# ASPHALT PAVEMENT

# INSPECTOR'S MANUAL


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**May 1990**

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**Statewide Design & Engineering Services Division**
**Design & Construction Standards**


**July 2002, Third Edition**

# FOREWORD

The information currently available on asphalt paving would fill a small library. Furthermore, DOT&PF's Alaska Construction Manual describes procedures for the Department's staff to use on all aspects of construction projects. This manual draws on the Alaska Construction Manual and other sources but does not attempt to replace them as a reference for official Department policy. It is intended to present portions of this information needed by laydown and asphalt plant inspectors in a convenient form. It also presents information of value to paving materials inspectors. Material test procedures are so detailed, however, and test requirements so variable between projects, that this manual presents only rather general information about them.

More information on asphalt and paving is available in the publications listed in Appendix F (Further Reading). Many of these are available at your construction project office or the regional materials office. A copy of the Alaska Construction Manual should also be at the project office.

The Alaska Transportation Technology Transfer Center can provide a wealth of videotapes and publications dealing with paving and other transportation issues. Their address and phone number are listed in Appendix F.

Many individuals and agencies assisted in the preparation of this manual by reviewing draft versions and by making photographs and figures available. Ed Schlect of the Asphalt Institute is notable in this regard. Nicole Greene and Sheree Warner spent many hours preparing the text for publication. The authors appreciate and acknowledge this help.

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The third revision of this manual was accomplished with the help of Myles A. Comeau, Paving Inspector for Northern Region for reviewing the manual for changes and recommendations. Jack Phipps, Transportation Maintenance Manager for Northern Region added the section on *Necessities for a Successful High Float Project* that was presented at the Asphalt Summit in 1997. R. Scott Gartin, Statewide Materials, Pavement Management Engineer for his paper on *Pavement and Surface Treatments used in Maintenance, Rehabilitation, and construction.* John S. Ball, III for his article *Like Night and Day* courtesy *The Asphalt Contractor.* Gary L. Eddy, P.E., Construction Standards Engineer, for reformatting, making corrections, printing and placing the Manual on the ADOT & PF Design & Construction Standards Home Page.

Readers should consult the Asphalt Institute MS-19, a Basic Emulsion Manual for information regarding High Float and Chip Seal surface treatments. In October 2001, the *"Asphalt Surface Treatment Guide" by Robert L. McHattie, P.E. was completed for the Department. This is not a Design Guide, it covers materials selection and quality, construction methods, and troubleshooting three types of asphalt surface treatments used in Alaska.*

# Table of Contents

# 1. BACKGROUND

## 1.1. Hot Asphalt Concrete Paving: A Brief Description

Contractors or their suppliers make asphalt concrete. It is placed on airport, ferry terminal and highway surfaces where it provides a hard, smooth driving surface, seals out water and controls dust. The design service life for asphalt pavements is generally 10 to 20 years. Asphalt products, their placement and inspection represent approximately 25 percent of DOT&PF's annual capital expenditures.

Asphalt concrete normally has three basic components: asphalt cement, aggregate, and an anti-strip additive (there are also some air voids). Chemical modifiers may also be used to enhance and control various properties of the asphalt. Asphalt concrete is manufactured in accordance with a mix design, which defines the mix proportions, temperatures, etc.

Asphalt cement is a residual of petroleum refining. It becomes fluid at high temperatures but is relatively stable at room temperatures. These "thermoplastic" properties make it an excellent construction material.

Asphalt cement's following properties: viscosity (AC grading), penetration (Penetration Grading), aged residue (AR), and performance (PG based on ambient temperature of use in degrees Celsius) classify asphalt cement. Grades AC-2.5, AC-5, or AC-10 are usually used in Alaska, with AC-2.5 being the softest grade of the three. Typical PG grades used in Alaska include PG52-28, PG58-28 and PG64-28. Most asphalt concretes typically contain 5 to 6 percent asphalt cement to which ¼ of 1% (of the asphalt cement weight) of anti-strip agent is added. The anti-strip agent is added to the asphalt cement at the refinery and helps to bond the asphalt to the aggregate.

Asphalt concrete gets most of its strength from the aggregate, which makes up most of the mix. The Contractor or his supplier generally produces aggregate of a desired size distribution (gradation) by crushing and screening gravel in a rock crushing plant.

Asphalt concrete or "hot mix" may be produced at either a permanent commercial plant or at a mobile plant set up in the Contractor's pit. Aggregate is fed into the plant where it is dried, heated and mixed with the asphalt cement.

Trucks haul the hot mix to the construction site where it is placed on the roadway, runway, or taxiway by a paving machine. The paving machine spreads, smoothes, and partially compacts the asphalt.

A series of rolling operations provide further compaction. Immediately behind the paver is a "breakdown" roller, which achieves most of the required compaction. It usually has two steel drums that may be equipped with vibrators. "Intermediate" rolling, normally done by a rubber-tired roller, follows the breakdown roller.

Finish rolling is done by a static (non-vibratory) steel drum roller, which removes roller marks and surface blemishes.

## 1.2. Airport, Highway, and Marine Facility Pavements

Airport and highway pavements are built for different types and amounts of traffic. Airport and highway pavements are therefore built with different asphalt mix designs, compaction requirements and surface tolerances.

Airport and highway Standard Specifications are referenced throughout this manual (an example for Airports: P-401-4.11, for Highways: 401-3.13). Highway specifications are based on the 2002 edition. Airport specifications are based on the 2001 revision of the specifications. Marine facility specifications are not addressed directly in this manual, since relatively little asphalt is used for these facilities. Marine asphalt specifications are based on highway specifications for Type I asphalt concrete, but require the contractor to design the mix rather than the State. This method of determining the mix design is similar to the airport method.

**Figure 1-1 Typical Paving Operation**

Airport and highway pavement construction concepts, methods and equipment are very similar. Where appropriate, this manual points out the similarities and differences between airport and highway construction requirements.

## 1.3. Safety

### *1.3.1 Safety Equipment Checklist*

You should have:

- ❑ A hard hat
- ❑ A reflective safety vest
- ❑ Emergency phone numbers.
- ❑ Knowledge of Contractor's Job Safety Program and any required training.
- ❑ Informed the Contractor's on site supervisor of your presence before moving about the plant or equipment.

When working around hot asphalt (e.g. at plants and distributors), you should have:

- ❑ Heavy gloves
- ❑ Heavy, long-sleeved shirt or jacket
- ❑ Eye protection (goggles)

Your vehicle should have:

- ❑ A first aid kit
- ❑ A fire extinguisher
- ❑ Strobe light
- ❑ At airports, a radio for communications.

You should know:

- ❑ Where the nearest hospital, clinic or ambulance service is located
- ❑ Who on the job site has had first aid training?

Furthermore, goggles and a respirator are recommended where dust or flying rock may be a problem (e.g. near crushers). Noise protection may be needed around crushers and other noisy equipment. Permanent hearing loss takes only minutes at high noise levels.

### *1.3.2 Safety on the Paving Project*

Immediately report unsafe conditions to the Contractor. If he does not correct the problem inform the Project Engineer. The problem should be documented and who was informed of the problem. Do not work in an unsafe situation.

#### *1.3.2.1 Hot Asphalt Burns*

Asphalt temperatures at an asphalt plant; commonly exceed 300°F. Metal surfaces of plant equipment often range between 150°F and 400°F. Consequently, contact with hot asphalt or with plant equipment can severely burn exposed flesh. You should:

- be familiar with the equipment you work around and its operation
- avoid hazardous situations and remain alert at all times
- stand well back during asphalt loading operations
- use only safe and properly operating sampling equipment.

If a burn does occur, follow the guidelines given on the next page.

#### *1.3.2.2 Steam and Explosions*

Water can expand over 1,000 times when it boils. Even a small amount of water trapped in the piping can turn to steam and explode when a distributor or tank is loaded with hot asphalt. Tanks that have been used for emulsion or which have been empty long enough for condensation to occur must be cleaned before using for heated asphalt cement.

Some asphalt products (especially rapid curing cutbacks) contain volatiles, which can explode. Partially empty asphalt tanks, like partially empty gasoline tanks, are extremely dangerous. Tank inspections may be made using a mirror to reflect sunlight or a flashlight. *Never* use a match or open flame when looking into a storage tank. *Never* smoke around an asphalt storage tank.

Tanks can explode (burst) if pressure is allowed to build up in the tank while the contents are being heated. This may happen on some distributors if a top hatch is not opened while the contents are being heated.

#### *1.3.2.3 Open Belts or Pulleys*

Belts and hazardous machinery are required to have guards. Reciprocating feeders, cold-feed belts, etc. should have emergency electrical cutoffs. Know where these cutoffs are. Stay clear of areas you have no business in.

#### *1.3.2.4 Fumes from Asphalt Tanks*

Asphalt fumes in sufficient concentrations can be harmful to your health. The intensity of the fumes when a storage tank hatch is opened is greater than you would anticipate. They can cause you to lose consciousness if you are not careful.

# FIRST AID
## FOR HOT ASPHALT CEMENT BURNS

ASPHALT PAVEMENT ASSOCIATION OF OREGON

**In the event of a HOT ASPHALT CEMENT BURN:**

**COOL the asphalt cement and affected parts of the body immediately.**

**Methods of cooling (in order of preference):**

1. **Completely submerge affected area in ice water;**
2. **Completely submerge affected area in tap water;**
3. **Place affected area under running water.**

**DO NOT DELAY**

Use any available water, cooler than body temperature, while arranging for better cooling.

**CAUTION: DO NOT apply ice directly to affected area.**

LEAVE cooled asphalt cement on affected area.
Discontinue cooling with ice or ice water when the asphalt has cooled.
Proceed with the following:

**MINOR ASPHALT CEMENT BURNS – at first opportunity get victim to physician.**

Includes:
Injury to small areas of fairly insensitive flesh involving a small quantity of asphalt cement.

**SERIOUS ASPHALT CEMENT BURNS – as soon as possible get victim to:**
Hospital Emergency Room or Victim's Physician

Includes:
Injury to the head, face or extremities;
Injury when large amounts of asphalt cement are involved;
Evidence of nausea or faintness.

**TREATMENT FOR SHOCK**

In the event shock occurs, do the following:

1. Keep victim lying down and quiet.
2. Keep victim covered with a blanket or something similar to keep body temperature at normal, 98°F (37°C).
3. Keep victim's head lower than feet to promote blood supply to head and chest.

**DO NOT ATTEMPT TO REMOVE THE ASPHALT CEMENT**
with products containing solvents or ammonia.
Natural separation will occur in about 48-72 hours.
If necessary, for early removal, soak bandage in mineral oil and place over affected area for 2 to 3 hours.
Early forced removal may result in unnecessary pain or increase the depth of the burn.

Provided By:
**THE ASPHALT PAVEMENT ASSOCIATION OF OREGON**
3747 Market St. N.E., Salem, OR 97301 (503) 363-3858

*FIGURE 1-2 First Aid for Hot Asphalt Cement Burns*

Hydrogen sulfide, a gas contained in some asphalts, can be lethal in high concentrations. Asphalt cement made from Alaska North Slope or Kenai crude oil is generally low in hydrogen sulfide. Asphalt cement from other crude oil sources may have high concentrations of this gas. To prevent overexposure to hydrogen sulfide and other fumes, follow these guidelines:

- ❑ Keep your face at least two feet away from asphalt tank hatch openings.
- ❑ Stay upwind of open hatches.
- ❑ Avoid breathing fumes when opening hatches or taking samples.

In case of overexposure to fumes, do the following:

- ❏ Move the victim immediately to fresh air.
- ❏ Administer oxygen if breathing is difficult.
- ❏ Start artificial respiration if breathing stops.
- ❏ Have the victim examined by a physician immediately.

#### *1.3.2.5 Rotary Broom Dust Cloud Accidents*

Visibility around a rotary broom may be reduced to zero, if water isn't applied to the surface before sweeping. Blinking amber lights and/or red flags should be attached to all rotary brooms. In extreme cases, pilot cars may be necessary.

#### *1.3.2.6 Lute or Rake Handle Collisions*

Passing vehicles or workers may not see lute handles and run into them. It is a good idea for the rakers to put day-glow orange paint or flags on the end of the lute handles.

#### *1.3.2.7 Operating Rollers in Late Evening*

Rollers finish working after the rest of the crew quits. The Contractor must quit work early enough so that rollers can finish before dark or else provide adequate lighting. Traffic control must be maintained until the rollers have left the roadway.

#### *1.3.2.8 Slippery Surface on Prime or Tack Coat*

Special caution is needed on newly primed or tacked surfaces. Rain on fresh oil creates one of the most hazardous driving conditions known. If this happens, pilot cars driving very slowly should be used to escort all traffic. *Keep all traffic off tack or prime coat that hasn't broke!*

#### *1.3.2.9 Electric Lines*

All electric lines around crushers and plants should be located where construction equipment cannot run over or otherwise damage them.

End dumps can also reach high voltage wires while dumping into the paver. The paving crew should be vigilant where potential hazards exist.

#### *1.3.2.10 Blind Spots*

Pavers, rollers and trucks almost always have blind spots where the operator or driver cannot see. The inspector should be aware of these. He should not enter them without first getting someone's attention (the operator or driver or dump man) so they can protect him. Especially avoid blind pinch points. The inspector should also protect others on the crew when they are in these blind spots.

#### *1.3.2.11 Traffic*

Above all, ensure that traffic control is in place and being heeded by both the public and the paving crew. Even then, the crew should always maintain an awareness of the nearby traffic and protect each other. Traffic causes more injuries and fatalities than any other aspect of road construction.

#### *1.3.2.12 Paving at night*

See the article in Section 16 *Like Night and Day by John S. Ball, III.* The article is reprinted with the permission of *The Asphalt Contractor*. The article discusses paving at night with many safety recommendations that should be taken into consideration when working at night.

**Think Safety First!**

### 1.3.3 Documenting Accidents

Part of your job as an inspector is documenting accidents. Ask the basic questions: Who? What? When? Where? and How? Stick to the facts; don't make judgments of right and wrong. Take plenty of photos, not only of the accident itself but also of nearby signs and other contributing factors. If the police are involved get their report number. Inform the Project Engineer immediately. Use a Work Zone Accident Report (form 25D-123) to document an accident involving vehicles. There are other forms for reporting injuries and damage or theft of property and equipment. Ask your Project Engineer should the need arise.

## 1.4. Plans and Specifications

The contract will generally contain most or all of the following documents. Together they describe what will be built on the project and how it will be done. When one part of the contract conflicts with another part, one portion of the contract carries more authority or "supersedes" the other. The following is the order of authority (Highway 105-1.04) (Airport GCP 50-04):

1. Special Provisions:

   Additions to and/or changes in the standard specifications, which apply to a specific project.

2. Plan sheets:

   A. Typical section: shows the cross sectional view of various portions of the project including asphalt thickness.

   B. Plan view of the project.

   C. Tables of project improvements.

   D. Notes and project specific information.

3. Standard Modifications to the Standard Specifications:

   Contains additions to and/or changes in the standard specifications.

4. Standard Specifications:

   Contains all directions, provisions and requirements pertaining to performance of the work.

5. Standard Drawings:

   Drawings showing details of the work.

### 1.4.1 Airport Projects

The most important documents for an airport asphalt inspector are the mix design and the following sections of the Construction Specifications:

P-401 Plant Mix Bituminous Pavements
P-602 Bituminous Prime Coat
P-603 Bituminous Tack Coat

### 1.4.2 Highway Projects

The most important documents for a highway asphalt inspector are the mix design and the following sections of the Construction Specifications:

| | |
|---|---|
| 401 | Asphalt Concrete Pavement |
| 402 | Tack Coat |
| 403 | Prime Coat |
| 702 | Asphalt Materials |
| 703 | Aggregates |

## 1.5. Traffic Control

### *1.5.1 Air Traffic Control*

Airports are built and maintained to provide safe landing environments for the flying public. This is the primary function of airports. *Concern for the safety of the aviator is the most important aspect of airport construction.*

As a member of the asphalt inspection team you may or may not be directly concerned with the impact of the construction project on air traffic control. Ask your Project Engineer if you are not sure. Standard Specifications Sections 40-04, 70-08, 70-09, 70-14, and 80-04 contain air traffic control information. The special provisions may include project specific air traffic control information.

### *1.5.2 Air Traffic Control Checklist*

- ❑ What are the minimums for runway length and width reduction?
- ❑ What are the requirements for temporary runway markings?
- ❑ Has written notice of the construction activities been filed with the area Flight Service Station (FSS)?
- ❑ Has Airport Security been notified? What are their requirements?
- ❑ Does all of the Contractor's equipment have identification markings?
- ❑ What radio contact with the tower is required?
- ❑ Who is the Contractor's 24-hour representative? What is his phone number? Have the airport authorities been given that phone number?
- ❑ Don't forget to inform the airport authorities of any changes in operations?

### *1.5.3 Avoiding Accidents*

Accident records indicate that the following items contribute to the majority of the construction related aircraft accidents:

1. Heavy equipment that is left for long periods of time near aircraft movement areas.

2. Interference in radio communication or navigational aids by Contractor's equipment or stockpiles.

3. Oversize equipment in flight paths.

Identify these situations and have the Contractor correct them *immediately*.

### *1.5.4 Highway Traffic Control*

DOT&PF constructs highways for the use of the traveling public. Their safety is our primary concern. During construction it is easy to overlook this; the importance of creating a highway may seem to overshadow the reason why we are building the road. *The most important aspect of highway construction is the protection and* *guidance of the motorist.* Your duties may include inspection and documentation of some or all aspects of traffic control. Ask your Project Engineer if you are not sure. Section 643 of the Standard Specifications contains traffic control information. The special provisions may contain project specific traffic control information. The Project Plans sometimes include the Traffic Control Plan.

### *1.5.5 Highway Traffic Control Checklist*

- ❏ Do you have the *approved* Traffic Control Plan? (643-1.03)(98) Make sure the Contractor adheres to this plan. Any changes require higher approval.
- ❏ Do you have the name and phone number of the Contractor's 24-hour Worksite Traffic Supervisor? (643-1.04)(98)
- ❏ What will be the hours of operation?
- ❏ Photograph and document *all* signs, flagmen, pilot cars etc. A photo record of traffic control is often very important if there are court proceedings following an accident.
- ❏ Are all flagmen certified? (643-3.04, 4.)(98) Certification is required and their flags and paddles must meet the specifications for size, shape and reflectivity.
- ❏ Do all the devices (signs, cones, barricades, etc.) meet the requirements of the Alaska Traffic Manual? Are they clean and in good repair? (643-3.04)(98) + 643-201(98)
- ❏ Vehicles, idle equipment, and stockpiles must be parked outside the clear zone at all times. (643-3.04)(98) Statistics show that this is a major cause of construction zone accidents.
- ❏ Is traffic flowing smoothly and safely around the paving operation? You may discover unforeseen traffic control problems by driving through the project both in daylight and darkness.
- ❏ Traffic control systems left unattended at night, especially on weekends, requires special care. Night drivers often suffer from impaired vision and reflexes. Be sure that all the devices left up at night are reflectorized.

# 2. GENERAL GUIDELINES for the INSPECTOR

## 2.1. Introduction

Your primary duties are to help assure that all work on the project is performed in reasonably close conformity with the plans and specifications and that payment is made to the contractor commensurate with the work performed.

This requires that you understand the plans and specs for the work you inspect that you stay alert to the contractor’s activities, and that you keep accurate records. You also need to recognize problems when you see them, anticipate them whenever possible, and exercise diplomacy in resolving them with the contractor.

## 2.2. Asphalt Paving Inspection

Asphalt inspection is a team effort that consists of the following jobs:

- ❑ Inspection of aggregate production and stockpiling
- ❑ Prepaving grade inspection
- ❑ Prime and/or tack inspection
- ❑ Plant Inspection
- ❑ Laydown inspection
- ❑ Materials testing
- ❑ Density Testing
- ❑ Traffic control inspection

You may be responsible for any of the jobs listed. Ask your Project Engineer to define your duties for you if you are unsure what they are. If you are not responsible for these duties you should know who is.

## 2.3. General Responsibilities of the Inspector

- Know the plans and specifications for the pay items you are inspecting, including specifications specific to the project (special provisions, etc.)

- Be alert for any potentially unsafe conditions or any situations that may delay construction and report them to your supervisor.

- Identify nonconforming work or materials as early as possible; anticipate problems where possible. Notify the Contractor immediately and make a record of it. Follow up on corrective work and make a record of it too. If the Contractor can’t or won’t fix the problem, notify your supervisor.

- Avoid any inspection, testing, or other activity that could be construed as the Contractor’s responsibility. If you don’t, the Contractor may not be held accountable for his work if there is a claim or other contract dispute.

- Be prepared to make inspections and tests promptly. Do not make hasty or premature decisions. The Contractor is expected to give you adequate notice of when he will be ready for inspection and testing.

- If specifications don’t cover a particular situation or tolerances seem unrealistic, contact your supervisor for guidance. Report problems you can’t handle and see that they get resolved before an expensive and time-consuming correction is required.

## 2.4. Record Keeping

Complete and accurate records of the amount and quality of the work performed are required. They document that work is performed in accordance with the plans and specifications and assure the Contractor receives proper payment for his work. Records also provide a means to maintain control of the work during construction and document the reasons for decisions and actions taken.

Project records must be sufficiently clear and complete to be understood by people unfamiliar with the details of the project and to sustain audit. Failure to keep such records is a failure to account properly for the expenditure of public funds. The importance of maintaining adequate and proper records cannot be overemphasized. Memory cannot replace valid permanent documents.

Records of the amount and quality of work performed should include the "four W's" as follows:

**WHAT**

Identify the pay item involved (by both name and item number) and the quantity involved.

**WHERE**

List the project name and number as well as the specific location, such as project station and lane or offset.

**WHEN**

Note both the date and the time of day.

**WHO**

Sign the record. Initials are not acceptable unless your signature also appears in the record (in a book this may be done once on an index page in the front of the book).

It is particularly important to have a record of any problems on the job (such as nonconforming work or changed conditions). This record should include any instructions given to the Contractor, or agreements made with him, to resolve the problem. Remember that the records have legal importance if there is a claim or other contract dispute.

Forms are available for nearly all materials tests and for inspectors' daily reports. Pay item books and diaries may be organized somewhat differently on every project. You should know what records you are to keep and in what form before you begin work on any project; ask your supervisor.

## 2.5. Authority of the Inspector

- The inspector has the authority to approve materials and workmanship that meet the contract requirements. Approval should be given promptly. Section 105-1.09 of the highway specifications and airports GCP 50-09 authorizes the inspector to reject work or materials. The inspector must keep the Project Engineer informed of any material rejection. The inspector must thoroughly document the reason for rejection and the amount of material rejected.

- The Inspector does not have the authority to order the Contractor to stop his operation. Authority for the issuance of a stop order should be left to the judgment of the Project Engineer.

- The inspector does not have the authority to approve deviations from the contract requirements.

- The inspector should not require the Contractor to furnish more than what is required by the plans and specifications, nor allow anything less.

- The inspector should not under any circumstances attempt to direct the Contractor's work; otherwise, the Contractor may be relieved of his responsibility under the contract.

- Instructions should be given to the Contractor's supervisors, neither to his workmen nor his subcontractors.

## 2.6. Relationship with the Contractor

You should maintain a professional, agreeable, and cooperative attitude with the Contractor and his work force. Your goal should be to help build a good facility within the contract time, not to harass and delay the Contractor.

Avoid familiarity and accept no personal favors from the Contractor. Tact should be used when pointing out deficiencies to the Contractor and his staff. Your behavior can improve or disrupt the relationship between the Contractor, inspection personnel and the DOT&PF.

- Don't let personality differences or your opinions of the Contractor interfere with your working relations with him. Don't pre-judge the Contractor. Begin with the premise that the Contractor is fair-minded and intends to do a good job. Honor commitments made during partnering with the Contractor

- Criticism on or off the job of the Contractor or the Contractor's employees by the inspector is unwarranted and hurts Contractor relations.

- If you make a wrong decision, admit it. It is recognized that no one is perfect.

- Be courteous to the public and respect their rights. The resulting good public relations will benefit all concerned.

- Never get involved in the Contractor's labor relations. This is the Contractor's responsibility.

# 3. MATERIALS

## 3.1. Responsibilities of the Materials Inspector

### *3.1.1 Materials Testing Requirements*

Materials are inspected and tested to assure that they are the types and quality called for in the contract specifications. Occasionally, some of the materials testing are contracted out. Much of the testing has also been made part of the contractor's quality control responsibilities. *Both you and the Regional Materials Laboratory have responsibilities in this area; you should coordinate your work with them.* The Regional Lab can provide you with information about the overall materials and inspection program for your project. Since this may differ between regions and specific projects, only general information is given in this manual.

The Project Engineer or the QA Rover prepares a schedule of "Materials Testing Requirements" for every project. It lists the materials standards and the type and frequency of tests required for each pay item in the contract. Ask your immediate supervisor or the Project Engineer if you have any questions about these requirements.

### *3.1.2 Test Categories*

DOT&PF divide materials tests into four categories:

- Quality:
  The State or Regional Materials Laboratory generally does quality tests. They are made to determine if raw material from a particular source (such as an asphalt supplier or a gravel pit) has acceptable qualities. Gravel, for example, is tested for hardness and durability.

- Acceptance:
  Project materials inspectors perform acceptance tests. They document whether a specific lot of a pay item (such as asphalt concrete) meets particular specifications for the item (such as gradation). Materials are accepted and paid for by the Department based on acceptance tests. On almost any paving project, you will be responsible for acceptance tests for density, asphalt content, gradation, fracture, and pavement thickness. These tests are briefly described in Section 3.2.1.

- Assurance:
  The Regional Lab usually performs assurance tests. These are used as checks on your acceptance tests and assure that you are using the right procedures and that your test equipment is working correctly.

- Information:
  Information sampling must be approved or at the request of the Project Engineer. Be cautious with sampling for informational purposes. Information tests are made on samples taken during the production of materials prior to the point of acceptance. Tests taken to investigate apparent changes in the product are informational and may serve to detect production problems before the scheduled acceptance test, thus averting the rejection of a large quantity or the imposition of a price reduction. The gradation of aggregates, for example, is often checked as it is being crushed. Either project materials personnel or the Regional Laboratory may make information tests. Do not use information tests to replace Quality Control tests that are the responsibility of the contractor, as this may make the DOT&PF responsible for out of specification material.

### *3.1.3 Testing Procedures*

There are detailed procedures for each type of test that must be followed carefully. You should have a set of the test procedures for all tests you will be using on your project.

DOT&PF uses AASHTO, ATM, and ASTM standards for materials and test procedures

- AASHTO stands for the American Association of State Highway and Transportation Officials. A "T" designates AASHTO tests (Example: AASHTO T195). An "M" designates AASHTO specifications (Example: AASHTO M156).

- The Alaska Test Manual was issued by the Alaska DOT/PF Division of Statewide Design and Engineering Services, Statewide Materials Section in January 2000. Some Alaska Test Manual designations have been changed to WAQTC designations and include Field Operating Procedures (FOP's) for many AASHTO tests. WAQTC is the Western Alliance for Quality in Transportation Construction.

- ASTM stands for American Society for Testing and Materials.

The objective of testing is to assure that materials meet the standards required by the contract. The objective is not to obtain the required number of passing test reports. Samples should always represent the total quantity of material for which the test is intended, not fragments of it. Never take a sample or make a test with the predetermined objective to pass or fail the material or work.

### 3.1.4 When toTest

The "Materials Testing Requirements" schedule normally ties the need for tests to the amount of material such as one per 500 tons of paving mix. To know *when* to test you must therefore keep track of *how much* material has been produced.

To ensure your samples are representative of the total amount of a material, avoid "pattern sampling". Don't take samples at the same time every day, for example.

Although you will not do the quality or assurance tests yourself, you will probably be responsible for keeping track of them and notifying the Regional Materials Laboratory when one is needed. You may also be asked to take samples for some of these tests.

If asked to take asphalt cement samples, be sure you have read the Safety section of this manual (Section 1.3).

If you have questions about when to test or how to run a test, contact the Regional Materials Laboratory.

## 3.2. Brief Description of Tests

### 3.2.1 Acceptance Testing

Remember to inform the Project Engineer or your supervisor of all test results as soon as possible. Also, notify the Contractor immediately if any out-of-specification material is found. If problems aren't reported quickly work may have to be needlessly redone – or the Department may not get as good a facility as it is paying for. During the prepaving meeting, the test methods to be used, the method of determining random sampling points should be discussed.

#### 3.2.1.1 Pavement Price Adjustment

Price adjustment procedures are usually a part of highway and airport contracts. Highway and Airports use different price adjustment spreadsheets. Check each project's specifications for this requirement. The procedure provides a basis for deciding whether to accept, reduce payment, or reject the paving material depending on both its degree of conformance with the specifications and its variability. The price adjustment requires the use of a scheme of randomly selected samples. See Appendix F for a discussion of random sampling and a table of random numbers. See Figure 3.1 for a sample Asphalt Adjustment form using an Excel spreadsheet.

#### 3.2.1.2 Asphalt Cement Content

Hot mix asphalt concrete is tested to determine if it contains the asphalt cement content specified by the mix design. Samples for the determination of asphalt cement content will be taken from behind the screed prior to initial compaction or at the end of the auger.

Usually the test is performed with a nuclear asphalt content gauge (WAQTC TM 4). WAQTC TM 3 does calibration of the gauge. The gauge detects the amount of hydrogen atoms in a sample.

It must be calibrated for each paving mix in order to convert this to asphalt content. You must be trained and licensed to operate the gauge.

Asphalt cement content may be determined using an ignition oven (WAQTC FOP for AASHTO T 308 or WAQTC TM 4). In the first two cases the asphalt is removed from a sample using a solvent. The amount of asphalt is calculated from the difference between the weights of the sample before and after this is done. The ignition oven doesn't use solvent to remove asphalt but rather burns it away, eliminating the use of hazardous solvents.

#### *3.2.1.3 Gradation*

A gradation describes the relative size distribution of the particles in an aggregate sample. Oven dried aggregate is shaken through a set of sieves, as illustrated in Figure 3-2. Smaller particles are washed through the sieves to separate fines (clay and silt), which may be adhering to them. The weight of the material passing through each sieve size is compared with the weight of the original sample and is expressed as a percentage.

English sieve sizes are given in two ways: Large sizes (sieves with holes ¼ inch or more) are named by the opening width, i.e. 1-inch, 3/8-inch etc. Smaller sieves are numbered, i.e. #4, #200 etc. The number corresponds to the number of openings per linear inch of screen.

See the following table for equivalent metric sieve sizes:

| **Sieve Sizes** | |
|---|---|
| **English** | **Metric** |
| 4" | 100 mm |
| 3" | 75 mm |
| 2" | 50 mm |
| 1 ½" | 37.5 mm |
| 1" | 25 mm |
| ¾" | 19 mm |
| 5/8" | 16 mm |
| ½" | 12.5 mm |
| 3/8" | 9.5 mm |
| ¼" | 6.3 mm |
| #4 | 4.75 mm |
| #6 | 3.35 mm |
| #8 | 2.36 mm |
| #10 | 2.00 mm |
| #16 | 1.18 mm |
| #20 | 850 µm |
| #30 | 600 µm |
| #40 | 425 µm |
| #50 | 300 µm |
| #60 | 250 µm |
| #70 | 212 µm |
| #80 | 180 µm |
| #100 | 150 µm |
| #200 | 75 µm |

| | | | 1" | 3/4" | 1/2" | 3/8" | #4 | #8 | #16 | #30 | #50 | #100 | #200 | %AC | %Comp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper Spec. Limit | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 98 |
| | Target Value | | | | | | | | | | | | | | |
| | Lower Spec. Limit | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 92 |
| | Sample | Date | LOT: | >>>Enter Job & Lot Name Here<<< | | | | | | | | Press F9 for calculations | | | |
| # | No. | Sampled | 1" | 3/4" | 1/2" | 3/8" | #4 | #8 | #16 | #30 | #50 | #100 | #200 | %AC | %Comp |
| 1 | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | |
| | Mean | | | | | | | | | | | | | | |
| | Standard Deviation | | | | | | | | | | | | | | |
| | Largest Deviation | | | | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### |
| | Test Criterion | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Critical Test Crit | | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |

**OUTLIERS**

| Sample No. | 1" | 3/4" | 1/2" | 3/8" | #4 | #8 | #16 | #30 | #50 | #100 | #200 | %AC | %Comp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |

**INLIERS**

| | 1" | 3/4" | 1/2" | 3/8" | #4 | #8 | #16 | #30 | #50 | #100 | #200 | %AC | %Comp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |

| | | 3/4" | 1/2" | 3/8" | #4 | #8 | #16 | #30 | #50 | #100 | #200 | %AC | %Comp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Samples | | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| Mean Average | | | | | | | | | | | | | |
| Sandard Deviation | | | | | | | | | | | | | |
| Upper Quality Index | | | | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### |
| Lower Quality Index | | | | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### |
| Percent in Upper Limit | | | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### |
| Percent in Lower Limit | | | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### |
| Quality Level | | | | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### | ###### |
| Pay Factor | | | | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| Weight Factor | | 4 | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 20 | 40 | |
| Price Adjustment | | ##### | ###### | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | |
| Composite Pay Factor | #VALUE! | | | | | | | | | | | | |
| Density Pay Factor | #N/A | | | | | | | | | | | | |
| **Minimum Pay Factor** | #VALUE! | | | | | | | | | | | | |

**Figure 3-1 Asphalt Adjustment (xls)**

The percentage passing certain sieve sizes must be within a range specified in the mix design report. Mixes that vary from the high end of the approved gradation range on one sieve to the low end on the next sieve (or vice versa) are generally undesirable. This is prohibited by Airport Specifications
P-401-3.2.

There may also be a specification that, when plotted on a 0.45 power gradation chart, the points for some sieves lie above the maximum density line. (The 0.45 power gradation chart is discussed in part 4 of this section).

When asphalt content is being tested with a nuclear gauge, aggregate samples for gradation testing are taken from the aggregate cold feed belt of the dryer drum at the asphalt plant. For batch plants, bins or dry Batch samples are taken for gradation testing. If asphalt content is being tested by ignition, the same sample may be used for gradation testing. Gradation testing will be determined by WAQTC FOP for AASHTO T 30 when the ignition method is used. Otherwise, gradation testing will be determined by WAQTC FOP for AASHTO T27/T11, Sieve Analysis of Fine and Coarse Aggregates and Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing. Airport specifications may require ASTM C 117 and C136 for gradation testing.

#### *3.2.1.4 Fracture Testing*

The fracture test, WAQTC TM 1 (Determining the percentage of fracture in coarse aggregate) is a visual determination of whether the larger aggregate particles are sharp-edged or rounded. Samples for fracture testing may be taken from the aggregate cold feed belt at the asphalt plant or completed from the gradation sample.

The degree of fracture specified may vary with projects. Highway projects once required that 80% or more of the particles retained on a #4 sieve have at least one fractured face. Since the requirement may vary, check the specifications for your project (or ask the Regional Materials Laboratory).

#### *3.2.1.5 Density and Depth*

Compaction tests are taken on the pavement after final rolling by one or both of the following methods:

1) Specific Gravity Testing on samples cored from the pavement, in accordance with WAQTC FOP for AASHTO T 166 / T 275 (Bulk specific gravity of compacted bituminous mixtures) Just prior to coring, the location for mat density should be marked by the State inspector. If joint density is required in the specifications, the core should be centered over the joint so both mats are in the core.
2) Nuclear Density Gauge Testing in accordance with WAQTC TM 8 (In-Place Density of Bituminous Mixes Using the Nuclear Moisture-Density Gauge). Correlation with densities when using the Nuclear Density Gauge, will be determined for each project as per WAQTC TM 8.

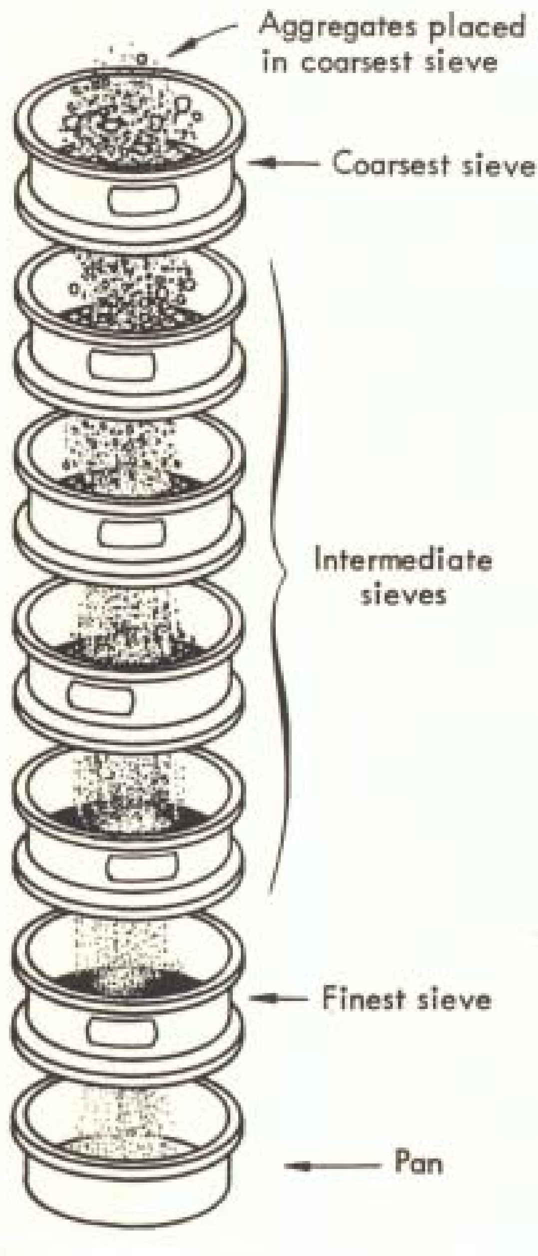
The nuclear density gauge senses the reflection of gamma rays sent into the pavement; the greater the density, the more reflected rays are absorbed. The gauge must be correlated with a mixture change in the typical section or using a different nuclear gauge. You must be trained and licensed to operate the equipment.

In the specific gravity test, the samples are weighed while submerged in water, after removing them from the water and patting the surface dry, and again after oven drying. The specific gravity is computed from these three weights.

Most commonly, the target value for density is usually 94% +4 / -2 % of the maximum specific gravity (MSG), as determined by WAQTC FOP for AASHTO T 209 (Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures).

### *3.2.1.6 Ross Count (AASHTO T 195)*

The Ross Count is a visual determination of how well the asphalt plant is coating the aggregate. The Ross Count is performed on asphalt concrete at the asphalt plant. Inadequate coating of the aggregate can often be corrected by increasing the mixing time. The Ross Count is an acceptance test for batch plants and an informational test for dryer or drum mix plants. Inadequate coating in dryer-drum plants is more likely to involve the fines, which must be detected by visual examination.




Courtesy of the Asphalt Institute

**Figure 3-2 Gradation Testing**

**Figure 3-3 Density Testing with a Nuclear Gauge**

### *3.2.2 Quality Requirements and Documentation*

#### *3.2.2.1 Aggregates*

Project personnel must make sure that only approved sources are used for making aggregates. Materials sources are approved for the project based on quality tests done by the Regional Lab. Brief descriptions of these tests are given below for your information.

The Degradation Value of Aggregates (ATM 313):

Aggregates degrade differently when they are wet than when they are dry. ATM 313 measures how an aggregate will degrade when shaken with water. A minimum value is specified. A higher degradation of aggregate number indicates a more durable material.

#### *3.2.2.2 Asphalt Cement*

A set of quality tests must be performed each time asphalt cement is added to a supplier's storage tank. The supplier sends copies of the test reports to the Regional Materials Engineer.

Asphalt cement delivered to the project must be accompanied by the supplier's certification that the shipment has passed the required quality tests. A DOT&PF employee must check the certification and keep a record of the deliveries. The State inspector samples the asphalt cement at the plant before it is mixed with the hot aggregate. The frequency is noted in the Alaska Construction Manual. These samples are further sent to the central lab for informational testing.

### *3.2.3 Check Marshall Tests*

Check Marshall tests are made on the asphalt concrete, which is produced on the project to determine if it has sufficient stability. (Stability is a measure of the pavement's compressive strength). The Regional Laboratory does the tests, but project materials inspectors may be asked to obtain the samples.

ATM 417 is the bituminous mix design by the Marshall method. ATM 410 is preparing and testing Marshall specimens from production hot mix in the Regional Lab.

### 3.2.4 Materials Handling

#### 3.2.4.1 Asphalt Cement

Special care is required to work safely around hot asphalt storage tanks. Read Section 3.1 Safety before approaching an asphalt storage tank.

Asphalt products must be kept free of contamination and must not be overheated. Storage tanks are heated to keep the asphalt fluid, but overheating causes oxidation of the asphalt. This will result in premature aging (shorter life) of the pavement. The storage temperature generally must be no more than 330 ºF for asphalt cement and 50-125 ºF for prime coat. A thermometer should be located on the asphalt cement tank. Storage temperatures are discussed in the Highways specification 702-2.04 and there is no equivalent Airport Specification. The specifications may be different on your particular project (check them). The Job Mix Design will specify the allowable mixing temperature range for your project.

#### 3.2.4.2 Aggregates

Proper stockpiling is the responsibility of the Contractor. The stockpile site must be cleared and leveled prior to stockpiling. Stockpiles of different materials should be kept separate to prevent contamination. If you observe improper stockpiling inform the Contractor and the Project Engineer. Stockpiling is discussed in Airport Specifications 660.3 and Highway Specifications 305.

Poor stockpiling techniques result in larger particles rolling to the bottom of the stockpile, leaving the fines behind. This separation of different sizes is called segregation. Segregation results in out-of-specification asphalt concrete (some with too much large aggregate, some with too little). Both types result in weak pavement that will deteriorate rapidly.

It is the inspector’s responsibility to watch for and report segregation any time the aggregate is handled or moved. Stockpiles should be built in layers to prevent segregation. Specifications allow only rubber-tired equipment on stockpiles. Steel-tracked equipment will crush the aggregate, causing excess fines, failing tests and inferior pavement

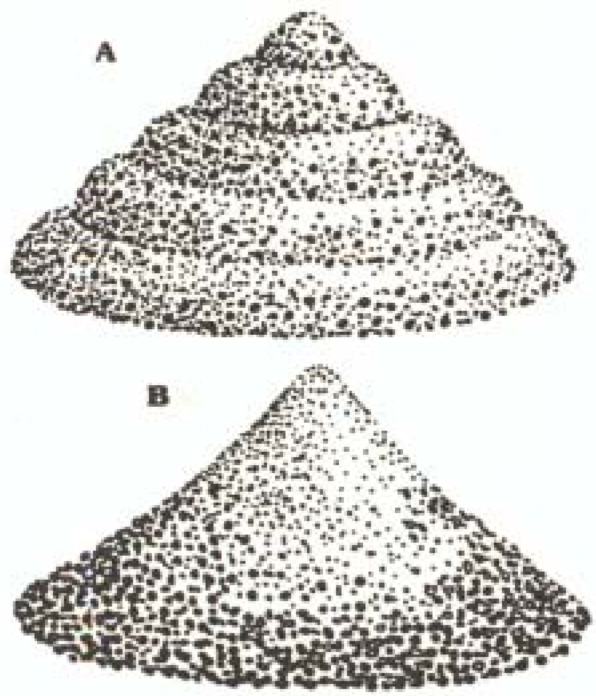
## 3.3. MARSHALL MIX DESIGN: AN OVERVIEW

Asphalt paving mixtures for DOT&PF are designed by the Regional Materials Laboratory or by a lab hired by the contractor. In either case, the design is usually the Marshall Method. Project materials inspectors do not design paving mixes, but need some understanding of the process and the mix design report.

On both Airport and Highway Projects, the Asphalt Mix Design becomes part of the contract. The asphalt content, aggregate and temperature specifications listed on the mix design supersede the authority of the standard specifications. The Contractor must produce a mix that meets the requirements of the mix design.

If any materials or ratio of materials used in the asphalt cement are different than that approved in the mix design, that approval must be obtained from the Regional Quality Assurance or Materials Engineer through the Project Engineer.

This section contains some basic information about mix design. More complete information may be found in the Asphalt Institute publication *Mix Design Methods for Asphalt Concrete (MS-2).* Standard specifications relating to mix design are found in Sections 401-2.01, 702, and 703 (Highways) and in Section P-401-3.2 (Airports).




(A) Correct and (B) Incorrect Methods For Storing Aggregate Containing Large and Small Particles.

**Figure 3-4 Storing Aggregates**

### *3.3.1 Marshall Method*

Samples of the proposed mix materials are used in the design procedure. Careful sampling is very important to the quality of the design and the pavement built from it. If the aggregate or asphalt source changes, a new mix design must be prepared.

Aggregate is mixed with different percentages of asphalt cement in the lab. For each amount of asphalt, compacting the mix in a mold makes several test specimens. The specimens are tested for specific gravity and voids content.

They are also tested for stability and flow under compression in a testing machine. Stability is a measure of how much load the specimen can sustain. Flow is a measure of how much the specimen deforms under the load. The optimum asphalt percentage in the mix is determined from the results of this testing. The results are given in a Mix Design Report.

### *3.3.2 The Mix Design Report*

The mix design report contains information needed by project materials inspectors. An example is shown on the next page. The following information can be determined from the mix design:

1. Type of Mix:

   Highway projects use one of three types of mix, which differ in the maximum aggregate size. Open grading is no longer included in the specifications. (Highways 703-2.04 Airports Specifications have 4 types based on maximum aggregate size and 2 categories for test values based on aircraft gross weight. (Airports P-401-3.2)

Stone Mastic Asphalt (SMA) is used to resist studded tire wear in urban areas with high traffic volumes. This mix uses a larger portion of coarse aggregates. SMA is an open mix requiring the use of mineral filler and cellulose (or synthetic) fiber to prevent drain down of the asphalt. SMA's rely on the stone to stone contact of the coarse aggregate and don't compact very much.

2. Aggregate Source:

The project plans and specifications normally indicate where the pit(s) is located.

3. Asphalt Source:

Asphalts from different suppliers have different properties, which may affect the placing, rolling, and final product. The asphalt used on the project must be from the same source as that used in the mix design.

4. Asphalt Cement Grade:

DOT&PF normally uses AC 2.5, AC 5, or AC 10 or PG grades PG52-28, PG58-28 and PG64-28. The numbers relate to the viscosity of the asphalt. Like the grades of motor oil, a higher number indicates a more viscous (thicker or harder) asphalt.

5. Percentage of anti-strip additive required, if any. This is usually ¼ of 1%.

6. Compacting Temperature:

The recommended temperature range for the initial "breakdown" rolling. (See Chapter VI: Laydown)

7. Mixing Temperature:

The required plant mixing temperature range.

8. Optimum Asphalt content:

The design asphalt content at which the mix has the best combination of stability, air voids and density. The asphalt content must be within the indicated range.

9. Mix Design Criteria:

Includes the desired stability, flow, compaction level (50 or 75 blows), dust-asphalt ratio and void relationships that were used to design the mix. (These are not acceptance or field specifications.)

10. Unit weight at Optimum:

The maximum lab density of the designed mix, expressed in pounds per cubic foot. See section 3.2.1.5 Density and Depth.

11. Aggregate:

The size distribution of the asphalt aggregate particles. The percentage of the aggregate passing on a given sieve size must fall within the specified range.

## 3.4. The 0.45 Power Chart

Nearly all the volume of dense-graded asphalt pavement is filled by aggregate particles. The remaining spaces (voids) are filled with asphalt or air. In general, the fewer the voids, the stronger and more waterproof the pavement.

The mix must have some voids, however. Beyond a certain point, a reduction in voids lowers stability. It can also lead to asphalt "bleeding' out of the mix under compaction, which creates a very slick driving surface.

The 0.45 power chart, shown in Figures 3-6 and 3-7, can help to avoid this. To use it, plot the results of a test on the chart. Then draw a straight line from percent passing the largest sieve size retaining aggregate to the origin (0% retained / 0inches).

The straight line is called the maximum density line. If the plotted lies on or very close to this line, there will not be enough voids in the compacted mix. In a good mix, all the plotted points will lie either 2 to 4 % above the line (a fine textured mix) or 2 to 4% below the line (a coarse-textured mix).

The shape of the curve connecting the plotted points indicates some properties of the mix. If it crosses the maximum density line the mix is "gap graded" and will tend to segregate. A hump in the fine sand portion (#40 to #80 sieve) may indicate a "tender" mix which is hard to handle, difficult to compact and may be too soft after it cools.

VMA is specified in the Standard Specifications. (Highways (401-2.01) and Airports P-401-3.2) The VMA mix design requirements may be waived if the conditions are met in 401-2.02 Highways.

