MAINTENANCE GUIDEBOOK III - PAVEMENT MAINTENANCE
CHAPTER THREE - BITUMINOUS PAVEMENTS

SECTION A BITUMINOUS PAVEMENT CONSTRUCTION TYPES

1. APPLICATION OF BITUMINOUS PAVEMENT

The predominant uses for bituminous pavements are roadways and parking lots; however, such pavements are also used for playgrounds, basketball courts, and pedestrian walkways. Bituminous pavements for roadways and parking lots are designed to sustain the heavy loads of cars and trucks, but those used in recreational and pedestrian areas do not require as much structural strength.

All pavements have certain common features related to their construction. Whether built for vehicular, pedestrian, or recreational uses, they consist of subbase, base, and surface course. Variations in the depth and types of materials required for a given pavement will dictate the pavement's ability to handle adequately the intended loads, ranging from heavily loaded vehicular traffic to light foot traffic. Figure 3-1 shows a typical section for bituminous pavement.

2. TYPES OF FAILURES

Numerous types of failures may be encountered in a bituminous pavement structure. The first signs of failures show up on the pavement surface. Typical defects found in bituminous pavements and their causes include:

- **Lane or shoulder dropoff:** a difference in elevation of the lane adjacent to the shoulder caused by settlement or erosion of the shoulder material.
- **Bleeding:** a black film on the surface of the pavement caused by excessive liquid asphalt in the mix or poor gradation of the mix.
- **Bumps and sags:** upward displacement of the pavement caused by frost heaves, traffic loads, or concrete slab buckling under a bituminous pavement overlay.
- **Rutting:** a depression in the wheel paths resulting from poor compaction of the subgrade or a weak mix.
- **Shoving:** permanent longitudinal displacement of the pavement caused by heavy loads and/or heavy vehicles braking or turning.
- **Swell:** upward rise in the pavement caused by swelling soil (usually clay) or growth of tree roots.
- **Raveling or weathering:** wearing away of the pavement caused by loss of liquid asphalt and fine aggregate in the pavement.
- **Pothole:** local depression caused by the thawing of ice accumulated in the subbase.

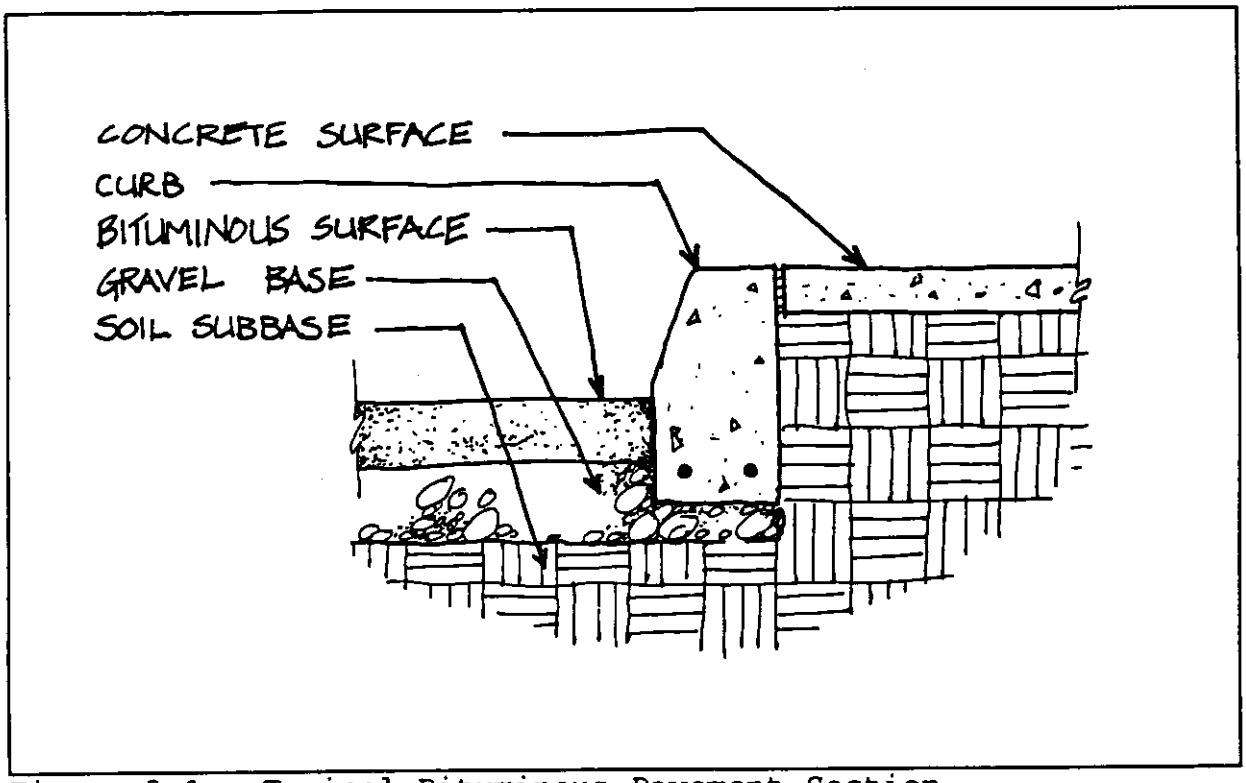

Figure 3-1: Typical Bituminous Pavement Section

SECTION B BITUMINOUS-ASPHALT MATERIALS

The primers, seal coats, or sealers and patching mixes described in this manual are materials primarily designed and formulated for use in repairing and maintaining bituminous pavements. There are many locally supplied products for bituminous pavement maintenance and repairs. Local suppliers should be contacted to obtain these products or their equals. The suppliers employ or have access to technical representatives who have up-to-date information on such products and their applications. It is recommended that HAs periodically contact the suppliers for such information.

Asphalt products will not adhere to coal-tar pitch, nor will coal-tar pitch products stick to asphalt; they are incompatible. However, asphalt emulsions and tar emulsions will adhere to both asphalt and coal-tar pitch, and are recommended.

Ready-to-use primers and sealers are basically water emulsions, which require no heating and are easily applied by maintenance crews. *However, before opening any container and applying its contents, the manufacturer's directions should be carefully read and followed.* All water-emulsion products should be stored where they will not be subject to freezing and applied only when the temperature is above 45°F. Since they are water soluble, they should not be applied in the rain or when rain is expected.

1. PRIME COAT

A prime coat is a free-flowing liquid bituminous material applied to a pavement surface, commonly in the construction of roads. Priming waterproofs the surface, plugs capillary voids, coats and bonds loose particles, and promotes adhesion with the new surface course. A prime coat, which is applied with an asphalt distributor, is not used often for patch repairs, although it is effective for patching small areas where the surface of the base is extremely dry.

2. EASY-FLOW EMULSION-TYPE SEAL COATS OR SEALERS

The bituminous surface to be treated or given a seal must be clean of all dust, dirt, loose materials, oil, and grease. If oil or grease are or have been present, the surface should be thoroughly washed with a nonfoaming detergent such as trisodium phosphate (mix 1 cup to 1 gallon of water).

