 in to No. 4</td>
<td>35-45</td>
<td>0.30-0.35</td>
<td>No. 4 to 16</td>
<td>15-25</td>
<td>0.35-0.50</td>
<td>15-25</td>
<td>0.25-0.35</td>
<td>8-12</td>
<td>75</td>
<td>1.10</td>
<td></td>
</tr>
</tbody>
</table>

SKIN PATCH

7-33. A skin patch is a single surface treatment used to correct cracking and raveling on a small area of a wearing surface. It seals the defective area and reconditions the wearing surface. Sweep the damaged area, and apply a coat of asphalt cutback (usually RC-800) at a predetermined rate. Cover the bitumen with FA (1/4-inch stone or clean, coarse sand). Use 1 gallon of bitumen per 100 pounds of aggregate regardless of the aggregate size. Lightly roll or tamp the aggregate to seal it.

SEAL COAT

7-34. A seal coat is a single surface treatment used to seal large cracked or raveled areas. Basically, it is a sprayed application of bitumen that is covered with a thin layer of aggregate. Depending on the aggregate size, use about 1 gallon of bitumen per 100 pounds of aggregate. Use double surface treatments if necessary.
CRATERS

7-35. Bombs, shells, land mines, and cratering charges may produce extensive craters in roads and airfields. Surface damage presents no unusual repair problem, but an explosion may displace large areas of subgrade or cause instability. Drainage may be disrupted, allowing water to penetrate the broken surface, accumulate, and soften the subgrade. The subgrade's stability must be restored to support traffic and prevent undue settling of the surface. To repair a crater—

- Remove the damaged surfacing around the edges of the crater and the surfacing that is not firmly bonded to the base course.
- Trim the surface and the base course to a sound vertical edge.
- Remove water, mud, and debris from the crater and trim its sides.
- Fill the crater with successive 6- to 8-inch layers up to the original level of the subgrade. Thoroughly tamp and compact each layer with hand or pneumatic tamping tools.
- Pull or drive compaction equipment across the filled crater. A dozer can be used to compact granular materials, but it is not satisfactory for general compaction because of its low ground-bearing pressure (6 to 9 psi).
- Repair the base course and the surface.

7-36. Use gravel, rock, masonry, or other suitable debris (dry material no more than 12 inches in diameter) as backfill material. In an emergency, if sufficient backfill material is unavailable, take material from the shoulders or the edges of a repaired surface and replace the material later. Ensure that borrowing the material will not weaken the road structure.

7-37. A sand grid (cellular confinement system) can also be used to repair a crater (see Figure 7-3, page 7-12). Installed in 8-inch layers, a sand grid provides excellent trafficability and stabilizes poorly graded or cohesionless soils. If the situation permits and an enemy attack is anticipated, prepare stockpiles or material borrow pits at convenient sites.

CAUTION
Do not use hot mix on sandbags.
Figure 7-3. Expedient Crater Repair

Subgrade rebuilt with gravel, rock, masonry debris, sandy soil, or other select material.

Subgrade rebuilt with sandbags and earth.
PART TWO
Concrete Pavements

Portland cement (commonly referred to as concrete) is a hydraulic cement that is manufactured from carefully selected materials under closely controlled processes. Calcareous (limestone, marl) and argillaceous (shale, clay) materials are generally used in manufacturing portland cement. Blast-furnace slag is sometimes used to supply part of the ingredients. The raw materials are crushed and pulverized, mixed in proper proportions for the correct chemical composition, and fed into rotary kilns where they are calcined at a temperature of about 2,700°F to form a clinker. The clinker is cooled and then pulverized with a small amount of gypsum to regulate the setting time. The pulverized product is the finished portland cement. It is finely ground so that nearly all of it passes a sieve having 200 meshes per lineal inch or 40,000 openings per square inch. When portland cement is mixed with water, a paste is formed that sets, becomes firm, and then hardens for an indefinite period.

Wire mesh is sometimes used in concrete pavement to control cracks caused by shrinkage and changes in temperature. The load-bearing capacity of concrete pavement is distributed by beam action over a wide area. Concrete is essentially a mass of artificial conglomerate stones consisting of strong, inert materials in a granular or fragmental (aggregate) form. The materials are bound together by a hardened, water-cement paste. The quality of concrete depends on the proportion of water to cement, the manner in which the concrete is handled and placed after it is mixed, and the thoroughness of curing. For best results, carefully select materials and ensure that they are properly handled, stored, and measured.

Concrete is used to pave roads, runways, taxiways, and other surfaces that carry heavy wheel loads and heavy volumes of traffic. However, concrete pavement is not normally constructed in the TO because mixing, placing, and curing it usually requires more manpower and time than bituminous pavement. An adequate subgrade and base are as important for concrete pavement as they are for bituminous pavement. Even though concrete bridges weak spots in the subgrade, repeated loading leads to fatigue failure at weak spots.