25-229
R-1/2000
S.E. REGION

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

## ASPHALT MARSHALL MIX DESIGN (U.S. STAND.)

| | | | | | |
|---|---|---|---|---|---|
| TEST OF | ASPHALT CONCRETE PAVEMENT, TYPE II / B | | ITEM NO. 401 | | LAB NO. 00C-460 |
| PROJECT NO. | STP-0904(1) | PROJECT NAME | KTN THIRD AVENUE EXTENSION | | |
| SAMPLED FROM | CONTRACTOR | EXAMINED FOR | AASHTO T 27/11, 84/85, 209, 166, 269, 245, ASTM D 4791, 5821 | | |
| DEPTH | N/A | FIELD NO. | N/A | DATE SAMPLED | CONTRACTOR |
| SOURCE | SEE BELOW | SUBMITTED BY | CONTRACTOR | DATE RECEIVED | 10/21/00 |
| LOCATION | KETCHIKAN, ALASKA | REPRESENTS | 1 / SOURCES | DATE REPORTED | 10/25/00 |

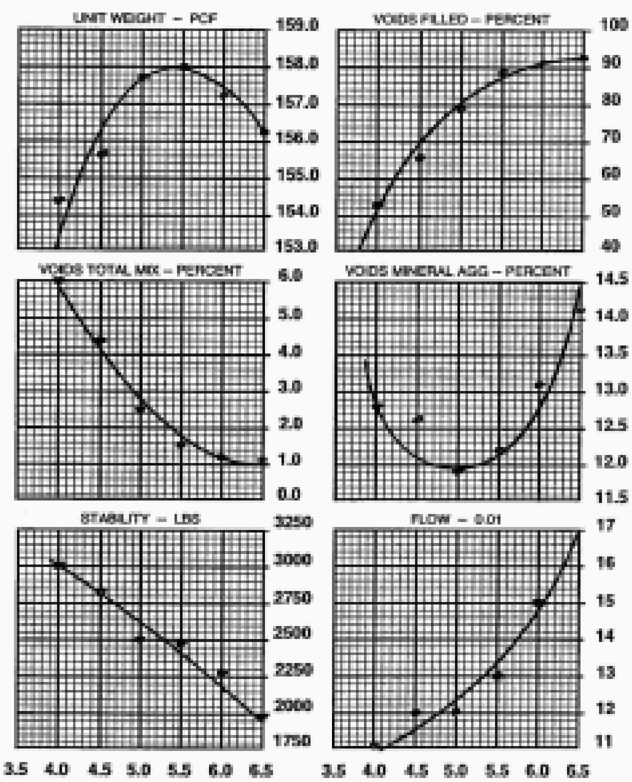
AS RECEIVED

| % PASSING | CSE | INT | FNE | TARGET | SPECS |
|---|---|---|---|---|---|
| ASPH CONTENT | | | | | |
| AGG BLEND % | 15 | 85 | | | |
| 1-1/2" | | | | | |
| 1" | | | | | |
| 3/4" | 100 | 100 | | 100 | 100 |
| 1/2" | 84 | 88 | | 86 | 79 - 93 |
| 3/8" | 46 | 73 | | 69 | 62 - 76 |
| #4 | 4 | 47 | | 45 | 38 - 52 |
| #8 | 1 | 35 | | 32 | 26 - 38 |
| #10 | | | | | |
| #16 | 1 | 26 | | 24 | 18 - 30 |
| #20 | | | | | |
| #30 | 1 | 20 | | 19 | 14 - 24 |
| #40 | | | | | |
| #50 | 1 | 15 | | 14 | 10-18 |
| #80 | | | | | |
| #100 | 1 | 11 | | 10 | 7-13 |
| #200 | 1.0 | 8.0 | | 6.6 | 4.6 - 8.6 |
| FRACTURE % | | | | 100 | > 80 |
| THIN ELONG % | | | | | |
| BULK SPG | | | | 2.724 | |
| SD SPG | | | | | |
| APPARENT SPG | | | | | |
| ABSORPTION % | | | | | |
| BLEND AVG | | | | 2.784 | |
| EFFECTIVE SPG | | | | 2.816 | |

MIXTURE AT TARGET

| | MARSHALL | SPECS |
|---|---|---|
| ASPHALT CONTENT % | 5.2 | 4.8 - 5.6 |
| UNIT WEIGHT--PCF | 157.8 | |
| VOIDS FILLED-% | 82 | |
| VOIDS TOTAL MIX--% | 2.4 | 2-5 |
| VOIDS MINERAL AGG--% | 12.0 | |
| STABILITY--LBS | 2600 | > 1400 |
| FLOW--0.01 MM | 13 | 8-16 |
| MAXIMUM SPG | 2.502 | |
| MAX UNIT WEIGHT--PCF | 161 | |
| NUMBER OF BLOWS | 50 | 50 |
| MIX TEMP--DEG F | 300 | |
| COMP TEMP--DEG F | 280 | |
| ASPHALT BRAND | U.S. OIL | |
| ASPHALT TYPE | PG 58-28 | |
| ASPHALT SPG | 1.030 | |
| ANTI STRIP | ARMAZ | 0.3% |

% ASPHALT BY WEIGHT OF TOTAL MIX




REMARKS: 15% MOORES QUARRY CSE CONCRETE AGG
85% MOORES QUARRY IN[TERMEDIATE] APPROVED
SUBJECT TO FIELD INSPECTION
BRUCE E. BRUNETTE, P.E.
REGIONAL MATERIALS ENGR. 10-25-00

PNH

THE MATERIAL AS SUBMITTED CONFORMS TO SPECIFICATIONS
YES ( ) NO ( ) N/A

CHECKED BY: JEFFREY A. HART, LAB. SUP.

SIGNATURE: BRUCE E. BRUNETTE, P.E.

STATE OF ALASKA — 49TH — Bruce E. Brunette PE 9707 — REGISTERED PROFESSIONAL ENGINEER

THE TEST RESULTS ARE ONLY REPRESENTATIVE OF THE MATERIALS SUBMITTED
TESTS ARE PERFORMED IN ACCORDANCE WITH STANDARD AASHTO/ASTM OR FHWA/NA APPROVED ATM TEST PROCEDURES

**Figure 3-5 Sample Mix Design Report**

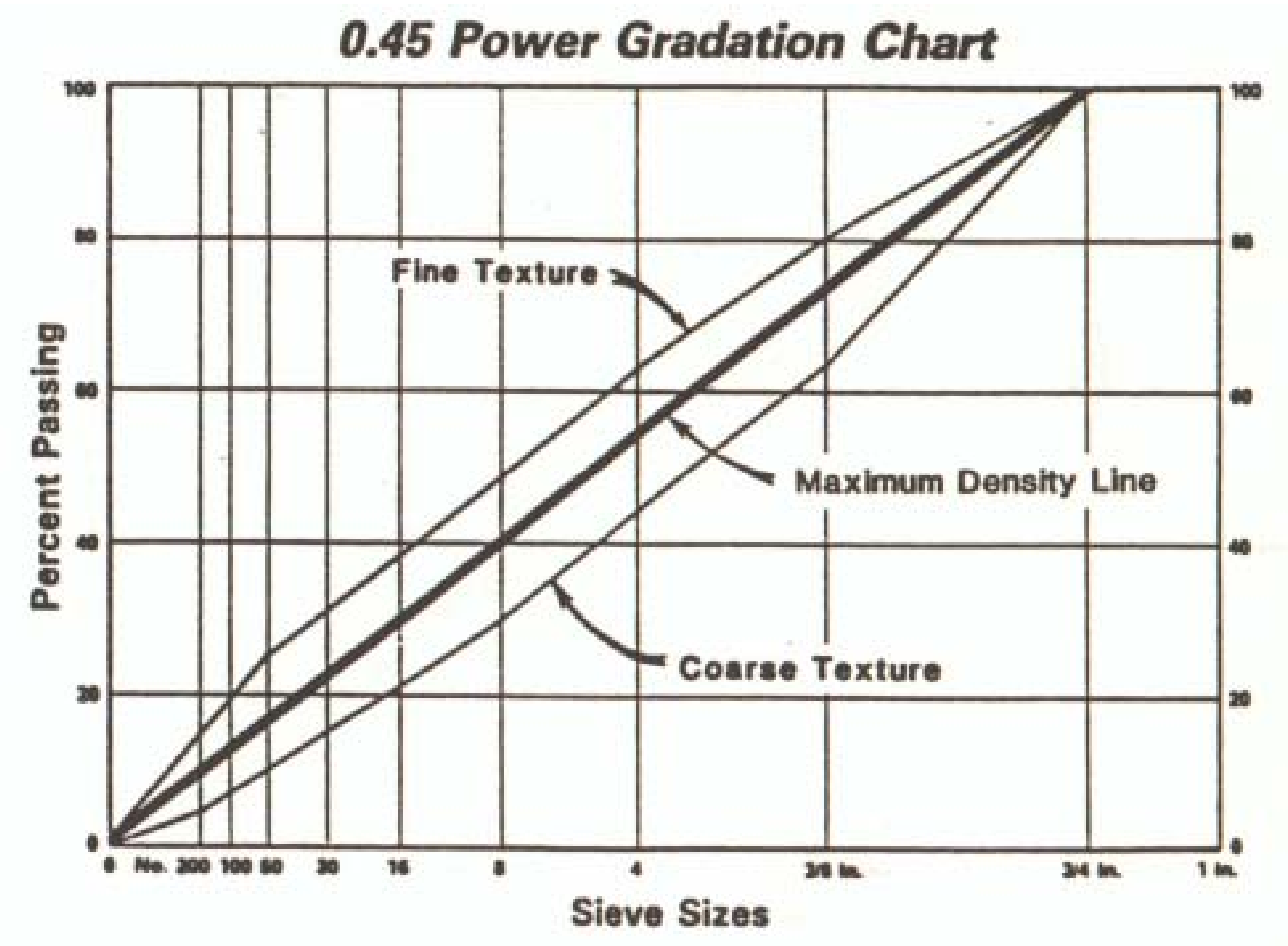



**Figure 3-6 0.45 Power Chart showing Fine & Coarse Textures**

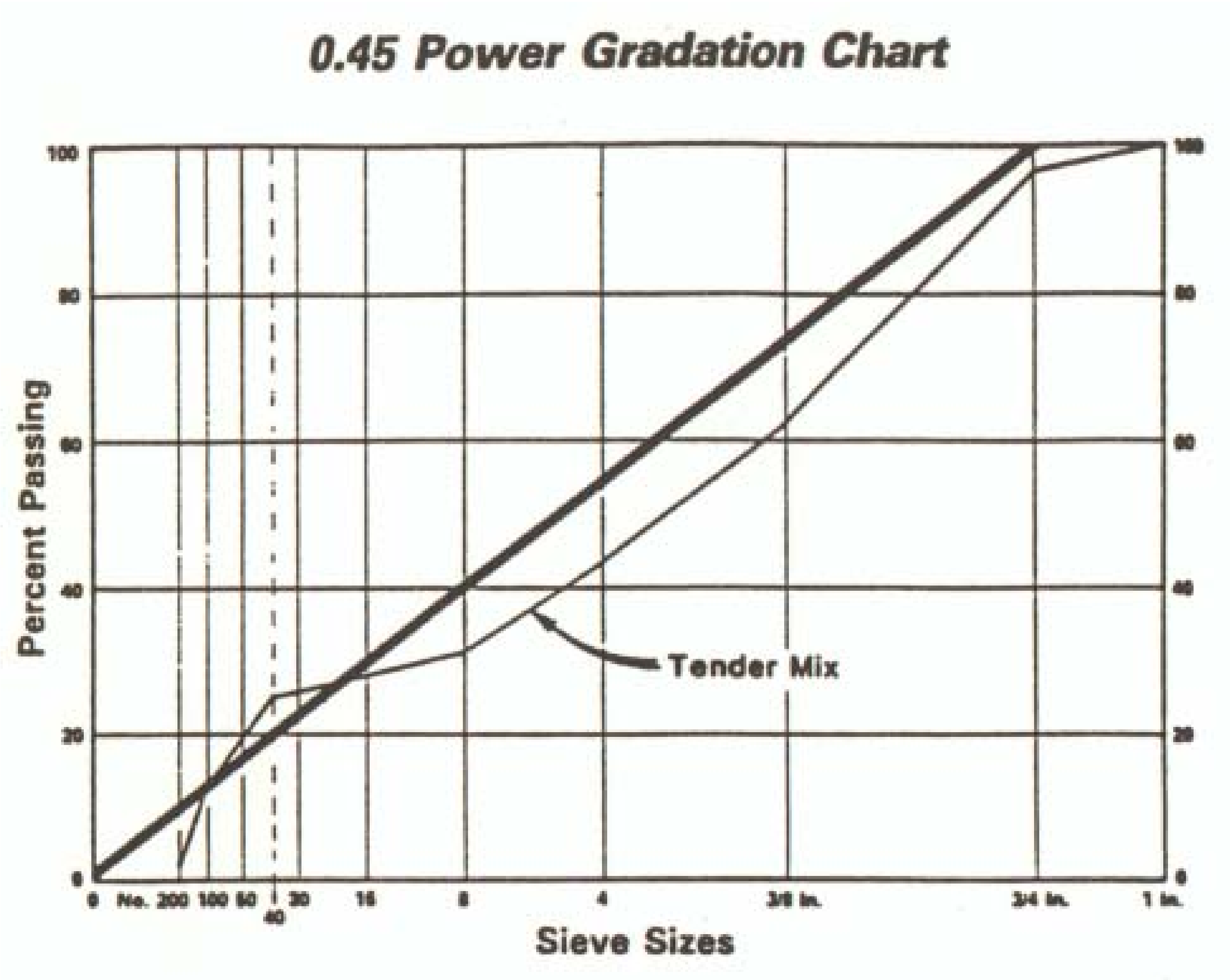



**Figure 3-7 Power Chart showing a Tender Mix**

# 4. ASPHALT PLANT

## 4.1. Introduction

Asphalt plants heat and dry the aggregate and mix it with the appropriate amount of asphalt cement, in accordance with the project mix design. There are two main types of asphalt plants: batch plants and dryer drum plants. These are briefly described below.

Standard Highway Specification 4.01-3.03 requires that the Asphalt Plant be calibrated as specified in AASHTO M-156, Airport Specification 401-4.2 requires the Asphalt Plant conform to ASTM D 995.

The Asphalt Institute's Manuals MS-3 *Asphalt Plant Manual* and MS-22 *Principles of Construction of Hot-Mix Asphalt Pavements* contain much more information on asphalt plants.

## 4.2. Batch Plants

Batch plants make asphalt concrete one batch at a time. This is done by placing measured amounts of different sized aggregate and asphalt cement in a "pugmill" where they are mixed. The pugmill is then emptied and the process repeated. The aggregate and asphalt cement is heated before they are placed in the pugmill. The process is shown in the diagram on the next page.

Aggregate at the plant starts at the *cold bins* (see Figure 4-1). There are usually three or four bins for different sizes of aggregate. The aggregate empties through the bottom of the bins through feeders (most operate with a small belt or a vibrator). The feeders are equipped with adjustable *cold feed gates*. Aggregate in different bins is released at different rates to form the proportional combination of material for the mix design. The correct proportions are obtained by calibrating the gates and adjustingthe variable speed feeder belt. Aggregate from all the feeders is deposited on a main cold feed conveyor.

The *cold elevator* carries the proportioned aggregate from the conveyor to the *dryer*, which heats and dries it. The dryer consists of a revolving cylinder, a large burner, and a fan. The revolving cylinder is lined with long vanes called "flights" which spread the aggregate into a veil to insure proper drying. The burner is located at the lower end of the dryer, so while the aggregate is moving downwards the hot gases are moving up. This is known as "counter flow".

The exhaust gases from the dryer contain dust that is removed in the baghouse or wet scrubber before the hot gases are released into the atmosphere. This emission is regularly tested. A permit issued by the State of Alaska Department of Environmental Conservation is posted at the plant. The fines are called mineral filler and are recycled into the hot aggregate or the fines are imported for mineral filler.

The *hot elevator* carries the aggregate from the dryer to a *screening unit.*

Motors shake a set of screens, which sort the heated aggregate by size and deposit it into a new set of aggregate bins, the *hot bins*.

Below the hot bins is the *weigh box*. The weigh box is filled and weighed successively with aggregate from each of the hot bins (see Figure 4-2). If mineral filler is used, it is taken from the *mineral filler storage* and also measured into the weigh box at this time.

The amounts are controlled to produce a batch of aggregate with the correct size, which is then released into the *pugmill*. The aggregate is "dry mixed" briefly before the asphalt cement is added.

The asphalt is continuously circulated from *hot asphalt cement storage* tanks through a piping system. Both tanks and the piping are heated. Asphalt cement can be drawn from the piping into the *asphalt weigh bucket*, which measures the amount needed for a batch of paving mix.

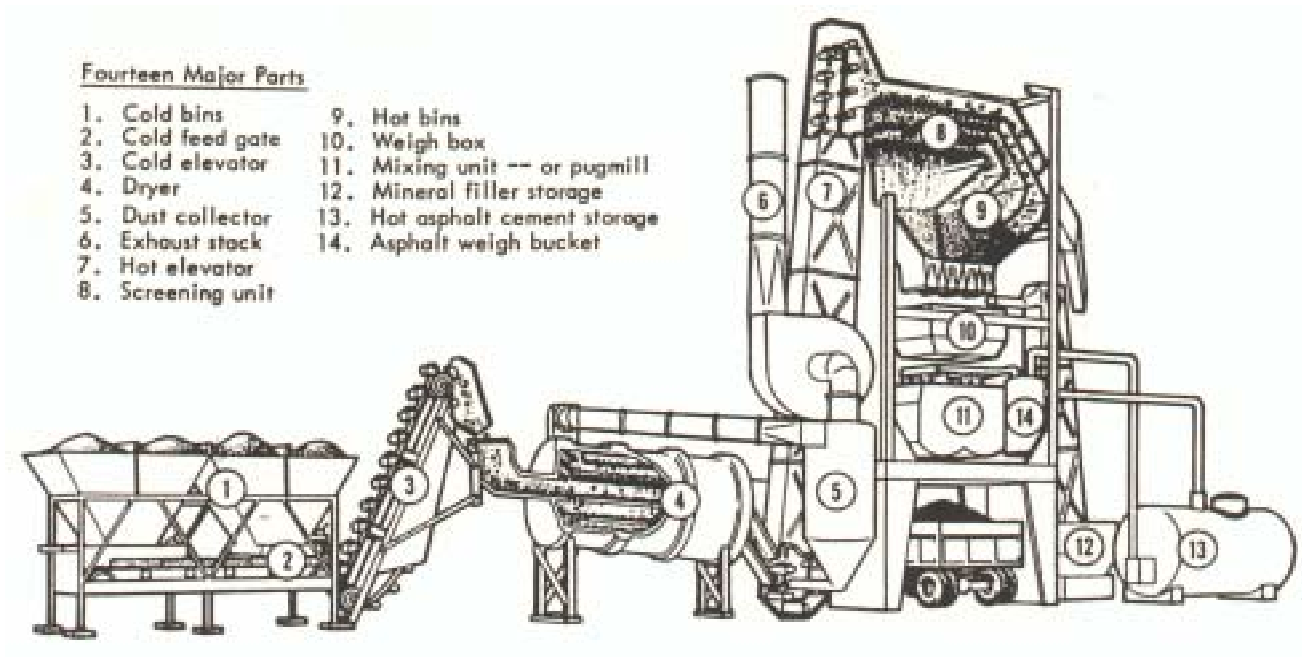



**Figure 4-1 Asphalt batch mix plant and its components (modern plants also include a baghouse in addition to the dust collector shown as 5 above and the cold elevator (3) has been replaced by conveyors). Courtesy The Asphalt Institute**

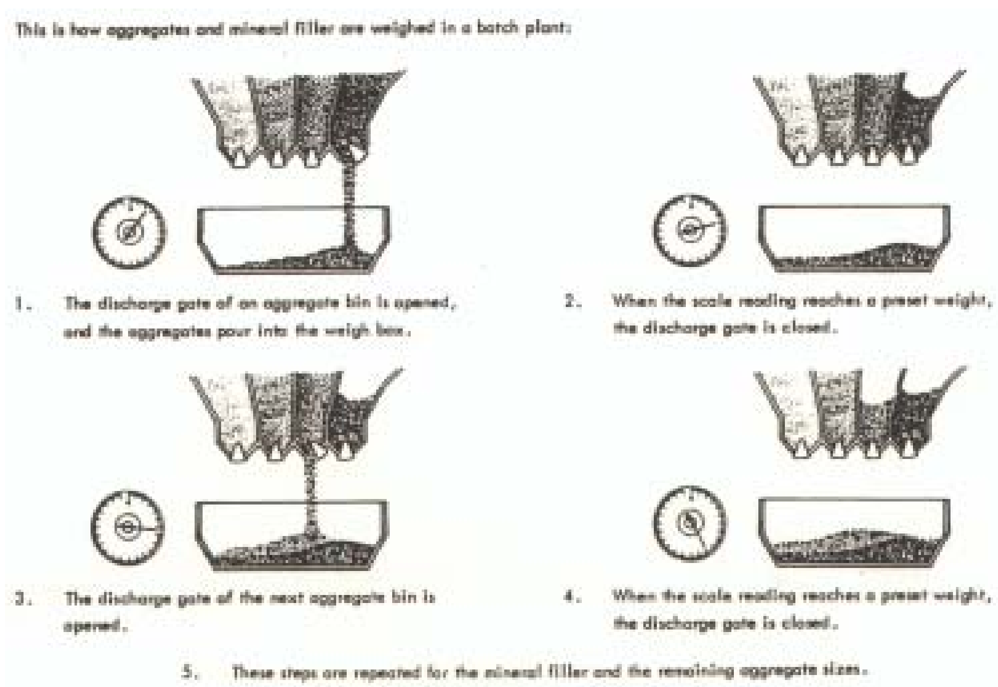



**Figure 4-2 Weigh box Operation**
**Courtesy Tennessee Department of Transportation**

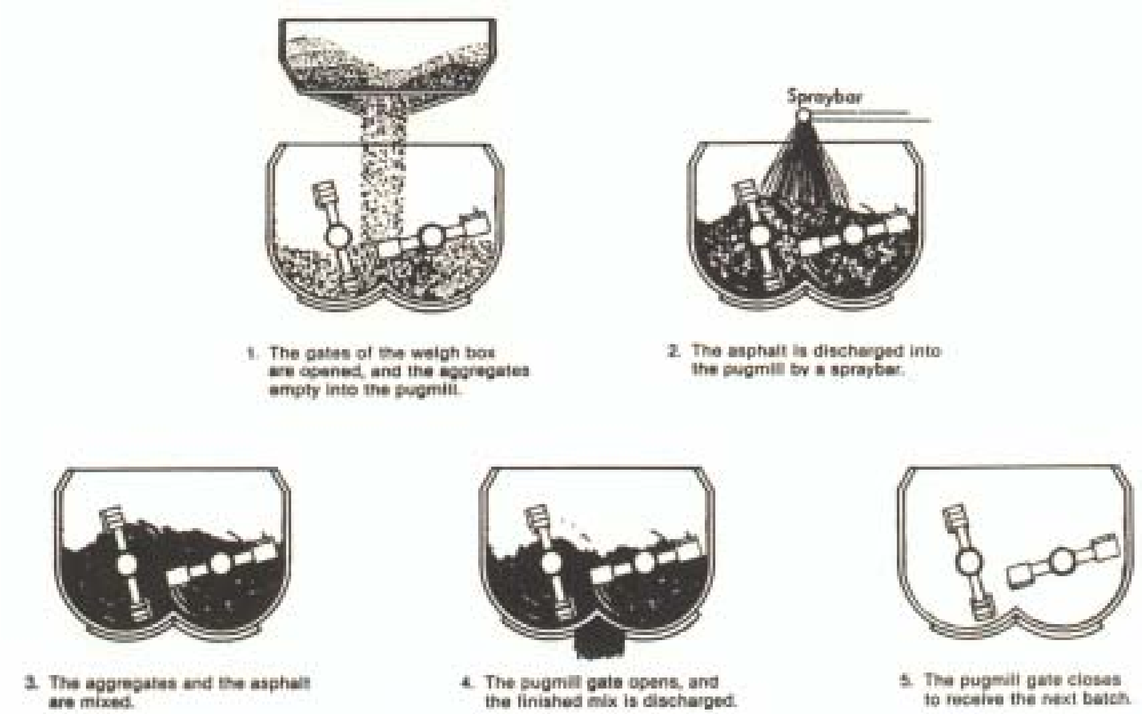



**Figure 4-3 Pugmill Operations**
**Courtesy of the Asphalt Institute**

Once asphalt cement from the weigh bucket is added to the pugmill, the batch is "wet mixed" just long enough to coat the aggregate with asphalt. The mix is then discharged into trucks either directly or after temporary storage in a "surge silo".

## 4.3. Dryer Drum-Mix Plants

Dryer drum-mix plants combine and heat aggregate and asphalt cement continuously. Measured amounts of different sized aggregate are fed into the upper end of the dryer. The asphalt cement is added near the middle of the dryer. The asphalt cement is added near the middle of the dryer, where it mixes with aggregate, which has already been heated and dried. The process is shown in Figure 4-4.

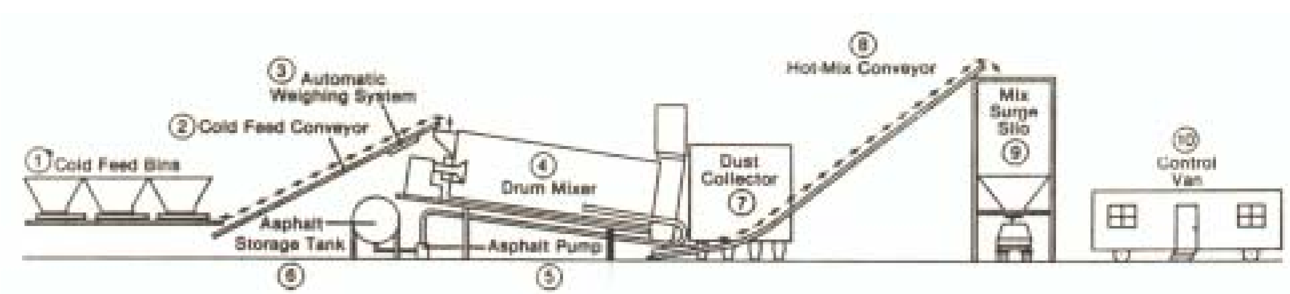



**Figure 4-4. Basic Drum-Mix Plant**
**Courtesy of the Asphalt Institute**

The aggregate at a drum dryer plant starts at a set of *cold bins*, just like at a batch plant. The gates on the bin feeders are calibrated and adjusted to release the correct proportions of the different sized aggregate onto the *cold feed conveyor*.

The conveyor has an *automatic weighing system*, which includes a belt speed indicator. The weighing system is interlocked with the *asphalt pump* so that (when properly calibrated) the correct amount of liquid asphalt is added to the aggregate in the dryer. Since the asphalt must be delivered in proportion to the *dry* weight of aggregate, the metering system must be adjusted to account for the moisture content of the aggregate. The *hot asphalt storage* tanks and circulation system are similar to those for batch plants.

The *drum mixer* consists of a revolving cylinder lined with flights, a large burner, and a fan, like a batch plant dryer. Unlike batch plant dryers, asphalt cement can be added within the dryer, where it mixes with the aggregate. The asphalt is added roughly halfway down the length of the drum. This is known as "parallel flow". The flame in a drum dryer should be short and "bushy". Parallel flow and a short flame are used so that the gases are cool enough by the time they reach the lower end of the drum that they will not burn the asphalt.

In dryer drum-mix plants, the burner is at the upper end of dryer, so both the aggregate and the hot gases move downwards through the drum.
As with batch plants, gases leaving the drum pass through a *dust collector* and exhaust stack, and some of the fines from the dust collector may be recycled back into the mix.

The paving mix leaves the drum and is carried by a *hot mix conveyor* to the *mix surge silo*, from which it is discharged into trucks.

Dryer drum plants do not have screens, hot bins, a weigh box, an asphalt weigh bucket or a pugmill.

## 4.4. Proper Plant Operation

### *4.4.1 General*

The best and most consistent asphalt concrete will result when it is produced steadily at the rate needed by the paving operation. Startups and shutdowns, as well as constant tinkering with gate openings and other controls, are a sign of a poor operation. Major adjustments should be made *before* a production run; only fine-tuning should be needed during the run.

The entire plant must be brought up to operating temperature before the start of a production run. Running "dry" aggregate (no asphalt) through the plant does this. The “dry run” aggregate may be checked for moisture, which avoids wasting out-of-spec “wet” paving mix. On continuous mix plants, when no asphalt is added, a check of the aggregate gradation at the end of the process may be done. Running dry aggregate results in heavy dust emissions, so most operators add a small amount of asphalt to avoid violating their environmental permits.

### *4.4.2 Stockpiling*

A good mix will not come out of a plant, if the aggregates going into it are bad. Many problems in mix production can be traced back to the cold aggregate. Even if good material comes out of the crusher, bad material will go into the cold bins, if aggregate becomes contaminated or segregated during stockpiling or cold bin loading. Proper stockpiling is discussed in Section 3.2.4.2.

### *4.4.3 Cold Bins*

The gates on cold bins should be calibrated to determine how much material they release at different settings. Proper operation of the cold feed is crucial to the entire plant operation and depends on the gate settings. Calibration charts, rather than trial and error methods, should guide any adjustments to the gates. Gate adjustments should seldom be needed during production. Frequent adjustments may indicate improper initial setup or variation in the aggregates due to crushing or stockpiling problems.

The level of material in each bin should be maintained so that there is no danger of them running out.

Overfilling or careless loading, however, can result in one aggregate size spilling over into a bin for another.

Cold bins need to be watched to assure material is flowing smoothly from the gates. Aggregate, especially sand sizes can plug up or "arch over" in the bins.

### 4.4.4 Cold Feed

Varying the feeder belt (or vibrator) speed controls the amount of aggregate fed into the plant, not bin gate openings. The gates should be preset so that during normal operation the belts run at 50-80% of their maximum speed.

Feeder Belt (or vibrator) speeds are usually adjusted to match plant production with the demand from the mix (that is, the rate of paving). Cold feed adjustments must be coordinated with burner adjustments on the dryer. For a given burner setting, a slower feed rate results in a higher output temperature, and vice versa. Watch for loss of calibration due to spillage or drag caused by misalignment of the Feeder Belt.

On a drum dryer plant, the weighing system and belt speed on the main cold feed conveyor controls the asphalt feed rate. It is important to check the belt speed indicator for slippage, especially when a plant first starts up a production run. Watch for loss of calibration, due to belt tension errors caused by build up of aggregate at the tail roller, misalignment of the belt and frozen rollers. Also watch for friction or obstruction of the load cell mechanism.

### 4.4.5 Asphalt Cement Storage

Most plants have at least two tanks, which must be level for tank stick measurements to be accurate. Both the tanks and the circulation system piping must be heated.

Asphalt oxidizes quickly at high temperatures, so exposure to air needs to be minimized. For this reason the circulation return line must discharge below the surface of the asphalt in the tank.
Keeping the storage temperature below the specified maximum (usually about 325$^{o}$F) minimizes both oxidation and the danger of explosion.

**Figure 4-5 Asphalt Cement Storage Tanks**

Temperature corrections must be made to tank measurements, asphalt expands with rising temperatures. Correction multipliers listed in Appendix C convert measured quantities to the standard 60$^{o}$F basis. Temperature correction is also needed when calibrating asphalt pumps in dryer drum plants.

Asphalt deliveries must be carefully documented.

### *4.4.6 Batch Plant Dryer*

The temperature of the aggregate leaving the dryer is affected by the feed rate, the time the aggregate stays in the dryer, and the burner setting. Residence time in the dryer is usually 3 to 4 minutes. Dryers are usually tilted about 3 to 5 degrees from horizontal; the steeper the tilt, the faster the aggregate passes through.

For even, efficient heating, the dryer should spread the aggregate in an even veil across the center of the drum. This is affected by the arrangement of the flights and the speed of the drum (usually about 8 to 10 rpm).

Burner and draft fan adjustments are also important to dryer operation. In an efficient dryer there is complete combustion of the fuel and the exhaust gases leave the drum about 20 degrees hotter than the aggregate. Incomplete fuel combustion is indicated by oily residue on the aggregate and/or black, oily exhaust. This is bad for the mix and increases air pollution and fuel costs.

The production rate of the entire plant is dependent upon the dryer’s efficiency. Asphalt concrete can’t be produced any faster than the aggregate can be heated and dried.

### *4.4.7 Drum-mixer Dryer*

The information about batch plant dryers also applies to drum-mixer dryers. An exception is that exhaust gases in drum mixers are much hotter than the mix produced, due to the lower efficiency of the parallel flow system. Residence time in the dryer of a drum-mix plant is very important since it is also the mixer. If residence time is too short, the aggregate may not be completely coated with the asphalt. Over-mixing, on the other hand, leads to oxidization (premature aging and embrittlement) of the asphalt cement.

### *4.4.8 Dust Collector*

Good operation of the dust collection system not only reduces air pollution but also helps produce a good mix.

The pressure drop in a baghouse is typically 2 to 6 inches of water. If the bags become plugged, the pressure drop increases and the draft will be retarded. This results in poor fuel combustion and a bad paving mix.

If fines from the dust collector are recycled back into the mix, the feed must operate smoothly. If the flow of fines is uneven, the plant will produce a bad mix, with alternately too many and too few fines.

### *4.4.9 Hot Mix Storage and Loading*

Hot mix conveyors should have scrapers to prevent carryover (belt drippings).

Segregation is the biggest problem in storage and loading. It can be minimized during silo loading by baffles or batching mechanisms. Trucks should be loaded by dumping the mix in a series of overlapping heaps. Dribbling or flinging the mix when loading either silos or trucks leads to segregation and should be avoided.

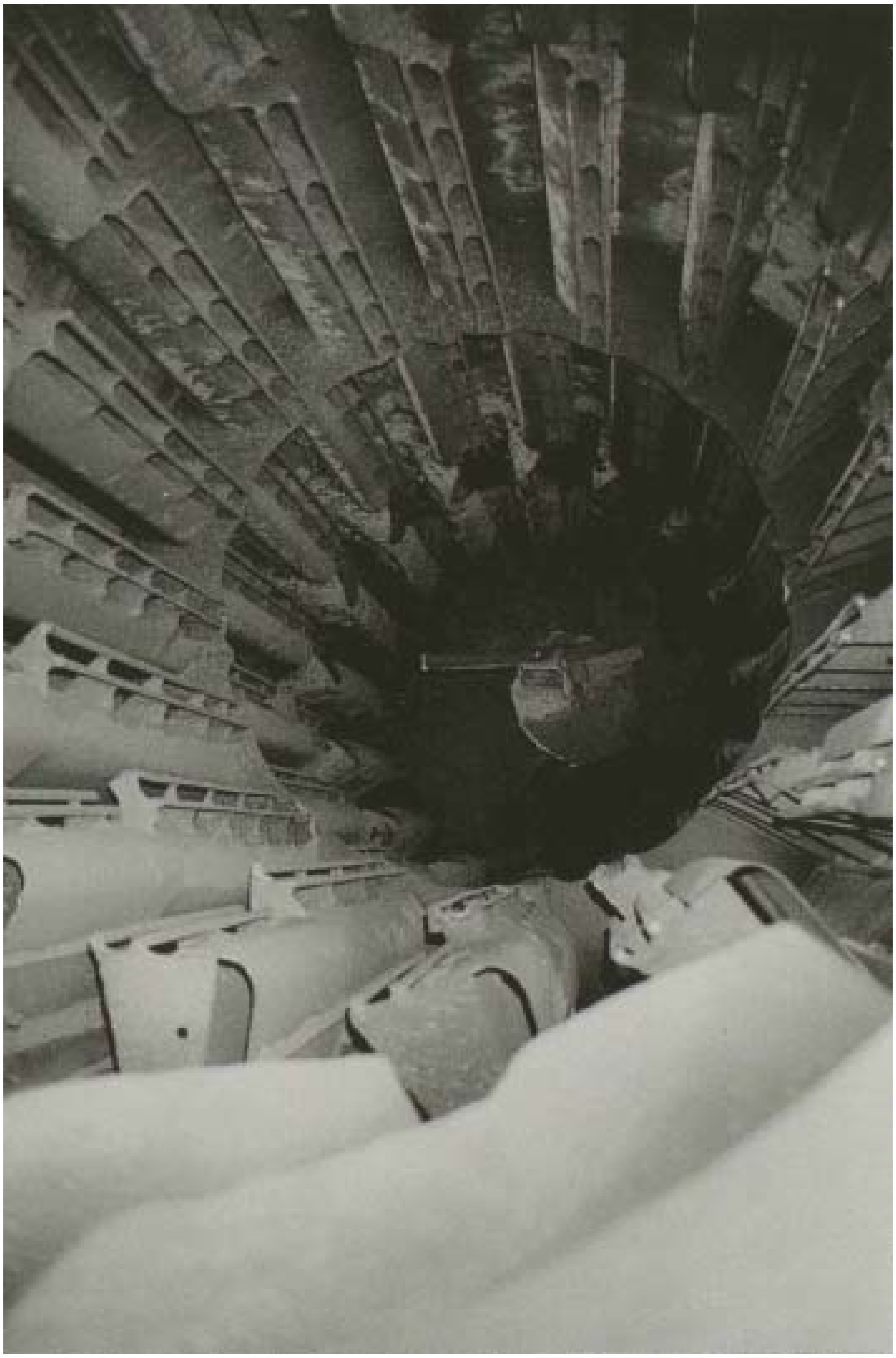


**Figure 4-6 Flights in a Drum-mix Dryer**

Segregation in a silo is more likely if it is completely emptied several times during a shift.  Use of a strain gauge bin level indicator is desirable since most high/low bin indicators are unreliable. It is desirable to keep the silo 1/3 to 2/3 full.  Cooling is a problem if the mix is held too long in a silo, especially if the amount of mix is small or the silo is not insulated.

**Figure 4-7  Hot Asphalt Storage Silos**
**(The remaining items of Section 4.4 apply only to batch plants)**

### *4.4.10  Screening Unit*

Proper, consistent aggregate in a batch plant depends on the hot screening operation.  Motors and bearing must be in good condition to assure adequate screen speed.  Worn screens develop holes, which allow oversize aggregate to fall into the bins for smaller material.

The opposite problem can also occur.  Aggregate must stay on the finer screens long enough for the small material to pass through them.  An excessive feed rate results in “carryover” of smaller particles into the coarse aggregate bins.  Carryover may result if the screens are plugged.

### *4.4.11  Hot Bins*

Temperature control is best when production is steady and material is not allowed to stay in the hot bins too long.  Bin gates must not leak when closed.

Bins should have telltales to warn if a bin is nearly empty and automatic cutoffs to stop batching, if a bin is completely empty. The plant must continue to operate to refill the empty bin.

Overflow pipes on hot bins must be kept clear to prevent material from one bin from spilling into the next (which results in an improper gradation mix).  Overflow usually indicates improper gradation of the aggregate entering the plant, i.e. a problem with the crusher, the stockpiling, the cold feed bin loading, or gate settings.  It may also result from problems with the hot screening unit (worn screens or carryover).

### *4.4.12  Weigh Box*

The scales operate in a dusty environment, so the accuracy and cleanliness of the system should be checked daily.  Scales may become inaccurate, if fulcrums, knife edges, or other parts become dirty or if moving parts bind against each other.  A weight indicator (dial or beam), which does not move freely or go to zero at no load needs immediate attention.  Weigh box gates should not leak when closed.

### *4.4.13  Asphalt Weigh Bucket*

Asphalt scales and meters need to be checked and calibrated for accuracy.  Asphalt and dust may build up on or in the bucket, so its empty (tare) weight must be checked often.  Cutoff valves must not allow excess asphalt to drip into a pugmill batch.

### *4.4.14  Pugmill*

Mix time should be the minimum needed to adequately coat the aggregate with asphalt,as determined by Ross Count tests.  Overmixing leads to oxidation (premature aging and embrittlement) of the asphalt.

Excessive clearance between paddle tips and the pugmill liner result in “dead spots” of unmixed material in the mixer.  Paddles wear with time, so the clearance needs periodic adjustment to stay within specifications.  The clearance between paddle tips and pugmill is generally 3/8” to 5/8”.

Nonuniform mixing will result, if the mixer is filled higher than the reach of the paddles or, conversely, if there is very little material in the batch.  This is easily avoided by following the manufacturer’s recommended batch sizes.

# 5. SURFACE PREPARATION

**(PRIME & TACK COATS)**

## 5.1. Preparing Existing Pavement (Tack Coat)

Pavements deteriorate with time. Air, water, traffic and temperature cycles all shorten pavement life. Existing pavements are overlaid to correct surface irregularities, to strengthen the pavement structure and to seal out air and water.

Preparation for a pavement overlay includes *cleaning* dirt and debris off the old pavement and applying a *tack coat*. Tack is an asphalt product (usually an emulsion), which is sprayed on existing pavement in a thin film. It provides a bond between old and new pavement.

If the old pavement has severe dips or ruts, it may require leveling with asphalt concrete prior to the overlay. It may also be necessary to raise manhole covers, storm water inlets and similar objects.

### *5.1.1 Leveling*

If a need for filling dips and ruts is anticipated, it will generally be indicated on the typical section in the plans for the project. Small holes and cracks are filled by hand with a shovel and a rake. Larger dips will require leveling with a motor grader (blade) or with a paving machine.

Normal procedure is for the inspector to stretch a string line across the dip to determine its depth and then mark the edges of dip with orange paint. Depth in the dip is marked in tenths of feet of asphalt fill required. The Contractor then fills it to the depth and dimensions indicated. Deep dips must be filled in successive layers, starting at the deepest point and working radially outward. Each lift must be compacted separately with the rubber-tired roller.

All old pavement surfaces must be cleaned and tacked prior to leveling.

### *5.1.2 Surface Preparation for Tack Coat*

The Contractor must clean the old pavement if it is dirty or covered with debris (Highways 401-3.07, Airports 401-4.9). A power broom is normally used, but in extreme cases flushing with water may be necessary. The worst enemy of a tack coat is *dry dust*. A slightly damp (not wet) surface is preferable to a dry, dusty one. If all the dust cannot be removed, the old surface should be moistened slightly 0.05-0.10 gal/sq. yd. using a water truck with a high-pressure spray bar.

Curbs, manholes, inlets, and the like are usually dirty and require cleaning with a hand broom prior to the application of a tack coat.

### *5.1.3 Tack Coat*

The Standard Specifications call for STE-1 Emulsified Asphalt to be used for tack coats (Highways 402-2.01, Airports 603). On some contracts the special provisions may call for a heavy grade of cutback asphalt instead.

A distributor truck applies the tack. Proper operation of the distributor truck is the key to a good tack job. See the description of the distributor truck in Section 5.3 for details.

Application rates vary and will be set forth in the contract (Highways 402-3.04 and Airports 603-2.1 specify 0.04-0.10 gals/sq.yd.. The tack coat should give a uniform coat without excess. The inspector may adjust the application rate if the coverage is too heavy or too light. As a general rule, a small amount of the existing pavement should show through the tack coat. Too much tack can cause slippage between old and new pavements or bleeding.

Care must be taken to prevent spray overlap or missed areas at longitudinal joints between shots of tack. Missed spots can be tacked with the hand sprayer, but the result will be better if the application is done right in the first place.

**Figure 5-1 Power brooming before tacking**

At transverse joints, building paper should be placed over the end of the old shot of tack and the new shot should begin on the paper (Airports 610.4b).

The tack should be applied the same day the surface is paved and must be in good condition when the paving machine reaches it. It is the Contractor's responsibility to protect the tacked surface from damage until the pavement is placed (Airports 610.4b).

Tack should be allowed to break before paving begins. When it breaks it will change from chocolate brown to black and from gooey (it will stick to your fingers) to tacky (it will feel sticky but will not stick to your fingers). Paving before the tack breaks results in the equipment picking the tack up off the road, which defeats the benefit of the tack.

Weather limitations given in the contract (Highways 402-3.01, Airports 603-3.1) should be strictly adhered to. Rain can wash unbroken emulsion off the grade, ruining the tack and creating a serious pollution problem. It can cause a serious public relations problem with the traveling public, if this oil is splashed on their cars. And it can cause extremely hazardous driving conditions. Tacking is never allowed in rainy weather.

Tack is normally paid for by weight. Asphalt emulsion (STE-1) is diluted with an equal amount of water prior to application. CSS-1 is paid for before it is diluted.
The distributor truck is weighed before and after the application and during the mixing process to determine the amount of tack that was placed.

Curbs, manholes, and other surfaces on which asphalt concrete will be placed or abutted must be tacked by hand prior to paving.  Surfaces of curbs, etc. that will *not* have pavement placed on them must be protected from over spray from the distributor.

## 5.2. Preparing an Aggregate Surface (Prime Coat)

Liquid asphalt materials with high penetration qualities are used for prime coats.  They are sprayed onto an aggregate surface, where they coat and bond the aggregate.  Prime coats provide a temporary waterproofing of the base course surface and a permanent bond between the base course and asphalt concrete pavement.  Prime coats may also preserve the finished base coarse for a few days if traffic must be allowed on it before paving begins, especially in wet weather. They also provide a zone of transition in asphalt content between the pavement and the untreated material below.

Occasionally priming is deleted from a paving project.  This may be considered late in the season when air temperatures are too cold for priming but still allows paving.  Prime coats serve a real purpose in the pavement structure, however, so deletion is normally not allowed.  Deletion of a prime coat must be approved at the Regional level.

Sometimes an *asphalt treated base* is used instead of a primed base.  This is briefly described in Section 5.2.5 of this chapter.

### *5.2.1 Alignment, Grade, and Compaction*

Alignment is the horizontal positioning of the road or runway; grade is the vertical positioning.  The plans describe the alignment and grade of a "profile line" for the road, runway, or taxiway.  This is most often the centerline of the structure.  The alignment and grade of other points relative to the profile line is shown in one or more "typical sections" in the plans.

The alignment and grade must be checked and approved by the grade inspector prior to priming.  This ensures that the road or runway is in the correct location.  This sounds simple but stakes are lost during construction and mistakes do occur.

The surface width of the road or runway must also be checked; sometimes it is narrower than the planned paving width and must be corrected.  The position and slope of the crown must be checked too (or just the slope in a superelevated section).

Compaction of the base course must be checked and approved prior to priming.  The check is made by means of density tests performed by materials inspectors.

### *5.2.2 Surface Preparation for Prime Coat*

A good prime coat requires a base course surface that is smooth, properly crowned, and free from washboarding, ruts and standing water.  This must be checked immediately before the prime coat is applied (Highways 403-3.03 and Airports 602-3.3).

On very tight, dense bases sweeping with a power broom may be needed to remove a dust seal that has built up under traffic.  More often the base is "tight bladed" with a motor grader.  This slightly loosens the surface, which helps the prime penetrate.  It also removes any loose rock.

As with tack coats, the worst enemy of a prime coat is *dry dust*.  The surface of the base course should be slightly damp (*not* wet) for the prime to penetrate properly.  Dry dust can be eliminated with a light fog of water sprayed under high pressure from a water truck.  Whether to water, and how much to water, is a decision which must be made by the inspector.  This decision is based on how moist the grade is, how hot and sunny it is and how soon it will be primed.  Too little moisture and the prime will not penetrate; too much and it will puddle up or even run off the grade.

### 5.2.3 Prime Coat

Highways Standard Specification 403-2.01 allows MC-30 Liquid Asphalt or CSS-1 Emulsified Asphalt as prime coat material. Airport Standard Specification 602-2.1 allows MC-30 or CMS-2S Emulsified Asphalt. Contract special provisions may allow other materials. When emulsified asphalt is used, it is diluted with an equal amount of water prior to application.

The distributor truck sprays the prime material on. See the description of the distributor truck in section 5.3 of this chapter for details.

The layout of widths and lengths to be primed should be determined before application. A small amount of material 100 gallons or more should be left in the distributor at the end of each shot to prevent uneven application. The area, which can be covered by a load, must therefore be calculated ahead of time.

The rate of application is usually determined from the amount of material that will be absorbed in a 24-hour period. Ideally a trial section is laid out the first day. The application rate may require adjustment by the inspector if the coverage is too heavy or too light. It is sometimes necessary to split the application into two shots.

A variation of up to 0.02 gallons per square yard is acceptable (Highways 402-3.02, Airports 602-3.2 allows a 10% variance). Most contractors control the spread closer than this. Even in small areas it is better to use the spray bar instead of the hand sprayer if it is possible to maneuver the truck.

Care must be taken to prevent spray overlap or missed areas at longitudinal joints between shots of prime. Excess material can be mopped up from overlapped areas and missed spots can be primed with the hand sprayer, but the result will be better if the application is done right in the first place. If gaps are left in the prime coat where traffic will be allowed, the gaps will become potholes in the finished base coarse.

At transverse joints, building paper should be placed over the end of the old shot of prime and the new shot should begin on the paper (Highways 403-3.04).

Once the prime material has been absorbed enough that tires will not pick it up, traffic may be allowed on the surface. It is the Contractor's responsibility to protect the surface from damage until the pavement is placed (Highways 403-3.04, Airports 602-3.3).

Weather limitations are given in the contract (Highways 403-3.01, Airports 602-3.1) and should be strictly adhered to. Rain can wash fresh prime material off the grade, ruining the application and creating a serious pollution problem. It can cause a serious public relations problem with the traveling public, if this oil is splashed on their cars. It can cause extremely hazardous driving conditions. Priming is never allowed in rainy weather.

Prime is normally paid for by weight. Emulsified asphalt is diluted with an equal amount of water prior to application. The state pays only for the undiluted emulsion, not for the dilution water. The distributor is weighed before and after the application and during the mixing process to determine the amount of prime that was placed.

If asphalt concrete will be placed against the surface of curbs, manholes, etc., these surfaces must be tacked (usually by hand). Surfaces of curbs, etc. that *won't* be paved must be protected from the distributor spray.

### 5.2.4 Blotter Material

The Contractor is required to have clean sand available to use as blotter material. He must have an aggregate spreader to apply it, and a rotary broom to sweep surfaces on which blotter material has been placed (Highways 403-3.05, Airports 602-3.3).

**Figure 5-2  Distributor Truck**

Blotter sand is not normally used, but is sometimes spread on an uncured prime coat.  The most common reasons for using it are (1) because traffic must be allowed on the prime before it has cured, and (2) because imminent rain threatens to wash uncured prime off the grade.

The use of blotter sand less than four hours after applying the prime is allowed only with written permission (Highways 403-3.05, Airports 602-3.3 after 48 hours).  It is almost impossible to apply blotter without getting thick spots that eventually “reflect” through the surface.  Because of this the use of blotter sand should always be avoided if possible.  If the base won’t absorb the prime material within four hours, the application rate probably needs to be reduced.

### *5.2.5 Emulsified Asphalt Treated Base*

Asphalt treatment is used to strengthen the base course prior to paving.  Asphalt treatment can be an alternative to placing thicker pavement layers or to replacing a degrading or damaged base course.  Only a very brief description of asphalt treated bases is given here.  A good source of additional information is Chapter 13 of the Asphalt Institute’s *Asphalt Handbook* (MS-4).