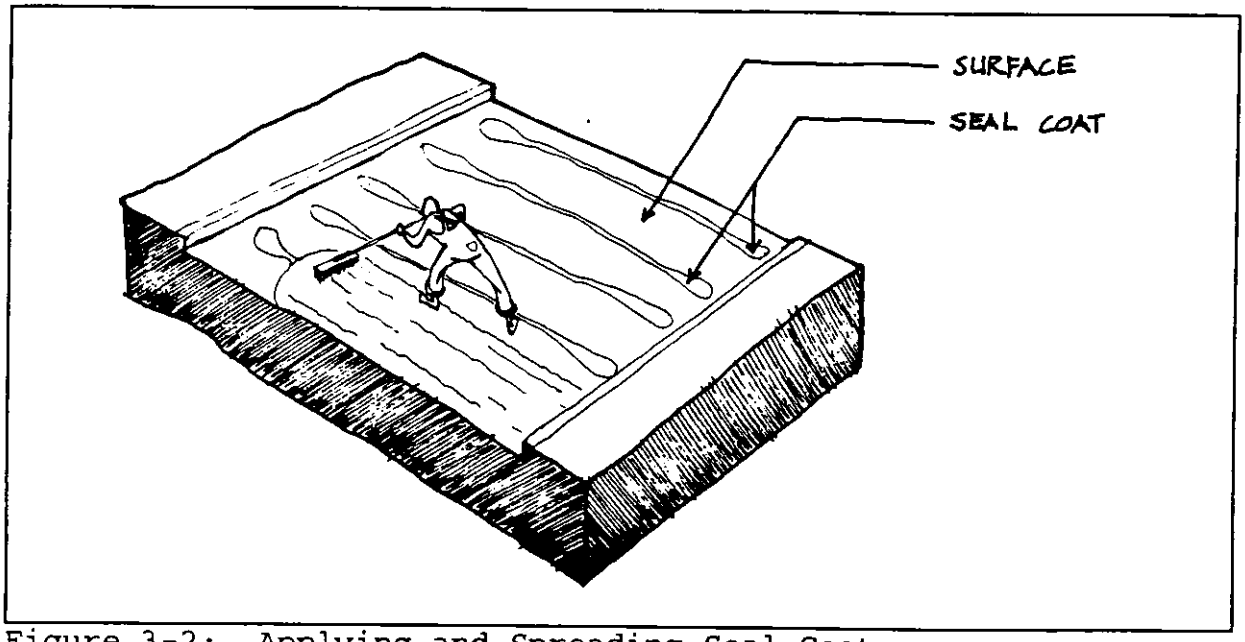

Figure 3-2: Applying and Spreading Seal Coat

Stir the sealer until it is of uniform color and consistency. Should it require thinning, add clean water according to the directions on the container, and stir it again until the material is uniform. Pour a small amount of the sealer on the pavement surface in parallel lines and spread it with a broom or rubber-faced squeegee. (See Figure 3-2) A smooth finish with a puddle- and ridge-free surface should result. The rate of coverage will vary from 75 to 100 square feet per gallon of sealer, depending upon the porosity and roughness of the surface to be treated. The surface must be thoroughly dry before being opened to either pedestrian or vehicular traffic. As soon as the work is completed, all tools should be cleaned by washing with water or petroleum solvent.

3. COAL-TAR PITCH EMULSION OR SYNTHETIC-RUBBER MODIFIED TAR OR ASPHALT-EMULSION SEAL COAT OR SEALER

These materials are formulated for use in deteriorated areas damaged by spillage of petroleum products. They dry to a uniform black color. When thoroughly dry, they are water-resistant, wear well, and can maintain abrasive and antiskid surfaces under traffic. They are also adaptable to an admixture of sand for skin patches. They are applied in the same manner as the heavy-bodied emulsion sealers. A manufacturer's technical representative should be contacted for advice regarding construction procedures and proportioning of abrasives.

4. HEAVY-BODIED EMULSION SEAL COAT OR SEALERS

The coal-tar pitch emulsion, synthetic-rubber modified tar or asphalt emulsion, and the heavy-bodied emulsion seal coat are applied in the same manner—a two-coat process. The surface should be repaired where necessary and thoroughly cleaned. For the first coat, mix the material thoroughly until it is uniform in color and consistency. A sealer for the first coat should be made by thinning or diluting one part of the material with one part of clean water, and stirred again until the mix is uniform and flows readily.

The first coat or seal coat should be poured in parallel lines on a damp, not wet, surface, then spread evenly with a soft-bristle nylon broom or a rubber-faced squeegee at a rate of 1 gallon of the diluted seal coat to 100 square feet of surface.

After the first coat has dried, the material for the second coat should be stirred until it is homogeneous in color and consistency. The second coat does not normally need to be diluted. This coat should be applied at right angles to the first coat. It should be poured on the surface in parallel lines and spread with a squeegee, pulling the material slightly toward the body to obtain a smooth uniform finish without ridges. The second coat will usually cover 50 to 75 square feet per gallon. The surface should dry for 8 to 24 hours before being opened up to traffic.

5. JOINT-AND-CRACK SEALERS

Joint-and-crack sealers are products formulated to seal both expansion and contraction joints and any cracks. They should not be considered the same as surface sealers because they are not formulated for that use. When used for Portland-cement concrete pavements, they should be used in joints only, unless the manufacturer of the product specifically states otherwise.

Joints and cracks 3/8-inch or wider should be examined to see if the joint or crack opening extends completely through the pavement. If it does, it should be filled, but not compacted, with oakum or dry fine sand up to approximately 1-1/2 inches below the level of the pavement surface prior to application of the bituminous filler.

Bulk joint-sealing material should be transferred from the container into a spout or conical pouring can, and then poured into the opening. The sealant should be used sparingly, pouring only sufficient material to fill the opening flush with the surface. Overfilling produces objectionable buildup, causing bumps. All material above the surface should be removed or wiped off with a squeegee. Where the pavement surface is sloping in the direction of the joints or cracks, dams should be made with small pieces of cardboard. These are cut a little wider than the openings, bent vertically and placed in the opening, and straightened to hold them in place. Space them to prevent the sealing compound from flowing out of place before it has set. Where material overflows the joint or crack, the excess should be smoothed or wiped off with a trowel or squeegee (see Figure 3-3).