Emulsified asphalt treated base is produced by mixing base course material with emulsified asphalt and sometimes a few percent Portland cement.  Portland cement is what the term "cement" usually means and is lime-based.  The use of the term Portland cement differentiates it from asphalt cement, which is petroleum-based.  Portland cement is added for the following reasons:

1. It may improve workability.
2. The hydration of the Portland cement dries the treated base.  This helps the emulsified asphalt to break more rapidly
3. It adds to the final strength of the base.

The proportions of the components will be listed in an emulsified asphalt mix design report similar to the ones for asphalt concrete.

An Emulsified Asphalt Treated Base can by produced using existing or new base course material. It can be mixed on grade by heavy equipment or by specially made traveling plants. It can be produced in a central mixing plant.

## 5.3. Distributor Truck

Trailer-mounted distributors are made, but nearly all distributors used in Alaska are truck-mounted units similar to the one shown in the diagram (Figure 5-3). The distributor tank is insulated and has a heating system (burner and flues) to maintain the asphalt material at the proper temperature. The pump circulates the material inside the tank and pumps it to the spray bar and hand sprayer. The bitumeter wheel drives a speedometer and odometer accurate at the low speeds used when priming or tacking (the speedometer usually reads in feet per minute).

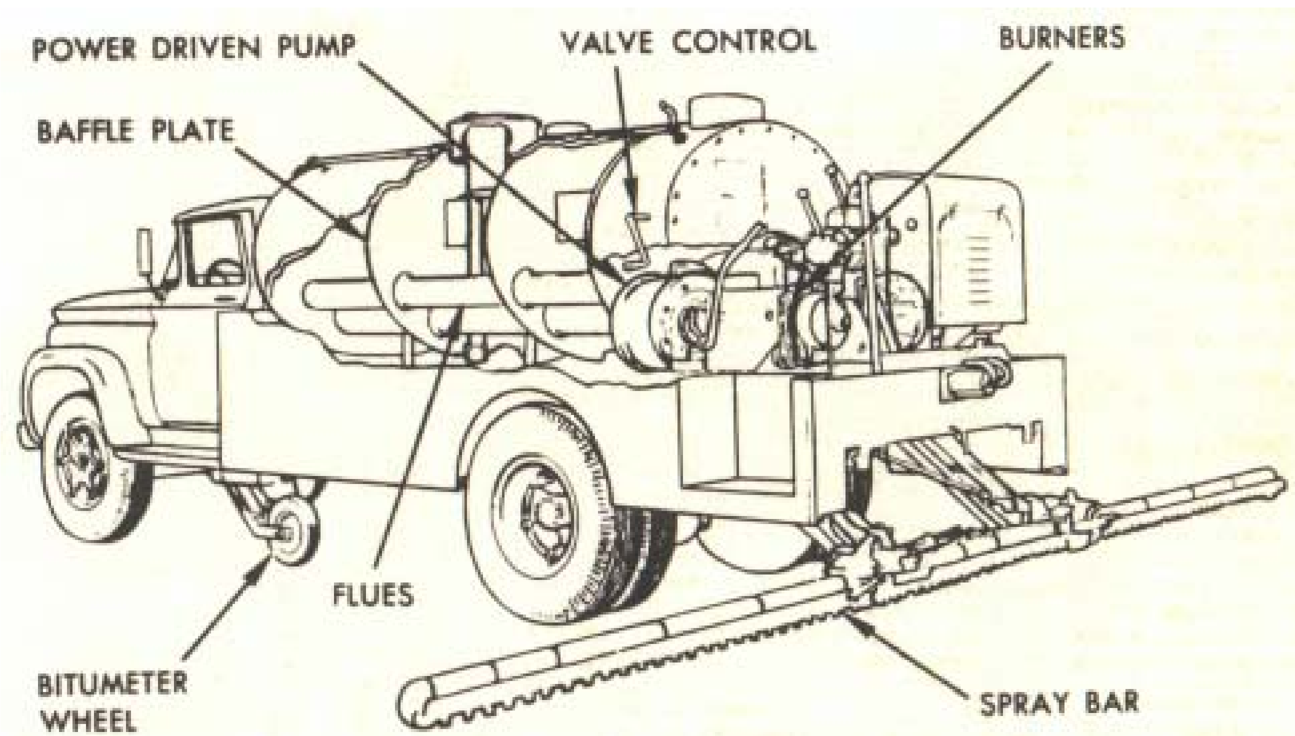



**Figure 5-3 Typical Distributor Truck**
**Courtesy of the Asphalt Institute**

Specifications require that the distributor have a pump tachometer, pressure gauges, and a tank thermometer. It must have a circulating spray bar (the material is pumped through the bar and back into the tank as well as out the nozzles). The distributor truck has a flow rate gauge; it measures gallons per minute.

The tank must be calibrated in 50-gallon increments or smaller (so volume measurements can be made).

The distributor truck is one of the most dangerous pieces of equipment on a paving spread. It has the potential for explosion from hot asphalt turning trapped water (in the piping system) into steam, from fumes being ignited, and from pressure building up during heating operations. There is also the potential of being burned at almost any time during distributor operations, either by the oil itself or the piping or the heating system. It is possible to be overcome by the fumes if proper care is not taken.

Proper operation of the distributor is the key to a good tack or prime coat. It should spray the right amount of tack or prime liquid on to the surface in a uniform film. This requires good equipment, trained operators, and proper adjustment of the following:

1. The height of the spray bar above the surface
2. The speed (pressure and capacity) of the pump
3. The speed of the truck
4. The size and angle of nozzles on the spray bar

The yield can be calculated with four factors in the equation: speed of the truck (feet per minute), length of the spray bar being used (feet), flow rate setting of the pump (gallons per minute), and the desired yield (gallons per square yard).

$$\text{Yield (gal / yd}^2\text{)} = \frac{\text{flow rate (gal/min)}}{\text{Speed (ft / min)} \times \frac{\text{width (ft)}}{9}}$$

The contractor will choose to hold the speed or the flow rate constant for a given width and yield, then calculate the remaining factors. Most distributors have a cardboard "slide rule" that makes this calculation even simpler.

Most distributors use a triple lap spray system (see Figure 5-4); a few use double lap. Closing off two out of every three nozzles can check spray bar height on the triple lap system (or every other one on a double lap). This change should result in a single, uniform coverage. If there is a gap between spray fans the bar is too low; if there are doubly covered streaks the bar is too high. The test may be made on the approved surface. After the bar is set, the test area can be retacked or reprimed to bring the total coverage (“yield”) up to the required amount.

The pump should be operated at the highest speed (pressure) that will not atomize the prime or tack spray. The asphalt coming out of each nozzle should look like a triangular black rubber sheet, not a fog or mist.

Contractors can usually make a good first guess of the pump and truck speeds necessary to achieve the required “yield” (measured in gallons per square yard). The quantity of tack or prime material sprayed on an initial, small area is carefully measured and the yield is calculated. Adjustments (usually to the truck speed) can then be made so that the yield matches plan amounts. Short shots should be repeated until the correct amount of tack or prime is being placed.

Nozzles (“snivvies”) must all be the same size and set at the angle specified by the distributor manufacturer. This is $30^{o}$ to the spray bar for Etnyre machines, $60^{o}$ for Grace, $15^{o}$ for Littleford, and $25^{o}$ for Roscoe. The fan of material sprayed from a nozzle should be uniform from edge to edge. If it isn’t, the nozzle is clogged, worn or damaged. The fan from all the nozzles should look the same. If they don’t, the pressure may be too low or the nozzles may be different sizes or clogged. If nozzles need to be replaced, the complete set should be changed at the same time to assure uniform operation. Distributors must be kept clean to operate properly, either with steam cleaning or scrubbing with solvent. This is particularly important if emulsions are used, since residues can set or “break” inside the equipment, fouling or clogging it.

## 5.4. Responsibilities of the Inspector

Alignment and grade (or leveling) must be checked and approved by the grade inspector prior to priming or tacking. An approved grade may deteriorate under traffic or weather, however. You must therefore inspect and approve the grade immediately before priming or tacking. You must also decide if the surface needs to be moistened prior to priming or tacking. The finished asphalt surface will only be as good as the surface upon which it is laid.

Your measurements, comments, and other information are normally kept in a Prime (or Tack) Log, which is described in the next section. Any unacceptable or out-of-specification condition should be noted in the log. The Contractor should be notified *immediately* of any such condition and corrective action taken prior to priming or tacking.

The prime or tack application should be watched constantly to see if the amount of material applied appears appropriate. If not, the yield may need to be adjusted. It takes good judgment and experience to make the proper adjustments to the yield.

You should keep the Project Engineer informed of the progress of work especially if there are problems.

The following checklists should help you in your work.

**Preliminary Inspection Checklist**

- ❑ Have the Prime or Tack log, a 50 foot tape, and an air temperature thermometer
- ❑ Distributor has tachometer, pressure gauges, circulating spray bar, and bitumeter/odometer
- ❑ Tank is calibrated and has a thermometer
- ❑ All nozzles are the same size and set at same angle
- ❑ Plan yield (gals/sq.yd.) has been converted to gals/station for proposed shot width
- ❑ Maximum distance that can be shot with one load has been calculated
- ❑ Spray bar is set at proper height using test strip
- ❑ All nozzles spray a uniform fan of material without misting or fogging
- ❑ Yield on first small area is carefully checked and pump/truck speed adjustments made
- ❑ Speed adjustments checked on additional small areas until proper yield is obtained

**Inspection Checklist for each Shot**

- ❑ Rain is not likely before tack or prime cures
- ❑ (Tack coat) Old pavement cleaned, leveled, and/or watered if needed
- ❑ (Prime coat) Base Course tight-bladed and/or watered if needed
- ❑ Surface is adequately warm
- ❑ Building paper is used at beginning of shot
- ❑ Number and effect of any equations is noted in log
- ❑ Time and weather noted in log
- ❑ Tank and air temperatures within specs and logged
- ❑ Beginning and ending tank readings taken and logged
- ❑ Yield calculated using temperature-corrected volumes or spread rate
- ❑ Location of the area primed or tacked noted on truck weight ticket
- ❑ An approved traffic control plan is in place and *Fresh Oil* signs are in place at all access points if traffic is allowed on the oil

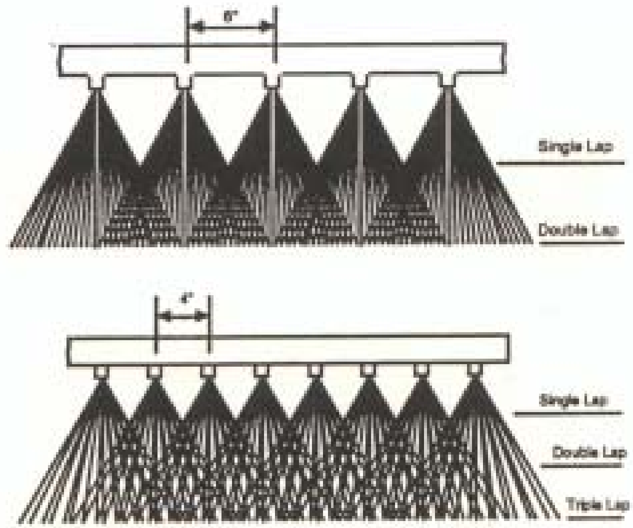
**Routine Inspection Checklist**

- ❑ (Prime coat) Base course has received grade approval and has passed density tests
- ❑ Manholes, curbs, etc. are hand primed or tacked
- ❑ Bitumeter wheel is free of asphalt buildup
- ❑ All nozzles spray a uniform fan of material without misting or fogging
- ❑ Spray bar cutoff is positive and immediate
- ❑ Distributor truck is weighed after each shot
- ❑ Traffic is kept off uncured prime or tack
- ❑ Blotter sand is spread on any uncured prime that is threatened by rain or early traffic

**DISTRIBUTOR**

It is most important that the distributor be properly adjusted and operated to uniformly apply the proper amount of asphalt.

The bar and its snivies (nozzles) must be properly set to obtain a uniform shot (application). The snivy size, spacing, and angle in relation to the bar determine the height of the bar.

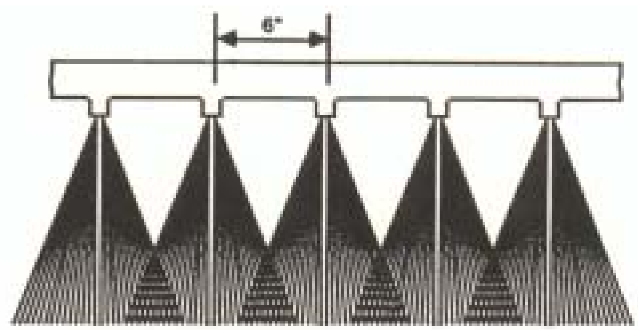



13.1.

**Figure 5-4a. Distributor Adjustments**
**Courtesy of Washington State Department of Transportation**

Streaking will occur

- if the asphalt is too cold;
- when the viscosity of the asphalt is too high;




- if the snivies are not all at the same angle;

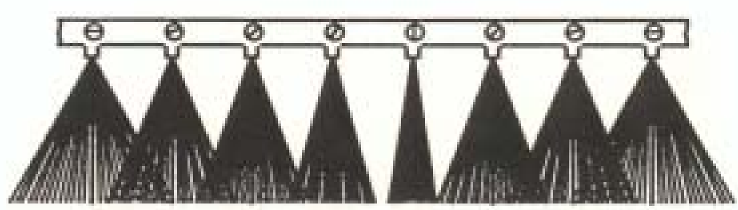
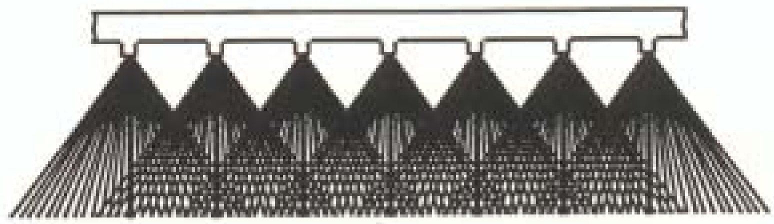


**Figure 5-4b. Distributor Adjustments (Cont.)**

- when the bar is too high;



- when the bar is too low;

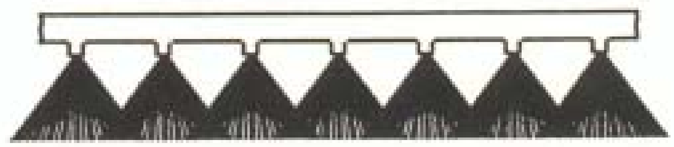


**Figure 5-4c. Distributor Adjustments (Cont.)**

- when the bar pressure is too high. It cuts furrows because the snivies are too small and/or there is too much pump pressure.

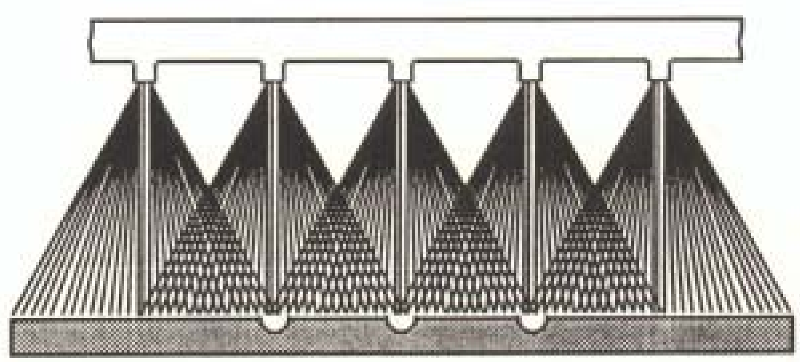


**Figure 5-4d. Distributor Adjustments (Cont.)**

- When the bar varies in height from a full to an empty distributor, blocking or locking against the overload springs will reduce or eliminate this variance in height.
- When the bar is too long and/or the snivy openings are too large for the pump capacity, this results in narrow and fluttering fans. Smaller snivies and/or higher pump capacity will correct this.
- If the pump pressure is too low it will create narrower spray fans and fluttering.
- If the distributor tank is allowed to run completely empty, an irregular pattern of misses and fluttering will occur across the bar. For this reason, the shot should be terminated while approximately 100 gallons are left in the distributor.

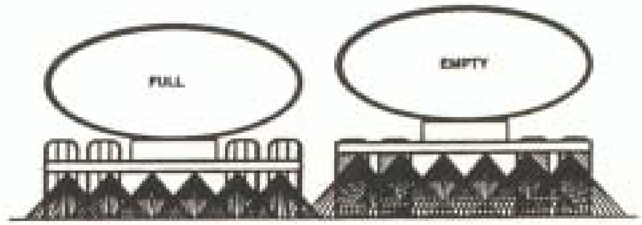



**Figure 5-4e. Distributor Adjustments (Cont.)**

## 5.5. Prime and Tack Logs

An example of a page from a tack and a prime log are included at the end of this section. The logbooks should be clearly marked with the name and number of the project as well as the pay item (prime or tack). Pages should be prepared with column headings, etc. ahead of time so you don't have to do this while you should be inspecting the work.

You must sign each page of the log. You can use initials only if there is an index to them in log with your signature (for example J.A.S. = John A. Smith).

Someone unfamiliar with the project should be able to look at your log and determine:

- The *location* of each prime or tack shot
- The *area* covered by the shot
- The *date* and *time* of the shot and the *weather* condition
- The *quantity* of material used on a shot and its *temperature*
- The *plan spread rate* ("yield") and the *actual spread rate*

The station and lane (or offset) information show the location. The width of the shot multiplied by its length gives the area. You must *note any equations* and their effect to determine the length correctly. Notice that in the example log pages, the plan spread rate ("Theo. Spread") has been converted from gals/sq.yd. to gals/station. The actual spread you get on the project can then be calculated in gals/station too. This is easier than calculating gals/sq.yd., so it saves time and reduces the chances for errors. The gallons per station method works well if most of the shots will be the same width, usually on a rural job. However, if the width of the road changes frequently, using gallons per square yard is less confusing (though more arithmetic).

The conversion is simply the plan spread (gals/sq.yd.) multiplied by the number of square yards shot per station. The width of the shot in feet times the length (100 feet) will give the number of square feet; dividing this answer by 9 will convert the area to square yards (9 sq.ft. = 1 sq.yd.):

Width (in feet) x 100/9 = Width x 11.11 = Area in square yards, so

*Spread (gals/sq.yd) x width (in feet) x 11.11 = Spread (gals/sta.)*

**Example**

In the sample prime log, the plan spread rate ("Theo. Spread") is 0.30 gals/sq.yd. and the width of the shot is 13 feet, so

0.30 x 13 x 11.11 = 43.33 gals/station

The actual spread rate is simply the number of gallons of material used on a shot ("before" gallons minus "after" gallons) divided by the number of stations covered by the shot. The standard temperature at which the volume of asphalt materials is measured is 60$^{o}$F. Since asphalt materials expand when heated, volume measurements won't be in "standard gallons if they aren't made at 60$^{o}$.

"Hot gallons" must therefore be adjusted to "standard gallons" by multiplying them by a correction factor. Appendix C has tables listing these correction factors for different temperatures. Note that there are tables for three categories of materials. You have to use the correction factor from the right table (the Group I table for cutbacks, the emulsified asphalt table for emulsions).

**Example**

The first correction factor listed in the sample prime log is 0.9662. This is the factor listed in the Group I table for 146$^{o}$F, the tank temperature shown in the log. (Since the Group I table has been used, the sample log must be for a cutback asphalt.) The "standard" or "Net Gal" is therefore

1150("Hot Gal") x 0.9662 = 1111 "Net Gal"

If the material is nearly the same temperature on every shot, the plan spread rate can be converted from "standard" gallons/sta. to an equivalent number of "hot" gallons/sta. The actual spread in "hot" gallons can then be compared directly with the plan "hot" spread rate; you don't have to convert your tank measurements. This saves time and cuts down on chances for errors.

The log should also note any unusual events that occur during the prime or tack operation. If any material is wasted, you should note how much and why. You should also note if the operation stops due to equipment problems or weather. If blotter sand is used, note where and the reason for it.

**SAMPLE TACK LOG** (Showing how to record waste)

Date: 7/5/72 Lane: Right Width: 12' Theo. Spread = 0.10 Gal/sq yd = 13.33 Gal/Sta

Number & Effect of Equations this Section 0-0 Lab No. 66A-1597 Seals 6022 - 6023

| Sta. | Temp °F | Tank Readings or Wt Before | Tank Readings or Wt After | Net Gal or # | Temp Corr. or Unit Wt | Net Gal | Distance in Sta. | Spread Gal/Sta. | Time of Day | Weather |
|---|---|---|---|---|---|---|---|---|---|---|
| 100+00 | | | | | | | | | | |
| | 110° | 1150 | 870 | 280 | 0.9610 | 269 | 20.00 | 13.45 | 11:30A | 86° Clear |
| 120+00 | | | | | | | | | | |
| | 110° | 870 | 580 | 290 | 0.9610 | 279 | 20.00 | 13.95 | 1:00P | 89° Clear |
| 140+00 | | | | | | | | | | |
| Waste | 110° | 580 | 525 | 55 | 0.9610 | (-53) | Cleaning out spray bar in old pit. | | | |
| 140+00 | | | | | | | | | | |
| | 110° | 525 | 250 | 275 | 0.9610 | 264 | 20.00 | 13.20 | 2:30P | 92° Clear |
| 160+00 | | | | | | | | | | |

Checked By: Ted King 7/5/72 Phill Monis 7/5/72

**Figure 5-5 Sample Tack Log**

SAMPLE PRIME LOG

Date: 7/21/72 Lane: Left Width: 13' Theo Spread: 0.30 Gal/Sq yd = 43.33 Gal/Sta.

Number & Effect of Equations this Section: 0-0 Lab No. 664-1642 Seals: 8421-8418

| Sta. | Temp °F | Tank Reading or Wt Before | Tank Reading or Wt After | Net Gal or # | Temp Corr. or Unit Wt | Net Gal | Distance in Sta. | Spread Gal/Sta | Time of Day | Weather | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 355+00 | | | | | | | | | | | |
| | 146° | 1250 | 100 | 1150 | 0.9662 | 1111 | 25.00 | 44.44 | 5:30A | 67° Clear | |
| 380+00 | | | | | | | | | | | |
| | 148° | 1260 | 220 | 1040 | 0.9655 | 1004 | 23.50 | 42.72 | | | |
| 403+50 | | | | | | | | | | | |
| | 150° | 1275 | 75 | 1200 | 0.9647 | 1158 | 27.00 | 42.89 | 8:35A | 71° Clear | |
| 430+50 | | | | | | | | | | | |
| | 146° | 1270 | 90 | 1180 | 0.9662 | 1140 | 25.50 | 44.71 | | | |
| 456+00 | | | | | | | | | | | |
| | 147° | 1245 | 120 | 1125 | 0.9659 | 1088 | 25.00 | 43.53 | 9:50A | 73° Clear | |
| 481+00 | | | | | | | | | | | |
| | ℄ Lane 13 Ft Wide | | | | | | | | | | |
| 355+00 | | | | | | | | | | | |
| | 147° | 1275 | 105 | 1170 | 0.9659 | 1130 | 26.00 | 43.46 | 10:15A | 76° Clear | |
| 381+00 | | | | | | | | | | | |
| | 146° | 1165 | 125 | 1040 | 0.9662 | 1005 | 23.00 | 43.70 | | | |
| 404+00 | | | | | | | | | | | |
| | 145° | 1235 | 70 | 1165 | 0.9666 | 1126 | 26.00 | 43.31 | 11:00A | 76° O'Cast | |
| 430+00 | | | | | | | | | | | |
| | 144° | 1275 | 95 | 1180 | 0.9670 | 1141 | 26.50 | 43.06 | 12:00 Noon | | |
| 456+50 | | | | | | | | | | | |
| | 144° | 1270 | 160 | 1110 | 0.9670 | 1073 | 24.50 | 43.80 | 1:30P | 78° O'Cast | |
| 481+00 | | | | | Total = | 10976 ÷ | 252 = | 43.56 Ave. Spread | | | |
| | checked By: Ted King 7/22/72 | | | | | | | | Phill Morris 7/21/72 | | |

**Figure 5-6 Sample Prime Log**

# 6. LAYDOWN

## 6.1. Responsibilities and Authority of the Laydown Inspector

### *6.1.1 Areas of Responsibility*

There are many aspects of a paving operation, which require monitoring and inspection. As the laydown inspector you have the prime responsibility for:

- *Paving Mix Quantities & Thickness*
- *Rolling & Compaction*
- *Joint Preparation & Construction*
- *Raking*
- *Surface tolerances*

You will have help in these areas from the scale operator (who measures quantities) and, on most jobs, a ticket taker.

You may also have the prime responsibility for:

- *Final Grade (and Prime or Tack) Approval*
- *Traffic Control*

If others have the prime responsibility in these areas, you still must work with them. Traffic may ruin a surface, which a grade inspector has approved for paving. If so, you must not allow paving until the problem is repaired and/or the grade inspector has a chance to check the area again. An approved traffic control plan may need revision as the work moves down the road. Signs can blow over. You must remain alert to these needs.

You will always share responsibility for the *quality of the paving mix*. A materials inspector does the density and asphalt content tests on the pavement, but you must make sure these are being done as required. The plant inspector is responsible for seeing that good mix leaves the plant, but you must be alert to the mix quality too. Mix can become too segregated, cold, or contaminated after it leaves the plant. Materials testing is discussed in Chapter 3 of this manual; plant inspection is discussed in Chapter 4.

Laydown inspection can be hectic and demanding. Be sure you read the specifications, gather tools and equipment, and calculate the spread prior to the start of paving. Be sure there are good communications between you, the contractor, and the grade, materials, and plant inspector.

The laydown inspector may reject the condition of the grade as being unsuitable for paving. The laydown inspector may also reject loads of asphalt concrete based on quality, contamination or temperature.

You must document any rejection you make and the reasons for it.

Knowing what good concrete looks like, both in the trucks and on the grade, requires some experience. The *Trouble Shooting Guide* (Appendix A) lists the most common problems and their probable causes.

### *6.1.2 Records*

Records of the paving operation may be organized differently on different projects, but they usually include *Weight Tickets,* the *Asphalt Concrete Field Book (Paving Log),* and the *Inspector's Daily Report.*

Weight tickets are issued for each truckload of asphalt concrete at the scales. They are collected at the paver and the time and location that the mix is placed is written on them. The ticket taker does this, if there is one. If there isn't one, the laydown inspector must do this.

The Asphalt Concrete Field Book (Paving Log) is used to record the placement of individual loads, to calculate the yield, and to note temperature measurements, weather conditions, etc.  This is discussed in more detail in Section 6.3. Placement.  A sample page of a paving log is included at the end of this chapter.

The Inspector's Daily Report is used to summarize the day's activities.  This includes a listing of the contractor's men and equipment and their hours and locations of work.  It also includes a record of the conditions of work – the pace of it and its quality, work stoppages and the reason for them, etc.  Construction problems should be noted, along with the steps taken to correct them.

On some projects the Inspector's Daily Report covers a number of items of work other than just the paving operation.  This is the case on the sample report shown at the end of this chapter.  If someone else is completing the Inspector's Daily Reports, the laydown inspector may limit his or her records of work to the Paving Log.  Make sure you know what records you are required to keep *before* work begins.

### *6.1.3 Laydown Inspector's Checklists*

**Inspector's Equipment Checklist**

- ❑ Straight Edge 15' 9"
- ❑ Air Thermometer
- ❑ Surface Thermometer
- ❑ Asphalt Thermometer
- ❑ 50' Tape
- ❑ Pavement Depth Gauge, Ruler or Tape
- ❑ Clip Board
- ❑ Paving Log
- ❑ Calculator

**Preliminary Checklist (Before Paving)**

- ❑ Trucks adequate (checklist in Section 6.2)
- ❑ Paver(s) adequate (checklist in Section 6.2)
- ❑ Rollers adequate (checklist in Section 6.2)
- ❑ Grade and prime (or old pavement and tack) acceptable for paving
- ❑ Weather warm enough & dry enough for paving
- ❑ Stringline or other paver guide in place
- ❑ Screed heated before paving begins
- ❑ Screed blocked  to loose depth before paving begins
- ❑ Cold joint surfaces cleaned and prepared adequately

**Production Checklist (During Paving)**

- ❑ Paver starting and stopping minimized
- ❑ Placement location and time marked on all weight tickets
- ❑ Mix temperature within specs for laydown
- ❑ No visible segregation or contamination
- ❑ Mix appearance not too wet or dry
- ❑ Hopper never completely emptied; feed augers always at least 2/3 full
- ❑ Yield calculated periodically and thickness adjustments made as needed
- ❑ No flinging (broadcasting) or long distance raking of hand placed material

- ❏ Joints and edges raked properly
- ❏ Rolling begins as soon as possible without shoving
- ❏ Proper rolling sequence followed
- ❏ Compaction finished before mat cools to 185ºF
- ❏ Good mat surface texture without roller checking
- ❏ Surface smoothness within tolerance (including joints)
- ❏ Materials inspector makes tests as needed
- ❏ Traffic stays off mat until it cools to 140ºF
- ❏

## 6.2. Equipment

### *6.2.1 Hauling Units (Trucks)*

Airports 401-4.3 and Highways 401-3.04 contain the Standard Specifications for trucks. All trucks must have canvas covers to protect the hot mix from the weather if needed. Truck beds should be lightly treated with an approved bed release agent.

Diesel fuel can dissolve asphalt cement, causing it to ooze (“bleed”) to the pavement surface after paving. The uncoated aggregate left behind may ravel, resulting in potholes. *Diesel is not an approved bed release agent.* For the same reason, trucks leaking fuel, lubricating or hydraulic oil must not be allowed.

Truck weights must be within legal limits unless permission has been given otherwise. Ask your Project Engineer for the current formula or form to calculate the legal loads

**Figure 6-1 Truck Dumping into Paver**

for the Contractor’s trucks. Overloads are sometimes allowed on gravel embankments before they have been paved. They should be avoided on bridges and paved surfaces (even old pavements which will be overlaid).

**Truck Inspection Checklist**

- ❏ Trucks are equipped with covers
- ❏ Approved bed release agents are used
- ❏ Legal loads are calculated for each truck

- ❑ Trucks are not leaking oils or fuels
- ❑ Truck beds are clean (free of dirt)

### *6.2.2 Pavers*

Standard Specifications for pavers are found in Highways 401-3.05 and Airports 401-4.4. Pavers are also called paving machines or laydown machines. They consist of a tractor unit, which pulls an activated screed (see Figure 6-2). The screed spreads the asphalt concrete and partially compacts it by using either *tampers* or *vibrators*.

**Tractor Unit**

The tractor provides power for forward motion and for spreading the asphalt concrete. The tractor unit has a hopper, feed slats, feed gates, augers (screws), engine, transmission, and controls. The feed slats, feed gates, and augers should be adjusted so that the augers and feed slats are running most of the time and the feed augers are about 1/2 full. Sensors that detect the amount of asphalt reaching the end of the screed control the augers. These need to be properly located and adjusted to keep the augers running most of the time and 1/2 full. The NAPA paving handbook recommends keeping the mix level at the midpoint of the augers rather than ¾ full as recommended by the Asphalt Institute.

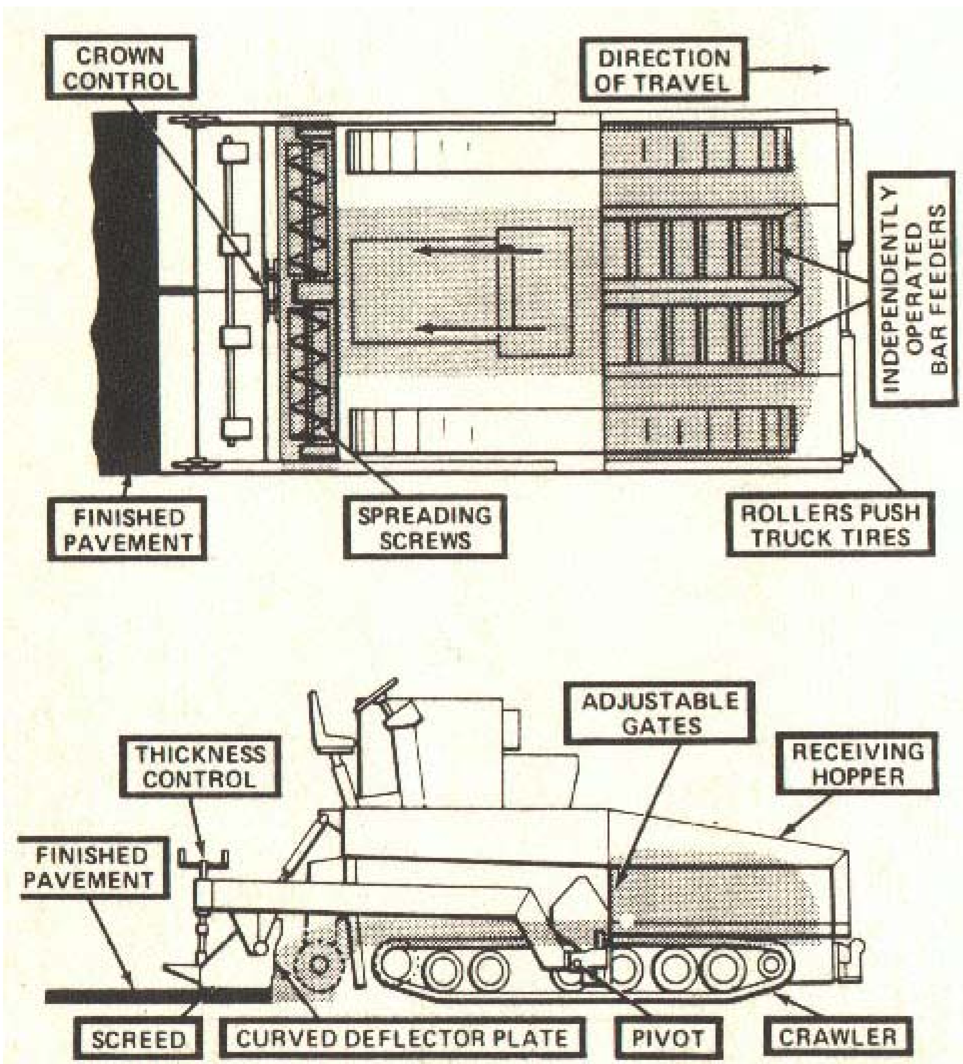



**Figure 6-2 Basic Paver Components**
**Courtesy of the Asphalt Institute**

## Screed Unit

The screed includes the tamper and/or vibrator, thickness controls, crown controls and heater. Automatic screed controls are required (Highways 401-3.05, Airports 401-4.4).

Tamper or Vibrator: The screed strikes off the surface of the asphalt concrete. Some pavers have vibrators to make the screed oscillate, which partially compacts the mix. On other pavers there are tamper bars for this purpose. Some pavers have both. About 80% of the compaction is accomplished by the screed. Paving crews should not be allowed to turn the vibrator off.

Thickness Controls: The screed is attached to the tractor by long leveling arms and rides on top of the new mat like a water skier towed behind a boat. This arrangement compensates for irregularities in the existing surface and helps to produce a smooth pavement. The mat thickness is controlled by the head of asphalt built up on the augers and on the screed angle. The head of asphalt on the augers should be constant under normal operation. The thickness controls change the angle of the screed. It may take about 50 feet for a paver to completely react to any adjustments to the thickness controls.

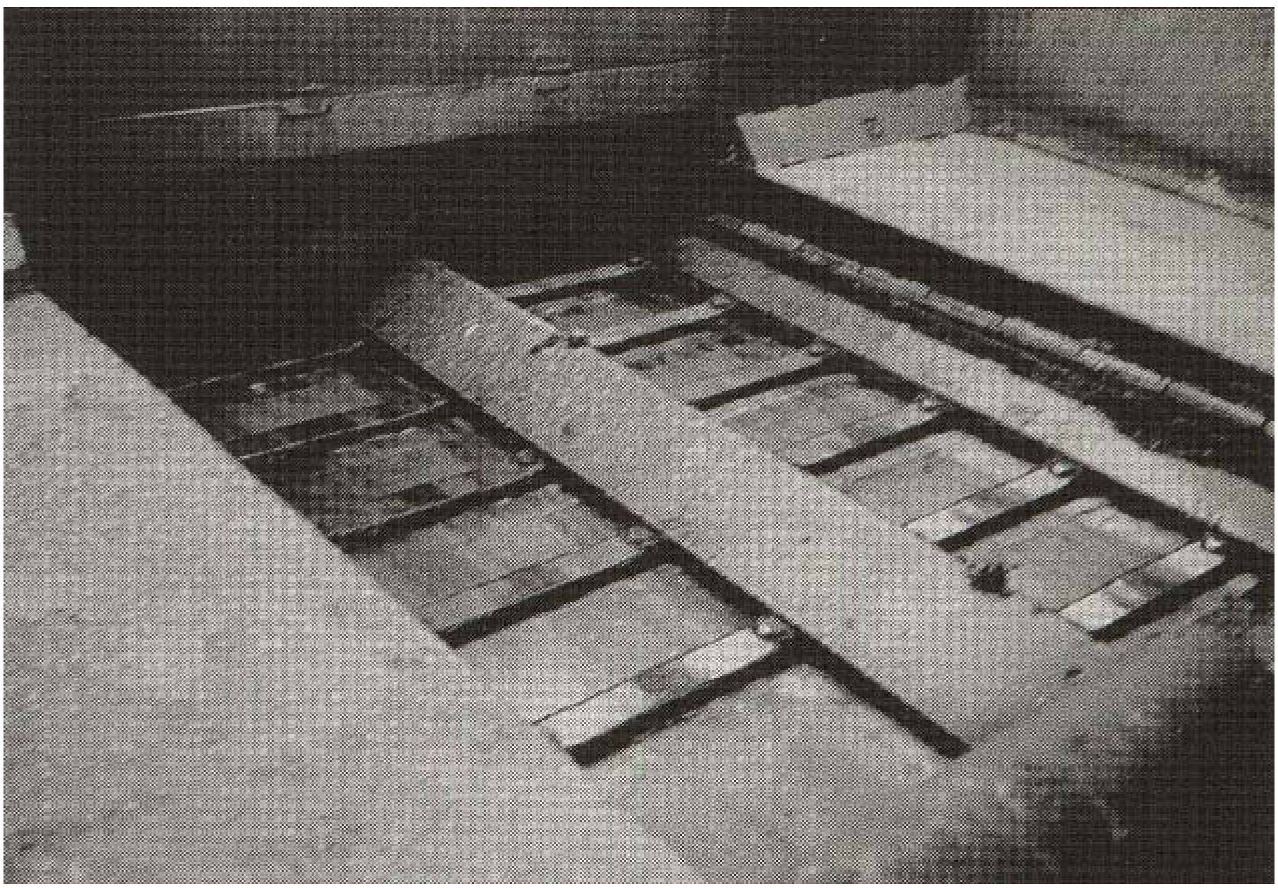


**Figure 6-3 Paver Feed Slats**

Crown Controls: These can put a vertical angle ("crown") in the front and/or back of the screed. The front of the screed should be crowned slightly higher than the rear so that asphalt flows into the "shadow" left by the auger differential. A stripe will appear down the center of the mat if this is not done correctly. The screed crown should match the crown (if any) on the grade or an existing pavement. If the screed crown is improperly set the mat may be too thin in places and tear during placement or too thick in places, causing an over-run in quantities.

Heater: The screed heater is used to warm the screed surfaces before paving begins. It is generally not used at other times. Overheating will cause the screed to warp and require the plates to be replaced.

**Automatic Screed Controls**

Automatic screed controls allow the screed to follow a smooth line, even if there are irregularities in the surface being paved. Many automatic screed controls have a long ski, which rides smoothly over the grade. A stringline or other device is used on other pavers. An automatic sensor detects any vertical movement of the ski (or stringline). The sensor signals the screed control which raises or lowers the tow point on both sides of the screed to compensate for the grade changes.

The manual controls are used until the correct pavement thickness is achieved. The automatic controls are then switched on to maintain the required depth. If everything is working correctly, few other adjustments are needed. Once the automatic screed controls (and the hydraulic valve to the tow point hydraulic ram) are turned on, the manual screed controls no longer have any effect. The automatic controls will override them. The tow point ram should be watched to make sure it is working in conjunction with the automatic controls. It should be centered well enough so that it won't go into the stops. Check both sides of the paver.

This side slope or crown is sensed by reference to a (vertical) pendulum. The automatic controls raise or lower one side of the screed to keep the side slope at the amount set on a dial. When the side slope changes, as it does approaching the superelevation on a road curve, the “automatic” side slope controls must be worked manually.

Automatic controls do a good job when they work properly. There should be little need for tinkering with the controls, except when a side slope is changing. Even so, inspectors and operators must remain alert to what the paver is doing. When the controls go haywire you can have a sorry mess in a hurry. The screed may jerk up and down, for instance, causing a long ripple in the pavement surface.

**Figure 6-4 Checking pavement thickness**

**Paver Inspection**

The Standard Specifications require pavers to have certain equipment, but they do not describe the equipment’s required condition. Instead they require pavers to be capable of producing a pavement with a specified grade, smoothness, etc. (Highways 401-3.05, Airports 401-4.4). A paver in bad condition won’t produce such a mat and is unacceptable.  The following checklists will help to inspect pavers.

**Paver Inspection Checklist**

The tractor unit should be checked for:

- ❑ Loose or worn tracks
- ❑ Frozen or worn rollers
- ❑ Clutch adjustments
- ❑ Clean slat feeders and conveyor belting
- ❑ Tire pressure (rubber-tired pavers)
- ❑ Engine performance and governor

Tamper type screeds should be checked for:

- ❑ Worn Tampers
- ❑ Tamper clearance from nose of screed plate (0.015" – 0.020")
- ❑ Tamper stroke (1/8" total and 1/64" below screed)

Oscillating type screeds should be checked for:

- ❑ Parallel and true alignment of oscillating screed and vibrating compactor
- ❑ Vibrators adjusted and working.  Paving crews should not be allowed to turn the vibrator off.

Either type screed should be checked for:

- ❑ Warped or worn-thin screed plate.  A string line can be used to check the screed surface.
- ❑ Uniform heater action
- ❑ Both ends of box closed
- ❑ Augers working and correctly spaced
- ❑ Thickness and crown controls working
- ❑ Screed extensions have full augers and vibration
- ❑ Counter-flow augers used to push material under the center box are oriented correctly

### *6.2.3 Pickup Machines*

Some contractors use belly dump trucks, which dump hot mix in windrows on the grade.  Then a pickup machine (also called a windrow elevator) is used to deposit the mix into the paver.  The windrows of hot mix must be the right size and in the correct location to give the proper spread without segregation.

A skilled dump man is important to good windrowing.  He must tell the truck drivers where to start dumping and how fast to drive and know when and if to adjust the truck gate widths.

Windrows tend segregate in their long direction, with too much coarse material at the end.  Long, thin windrows that overlap help compensate for the lineal segregation.  Windrow length is a function of vehicle speed and belly gate width.

Windrowed asphalt concrete cools rapidly.  You must carefully monitor the temperature of the windrows.  If they are cooling too rapidly the contractor may have to hold the mix in the trucks longer and slow plant production.  *Overheating the asphalt at the plant is not an acceptable solution to this problem.*

The pickup machine must pick up as much asphalt concrete as possible.  Paving mix left on the existing surface cools faster than the rest of the mix and may result in an area with low density.  It may also leave a

**Figure 6-5  Pickup Machine and Paver**

strip of segregated mix along each edge of the windrow.

### *6.2.4 Rollers*

Standard Specification for rollers is found in Highways 401-3.06 and Airports 401-4.5.

**Steel Wheel Rollers**

Steel wheel rollers have one powered steel drum and either a steering (guide) drum or rubber tired steering wheels. A scraper keeps the drum clean. A reservoir supplies water to wet the drum surface, which prevents asphalt pick-up. Diesel is *not* allowed as a drum wetting agent.

The weight on the drive drum should be at least 250 pounds per inch of width for breakdown and intermediate rollers. Usually less weight is used for finish rolling.

The pavement surface will be smooth only if the drum surface is smooth and true. The drum face should be checked with a strait edge or string line before paving to see if it is warped. Also look for pits in the drum surface. Check the pavement surface carefully, after rolling at the beginning of the project.

The transmission, brakes, and drum bearings must be in good condition. Wheel bearing wobble or rough starts and stops leave marks in the pavement.

**Figure 6-6 Steel Wheel Roller**

### Vibratory Rollers

Steel drum rollers used for breakdown rolling usually are equipped with vibrators. Both the frequency and the amplitude of the vibration can be varied to achieve the best compaction.

There should be at least ten downward impacts per foot of travel of the roller. This requires a minimum of 880 vibrations per minute for every mile per hour of roller speed. If the roller is moving too fast for the vibration rate, a short wavy pattern will appear in the asphalt surface. Use a straight edge to monitor this, and increase the frequency or slow the roller if it is a problem.

The vibration amplitude should be high enough to get the desired compaction. If set too high, however, the roller may bounce, break the aggregate and de-compact the mat. The manufacturer's recommendations should be followed. Usually low amplitude is used for pavements less than two inches thick, medium amplitude for pavements which are two to four inches thick, and high amplitude for pavements over four inches thick.

### Pneumatic (Rubber Tired) Rollers

Pneumatic rollers have smooth rubber tires instead of steel drums. They usually have two axles with three to five tires per axle. They should weigh 3000 pounds per wheel. The weight can be adjusted by adding ballast.

Between tires, tire pressures should not vary more than five psi. Some pneumatic rollers have an air system that automatically adjusts the tire pressure to a given setting that is controlled by the operator. All of the tires are connected to this air system and should be the same air pressure, unless a tire has been punctured or an air line damaged. A soft tire leaves a ridge of uncompacted asphalt, which may become a string of potholes a few years later.

Pneumatic rollers are generally used for intermediate rolling. They work the aggregate in a kneading action, which provides a more tightly knit mat than can be obtained by a steel drum roller. When used for intermediate rolling tire pressure should be about 90 psi when hot and 70 or 75 psi when cold.

Pneumatic rollers have independent wheel suspension. They find weak spots and holes in the base course that a steel wheel roller would bridge over. This is especially beneficial in compacting leveling courses on irregular surfaces or in wheel ruts.

Fresh asphalt concrete sticks to cold tires. Sticking may be a problem the first few minutes until the tires heat up. Skirts around the base help prevent heat loss from the tires, and are especially helpful in cold and windy weather. If a pneumatic roller continues to pick up asphalt it is because the tires are still too cold. The problem can be alleviated by working the roller closer to the paver (this may require the breakdown roller to work closer to the paver as well) or by improving the skirts so more heat is held around the tires.

**Roller Inspection Checklist**

- ❑ Number of rollers adequate for the job
- ❑ Weight of rollers adequate and/or meets specs
- ❑ Rollers start and stop smoothly
- ❑ Steel drums not warped or pitted
- ❑ Drums have scrapers and are wetted with water
- ❑ Pneumatic roller tires have smooth treads
- ❑ Tire pressures differ by less than 5 psi

**Figure 6-7 Pneumatic Roller**

## 6.3. Placement

Standard Specifications for placement are found in Highways 401-3.12 and Airports 401-4.10.

The base and prime (or for old pavement and tack) must be inspected just before paving. Any oil puddles, soft spots, or potholes must be corrected before paving begins. Asphalt concrete must not be placed on a wet, frozen, or unstable base. Air temperature must be at least 40$^{o}$F (Highways 401-3.01, Airports 401-4.1 for 3” or more).

Before paving the contractor should determine what the "loose depth" of uncompacted material is needed to produce the desired compacted depth. Loose depth is usually about 25% more than compacted depth.

The screed should be set on blocks of loose depth thickness when starting on an unpaved grade. When starting paving against a transverse joint, the screed is set on boards resting on the end of the old pavement. The boards should be as thick as the difference between loose and compacted depth. This assures that the paver places the full loose depth when starting.

Airport projects require test strips to assure that pavement produced will meet specifications. Test strips may be required on highway projects too.

The first strip paved on airport projects (after the test strips) is normally the highest part of the surface. On a crowned runway or taxiway, this is along centerline. On both, airport and highway projects, the contractor must have a stringline, curb or other means to align the paving. The screed must be heated before mix is added to the paver.

**Figure 6-8 Paver in Operation**

A bump forms every time the paver stops, so it is desirable to have the paver keep moving continuously at a uniform speed. A balance between paver speed, plant output, the number of trucks and the haul distance is needed to accomplish this. Trucks should be dispatched from the plant at a uniform rate during continuous paving so that the paver speed can be set to maintain a continuous operation.

Trucks should not jolt the paver when they back up to it, or a bump in the mat may result. The rollers on the paver should push against both sets of rear wheels on the trucks.

Coarse aggregate tends to roll to the tailgate of a truck. Trucks should be unloaded in a surge, which minimizes this potential cause of segregation.

Keeping the paver's hopper partially full at all times also reduces the potential for segregation. Any coarse aggregate, which rolls to the tailgate of a truck, drops into the hopper first. If the hopper is empty the coarse aggregate will all be fed to the screed at the same time. A line of coarse (segregated) material across the mat will result. If the hopper is partially full the coarse aggregate tends to mix back in with the rest of the asphalt concrete.

The paver should place the mix wherever possible. If it must be placed by hand, it should be shoveled to the required location. Flinging the mix with a shovel or raking it for long distances causes segregation. Surface tolerance and segregation require special care whenever pavement is placed by hand.

### *6.3.1 Hand Raking*

Hand raking should not be done unless absolutely necessary. The most uniform surface texture can be obtained by keeping the handwork behind the screed to a minimum. The raker should be alert to a crooked edge on the mat so he can straighten it immediately. He does this by either removing or discarding the mix that bows outside the edge line or by adding mix from the hopper if the edge of the mat is indented. He will occasionally need to work along the longitudinal joint. If the paver follows the guideline, the back work will not be necessary.

Surplus hot-mix should not be cast across the mat surface as this will result in non-uniformity of the surface texture, even after proper compaction is obtained.

## 6.4. Joints

The Standard Specifications for joints are found in Highways 401-3.14 and Airports 401-4.12.

### *6.4.1 Transverse Joints*

Transverse joints are placed wherever paving is ended and begun again at a later time. The cold pavement edge must be clean, tacked and in good condition. Two ways of forming a clean edge are illustrated in Figure 6-10. A lumber bulkhead must be placed just after the paver leaves, while the mat is hot. The end of the hot mat is cut to a clean, straight edge with shovels, the board placed against it, and the ramp formed against the board.

A somewhat similar joint can be made with paper in place of the board. Sawcut faces may be required by project specifications. They are made in cold mats just before the new pavement is laid.

The fresh mix at the joint should be “loose depth” (thicker than the previously compacted pavement). Inexperienced rakers may try to rake the hot asphalt concrete to the thickness of the cold mat. This may look better before the joint is rolled but results in a low spot along the joint after compaction.

Transverse joints should be rolled parallel to the joint (crosswise to the paving direction) before any other rolling begins on the new mat. Transverse joints must be compacted in static mode (with the vibrator off) since the vibrator may crack cold pavement.

### *6.4.2 Longitudinal Joints*

Longitudinal joints run in the direction of paving. They are generally weak spots in the pavement and should be kept out of high traffic areas whenever possible. On highway projects they must be placed at lane lines or centerline (401-3.14) (98). On airport projects paving strips are normally at least 25 feet wide, which minimizes longitudinal joints (660.14e).

Most longitudinal joints are formed by placing hot asphalt concrete against cold pavement. The cold pavement edge may need sweeping (especially if vehicles have driven on it) and must be tacked.
The new mat is placed with a one or two-inch overlap on the old mat, as shown in Figure 6-9. The coarse aggregate should be raked out of this excess and wasted. The remainder of the excess is pushed back to form a bump at the edge of the new mat, as the figure shows.

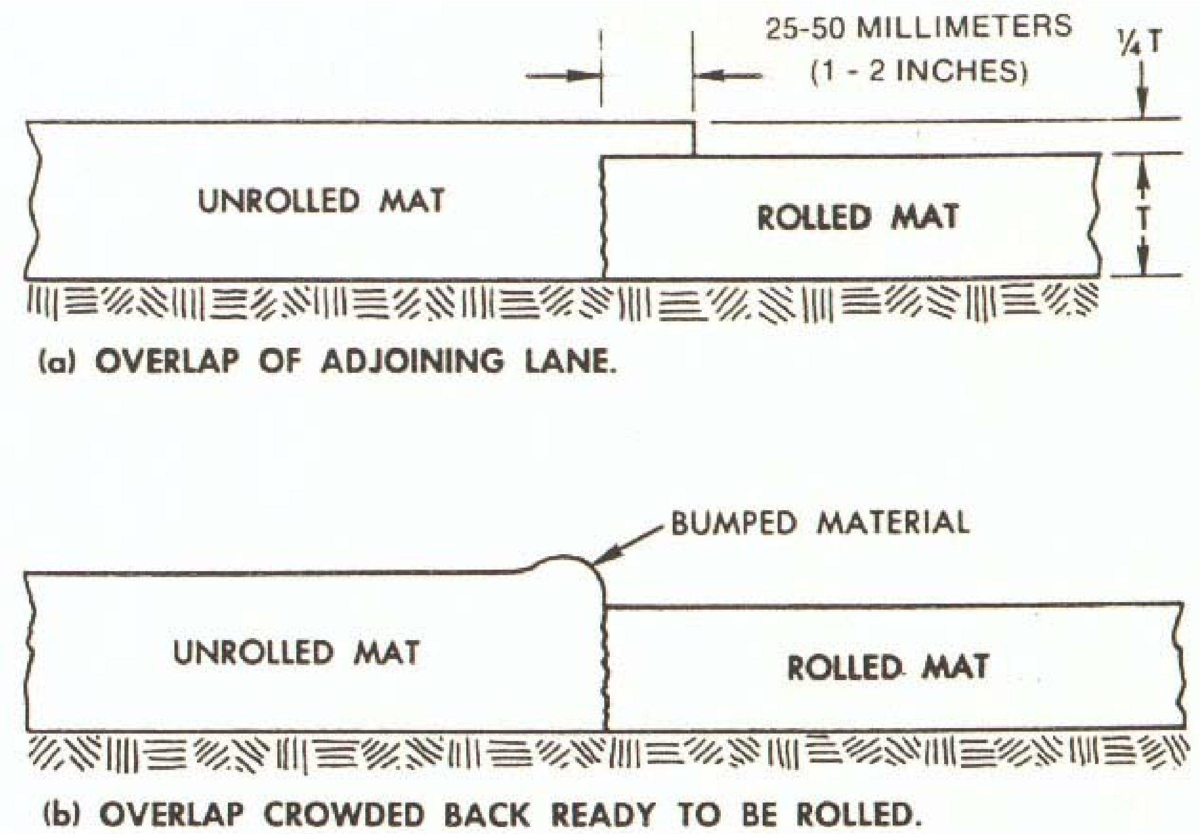



**Figure 6-9 Longitudinal Joint Formed against a Cold Mat**
**Courtesy of the Asphalt Institute**

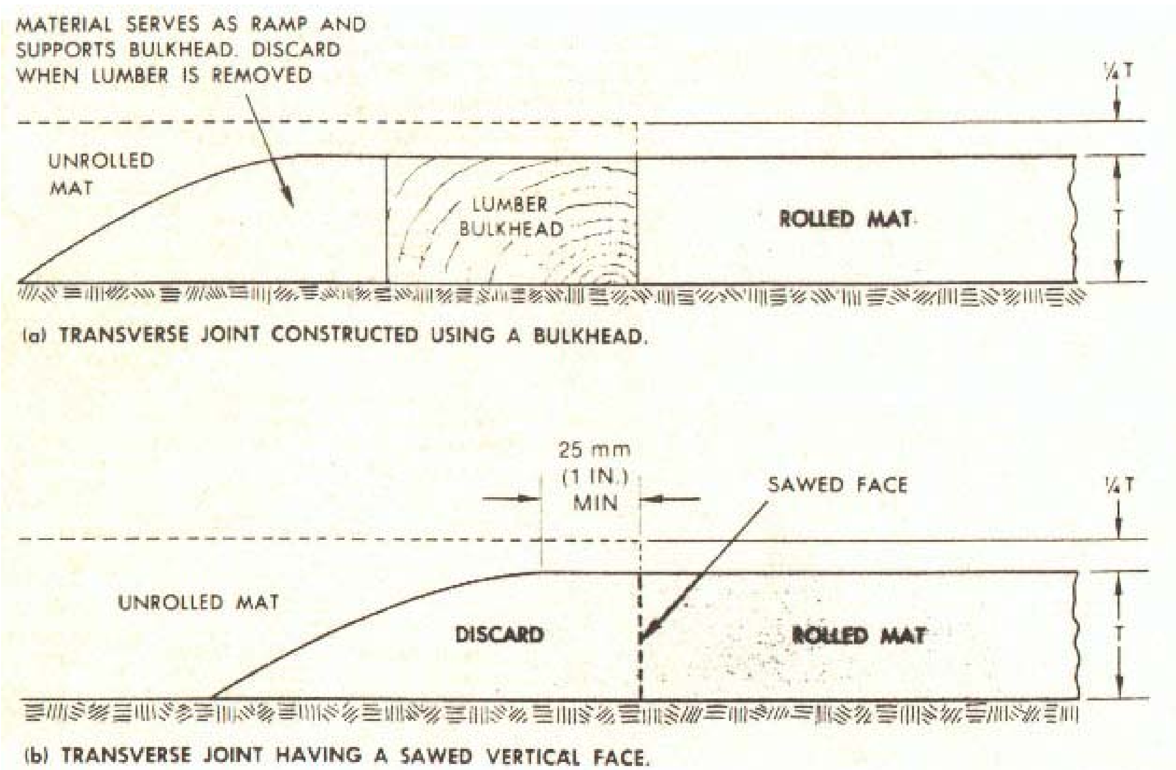



**Figure 6-10 Transverse Joint Construction**
**Courtesy of the Asphalt Institute**

*Many rakers work very hard to push back the material at the edge of the joint and fling it on to the hot mat. This is a poor procedure, which will result in a weak joint and an open surface texture along the joint.* If the raker does not pile up the correct amount of asphalt at the joint the asphalt at that point will be of lower density then the rest of the mat.

The breakdown roller then "pinches" the longitudinal joint with a small part of the drum on the old mat and part of the drum on the new mat. Rollers should operate in static mode, as for transverse joints. The joint should be pinched before the breakdown rolling on the rest of the mat.

If two pavers are working in adjacent lanes a hot longitudinal joint may be formed. In this case the rollers behind the first paver should leave the edge of the mat uncompacted. The rollers behind the second paver compact this edge along with the second strip as shown in Figure 6-11.

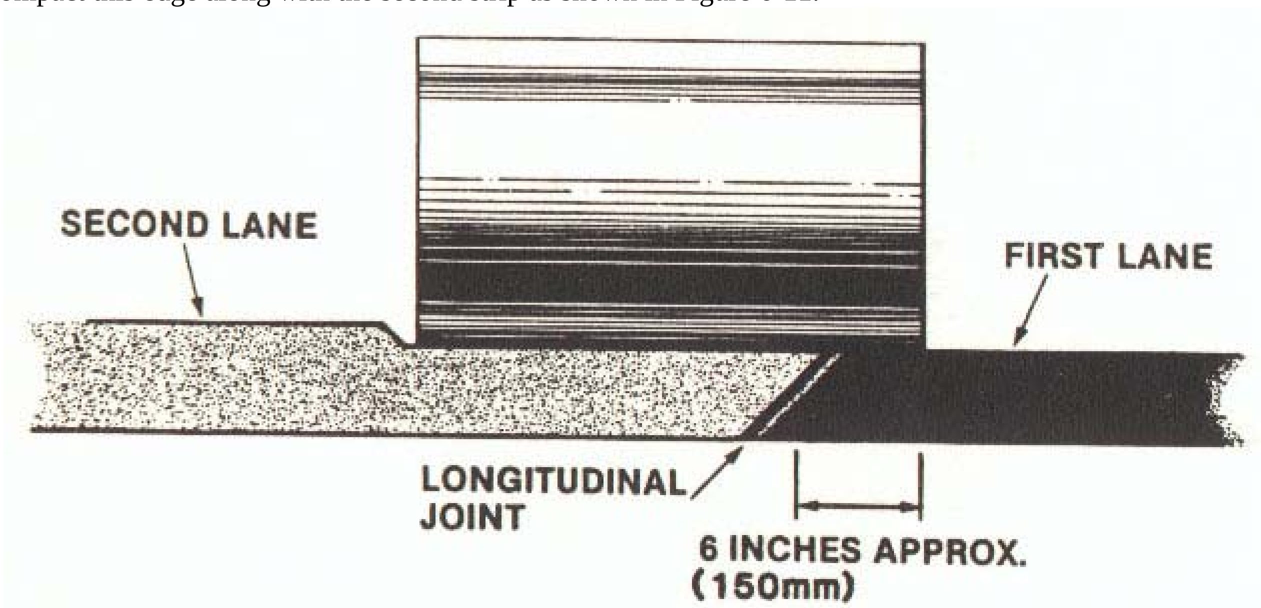



**Figure 6-11 Rolling a Hot Longitudinal Joint**
**Courtesy of the Asphalt Institute**

Surface smoothness tolerances are the same at joints as everywhere else in the mat. It is a good idea to check joints with a straightedge while the material is still hot; if there is a problem the rakers can often correct it.

## 6.5. Compaction

Standard Specifications for compaction are found in Highways 401-3.13 and Airports 401-4.11.

Proper compaction is important to the life of the pavement. It increases the strength and stability of the mix and closes gaps through which water and air can penetrate and cause damage. Insufficiently compacted pavements shove, rut and ravel from traffic and age faster than properly compacted mats. Over-compacted pavements flush (bleed liquid asphalt at the surface) and will lose stability. Over-compaction can also loosen the mat and check (crack) the pavement surface.

Asphalt pavements are at about 80% density as they leave the paver. The remainder of the compaction is mostly done by initial or "breakdown" rollers (usually vibratory steel wheel) and somewhat by intermediate rollers (usually pneumatic). The pavement is then rolled with a steel wheel finish roller to remove surface irregularities.

The amount of rolling required depends on several factors, including the size of the rollers, the paving mix and mat thickness, the surface temperature, and the weather.  One reason for placing test strips when paving first begins is to find out how many roller passes will be needed to get the required density.

Rollers should have the drive drum or wheels forward in the paving (that is, closest to the paver).  If a steering drum precedes the drive drum onto the mix, it can shove the asphalt instead of compacting it, as shown in Figure 6-12.  This is usually less of a problem with pneumatic rollers, but the drive wheels should be forward for them too.

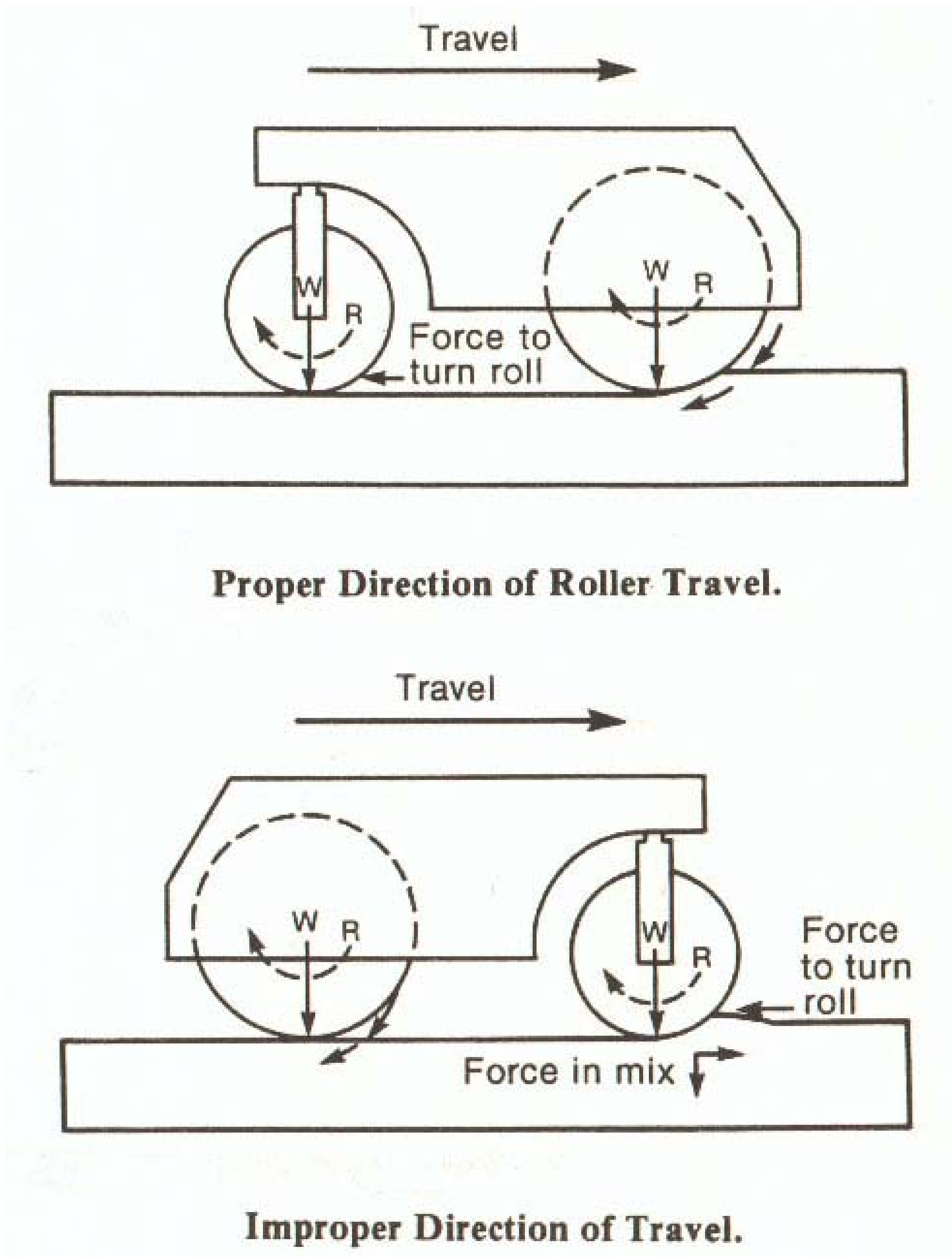


**Figure 6-12  Proper & Improper Rolling Direction**
**Courtesy of the Asphalt Institute**

On highways projects the most important place to achieve compaction is along the wheel paths where truck traffic will run.  Roller operators sometimes tend to roll the center of the lane more than the wheel paths.  As the inspector you should see that this doesn't happen.

**Temperature**

The asphalt concrete will "shove" (move out from under the roller) if the mix is rolled when it is too hot. This causes a rough surface. Rolling should begin as soon as the pavement has cooled enough to support the rollers without shoving. If the mat shoves below 275°F, you have poor mix design. Inform the Project Engineer immediately.

Figure 6-13 contains graphs, which show the approximate amount of time for compaction depending on the temperature of the base and the temperature of the mix at the screed. A software package named "PaveCool" is available, it factors in more variables to the cooling process in determining the amount of time for compaction.

Rolling a pavement after it has cooled below 175°F will provide little or no additional compaction, but may cause checking (cracking) of the surface.

**Initial or Breakdown Rolling**

Joints, if there are any, should be rolled first (see Section 6.4). Except for hot longitudinal joints, they should be rolled in static mode.

The main breakdown rolling is then done with a vibrator on (if there is one). The operator should drive the roller toward the paver and then return *on the same path*. He or she then moves the roller over for the next pass. Turning movements should be made on previously compacted areas to avoid roller marks that are difficult to remove. Succeeding passes should overlap previous ones.

Breakdown rollers should make two complete passes over the entire area (or more if needed to get the required density). Maximum roller speed should be 3 mph for vibratory rollers and 4 mph for static rollers.

Rolling patterns vary with the width of paving, the equipment, the number of passes needed, etc. The Standard Specifications for highways require that the passes progress from the lowest side of the mat to the highest, while for airport projects the rolling begins at the longitudinal joint and progresses across the mat.

**Intermediate Rolling**

Pneumatic rollers usually do intermediate rolling. Intermediate rolling should consist of three complete passes over the mat (or more if needed to get the required density). The rolling should progress across the mat in the same way as the breakdown rolling. Pneumatic rollers can sometimes help "heal" checking that may have occurred during breakdown rolling.

**Finish Rolling**

The finish roller removes any roller marks and smoothes surface imperfections. You should inspect the new pavement, using a straight edge as needed. Inform the roller operator if any areas need surface improvement. Occasionally the finish roller will crack the new asphalt as it rolls. This is usually caused when the top and bottom surfaces of the asphalt have hardened (cooled) while the center is still soft (hot). Typically this happens in the surface temperature range of 150-170°F. The finish roller needs to work either closer to or farther back from the paver to prevent this problem. The rubber-tired roller can usually drop back and heal these cracks if they occur.

**Traffic Control**

Traffic should be kept off the finished pavement until it cools to 140°F. Traffic on a hot pavement can cause bleeding, rutting, or checking, and may leave permanent marks in the surface. You should make sure that traffic control is maintained in the area, until regular traffic patterns can be resumed.

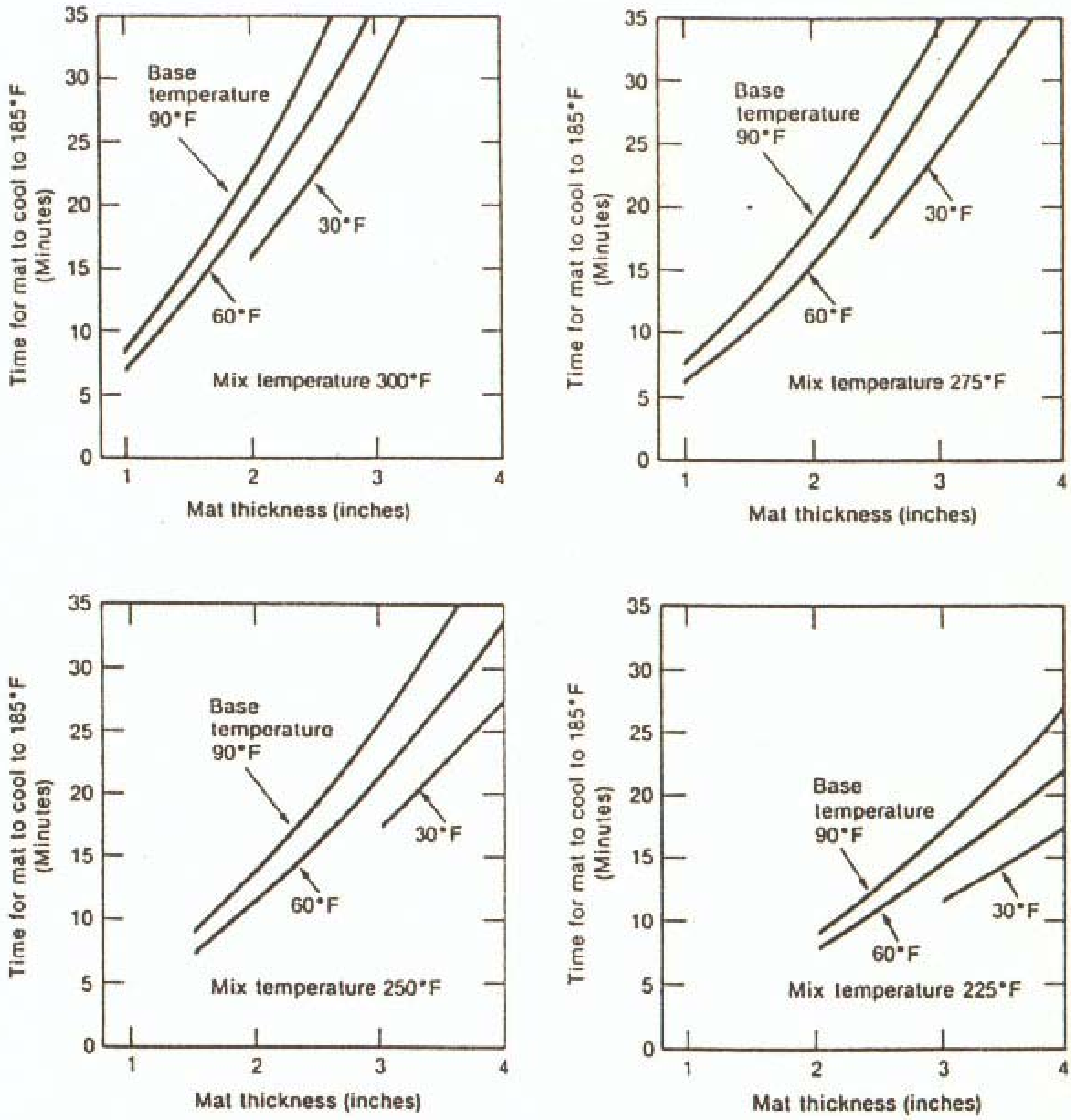



**Figure 1 — Times for asphalt to cool to 185°F.**

Wind velocity—10 knots. Atmospheric temperature—same as base.

Note: "Base Temperature" is the temperature of the surface upon which the asphalt mat is placed.

*185°F is the temperature of the mat measured ¼ to ½ inch below the mat surface. The average temperature of the entire mat thickness when this temperature is reached, is approximately 175°F.

On a subgrade (base temperature) of 30°F, placing of thicknesses less than those shown on the curves is not recommended.

**Figure 6-13 Time Allowed for Compaction**
**Courtesy of the Asphalt Institute**

## 6.6. Spread Calculations and Control

Asphalt concrete is expensive so quantities must be carefully controlled. Screed operators usually monitor paving by checking the mat thickness with a metal probe rod or other device. The mat just behind the paver must be thicker than shown in the plans (by about 25%) so that it will be the same as on the plans after the rollers compact it. One reason for test strips is to determine what the "loose depth" must be.

Paving inspectors should check loose depth periodically and record it in the Asphalt Concrete Field Book (Paving Log). This procedure isn't very exact, however, nor does it directly monitor what is actually paid for, which is almost always the *weight* of asphalt concrete, not the thickness or volume.

By carefully monitoring the *weight* of asphalt concrete used and the *area* over which it is spread, you can calculate how manylb/yd$^2$ are actually being used. This figure, called the "spread" or the "yield", can then be compared with the "theoretical" amount needed based on the plan thickness and the "target" density from the mix design.

The figures for yield calculations are kept in the Paving Log; a sample page is shown in Figure 6-15. You should also keep track of the total (cumulative) yield for the project and inform the Project Engineer of any potential quantity over-runs or under-runs.

Project Engineers may ask the inspector to keep the yield a little under the theoretical value (that is, to keep the pavement a little thinner than planned) as a contingency against an asphalt quantity over-run. This is undesirable, since pavement life is roughly proportional to the *square* of the thickness. Project funding constraints, however, may make this an economic necessity.

### *6.6.1 Spread and Yield Ratio Calculations*

The following information is needed to make the calculations:

| *Data* | *Source* |
|---|---|
| 1. Pavement thickness | Typical section (plans) |
| 2. "Target" density | Mix design sheet (Marshall Weight) |
| 3. Paver width | Measured in the field |
| 4. Distance paved | Measured in the field |
| 5. Asphalt weight tickets | Project scales via the truck driver |

**Theoretical Yield**

The first two figures are used to calculate the "theoretical yield" in pounds per square yard (#/sq.yd.). This can be done using the following formula:

*Theoretical yield = 0.75 x thickness (in) x target density (pcf)*

For a 2" thickness and a lab density of 152 pcf the theoretical yield is 0.75 x 2 x 152 = 228 #/sq.yd. This is the "Theo. Yield" shown on the sample Paving Log page (Figure 6-15).

If the lane width remains constant, the theoretical yield can be converted to pounds per station (#/sta). This saves calculating areas in the field. In the sample Paving Log, the lane width is 12', so there are 1200 square feet of pavement per station. The theoretical yield is therefore 1200/9 (sq.ft./sq.yd.) x 228 = 30,400 #/sta, which is the figure shown in the log.

**Actual Yield**

The truck driver should have his ticket marked with gross, tare, and net weights for each load of mix. Inform the contractor of any overweight trucks. The lane and stationing where the load is placed should be marked on the back of the tickets, along with the time. All the information needed to calculate the yield is thus on the ticket.

The first entry in the sample shows that a truckload of mix with a net weight of 30,880 pounds was used to pave 70 feet or 0.70 stations. The *actual* yield for that truck was 30880/0.70 = 44144 #/sta, which is rounded 44,110 in the log. The inspector has noted "off on yield" in the log since this is much more than the theoretical yield.

Usually the weight of four or five truckloads is added together and yield is calculated for the combined total. This has been done for the other loads recorded in the sample Paving Log.

If lane widths don't remain constant you can't calculate the theoretical yield in pounds per station. this happens when paving approaches, left turn pockets, gores, etc.

In these situations you must first calculate the area paved (in square yards). You can then calculate the actual yield in pounds per square yard. Alternatively, you can calculate the "theoretical" weight for the area and compare it to the actual weight used. This is simpler when a similar area occurs repeatedly on a job. You might calculate the "theoretical" weight needed to pave any residential approach on the project, for example. This can be done ahead of time, saving work in field.

**Yield Ratio**

The actual spread or yield divided by the "theoretical" one is called the *yield ratio*. If the actual yield is the same as the theoretical one the yield ratio will equal to 1.00. A yield ratio greater than one indicates a thicker pavement than planned. A yield ratio less than one indicates a thinner pavement than planned. The *yield ratio* for the first truckload in the sample log is 44,110/30,400 = 1.45. This indicates the pavement is 45% too thick (almost an inch).

### *6.6.2 Adjusting the Spread*

If the actual yield you calculate differs from the theoretical one, your distance estimate may be inaccurate. For an accurate estimate the paver must have the same amount of asphalt in it at the beginning and end of the yield calculation section.

Small errors in your distance are less significant on longer sections. Don't ask for thickness adjustments based on the yield for a single truckload. But if the yield is consistently high after several loads the pavement is being placed too thick. Similarly, if the actual yield is consistently low, the pavement is too thin.

When this happens the screed operator should adjust the thickness controls. It takes as much as 50 feet for the paver to completely react to an adjustment. Let the screed stabilize to the new conditions before making a new yield calculation to check the adjustment. Making adjustments too rapidly can create a bump in the mat. Limit adjustments to ¼ turn in 50 feet.

The point here is that you have to control the spread without demanding constant tinkering with the controls. Checking the yield at 1000-foot intervals is usually adequate to maintain depth control after the first few loads of the day. Jacking the screed up and down will result in rough pavement as well as destroy your credibility.

Remember that *you must not operate the screed controls yourself*. If you do, the Department will be held responsible for any improper work rather than the Contractor. If the screed operator will not correct the asphalt thickness problems contact the paving foreman and the Project Engineer.

## 6.7. Inspecting the Finished Mat

The main areas of concern in the finished mat are the final *density*, the surface *smoothness*, and the surface *texture* (appearance).

Density testing is the materials inspector's responsibility, but you need to coordinate with the materials inspector to make sure the needed tests are done promptly so any problems can be corrected quickly.

Smoothness should be tested with a 16' straightedge for highway work (401-3.15) and 12' for Airports (401-5.2(f)(5)). The variation of the mat surface from the straightedge must not exceed 3/16" for highways or ¼" for airports in either the longitudinal or transverse direction. Smoothness tolerances are just as strict for joints as for the rest of the pavement.

It takes some experience to judge the appearance of a finished mat, but some problems are obvious. The texture of the mat should be uniform; that is, there should be no sign of segregation or raveling. There should not be pieces of wood, large stones, or other contamination in the mat, nor should there be "fat" (oily) spots or bleeding. There should be no cracking (checking) or tearing of the mat. The *Trouble Shooting Guide* (Appendix A) lists these and other common problems to look for, along with the most probable causes of them.

Defective areas of pavement must be marked, cut out, and replaced by the contractor. These patched areas, however, are almost never as high in quality as a pavement that is mixed and placed correctly in the first place.

Most defects in the finished mat can be avoided by careful inspection of the production and placement processes. Correcting defects is also easier the earlier in the process they are detected. If a consistent mix is produced, the pavement is placed in a dry weather on a firm base, and a good rolling pattern is established and followed, there should be no problem achieving required density. With good quality control, there should be no segregated or contaminated areas to be cut out and replaced. If the base is good and joints are properly built, the surface smoothness should be within tolerance.

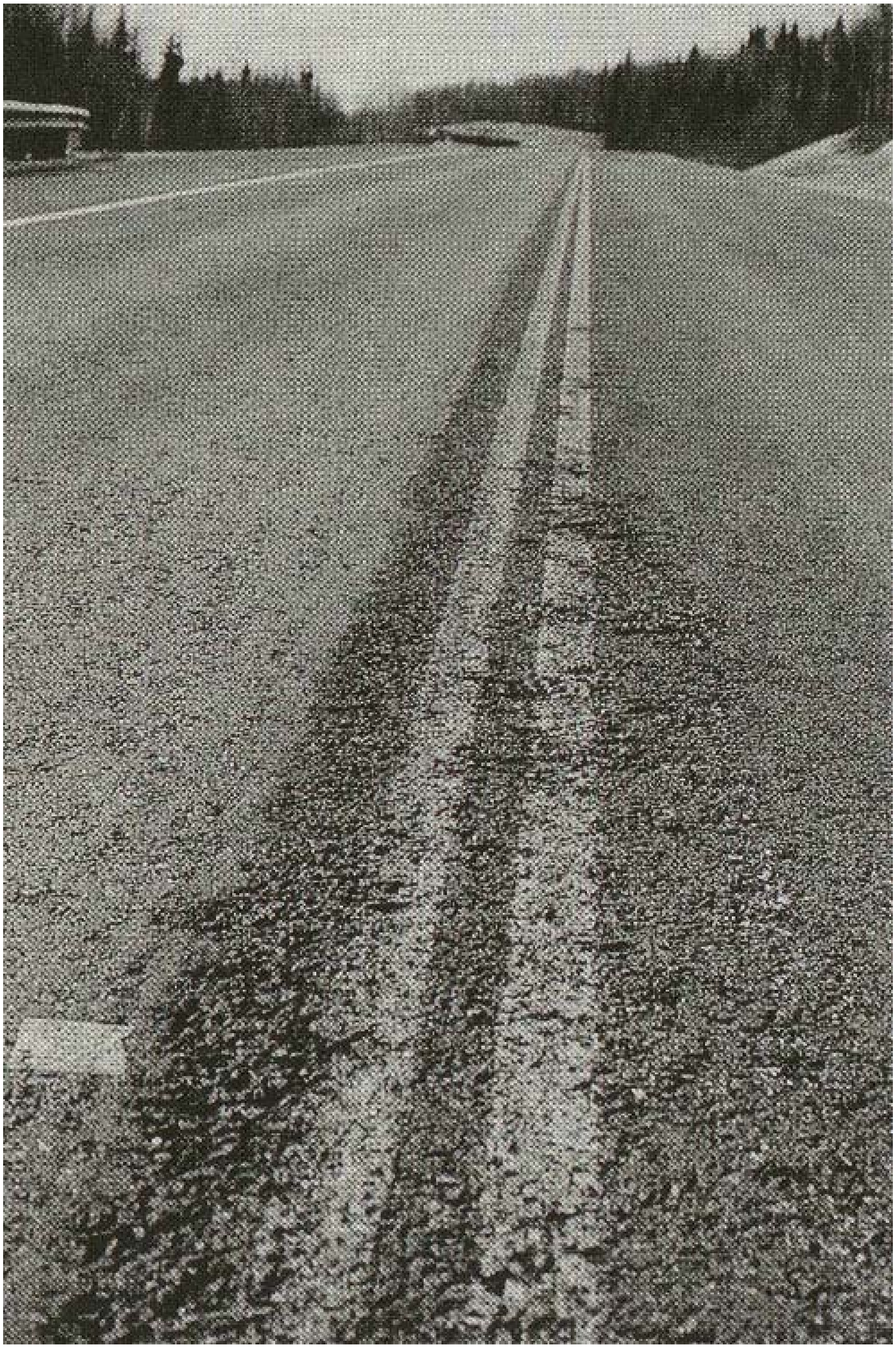


**Figure 6-14 Segregation Visible in the Finished Mat**

## SAMPLE PLANT MIX LOG

Date: 8/6/72 Lane: Left Width: 12' Theo. Yield = 228 #/sq. yd = 30,400 #/sta. 27

Number & Effect of Equations this Section: 1-758' Spec. Delivery Temp = 280 °F to 320 °F

| Sta. | Ticket Number | Load Wt. in # | Yield Wt. in # | Distance in Sta. | Yield #/Sta. | Temp °F | Time of Day | - - - Loose Depths or Remarks - - - |
|---|---|---|---|---|---|---|---|---|
| 1005+45 | | | | | | | | |
| | 1649 | 30,880 | 30,880 | .70 | 44,110 | 295 | 5:32 A | 2⅝, 2¾, 2⅝ Off on Yield |
| 1004+75 | | | | | | | | 61° Clear |
| | 1650 | 28,960 | | | | | | |
| | 1651 | 29,490 | | | | 292 | | |
| | 1652 | 30,290 | | | | | | |
| | 1653 | 30,420 | | | | 284 | | |
| | 1654 | 28,780 | | | | | 6:00A | |
| 999+60 | | | 147,940 | 5.15 | 28,730 | | | |
| | 1655 | 29,020 | | | | | | |
| Equa. | 1656 | 28,720 | | | | 296 | | Equa. = 998+50 Ahd / 990+92 Bk -758' |
| | 1657 | 28,880 | | | | | | |
| | 1658 | 30,660 | | | | 295 | 6:30A | 66° Clear Last Load |
| 988+70 | | | 117,280 | 3.32 | 35,330 | | | |

Checked by: Ted King 8/8/72 Phil Morris 8/6/72

**Figure 6-15 Sample Plant Mix Log**

25D-186
(5/83)

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES

1 Print entries in ink.
2 Original remains in book.

INSPECTOR'S DAILY REPORT

FMS No. B59402

Project No: RS-0750(4)

Project Name: Denali Highway, Maclaren River West

Weather: Sctd clouds, low 70's, calm

Shift: 7:00 A.M. to 6:30 PM

Contractor's Representative and Title: R. Malone, Foreman

**Contractor's Equipment**

| No | Description or Type | Size or Capacity | Hours Worked | Hours Stdby | Hours Down | Remarks |
|---|---|---|---|---|---|---|
| 1 | Barber Green Paver | SA-141 | 4 | | | |
| 1 | Hyster Roller 8-12t | C-350B | 4½ | | | |
| 1 | Pneumatic Roller | C-550A | 9 | 1½ | | |
| 1 | CAT Grader | 12E | 11 | | | |
| 1 | Ford Tractor | 420 | 4 | | | |
| | w/ Power Broom | 6' | | | | |
| 1 | GMC Flatbed | 2 ton | 1 | | 10 | Brakelines |
| 3 | End Dumps | 10 yd. | 11 | | | |
| 1 | CAT Loader @ Pit | 966C | 11 | | | |

**Contractor's Work Force**

| No. | Classification/Duties |
|---|---|
| 1 | Foreman |
| 3 | Operators |
| 3 | Teamsters |
| 2 | Laborers |
| 2 | Flagmen |
| 1 | Operator @ Pit |

**Limits of Work/Material Placement**

| Item No | Description | Source (Limits) From | Source (Limits) To | Placement (Limits) From | Placement (Limits) To | Approx. Quantity | Sections/Work Completed & Accepted |
|---|---|---|---|---|---|---|---|
| 113(1) | Flagging | | | | | 21 M.H. | (2@7:30-6:30) |
| 203(5B) | Borrow "A" | Anther | Pit | 234~ | 248~ | 241 t. | |
| 301(1) | Base Course | Pit Stockpile | | 178~ | 227+50 | 171.4 t | 211~ to 227+50 |
| 401(1) | Asphalt Concrete, Type II | | | 211+30 Rt & Lt. | 226+65 Rt & Lt. | 290.56t | |

DIARY: (Include report of day's operations, contractor's production rates and efficiency, unusual conditions or problems encountered, orders given and received, discussions with contractor, etc.)

Work began at 7:00 am. Two men swept sections of project where existing pavement remains with a power broom, 7:00-11:00. In gravel sections, placed base course to bring low areas to grade, Finishing with grader and pneumatic roller, in morning. Continued with one truck and grader working on low shoulder areas through afternoon.

Commenced placement of asphalt pavement leveling course at 2:30 p.m., through end of shift. Approximately one day of leveling work remaining. Even with short haul from Contractor's batch plant at pit, 2 trucks not enough to keep paver going steady - delays of 5 to 15 minutes waiting for trucks. Discussed delays with Foreman relative to upcoming overlay work - he figures 3 trucks will keep paver moving without delays/stops.

Two Flagmen used with on-road operations, 7:30-6:30

Date 6-28-82 Inspector's Signature: [signature] Page No.: 27

00601

**Figure 6-16 Sample Inspector's Daily Report**

# 7. Open-Graded and Recycled Asphalt Concretes

## 7.1. Open-Graded Asphalt Concrete

Open-graded hot mix asphalt concretes are used as friction surfaces to reduce vehicle hydroplaning. They are generally placed as overlays on new or existing pavements. Open-graded asphalt concrete is made with a relatively large proportion of coarse aggregate and a small proportion of fine aggregate. This leaves voids (openings) in the mix, which allow water to drain. This, combined with the coarse surface texture, provides a skid resistant surface. The coarse material provides the structural strength of the pavement. The fines, combined with the asphalt cement, coat the coarse aggregate and cement it together. Open-graded asphalt concrete typically contains 20% or more air voids.

### *7.1.1 Construction Methods*

Construction requirements for open-graded asphalt concretes are given in the Special Provisions of the contract.

Open-graded pavements tend to ravel if not built correctly. In an open-graded asphalt concrete the aggregate is coated with a very thick film of asphalt cement. A hard grade of asphalt cement applied at a low temperature is used to get this thick coating. The maximum temperature listed in the mix design is very important. Mix temperatures above this temperature will result in a thin asphalt cement coating on the aggregate and raveling will occur.

The CSS-1 tack coat application rate for an open-graded asphalt is generally double that of a normal pavement 0.10 to 0.20 gallon per square yard. This helps secure the aggregate to the existing pavement and prevent raveling.

Nuclear density tests cannot be made accurately on open-graded mixes. A compaction methods specification should be in the special provision. The methods specification will list the size and type of rollers to be used and the number of passes that are required.

A fog seal of CSS-1 is generally placed on top of open-graded asphalt to bind the aggregate together and prevent raveling.

## 7.2. Recycled Asphalt Pavements

Recycling can produce a good quality pavement at a considerable economic savings. It also reduces the amount of asphalt and high quality aggregate needed.

### *7.2.1 Reclaimed Asphalt Pavement (RAP)*

Reclaimed asphalt pavement (RAP) is old asphalt pavement, which is broken up either by heavy equipment or by special cold planing machines. Generally RAP is screened and oversized material reprocessed prior to reuse.

Asphalts "age" over time. The asphalt cement in old pavements is harder and more brittle than when it was new. Recycling agents are added to RAP to restore desired properties to the old asphalt cement. Recycling agents are organic compounds, usually a light grade of asphalt (or an emulsion) with special additives.


**Figure 7-1  Cold planer at work**

RAP should not be stockpiled more than 10 feet high.  Above this height the weight will cause the particles to stick together.  For the same reason heavy equipment should not be allowed on the stockpile.  RAP tends to hold moisture, so stockpiles may need to be covered in rainy weather.

### *7.2.2 Hot Asphalt Recycling*

Hot mix recycling is a process where reclaimed asphalt pavement (RAP) is combined with a recycling agent, new asphalt cement, and new aggregate in a central mixing plant.

Asphalt plants have to be modified to permit recycling.  RAP contains old asphalt cement, which will burn if exposed to the burner flame in the dryer.  Batch plants operate in the normal manner at least as far as the hot elevator.  The new aggregate, however, is heated to a higher temperature than normal.  RAP is sometimes metered into this aggregate into the weigh box from its own special steep sided bin.  The heat from the aggregate heats the RAP to the desired temperature.

The recycling agent is added to the pugmill with the asphalt.  Pugmill mixing and laydown is done in a normal manner.  Batch plants can handle about 30% RAP and 70% new material.

In a dryer drum plant, clean aggregate is brought into the drum and heated in the normal manner.  RAP is fed into the midpoint of the drum along with the asphalt and recycling agent.  The drums used in these plants may be longer than normal.

Laydown and compaction of hot mixes containing RAP are the same as for conventional mixes.


**Figure 7-2 Belt to feed RAP into dryer drum**

### *7.2.3 Cold Mix Recycling*

Cold mix recycling may be done in place or at a central plant. Recycling agents and new materials may or may not be added to the RAP.

If no new asphalt cement is used, the relaid material forms a sort of asphalt treated base course, which “sets up” to some degree under compaction and traffic, especially in warm weather. Cold mix RAP can be used without additives as a surfacing course for gravel roads. This is frequently done in the Anchorage area.

If new asphalt cement is added in the cold mix recycling process, it is normally an emulsion. Cold mixes using RAP, recycling agents, emulsions, and new aggregate can be designed, placed, and compacted in a manner similar to hot asphalt pavements using all new materials.

# 8. Appendix A Trouble-Shooting Guide

**Hot-Mix Asphalt Pavements**

*Preface*

Working with hot-mix pavement is an art, not a science. The answer to every hot-mix problem cannot be found solely in a series of charts. However, the following information, coupled with common sense, experience and communication between the producer and project owner, will provide guidance for resolving most hot-mix problems.

## 8.1. Possible Causes of Deficiencies in Plant-Mix Pavements

| **Problems with asphalt mixture** / **Types of deficiencies that may be encountered in producing plant-mix paving** | Poor quality aggregate | Aggregate too wet | Inadequate bunker separation | Aggregate feed gates not properly set | Over-rated drier capacity | Drier set too steep | Improper drier operation | Temperature indicator out of adjustment | Aggregate temperatures too high | Worn out screens | Faulty screen operation | Bin overflows not functioning | Leaky bins | Segregation of aggregates in bins | Carryover in bins due to overloading screens | Aggregate scales out of adjustment | Improper weighing | Feed of mineral filler not uniform | Insufficient aggregates in hot bins | Improper weighing sequence | Insufficient asphalt | Too much asphalt | Faulty distribution of asphalt to aggregates | Asphalt scales out of adjustment | Asphalt Meter out of adjustment | Undersize or oversize batch | Mixing time not uniform | Improperly set or worn paddles | Faulty dump gate | Asphalt and aggregate feed not synchronized | Occasional dust shakedown in bins | Irregular plant operation | Faulty sampling |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mixture appears dull in truck | | | | | | | A | A | A | | | | | | | | | | | | A | | | | | | | | | | | A | |
| Mixture steams in truck | A | A | | | A | A | A | A | | | | | | | | | | | | | | | | | | | | | | | | A | |
| Mixture smokes in truck | | | | | | | A | A | A | | | | | | | | | | | | | | | | | | | | | | | A | |
| Mixture too fat | | | | | | | | | | | | | | | | B | B | A | A | | | A | A | B | C | B | | | | C | | A | |
| Mixture too brown or gray | | A | | | A | A | A | A | | | A | | | | | | | | | | A | | | B | C | B | | | | C | | A | |
| Mixture Burned | | | | A | | | A | A | A | | | | | | | | | | | | | | | | | | | | | | | A | |
| Mixture flattens in truck | | | | | | | | | | | | | | | | | | | | | | A | A | B | C | B | | | | C | | A | |
| Mixture in truck fat on one side | | | | | | | | | | | | | | | | | | | | B | | | A | | | B | B | A | | | | A | |
| Mixture in truck not uniform | | | | | | | | | | | A | A | A | A | A | B | B | A | A | B | | | A | B | C | | B | A | B | C | A | A | |
| Large aggregate uncoated | A | | | | A | A | A | A | | | | | | | | | | | | | A | | A | B | C | B | B | A | | C | | A | |
| Free dust on mix in truck | A | A | | | | | | | | | | | | | | | | | | B | | | | | | | | | B | | | | |
| Free asphalt on mix in truck | | | | | | | | | | | | | | | | B | B | | | | | A | A | B | C | B | | A | | C | | | |
| Truck weights do not check batch weights | | | | | | | | | | | | | B | | | B | B | | | B | | | | | | B | | | | | | | |
| Uniform Temperatures difficult to maintain | | A | | | A | A | A | A | | | | | | | | | | | | | | | | | | | | | | | | A | |
| Excess fines in mix | A | | A | A | | | | | | | A | A | A | A | A | B | B | A | A | | | | | | | B | B | | | C | A | | A |
| Agg. Grad. doesn't check job mix formula | A | | A | A | | | | | | A | A | A | A | A | A | B | B | A | A | | | | | | | B | | A | A | C | A | | A |
| Asphalt cont. doesn't check job mix formula | A | | | A | | | | | | | | | | | | B | B | | | | A | A | A | B | C | B | B | A | | C | | | A |

A = Applies to batch and drum-mix facilities  B = Applies to batch facilities  C = Applies to drum-mix plant facilities

## 8.2. Factors Influencing Tender Pavements

| Material or Mixture Variable | *8.2.1.1 Discussion* |
|---|---|
| ***8.2.2 Aggregate Gradation*** | Avoid large proportions of sandsize particles. Minus No. 200 material should be greater than 4 percent.<br><br>Mineral filler can add stability to a mixture. Small maximum size aggregate mixes have a greater tendency to be tender |
| ***8.2.3 Aggregate Type*** | Smooth, rounded aggregate particles are most likely to produce a tender mixture. Sand sized crushed particles can add stability to a mixture. |
| ***8.2.4 Asphalt Properties*** | Highly temperature susceptible asphalt's can aggravate tenderness problems. Slow setting asphalt's can cause tenderness problems. Less than anticipated hardening of the asphalt during hot mix hardening can cause tenderness. |
| ***8.2.5 Asphalt Content*** | High asphalt content can aggravate tenderness problems. High fluids content (asphalt plus water) can cause tenderness problems |

| Material or Mixture Variable | *8.2.5.1 Increasing Tenderness*<br>1 2 | 3 4 | 5 6 | 7 8 | 9 10 |
|---|---|---|---|---|---|
| ***8.2.6 Aggregate*** | | | | | |
| Shape | Angular | Subangular | Subrounded | Subrounded | Rounded |
| Texture | Very Round | Rough | Smooth | Smooth | Polished |
| Maximum Size | >3/4 – inch | <5/8 – inch | <1/2 – inch | <3/8 – inch | <1/4 – inch |
| -#30 to +#100* | Suitable | | Excessive | | Large Excess |
| -#200 | >6% | 5% | 4% | 3% | <2% |
| **Asphalt Cement** | | | | | |
| Content | Low | | Optimum | | High |
| Viscosity | High | | Medium | | Low |
| Penetration | Low | | Medium | | High |
| Hardening Index | High | | Medium | | Low |
| Temp. Susceptibility | Low | | Medium | | High |
| Setting characteristic | Fast | | Medium | | Slow |
| Asphaltene Content | >20% | | 10 to 20% | | <10% |
| **Mixture** | | | | | |
| Softening Additives | None | | Some | | Much |
| Moisture Content | >0.5% | | 1 to 2% | | >2.5% |
| **Construction** | | | | | |
| Rolling Temperature | Low | | Medium | | High |
| C-value (41) | >50 | | 30 – 50 | | <30 |
| Ambient Temp. | <70 | 80 | | 90 | >100 |

*Suitable quantity depends upon design gradation. Rounded sand size particles can produce a critical mixture.