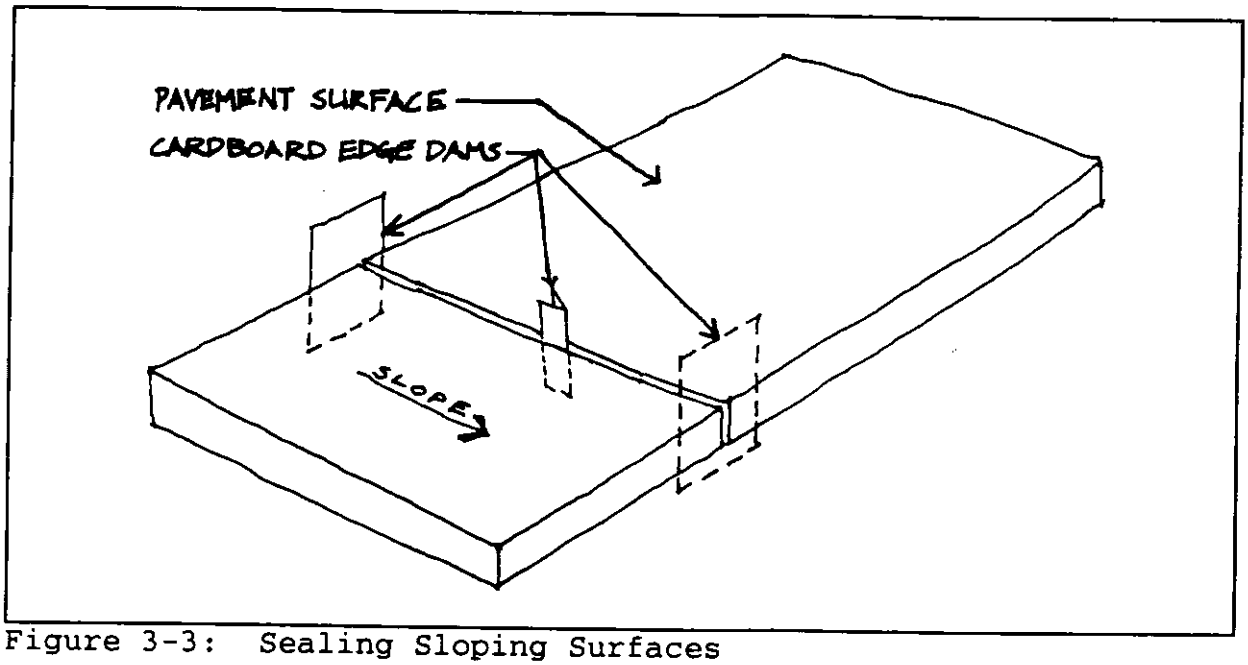

Figure 3-3: Sealing Sloping Surfaces

Immediately after filling the joint or crack and squeegeeing excess material off the surface, sprinkle fine sand over the area to prevent tracking by pedestrian or vehicular traffic.

6. PREPACKAGED OR PREMIXED PATCHING MIX

Prepackaged or premixed patching materials are very good for making emergency repairs. Emergency or temporary repairs should be made in accordance with the directions on the package. First, thoroughly clean, then fill the hole with the prepackaged mix to a level approximately one-half inch

above the surrounding surfaces. After thorough tamping to the level of the adjacent pavement surface, it is ready for traffic.

Permanent repairs and patches using pre-mixed or pre-packaged materials should be made in the following manner. The hole should be prepared, cleaned, and primed. The primer should be compatible with both the existing pavement material and the prepackaged or premixed patching mix. While the prime coat is still tacky, the patching mix should be shoveled, *not* dumped or dropped in place. Dumping or dropping would necessitate turning or moving the material to get a uniform texture. The patch mix should be leveled and spread with rakes, shovels, or lutes to get uniform placement.

Further, it should be placed and compacted in layers not exceeding two inches in depth. Then compacting should be done with hand or air tampers or rolled until the top layer is smooth and even with the adjacent surfaces. A straight edge or taut string may be used as a guide. (It is much better to have the patch slightly above the surrounding surfaces than below them.) After the patch has been allowed to set 8 to 24 hours, a sealer should be applied. When the sealer is dry, the pavement can be opened to traffic.

SECTION C RECOMMENDED REPAIRS TO CORRECT DEFICIENCIES

1. SHRINKAGE AND LOCALIZED CRACKING

a. Description of Deficiency

Shrinkage, checking, or cracking occurs in various shapes. These conditions may be found even on a comparatively new paving surface. The checking or cracking will first appear in the form of fine hairline cracks which are most prominent when wet. If immediate corrective action is not taken, the size of cracks increases. This condition can be caused by any or all of the following:

- Bitumen layer not thick enough;
- Overheating of bitumen (when mixed in the plant);
- Age of pavement;
- Moisture-sensitive aggregate in the mix;
- Brittleness due to insufficient use or defective bitumen in the mix.

The various cracking patterns (see Figure 3-4) include the following:

- **Hairline cracks:** caused by asphalt shrinkage or hardening, lack of compaction during construction.
- **Block cracks:** cracks that divide the pavement into rectangles caused by asphalt shrinkage or hardening.

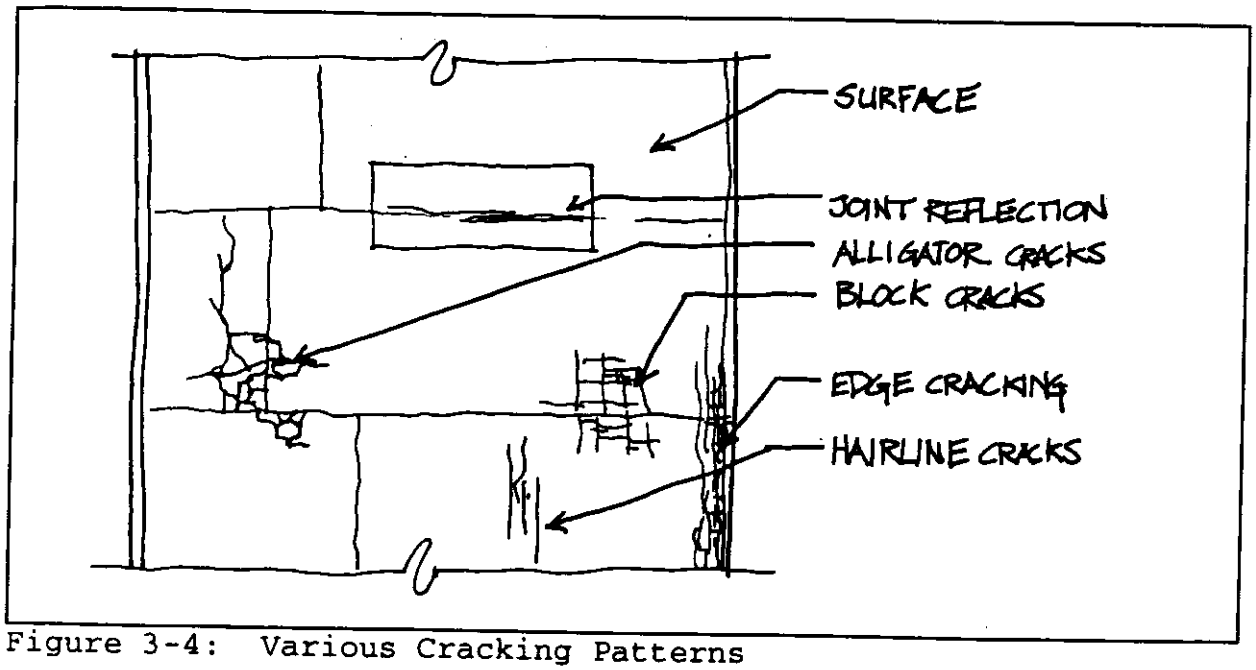

Figure 3-4: Various Cracking Patterns

- **Alligator cracks:** polygon-shaped cracks connected together, caused by repeated loads on a weak base and/or subbase, or movement of the subbase.
- **Edge cracking:** cracks close to the outer edge of the pavement caused by a weak base or subbase or a thin pavement section.
- **Joint reflection:** cracks in an overlay at the joints of concrete pavement.
- **Slippage cracks:** cracks that exist in the shape of half-moons and point away from the direction of traffic and are caused by loss of bond between pavement lifts, resulting from dust or dirt on pavement at time of paving, and heavy vehicles braking or turning.

b. Materials, Equipment, and Personnel Required

Listed below are the materials, equipment, and personnel necessary to repair crack defects.