(Reference No. 2)

## 8.3. Mat Problem Trouble Shooting Guide

Causes

| Mat problems | Cold mix temperature | Variation of mix temperature | Moisture in mix | Mix segregation | Improper mix design (asphalt) | Improper mix design (aggregate) | Parking roller on hot mat | Reversing or turning too fast of rollers | Improper rolling operation | Improper base preparation | Truck holding brakes | Trucks bumping finisher | Improper mat thickness for maximum aggregate size | Improper joint overlap | Sitting long period between loads | Grade reference inadequate | Grade control wand bouncing on reference | Grade control hunting (sensitivity too high) | Grade control mounted incorrectly | Vibrators running too slow | Screed extensions installed incorrectly | Screed starting blocks too short | Incorrect nulling of screed | Kicker screws worn out or mounted incorrectly | Feeder gates set incorrectly | Running hopper empty between loads | Moldboard on strikeoff too low | Cold screed | Screed plates not tight | Screed plates worn out or warped | Screed riding on lift cylinders | Excessive play in screed mechanical connection | Overcorrecting thickness control screws | Too little lead crown in screed | Too much lead crown in screed | Finisher speed too fast | Feeder screws overloaded | Fluctuating head of material |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poor mix compaction | X | X | X | | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Roller marks | | X | | | | | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bleeding or fat spots in mat | | X | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mat shoving under roller | | X | X | | X | X | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Transverse Cracking (checking) | | X | X | | X | X | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Poor transverse joint | X | | | | | | | | X | | | | | | | | | | | | | + | + | | | | | | + | | + | + | | | | | + | |
| Poor longitudinal joint | X | | | | | | | | X | | | | | + | | | + | + | + | | | | | | | | | | | | + | | + | | | | + | + |
| Poor precompaction | X | | | | | | | | | X | | | X | | | | | | | + | | | | | | | | | | | + | | | | | + | | |
| Auger shadows | | | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | |
| Screed not responding to correction | X | X | | | | | | | | | | | X | | | | | | + | | | | | | | | | | + | | + | + | | | | + | | |
| Screed marks | | | | | | | | | | | X | X | | | | | | | | + | + | | | | | | | | | | | + | | | | | | |
| Mat texture-nonuniform | X | X | | X | X | X | | | | X | | | X | | + | | | | | | + | | | | | + | | + | + | + | + | | | | | + | + | + |
| Tearing of mat—outside streaks | X | | | | | | | | | | | | | | | | | | | | | | | | + | | + | + | | + | | | | | + | | | |
| Tearing of mat—center streak | X | | | | | | | | | | | | | | | | | | | | | | | + | + | | | + | | + | | | | + | | | | |
| Tearing of mat—full width | X | X | X | X | X | X | | | | | | | X | | | | | | | | | | | | | | | + | | + | | | | | | + | | |
| Wavy surface—long waves | | X | | X | | | X | X | | X | X | X | | | + | + | | | + | | | | | | + | + | | | | | + | + | + | | | | + | + |
| Wavy surface—short waves (ripples) | | X | | X | X | X | | | X | X | | | | | | + | + | + | + | | | | | | | | | | + | | + | + | | | | + | + | + |

1. Find the problem above. 2. +'s indicate causes related to the paver. X's indicate other problems to be investigated. Note: Many times a problem can be caused by more than one item, therefore, it is important that each cause listed is eliminated to assure solving the problem.Possible

## 8.4. Causes of Imperfections in Finished Pavements

| **Types of pavement imperfections** / **Possible causes of imperfections in finished pavement.** | Insufficient or non-uniform tack coat | Improperly cured prime or tack | Mixture too coarse | Excess fines in mixture | Insufficient asphalt | Excess asphalt | Improperly proportioned mixture | Unsatisfactory batches in load | Excess moisture in mixture | Mixture too hot or burned | Mixture too cold | Poor spreader operation | Spreader in poor condition | Inadequate rolling | Rolling at the wrong time | Over-rolling | Rolling mixture when too hot | Rolling mixture when too cold | Roller standing on hot pavement | Overweight rollers | Roller vibration | Unstable base course | Excessive moisture in subsoil | Excessive prime coat or tack coat | Poor handwork behind spreader | Excessive hand raking | Labor careless or unskilled | Excessive segregation in laying | Faulty allowance for compaction | Operating finishing machine too fast | Mix laid in too thick course | Traffic put on mix while too hot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bleeding | | | | | | X | X | X | | | | | | | | | | | | | | | | X | | | | | | | | |
| Brown, dead appearance | | | | | X | | | | X | X | | | | | | | | | | | | | | | | | | | | | | |
| Rich or fat spots | | | | | | X | X | X | | | | | | | | | | | | | | | | X | | | | X | | | | |
| Poor surface texture | | | X | X | | | X | X | | | X | X | X | X | X | X | X | X | | | | | | | X | X | X | X | | X | | |
| Rough uneven surface | X | X | X | | | | X | X | | | X | X | X | X | X | | X | X | X | X | X | X | | | X | X | X | X | | X | | |
| Honeycomb or raveling | | | X | | X | | X | X | | | X | X | X | X | X | | | X | | | | | | | X | X | X | X | | | | |
| Uneven joints | | | X | | | | | | | | X | X | X | X | X | | X | X | | | | X | | | X | X | X | X | X | | | |
| Roller marks | | | | X | | X | X | | | | X | | | X | X | | X | X | X | X | | | | | | | X | | | | | |
| Pushing or waves | X | X | | X | | X | X | X | X | | | X | X | | X | | X | | | X | X | X | | | | X | | | | | X | X |
| Cracking (many fine cracks) | | | | X | X | | X | | | | | | | | X | X | X | | | X | | X | X | | | | | | | | | |
| Cracking (large long cracks) | | | | | | | | | | | | | | | | X | | | | X | | X | X | | | | | | | | | |
| Rocks broken by roller | | | X | | | | X | | | | X | X | X | | X | X | X | | | X | | | | | | | | | | | | |
| Tearing of surface during laying | | | X | | X | | X | | | X | X | X | X | | | | | | | | | X | | | | | | X | | X | | |
| Surface slipping on base | X | X | | X | | X | X | | X | | X | | | X | X | X | | X | | X | | X | X | X | | | | | | | | |

## 8.5. Effect of Construction Equipment and Construction Techniques on Asphalt Cement Properties

**Effect of Construction Equipment and Construction Techniques on Asphalt Cement Properties**

| Construction Related Factors | Usual Effect on Asphalt Cement Consistency | Mechanism |
|---|---|---|
| Drum Mixer Versus Batch Facility | Soften* | Lower mixing temperatures are utilized in drum mixers. Possible unburned fuel contamination. Low oxygen environment. |
| Vibratory Roller Versus Pneumatic | Harden | Vibratory equipment may not seal surface and pavement is permeable to air and water thus more rapid hardening during service. |
| Bag House Versus Wet Washer System | Usually Hardens | Bag house fines are returned to mix which often changes the apparent viscosity of the asphalt. |
| Transport of Asphalt Cement in Contaminated Transport | Soften | Residual products in transport (often-heavy fuel oil or cutback) soften asphalt cements. |
| Mixing of Asphalt Cement in Storage | Soften | Blending of same grade asphalt cement from two crude sources may chemically interact to form an out of grade product; separation of asphalts may also occur. |
| Use of Antistrip Chemical in Asphalt Cement | Soften | Chemical interaction usually results in softening of this asphalt. |
| High Mixing Temperature | Harden | Higher mixing temperatures promote more rapid oxidation and volatilization of asphalt. |
| Hot Storage of HMA | Harden | Prolonged storage of hot mixes will promote oxidation and volatilization of asphalt unless the bin has a perfect sealing system or sealed with the injection of inert gas. |

*Excessive hardening can occur if proper flight maintenance is not practiced and/or production quantities are low.

(Reference No. 4)

## 8.6. Summary Table of Influences of Compaction

| Summary Table of Influences of Compaction. | | |
|---|---|---|
| **Aggregate** | | |
| Smooth Surfaced | Low interparticle friction | Use light rollers<br>Lower mix temperature |
| Rough Surfaced | High interparticle Friction | Use heavy rollers |
| Unsound | Breaks under steel-wheeled rollers | Use sound aggregate<br>Use pneumatic rollers |
| Absorptive | Dries mix – difficult to compact | Use asphalt in mix |
| **Asphalt** | | |
| Viscosity | | |
| - High | Particle movement restricted | Use heavy rollers<br>Raise temperature |
| - Low | Particles move easily during compaction | Use light rollers<br>Lower temperature |
| | | |
| Quantity | | |
| - High | Unstable & plastic under roller | Decrease asphalt in mix |
| - Low | Reduced lubrication – difficult compaction | Increase asphalt in mix<br>Use heavy rollers |
| **Mix** | | |
| Excess Coarse Aggregate | Harsh mix – difficult to compact | Reduce coarse aggregate<br>Use heavy rollers |
| Oversanded | Too workable – difficult to compact | Reduce sand in mix<br>Use light rollers |
| Too Much Filler | Stiffens mix – difficult to compact | Reduce filler in mix<br>Use light rollers |
| Too Little Filler | Low cohesion – mix may come apart | Increase filler in mix |
| **Mix Temperature** | | |
| High | Difficult to compact – mix lacks cohesion | Lower mixing temperature |
| Low | Difficult to compact – mix too stiff | Raise mixing temperature |
| **Course Thickness** | | |
| Thick Lifts | Hold heat – more time to compact | Roll<br>normally |
| Thin Lifts | Lose heat – less time to compact | Roll before mix cools<br>Raise mix temperature |
| **Weather Conditions** | | |
| Low Air Temperature | Cools mix rapidly | Roll before mix cools |
| Low Surface Temperature | Cools mix rapidly | Raise mix temperature |
| Wind | Cools mix – crusts surface | Increase lift thickness |
| * Corrections may be made on a trial basis at the plant or job site. Additional remedies may be derived from changes in mix design. | | |
| | | (Reference No. 1) |

## 8.7. Pavement Distress and Possible Causes and Rehabilitation Alternatives

**Pavement Distress and Possible Causes and Rehabilitation Alternatives**

| Type of Distress | Possible Causes | Rehabilitation Alternatives |
|---|---|---|
| Rutting | Structural deficiency<br>Hot Mix Concrete mix design<br>Asphalt cement properties<br>Stability of pavement layers<br>Compaction (density) – all layers | Cold milling including profile requirements, with or without overlay<br>Heater scarification with surface treatment or thin overlay<br>Replacement (particularly applicable to corrugations in localized areas) |
| Raveling | Low asphalt content<br>Excessive air voids in Hot Mix Asphalt Concrete<br>Hardening of asphalt<br>Water susceptibility (stripping)<br>Aggregate characteristics<br>Hardness and durability of aggregate | Dilute emulsions or rejuvenating “fog seal”<br>Seal coat with aggregate<br>Slurry seal<br>Thin Hot Mix Asphalt Concrete overlay |
| Flushing (Bleeding) | High asphalt content<br>Excessive densification of Hot Mix Asphalt Concrete during construction or by traffic (low air void content)<br>Temperature susceptibility of asphalt (soft asphalt at high temperatures)<br>Excess application of “fog” seal or rejuvenating materials<br>Water susceptibility of underlaying asphalt stabilized layers together with asphalt migration to surface | Overlay of open graded friction course<br>Seal coat (well designed with good field control during construction)<br>Cold milling with or without seal coat or thin overlay<br>Heater-scarification with seal coat or thin overlay<br>Heat surface and roll-in coarse aggregate |
| Alligator Cracking | Structural deficiency<br>Excessive air voids in Hot Mix Asphalt Concrete<br>Asphalt cement properties<br>Stripping of asphalt from aggregate<br>Construction deficiencies | Seal coat<br>Replacement (dig-out and full depth Hot Mix Asphalt Concrete replacement in failed areas)<br>Overlay of various thickness' with or without special treatments to minimize crack reflection<br>Recycle (central plant or in-place)<br>Reconstruction |
| Longitudinal Cracking | Load Associated<br>Structural deficiency<br>Excessive air voids in Hot Mix Asphalt Concrete<br>Asphalt cement properties<br>Stripping of asphalt from aggregate<br>Aggregate Gradation<br>Construction deficiencies<br><br>Non Load Associated<br>Volume change potential of foundation soil<br>Slope stability of fill materials<br>Settlement of fill or in-place materials as a result of increased loading<br>Segregation due to laydown machine<br>Poor joint Construction<br>Other construction deficiencies | Crack sealing<br>Seal coat (applied to areas with cracking)<br>Replacement (dig-out and replace distressed areas)<br>Thin overlay with special treatment to seal cracks and minimize reflection cracking<br>Asphalt-rubber membrane with aggregate seal or thin overlay<br>Heater-scarification with a thin overlay |
| Transverse cracking | Hardness of asphalt cement<br>Stiffness of Hot Mix Asphalt Concrete<br>Volume changes in base and subbase<br>Unusual soil properties | Crack sealing<br>Seal coat<br>Overlay with special treatment to seal cracks and minimize reflection cracking<br>Asphalt-rubber membrane with aggregate seal or thin overlay<br>Heater scarification with a thin overlay |
| Roughness | Presence of physical distress (cracking, rutting, corrugations, potholes, etc.)<br>Volume change in fill and subgrade materials<br>Non-uniform construction | Overlay<br>Cold milling with or without overlay<br>Heater scarification with overlay<br>Heater planing with overlay (primarily for local areas and areas with corrugations)<br>Recycle (central plant or in-place) |

(Reference No. 5)

## 8.8. References


1. "Principles of Construction of Hot-Mix Asphalt Pavements". Manual Series No. 22, The Asphalt Institute (January 1983)

2. Epps, J.A., Button, J.W. and Gallaway, B.M., "Paving With Asphalt Cements Produced in the 1980's". NCHRP Report 269 (December 1983)

3. "Specifications for Asphalt Concrete and Other Plant-Mix Types". Specification Series No. 1, The Asphalt Institute (November 1984)

4. "Making the Most of Temperature/Viscosity Characteristics". Information Series 102, National Asphalt Pavement Association (1988)

5. Finn, F.N. and Epps, J.A., "Guidelines for Flexible Pavement Failure Investigations". Research Report 214-16, Texas Transportation Institute (July 1980)

6. "Hot Mix Asphalt Materials, Mixture Design and Construction". NAPA Research and Education Foundation, 2nd edition, 1996


## 8.9. Other References


"Construction Inspection Techniques for Flexible Pavements". Federal Highway Administration (May 1986)

"Constructing Quality Hot-Mix Asphalt Pavements". (A Trouble-Shooting Guide), Information Series 112, National Asphalt Pavement Association (1987)

# 9. Appendix B Asphalt Material Temperature/Volume Corrections (English units)

**Note: the following tables are published courtesy of the Asphalt Institute.**

## 9.1. Table B-1 Temperature/volume corrections for emulsified asphalts, Metric and English

**Table B-1 Temperature/Volume Corrections for Emulsified Asphalts**

Legend: t = observed temperature in degrees Celsius (Fahrenheit)

M = multiplier for correcting volumes to the basis of 15.6$^{o}$C (60$^{o}$F)

*Multiplier (M) for $^{o}$C is a close approximation.

| $^{o}$C t | $^{o}$F | M* | $^{o}$C t | $^{o}$F | M* | $^{o}$C t | $^{o}$F | M* | $^{o}$C t | $^{o}$F | M* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.0 | 50 | 1.00250 | 29.4 | 85 | 0.99375 | 48.9 | 120 | 0.98500 | 68.3 | 155 | 0.97625 |
| 10.6 | 51 | 1.00225 | 30.0 | 86 | 0.99350 | 49.4 | 121 | 0.98475 | 68.9 | 156 | 0.97600 |
| 11.1 | 52 | 1.00200 | 30.6 | 87 | 0.99325 | 50.0 | 122 | 0.98450 | 69.4 | 157 | 0.97575 |
| 11.7 | 53 | 1.00175 | 31.1 | 88 | 0.99300 | 50.6 | 123 | 0.98425 | 70.0 | 158 | 0.97550 |
| 12.2 | 54 | 1.00150 | 31.7 | 89 | 0.99275 | 51.1 | 124 | 0.98400 | 70.6 | 159 | 0.97525 |
| 12.8 | 55 | 1.00125 | 32.2 | 90 | 0.99250 | 51.7 | 125 | 0.98375 | 71.1 | 160 | 0.97500 |
| 13.3 | 56 | 1.00100 | 32.8 | 91 | 0.99225 | 52.2 | 126 | 0.98350 | 71.7 | 161 | 0.97475 |
| 13.9 | 57 | 1.00075 | 33.3 | 92 | 0.99200 | 52.8 | 127 | 0.98325 | 72.2 | 162 | 0.97450 |
| 14.4 | 58 | 1.00050 | 33.9 | 93 | 0.99175 | 53.3 | 128 | 0.98300 | 72.8 | 163 | 0.97425 |
| 15.0 | 59 | 1.00025 | 34.4 | 94 | 0.99150 | 53.9 | 129 | 0.98275 | 73.3 | 164 | 0.97400 |
| 15.6 | 60 | 1.00000 | 35.0 | 95 | 0.99125 | 54.4 | 130 | 0.98250 | 73.9 | 165 | 0.97375 |
| 16.1 | 61 | 0.99975 | 35.6 | 96 | 0.99100 | 55.0 | 131 | 0.98225 | 74.4 | 166 | 0.97350 |
| 16.7 | 62 | 0.99950 | 36.1 | 97 | 0.99075 | 55.6 | 132 | 0.98200 | 75.0 | 167 | 0.97325 |
| 17.2 | 63 | 0.99925 | 36.7 | 98 | 0.99050 | 56.1 | 133 | 0.98175 | 75.6 | 168 | 0.97300 |
| 17.8 | 64 | 0.99900 | 37.2 | 99 | 0.99025 | 56.7 | 134 | 0.98150 | 76.1 | 169 | 0.97275 |
| 18.3 | 65 | 0.99875 | 37.8 | 100 | 0.99000 | 57.2 | 135 | 0.98125 | 76.7 | 170 | 0.97250 |
| 18.9 | 66 | 0.99850 | 38.3 | 101 | 0.98975 | 57.8 | 136 | 0.98100 | 77.2 | 171 | 0.97225 |
| 19.4 | 67 | 0.99825 | 38.9 | 102 | 0.98950 | 58.3 | 137 | 0.98075 | 77.8 | 172 | 0.97200 |
| 20.0 | 68 | 0.99800 | 39.4 | 103 | 0.98925 | 58.9 | 138 | 0.98050 | 78.3 | 173 | 0.97175 |
| 20.6 | 69 | 0.99775 | 40.0 | 104 | 0.98900 | 59.4 | 139 | 0.98025 | 78.9 | 174 | 0.97150 |
| 21.1 | 70 | 0.99750 | 40.6 | 105 | 0.98875 | 60.0 | 140 | 0.98000 | 79.4 | 175 | 0.97125 |
| 21.7 | 71 | 0.99725 | 41.1 | 106 | 0.98850 | 60.6 | 141 | 0.97975 | 80.0 | 176 | 0.97100 |
| 22.2 | 72 | 0.99700 | 41.7 | 107 | 0.98825 | 61.1 | 142 | 0.97950 | 80.6 | 177 | 0.97075 |
| 22.8 | 73 | 0.99675 | 42.2 | 108 | 0.98800 | 61.7 | 143 | 0.97925 | 81.1 | 178 | 0.97050 |
| 23.3 | 74 | 0.99650 | 42.8 | 109 | 0.98775 | 62.2 | 144 | 0.97900 | 81.7 | 179 | 0.97025 |
| 23.9 | 75 | 0.99625 | 43.3 | 110 | 0.98750 | 62.8 | 145 | 0.97875 | 82.2 | 180 | 0.97000 |
| 24.4 | 76 | 0.99600 | 43.9 | 111 | 0.98725 | 63.3 | 146 | 0.97850 | 82.8 | 181 | 0.96975 |
| 25.0 | 77 | 0.99575 | 44.4 | 112 | 0.98700 | 63.9 | 147 | 0.97825 | 83.3 | 182 | 0.96950 |
| 25.6 | 78 | 0.99550 | 45.0 | 113 | 0.98675 | 64.4 | 148 | 0.97800 | 83.9 | 183 | 0.96925 |
| 26.1 | 79 | 0.99525 | 45.6 | 114 | 0.98650 | 65.0 | 149 | 0.97775 | 84.4 | 184 | 0.96900 |
| 26.7 | 80 | 0.99500 | 46.1 | 115 | 0.98625 | 65.6 | 150 | 0.97750 | 85.0 | 185 | 0.96875 |
| 27.2 | 81 | 0.99475 | 46.7 | 116 | 0.98600 | 66.1 | 151 | 0.97725 | | | |
| 27.8 | 82 | 0.99450 | 47.2 | 117 | 0.98575 | 66.7 | 152 | 0.97700 | | | |
| 28.3 | 83 | 0.99425 | 47.8 | 118 | 0.98550 | 67.2 | 153 | 0.97675 | | | |
| 28.9 | 84 | 0.99400 | 48.3 | 119 | 0.98525 | 67.8 | 154 | 0.97650 | | | |

**Courtesy of the Asphalt Institute**

## 9.2. Table B-2 Temperature/volume corrections for asphalt materials, specific gravity above 0.966

**Table B-2 Temperature/Volume Corrections for Asphalt Materials**
Group O-Specific Gravity at 60º F above 0.966
Legend: t=Observed temperature in degrees Fahrenheit
M=Multiplier for correcting oil volume to the basis of 60ºF

| t | M | t | M | t | M | t | M | t | M | t | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 1.0211 | **45** | 1.0053 | **90** | 0.9896 | **135** | 0.9740 | **180** | 0.9587 | **225** | 0.9436 |
| **1** | 1.0208 | **46** | 1.0049 | **91** | 0.9892 | **136** | 0.9737 | **181** | 0.9584 | **226** | 0.9432 |
| **2** | 1.0204 | **47** | 1.0046 | **92** | 0.9889 | **137** | 0.9734 | **182** | 0.9580 | **227** | 0.9429 |
| **3** | 1.0201 | **48** | 1.0042 | **93** | 0.9885 | **138** | 0.9730 | **183** | 0.9577 | **228** | 0.9426 |
| **4** | 1.0197 | **49** | 1.0038 | **94** | 0.9882 | **139** | 0.9727 | **184** | 0.9574 | **229** | 0.9422 |
| **5** | 1.0194 | **50** | 1.0035 | **95** | 0.9878 | **140** | 0.9723 | **185** | 0.9570 | **230** | 0.9419 |
| **6** | 1.0190 | **51** | 1.0031 | **96** | 0.9875 | **141** | 0.9720 | **186** | 0.9567 | **231** | 0.9416 |
| **7** | 1.0186 | **52** | 1.0028 | **97** | 0.9871 | **142** | 0.9716 | **187** | 0.9563 | **232** | 0.9412 |
| **8** | 1.0183 | **53** | 1.0024 | **98** | 0.9868 | **143** | 0.9713 | **188** | 0.9560 | **233** | 0.9409 |
| **9** | 1.0179 | **54** | 1.0021 | **99** | 0.9864 | **144** | 0.9710 | **189** | 0.9557 | **234** | 0.9405 |
| **10** | 1.0176 | **55** | 1.0017 | **100** | 0.9861 | **145** | 0.9706 | **190** | 0.9553 | **235** | 0.9402 |
| **11** | 1.0172 | **56** | 1.0014 | **101** | 0.9857 | **146** | 0.9703 | **191** | 0.9550 | **236** | 0.9399 |
| **12** | 1.0169 | **57** | 1.0010 | **102** | 0.9854 | **147** | 0.9699 | **192** | 0.9547 | **237** | 0.9395 |
| **13** | 1.0165 | **58** | 1.0007 | **103** | 0.9851 | **148** | 0.9696 | **193** | 0.9543 | **238** | 0.9392 |
| **14** | 1.0162 | **59** | 1.0003 | **104** | 0.9847 | **149** | 0.9693 | **194** | 0.9540 | **239** | 0.9389 |
| **15** | 1.0158 | **60** | 1.0000 | **105** | 0.9844 | **150** | 0.9689 | **195** | 0.9536 | **240** | 0.9385 |
| **16** | 1.0155 | **61** | 0.9997 | **106** | 0.9840 | **151** | 0.9686 | **196** | 0.9533 | **241** | 0.9382 |
| **17** | 1.0151 | **62** | 0.9993 | **107** | 0.9837 | **152** | 0.9682 | **197** | 0.9530 | **242** | 0.9379 |
| **18** | 1.0148 | **63** | 0.9990 | **108** | 0.9833 | **153** | 0.9679 | **198** | 0.9526 | **243** | 0.9375 |
| **19** | 1.0144 | **64** | 0.9986 | **109** | 0.9830 | **154** | 0.9675 | **199** | 0.9523 | **244** | 0.9372 |
| **20** | 1.0141 | **65** | 0.9983 | **110** | 0.9826 | **155** | 0.9672 | **200** | 0.9520 | **245** | 0.9369 |
| **21** | 1.0137 | **66** | 0.9979 | **111** | 0.9823 | **156** | 0.9669 | **201** | 0.9516 | **246** | 0.9365 |
| **22** | 1.0133 | **67** | 0.9976 | **112** | 0.9819 | **157** | 0.9665 | **202** | 0.9513 | **247** | 0.9362 |
| **23** | 1.0130 | **68** | 0.9972 | **113** | 0.9816 | **158** | 0.9662 | **203** | 0.9509 | **248** | 0.9359 |
| **24** | 1.0126 | **69** | 0.9969 | **114** | 0.9813 | **159** | 0.9658 | **204** | 0.9506 | **249** | 0.9356 |
| **25** | 1.0123 | **70** | 0.9965 | **115** | 0.9809 | **160** | 0.9655 | **205** | 0.9503 | **250** | 0.9352 |
| **26** | 1.0119 | **71** | 0.9962 | **116** | 0.9806 | **161** | 0.9652 | **206** | 0.9499 | **251** | 0.9349 |
| **27** | 1.0116 | **72** | 0.9958 | **117** | 0.9802 | **162** | 0.9648 | **207** | 0.9496 | **252** | 0.9346 |
| **28** | 1.0112 | **73** | 0.9955 | **118** | 0.9799 | **163** | 0.9645 | **208** | 0.9493 | **253** | 0.9342 |
| **29** | 1.0109 | **74** | 0.9951 | **119** | 0.9795 | **164** | 0.9641 | **209** | 0.9489 | **254** | 0.9339 |
| **30** | 1.0105 | **75** | 0.9948 | **120** | 0.9792 | **165** | 0.9638 | **210** | 0.9486 | **255** | 0.9336 |
| **31** | 1.0102 | **76** | 0.9944 | **121** | 0.9788 | **166** | 0.9635 | **211** | 0.9483 | **256** | 0.9332 |
| **32** | 1.0098 | **77** | 0.9941 | **122** | 0.9785 | **167** | 0.9631 | **212** | 0.9479 | **257** | 0.9329 |
| **33** | 1.0095 | **78** | 0.9937 | **123** | 0.9782 | **168** | 0.9628 | **213** | 0.9476 | **258** | 0.9326 |
| **34** | 1.0091 | **79** | 0.9934 | **124** | 0.9778 | **169** | 0.9624 | **214** | 0.9472 | **259** | 0.9322 |
| **35** | 1.0088 | **80** | 0.9930 | **125** | 0.9775 | **170** | 0.9621 | **215** | 0.9469 | **260** | 0.9319 |
| **36** | 1.0084 | **81** | 0.9927 | **126** | 0.9771 | **171** | 0.9618 | **216** | 0.9466 | **261** | 0.9316 |
| **37** | 1.0081 | **82** | 0.9923 | **127** | 0.9768 | **172** | 0.9614 | **217** | 0.9462 | **262** | 0.9312 |
| **38** | 1.0077 | **83** | 0.9920 | **128** | 0.9764 | **173** | 0.9611 | **218** | 0.9459 | **263** | 0.9309 |
| **39** | 1.0074 | **84** | 0.9916 | **129** | 0.9761 | **174** | 0.9607 | **219** | 0.9456 | **264** | 0.9306 |
| **40** | 1.0070 | **85** | 0.9913 | **130** | 0.9758 | **175** | 0.9604 | **220** | 0.9452 | **265** | 0.9302 |
| **41** | 1.0067 | **86** | 0.9909 | **131** | 0.9754 | **176** | 0.9601 | **221** | 0.9449 | **266** | 0.9299 |
| **42** | 1.0063 | **87** | 0.9906 | **132** | 0.9751 | **177** | 0.9597 | **222** | 0.9446 | **267** | 0.9296 |
| **43** | 1.0060 | **88** | 0.9902 | **133** | 0.9747 | **178** | 0.9594 | **223** | 0.9442 | **268** | 0.9293 |
| **44** | 1.0056 | **89** | 0.9899 | **134** | 0.9744 | **179** | 0.9590 | **224** | 0.9439 | **269** | 0.9289 |

**Courtesy of the Asphalt Institute**

## Table B-2 (Continued) Temperature/Volume Corrections for Asphalt Materials

Group O-Specific Gravity at 60º F above 0.966

Legend: t=Observed temperature in degrees Fahrenheit

M=Multiplier for correcting oil volume to the basis of 60ºF

| t | M | t | M | t | M | t | M | t | M | t | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **270** | 0.9286 | **310** | 0.9154 | **350** | 0.9024 | **390** | 0.8896 | **430** | 0.8768 | **470** | 0.8643 |
| **271** | 0.9283 | **311** | 0.9151 | **351** | 0.9021 | **391** | 0.8892 | **431** | 0.8765 | **471** | 0.8640 |
| **272** | 0.9279 | **312** | 0.9148 | **352** | 0.9018 | **392** | 0.8889 | **432** | 0.8762 | **472** | 0.8636 |
| **273** | 0.9276 | **313** | 0.9145 | **353** | 0.9015 | **393** | 0.8886 | **433** | 0.8759 | **473** | 0.8633 |
| **274** | 0.9273 | **314** | 0.9141 | **354** | 0.9011 | **394** | 0.8883 | **434** | 0.8756 | **474** | 0.8630 |
| **275** | 0.9269 | **315** | 0.9138 | **355** | 0.9008 | **395** | 0.8880 | **435** | 0.8753 | **475** | 0.8627 |
| **276** | 0.9266 | **316** | 0.9135 | **356** | 0.9005 | **396** | 0.8876 | **436** | 0.8749 | **476** | 0.8624 |
| **277** | 0.9263 | **317** | 0.9132 | **357** | 0.9002 | **397** | 0.8873 | **437** | 0.8746 | **477** | 0.8621 |
| **278** | 0.9259 | **318** | 0.9128 | **358** | 0.8998 | **398** | 0.8870 | **438** | 0.8743 | **478** | 0.8618 |
| **279** | 0.9256 | **319** | 0.9125 | **359** | 0.8995 | **399** | 0.8867 | **439** | 0.8740 | **479** | 0.8615 |
| **280** | 0.9253 | **320** | 0.9122 | **360** | 0.8992 | **400** | 0.8864 | **440** | 0.8737 | **480** | 0.8611 |
| **281** | 0.9250 | **321** | 0.9118 | **361** | 0.8989 | **401** | 0.8861 | **441** | 0.8734 | **481** | 0.8608 |
| **282** | 0.9246 | **322** | 0.9115 | **362** | 0.8986 | **402** | 0.8857 | **442** | 0.8731 | **482** | 0.8605 |
| **283** | 0.9243 | **323** | 0.9112 | **363** | 0.8982 | **403** | 0.8854 | **443** | 0.8727 | **483** | 0.8602 |
| **284** | 0.9240 | **324** | 0.9109 | **364** | 0.8979 | **404** | 0.8851 | **444** | 0.8724 | **484** | 0.8599 |
| **285** | 0.9236 | **325** | 0.9105 | **365** | 0.8976 | **405** | 0.8848 | **445** | 0.8721 | **485** | 0.8596 |
| **286** | 0.9233 | **326** | 0.9102 | **366** | 0.8973 | **406** | 0.8845 | **446** | 0.8718 | **486** | 0.8593 |
| **287** | 0.9230 | **327** | 0.9099 | **367** | 0.8969 | **407** | 0.8841 | **447** | 0.8715 | **487** | 0.8590 |
| **288** | 0.9227 | **328** | 0.9096 | **368** | 0.8966 | **408** | 0.8838 | **448** | 0.8712 | **488** | 0.8587 |
| **289** | 0.9223 | **329** | 0.9092 | **369** | 0.8963 | **409** | 0.8835 | **449** | 0.8709 | **489** | 0.8583 |
| **290** | 0.9220 | **330** | 0.9089 | **370** | 0.8960 | **410** | 0.8832 | **450** | 0.8705 | **490** | 0.8580 |
| **291** | 0.9217 | **331** | 0.9086 | **371** | 0.8957 | **411** | 0.8829 | **451** | 0.8702 | **491** | 0.8577 |
| **292** | 0.9213 | **332** | 0.9083 | **372** | 0.8953 | **412** | 0.8826 | **452** | 0.8699 | **492** | 0.8574 |
| **293** | 0.9210 | **333** | 0.9079 | **373** | 0.8950 | **413** | 0.8822 | **453** | 0.8696 | **493** | 0.8571 |
| **294** | 0.9207 | **334** | 0.9076 | **374** | 0.8947 | **414** | 0.8819 | **454** | 0.8693 | **494** | 0.8568 |
| **295** | 0.9204 | **335** | 0.9073 | **375** | 0.8944 | **415** | 0.8816 | **455** | 0.8690 | **495** | 0.8565 |
| **296** | 0.9200 | **336** | 0.9070 | **376** | 0.8941 | **416** | 0.8813 | **456** | 0.8687 | **496** | 0.8562 |
| **297** | 0.9197 | **337** | 0.9066 | **377** | 0.8937 | **417** | 0.8810 | **457** | 0.8683 | **497** | 0.8559 |
| **298** | 0.9194 | **338** | 0.9063 | **378** | 0.8934 | **418** | 0.8806 | **458** | 0.8680 | **498** | 0.8556 |
| **299** | 0.9190 | **339** | 0.9060 | **379** | 0.8931 | **419** | 0.8803 | **459** | 0.8677 | **499** | 0.8552 |
| **300** | 0.9187 | **340** | 0.9057 | **380** | 0.8928 | **420** | 0.8800 | **460** | 0.8674 | | |
| **301** | 0.9184 | **341** | 0.9053 | **381** | 0.8924 | **421** | 0.8797 | **461** | 0.8671 | | |
| **302** | 0.9181 | **342** | 0.9050 | **382** | 0.8921 | **422** | 0.8794 | **462** | 0.8668 | | |
| **303** | 0.9177 | **343** | 0.9047 | **383** | 0.8918 | **423** | 0.8791 | **463** | 0.8665 | | |
| **304** | 0.9174 | **344** | 0.9044 | **384** | 0.8915 | **424** | 0.8787 | **464** | 0.8661 | | |
| **305** | 0.9171 | **345** | 0.9040 | **385** | 0.8912 | **425** | 0.8784 | **465** | 0.8658 | | |
| **306** | 0.9167 | **346** | 0.9037 | **386** | 0.8908 | **426** | 0.8781 | **466** | 0.8655 | | |
| **307** | 0.9164 | **347** | 0.9034 | **387** | 0.8905 | **427** | 0.8778 | **467** | 0.8652 | | |
| **308** | 0.9161 | **348** | 0.9031 | **388** | 0.8902 | **428** | 0.8775 | **468** | 0.8649 | | |
| **309** | 0.9158 | **349** | 0.9028 | **389** | 0.8899 | **429** | 0.8772 | **469** | 0.8646 | | |

**Courtesy of the Asphalt Institute**

## 9.3. Table B-3 Temperature/volume corrections for asphalt materials, specific gravity above 0.850 to 0.966

**Table B-3 Temperature/Volume Corrections for Asphalt Materials**

Group 1-Specific Gravity at 60º F above 0.850 to 0.966

Legend: t=Observed temperature in degrees Fahrenheit

M=Multiplier for correcting oil volume to the basis of 60ºF

| t | M | t | M | t | M | t | M | t | M | t | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0** | 1.0241 | **45** | 1.0060 | **90** | 0.9881 | **135** | 0.9705 | **180** | 0.9532 | **225** | 0.9361 |
| **1** | 1.0237 | **46** | 1.0056 | **91** | 0.9877 | **136** | 0.9701 | **181** | 0.9528 | **226** | 0.9358 |
| **2** | 1.0233 | **47** | 1.0052 | **92** | 0.9873 | **137** | 0.9697 | **182** | 0.9524 | **227** | 0.9354 |
| **3** | 1.0229 | **48** | 1.0048 | **93** | 0.9869 | **138** | 0.9693 | **183** | 0.9520 | **228** | 0.9350 |
| **4** | 1.0225 | **49** | 1.0044 | **94** | 0.9865 | **139** | 0.9690 | **184** | 0.9517 | **229** | 0.9346 |
| **5** | 1.0221 | **50** | 1.0040 | **95** | 0.9861 | **140** | 0.9686 | **185** | 0.9513 | **230** | 0.9343 |
| **6** | 1.0217 | **51** | 1.0036 | **96** | 0.9857 | **141** | 0.9682 | **186** | 0.9509 | **231** | 0.9339 |
| **7** | 1.0213 | **52** | 1.0032 | **97** | 0.9854 | **142** | 0.9678 | **187** | 0.9505 | **232** | 0.9335 |
| **8** | 1.0209 | **53** | 1.0028 | **98** | 0.9850 | **143** | 0.9674 | **188** | 0.9501 | **233** | 0.9331 |
| **9** | 1.0205 | **54** | 1.0024 | **99** | 0.9846 | **144** | 0.9670 | **189** | 0.9498 | **234** | 0.9328 |
| **10** | 1.0201 | **55** | 1.0020 | **100** | 0.9842 | **145** | 0.9666 | **190** | 0.9494 | **235** | 0.9324 |
| **11** | 1.0197 | **56** | 1.0016 | **101** | 0.9838 | **146** | 0.9662 | **191** | 0.9490 | **236** | 0.9320 |
| **12** | 1.0193 | **57** | 1.0012 | **102** | 0.9834 | **147** | 0.9659 | **192** | 0.9486 | **237** | 0.9316 |
| **13** | 1.0189 | **58** | 1.0008 | **103** | 0.9830 | **148** | 0.9655 | **193** | 0.9482 | **238** | 0.9313 |
| **14** | 1.0185 | **59** | 1.0004 | **104** | 0.9826 | **149** | 0.9651 | **194** | 0.9478 | **239** | 0.9309 |
| **15** | 1.0181 | **60** | 1.0000 | **105** | 0.9822 | **150** | 0.9647 | **195** | 0.9475 | **240** | 0.9305 |
| **16** | 1.0177 | **61** | 0.9996 | **106** | 0.9818 | **151** | 0.9643 | **196** | 0.9471 | **241** | 0.9301 |
| **17** | 1.0173 | **62** | 0.9992 | **107** | 0.9814 | **152** | 0.9639 | **197** | 0.9467 | **242** | 0.9298 |
| **18** | 1.0168 | **63** | 0.9988 | **108** | 0.9810 | **153** | 0.9635 | **198** | 0.9463 | **243** | 0.9294 |
| **19** | 1.0164 | **64** | 0.9984 | **109** | 0.9806 | **154** | 0.9632 | **199** | 0.9460 | **244** | 0.9290 |
| **20** | 1.0160 | **65** | 0.9980 | **110** | 0.9803 | **155** | 0.9628 | **200** | 0.9456 | **245** | 0.9286 |
| **21** | 1.0156 | **66** | 0.9976 | **111** | 0.9799 | **156** | 0.9624 | **201** | 0.9452 | **246** | 0.9283 |
| **22** | 1.0152 | **67** | 0.9972 | **112** | 0.9795 | **157** | 0.9620 | **202** | 0.9448 | **247** | 0.9279 |
| **23** | 1.0148 | **68** | 0.9968 | **113** | 0.9791 | **158** | 0.9616 | **203** | 0.9444 | **248** | 0.9275 |
| **24** | 1.0144 | **69** | 0.9964 | **114** | 0.9787 | **159** | 0.9612 | **204** | 0.9441 | **249** | 0.9272 |
| **25** | 1.0140 | **70** | 0.9960 | **115** | 0.9783 | **160** | 0.9609 | **205** | 0.9437 | **250** | 0.9268 |
| **26** | 1.0136 | **71** | 0.9956 | **116** | 0.9779 | **161** | 0.9605 | **206** | 0.9433 | **251** | 0.9264 |
| **27** | 1.0132 | **72** | 0.9952 | **117** | 0.9775 | **162** | 0.9601 | **207** | 0.9429 | **252** | 0.9260 |
| **28** | 1.0128 | **73** | 0.9948 | **118** | 0.9771 | **163** | 0.9597 | **208** | 0.9425 | **253** | 0.9257 |
| **29** | 1.0124 | **74** | 0.9944 | **119** | 0.9767 | **164** | 0.9593 | **209** | 0.9422 | **254** | 0.9253 |
| **30** | 1.0120 | **75** | 0.9940 | **120** | 0.9763 | **165** | 0.9589 | **210** | 0.9418 | **255** | 0.9249 |
| **31** | 1.0116 | **76** | 0.9936 | **121** | 0.9760 | **166** | 0.9585 | **211** | 0.9414 | **256** | 0.9245 |
| **32** | 1.0112 | **77** | 0.9932 | **122** | 0.9756 | **167** | 0.9582 | **212** | 0.9410 | **257** | 0.9242 |
| **33** | 1.0108 | **78** | 0.9929 | **123** | 0.9752 | **168** | 0.9578 | **213** | 0.9407 | **258** | 0.9238 |
| **34** | 1.0104 | **79** | 0.9925 | **124** | 0.9748 | **169** | 0.9574 | **214** | 0.9403 | **259** | 0.9234 |
| **35** | 1.0100 | **80** | 0.9921 | **125** | 0.9744 | **170** | 0.9570 | **215** | 0.9399 | **260** | 0.9231 |
| **36** | 1.0096 | **81** | 0.9917 | **126** | 0.9740 | **171** | 0.9566 | **216** | 0.9395 | **261** | 0.9227 |
| **37** | 1.0092 | **82** | 0.9913 | **127** | 0.9736 | **172** | 0.9562 | **217** | 0.9391 | **262** | 0.9223 |
| **38** | 1.0088 | **83** | 0.9909 | **128** | 0.9732 | **173** | 0.9559 | **218** | 0.9388 | **263** | 0.9219 |
| **39** | 1.0084 | **84** | 0.9905 | **129** | 0.9728 | **174** | 0.9555 | **219** | 0.9384 | **264** | 0.9216 |
| **40** | 1.0080 | **85** | 0.9901 | **130** | 0.9725 | **175** | 0.9551 | **220** | 0.9380 | **265** | 0.9212 |
| **41** | 1.0076 | **86** | 0.9897 | **131** | 0.9721 | **176** | 0.9547 | **221** | 0.9376 | **266** | 0.9208 |
| **42** | 1.0072 | **87** | 0.9893 | **132** | 0.9717 | **177** | 0.9543 | **222** | 0.9373 | **267** | 0.9205 |
| **43** | 1.0068 | **88** | 0.9889 | **133** | 0.9713 | **178** | 0.9539 | **223** | 0.9369 | **268** | 0.9201 |
| **44** | 1.0064 | **89** | 0.9885 | **134** | 0.9709 | **179** | 0.9536 | **224** | 0.9365 | **269** | 0.9197 |

**Table B-3 (Continued) Temperature/Volume Corrections for Asphalt Materials**

Group 1-Specific Gravity at 60º F above 0.850 to 0.966

Legend: t=Observed temperature in degrees Fahrenheit

M=Multiplier for correcting oil volume to the basis of 60ºF

| t | M | t | M | t | M | t | M | t | M | t | M |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **270** | 0.9194 | **310** | 0.9047 | **350** | 0.8902 | **390** | 0.8760 | **430** | 0.8619 | **470** | 0.8481 |
| **271** | 0.9190 | **311** | 0.9043 | **351** | 0.8899 | **391** | 0.8756 | **431** | 0.8616 | **471** | 0.8478 |
| **272** | 0.9186 | **312** | 0.9039 | **352** | 0.8895 | **392** | 0.8753 | **432** | 0.8612 | **472** | 0.8474 |
| **273** | 0.9182 | **313** | 0.9036 | **353** | 0.8891 | **393** | 0.8749 | **433** | 0.8609 | **473** | 0.8471 |
| **274** | 0.9179 | **314** | 0.9032 | **354** | 0.8888 | **394** | 0.8746 | **434** | 0.8605 | **474** | 0.8468 |
| **275** | 0.9175 | **315** | 0.9029 | **355** | 0.8884 | **395** | 0.8742 | **435** | 0.8602 | **475** | 0.8464 |
| **276** | 0.9171 | **316** | 0.9025 | **356** | 0.8881 | **396** | 0.8738 | **436** | 0.8599 | **476** | 0.8461 |
| **277** | 0.9168 | **317** | 0.9021 | **357** | 0.8877 | **397** | 0.8735 | **437** | 0.8595 | **477** | 0.8457 |
| **278** | 0.9164 | **318** | 0.9018 | **358** | 0.8873 | **398** | 0.8731 | **438** | 0.8592 | **478** | 0.8454 |
| **279** | 0.9160 | **319** | 0.9014 | **359** | 0.8870 | **399** | 0.8728 | **439** | 0.8588 | **479** | 0.8451 |
| **280** | 0.9157 | **320** | 0.9010 | **360** | 0.8866 | **400** | 0.8724 | **440** | 0.8585 | **480** | 0.8447 |
| **281** | 0.9153 | **321** | 0.9007 | **361** | 0.8863 | **401** | 0.8721 | **441** | 0.8581 | **481** | 0.8444 |
| **282** | 0.9149 | **322** | 0.9003 | **362** | 0.8859 | **402** | 0.8717 | **442** | 0.8578 | **482** | 0.8440 |
| **283** | 0.9146 | **323** | 0.9000 | **363** | 0.8856 | **403** | 0.8714 | **443** | 0.8574 | **483** | 0.8437 |
| **284** | 0.9142 | **324** | 0.8996 | **364** | 0.8852 | **404** | 0.8710 | **444** | 0.8571 | **484** | 0.8433 |
| **285** | 0.9138 | **325** | 0.8992 | **365** | 0.8848 | **405** | 0.8707 | **445** | 0.8567 | **485** | 0.8430 |
| **286** | 0.9135 | **326** | 0.8989 | **366** | 0.8845 | **406** | 0.8703 | **446** | 0.8564 | **486** | 0.8427 |
| **287** | 0.9131 | **327** | 0.8985 | **367** | 0.8841 | **407** | 0.8700 | **447** | 0.8560 | **487** | 0.8423 |
| **288** | 0.9127 | **328** | 0.8981 | **368** | 0.8838 | **408** | 0.8696 | **448** | 0.8557 | **488** | 0.8420 |
| **289** | 0.9124 | **329** | 0.8978 | **369** | 0.8834 | **409** | 0.8693 | **449** | 0.8554 | **489** | 0.8416 |
| **290** | 0.9120 | **330** | 0.8974 | **370** | 0.8831 | **410** | 0.8689 | **450** | 0.8550 | **490** | 0.8413 |
| **291** | 0.9116 | **331** | 0.8971 | **371** | 0.8827 | **411** | 0.8686 | **451** | 0.8547 | **491** | 0.8410 |
| **292** | 0.9113 | **332** | 0.8967 | **372** | 0.8823 | **412** | 0.8682 | **452** | 0.8543 | **492** | 0.8406 |
| **293** | 0.9109 | **333** | 0.8963 | **373** | 0.8820 | **413** | 0.8679 | **453** | 0.8540 | **493** | 0.8403 |
| **294** | 0.9105 | **334** | 0.8960 | **374** | 0.8816 | **414** | 0.8675 | **454** | 0.8536 | **494** | 0.8399 |
| **295** | 0.9102 | **335** | 0.8956 | **375** | 0.8813 | **415** | 0.8672 | **455** | 0.8533 | **495** | 0.8396 |
| **296** | 0.9098 | **336** | 0.8952 | **376** | 0.8809 | **416** | 0.8668 | **456** | 0.8529 | **496** | 0.8393 |
| **297** | 0.9094 | **337** | 0.8949 | **377** | 0.8806 | **417** | 0.8665 | **457** | 0.8526 | **497** | 0.8389 |
| **298** | 0.9091 | **338** | 0.8945 | **378** | 0.8802 | **418** | 0.8661 | **458** | 0.8522 | **498** | 0.8386 |
| **299** | 0.9087 | **339** | 0.8942 | **379** | 0.8799 | **419** | 0.8658 | **459** | 0.8519 | **499** | 0.8383 |
| **300** | 0.9083 | **340** | 0.8938 | **380** | 0.8795 | **420** | 0.8654 | **460** | 0.8516 | | |
| **301** | 0.9080 | **341** | 0.8934 | **381** | 0.8792 | **421** | 0.8651 | **461** | 0.8512 | | |
| **302** | 0.9076 | **342** | 0.8931 | **382** | 0.8788 | **422** | 0.8647 | **462** | 0.8509 | | |
| **303** | 0.9072 | **343** | 0.8927 | **383** | 0.8784 | **423** | 0.8644 | **463** | 0.8505 | | |
| **304** | 0.9069 | **344** | 0.8924 | **384** | 0.8781 | **424** | 0.8640 | **464** | 0.8502 | | |
| **305** | 0.9065 | **345** | 0.8920 | **385** | 0.8777 | **425** | 0.8637 | **465** | 0.8498 | | |
| **306** | 0.9061 | **346** | 0.8916 | **386** | 0.8774 | **426** | 0.8633 | **466** | 0.8495 | | |
| **307** | 0.9058 | **347** | 0.8913 | **387** | 0.8770 | **427** | 0.8630 | **467** | 0.8492 | | |
| **308** | 0.9054 | **348** | 0.8909 | **388** | 0.8767 | **428** | 0.8626 | **468** | 0.8488 | | |
| **309** | 0.9050 | **349** | 0.8906 | **389** | 0.8763 | **429** | 0.8623 | **469** | 0.8485 | | |

**Courtesy of the Asphalt Institute**

## 9.4. Table B-4 Weights and volumes of asphalt materials (approximate)

**TABLE B-4 Weights and volumes of asphalt materials** (approximate)

| Type and Grade | Pounds per Gallon | Pounds per Barrel* | Gallons per Ton | Barrels per Ton* |
|---|---|---|---|---|
| AC-2.5 | 8.4 | 353 | 238 | 5.7 |
| AC-5 | 8.5 | 357 | 235 | 5.6 |
| AC-10 | 8.5 | 357 | 235 | 5.6 |
| AC-20 | 8.5 | 357 | 235 | 5.6 |
| AC-40 | 8.6 | 361 | 233 | 5.5 |
| AR-1000 | 8.4 | 353 | 238 | 5.7 |
| AR-2000 | 8.5 | 357 | 235 | 5.6 |
| AR-4000 | 8.5 | 357 | 235 | 5.6 |
| AR-8000 | 8.5 | 357 | 235 | 5.6 |
| AR-16000 | 8.6 | 361 | 233 | 5.5 |
| 200-300 pen. | 8.4 | 353 | 238 | 5.7 |
| 120-150 pen. | 8.5 | 357 | 235 | 5.6 |
| 85-100 pen. | 8.5 | 357 | 235 | 5.6 |
| 60-70 pen. | 8.5 | 357 | 235 | 5.6 |
| 40-50 pen. | 8.6 | 361 | 233 | 5.5 |
| Emulsified Asphalts | 8.3 | 349 | 241 | 5.7 |
| MC-30 | 7.8 | 328 | 256 | 6.1 |
| RC-, MC-, SC-70 | 7.9 | 332 | 253 | 6.0 |
| RC-, MC-, SC-250 | 8.0 | 337 | 249 | 5.9 |
| RC-, MC-, SC-800 | 8.2 | 343 | 245 | 5.8 |
| RC-, MC-, SC-3000 | 8.3 | 349 | 241 | 5.7 |

*A barrel equals 42 U.S. Gallons.