- Materials Required:
  - Hairline cracks - Easy-flow emulsion seal coats or sealers;
  - Block and alligator cracks - Coal-tar pitch emulsion or synthetic-rubber modified or asphalt-emulsion seal coat or sealer, or heavy-duty emulsion mixes;
  - Edge cracks - Prepackaged mix.
- Equipment Required:
  - Dump truck;
  - Air compressor;
  - Pour pots;
  - Street brooms, hand shovels, pick, hand tamp;

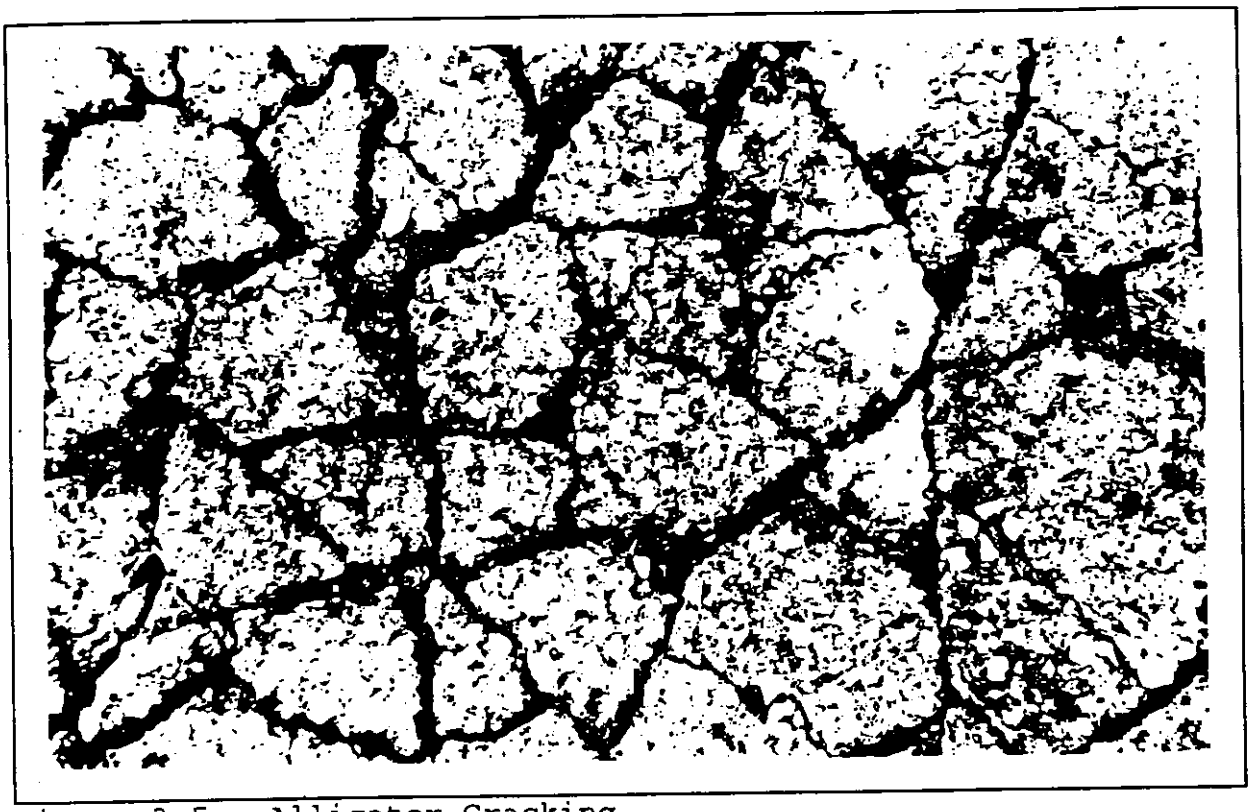

Figure 3-5: Alligator Cracking

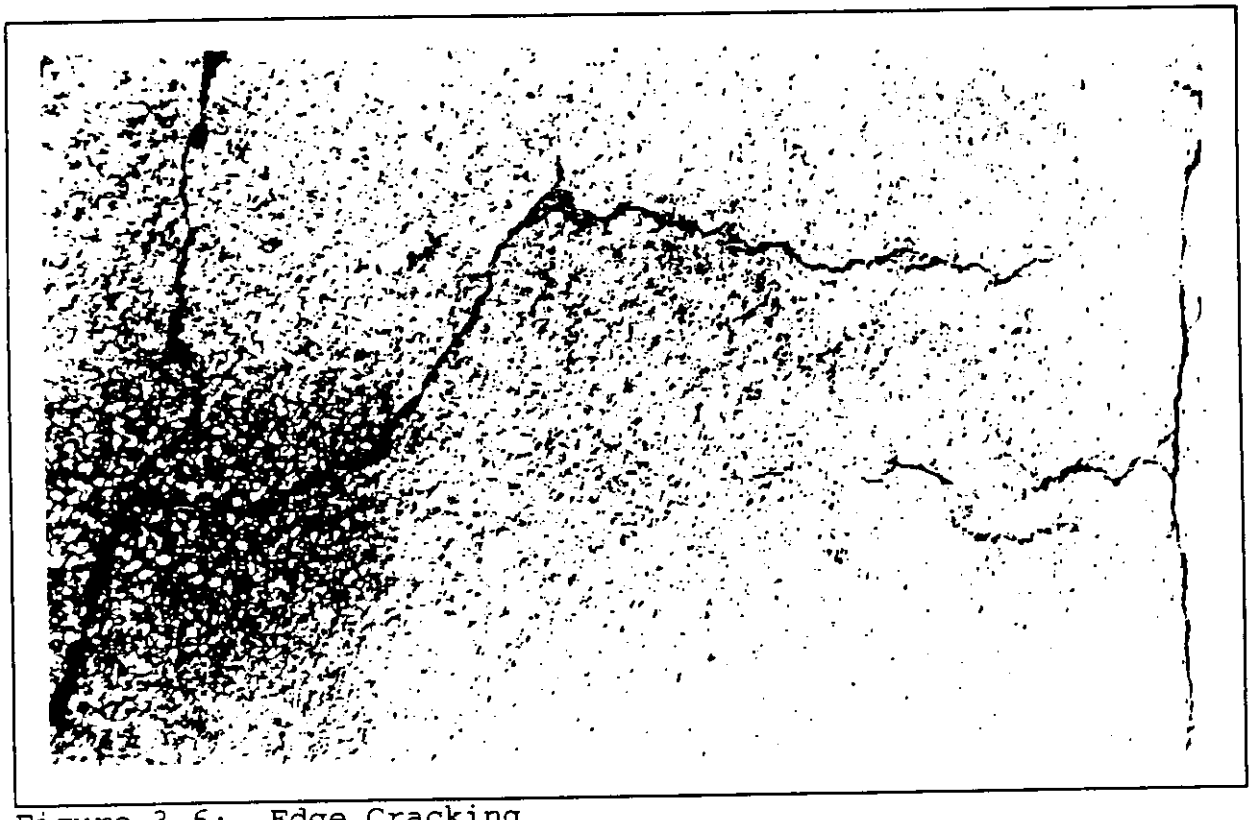

Figure 3-6: Edge Cracking

- Traffic signs and devices (cones, flags, etc.).
- Personnel Required:
  - Supervisor, if available and needed;
  - Laborers
  - Flaggers, if necessary.

c. Recommended Repair Procedure

The following procedures are applicable to the previously discussed cracking patterns:

- Set up signs for maintaining traffic as needed. Refer to the Manual for Uniform Traffic Control Devices (MUTCD).
- Flag traffic, if required.
- Broom and blow off area to be patched to remove loose materials.
- Blow out cracks; if existing surface comes loose, use prepackaged patch material.
- Tamp prepackaged mix.
- Seal cracks and lightly scatter sand over fresh oil to prevent tracking by traffic.
- Clean up any loose sand.
- Move to next patch.
- Repeat work method.

Methods for correcting these defects depend upon the amount and size of cracks, the degree of surface fatigue, and whether complete pavement failure has occurred.

Method 1: Where there are hairline or small cracks not over one-eighth inch, or very slight settlements. Correct hairline cracks as described in Section B, Part 2: Easy-Flow Emulsion-Type Seal Coats or Sealers.

Method 2: When the surface shows greater signs of distress, such as open cracks or deep pitting, but the base and subbase are stable. The distressed condition may be corrected by removing all dirt and loose particles from the cracks, cleaning the surface, and applying one of the following:

- A heavy-bodied emulsion seal coat or sealer;
- A coal-tar pitch emulsion;
- A synthetic-rubber modified tar;
- An asphalt-emulsion sealer or seal coat.

Allow patch to cure before opening to traffic.

2. LONGITUDINAL AND TRANSVERSE CRACKING

a. Description of Deficiency

Longitudinal cracks run parallel to the length of pavement and transverse cracks run perpendicular to the length of pavement (See Figure 3-7). These cracks are caused by:

- Underlying concrete joints reflecting through a bituminous overlay;
- Contraction or movement in the base or subbase;
- Shrinkage or swelling of the subbase soils.

b. Materials, Equipment, and Personnel Required

- Materials Required:
  - Joint sealing compound;
  - Sand to cover fresh bitumen and prevent tracking by traffic.
- Equipment Required:
  - Dump truck;
  - Bitumen heater;
  - Pour pot;
  - Air compressor with extra hose and fitting to blow out joints (usually 4 or 5 feet of pipe with one end hammered to a narrow rectangular opening and the other end adapted to clamp to the compressor hose);
  - Street broom, hook for removing dead sealant in cracks;
  - Hand shovel for transporting small amounts of bitumen;
  - Signs and traffic devices.
- Personnel required:
  - Supervisor, if available;
  - 4 laborers (more if flagging traffic is needed);
  - Truck driver, if available and needed.

c. Recommended Repair Procedure

Sealing cracks and joints prevents seepage of water into the subbase, which causes its instability. Sealing the cracks also prevents dirt from plugging the joint, which in turn allows the pavement to expand.

This operation is best done during warm, dry weather. Set up required signs and traffic devices, if necessary. The method of sealing varies with the size of the opening involved. First, the cracks

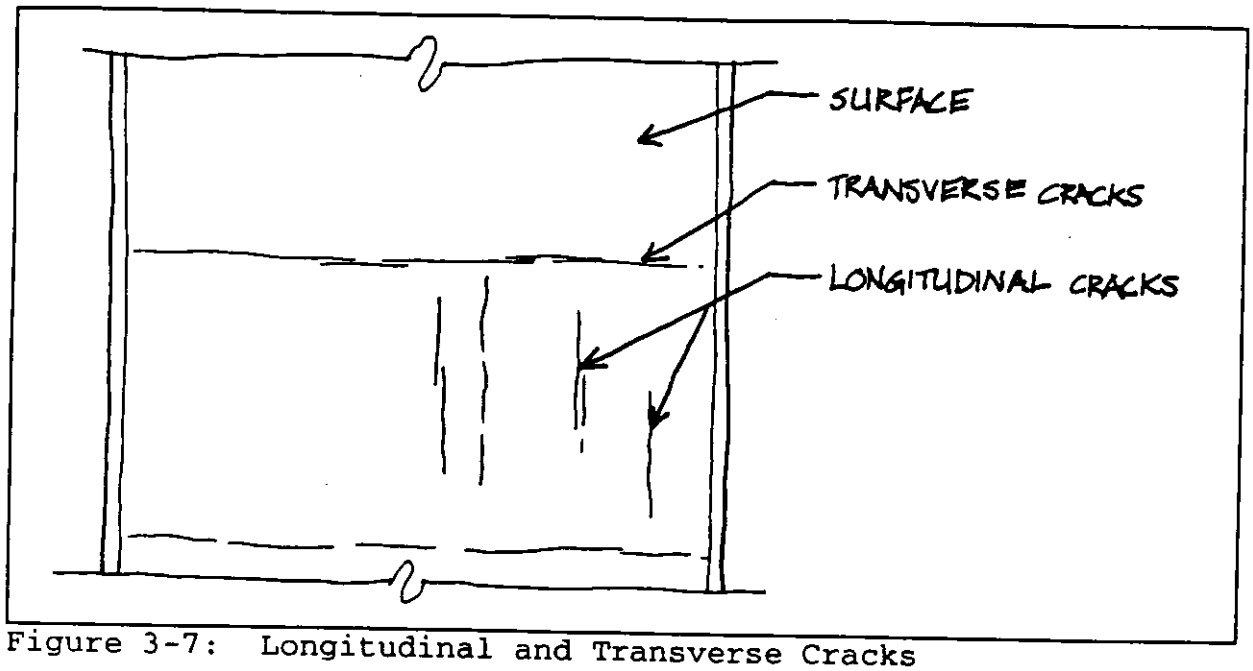

Figure 3-7: Longitudinal and Transverse Cracks

or joints should be thoroughly cleaned of all dust, dirt, dead sealing material, broken rock, or gravel by using a broom, brush, or air compressor. Embedded rock, gravel, or dead sealing material can be removed with a hook or screwdriver. The sides of the crack or joint should be dry before a sealer is applied. A blow torch should be used, if necessary, but care should be taken not to burn the existing bitumen in the crack or joint.