NOTES: Since the specific gravity of asphalt materials varies, even for the same type and grade, the weight and volume relationships shown above are approximate and should be used only for general estimating purposes. Where more precise data are required, they must be computed on the basis of laboratory tests on the specific product.

The approximate data shown above are for materials at 60°F.

**Courtesy of the Asphalt Institute**

# 10. Appendix C Mathematical Formulas

## 10.1. Quantities in Partly Filled Cylindrical Tanks in Horizontal Position

**TABLE D-1**

Quantities in Partly Filled Cylindrical Tanks in Horizontal Position

courtesy of the Asphalt Institute

| % Depth Filled | % of Capacity | % Depth Filled | % of Capacity | % Depth Filled | % of Capacity | % Depth Filled | % of Capacity |
|---|---|---|---|---|---|---|---|
| 1 | 0.20 | 26 | 20.73 | 51 | 51.27 | 76 | 81.50 |
| 2 | 0.50 | 27 | 21.86 | 52 | 52.55 | 77 | 82.60 |
| 3 | 0.90 | 28 | 23.00 | 53 | 53.81 | 78 | 83.68 |
| 4 | 1.34 | 29 | 24.07 | 54 | 55.08 | 79 | 84.74 |
| 5 | 1.87 | 30 | 25.31 | 55 | 56.34 | 80 | 85.77 |
| 6 | 2.45 | 31 | 26.48 | 56 | 57.60 | 81 | 86.77 |
| 7 | 3.07 | 32 | 27.66 | 57 | 58.86 | 82 | 87.76 |
| 8 | 3.74 | 33 | 28.84 | 58 | 60.11 | 83 | 88.73 |
| 9 | 4.45 | 34 | 30.03 | 59 | 61.36 | 84 | 89.68 |
| 10 | 5.20 | 35 | 31.19 | 60 | 62.61 | 85 | 90.60 |
| 11 | 5.98 | 36 | 32.44 | 61 | 63.86 | 86 | 91.50 |
| 12 | 6.80 | 37 | 33.66 | 62 | 65.10 | 87 | 92.36 |
| 13 | 7.64 | 38 | 34.90 | 63 | 66.34 | 88 | 93.20 |
| 14 | 8.50 | 39 | 36.14 | 64 | 67.56 | 89 | 94.02 |
| 15 | 9.40 | 40 | 37.39 | 65 | 68.81 | 90 | 94.80 |
| 16 | 10.32 | 41 | 38.64 | 66 | 69.97 | 91 | 95.55 |
| 17 | 11.27 | 42 | 39.89 | 67 | 71.16 | 92 | 96.26 |
| 18 | 12.24 | 43 | 41.14 | 68 | 72.34 | 93 | 96.93 |
| 19 | 13.23 | 44 | 42.40 | 69 | 73.52 | 94 | 97.55 |
| 20 | 14.23 | 45 | 43.66 | 70 | 74.69 | 95 | 98.13 |
| 21 | 15.26 | 46 | 44.92 | 71 | 75.93 | 96 | 98.66 |
| 22 | 16.32 | 47 | 46.19 | 72 | 77.00 | 97 | 99.10 |
| 23 | 17.40 | 48 | 47.45 | 73 | 78.14 | 98 | 99.50 |
| 24 | 18.50 | 49 | 48.73 | 74 | 79.27 | 99 | 99.80 |
| 25 | 19.61 | 50 | 50.00 | 75 | 80.39 | | |

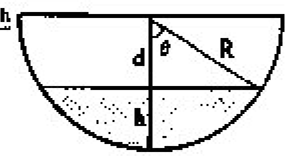
Full capacity of tank in U. S. gallons $= \dfrac{0.7854 \times D^2 \times L}{231}$

**Note:** The formula for direct computation of quantity when tank is less than half full is shown below. When more than half full, compute the full capacity of the tank as noted above; consider the shaded portion to represent the unfilled portion at the top of the tank and compute its volume as indicated below; then, deduct the volume determined for the unfilled portion from the total volume of the tank to arrive at the volume of the filled portion.

First, compute $\theta$ where $\cos\theta = \dfrac{d}{R} = \dfrac{R-h}{R}$

Then $A = \pi R^2 \dfrac{\theta}{180} - R \sin\theta\,(R-h)$

And $V = \dfrac{L\left[\pi R^2 \dfrac{\theta}{180} - R\sin\theta(R-h)\right]}{231}$



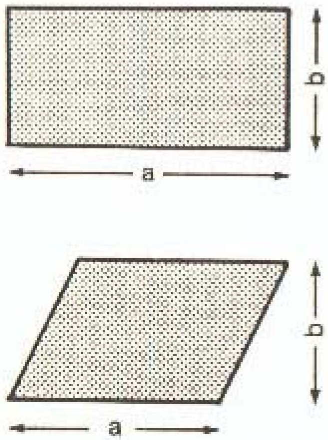

Where A = Cross section area of filled portion of tank in sq in
V = Volume of filled portion of tank in U.S. gallons
L = Length of interior of tank in inches
D = Diameter of interior of tank in inches
R = Radius of interior of tank in inches
h = Depth of liquid in inches
d = R − h, inches

**Note:** The volume occupied by any piping, fittings or other material inside the tank must be deducted from the volume computed by use of the table or formula.

## 10.2. Areas of Plane Figures

TABLE D-2

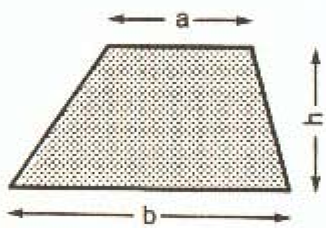
# AREAS OF PLANE FIGURES




### RECTANGLES AND PARALLELOGRAMS

Area = ab

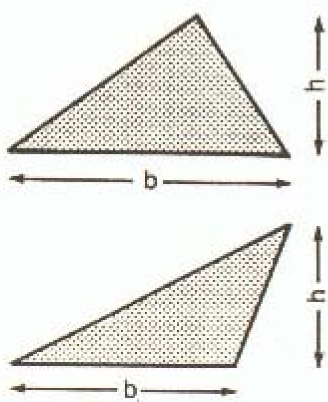
Example: a=60,b=30
Area = 60 x 30 = 1800 Ans.




### TRAPEZOIDS

Area = 1/2h(a+b)

Example: a=30,b=60,h=40
Area = 1/2x 40(30+60)
= 1800 Ans.




### TRIANGLES

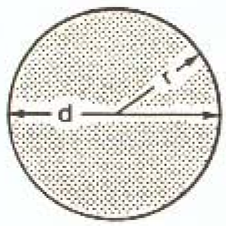
Area = 1/2bh

Example: b=40,h=30
Area = 1/2(40 x 30)
= 600 Ans.

TABLE D-2 (continued)

# AREAS OF PLANE FIGURES (CONTINUED)

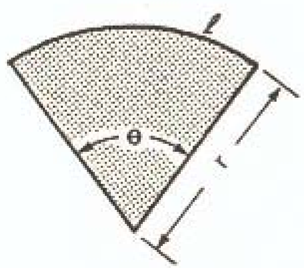
## CIRCLES




Area $= \pi r^2 = 3.1416\ r^2$ OR
$1/4 \pi d^2 = 0.7854\ d^2$

Examples: r=40 (d=80)
Area $= 3.1416 \times 40^2 = 5027$ Ans.
[$0.7854 \times 80^2 = 5027$ Ans.]

## SECTOR OF A CIRCLE

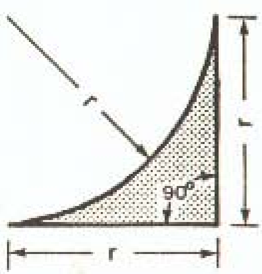



Area $= 1/2 \ell r$ OR
$\pi r^2(\theta \div 360) = 0.008727 r^2 \theta$

where $\ell$ = arc length
$\theta$ = angle in degrees

Examples: $r=2, \theta=30, \ell=1.05$
Area $= \frac{1}{2}(1.05 \times 2) = 1.05$ Ans.
[$0.008727(2^2 \times 30) = 1.05$ Ans.]

## SPANDRELS




Area $= 0.2146 r^2$

Example: r=40
Area $= 0.2146 \times 40^2$
$= 343.4$ Ans.

# 11. Appendix D Random Sampling of Construction Materials (from Alaska DOT/PF Sampling Module)

## 11.1. Significance

Sampling and testing are two of the most important functions in quality control (QC). Data from the tests are the tools with which the quality of product is controlled. For this reason, great care must be used in following standardized sampling and testing procedures.

In controlling operations, it is necessary to obtain numerous samples at various points along the production line. Unless precautions are taken, sampling can occur in patterns that can create a bias to the data gathered. Sampling at the same time, say noon, each day may jeopardize the effectiveness of any quality program. This might occur, for example, because a material producer does certain operations, such as cleaning screens at an aggregate plant, late in the morning each day. To obtain a representative sample, a reliable system of random sampling must be employed.

- One of the greatest single sources of error in materials testing is the failure to obtain a representative sample.
- Random numbers eliminate sampling bias.
- Random numbers determine time and/or location of sampling.

## 11.2. Scope

The procedure presented here eliminates bias in sampling materials. Randomly selecting a set of numbers from a table or calculator will eliminate the possibility for bias. Random numbers are used to identify sampling times, locations, or points with a lot or sublot. This method does not cover how to sample but rather how to determine sampling times, locations, or points.

## 11.3. Sampling Concepts

A lot is the quantity of material evaluated by QC procedures. A lot is a preselected quantity that may represent hours of production, a quantity or number of loads of material, or an interval of time. A lot may be comprised of several portions that are called sublots or units. The number of sublots comprising a lot will be determined by the agency's specifications.

## 11.4. Straight Random Sampling vs. Stratified Random Sampling:

Straight random sampling considers an entire lot as a single unit and determines each sample location based on the entire lot size. Stratified random sampling divides the lot into a specified number of sublots or units and then determines each sample location within a distinct sublot. Both methods result in random distribution of samples to be tested for compliance with the agency's specification.

- Straight: Entire lot is one unit.
- Stratified: Lot is divided into sublots or units.

Agencies stipulate when to use straight random sampling or stratified random sampling. AASHTO T 2, Sampling of Aggregates, for example, specifies a straight random sampling procedure.

## 11.5. Picking Random Numbers from a Table

Table 1 contains pairs of numbers. The first number is the "pick" number and the second is the Random Number, "RN". The table was generated with a spreadsheet and the cells (boxes at the intersection of rows and columns) containing the RNs actually contain the "random number function". Every time the spreadsheet is opened or changed, all the RNs change.

1. Selecta Pick number in a random method. The first two or last two digits in the next automobile license plate you see would be on way to select. Another would be to start a digital stop watch and stop it several seconds later, using the decimal part of the seconds as you Pick number.
2. Find the RN matching the Pick number.

## 11.6. Table 1 Random Numbers

| Pick | RN | Pick | RN | Pick | RN | Pick | RN | Pick | RN |
|---|---|---|---|---|---|---|---|---|---|
| 01 | 0.998 | 21 | 0.758 | 41 | 0.398 | 61 | 0.895 | 81 | 0.222 |
| 02 | 0.656 | 22 | 0.552 | 42 | 0.603 | 62 | 0.442 | 82 | 0.390 |
| 03 | 0.539 | 23 | 0.702 | 43 | 0.150 | 63 | 0.821 | 83 | 0.468 |
| 04 | 0.458 | 24 | 0.217 | 44 | 0.001 | 64 | 0.187 | 84 | 0.335 |
| 05 | 0.407 | 25 | 0.000 | 45 | 0.521 | 65 | 0.260 | 85 | 0.727 |
| 06 | 0.062 | 26 | 0.781 | 46 | 0.462 | 66 | 0.815 | 86 | 0.708 |
| 07 | 0.370 | 27 | 0.317 | 47 | 0.553 | 67 | 0.154 | 87 | 0.161 |
| 08 | 0.410 | 28 | 0.896 | 48 | 0.591 | 68 | 0.007 | 88 | 0.893 |
| 09 | 0.923 | 29 | 0.848 | 49 | 0.797 | 69 | 0.759 | 89 | 0.255 |
| 10 | 0.499 | 30 | 0.045 | 50 | 0.638 | 70 | 0.925 | 90 | 0.604 |
| 11 | 0.392 | 31 | 0.692 | 51 | 0.006 | 71 | 0.131 | 91 | 0.880 |
| 12 | 0.271 | 32 | 0.530 | 52 | 0.526 | 72 | 0.702 | 92 | 0.656 |
| 13 | 0.816 | 33 | 0.796 | 53 | 0.147 | 73 | 0.146 | 93 | 0.711 |
| 14 | 0.969 | 34 | 0.100 | 54 | 0.042 | 74 | 0.355 | 94 | 0.377 |
| 15 | 0.188 | 35 | 0.902 | 55 | 0.609 | 75 | 0.292 | 95 | 0.287 |
| 16 | 0.185 | 36 | 0.674 | 56 | 0.579 | 76 | 0.854 | 96 | 0.461 |
| 17 | 0.809 | 37 | 0.509 | 57 | 0.887 | 77 | 0.240 | 97 | 0.703 |
| 18 | 0.105 | 38 | 0.013 | 58 | 0.495 | 78 | 0.851 | 98 | 0.866 |
| 19 | 0.715 | 39 | 0.497 | 59 | 0.039 | 79 | 0.678 | 99 | 0.616 |
| 20 | 0.380 | 40 | 0.587 | 60 | 0.812 | 80 | 0.122 | 00 | 0.759 |

13.2.

## 11.7. Examples of Straight Random Sampling Procedures Using Random Numbers

**Sampling from a Belt or Flowing Stream:** Agencies specify the frequency of sampling in terms of time, volumes, or masses. The specification might call for one sample from every 1,000,000 kg (1000 t) or 1100 Tons (T) of aggregate. IF the random number was 0.317, the sample would be taken at (0.317)(1,000,000 kg) = 317,000 kg (317 t). Or (.317)(1100 T) = 349 T.

- A very small RN – say 0.001 – might not be usable. An aggregate crusher takes a few minutes to get to full production (the jaw, cones, screen decks and belts). An RN of 0.001 might result in taking a sample too soon. If this occurs, you may need to pick a new random number.

One sample per day might also be specified. If the day were 9 hours long and the random number 0.199, the sample would be taken at (0.199)(9 hrs) = 1.79 hr = 1 hr 48 minutes into the day. AASHTO T 2 permits this time to be rounded to the nearest 5 minutes.

**Sampling from Haul Units:** Based on the agency's specifications – in terms of time, volume, or mass – determine the number of haul units that comprise a lot. Multiply the selected random number(s) by the number of units to determine which unit(s) will be sampled.

For example, if 20 haul units comprise a lot and one sample is needed, pick on RN. If the RN were 0.773, then the sample would be taken from the (0.773)(20) – 15.46, or 15$^{th}$ haul unit.

**Sampling from a Roadway with Previously Place Material:** The agency's specified frequency of sampling – in time volume, or mass – can be translated into a location on a job. For example, if a sample is to be taken every 800 $m^3$ (1000 $yd^3$) and material is being placed 0.15 m (0.50’) thick and 4.0 m (13’) wide, then the lot is 1330 m (4154”) long. You would select two RNs in this case. To convert $yd^3$ to $ft^3$ multiply by 27.

The first RN would be multiplied by the length to determine where the sample would be taken along the project. The second would be multiplied by the width to determine where, widthwise, the sample would be taken. For example, a first RN of (0.759)(1330 m) or (4154’) = 1010 m or 3153’ from the beginning. A second RN of 0.255 would specify that the sample would be taken at (0.255)(4.0 m) or (13’) = 1.02 m or 3.3’ from the right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1’) to the edge. If the RN specifies a location closer than 0.3 m (1’), then 0.3 m (1’) is added to or subtracted from the distance calculated.

**Sampling from a Stockpile:** AASHTO T 2 recommends against sampling from stockpiles. However, some agencies use random procedures in determining sampling locations from a stockpile. Bear in mind that stockpiles are prone to segregation and that a sample obtained from a stockpile may not be representative. Refer to WAQTC FOP for AASHTO T 2 for guidance on how to sample from a stockpile.

- Show an example from agency specifications.

**In-Place Density Testing:** Agency specifications will indicate the frequency of tests. For example, one test per 500 $m^3$ (666 $yd^3$) might be required. If the material is being placed 0.15 m (0.50’) thick and 10.0 m (33’) wide, then the lot is 333 m (1090’) long. You would select two RNs in this case.

The first RN would be multiplied by the length to determine where the sample would be taken along the project. The second would be multiplied by the width to determine where, widthwise, the sample would be taken. For example, a first RN of 0.387 would specify that the sample would be taken at (0.387)(333 m) or (1090’) = 129 m or (442’) from the beginning. A second RN of 0.588 would specify that the sample would be taken at (0.588)(10 m) or (33’) = 5.88 m or (19’) from the right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1’) to the edge. If the RN specifies a location closer than 0.3 m (1’), then 0.3 m (1’) is added to or subtracted from the distance calculated.

# 12. Appendix E Asphalt Glossary of Terms

The definitions for the following terms are those commonly used in the transportation industry, and particularly by the Alaska DOT&PF. Though some of these terms may seem fundamental, they are provided so that everyone, regardless of their field experience can, from this quick reference guide, develop an understanding of this often-unique nomenclature.

**AASHTO**-The acronym for the American Association of State Highway and Transportation Officials. A "T" designates AASHTO tests (Example: AASHTO T195). An "M" designates AASHTO specifications (Example: AASHTO M156).

**Abrasion Testing** - Aggregates break and erode as they are moved around by heavy equipment, plant machinery and laydown equipment. The Los Angeles (LA) Abrasion machine tumbles the aggregate in a standard manner to determine if the aggregate is durable enough to be made into processed aggregate. See also section 703 of the Standard Specifications for Highway Construction, 1988.

**Absorption** - Refers to the amount of asphalt absorbed into the aggregate in a mix, expressed as a percentage of aggregate.

**Adhesion** - Adhesion is the asphalt's ability to stick to the aggregate in the paving mixture.

**Affinity (Attraction) for Asphalt** - An aggregate's affinity, or attraction for asphalt is its tendency to accept and retain an asphalt coating. Limestone, dolomite, and traprock have high affinities for asphalt and are referred to as hydrophobic (water-hating) because they resist the efforts of water to strip asphalt from them. Hydrophilic (water-loving) aggregates, such as quartz have low affinities for asphalt. They tend to separate from asphalt films when exposed to water.

**Aggregate** - Any combination of one or more hard granular mineral material, either natural or crushed, from very fine to large rocks, selected because of its characteristics for a specific purpose, such as sand, gravel, crushed stone, ballast, etc., used for mixing in graduated fragments.

<u>**Types**</u>**:**

**Blended Aggregate** - The combination of coarse and fine aggregates meeting gradation requirements for the material specified.

**Coarse Aggregate** - Typically, aggregate retained on the no. 4 sieve, but the designation is dependent on the specification requirements.

**Coarse Graded Aggregate** - One having a continuous grading in sizes of particles from coarse through fine with a predominance of coarse sizes.

**Dense Graded Aggregate** - An aggregate that has a particle size distribution near the maximum density line when plotted on a 0.45 power gradation chart.

**Fine Aggregate** - Aggregates passing the 4.75mm (No. 4) or other specified sieve, but the designation is dependent on the specification requirements.

**Fine Graded Aggregate** - One having a continuous grading in sizes of particles from coarse through fine with a predominance of fine sizes.

**Mineral Filler** - Very fine aggregate, predominantly passing the 0.075mm sieve and free of organics.

**Natural Aggregates** - Aggregates in their natural form, with little or no processing.

**Open Graded Aggregate** - One containing little or no mineral filler in which the void spaces in the compacted aggregate are relatively large.

**Poorly Graded Aggregates** - An aggregate gradation with high variability in the amounts passing each successive sieve, having angles when plotted on a gradation chart.

**Processed Aggregates** - Aggregates that have been crushed and screened in preparation for use.

**Synthetic Aggregates** - Artificial aggregates that are the by-products of industrial production processes such as slag from ore refining. The most common form is the lightweight aggregate used in concrete.

**Well Graded Aggregate** - Aggregate graded from the maximum size down to filler with a smooth curve when plotted on a gradation chart.

**Aggregate Loss** - Refers to undesirable loss of aggregates in an asphalt pavement or surface treatment. The most common causes of aggregate loss from a pavement are; lack of compaction, too little asphalt binder, lack of anti-stripping agents, poor quality aggregate, and, dirty aggregate. In mixes using emulsified asphalt, aggregate loss may result from use of an inappropriate ionic grade.

**Aggregate Storage Bins** - Bins that store the necessary aggregate sizes for feeding to an asphalt plant in substantially the same proportions as are required in the finished mix. Also called "Cold Bins".

**Anionic** - A material having negative electrical charge (see Emulsified Asphalt).

**Anti-stripping Agents** - Anti-stripping agents are usually blended with asphalt binders in order to improve bonding characteristics between the binder and the aggregate. Lime or cement are amongst the most common anti-stripping agents. Chemical anti-stripping agents such as PaveBond or Arr-Maz are also commonly used in Alaska. Chemical anti-stripping agents are usually added by the asphalt cement suppliers.

**Arctic Grade Asphalt** - Refers to paving asphalt cement that has been modified, usually by rubber derivative materials such as latex or polymer, for the purpose of enhancing low temperature characteristics. Arctic Grade Asphalt has been used, with varied success, to reduce thermal cracking of pavement in cold climates. A standard grading system has not as yet been developed for Arctic Grades.

**Asphalt** - A dark brown to black cementitious material in which the predominating constituents are bitumen's that occur in nature or are obtained as residue in petroleum distillation. Asphalt imparts controllable flexibility to mixtures of mineral aggregates with which it is usually combined. It is highly resistant to the action of most acids, alkalies, and salts. Although a solid or semi-solid at ordinary atmospheric temperatures, asphalt may be readily liquefied by applying heat or by dissolving it in petroleum solvents of varying volatility or by emulsifying it.

**Asphalt Blocks** - Asphalt concrete molded under high pressure. The type of aggregate mixture composition, amount and type of asphalt, and the size and thickness of the blocks are varied to suit usage requirements.

**Asphalt, Blown or Oxidized** - Asphalt that is treated by blowing air through it at elevated temperature to give it desired characteristics for certain special uses such as roofing, pipe coating, undersealing portland cement concrete pavements, membrane envelopes, and hydraulic applications.

**Asphalt, Catalytically Blown** - An air-blown asphalt produced by using a catalyst during the blowing process.

**Asphalt Cement** - Asphalt that is refined to meet specifications for paving, industrial, and special purposes. The term is often abbreviated to "AC" or referred to as "binder" when used in an asphalt hot mix.

**Asphalt Cement Grade** - See Binder Classification.

**Asphalt Concrete** - Also referred to as Asphalt Concrete Pavement (ACP), Hot Mix Asphalt (HMA), flexible pavement, hot bituminous pavement and several other names. It is the material most commonly used for surfacing roadways and airports, subject to high traffic, in Alaska. It is a high quality, controlled, hot mixture of asphalt cement and graded aggregate, thoroughly compacted into a uniform dense mass.

**Asphalt Content** - Refers to the content of asphalt cement in an asphalt concrete paving mixture. Asphalt content is currently always expressed as a percent of the total mix weight. In the 1970s and earlier, the Alaska DOT&PF used to express asphalt contents as a percentage of the aggregate weight.

**Asphalt, Cutback** - See cutback asphalt definition.

**Asphalt Distributor** - A truck mounted asphalt tank including heating elements, a pump and a spray bar on the back for spraying asphalt on a prepared surface. The asphalt distributor applies the desired volume of asphalt (gal. /s.y. or l./sq.m.) for asphalt surface treatments, tack coats and prime coats.

**Asphalt Filler, Preformed** - Premolded strips of asphalt mixed with fine mineral substances, fibrous materials, cork, sawdust, or similar materials; manufactured in dimensions suitable for construction joints.

**Asphalt Joint Sealer (Filler)** - An asphalt product used for sealing cracks and joints in pavement and other structures.

**Asphalt Leveling Course** - A course (asphalt aggregate mixture) of variable thickness used to eliminate irregularities in an existing asphalt surface prior to placing the final wearing course.

**Asphalt Plants** - See Batch Plant, and Dryer Drum Plant**.**

**Asphalt Rock**Error! Bookmark not defined. (Rock Asphalt) **–** Porous rock such as sandstone or limestone that has become impregnated with natural asphalt through geologic process.

**Asphalt Soil Stabilization (soil treatment)** - Treatment of naturally occurring non-plastic or moderately plastic soil with cutback or emulsified soil mixture produce water-resistant base or subbase courses of improved load-bearing qualities.

**Asphalt Surface Treatments** - Asphalt surface treatment is a broad term embracing several types of asphalt or asphalt-aggregate applications, usually less than 25 mm (1 inch) thick, to a road surface. The types range from a single application of emulsified asphalt followed by graded aggregate to multiple surface layers made up of alternating applications of asphalt and different sized aggregates. See also Single Surface Treatments and Multiple Surface Treatments.

**Asphalt Treated Base** - A base course constructed using hot asphalt cement as a binder, often referred to with the acronym "ATB". See Treated Base Courses for further descriptions of types.

**Asphaltenes** - The high molecular weight hydrocarbon fraction of asphalt.

**ASTM** - The acronym for the American Society for Testing and Materials.

**ATM** - Stands for Alaska Test Manual. The Headquarters Materials Section developed these tests. ATM tests are designated with a "T" (Example: ATM T-4).

**Automatic Cycling Control (batch plant)** - In a batch plant, a control system in which the opening and closing of the weigh hopper discharge gate, the bituminous discharge valve, and the pugmill discharge gate are actuated by means of self-acting mechanical or electrical machinery without any intermediate manual control. The system includes preset timing devices to control the desired periods of dry and wet mixing cycles.

**Automatic Dryer Control (batch plant)** - In a batch plant, a system that automatically maintains the temperature of aggregates discharged from the dryer within a preset range.

**Automatic Proportioning Control (batch plant)** - In a batch plant, a system in which proportions of the aggregate and asphalt fractions are controlled by means of gates or valves which are opened and closed by means of self-acting mechanical or electronic machinery without any intermediate manual control.

**Average Daily Traffic** *(ADT)* - Is the average volume for a 24-hour period. It is normally the annual total volume divided by 365 unless otherwise stated.

**Axle Load** - The total load transmitted to the pavement by all wheels of either a single or tandem axle, usually expressed in kilonewtons (kN).

**Bag House** - A contained fabric filter which removes dust from the exhaust gases of dryer drums on batch plants and drum plants. The fabric filters are sewn in the shape of cylindrical bags, several hundred of which are contained in the bag house. Bag houses are used to avoid air pollution during hot mix asphalt production. Bag houses are equipped with mechanical means of shaking and cleaning the filters during production of mix.

**Bag House Fines** - The dust, which falls out of the bag house, off of the filters. This material may be fed back in to the asphalt mix or wasted. Wasted bag house fines are often put into contained settling ponds.

**Bank Gravel** - Gravel found in natural deposits, usually more or less intermixed with fine material, such as sand or clay, or combinations thereof. Gravelly clay, gravelly sand, clayey gravel, and sand gravel indicate the varying proportions of the materials in the mixture.

**Base Course** (*BC*) - The layer or layers of specified material of designed thickness placed on a subbase or a subgrade to support a surface course. Most base courses are constructed with crushed aggregates and therefore called Crushed Aggregate Base Course.

**Batch Plant** - A stationary manufacturing facility for producing asphalt paving mixtures that proportions the aggregate constituents into the mix by screening and weighing batches, then adds asphalt material by either weight or volume in a pugmill. Batch plants make asphalt concrete one batch at a time. Measured quantities of aggregates are first run through a dryer drum and into hot bins for storage. A bag house filters dust emitted from the dryer drum. The aggregates are then sent through hot screens, to control the gradation, and dropped into a pugmill where they are mixed with hot asphalt. The pugmill is then dumped of the "batch" and the process repeated. Dumped batches are either placed directly into trucks or conveyed to a silo for storage. Since batch plants are stationary facilities, they are usually only found in larger metropolitan areas where demand keeps them in operation. Batch plants are rated according to the maximum batch weight in tons they can produce and the weight they can produce, per hour. Larger batch plants can produce 5 tons or more of mix with each batch and over 300 tons per hour.

**Binder** - Material used to stabilize or cement together loose soil or aggregate. In Hot Mix Asphalt and Asphalt Treated Bases, the binder is asphalt cement.

**Binder Classification (Grades)** - Refers to the specification grade that a particular asphalt cement meets. There are many specifications used for asphalt grading. The first developed grading system was Penetration Grading, followed by Viscosity Grading. Viscosity grading may be done on original asphalt (AC-grades - Note: AC-10 is seldom used) or on asphalt residue from the Rolling Thin Film Oven (AR-grades). Other grades one may find include Arctic Grades, Performance Based Asphalt (PBA-grades), Performance Graded (PG-grades) and assorted modifications of the above.

**Superpave Binder** - See Performance Graded Asphalt.

**Bitumen** - A mixture of hydrocarbons which occur naturally or result from chemical processing. Asphalt and Tar are examples.

**Bituminous Surface Treatment** *(BST)* - See Multiple Surface Treatments.

**Blast-Furnace Slag –** The nonmetallic product, consisting essentially of silicates and alumino-silicates of lime and of other bases, that is developed simultaneously with iron in a blast furnace.

**Bleeding or Flushing** - The upward movement of asphalt in an asphalt pavement or surface treatment resulting in the formation of a film of asphalt on the roadway surface. The most common cause is too much asphalt in one or more of the pavement courses, resulting in asphalt coming to the surface under traffic and with heat expansion. Bleeding or flushing usually occurs in hot weather.

**Block Cracks** - See Cracks.

**Blotter Material** - Fine material (clean sand, crusher dust, etc.) sometimes spread on an uncured prime coat to allow traffic on the prime before it is cured and to protect the uncured prime from being washed off the grade when rain threatens. The use of blotter sand less than 4 hours after applying the prime is allowed only with written permission. Blotter material may also be used to mitigate bleeding.

**Breaking** - Refers to the process of emulsified asphalt curing or setting by evaporation.

**Break Down Roller** - The large roller that is the first to start compaction of a freshly laid asphalt concrete pavement. Often vibratory rollers are used for the first few passes of break down rolling.

**Cape Seal** - Cape seal combines a single shot asphalt surface treatment with a slurry seal or microsurfacing. Done properly, it provides the rough, knobby surface of a chip seal to reduce hydroplaning yet has a tough sand matrix for durability.

**Cationic** - A material testing positive in a particle charge test. (See Emulsified Asphalt).

**Channels (Ruts)** – Grooves that may develop in the wheel tracks of a pavement. Channels may result from consolidation or lateral movement under traffic in one or more of the underlying courses, or by displacement in the asphalt surface layer itself. They may develop under traffic in new asphalt pavements that had too little compaction during construction or from plastic movement in a mix that does not have enough stability to support the traffic.

**Clinker –** Generally a fused or partly fused by-product of the combustion of coal, but also including lava and portland-cement clinker, and partly vitrified slag and brick.

**Coal Tar** – A dark brown to black cementitious material produced by the destructive distillation of bituminous coal.

**Check Marshall Test** - Alaska uses this test method. The Check Marshall Test is made on the asphalt concrete, which is produced on the project to determine if it has sufficient stability. (Stability is a measure of the pavement sample's dimetral strength). The purpose of the Marshall Method is to verify the optimum asphalt content for a particular blend of aggregate. The method also provides information about the properties of the resulting asphalt hot mix, density and void content that must be met during pavement construction. The optimum levels of density and void content are established by the job mix formula. Check Marshall Testing is done by the Regional Laboratory.

**Chips** - Small angular fragments of stone containing little to no dust. They are used in Asphalt Surface Treatments. See Table 7035 of the Standard Specifications for Highway Construction, 1988.

**Chip Seal** - See Single Surface Treatments.

**Cohesion** - Cohesion is the ability of the asphalt to hold the aggregate particles firmly in place in the finished pavement.

**Cold Feed** - Refers to the conveyors between the aggregate bins and the drum mixer or dryer drum in an asphalt plant that carry cold aggregates to the plant.

**Cold-laid Plant Mixture** - Plant mixes, using emulsified asphalt that may be spread and compacted at atmospheric temperature.

**Cold Mix** - A mixture of emulsified asphalt and aggregate used for patching. This mixture is workable at temperatures above freezing.

**Cold Recycling** - Cold mix recycling may be done in place or at a central plant with a pugmill. Existing asphalt pavement is crushed to a specified maximum size and placed on the roadway with or without the addition of emulsified asphalt. When the process is done by a train of equipment performing the tasks of crushing, treating and relaying the material, it is referred to as Cold in Place Recycling (CIPR).

**Compaction** - Compaction is the act of achieving density by compressing a given volume of material into a smaller volume. The compaction process begins with break down rolling, then intermediate rolling and finally finish rolling. The percent compaction attained by the rolling of the hot mix can be estimated with a nuclear densometer, but is usually measured for acceptance by coring out samples whose density is measured in a laboratory and related to a maximum (Rice) density.

**Consistency –** Describes the degree of fluidity or plasticity of asphalt cement at any particular temperature. The consistency of asphalt cement varies with temperature; therefore, it is necessary to use a common or standard temperature when comparing the consistency of one asphalt cement with another. The standard test temperature is 140$^{o}$F (60$^{o}$C).

**Composite Pavement** - A pavement structure composed of an asphalt concrete wearing surface and portland cement concrete slab.

**Continuous Mix Plant** - A manufacturing facility for producing asphalt paving mixtures that proportions those aggregate and asphalt constituents into the mix by a continuous proportioning system without definite batch intervals. Also called a Drum Mix Plant. See the definition for Drum Mix Plant for further details.

**Coring Machine** - Coring machines are used to remove core samples of the completed mix, which are tested to measure the level of pavement compaction and thickness for acceptance.

**Corrugations (Washboarding) and Shoving –** Are types of pavement distortion. Corrugation is a form of plastic movement typified by ripples across the asphalt pavement surface. Shoving is a form of plastic movement resulting in localized bulging of the pavement surface. These distortions usually occur at points where traffic starts and stops, on hills where vehicles brake on the downgrade, on sharp curves, or where vehicles hit a bump and bounce up and down. They occur in asphalt layers that lack stability. Lack of stability may be caused by a mixture that is too rich in asphalt, has too high a proportion of fine aggregate, has coarse or fine aggregate that is too round or too smooth, or has asphalt cement that is too soft. It may also be due to excessive moisture, contamination due to oil spillage, or lack of aeration when placing mixes using liquid asphalts.

**Cracks** - Breaks in the surface of an asphalt pavement. The common types are:

**Alligator Cracks** - A slang term for fatigue cracking of asphalt concrete pavement which results in interconnected cracks forming a series of small shapes that resemble an alligator's skin. In some localities, outside Alaska, these are referred to as “turtleback” cracks. These cracks are caused by application of excessive traffic repetitions to the pavement for the support provided by underlying layers.

**Block Cracks** - Interconnected cracks, some-times called “Shrinkage Cracks” forming a series of large blocks usually with sharp corners or angles. Shrinkage and daily temperature cycling cause them. Block cracking is a sign that the asphalt has aged and hardened significantly. It often occurs on older pavement areas with little or no traffic.

**Construction Joint Cracks** - Longitudinal or transverse separations along the seam between two paving panels caused by a weak bond between the panels and/or lack of compaction at the joint.

**Edge Joint (Curb Line) Cracks** - The separation of the joint between the pavement and the shoulder, commonly caused by the alternate wetting and drying beneath the shoulder surface. Other causes are shoulder settlement, mix shrinkage and, trucks straddling the joint. Longitudinal cracks between the traveled way and a paved shoulder may be caused by use of a different structural section of the shoulder or inadequate snow removal on the shoulders.

**Fatigue Cracks** - Interconnected cracks forming a series of small blocks resembling an alligator’s skin or chicken wire. They are caused by excessive repetitions of heavy traffic for the given thickness of pavement and structural support provided by underlying layers.

**Lane Joint Cracks –** Longitudinal separations along the seam between two paving lanes caused by a weak seam between adjoining spreads in the courses of the pavement.

**Longitudinal Cracks** - Cracks that run in the direction of travel.

**Reflection Cracks** - Cracks in asphalt overlays that reflect the crack pattern in the pavement structure underneath. They are caused by vertical or horizontal movements in the pavement beneath the overlay, brought on by expansion and contraction with temperature or moisture changes. Lack of support for an overlay over an existing crack also contributes to reflection.

**Shrinkage Cracks** – Are interconnected cracks forming a series of large blocks usually with sharp corners or angles. Frequently they are caused by volume change in either the asphalt mix or in the base or subgrade.

**Slippage Cracks** - Crescent-shaped cracks that are open in the direction of the thrust of wheels on the pavement surface. They result from braking and turning wheels on pavement that lacks a good bond between the surface layer and the course beneath.

**Thermal Cracks** - See Transverse Cracks.

**Transverse Cracks** - Cracks that run perpendicular to the direction of traffic. Unless caused by a poor construction joint, these cracks are usually caused by longitudinal shrinkage of the pavement and the support layers when at very low temperatures.

**Crack Sealing** - Pavement maintenance operations, cleaning out cracks and using asphalt materials to fill and seal cracks to impede infiltration of moisture into the supporting layers. Modern crack sealing compounds contain rubberized agents to help maintain flexibility even at very low temperatures.

**Critical Fines Content** *($P_{cr}$)* - The limiting fines content ($P_{0.075}$) above which frost action affects the strength of the pavement structure. The Critical Fines Content ($P_{cr}$) varies with the depth below the Surface Course.

**CRS-2** - A cationic rapid setting emulsified asphalt, used primarily for fog seals, sand seals, and chip seals.

**Crusher-Run** - The unscreened product of a rock crusher.

**Curing** - In asphalt concrete, curing involves the chemical and physical changes the mix goes through as it cools and is initially subjected to traffic. See Cut-Back Asphalt and/or Emulsified Asphalt definitions. See also Breaking.

**Cut-Back Asphalt** - Cut-Back asphalt is asphalt, which has been liquefied by blending with naphtha, kerosene or fuel oil to allow mixing or spraying at lower temperatures than pure asphalt would. Cutback asphalt cures by the evaporation of the solvent, which amounts to from 33 % to 50 % by weight of the material. There are potential environmental problems with its use. Currently, Cut-Back asphalt is only used for Prime Coat and some crack sealing. The following grades of Cut-Back asphalt are standard:

**Rapid-Curing (RC) Asphalt** - Cutback asphalt composed of asphalt cement and naphtha or gasoline-type diluent that will evaporate quickly. Example: RC-800 has been used for crack sealing.

**Medium-Curing (MC) Asphalt** - Cutback asphalt composed of asphalt cement and kerosene-type diluent of medium volatility. Example: MC-30 is sometimes used for Prime Coat.

**Slow-Curing (SC) Asphalt** - Cutback asphalt composed of asphalt cement and oils of low volatility. Example: SC-250 has been used as to control dust on gravel roads. However, its use has stopped due to environmental concerns that contaminated runoff may get into waterways.

**Road Oil** - heavy petroleum oil, usually one of the slow curing (SC) grades.

Note: The numbers following the acronyms above refer to the viscosity grade of the material. Higher numbers indicate higher viscosity Cut-Backs.

**Degradation Tests** - The Degradation Test determines the durability of aggregate in the presence of water and agitation during the construction process. With degradation values of 20 to 45 the value “may” be susceptible to degradation. Below 20 the material will be susceptible to degradation.

**Delivery Tolerances** – Permissible variations from the exact desired proportions of aggregate and bituminous material as delivered into the pugmill.

**Density** - The unit weight of a material in terms of mass per unit volume, e.g., grams/cm$^3$ or lbs/ft$^3$. The density of a compacted asphalt paving mixture is determined for the following purposes:

(1) On laboratory compacted specimens to:

a. Provide a basis for computing the percent of air voids and voids in the mineral aggregate in the compacted mixtures; an integral part of some asphalt paving mixture design procedures.
b. Provide an indication of the optimum asphalt content in some mix design procedures.
c. Establish a basis for controlling compaction during construction of the asphalt pavement.
d. Provide a basis for calculating the spread required for a given thickness of pavement.

(2) On specimens obtained from pavements to check density of pavement and effectiveness of rolling operations.

**Densification** - The act of increasing the density of a mixture during the compaction process.

**Design Lane** - The lane on which the greatest number of equivalent 80 kN single-axle loads is expected. Normally this will be either lane of a two-lane roadway or an outside lane of a multi-lane highway.

**Distortion** - Pavement distortion is any change of the pavement surface from its original shape.

**Distributor** - See Asphalt Distributor.

**Double Shot Seal Coat** - See Multiple Surface Treatments.

**Drainage** - Refers to the ability of a structural section to allow moisture to be removed from its surface, subsurface, roadway edges. The level of drainage provided by design, construction and maintenance of a paved section is the most important factor determining how long it will last.

**Drainage Coefficients** - Factors used to modify layer coefficients in the AASHTO pavement design process as an indicator how well the pavement structure can handle the adverse effect of water infiltration.

**Drum Mix Plant** - Drum-mix plants combine and heat aggregate and asphalt cement continuously. May also be called a Continuous Mix Plant. Measured amounts of different sized aggregates are fed into the upper end of the dryer. The asphalt cement is added near the middle of the drum, where it mixes with aggregate that has already been heated and dried. The aggregate at a drum plant starts at a set of cold bins, just like at a batch plant. The hot asphalt storage tanks and pumping systems are also similar to those for batch plants. The drum mixer consists of a revolving cylinder lined with flights, a large burner, and a fan, like a batch plant dryer. Unlike batch plant dryers, asphalt cement is sprayed on the aggregate and mixed within the drum. The burner is at the upper end of the dryer, so both the aggregate and the hot gases move downwards through the drum. This is known as "parallel flow". Parallel flow and a short flame are used so that the gases are cool enough by the time they reach the lower end of the drum that they will not burn the asphalt. Most drum mix plants have an inlet, near where the asphalt is applied to allow the addition of recycled asphalt pavement (RAP). Hot mix asphalt that comes out the lower end of the drum is conveyed to truck loading facilities or a silo for storage. A bag house is used to filter dust emitted from the lower end of the drum. Drum Mix Plants are portable and therefore the most common type of asphalt plant used in Alaska, especially outside of larger cities.

**Dryer** - An apparatus that will dry the aggregates and heat them to the specified temperatures in Batch Plants.

**Dry Mixing Time** - Residence time of aggregate as it drops into the pugmill of a batch plant, prior to the addition of asphalt.

**Ductility** - The ability of a substance to be drawn out or stretched thin without breaking. Ductility tests are used in many types of asphalt grading.

**Durability** - A general term that describes asphalt paving mixture ability to resist disintegration with age, weathering and traffic. Time and low traffic volumes have distinct impacts on a pavements overall durability. Included under weathering are changes in the characteristics of the asphalt, such as oxidation and volatilization, and changes in the pavement and aggregate due to the action of water, including freezing and thawing.

**Dust Control** - Dust control operations use spray trucks equipped with stirring mechanisms and graders.

**Dust Palliative** - The use of a dilute asphalt emulsion (used motor oils are also an accepted form), sprayed directly on an unpaved road surface for the purpose of controlling dust is known as dust laying or the application of a dust palliative. The actual dilution depends on the condition of the existing surface. Some penetration is expected.

**Dust Ratio** - An asphalt mix property used for assessing acceptance during the mix design process. It is the number resulting from dividing the percent passing the 0.075 mm sieve in the aggregate gradation and the percent of asphalt as a percent of mix.

**Effective Asphalt Content** - The amount of asphalt in a paving mix ***not*** absorbed by the aggregates. It is the portion of asphalt available for coating and adhesion between aggregate particles. Typical acceptable values range from 0.6 to 1.2.

**Embankment Foundation** - The material below the original ground surface whose physical characteristics affect the support of the embankment.

**Emulsified Asphalt** - Emulsified asphalt is made by combining ground asphalt, emulsifying agents and water. They cure by "breaking", which is the process of water removal by evaporation or steaming off. Asphalt emulsions are divided into three categories: anionic, cationic, and nonionic. In practice the first two types are ordinarily used in roadway construction and maintenance. The anionic (electronegatively charged) and cationic (electropositively charged) classes refer to the electrical charges surrounding the asphalt particles. With nonionic emulsions, the asphalt particles are neutral. Cationic emulsions are used with aggregates that are negatively charged. Anionic emulsions are used with positively charged aggregates. Opposite charge characteristics create attraction. The relative setting time of either slow setting (SS), medium setting (MS) or rapid setting (RS) emulsions also categorizes emulsified asphalts further.

**Emulsified Asphalt Mix (Cold Mix) –** A mixture of emulsified asphalt and aggregate; produced in a central plant (plant mix) or mixed at the road site (mixed-in-place).

**Emulsified Asphalt Specifications** - AASHTO and ASTM have developed standard specifications for the following grades of emulsions:

| EMULSIFIED ASPHALT | CATIONIC EMULSIFIED ASPHALT |
|---|---|
| RS-1 | CRS-1 |
| RS-2 | CRS-2 |
| MS-1 | -------- |
| MS-2 | CMS-2 |
| MS-2h | CMS-2h |
| HFMS-1 | -------- |
| HFMS-2 | -------- |
| HFMS-2h | -------- |
| HFMS-2s | -------- |
| SS-1 | CSS-1 |
| SS-1h | CSS-1h |

The "h" that follows certain grades simply means that harder base asphalt is used. The "HF" preceding some of the MS grades indicates high-float. The “s” that follows certain grades means that it contains solvent or other oil distillates intended to improve coating of aggregates. If a polymer additive is included in the emulsion, the letter “p” will be added.

**Emulsified Asphalt Treated Base** - A product of mixing base course material with emulsified asphalt and sometimes a few percent Portland cement. It can be mixed on grade by heavy equipment or by specially made traveling plants. It can also be produced in a central mixing plant. Emulsified Asphalt Treated Bases are used to bind up fines in base course material and to reduce actions of frost and high moisture. They also can create an effective structural support layer so that the otherwise required thickness of pavement or subbase can be reduced in a particular situation.

**Emulsion** - A suspension of solid materials in water

**Emulsion Slurry Seal** - A mixture of emulsified asphalt, fine aggregate and mineral filler, with water added to produce slurry consistency that is applied to a previously paved surface.

**Equivalent Single Axle Loads** *(ESAL)* - Traffic on highways and streets varies both in the number of vehicles and in the magnitude of loading. The cumulative effects of traffic loads are important factors in the structural design of a pavement. The effect on the pavement performance of any combination of axle loads of varying magnitude is equated to the number of standard 80 kN (18,000 lb.) dual tired, single-axle loads required to produce an equivalent effect (i.e. the single axle load). In design of pavement structural sections the total number of ESALs is a summary of equivalent single 80 kN (18,000 lb.) single axle loads expected from the combination of all vehicle classes for the design period.

**Excess Fines** - The fines contents above the Critical Fines content content ($P_{0.075}$ - $P_{cr}$).

**Excess Fines Factor** *(EFF)* - A factor that includes the effects of the Excess Fines and the applied stress at a given depth ($(\Delta\ SFR)(P_{0.075} - P_{cr})^{0.8}$).

**Extraction** - Extraction is the procedure used for separating the asphalt from the mineral aggregates in an asphalt paving mixture using a chemical solvent, such as Trichloroethylene. The purpose of the extraction is to provide a basis for determining the asphalt content of a mixture and to provide asphalt-free aggregates for a gradation analysis. Trichloroethylene and any other chlorinated solvents are now considered a hazardous substances and their use has ceased in Alaska DOT&PF laboratories. Ignition ovens and nuclear asphalt content gages are currently used to determine asphalt contents. A closed system extraction method using toluene can still be used when gradation or asphalt recovery is needed.

**Falling Weight Deflectometer** *(FWD)* - The FWD is a trailer mounted device that drops a known weight from known heights on a pavement surface while automatically measuring the resulting peak stress and deflections. The drop stress is usually intended to simulate dynamic traffic loading. The data collected with the FWD is used to back calculate elastic moduli of the supporting layers. Once the elastic moduli are known, structural design can proceed in determining critical stresses and strains in the structure.