3. RAVELLING

a. Description of Deficiency

Ravelling and abrasion of the surface is caused when the loss of fine surface materials roughens the surface pavement. Pitting, as the word implies, consists of small depressions where individual particles of embedded aggregate have popped out. There are two basic causes for these conditions:

- Wear and tear by traffic;
- Inherent faults of the paving mixture such as too little bitumen, burning of bitumen, or disintegration of the aggregate resulting from excessive temperatures during plant drying and mixing processes.

b. Materials and Equipment Required

- Material Required:
  - Easy-flow emulsion sealer.

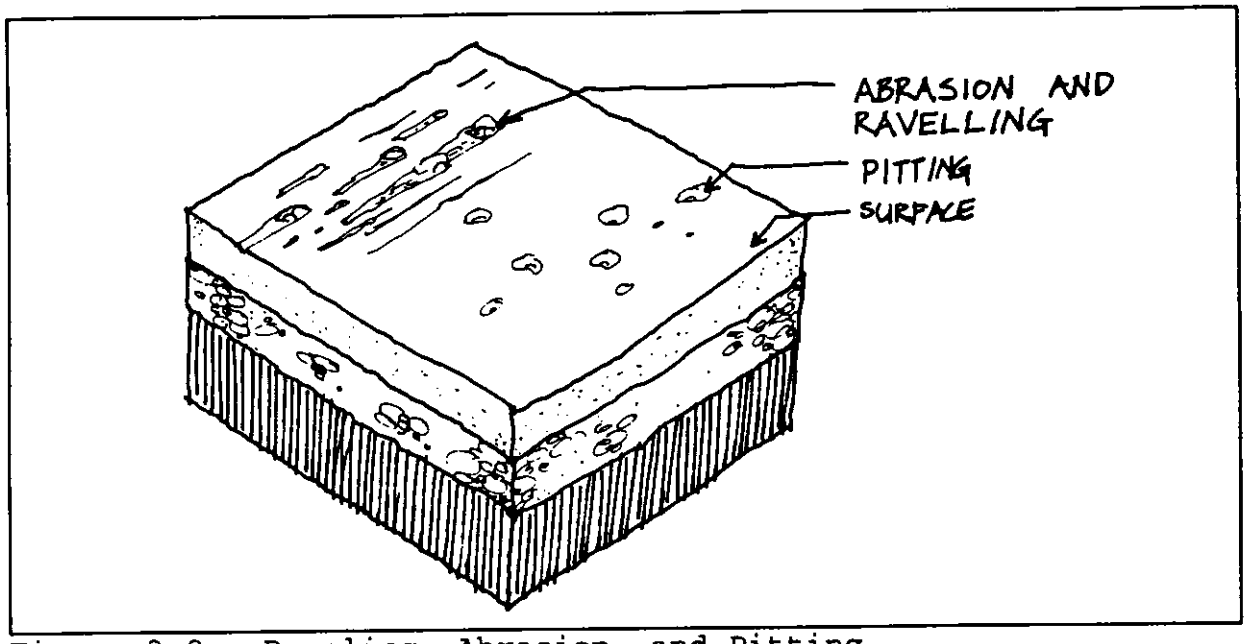

Figure 3-8: Raveling, Abrasion, and Pitting

- Equipment Required (for small areas):
  - Dump truck;
  - Squeegees;
  - Signs and cones;
  - Hand shovels (square point), brooms.

c. Recommended Repair Procedure

To correct this condition, provided that the raveling, abrasion, or pitting has not progressed too far, apply a coat of easy-flow emulsion seal coat or sealer. This will hold the surface particles in place and prevent further raveling. If the raveling, abrasion, or pitting is pronounced or well advanced, apply a heavy-bodied emulsion seal coat or sealer.

An application of a coal-tar pitch emulsion or synthetic-rubber modified-tar or asphalt emulsion seal coat or sealer may also be used to correct this condition. For large areas, a light coat of an RC or MC oil should be applied with an asphalt distributor. Consult a local supplier for the type and application rate. For areas that have become seriously pitted, a single or double surface treatment or a bituminous overlay should be done.

Do not allow traffic to use the repaired area until it has been thoroughly cured, because traffic will strip it off and track it onto the adjacent areas.

4. RUTTING

a. Description of Deficiency

This type of distress causes the pavement surface to become rough, warped, uneven, and depressed in the wheel paths. It may also crack in various patterns. It creates a hazard for both foot and vehicular traffic. Water accumulates in the depressed areas and penetrates into the foundation, which makes conditions worse.

Distortion and settlement are usually due to foundation weaknesses, such as poor compaction of the subbase or a soft spongy subbase caused by water penetration, in combination with repeated stopping and starting of vehicles. The methods of repair depend upon the extent of damage.

b. Materials and Equipment Required

For small areas with minor rutting, prepackaged mix or premixed patch material is required, as well as emulsion for sealing cracks.

c. Recommended Repair Procedures

Where cracking is not extensive and the depression or settlement is not over one-half inch, the repair can be made by applying a skin patch or slurry. The slurry material is made by adding fine mineral aggregate, such as graded sand or heavy-bodied emulsion sealer, coal-tar pitch emulsion, synthetic-rubber modified-tar, or asphalt-emulsion sealer. The fine aggregate should be clean, well-graded sand passing a number-16 sieve, and should usually be proportioned at four pounds of fine aggregate to one gallon of sealer, unless otherwise specified on the label of the emulsion container. This is generally referred to as "slurry." The slurry is applied in the same manner as heavy-bodied sealer. An alternate material is a prepackaged or hot-mixed bituminous concrete.

The depressed area may be leveled to marked lines or with a straight edge to create a smooth surface. If hot mix is used, the ruts should be adequately "tacked," and the area to be "feathered-in" should also be tacked for about 6 inches beyond the feathering. Too much tack can be detrimental, causing the new patch to move.

5. SHOVING

a. Description of Deficiency

This problem is very similar to rutting in appearance, occurring in places where there is frequent braking and stopping, such as at a stop sign, or turning of heavily loaded vehicles. There is no failure in the base or subbase; the surface is displaced or shoved to the side without break up.

b. Materials, Equipment, and Personnel Required

- Materials Required:
  - Hot mix bituminous or prepackaged mix;
  - Tack coat.
- Equipment Required (for small areas and minor shoving):
  - Dump truck;
  - Traffic signs and cones;
  - Hand shovels, lute, asphalt rakes, brush for applying tack coat;
  - Hand brooms.
- Personnel Required:
  - Supervisor, if available and needed;
  - Laborers;
  - Truck Driver, if available and needed.

c. Recommended Repair Procedures

For minor repairs, the most practical solution is to fill the ruts with hot mix so they are brought up to the original level of the pavement.