**Fatigue Cracking** - See Cracking.

**Fatigue Resistance** - The ability of asphalt pavement to withstand repeated flexing or slight bending caused by the passage of wheel loads. As a rule, the higher the asphalt content and the lower the air void content in an asphalt mix, the greater the fatigue resistance. However, a mix with too high an asphalt content or too low an air void content will tend to rut under traffic loading.

**Fat Spots** - Fat spots in an asphalt mixture are isolated areas where asphalt cement has come to the surface of the mix during the laydown and compaction operation. These spots can occur very erratically and irregularly, or they may be numerous and in a fairly regular pattern. Fat spots can be caused by excessive moisture in the mix or the accumulation of asphalt cement on the plant lay-down machines or rollers that drop the accumulation on the mat.

**Fines Content** *($P_{0.075}$)* - The average percentage by weight of material passing the 0.075 mm sieve.

**Flash Point** - Asphalt cement, if heated to a high enough temperature, will release fumes that will flash in the presence of a spark or open flame. The temperature at which this occurs is called the flash point and is well above the temperatures normally used in paving operations. The Cleveland Open Cup is a flash point test used in grading asphalt. The results are used to assure safety during mixing and handling of asphalt.

**Flexibility** - Generally, a term used to describe the ability of an asphalt pavement structure to conform to settlement of the foundation. It is also sometimes referred to as the ability of asphalt pavements to heal during warm weather. Flexibility of an asphalt paving mixture can be enhanced by a high asphalt content.

**Flexible Pavement** - Another term for asphalt concrete pavement.

**Fog Line** - A longitudinal white line delineating the edge of the traveled way on a road.

**Fog Seal** - A light application of asphalt emulsion, without mineral aggregate cover, on an existing pavement. Fog seals are a maintenance operation used to seal an older pavement to reduce oxidation.

**Fracture Test** - The fracture test, WAQTC TM 1, is a visual determination of whether the larger aggregate particles are sharp-edged or rounded, expressed as percent fracture. Samples for fracture testing are taken to assure that crushed aggregates have at least the minimum specified percent of fractured particles.

**Full-Depth Asphalt Pavement** – The term Full-Depth (registered by The Asphalt Institute with the U.S. Patent Office) certifies that the pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A Full-Depth asphalt pavement is laid directly on the subgrade.

**Grade Depressions** – Are localized low areas of limited size, which may or may not be accompanied by cracking.

**Gap-Graded Asphalt** - A gap-graded asphalt mix is essentially the same as an open-graded mix; however, the amount of fine aggregate incorporated into the mix is usually greater than the amount of fine aggregate used in the open-graded mix. Gap-Graded can occur because of aggregate gradations but can also be a design feature. The production, placement, and compaction of a gap-graded HMA mix are similar to the processes used for an open-graded mix.

**Gradation** - A general term, which describes the relative size distribution of the particles in an aggregate sample. The percentage passing various sieve sizes, from the largest (100% passing) to the smallest (0.075 mm) show the gradation of the material.

**Gradation Chart** - A chart where the percent passing various sieve sizes can be plotted, giving a visual demonstration of an aggregate's size distribution. Gradation charts with the sieve sizes (in mm) raised to 0.45 power on the x axis are most commonly used with paving aggregates. A straight line plotted on a 0.45 power gradation chart is said to be a maximum density line, which is usually avoided in asphalt mix production. Gradations near the maximum density line have little space for asphalt, making the optimum asphalt range very small.

**Grooves** - Grooves are sometimes cut into pavement to increase traction, increase moisture runoff and to make ice removal easier. They are usually cut transverse to the direction of traffic. In Alaska grooves are commonly used on runway pavements at larger airports.

**Heavy Trucks** - Two axle, six-tire trucks or larger. Pickup, panel and light four-tire trucks are not included. Trucks with heavy-duty wide-base tires are included.

**High Float Emulsion** - See Single Surface Treatment.

**High Float Asphalt Surface Treatment** - See Single Surface Treatment.

**Hot Asphalt Recycling** - Hot mix recycling is a process where reclaimed asphalt pavement (RAP) is combined with new asphalt cement and new aggregate in a central mixing plant. The amount of RAP allowed in a mix must be carefully considered since its addition cools the mix, which may impede proper asphalt coating of aggregates and hamper lay-down operations.

**Hot Aggregate Storage Bins** - In a batch plant, bins that store the heated and separated aggregates prior to their final hot screening into the pugmill.

**Hot-Laid Plant Mixture** - See Asphalt Concrete.

**Hot Mix Asphalt** *(HMA)* - See Asphalt Concrete.

**Hveem Method** - Alaska does not use this method.

**Ignition Oven** - The ignition oven is a furnace designed to determine estimated asphalt cement content of an asphalt concrete mixture by burning off and exhausting the asphalt cement out, leaving only aggregates. Weighed samples of mixture are heated at approximately 1100 degrees Fahrenheit (593 deg. C.) for 1 hour and the remaining aggregate weighed after cooling. From this an estimate of the asphalt content of the mix can be determined. Ignition ovens are equipped with pollution control devices on their exhaust stacks and are therefore much less hazardous to the environment than previously used chemical extraction methods.

**Impermeability** - A materials resistance to the flow of air and water through it.

**In Situ** - In the natural or original position.

**Initial Traffic Number** *(ITN)* - The average daily number of equivalent 80 kN single-axle load applications expected for the design lane during the first year.

**Intermediate Course (sometimes called binder course)** - An asphalt pavement course between a base course and an asphalt surface course.

**Job-Mix Formula** - The term job-mix formula refers to an acceptable product of an asphalt concrete mix design, including aggregate gradation, optimum percent asphalt content and other substantiating data determined in the process.

**Lay-down Machine** - Asphalt pavers are also called lay-down machines. They are a self-propelled machine that is used for placing asphalt concrete pavement. They consist of a tracked or wheeled tractor unit that pulls an activated screed. The screed spreads the asphalt concrete and partially compacts it by using its weight and sometimes vibrators.

**Layer Coefficient (a1, a2, a3)** - These are used in the AASHTO Pavement Design Procedure, which Alaska does not use.

**Layton Box** - A box that is mounted on the tailgate of an end dump truck containing asphalt concrete mix. When the dump truck raises the bed, the hot mix slides into the Layton box, which allows paving in small areas such as trails and driveways.

**Lift** - A layer or course of paving material applied to a base or a previous layer.

**Longitudinal Joint** - Longitudinal joints run in the direction of paving. They are generally weak spots in the pavement and should be kept out of high traffic areas whenever possible. On highway projects they must be placed at lane lines or centerline. On aviation projects paving strips are normally at least 25 feet wide, which minimizes longitudinal joints. Most longitudinal joints are formed by placing hot asphalt concrete against cold pavement.

**Lute (Asphalt Rake)** - A metal rake with triangular teeth used to help finish hot asphalt overlays before rolling.

**Manual Proportioning Control** - In a hot or batch plant, a control system in which proportions of the aggregate and asphalt fractions are controlled by means of gates or valves, which are opened and closed by manual means. The system may or may not include power assist devices in the actuation of gate and valve opening and closing.

**Map Cracks** - See Cracks/Block Cracks.

**Marshall Method** - This method is used in Alaska. The Marshall Method for asphalt paving mixtures may be used for laboratory design and field control of mixtures containing asphalt cement and aggregates not exceeding one inch in maximum size. Principal features of the test are density-voids analysis and stability-flow test on specimens of compacted asphalt paving mixtures. Equipment and procedures for the Marshall tests are outlined in AASHTO Method of Test T245 and ASTM Method of Test D1559.

**Mastic** - A mixture of asphalt and fine mineral material in such proportions that it may be poured into place and compacted by troweling to a smooth surface.

**Maximum Density Line** - A straight line, plotted on a 0.45 power gradation chart that theoretically would indicate a gradation with little void space for asphalt cement. A generally accepted method for illustrating the line is to connect the 0.0 point on the chart to the smallest sieve size with 100% of the material passing it.

**Maximum Fines Content** ($P_{max}$) - The maximum allowable fines content of a material at a given depth below the surface course.

**Maximum Size for Aggregate –** One sieve larger than nominal maximum size.

**Maximum Specific Gravity** - Refers to a theoretical maximum specific gravity of a paving mixture, a zero air void condition, as determined by AASHTO T-209. The Rice Specific Gravity of a mix is used to calculate the percent air voids in a mix and the percent compaction. It is used as the reference for acceptance of asphalt concrete pavement compaction. The percent of Rice a mix has is its percent compaction. If you take 100% minus the percent compaction, you will find the percent volume of air voids in the mix. Also called "Rice Specific Gravity".

**Medium-Setting Emulsions** - See Emulsified Asphalt.

**Mesh** - The square opening of a sieve.

**Mineral Dust** - The dust portion of the fine aggregate passing the 0.075 mm (no. 200) sieve.

**Mineral Filler** - A finely divided mineral product at least 70 percent of which will pass a 0.075 mm (no. 200) sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

**Mix Design Methods** - See definitions for each of the following:

Marshall Methods
Superpave Procedures (Gyratory)
Hveem Methods (Stabilometer)

**Mix Design Report** - The mix design report contains information needed by project materials inspectors. On both aviation and highway projects, the Asphalt Mix Design becomes part of the contract. The asphalt content, aggregate and temperature specifications listed on the mix design supersede the authority of the standard specifications.

**Mixed-in-Place (Road-Mix)** - An asphalt course produced by mixing mineral aggregate and cutback or emulsified asphalt at the road site by means of travel plants, motor graders, or special road-mixing equipment.

**Multiple Surface Treatment** - Two or more surface treatments using asphalt and aggregate placed one on the other. The aggregate maximum size of each successive treatment is usually one-half that of the previous one, and the total thickness is about the same as the nominal maximum size aggregate particles of the first course. A multiple surface treatment is a denser wearing and waterproofing course than a single surface treatment, and it adds some strength but is not normally assigned a structural coefficient. The following is a list of various MST's:

**Bituminous Surface Treatment** *(BST)* - Another term for an emulsified Asphalt Surface Treatment (AST). A BST typically indicates a double shot AST where the process of surface preparation, application of emulsified asphalt with a distributor and application of graded aggregate chips with a chip spreader is done two or more times. In the Yukon Territory, the term BST is used as the name for High Float Surface Treatments.

**Double Shot Seal Coat** - Similar to the chip seal but in a double application. It is durable, provides some leveling and is available in a number of textures.

**Triple Seal** - The triple seal uses three applications of binder and three sizes of chips using CRS-2 or RS-2. It provides up to a 2-cm thick, flexible pavement. It levels as well as providing a sealed, tough-wearing surface.

**Natural (Native) Asphalt** - Asphalt occurring in nature, which has been derived from petroleum by natural processes of evaporation of volatile fractions leaving the asphalt fractions. The native asphalt of most importance is found in the Trinidad and Bermudas Lake deposits. Asphalt from these sources often is called Lake Asphalt.

**Nominal Maximum Size for Aggregate –** One sieve larger than the first sieve to cumulatively retain more than 10 percent.

**Nuclear Gauges/Nuclear Density** - Nuclear gauges are used to monitor and check compaction levels of mixes. The nuclear density gauge senses the reflection of gamma rays sent into the pavement; the greater the density, the more rays are reflected. The gauge must be calibrated for each paving mix.

**Oil Content** - See Asphalt Content.

**Open-Graded Asphalt Mix (Friction Course)** - Open-graded hot mix asphalt concrete is used as friction surfaces to reduce hydroplaning. They are generally placed as overlays on new or existing pavements. Open-graded asphalt concrete is made with a relatively large proportion of coarse aggregate and a small proportion of fine aggregate. This leaves voids (openings) in the mix that allows water to drain. This, combined with the coarse surface texture, provides a skid resistant surface. The coarse material provides the structural strength of the pavement. The fines, combined with the asphalt cement, coat the coarse aggregate and cement it together. Open-graded asphalt concrete typically contains 20% or more air voids.

**Optimum Asphalt Content** - A term used for the Marshall Design method. It is the design asphalt content at which the mix has a certain combination of stability, air voids and density.

**Overlay** - Overlays are a means of rehabilitation of distressed existing asphalt concrete pavement. They may be used to increase the design life before distress is shown. They are most appropriately applied before the existing pavement has become too rough, cracked and rutted. An application of emulsified asphalt tack coat is applied on the existing pavement prior to the overlay. The thickness requirement for the overlay is a function of the structural condition of the existing pavement and the predicted future traffic loading.

**Patching** - Mending or repairing a roadway surface usually with asphalt and aggregates.

**Pavement Design Methods:**

California Bearing Ratio (aviation)(FAA)

Excess Fines Method (highway) (See Guide for Pavement Design)(PCM 1180)

Mechanistic Method (highway)(PCM 1180)
AASHTO Pavement Design Methods (highway)

**Pavement Design Period** ***("n")*** - The number of years that a pavement is expected to carry a specific traffic volume and retain a serviceability level at or above a designated minimum value without rehabilitation. This is optimized by the Pavement Management System.

**Pavement Performance** - The trend of service-ability with load applications.

**Pavement Price Adjustment** - See Quality Level Analysis.

**Pavement Rehabilitation** - Work undertaken to extend the service life of an existing facility. This includes placement of additional surfacing material and/or other work necessary to return an existing roadway, including shoulders, to a condition of structural or functional adequacy. This could include the complete removal and replacement of the pavement structure.

**Pavement Structure** - The combination of select material, subbase, base, and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed (1 meter below the asphalt concrete layer).

**Pavement Structure Combination** - **or Composite-Type** - When the asphalt pavement is on old portland cement concrete pavement, a portland cement concrete base, or other rigid-type base or on a granular base, the pavement structure is referred to as a combination - or composite-type pavement structure.

**Penetration** - The consistency of a bituminous material expressed as the distance in tenths of a millimeter (0.1mm) that a standard needle penetrates vertically a sample of the material under specified conditions of loading, time, and temperature. It can also refer to the depth the prime coat penetrates into the base.

**Penetration Grading –** Of asphalt cements is a classification system based on penetration in 0.1 mm at 25$^{o}$C (77$^{o}$F). There are five standard paving grades, 40-50, 60-70, 85-100, 120-150, and 200-300.

**Percent Trucks** ***(PTT)*** - The percent of Average Daily Traffic (ADT), which is heavy truck traffic.

**Predicted Deflection** ***($D_p$)*** - The predicted maximum probable deflection of a proposed pavement structure due to an 80 kN single axle load.

**Performance Graded Asphalt** - A product of the SHRP research program, sometimes termed Superpave or PG Graded Binder (Asphalt). A new asphalt grading system based on temperature extremes that the design pavement is expected to withstand. The laboratory grading system subjects samples of the binder to various tests at the extremes. Performance Graded Asphalt is shown with a PG grade. For example, a PG58-28 is a binder that is supposed to withstand temperatures from +58 degrees centigrade, down to -28 degrees centigrade. The high temperature is the maximum ambient temperature the mix is expected to withstand for any 7-day period during the design life. The low temperature is the one-day expected low pavement temperature during the design life of the pavement.

**Performance Period** - The period of time that an initially constructed or rehabilitated pavement structure will last (perform) before reaching its terminal serviceability; this is also referred to as the *design period*.

**Performance-Related Specifications** - Specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with fundamental engineering properties that predict performance. These characteristics (for example, air voids in asphaltic pavements, and strength of concrete cores) are amenable to acceptance testing at the time of construction. True performance-related specifications not only describe the desired levels of these quality characteristics, but also employ the quantified relationships containing the characteristics to predict subsequent pavement performance. They thus provide the basis for rational acceptance and/or price adjustment decisions. **-** *TRB Circular #457. Glossary of Highway Quality Assurance Terms.*

**Permafrost** - Permanently frozen subsoil.

**PG Grades** - See Performance Graded Asphalt.

**Pickup Machines** - Some contractors use belly dump trucks which dump hot mix in windrows on the grade. Then a pick up machine (also called a windrow elevator) is used to deposit the mix into the paver.

**Pit-Run** - Using aggregates from selected deposits as they exist naturally without further treatment such as screening.

**Plant Mix** - See Hot Mix Asphalt.

**Plant Screens** - In a hot or batch plant, the screens located between the dryer and hot bins that separate the heated aggregates into the proper hot bin sizes. Plant screens are also sometimes used with rock crushers and washing plants.

**Pneumatic-Tired Roller** - Self-propelled pneumatic rubber tired rollers have two to eight wheels in front and four to eight wheels in the rear. The wheels generally oscillate (axles move up and down) and some may wobble. Self-propelled pneumatic-tired rollers vary in weight. Ballast can be added to the machines to increase the weight. Some machines have the ability to change tire inflation while the roller is operating.

**Poise** - A centimeter-gram-second unit of absolute viscosity, equal to the viscosity of a fluid in which a stress of one dyne per square centimeter is required to maintain a difference of velocity of one centimeter per second between two parallel planes in the fluid that lie in the direction of flow and are separated by a distance of one centimeter.

**Prepared Roadbed** - In-place roadbed soils compacted or stabilized according to provisions of applicable specifications.

**Present Serviceability Index** *(PSI, p)* - A number derived by formula for estimating the serviceability rating from measurements of certain physical features of the pavement.

**Prime Coat (Highway & Aviation)** - A prime coat is a bituminous application used to prepare an untreated base for an asphalt surface. The prime penetrates into and seals the base and plugs the voids. It hardens the top, keeps the base from raveling, and helps bind the base to the overlying asphalt course. Highway Standard Specification 403-2.01 allows MC-30 Liquid Asphalt or CSS-1 Emulsified Asphalt as a prime coat. Aviation Standard Specification 600.2 allows MC-30 or CMS-2S Emulsified Asphalt. The contract special provisions may allow other materials.

**Project Design Life** *(N)* - The total number of years a pavement will be in service before it will be totally reconstructed. This includes the years of life extended by any asphalt overlays considered in the original design.

**Pumping** - The ejection of foundation material, either wet or dry, through joints or cracks, or along edges of rigid slabs resulting from vertical movements of the slab under traffic.

**Quality Level Analysis** - This is also called/ known as “Pavement Price Adjustment”, “Quality Control and Quality Assurance”, “incentive/ disincentive” and “penalty/ bonus”. The procedure provides a basis for deciding whether to accept, reduce payment, or reject the paving material depending on both its degree of conformance with the specifications and its variability. A statistically random sampling plan is used for asphalt acceptance testing whenever a price adjustment procedure is included in the contract. Pavement price adjustment is now always used on airport and highway projects.

**Quality Control (Process Control) Tests** - Quality Control tests are done by the contractor to ensure the quality of the materials prior to incorporation into the project. The tests allow the contractor to correct deviations from specifications prior to placing the material.

**Rapid-Setting Emulsions** - The rapid-setting grades are designed to react quickly with aggregate and revert from the emulsion state to asphalt. The RS grades produce a relatively heavy film. They are used primarily for spray applications, such as aggregate (chip) seals, sand seals, surface treatments, and asphalt penetration macadam. The RS-2 and CRS-2 grades have high viscosities to prevent runoff.

**Raveling** - The loss or dislodgment of surface aggregate particles, either from the edges inward or the surface downward. It is normally caused by lack of compaction, construction of a thin lift during cold weather, dirty or disintegrating aggregate, too little asphalt in the mix, or overheating of the asphalt mix. Studded tires have also been shown to contribute to raveling.

**Reclaimed Asphalt Pavement *(RAP)*** - Reclaimed asphalt (RAP) is the removed and/or processed materials containing crushed asphalt pavement. In the process of reuse, the RAP can be used for hot or cold recycling, mixing with base course, or used as a pure RAP base.

**Resilient Modulus** - A measure of the modulus of elasticity of roadbed soil or other pavement material.

**Rice Specific Gravity** - Same as Maximum Specific Gravity.

**Rigid Pavement** - A pavement structure which distributes loads to the subgrade, having as one course a Portland cement concrete slab of relatively high-bending resistance.

**Roadbed** - The graded portion of a highway within top and side slopes, prepared as a foundation for the pavement structure and shoulders. It extends to such a depth as to affect the support of the pavement structure.

**Roadbed Material** - The graded portion of a highway within top and side slopes prepared as a foundation for the pavement structure and shoulders. It extends to such a depth as to affect the support of the pavement structure.

**Roadmix** - A method of combining aggregates and asphalt by use of a grader.

**Roadway Structure** - A combination of select subbase, base course and surface course materials placed on a sub-grade that supports the traffic load and distributes it to the elements of the roadbed.

**Rock Asphalt Pavements** - Pavements constructed of rock asphalt, natural or processed and treated with asphalt or flux as may be required for construction.

**Ross Count** - The Ross Count is a visual determination of how well the asphalt is coating the aggregate. The Ross Count is performed on asphalt concrete at the asphalt plant. The Ross Count is an acceptance test for batch plants and an informational test for dryer-drum plants.

**Ruts** - Ruts are depressions that develop in the wheel tracks of a pavement. Ruts may result from consolidation or lateral movement under traffic in one or more of the underlying courses, or by displacement in the asphalt surface layer itself. They may also develop under traffic in new asphalt pavements that had too little compaction during construction or from plastic movement in a mix that does not have enough stability to support the traffic. Ruts can also be caused by studded tire wear.

**Sand Asphalt -** A mixture of sand and asphalt cement or cutback or emulsified asphalt. It may be prepared with or without special control of aggregate grading and may or may not contain mineral filler. Either mixed-in-place or plant mix construction may be employed. Sand asphalt is used in construction of both base and surface courses.

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**Sand Equivalent Test** - The sand-equivalent test indicates the relative proportion of detrimental fine dust or clay-like materials in mineral aggregates used for asphalt paving mixtures and mineral aggregates or soil used for base courses.

**Sand Seal** - A seal coat of spray-applied CRS-1 or RS-1 with a sand cover. It restores uniform cover and enriches dry, weathered pavement; reduces raveling.

**Scarify** - To loosen the surface by mechanical means.

**Screed Unit** - The screed unit is attached to the tractor unit on a lay-down machine by long screed pull arms on each side of the machine. The screed pull arms provide the screed with a floating action as it travels along the road, automatically compensating for surface irregularities within the "wheel base" of the paver. As the tractor unit pulls the screed into the material, the screed will seek the level where the path of its flat bottom surface is parallel to the direction of the pull, planing up or down to the required paving thickness as the screed angle of attack is adjusted.

**Seal Coat** - See Single Surface Treatment.

**Segregation** - Segregation is the separation of the coarse and fine aggregate particles in an asphalt mix. The segregation of the mix can occur at several locations during the mix production, hauling, and placing operation. Some mixes are more prone to segregate than others. Asphalt mixes that have large top-size coarse aggregates (1 inch or greater), low asphalt cement contents, and are gap graded will tend to segregate more readily when handled that a dense-graded mix containing optimum asphalt content and a smaller top-size coarse aggregate. Segregation affects pavement durability directly by increasing the air void content of the mix that increases the potential for moisture damage. Segregated locations are susceptible to raveling and, if bad enough, to total disintegration under traffic.

**Selected Material** - A suitable native material obtained from a specified source such as a particular roadway cut or borrow area, of a suitable material having specified characteristics to be used for a specific purpose.

**Serviceability** - The ability, at time of observation of a pavement, to serve traffic that uses the facility.

**Settlement Test** - The Settlement Test detects the tendency of asphalt globules to settle during storage of emulsified asphalt. The procedures and equipment are prescribed in AASHTO Method of Test T59 and ASTM Method of Test D244.

**Sheet Asphalt** - A hot mixture of asphalt cement with clean angular graded sand and mineral filler. Its use ordinarily is confined to surface course, usually laid on an intermediate or leveling course.

**Shoving** - Shoving of an asphalt concrete layer is the displacement of the mixture in any direction. An unstable or tender mix primarily causes shoving. It can take place during the compaction operation or can occur later under traffic.

**SHRP** - SHRP is the acronym for the Strategic Highway Research Program. It is a Federally funded research program, begun in 1987 as a five year research program, with goals of improving methods of design, construction and maintenance of asphalt concrete and Portland cement concrete pavements. SHRP research funds were partly used for the development of performance-base specifications to directly relate laboratory analysis with field performance. The research program was completed in 1995, with only the portion relating to long term pavement performance (LTPP) still ongoing.

**Sieve** - In laboratory work, an apparatus with square apertures that are used for separating sizes of material. Sieve sizes are given in two ways. Large sizes (sieves with holes 1/4 inch or more) are named by the opening width, i.e. 1 inch, 3/8 inch, etc. Smaller sieves are numbered, i.e. #4, #200, etc. The number corresponds to the number of openings per linear inch of screen.

**Sieve Analysis** - A weighed quantity of aggregate is shaken over a set of sieves having selected sizes of square openings. The sieves are nested together such that the one having the largest opening is on top and those of successively smaller openings are placed beneath. A pan is placed below the bottom sieve to collect all material passing through it. The shaking is normally accomplished with a mechanical sieve shaker. The weight of material passing each sieve is determined and expressed as a percent of the weight of the original or total sample.

**Sieve Test** - The sieve test compliments the settlement test and has a somewhat similar purpose. It is used to determine quantitatively the percent of asphalt present in the form of relatively large globules. The procedure and equipment for the sieve test are prescribed in AASHTO Method of Test T59 and ASTM Method of Test D244.

**Single Axle Load** - The total load transmitted by all wheels of a single axle extending the full width of the vehicle.

**Single Surface Treatments** - A single application of asphalt to any kind of road surface followed immediately by a single layer of aggregate of as uniform size as practicable. The thickness of the treatment is about the same as the nominal maximum size aggregate particles. A single surface treatment is used as a wearing and waterproofing course. The following is a list of SST's:

**Chip Seal** - A chip seal or "single shot" asphalt surface treatment is the spraying of emulsified asphalt material (CRS-2 or RS-2) followed immediately by a thin stone cover. This is rolled as quickly as possible to create adherence between the asphalt and the aggregate cover. The chips (or stones) range from 19-mm aggregates to sand and are predominately one sized. It produces an all-weather surface, renews weathered pavements, improves skid resistance and lane demarcation, and seals the pavement.

**High Float Emulsion** - AASHTO High float emulsion derives its name from the fact that the asphalt residue from distillation must satisfy a minimum float test in water at 60 Centigrade (140 F). High float emulsion has the capability of wicking up into fine materials unlike CRS-2 that basically only allows embedment of clean aggregate (chips). Typically HFMS-2s grade emulsion is used. That is: high float, medium setting, high viscosity with solvent emulsion. It is considered an anionic emulsion. This is a specific type of emulsion that may contain up to 7% oil distillates, which can result in a softer residue that is less sensitive to low temperature construction than CRS-2. The addition of solvent also helps the material coat aggregates and wick upward. High float emulsion tends to develop a weak gel structure immediately after spraying which creates resistance to flow on banked and crowned surfaces. In the Yukon Territory, a slightly different specification is used for High Float Emulsions based on penetration and other slight modifications to the AASHTO specification.

**High Float Asphalt Surface Treatment** - A single shot asphalt surface treatment where one application of high float emulsion is applied to the prepared surface followed by a single application of crushed gravel cover coat. The gradation of cover coat aggregate used in High Float Emulsion Surface Treatments are typically similar to those used for crushed aggregate base course (D-1), except with 100% passing the ¾” (19 mm) sieve rather than the 100% passing the 1” (25 mm) sieve as with D-1. The fine aggregates allowed in high float operations may cause segregation of larger materials and blockage in the chip spreader if they are not very dry. Therefore, strict moisture content control of cover coat materials must be maintained and High Float Asphalt Surface Treatments are more easily constructed in areas with dry climates, such as Interior Alaska. In the Yukon, a High Float Asphalt Surface Treatments are called a “BST”.

**Skid Resistance** - The ability of an asphalt paving surface, particularly when wet, to offer resistance to slipping or skidding. The factors for obtaining high skid resistance are generally the same as those for obtaining high stability. Proper asphalt content and aggregate with a rough surface texture are the greatest contributors. The aggregate must not only have a rough surface texture, but also resist polishing. Aggregates containing non-polishing minerals with different wear or abrasion characteristics provide continuous renewal of the pavement's texture, maintaining a skid-resistant surface.

**Slow-Setting Emulsions** - The slow-setting grades are designed for maximum mixing stability. They are used with high fines content, dense-graded aggregates. The SS grades have long workability times to ensure good mixing with dense-graded aggregates. All slow setting grades have low viscosities that can be further reduced by adding water. These grades, when diluted, can also be used for tack coats, fog seals, and dust palliatives. The SS type of emulsion depends entirely upon evaporation of the water for coalescence of the asphalt particles. The SS emulsions are generally used for dense-graded aggregate-emulsion bases, soil asphalt stabilization, asphalt surface mixes, and slurry seals.

**Slurry Seal** - A slurry seal is a maintenance operation intended to fill minor depressions and provide an easily swept surface. It is made with fine crushed aggregate mixed with quick-set emulsified asphalt (RS grades). The liquid slurry is machine-applied with a sled-type box, mounted on the back of a truck, containing a rubber-edged strike-off blade.

**Snivey** - A stainless steel nozzle attached to the spray bar on the back of a distributor that controls the shape and volume of asphalt being sprayed on the roadway.

**Softening Point** - The temperature at which asphalts reach an arbitrary degree of softening. The softening point is usually determined by the ring and ball test method.

**Solubility** - A measure of the purity of asphalt cement. It is that portion of the asphalt cement that is soluble in a specified solvent such as trichloroethylene. Inert matter, such as salts, frees carbon, or non-organic contaminants are insoluble.

**Specific Gravity** - Specific Gravity is the ratio of weight of any volume of material to the weight of an equal volume of water both at a specified temperature. Thus, a specific gravity of 1.05 means that the material is 1.05 times as heavy as water at the indicated temperature. The specific gravity of asphalt is usually determined for two reasons:

(1) To permit a calculation of voids of compacted asphalt paving mixes.

(2) To adjust quantities of aggregate components of a paving mix, where such components vary appreciably in specific gravity.

The specific gravity is determined by the hydrometer method as prescribed in AASHTO Method of Test T227 and ASTM Method of Test D3142.

**Stability** - The ability of asphalt paving mixture to resist deformation from imposed loads. Stability is dependent upon both internal friction and cohesion.

**Static Steel Wheel Roller** - Static steel wheel rollers normally range in weight from 3 to 14 tons. The gross weight can be adjusted by adding ballast, but this adjustment cannot be made while the roller is operating, and is not normally changed during the term of a paving project.

**Stoke** - A unit of kinematic viscosity, equal to the viscosity of a fluid in poises divided by the density of the fluid in grams per cubic centimeter.

**Stone Mastic (Matrix) Asphalt Pavement** *(SMA)* - SMA is a product that is relatively new in America. It was developed by contractors in Western Europe who are subject to giving warranties for their work against rutting. It is often used to rehabilitate areas with premature rutting failure due to studded tire wear. SMA optimizes stone on stone contact in the mix. It is gap graded, hot mix asphalt with a large proportion of coarse aggregates (amount passing 2 mm (0.08") limited to approximately 20 percent) and a rich asphalt cement/filler mastic. The coarse aggregates form a strong structural matrix. Asphalt cement, fine aggregate, filler and stabilization additive form a mastic that binds the structural matrix together. The coarse aggregates are highly fractured and roughly cubical stone. Relatively high asphalt contents (about 6.5 % of the total mix) provide for a durable pavement. A stabilizing additive, usually 0.3% cellulose from ground newspapers, is included in SMA to prevent hot asphalt cement from draining down during hauls.

**Stress Reduction Factor** *(SRF)* - The factor by which the stress of an applied load at the surface of a pavement is reduced at a given depth below the surface course.

**Structural Number** *(SN)* - <u>This is part of the AASHTO Pavement Design Procedure that Alaska does not use</u>.

**Subbase** *(SB)* - The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course (or in the case of rigid pavements, the portland cement concrete slab). If the subgrade soil is of adequate quality, it may serve as the subbase.

**Subgrade** - The top surface of a roadbed upon which the pavement structure and shoulders are constructed.

**Subgrade, Improved** - Subgrade, improved is a working platform achieved (1) by the incorporation of granular materials or stabilizers such as asphalt, lime, or portland cement, prepared to support a structure or a pavement system, or (2) any course or courses of select or improved material placed on the subgrade soil below the pavement structure. Subgrade improvement does not affect the design thickness of the pavement structure.

**Superpave Procedures** - The term *Superpave* stands for Superior Performing Asphalt Pavements and is a product of the SHRP asphalt research. The Superpave system incorporates performance-based asphalt materials characterization with design environmental conditions to improve performance by controlling rutting, low temperature cracking and fatigue cracking. The three major components of Superpave are the asphalt binder specification, the mix design and analysis system, and a computer software system.

The Superpave mix design process uses a gyration compactor to compact mixes. A gyratory compactor uses a rotating flat steel plate that is forced down upon the mix contained in a steel cylinder. The number of gyrations required for a mix design is determined from the expected equivalent single axle loads (ESALs) and the Design 7 day maximum air temperature.

The Superpave mix design differs most significantly from the currently used Marshall Mix Design Process in that it requires the designer to try various gradations in order to determine the one(s) that will meet the voids criteria at all three gyration levels.

**Surface Course** *(SC)* - One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer of flexible pavements is sometimes called "wearing course".

**Tack Coat** - A tack coat is a thin application of asphalt material applied to a previously paved surface to insure that an overlay will adhere to the existing surface. It is recommended to place a thin coat on any cold edges of new paving such as joints, gutter lines and around manholes, etc. For application, a slightly damp (not wet) surface is preferable to a dry, dusty one.

**Tandem Axle Load** - The total load transmitted to the road by two consecutive axles extending across the full width of the vehicle.

**Tar** - A material resulting from the process of combusting coal, sugar, wood, or other organic material.

**Test Categories** - Material tests are divide into five categories by DOT&PF:

> **QUALITY** - Quality tests are generally done by the State or Regional Materials Laboratory. They are made to determine if raw material from a particular source has acceptable qualities. Gravel for example is tested for hardness and durability.
>
> **ACCEPTANCE** - Project materials inspectors perform acceptance tests. They document whether a specific lot of a pay item (such as asphalt concrete) meets particular specifications for the item (such as gradation). Materials are accepted and paid for by the Department using acceptance tests.
>
> **ASSURANCE** - The Regional Lab usually performs assurance tests. These are used as checks on acceptance tests to assure that right procedures and test equipment are working correctly.
>
> **INFORMATION** - Information tests are made on samples taken during the production of materials prior to the point of acceptance. The gradation of aggregates, for example, is often checked as it is being crushed. Either project materials personnel or the Regional Laboratory may make information tests.
>
> **QUALITY CONTROL** - These tests are performed by the contractor to insure that the materials meet the contract requirements. Adjustments to the construction process are made if the materials begin going out of specifications.

**Thin Film Oven Test** - The Thin Film Oven (TFO) test actually is not a test. It is a procedure intended to subject a sample of asphalt to hardening conditions approximating those that occur in normal hot-mix plant operations. Viscosity or penetration tests made on the sample before and after the TFO test are considered to be a measure of the anticipated hardening.

**Traffic Equivalence Factor** *(e)* - A numerical factor that expresses the relationship of a given axle load to another axle load in terms of their effect on the serviceability of a pavement structure.

**Transverse Joint** - Transverse joints are placed wherever paving is ended and begun again at a later time.

**Travel Plant** - Travel-plants are self-propelled pugmill plants that mix the aggregates with asphalt, applied at a controlled rate, as they move along the road.

**Traveled Way** - The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

**Treated Base Courses** - Asphalt treated bases may be divided into two categories: 1) hot asphalt treated, and; 2) emulsified asphalt treated. These two categories may be further subdivided into *dense graded* and *open graded* (permeable) bases. Dense graded bases are the materials typically specified for highway construction. Open graded bases require special considerations. One purpose of any treated base is to provide improved structural support for paving. When asphalt treated base course is used, a portion of its thickness may be substituted for the thickness of Asphalt Concrete Pavement required by structural design.

**Dense Graded Asphalt Base** - Uses hot asphalt cement as a binder and is designed to be constructed much the same as Asphalt Concrete Pavement. These are usually D-1 gradation with asphalt binder.

**Open Graded Asphalt Base** - Made from crushed porous aggregates treated with hot asphalt binder. This material has seen limited use in particular applications. It is asphalt treated in order to provide stability during construction. Production and lay down of Open Graded Asphalt Treated Base is similar to Asphalt Concrete Pavement except compaction requirements, in terms of number of roller passes required, is determined by a test strip.

**Triple Seal** - See Multiple Surface Treatments.

**Truck Factor** - The Truck Factor is the number of equivalent 80 kN (18,000 lb) single-axle load applications contributed by one passage of a single vehicle. See also 'Equivalent Single Axle Loads' (ESAL).

**Unified Soil Classification System** *(USCS)* - USCS is a classification used in Airport construction projects. The Unified Soil Classification System is based on textural characteristics for those soils with such a small amount of fines that the fines do not affect soil behavior. It is based primarily on the characteristics that determine how a soil will behave when used as a construction material. The USCS places soils into three divisions:

1. Coarse-grained
2. Fine -grained, and
3. Highly organic

The USCS is designed so that visual inspection and simple field tests can classify these primary group soils. Tests used in the field identification are dilatency or shake test, dry strength, and toughness or consistency near the plastic limit. Unified Soil Classification Symbols for components, gradation and liquid limit are:

| Component | Symbol |
|---|---|
| Boulders | None |
| Cobbles | None |
| Gravel | G |
| Sand | S |
| Silt | M |
| Clay | C |
| Organic | O |
| Peat | Pt |
| Well-graded | W |
| Poorly-graded | P |
| High Liquid Limit | H |
| Low Liquid Limit | L |

**Unit Weight** - The ratio of weight to the volume of a substance. For example, the unit weight of water is 62.4 $lbs/ft.^3$ (or 1 $gram/cm^3$) at 4 degrees Centigrade.

**Vibratory (Vibrating) Roller** - Vibrating rollers are made with one or two smooth-surfaced steel wheels. They vary in static weight. Vibratory rollers are used for compacting any type asphalt mixture but should not be used in the vibratory mode when the mat thickness is 37.5 mm (1.5 inch) or less.

**Vibratory Screed** - The vibratory screed is highly effective in densifying initially the asphalt mat placed by the paver. Its operation is similar to the tamping screed but the compactive effort generated by the screed is derived from electric vibrators, rotating shafts with eccentric weights or hydraulic motors.

**Viscosity** - A measure of the resistance to flow. It is one method of measuring the consistency of asphalt.

**Absolute Viscosity** - A method of measuring viscosity using the poise as the basic measurement unit. This method utilizes a partial vacuum to induce flow in the viscometer.

**Kinematic Viscosity** - A method of measuring viscosity using the stoke as the basic measurement unit.

**Viscosity Grading** - A classification system of asphalt cements based on viscosity ranges at $140^{o}$f ($60^{o}$c). A minimum viscosity at $275^{o}$f ($135^{o}$c) is also usually specified. The purpose is to prescribe limiting values of consistency at these two temperatures. $140^{o}$f ($60^{o}$c) approximates the maximum temperature of asphalt pavement surface in service in the u.s.; $275^{o}$f ($135^{o}$c) approximates the mixing and laydown temperatures for hot asphalt pavements. There are five grades of asphalt cement based on the viscosity of the original asphalt at $140^{o}$f ($60^{o}$c).

**Voids/Voids in the Mineral Aggregate** *(VMA)* - Nearly all the volume of asphalt pavement is filled by aggregate particles. The remaining spaces (voids) are filled with asphalt or air.

**Void Volume** - Total empty spaces in a compacted mix.

**Wet Mixing Time** - The interval of time between the beginning of application of asphalt material and the opening of the mixer gate.

**Workability** - The ease with which paving mixtures may be placed and compacted.

**Yield** - Refers to the quantity of asphalt concrete pavement that is laid in the paving operation. An estimating factor is calculated, based on the expected unit weight of the compacted mixture, the width of the screed and the plan thickness of the mix. This estimating factor is in terms of weight per lineal measure of paving. Using this and net weights of mix from truck scale tickets, asphalt inspectors can see that the paving operation is proceeding properly towards the plan quantity of asphalt concrete mix and avoid overruns. Adjustments in the pavement thickness may be made, based on yield calculations, in order to match the plan tonnage of mix.

**Zeta Potential** - The measurement of zeta potential is a relatively new test for evaluating asphalt emulsions and is not an AASHTO or ASTM test. It measures stability in a colloid system with a laboratory device known as a zeta meter. The zeta meter measures the speed of move placed in an electrical field. This test has particular value in evaluating cationic emulsions. The level of zeta potential is a general indication of the setting characteristics of the emulsion.

# 13. Appendix F Further Reading

## 13.1 Required by Construction Contracts

Contracts refer to some or all of the following sources. The referenced policies and requirements for equipment, materials, and procedures thus become part of the contract itself.

Alaska DOT&PF:

Standard Specifications for Highway Construction, 1998 Metric Edition
Standard Airport Specifications
Alaska Test Manual
Alaska Construction Manual

American Association of State Highway and Transportation Officials (AASHTO), Suite 225, 444 N. Capitol St., N.W., Washington, DC 20004; (202) 624-5800:

Standard Specifications for Transportation Materials and Methods of Sampling and Testing (this is a 2 volume set updated regularly; Part I covers specifications, Part II covers tests)

American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103 (215) 299-5400:

Book of ASTM Standards, especially Part 15 on Road and Paving Materials, etc., (this is a multi-volume set updated annually)

## 13.2 General Reading:

The Asphalt Institute and the National Asphalt Paving Association both publish a series of educational handbooks and manuals. Some of the most useful are listed below.

The Asphalt Institute, P.O. Box 14052, Lexington, KY 40512-4052 (Northwest Office 2626 12$^{th}$ Court, S.W., Suite #4, Olympia, WA 98502; (206)786-5119):

MS-3 Asphalt Plant Manual
MS-4 The Asphalt Handbook
MS-6 Asphalt Pocketbook of Useful Information
MS-8 Asphalt Paving Manual
MS-19 Basic Asphalt Emulsion Manual
MS-22 Principles of Construction of Hot-Mix Asphalt Pavements

National Asphalt Pavement Association, 5100 Forbes Blvd., Lantham, MD 20706; phone (301) 731-4748:

Superintendent's Manual on Compaction
Hot Mix Asphalt Segregation: Causes and Cures

## 13.3 Transportation Technology Transfer Center:

The Transportation Technology Transfer Center, operated jointly by the Alaska DOT/PF and the University of Alaska, maintains a lending library of books, videotapes, manuals, and other information.

Call the center if you have questions about any aspect of paving or other transportation issues; they're there to help you. A list of publications and videos is available upon request. Their address is:

**TRANSPORTATION TECHNOLOGY TRANSFER PROGRAM (T-2)**
**2301 Peger Road**
**Fairbanks, Alaska 99709-6394**
**(907) 451-5320 Phone**
**(907) 451-2313 Fax**

# 14. Appendix G Necessities for a Successful High Float Project

# Necessities for a Successful High Float Project

By Jack Phipps, Transportation Maintenance Manager, Presented at the Asphalt Summit, 11/5/97

## 14.1 General Information

### *14.1.1 Road Grade*

A 3% crown is ideal on new construction or long maintenance patches. The crown on short patches over existing pavement needs to be the same as the rest of the road. I mention that because of the Parks Highway high float patching project, the contractor was trying to conform to the 3% crown specifications on all lengths of patches and the highway is less than 2%. Typically we try to produce a fairly smooth ride by filling the low areas and skimming over the high spots. This method will not reproduce the original profile, however it saves money and achieves an acceptable finish product.

### *14.1.2 Base Aggregate*

The specification for D-1 should be modified to insure 4-6% of the#200s. When using aggregates with a low degradation of aggregates, requires less 200s with soft or clay enriched aggregate because they tend to make fines as they are handled.

### *14.1.3 Base Moisture and Compaction*

Base moisture and compaction go hand in hand. The moisture on new construction is more forgiving than maintenance patches over asphalt. With patches, the aggregate is sometimes over-watered especially on the ends where the aggregate is thin and when the aggregate is high in 200s. Water often won't drain out and will cause shoving of the base and mat. Unfortunately this usually is not noticeable until you are all done surfacing.

### *14.1.4 Equipment*

The equipment is basically the same as chip patches or new construction. I recommend having two rubber-tired rollers working behind the chipper to insure good penetration of the aggregate into the oil.

### *14.1.5 Weather Restraints*

In the Interior we have tried to keep August 15 as a cutoff date for both chip sealing and high float. This will hopefully give a month before freezing weather starts. Both types of surfacing need several warm days to seat the aggregate in the oil. Past projects have shown that damage and aggregate loss is substantially increased the later in the summer we work.

### *14.1.6 Application Rates*

0.75 gallons per square yard is a good starting point, and approximately 75 pounds per square meter of D-1. The requirement for a computerized aggregate spreader is not needed. We put down the minimum amount of aggregate to prevent excessive bleeding and to minimize sweeping. With computerized or automatic controls the foreman, inspectors or operators tend to rely on the machine and stop using their judgment and/or experience to produce good product. Aggregate application rates change with gradation and moisture content, therefore the operator can't just set the computer and go.

### *14.1.7 Cover Coat Aggregate*

We use the same gradation as recommended for the base D-1, 100% passing the 1” sieve. The moisture needs to be kept under 3%. It will probably require the stockpile to be covered depending on the climate.

### *14.1.8 Cover Coat Compaction*

High float oil is more forgiving than CRS-2, allowing you to make more passes with the rubber tired rollers before it sets up. The more it's rolled, the better the results. After the cover coat starts to dry, a steel drum roller may be used. This sometimes aids in eliminating ridges in the mat.

### *14.1.9 Sweeping*

The new surface should be swept lightly before the loose aggregate form windrows that prevent water runoff or washboards from forming. Since high float oil is more pliable than CRS-2, it is more susceptible to water damage during its curing time.

## 14.2 Cost Effectiveness

1. Since high float is a one step process, there is approximately 40% time and equipment savings over the 2 shot chip seal. Although the actual lay down of high float is slightly slower than B chips, (due to the higher application rates); it doesn't require a second traffic control set-up, one additional sweeping and time and equipment for the second shot.
2. Material costs are 40% less using high float rather than a 2 shot B&E chip surface. Aggregate application rates total close to the same by weight, but B&E chips cost 50% more than D-1. The cost of high float oil is $270/ton and CRS-2 is$320/ton, a difference of 16%. The total application rate for a 2 shot CRS-2 is 25-30% more than high float. The labor, equipment and material savings of 40% with high float make it the most economical means of resurfacing roads. Also keeping in mind that with our short summers, because it's faster we get more done using high float. Many of the areas we repair in maintenance will require resurfacing within 1-3 years due to settlement, and doesn't justify a more expensive means of repair.
3. Two comments or complaints heard about high float are the rough-finished texture and the need to monitor the surface during the first week of curing. If the surface texture is truly a problem, an E or F chip seal can be applied at a later date. This will make total costs for the high float close to a B&E chip job, but thicker and more durable.

## 14.3 Problems Encountered in the Field

### *14.3.1 Lack of Flexibility to Make Changes in the Field*

Don't get stuck on the specifications - they should be a guide. An example is Pitman Road - the specifications called for 0.75 gallons per square yard and applying the cover coat immediately. The oil was running outside the shot width1.5 feet. Rather than wait a couple of minutes before covering the oil, allowing it to partially set, the shot rate was cut back to 0.6th which decreased the mat thickness. This was later changed back. Different material sources - base compaction - weather condition - aggregate moisture content, each affect how you fine tune application rates in the field.

### *14.3.2 Ridges - Rough Joints - Streaking*

Ridges at the meet lines are caused by excessive amounts of oil from either improper fan overlap or oil run off when making the matching shot. Fan overlap is generally driver error and letting the oil set a minute will usually eliminate oil run off. Rough joints can be avoided if the oil wave in front of the chipper is kept to a minimum and the distributor operator only overlaps 4-6" his previous stop point. All defects need to be corrected immediately, while the oil is still fresh, i.e.: Rake off excess D-1 at joints, cover any exposed oil and add oil to any bare spots. Two good laborers on the ground are a requirement. Streaking can often be eliminated by heating the oil to$185^0$ F., changing the distributor travel speed, changing nozzle fan angle or size, and / or changing the spray bar height.

### *14.3.3 Spreader Problems*

As I mentioned before, computerized chip spreaders aren't needed. After you spray the correct amount of oil, it is covered with whatever aggregate is needed to produce good results. This applies to maintenance patches as well as new construction. Wet cover coat material is the one major problem with chip spreaders, if wet it doesn't flow to the belts in the hopper and bridges in the spreader box. Keep the moisture content under 3%.

*In the past 28 years with Maintenance, I've tried about every way of repairing roads from RC-800 - pugmills - sandseals - 2 shot chip seals - hot mix to high floats. Although hot mix definitely has its place, high float is the most economical means of patching or resurfacing areas that historically settle.*

# 15. Appendix H Pavement and Surface Treatments used in Maintenance, Rehabilitation and Construction

# Pavement and Surface Treatments used in Maintenance, Rehabilitation and Construction

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This paper briefly discusses the proper applications, materials used and equipment requirements for the following for highway pavement construction, rehabilitation and maintenance in Alaska. Specific topics are listed below.

1. Brief Asphalt Materials Definitions
2. Asphalt Concrete Pavement
3. Crack sealing and filling
4. Chip Seal or single shot Asphalt Surface Treatment (AST)
5. Bituminous Surface Treatment (BST) or double shot Asphalt Surface Treatment
6. High Float Emulsion Asphalt Surface Treatment
7. Reclaimed and recycled asphalt pavement
8. Treated bases
9. Stone Mastic (Matrix) Asphalt Pavement (SMA)
10. Superpave Hot Asphalt Pavement
11. Relative Costs
12. Life Cycle Cost Analysis
13. Conclusions

For more in depth discussions, please refer to the Asphalt Institute and other publications.