- Set up traffic signs and cones, as applicable.
- Assign flagmen, if necessary to control traffic around repair area.
- Mark off area to be filled, and tack coat.
- Fill with hot mix.
- Allow hot mix to cool to prevent pick-up or shoving of new repair.
- Clean up site and take down signs.

For major repairs, the "shoved" surface must be milled or planed to the original surface level. It is likely that the hot mix will have to be placed in the wheel tracks to get a proper repair. Since the equipment required for this is probably not available to the HA, it may have to be done by contract.

An alternate method, if the equipment and skilled operator are available, is to plane the area with a grader. The area to be planed should first be heated to allow the grader to cut the surface to be removed. This is a slow process and is not recommended unless the shoved area is limited in size.

6. EDGE FAILURE

a. Description of Deficiency

This type of failure appears along the edges of a pavement not protected by curb, walk, or edging strip. As cracks appear, the surface begins to ravel, and both surface and foundation of the pavement begin to disintegrate (see Figure 3-9). The failure may be caused by poor construction, saturated subbase, insufficient thickness of surface material, and excessive loads. Subbase saturation is caused by water seeping through surface cracks or water standing because of blocked drains or low areas.

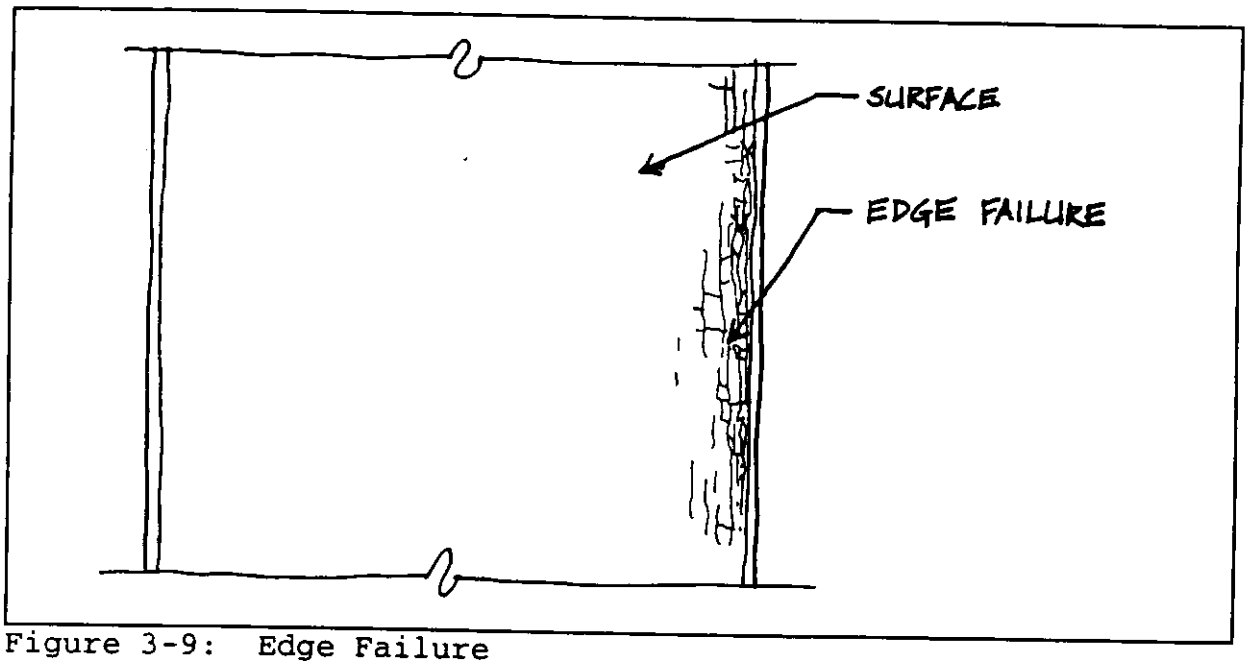

Figure 3-9: Edge Failure

Edge failure requires immediate action. It is one of the deficiencies which develop rapidly into complete failure requiring complete reconstruction. With the various causes of this type of failure, the following steps are suggested as soon as the first cracks appear:

- Check the drainage. If poor drainage is the cause of foundation failure, provide adequate drainage. In some instances, the installation of a concrete or brick inlet may alleviate the problem. The type and size of inlet and pipe to carry the water to a ditch, another pipe, or

wherever the water is to be discharged should satisfy the applicable requirements of the local jurisdiction. In some cases, it is advisable to engage the services of a professional engineer.

- Apply a seal coat. If the foundation is stable, the crack along the edge of pavement can be corrected by applying a heavy-bodied emulsion seal coat or sealer or a synthetic-rubber modified-tar or asphalt-emulsion seal coat or sealer.

If the edge failure has progressed to a condition where the surface has disintegrated and there is insufficient base thickness or unstable subbase, it will be necessary to remove the defective surface, base, and unstable material of the subbase and to replace them with suitable materials. The methods for this are basically the same as those described in Chapter Two for making a full-depth permanent patch.

b. Materials, Equipment, and Personnel Required

- Materials Required:
  - Subbase;
  - Seal coat compound or prepackaged mix or hot mix asphalt;
  - Tack coat.
- Equipment Required:
  - Back hoe;
  - Trucks for hauling away excavation and base, if used;
  - Truck for hauling patch material;
  - Hand shovels, asphalt rake, lute, brush for tack coat, street broom;
  - Traffic signs and cones.
- Personnel Required (as needed and available):
  - Supervisor;
  - Laborers;
  - Operator;
  - Truck drivers.

c. Recommended Repair Procedures

- Put up signs and traffic devices (cones, etc.).
- Dispatch trucks to pick up aggregate, if used.
- Excavate failed area.
- Square up hole.
- Refill subbase and base with new materials.
- Tack sides of hole.

- Repatch paved area.
- Clean up area.
- Take down signs.

7. PAVEMENT FAILURE/POTHOLES

a. Description of Deficiency

Potholes or pavement failures (see Figure 3-10) are among the most dangerous failures, and require immediate attention. Potholes start with a shallow surface failure which rapidly wears away, exposing the base and subbase and permitting water to gather and traffic to break down the bond, resulting in holes which look like pots.

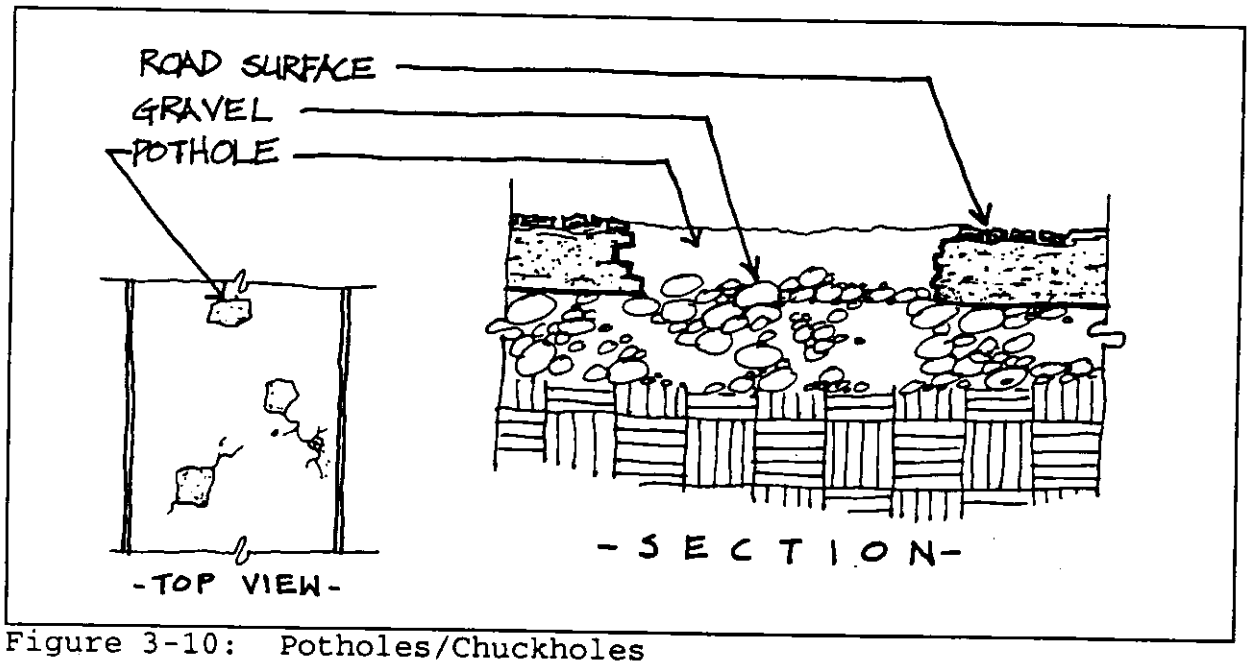

Figure 3-10: Potholes/Chuckholes

Potholes are generally caused by structural weakness or poor drainage, which, especially in the cold season, may result in complete localized failure of the road structure. Potholes or chuckholes continue to grow in size until repaired by patching; therefore, they should be repaired as soon as possible.

Potholes or chuckholes usually develop at the most unseasonable time of the year, when a permanent repair cannot be made effectively and emergency repairs should be considered. Cold premixed or prepackaged material should be used for a temporary patch. The repairs should be

checked frequently, depending on weather conditions, the amount of traffic, and the location of the pothole.

Pavements may also fail because of structural deficiencies such as:

- Surface deterioration due to weathering, cracking, raveling, or spalling;
- Failure caused by inadequate material strength, insufficient thickness of the base, cracking due to expansion, contraction, or movement of the subbase.
- Subbase weakness due to unstable, wet, or soft materials, or poor compaction.

Surface deterioration and delay in taking corrective action will cause a chain reaction whereby the surface, base, and subbase will fail completely or in part. Such a failure will require the removal of all defective materials and their replacement with a patch of sound and durable materials properly bonded to the surrounding area. See Chapter One for the sequence of steps required in making a good permanent patch.

b. Materials, Equipment, and Personnel Required

- Materials Required:

  Several materials are now available for use in making emergency repairs regardless of weather conditions (except freezing). It is necessary only to sweep out all excess water and loose materials and fill the hole with emergency repair materials, which are to be compressed or tamped in place with a tamper or shovel, then open for traffic.
- Equipment Required:
  - Truck;
  - Hand tamp;
  - Flags for flagging traffic.
- Personnel Required:
  - Laborers.

c. Recommended Repair Procedures

Determine whether poor drainage is a factor contributing to the failure. If it is, provisions should be made to get rid of the water and make a patch. For a permanent patch refer to Chapter Two.

8. PONDING/POOR DRAINAGE

a. Description of Deficiency

The greatest single enemy of any pavement is a saturated subbase or foundation caused by lack of proper drainage. It is a common occurrence, usually caused by buildup of soil on shoulders and adjacent areas which prevents water from draining from the paved surface and causes ponding. The ponded water seeps into the subbase along the edge of pavement, and gradually softens it, resulting in cracking and eventual settlement of the pavement affected by wheel loads. Water can also penetrate horizontally under the pavement and cause potholes.

One of the possible solutions to this problem is to regrade the adjacent area so that it slopes away from the edge of the pavement. The slope should be a minimum of 1/2" to 3/4" per foot where possible. The corrective work should be scheduled in the summer or fall.

b. Materials, Equipment, and Personnel Required

- Materials Required:
  - Grass seed;
  - Straw for mulch;
  - Lime and fertilizer as needed.
- Equipment Required (for small areas):
  - Dump truck;
  - Hand shovels;
  - Mattocks;
  - Picks, rakes, street brooms;
  - Construction and traffic signs.
- Equipment Required (for large areas):
  - Dump truck;
  - Hand shovels;
  - Mattocks;
  - Picks, rakes, street brooms;
  - Construction and traffic signs;
  - Excavator or motor grader (a rubber-tired loader is required to load trucks if a motor grader is used);
  - Dump trucks;
  - Mechanical brooms.

- Personnel Required:
  - Supervisor, if available and needed;
  - Laborers;
  - Truck driver, if available and needed;
  - Operators, as needed.

c. Recommended Repair Procedures

- Set out signs.
- Remove mail boxes or signs which will be in the way of grading (not required on small areas).
- Regrade built-up areas to meet pavement surface. Slope away from pavement at 1/2" to 3/4" per foot.
- Haul away excess material to a designated dump area.
- Re-seed and mulch where necessary.
- Clean up area.
- Take down signs.

Another solution to poor pavement drainage is to install a series of gravel- or stone-filled trenches in sump areas to carry the water from the edge of the pavement to an adjacent ditch. These trenches should be installed so that their bottoms are below the bottom of the pavement base. To get a good slope, it may be necessary to install them in a diagonal pattern through the shoulder to a ditch at a lower elevation. Ditches should be at least one foot wide. The stone or gravel should be well-graded with the maximum size passing a one-inch screen. A two-inch minimum cover of shoulder material for the top of drains should be provided.

- Personnel Required (for small areas):
  - Supervisor, if needed and available;
  - Laborers.
- Personnel Required (for large areas):
  - Supervisor, if needed and available;
  - Laborers;
  - Truck drivers;
  - Operators.

Note: In some cases, the construction of a swale or another drain structure, such as an inlet or drain pipes, are effective solutions to the problem.

Drainage Ditches and Swales: Base failures are also caused by poor maintenance of drainage ditches, which causes water to back up or drain slowly. High water in ditches prevents the subbase from draining, and allows the water from the ditch to penetrate the subbase. The solution to this problem is to clean out any debris, leaves, and silt so that the water can move

freely in the ditch. It may be necessary to establish a steeper grade and/or to increase the size of ditch for moving more water.

The resources (personnel and equipment) needed to solve this problem are the same as for the shoulder build-up problem. Seeding or other types of vegetative covers, if applicable, should be put down as soon as possible after any grading is done to prevent erosion.

END OF CHAPTER THREE