## 15.1 Asphalt Material Definitions

Brief definitions for asphalt materials used in road construction are given to help eliminate any confusion.

*Anti-stripping agents* are usually blended with asphalt binders in order to improve bonding characteristics between the binder and the aggregate. Particles of opposite electrical (ionic) charge attract each other and ones of like charge repel. Thus anti-stripping agents are used to give asphalt cement opposite charges of the aggregates. Chemical anti-stripping agents, such as PaveBond or Arr-Maz are most commonly used in Alaska. Asphalt cement suppliers usually add anti-stripping agents. Percentage requirements for anti-strip are typically around ¼% by weight of asphalt.

*Asphalt cement or binder* is a black, cement material, sometimes called Bitumen, that varies widely in consistency from solid to semi-solid at normal air temperatures. The main product of asphalt is derived from crude petroleum. It is the residue left over from refining processes that remove other petroleum products such as gasoline, kerosene and fuel oil.

At high temperatures (>140° C) asphalt cement is a liquid, which allows it to be mixed with or coat aggregate particles. As the asphalt cools it stiffens, becoming solid at some point below 0° C. The chemical contents of asphalt are primarily complex hydrocarbon molecules including asphaltenes, resins and oils. Some of the molecules contain sulfur, nitrogen and other elements. The physical properties of asphalt are durability, adhesion, temperature susceptibility, aging and hardening.

Typical asphalt binder grades used in Alaska AC-2.5, AC-5, PBA-2, PBA-3, Arctic Grades, and Performance Grades (PG). The AC grades are asphalt cements graded by viscosity at 60° C., with higher numbers indicating higher viscosities. The AC-2.5 has been used because it is theoretically more resistant to thermal cracking due to its softer nature. Recent research has not substantiated this theory. Also, AC-2.5 is prone to undesirable softening and rutting when air temperatures exceed 25° C. AC-5 has been found to exhibit similar thermal cracking characteristics to AC-2.5 and has better high temperature properties. Limited use of stiffer AC-10 and AC-20 grade asphalt in Alaska has shown higher instances of thermal cracking.

The PBA grade stands for "Performance Based Asphalt". These grades were/are a transitional grade between viscosity grade and performance grade (PG) asphalt binder discussed below. A PBA-2 grade is unmodified asphalt with stiffness slightly greater than AC-5 graded binder. PBA is produced in Washington and only available to the Pacific Rim. The PBA-3 grade is modified asphalt, with penetration and viscosity limits designed to resist low temperature cracking and rutting. Modifiers used in PBA-3 may be natural rubbers (latex) or synthetic rubbers (polymer). These modifiers increase the mix and compaction temperatures for construction and make the mix harder to work. PBA-3 asphalt costs substantially more than unmodified asphalt, thus the benefits of its application must be thoroughly considered.

Arctic Grade binders are modified asphalt with particular emphasis on low temperature cracking characteristics. They are designed with the intent of flattening the slope of the viscosity/temperature relationship in a given binder. Arctic Grade binders are often subject to AC grade viscosity requirements and a maximum pen-visc number. The pen-visc number (PVN) is a function of the penetration and viscosity tests on the binder. These binders are usually only used in extreme conditions, such as on the North Slope of Alaska.

Performance Grade binders are graded by the temperature range (Deg. C) of intended use. For example, a PG52-28 grade is intended for use in temperatures ranging from 52 to minus 28 degrees Centigrade. Standard grades vary by 6 degrees Centigrade. Typical PG grades used in Alaska include PG52-28, PG58-28 and PG64-28. Higher temperature grades are often made of modified asphalt and used in high traffic areas. Though temperature extremes in Alaska would dictate use of even lower, low temperature grades, they are not currently available. Performance Grade binders are part of the Super Pave system described later.

*Cutback asphalt* contains asphalt particles in a suspension with a solvent. Solvents range from heavy fuel oil consistence up to naphtha, depending on the curing time desired. Cutback asphalt cures by the evaporation of the solvent, which amounts from 33% to 50% by weight of the material. They are classed into SC (slow cure), MC (medium cure) and RC (rapid cure) along with a minimum viscosity. Cutback asphalt cures by the evaporation of the solvent. Application of cutback asphalt should be carefully considered due to potential environmental problems.

*Emulsified asphalt* is made by combining asphalt, emulsifying agents and water. A colloid mill breaks down molten asphalt into minute droplets in the presence of water and the emulsifying agents. Emulsifying agents usually contain a type of soap. They also impart desirable properties and are most influential in maintaining stable asphalt droplet suspension. Asphalt emulsions are categorized into cationic (positive charged), anionic (negative charge) and anionic (no charge). The charge on the emulsion is used to provide for the proper attraction between it and the aggregates used.

Asphalt emulsions normally contain approximately 40% water. They cure or "break", by the normal process of water removal by evaporation. Asphalt emulsions are further categorized by the relative setting (breaking) time. There are slow setting (SS), medium setting (MS) and rapid setting (RS) emulsions. Each type will have its proper place of application, which will is discussed below.

The amount of residual asphalt is of interest to those constructing emulsified asphalt treated materials. For example, a 3% application of emulsified asphalt will yield approximately 1.8% residual asphalt after breaking.

Mixtures of aggregates and slow curing asphalt emulsion are referred to as “cold mix” since they do not require heating in order to work. Cold mixes are used for emergency repairs of pavement such as patching potholes.

*Prime coats* are applied to prepared aggregate surfaces with the intended purpose of improving the bond between pavement and aggregate. They may be emulsified asphalt or cutback asphalt. Traffic should not be allowed to drive on prime coated surfaces until they have cured, which may take days. Use of prime coat may be problematic if the weather is cool (slowing cure rates) or if the weather is wet (causing possible runoff).

*Tack Coats* are a thin layer of emulsified asphalt applied prior to placement of asphalt concrete pavement on a hard surface such as existing pavement or concrete. The purpose of a tack coat is to provide a waterproof bond between new asphalt concrete pavement and existing surfaces. It is recommended to place a thin tack coat on any cold edges of new paving such as joints, gutter lines and around manholes, etc. Use of STE-1 grade (snap tack emulsion) is recommended for any tack coat application. It does not require dilution and breaks rapidly.

## 15.2 Asphalt Concrete, New Construction and Rehabilitation

### *15.2.1 Material used*

Asphalt Concrete Pavement is a combination of asphalt cement and aggregates, mixed in a plant. It may be called: Hot Mix Asphalt; Hot Asphalt Pavement; Asphalt Concrete and several other word combinations, sometimes including; Bitumen or Bituminous. The Asphalt Concrete Pavement terminology is used here since that is the current pay item for Alaska DOT/PF.

It is usually dense graded, meaning that the aggregate particles have closer contact with each other to stop permeability, and to provide a sound, tough, inert material that will resist disintegration under maximum traffic loads. Asphalt cement usually comprises 4% - 7% of asphalt concrete pavement. Higher asphalt content mixes are more durable and resistant to aging. However, high asphalt content mixes may be subject to deformation and rutting. Low asphalt content mixes are less durable and may tend to fatigue crack with repeated loads. It is important that optimum asphalt contents be developed and used.

The aggregates used with the asphalt are classified according to their sizes. These are as follows:

a. *Coarse aggregate* are crushed stone or crushed gravel consisting of sound, durable rocks greater than 4.75 mm (0.19”) in size. The materials must meet quality requirements in terms of wear, degradation, chemical loss and fracture.

b. *Fine aggregate* (smaller than 4.75 mm) are usually screened aggregates, sand and soil. They may be *natural*, uncrushed fines or crusher fines. Fine aggregates are subject to requirements regarding grading variability, plastic index (minimizing clay particles) and chemical loss.

c. *Blended aggregate* is the combination of the coarse and fine aggregates. It must meet gradation requirements for the Type of Asphalt Concrete Pavement specified. The maximum size (smallest sieve with 100% passing indicates the Type of Asphalt Concrete Pavement. A gradation with maximum size of 25 mm (1”) and meeting all other gradation requirements is a Type I. Gradations with maximum sizes of 19 mm (¾”) and 12.5 mm (½”) are Types II and III, respectively.

Asphalt Concrete Pavement mix designs determine: percent asphalt required; anti-strip requirements, mix and compaction temperatures for a given aggregate gradation. Mix designs are usually done according to the Marshall mix design methods, where a mechanical hammer is used to compact specimens, the number of hammer drops used according to the expected traffic loading. The mix must meet certain criteria. Three classes: A, B and C of asphalt concrete pavement may be designed. Class A pavement is for the highest traffic loading. Class C is for very low traffic. Class B is for intermediate traffic levels.

### 15.2.2 Construction Equipment Requirements for Asphalt Concrete Pavement

- *Pit Development and Extraction Equipment* will include any necessary equipment to prepare a material site, extract and haul aggregates to a crushing plant. Crushing plant includes crushers, conveyor belts, screens, loader, hauling equipment and controls.

- *Asphalt mix plant* includes aggregate bins, asphalt storage, heating and pumping equipment, conveyors, dryers, mixing equipment, truck loading equipment, storage silos and a control room. There are two types of asphalt mix plants: batch plants and drum (continuous feed) plants. Batch plants are stationary plants, which blend and discharge mix in batches of approximately 2 to 5 megagrams each. A megagram is equal to 1.1 tons. Drum plants are portable and work with a continuous feed of aggregates into the drum where they are dried and asphalt is applied.

- *Trucks* for hauling hot mix to the project. Belly dump trucks are usually used on larger projects when the paver is equipped with a windrow pickup machine. End dumping trucks are used for smaller projects where the mix is dumped directly into the paver.

- *Surface preparation equipment* may include a water truck and power broom for overlays, a rotomill (planer) for rut rehabilitation and all supporting construction equipment to build a structural section.

- *Distributor truck for Prime and/or Tack Coat application.* Prime coat may be applied to the base course prior to paving. Tack coat is applied to existing pavement and along edges of an Asphalt Concrete Pavement overlay.

- *Paver* includes receiving bin or pick up machines and lay down equipment. The screed drags along the back of the paver providing initial compaction. The screed height determines the depth or thickness of the Asphalt Concrete Pavement.

- *Rollers* usually include double steel wheeled and one rubber tired (pneumatic) roller for compaction of the mix.

- *Nuclear Gauges* are used to monitor and check compaction levels of the mix.

- *Coring machines* are used to remove core samples of the completed mix, which are tested to measure the level of compaction for acceptance.

- *Traffic control equipment and personnel.*

### 15.2.3 Proper applications of Asphalt Concrete Pavement

Asphalt concrete pavement is applicable to areas of high and/or heavy traffic and stable foundations, preferably with a permanent plant nearby. A life cycle cost study in the Yukon Territory found that asphalt surface treatments were more effective than asphalt concrete on roadways with less than 2000 ADT (average daily traffic) and permafrost areas. On roadways with ADT greater than 10,000 and high usage of studded tires (>40%), asphalt concrete pavement may not provide sufficient wear resistance. Use of Stone Mastic Asphalt, described later, may be considered to provide better wear resistance.

Paving should not be done on wet surfaces or in the rain, or at temperatures below approximately 5° C (40° F.), the mix cools too rapidly and proper compaction is hard to obtain, especially with thin paving lifts.

*New construction* of asphalt concrete pavement requires providing for drainage, preparation of the foundation (stripping, digging out unsuitable materials, blasting rock, surcharging, etc.) and construction of appropriate thicknesses of granular supporting layers including subbases and base courses. The appropriate thickness of asphalt concrete pavement used is a function of predicted future traffic loading, foundation support and the quality of materials available for base course and subbase. Pavement designs provide for limited frost protection using an appropriate thickness of non-frost susceptible material.

*Overlays* are a means of rehabilitation of distressed existing asphalt concrete pavement. They are most appropriately applied before the existing pavement has become too rough, cracked and rutted. An application of emulsified asphalt tack coat is applied on the existing pavement prior to the overlay. Existing cracks may be expected to reflect up through the new overlay within 1 to 3 years. Existing rutting or roughness is usually assumed to be 75% corrected per lift of overlay. Therefore, more than one lift of overlay or preleveling may be required to thoroughly correct problems. The thickness requirement for the overlay is a function of the structural condition of the existing pavement and the predicted future traffic loading.

*Reclaim existing pavement and overlay.* This rehabilitation process is used when the existing pavement has become very rough, cracked and it is usually less than 100 mm (4") in thickness. The existing pavement is ground up and mixed with a nominal thickness of the existing base. Emulsified asphalt may be applied into the mixture of broken old pavement and base course in situations where there are frost susceptible materials or additional support is required. The resulting blend is graded, compacted and then overlaid with new asphalt concrete pavement. A tack coat is not required since the overlay will be on basically granular or recently treated material. See the section on Reclaimed or Recycled Asphalt Pavement for more information.

*Plane surface and overlay.* Roadways that have become rough, rutted, cracked and have greater than 100 mm thickness of existing pavement are candidates for this type of rehabilitation. Areas with curb and gutters may require this type of rehabilitation to avoid complete removal or overlaying gutters. A rotomill or pavement planer is used to remove surface irregularities. Any large cracks may be filled with an acceptable crack sealer/filler following planing. The area to be overlaid is tack coated and paved over with the appropriate thickness of pavement.

A falling weight deflectometer (FWD) is used for structural analysis of existing structural sections, including paved and unpaved. It is a trailer mounted, nondestructive testing device with computer data logging. The FWD drops a weight on a rubber backed, circular plate that is mechanically lowered onto the surface being tested. This action is used to simulate the dynamic loading of the design vehicle. There are four possible levels of weight drops. Drop stress and maximum pavement deflections at seven locations, including the center, are monitored and recorded to computer screen, disk and a printer. This data is used to back calculate the modulus of each structural section layer, such as: pavement, base course, subbase course and subgrade. Using elastic theory, stresses and strains within the structural section are predicted and limiting criteria are applied. The limiting criteria are used to determine the structural capacity of the section in terms of numbers of equivalent single axle loads (ESALs) to failure. If the predicted number of ESALs to failure is less than what is expected in the design life, work must be done to improve the structure.

## 15.3 Crack sealing and filling

### *15.3.1 Background and materials used*

Cracks in pavements appear in many forms and they are caused by several internal and external factors associated with the roads. They may be caused by:

- thermal shrinkage of the pavement,
- by differential frost heave,
- by differential settlement of subgrade materials,
- by poor construction of joints in the pavement,
- by slope stability problems or

- by fatigue of pavement layer under traffic loading due to loss of support.

Cracks are sealed in order to prevent the intrusion of water into the underlying pavement layers. Once water gets into the supporting layers of the pavement, further cracking may be due to its affecting the differential, stability and support problems mentioned above. Crack sealing is more critical in wetter climates. The cracks must be wider than approximately 6mm (1/4") in width for crack sealing operations to be effective.

Crack sealants typically used are hot applied, low modulus, modified asphalt materials that retain flexibility down to -40° C. Modifiers used include rubber extender oils, reinforcing fillers and polymers. Some typical brands used consist of Crafco Roadsaver 231 and Koch Flex 270-ME. Sometimes hot AC-5 or emulsions may be used for temporary purposes. However, these do not have the low temperature flexibility Crafco and Koch type materials have.

Cleaning, routing and heating the crack edges is done prior to applying crack sealers. Wider cracks may not require routing. Sealant is heated and pumped through a hose to wand for application. The top of the sealant is then leveled and flattened with a squeegee. Sometimes the back edge of the wand may have a squeegee edge.

On the wider cracks and potholes, crack filling is usually done with a CRS-2 emulsion and chips. The chips are necessary to help fill and provide support. Very wide cracks and potholes may require filling and smoothing with cold or hot mixed asphalt concrete.

### *15.3.2 Equipment requirements for crack sealing and filling*

- *Joint preparation equipment.* Consists of tools designed to blow out, heat up or rout out cracks.
- *Heater***.** A double boiler heater with agitator and pump that is thermostatically controlled.
- *Application equipment* such as a wand or other device.
- *Traffic control equipment and personnel.*

### *15.3.3 Proper applications for crack sealing or filling*

Crack sealing and filling are generally maintenance operations, though it is sometimes done in conjunction with pavement rehabilitation projects. Most maintenance crack sealing is done on the narrow cracks, but over 6 mm (¼") in width, that appear within the first 3 years after construction.

Crack filling is done when cracks get wider than 25 mm. Crack filling usually involves placing and compacting cold or hot mix asphalt. Sometimes the bottom of a crack may be filled with fine aggregates, then emulsified asphalt, then more aggregates then squeegeed smooth.

## 15.4 Chip Seal (single shot Asphalt Surface Treatment)

### *15.4.1 Materials used*

A Chip Seal or "single shot" Asphalt Surface Treatment is the spraying of emulsified asphalt material followed immediately by a thin (one sized stone) cover. This is rolled as quickly as possible to create adherence between the asphalt and the aggregate cover. The chips (or stones) range from 19 mm aggregates to sand and are predominantly one sized. Sand seals are less costly and appropriate for use in areas with low volume traffic. As the expected traffic volume increases, the size of the aggregate is usually increased.

Typically, 12.5 mm maximum size aggregates or "E Chips" are used. The aggregates are required to be highly fractured, have high resistance to degradation in moist conditions and have low susceptibility to chemical loss.

The aggregates must be clean, having less than 1% dust, in order for the combination of emulsion and aggregate to work properly.

Use CRS-2, cationic rapid setting, high viscosity emulsion for chip seals. A latex modified CRS-2P is recommended for use in higher traffic areas and/or warmer climates. These emulsions will break within minutes of the time of application. So it is important to apply chips very soon after it is sprayed.

### 15.4.2 Construction Equipment Requirements for Chip Seals

*Pit development and extraction equipment.* This will include any necessary equipment to prepare a material site, extract and haul aggregates to a crushing plant.

*Crushing plant***,** includes crushers, conveyor belts, screens, loader, and controls. Washing over screens may be required to clean chips.

*Trucks* for hauling materials to the crushing plant and chips to the project.

*Surface preparation equipment* may include a water truck and power broom pavement applications, a grader and compactor for gravel applications and all supporting construction equipment to build a structural section for new construction. Leveling and patching may be done with either cold mix or hot mix asphalt.

*Emulsion distributor***.** Used to contain, heat and evenly apply CRS-2. Newer models are computer controlled and provide more accurate distribution of the desired amount of emulsion applied. It is very important to have even and proper distribution of emulsion for a good chip seal.

*Chip Spreader* is used to receive from trucks and evenly spread chips. The newer and better models are computer controlled and have augers in the front spreader bar to evenly distribute the chips and avoid segregation. Even and accurate spreading of the chips is very important to the success of a chip seal operation.

*Rollers* usually include two rubber tired (pneumatic) rollers for compaction of the treatment.

*Traffic control equipment, pilot car and personnel.*

### 15.4.3 Proper applications of single shot Chip Seals:

Primary applications of single shot Chip Seals is to extend the life of existing asphalt concrete pavements or rehabilitating older emulsified asphalt surface treatments. When fine cracks are too extensive to make crack sealing operations effective and Chip Seal may be used to seal the cracks. A Chip Seal applied to a rough, aged pavement is not expected to stop progressive distress. Chip seals are often done as a maintenance operation. They may also be used to improve skid resistance on paved surfaces. It is relatively inexpensive to construct and does not require the large expenditures for purchase and mobilization of an asphalt plant.

A good Chip Seal application is for existing pavements that have become aged, as indicated by whitish color and narrow cracking without excessive roughness or rutting. When cracking densities are such that normal crack sealing operations are not cost effective, chip seals should be considered. Chip seals are generally used where the volume of traffic is less than 10,000 ADT. A properly applied Chip Seal may be expected to extend the life of the pavement for 5 years or more.

Chip Seals could be applied to a prepared base course or on recycled in place asphalt material. However, since they are relatively thin, the use of a double shot Asphalt Surface Treatment or High Float Surface Treatment that will give longer life and are worth serious consideration.

Chip Seals are not used when existing pavements have wide cracks, deep ruts or are very rough. If these problems are localized, they may be patched or repaired by other means and then chip sealed. Chip seals also not recommended for heavy traffic urban areas or roadways with greater than 6% or 8% grade.

The minimum temperature for construction is about 10° C. (50° F.) and it should not be placed during or prior to expected rainfall. The asphalt emulsion will break too slowly at low temperatures. Rainy conditions may cause the emulsion to runoff into inappropriate areas. Therefore, the timing of construction is carefully planned and flexible.

Cured asphalt emulsion will coat approximately 2/3 of the thickness of the larger aggregates in the final product. Since the emulsion is approximately 40% water, this means that during construction, it must coat to the top of the larger aggregates. It is better to err in using too much emulsion than not enough. You can always add more aggregates or blotter to an over asphalted Chip Seal, but you cannot add more emulsion once the chips are placed.

## 15.5 Bituminous Surface Treatment (BST) or double shot Asphalt Surface Treatment:

### *15.5.1 Materials used:*

A BST is a double application Chip Seal similar to the single shot chip seal with a choke stone application. These are often referred to as Bituminous Surface Treatments or BSTs. However, our neighbors in the Yukon Territory call a High Float Surface Treatment a "BST." The pay item name we use to contract this work is "Asphalt Surface Treatment". Thus, the double shot Asphalt Surface Treatment terminology is used here.

On a prepared surface, CRS-2 is applied, immediately followed by chips. A modified CRS-2P is recommended for application in high speed and heavy traffic areas. Modified emulsions provide superior adhesion to chips and are less likely to become soft at warmer temperatures. They may also reduce thermal cracking. The chips are required to be predominantly one sized and clean. The first chip application may be twice as large in size as the second application. The idea being, that the second chip application will fit into voids left in the first. Often 25 mm or 19 mm maximum size chips will be applied in the first application. The treatment is rolled and left to cure for a few days.

The surface of the first treatment is prepared by sweeping. The second layer will then be placed with another application of CRS-2 and then using 12.5 mm or 9.5 mm (3/8") maximum size chips, which are to fit in and make a tight surface. However, when various sized chips are not available, a double application of same sized chips may be used.

### *15.5.2 Construction Equipment Requirements for double shot Asphalt Surface Treatments*

Same as for Chip Seals.

### *15.5.3 Proper applications for double shot Asphalt Surface Treatments*

A double shot Asphalt Surface Treatment may be used any place a single shot chip seal could be applied. Due to using two applications, they might be applied to surfaces, which have more cracking and raveling than might be desirable to place a single shot chip seal. If there are problems with a single shot chip seal application, it may be desirable to apply a section shot. Since it takes approximately twice the time and materials as a single shot chip seal, it is probably not cost effective for simply extending the life of the pavement.

They are more suitable for construction on prepared gravel surfaces since the second application makes a tighter and thicker layer. The total thickness of the treatment will be from 19 mm to 25 mm. They are used for surfacing and maintenance repairs in unstable foundation areas.

On stable foundations, the design structural section is calculated to be the same as would be suitable for a 50 mm (2”) asphalt concrete pavement. The crushed aggregate base course is then primary structural member, so must not be under designed. It is recommended to use a minimum of 150 mm (6”) crushed aggregate base course for asphalt surface treatments. If the base course is treated with asphalt emulsion, this thickness may be reduced.

Asphalt surface treatments are often used to upgrade existing gravel roads, controlling dust and reducing maintenance costs. They may be placed on frost susceptible materials (containing greater than 6% silt). However, frost susceptible materials directly under the proposed surface treatment should be treated with calcium chloride first. Calcium chloride tends to bind up the fines and suppresses the freezing point, making frost susceptibility less of a problem. Calcium chloride treatment is often done a year ahead of the surface treatment.

Emulsified asphalt surface treatments on unbound gravel support are not recommended for parking areas. At warmer temperatures, parked vehicles tend to sink into the surface treatment and the rubber tires may stick to the emulsion causing it to pick up when the vehicle is moved. They are not typically used on existing pavements that are very rough, have wide cracks or deep ruts. If these problems are localized, they may be patched or repaired by other means and then surfaced. Emulsified asphalt surface treatments are not recommended for heavy traffic urban areas or paces with greater than 6% or 8% profile grade.

The minimum temperature for construction is about 10° C. and it should not be placed during rainfall. Therefore, the timing of construction must be carefully planned and be flexible. Emulsion application amount for double shot Asphalt Surface Treatments are the same as for Chip Seals, i.e., final product with 2/3 aggregate embedment into the cured asphalt.

High Float Surface Treatments are cheaper and should be considered along with this treatment. A main justification for a double shot Asphalt Surface Treatment is when available equipment is not capable of placing the much larger quantities used on High Float Surface Treatments.

## 15.6 High Float Emulsion Asphalt Surface Treatment

### *15.6.1 Materials Used:*

High Float Emulsion derived its name from the asphalt residue test from distillation it must satisfy - a minimum float test in water 60° C (140° F.). High float emulsion has the capability of wicking up into the fine materials unlike CRS-2 that basically only allows embedment of clean aggregate.

In Alaska, typically HFMS-2s grade emulsion is most often used. That is: high float, medium setting, high viscosity with solvent emulsion. It is considered an anionic emulsion. An HFMS-2s is a specific type of emulsion that may contain up to 7% oil distillates, which can result in a softer residue that is less sensitive to low temperature construction than CRS-2. The emulsion tends to develop a weak gel structure immediately after spraying which creates a greater resistance to flow on banked and crowned surfaces. It is important to place cover coat material in the emulsion soon after it is sprayed, but not as critical as with CRS-2, since HFMS-2s is a medium setting emulsion. Crushed pit run material may be used, without having to wash, as is sometimes necessary for chip sealing. Cover coat material is simply a crushed aggregate base course, usually screened so that 100% passes the 19 mm sieve. A minimum amount of silt sized material is desirable, with up to 5% or 8% being allowed. The moisture content of the cover coat is limited to somewhat less (usually half) of the optimum moisture content of the cover coat in order to provide for proper flow through the chip spreader. Segregation of aggregates often occurs when too wet a cover coat is used.

Application rates are approximately double that of a single shot chip seal. Thus, High Float Surface

Treatments provide the possibility of constructing a surface similar to a double shot Asphalt Surface Treatment, except in one pass of the equipment.

### 15.6.2 Construction equipment requirements for High Float Surface Treatments

Basically the same as for chip seals, except the crushing plant may not be required to wash fines out of the aggregates. Also some of the older, smaller chip spreaders are not capable of laying down the high quantities needed in high float operations. Similar considerations must be taken for distributors, which must spray double volumes of emulsion. Newer, computer controlled chip spreaders and distributors are recommended for use with high float surface treatments in order to accurately provide for the large quantities needed. Chip spreader bars equipped with augers in order to keep the material moving and avoid segregation are recommended.

### 15.6.3 Proper applications for High Float Surface Treatments

See the text under double shot Asphalt Surface Treatments. High Float Surface Treatments are cheaper to construct than double shot chip seals since they require only one application of emulsion and cover coat. The cover coat is usually less expensive to produce since it may be simply crushed, screened, pit run material rather than needing the washing and wasting that is done in chip production.  However, High Float Surface Treatments appear to work best in dry climate areas where cover coats can be kept dryer to avoid segregation.

Use of emulsified asphalt surface treatments on unbound gravel support is not usually recommended for parking areas. At warmer temperatures, parked vehicles tend to sink into the surface treatment and the rubber tires may stick to the emulsion causing it to pick up when the vehicle is moved. They are not generally used on existing pavements with wide cracks, deep ruts or are very rough. If these problems are localized, they may be patched or repaired by other means and then surfaced. Emulsified asphalt surface treatments are not recommended for high traffic urban areas or areas with grades steeper than 6% to 8%..

High Float Surface Treatments may be placed at temperatures down to approximately 5° Centigrade (40° F.) and rising, making them better candidates for cooler areas. Placement during or immediately following rainfall should still be avoided. These surfaces initially may be very dusty and are swept after 3 to 7 days of curing. The dust actually helps control traffic speeding, but makes it hard to stripe the first year.  Usually the centerline is temporarily striped the first year. Then the centerline and fog lines are restriped the second year.

## 15.7 Reclaimed and Recycled Asphalt Pavement

### 15.7.1 Background and materials used

Reclaimed Asphalt Pavement (RAP) is the removed and/or processed material containing crushed asphalt pavement. It may be used in the construction of stabilized base course or recycled asphalt pavement.

Depending on the asphalt plant used and the expected application, between 15% and 50% of RAP may be added when constructing recycled asphalt pavement. With batch plants, RAP is added to the hot aggregate in the pugmill. Batch plants can take up to approximately 15% RAP before cooling effects compromise the product. Continuous asphalt plants can take higher percentages of RAP since it is input to the drum and heated Many states have standard Asphalt Concrete Pavement specifications indicating an allowable maximum percentage of RAP.

Base course may be constructed using pure RAP or mixing it with crushed aggregates. Optionally, an asphalt emulsion, such as CSS-1 (cationic slow setting) may be added for further stabilization.

### 15.7.2 Equipment requirements for RAP

If used for pavement, use the same equipment as listed under Asphalt Concrete Pavement with provisions for adding RAP. The crushing plant must be set up to crush old pavement into sizes that can be fed into the plant. Otherwise, you can use millings left from pavement planing. Batch plants must be equipped with a feeder, conveyor and appurtenances for adding RAP to the pugmill. Continuous plants must have a feeder, conveyor and a RAP inlet.

When used as base course, the material may come directly from a crushing plant or be crushed in place with a Reclaimer that is specifically designed for this type of operation such as a CAT RR-250 or a CMI RS-500. Emulsified asphalt, if used, may be pumped directly into a mixing chamber of the reclaimer from trucks or added later with a distributor and then bladed in.

Stabilized base course operations also require use of a grader and steel wheeled vibratory compactors.

Traffic control equipment and personnel are necessary for a safe operation.

### *15.7.3 Proper applications for RAP*

RAP may be used in the construction of a new asphalt concrete pavement or as a stabilized base course. Using it as asphalt concrete pavement takes special mix design and construction considerations. Generally, it is not used as a surface course, but as a lower lift paving. Consult your Regional Materials section for information on this.

Often RAP is allowed for direct substitution for Crushed Aggregate Base Course materials. Existing pavement that has become severely fatigued, rutted, rough or otherwise distressed may be reclaimed by grinding it and mixing it with an equivalent depth of the existing base course. This may be treated with an asphalt emulsion, such as CSS-1 to create a new stabilized base course that is suitable for surfacing. Emulsion treatment is usually reserved for poorer materials subject to conditions of high moisture. Combining crushed asphalt pavement and base course significantly decreases the compressibility of the material making it provide greater support under moist conditions.

## 15.8 Treated Base Course

### *15.8.1 Background and materials used*

This section introduces many of the treatments that may be used as stabilizers and dust palliatives on gravel surfaces. The focus, however, is on the asphalt treated varieties, which are dealt with in more depth.

Independent of the RAP base course applications described earlier, asphalt treated bases may be divided into two categories; 1) hot asphalt treated and 2) emulsified asphalt treated. These two categories may be further subdivided into *dense graded* and *open graded* (permeable) bases. Dense graded bases are the materials typically specified for highway construction. Open graded bases require special considerations.

There are many other treatments that can be applied to crushed granular materials. Portland cement is rarely used since its import is expensive. Small amounts of Portland cement (approx. 5%) are sometimes used in emulsified asphalt and sand mixtures to aid in breaking.

Some other stabilizing agents/dust palliatives, such as PermazymeR, use tree resins as a binding agent. They are added to water and sprayed upon the surface prior to grading and compaction. These agents work best when treated material contains clay. Most of the soil deposits in Alaska contain a little clay, so the application of these stabilizers is limited.

Calcium Chloride is often used for dust control on gravel roads. It is a salt, along with proper amounts of moisture, it binds silty aggregates and controls dust. The material is either applied dry in flake form and then wetted or mixed with water and sprayed on. Dust control operations require annual or biannual applications since the materials tend to leach out.

Calcium Chloride is sometimes used to treat base course materials that are to be paved in order to limit frost susceptibility. It depresses the freezing point and its binding properties limit capillary action.

Calcium Chloride is a demulsifier of emulsified asphalt. This means it will make the emulsified asphalt break quicker. Therefore, it is not normally used to treat roads that are to have an asphalt surface treatment applied in the near future.

One purpose of any treated base is to provide improved structural support for paving. When asphalt treated base course is used, a portion of its thickness may be substituted for the thickness of Asphalt Concrete Pavement required by structural design.

Dense graded Asphalt Treated Bases use hot asphalt cement as a binder and are designed and constructed much the same as Asphalt Concrete Pavement. These are usually a Crushed Aggregate Base Course, D-1 grading with asphalt binder. Approximately 4% hot asphalt cement is typically added in a plant.

Open Graded Asphalt Treated Base is made from crushed porous aggregates treated in order to provide stability during construction. Production and lay down of Open Graded Asphalt Treated Base is similar to Asphalt Concrete Pavement except compaction requirements, in terms of number of roller passes required are determined by a test strip. Approximately 3% hot asphalt cement is typically added in a plant. Density of Open Grade Asphalt Treated Base is only 60% to 70% of dense graded base or asphalt concrete pavement. This material is suited for areas with drainage problems that cause weakening of the base.

Dense graded Emulsified Asphalt Treated Bases are produced by any means available to combine the emulsified asphalt and crushed aggregates. Some mixing methods include: using a pugmill, using a mixing a mixing plant and road mixing. Slow setting CSS-1 or medium setting CMS-2 emulsified asphalt is used in production. The CSS-1 grade is the most forgiving, allowing more time to grade and shape before it breaks.

Open graded Emulsified Asphalt Treated Bases are rarely, if ever, used in Alaska. They have been successfully used in Washington and Oregon. Consult Regional or Statewide Materials for further information.

### *15.8.2 Equipment requirements for treated base course*

Construction of hot Asphalt Treated Base course requires virtually the same equipment as is needed for Asphalt Concrete Pavement. Any base course material will have to be crushed, necessitating use of a crushing plant, loader and hauling equipment.

Emulsified asphalt treated materials require various pieces of equipment, depending on the method of mixing that is used. The simplest road mixing process will only require distributors graders and rollers. Pugmill operations require emulsion storage, heating and pumping facilities.

Sometimes Emulsified Asphalt Treated is placed using conventional paving equipment. Is often placed using belly dump trucks, bladed into place with a grader and compacted using steel wheeled rollers.

Dust control operations use spray trucks equipped with stirring mechanisms and graders. If applied dry, a truck with feeding and distribution equipment for the particular material is needed.

Traffic control equipment and personnel are necessary for a safe operation.

### *15.8.3 Proper applications for treated bases*

The base course is a primary structural member in a paved section. It is therefore of great importance to provide proper materials. When Crushed Aggregate Base Course meeting standard quality requirements is not available, treatment is considered. If the treatment is cheaper than hauling standard materials, it is used.

Dense graded Asphalt Treated and Emulsified Asphalt Treated Bases are used in areas where the structural design indicates excessive thickness requirements of Asphalt Concrete Pavement. They provide for decreasing the pavement thickness requirements. Treated base courses may also be used to "lock up" fines in materials with excess silt sized particles or materials that tend to degrade.

When a road is to be rehabilitated and shows signs of base failure, you may choose to look at treating it. Signs of base course problems are premature fatigue cracking, premature rutting, potholes and breakouts. Rutting referred to here is from permanent deformation in supporting layers of the pavement – not the mix.

Open graded Asphalt Treated Base may be used in situations with poor drainage where embankments are frost susceptible and tend to saturate in the spring. It may be used as a substitute for crushed aggregate base course in areas, which have marginally degradable materials. The asphalt treatment is then used to coat the aggregates and protect them from degradation.

There does not appear to be a large cost savings between Asphalt Treated Base Courses and Asphalt Concrete Pavement. Therefore, the main justification for its use is not to save money on Asphalt Concrete Pavement.

Emulsified Asphalt Treated Bases are slightly cheaper, but there are problems getting enough asphalt into the base. Recall that asphalt emulsions contain approximately 40% water. Optimum moisture contents for crushed aggregate base course range around 4.5%. Added asphalt emulsion acts as moisture during the mixing and placing phases of construction. Therefore, even if the crushed aggregate base course was bone dry and you added 4.5% of emulsion, the residual asphalt content would only be approximately 2.7%, which is barely enough to coat the aggregate. In reality, the crushed material used will always have moisture content. If you add emulsion percentages to make the total of moisture and emulsion much higher than the optimum, it will be saturated and a mess.

## 15.9 Stone Mastic (Matrix) Asphalt Pavement (SMA)

### *15.9.1 Background and materials*

SMA is product that is relatively new in America. It was developed by contractors in central Europe who are subject to giving warrantees for their work against rutting. SMA optimizes stone on stone contact in the mix. It is a gap graded, hot mix asphalt with a large proportion of coarse aggregates with amounts retained above 2-mm (0.08") size at approximately 80 percent and a rich asphalt cement/filler mastic. The coarse aggregates form a strong structural matrix. Asphalt cement, fine aggregate, filler and stabilization additive form a mastic that binds the structural matrix together. The coarse aggregates form a strong structural matrix. Asphalt cement, fine aggregate, filler and stabilization additive form a mastic that binds the structural matrix together. Filler may be silt. The coarse aggregates are highly fractured and roughly cubical stone. Relatively high asphalt contents (about 6.5% of the total mix) provide for a durable pavement. A stabilizing additive, usually 0.3% cellulose from ground newspapers is included in SMA to prevent hot asphalt cement from draining down during hauls.

The Scandinavians found that SMA pavements resist studded tire wear better than dense graded pavements. They found that the major factor in studded tire wear resistance of SMA is the quality of coarse aggregate. Several new tests have been developed to test aggregate and mix for studded tire wear resistance. The materials laboratories in Anchorage and Juneau have Ball-Mill testers that apply impact loading to coarse aggregates under aqueous conditions in order to rate the wear resistance.

### *15.9.2 Equipment requirements for SMA*

Basically the same as for Asphalt Concrete Pavement with a few differences.

No rubber tired rollers are used since they tend to stick to the mix. However, three steel wheel rollers are recommended, using two for breakdown and one for finish rolling. Often a release agent, such as dish soap, must be added to the water that is sprayed on the drums of the steel wheeled rollers. This helps to avoid their picking up of the mix.

Injection equipment for adding stabilizing agent in the plant must be included in SMA production. In batch plants, the stabilizing additive is mixed with the aggregates in the pugmill, just prior to adding the asphalt. In drum plants, stabilizing additive is blown into the asphalt spray.

A separate bin for mineral filler is also included in the plant.

### *15.9.3 Proper applications for SMA*

The rotomill and overlay option, described in the Asphalt Concrete Pavement section, substituting SMA for the overlay, is used in rehabilitation of worn and rutted pavements. SMA is always placed as an overlay on a dense graded pavement surface. Since it is very coarse, it is not desirable to place it as base (bottom lift) paving where it may prematurely fatigue.

SMA is recommended for use in areas of high traffic flow where there is a high usage of studded tires and frequent winter thaw periods. In Anchorage, it has been seen that routes with ADT greater approximately 10,000 are subject to accelerated studded tire wear and rutting. Because of the expensive nature of SMA, it is not recommended for use in low traffic, rural and/or residential areas.

## 15.10 Superpave Asphalt Concrete Pavement

### *15.10.1 Background and materials*

The term *Superpave* stands for Superior Performing Asphalt Pavements. This refers to a relatively new product line that was developed by the Strategic Highway Research Program (SHRP), in which the mix design methods are dictated by the predicted traffic loading and the climate in the project area. It is a related asphalt mixture and binder specification that facilitates the selecting and combining of asphalt binders, aggregates and any necessary modifiers to acquire the level of pavement performance required.

Superpave utilizes a completely new system for testing, specifying, and selecting asphalt binders. The binders are called *performance grades* (PG max. temp.-min. temp.). There binders are thereby graded according to the maximum and minimum design temperatures (°C.) expected in the project area. The maximum design temperature is supposed to be maximum Design 7 day average pavement temperature. The minimum design temperature according to the current procedure, is the minimum air temperature expected on the project. Different percentile confidence limits may be used depending on the design needs. In Alaska, a designer may use PG52-34 grade asphalt binder. The high temperature grade is supposed to help the mix resist plastic deformation up to the design temperature under loads. The low temperature grade is supposed to help the mix resist thermal cracking. Unfortunately, in order to obtain a reasonably high confidence of thermal cracking resistance in many areas of Alaska, it would require low temperature PG grades below that which is physically impossible to formulate. Research is continuing to find asphalt modifiers that may help us.

The Superpave design process uses a gyratory compactor to compact mixes. A gyratory compactor uses a rotating flat steel plate that is forced down upon the mix contained in a steel cylinder. The number of gyrations required for a mix design is determined from the expected equivalent single axle truck loads (ESALs) and the Design 7 day maximum air temperature. The mix must meet voids criteria, in terms of % air voids, %voids in the mineral aggregate and % void filled with asphalt at three gyration levels. The goal of the process is to provide for a mix that has a strong aggregate skeleton that will not be tender and will resist rutting. Superpave mixes are not a coarse as SMA.

The Superpave mix design process differs most significantly from the Marshall mix design process in that it requires the designer to try various gradations in order to determine the one(s) that will meet the voids criteria at all three gyration levels. This process requires a minimum of three stockpiles to work up assorted blends with different gradations. It is geared for a contractor mix design. However, the current system used in Alaska calls for mix designs to be done by the state. Therefore, this process calls for closely working with a contractor to develop the mix design.

The above is just a brief overview of the Superpave methodology. For further information, contact your Regional or Statewide Materials Sections.

### *15.10.2 Equipment requirements for Superpave Asphalt Concrete Pavement*

See list for Asphalt Concrete Pavement. Due to the possibly more bony nature caused by design of a strong aggregate skeleton, the Superpave mix may be more difficult to compact than standard dense graded mixes. Therefore, special attention must be made to providing appropriate compaction equipment.

### *15.10.3 Proper applications for Superpave Asphalt Concrete Pavement*

Since low temperature PG grades have not been found that will resist thermal cracking in the coldest regions of Alaska, this is just another, more complex method of asphalt grading. However, it can help us understand what to expect from whatever grade is used. It can help us understand the effects of asphalt modification and realize the cost of any benefits.

The Superpave mix design process targets pavement rutting. This is not an appreciable problem in Alaska except mostly in heavy traffic urban intersections.

Superpave mixes being of a coarse nature than dense graded mixes are expected to be better at resisting studded tire wear. However, they are finer than Stone Mastic Asphalt mixes, so may not resist studded tire wear as well. The gradation requirements indicate that Superpave mixes will cost somewhere between Stone Mastic Asphalt and typical dense graded mixes. Their application would then be in areas subject to moderate studded tire wear or intersections with heavy truck traffic. Superpave mixes have been called “poor man’s SMA”.

## 15.11 Relative Costs

Table 1 gives estimates of relative costs ($) for application of the alternatives listed above that apply to the surface treatments. Alternatives for base course are shown in Table 2. The costs include only: design, construction, traffic control and striping (if applicable). These estimates are costs to the buyer, in this case the Alaska DOT&PF. For this presentation, a 50 mm overlay of standard asphalt concrete pavement is set at $1.00. This information is not intended for use in specific project estimating where particular details must be accounted for. These costs are intended to give the reader a general comparison.

Notice the asphalt surface treatments (ASTs) are the cheapest options. That does not mean they will always apply to the given situation. However, they are always worth serious consideration. In proper applications, they can extend the life of pavement by 5 or more years.

High Float or an AST may be used as the surfacing on a structural section. When properly designed and constructed, they can last over ten years, which is similar to the life of Asphalt Concrete Pavement. These treatments are especially applicable to unstable foundation areas since they are very flexible and reasonably easy to rehabilitate. It is more complicated and expensive to rehabilitate Asphalt Concrete Pavement placed on an unstable foundation.

Applications of Stone Mastic Asphalt are currently limited to the high traffic urban areas in Anchorage. It is cost effective to use, if it will last approximately 40% or more longer than standard Asphalt Concrete Pavement.

Using RAP in Asphalt Concrete Pavement shows no particular benefit since it costs approximately the same as standard mix yet it is not desirable for use as a wearing course. However, allowing its use in lower lifts of paving has the environmental benefit of cleaning up waste piles. If contractors are given standard specifications that allow for its use as they can best figure out, it may become cheaper.

Superpave designed Asphalt Concrete Pavement has only been used in the Southeast Region of Alaska as of this writing.

*Table 1: Estimated relative costs for surface repair and rehabilitation alternatives*

| **Alternative** | **Relative Cost** |
|---|---|
| 50 mm (2") Asphalt Concrete Pavement overlay | $1.00* |
| Reclaim existing pavement + 50 mm Asphalt Concrete Pavement overlay | $1.20 |
| Plane existing pavement + 50 mm Asphalt Concrete Pavement overlay | $1.50 |
| Crack Sealing | $0.02 |
| Chip Seal (single shot AST) | $0.35 |
| Double shot AST | $0.60 |
| High Float Surface Treatment | $0.40 |
| 50 mm Asphalt Concrete Pavement overlay using RAP | $1.00 |
| 50 mm Stone Mastic Asphalt overlay | $1.50 |
| Plane/rotomill existing pavement + 50 mm Stone Mastic Asphalt overlay | $2.00 |
| 50 mm Superpave Asphalt Concrete Pavement overlay | $1.35 |

* Set at $1.00 for this presentation.

Table 2 shows estimates for relative costs of base course alternatives. In this presentation, the relative cost of standard Crushed Aggregate Base Course is set at $1.00. That is *not* the same $1.00 as used in Table 1. The costs are for volumetric measure. The lower density of Open Graded Base Course, making greater coverage per unit weight, is accounted for. The other materials are assumed to have similar densities.

*Table 2: Estimated relative costs for base course alternatives*

| **Alternative** | **Relative Cost** |
|---|---|
| 150 mm (6") Crushed Aggregate Base Course | $1.00 |
| 150 mm Recycled/crushed asphalt pavement as Base Course (untreated) | $1.00 |
| Calcium Chloride, per application | $0.05 |
| 100 mm (4") Crushed Aggregate Base Course treated with 3% asphalt emulsion | $2.10 |
| 100 mm Crushed Aggregate Base Course treated with 4% asphalt cement | $2.20 |
| 100 mm Open Graded Base Course treated with 3% asphalt cement | $1.85 |

Most applications will call for only the standard Crushed Aggregate Base Course materials to be used. Recycled/crushed asphalt pavement is often substituted for Crushed Aggregate Base Course. The direct substitution is provided for in the Special Provisions for most paving projects. That is why the cost is shown equal in Table 2. If it is proposed to be specifically used for a project, the cost will increase, depending on availability. The addition of even crushed asphalt materials in base course increases its stiffness and decreases its compressibility in moist conditions.

Dust control agents are applied only when the gravel surface is to be operated on for an extended period of time. They should not be expected to last more than one year per application of the dust control agent.

Asphalt treatment of base course materials creates stiffer support and decreases the required thickness of Asphalt Concrete Pavement, other things being equal. There is a serious cost for this, as shown above. The emulsified asphalt treated base course is nearly as expensive as asphalt cement treated. This is because emulsion is approximately twice as expensive as asphalt cement. Emulsified base course is easier to work with, since it can be bladed into place. Asphalt cement treated bases require paving machines.

Open Graded, asphalt treated base course, shows up as the cheapest of the asphalt treated base courses. It has not seen much use in Alaska as of this writing, but the projects where it was used demonstrate superior performance. It provides structural support similar to other asphalt treated bases and also allows for drainage in springtime and other wet conditions.

## 15.12 Life Cycle Cost Analysis

This discussion is meant only as a simplistic introduction to concepts used in economic analysis of engineering alternatives. A formal recommended procedure is yet to be developed.

When different materials are being considered during the design of roadways, it is recommended to determine the life cycle cost of the alternatives. That is, to determine the present cost of each alternative if done or repeated over a period of time (analysis period). The analysis period is at least as long as the design life plus one reconstruction of the longest lasting alternative. The present value is the sum of all the expected costs incurred within the analysis period for each alternative. The present value of costs computation must take into account inflation. The equation to use for determining the present value of costs (PVC) for action *a*, in an analysis period of *n* years, based on current prices is:

$$\text{PVC} = (\text{Cost of action } a) * 1/((1+I)^n)$$

Where: $I$ = inflation rate (decimal)
n = years

For example, consider an asphalt concrete pavement overlay that presently costs $100,000 per lane kilometer (mile) to construct. Each overlay is expected to have a design life of 15 years and the analysis period is 30 years. The inflation rate is 4%. Then present values are:

| | | |
|---|---|---|
| 1st overlay at year 0 costs: | $\$100{,}000*(1/(1.04^{0})) =$ | $100,000 |
| 2nd overlay at year 15 costs: | $\$100{,}000*(1/(1.04^{15})) =$ | $ 55,526 |
| 3rd overlay at year 30 costs: | $\$100{,}000*(1/(1.04^{30})) =$ | $ 30,832 |
| | | |
| Life cycle cost of overlays (Sum) | | $186,358 |

This same process is used for other alternatives with different costs and design lives for the same analysis period. The alternative with the least expensive Life Cycle Cost is recommended as most cost effective.

Other costs such as maintenance and user costs may be considered. The present values of these are estimated using basic engineering economy principals with gradient cost functions. The present values of these costs are added to the Life Cycle Cost of the alternative, and the totals compared again. In some situations there may be benefits or salvage values to consider. These would be subtracted from the Life Cycle Cost and the final results compared. Be careful not to skew results with unrealistic assumptions.

## 15.13 Conclusions

1. We must be aware of practical surfacing/rehabilitation alternatives for the projects they are working on.
2. Provisions for surface and subsurface drainage have the greatest effect on the life of any alternative. Better drainage of water away from the pavement structure directly translates to longer life of the project.
3. Always consider Asphalt Surface Treatment (AST) in areas with less than 2,000 average daily traffic (ADT) unless profile grades are greater than 6% to 8%.

4. An AST is considered for areas with less than 10,000 average daily traffic.
5. Areas with unstable foundations should have AST applied when gravel surfacing is not acceptable.
6. AST’s are used for the first upgrade of a roadway from gravel.
7. Try to stick with one system or the other on a given project. That is, use either an Asphalt Concrete or AST throughout your project. This will save contractors from having to mobilize two spreads of equipment and personnel.
8. Calcium Chloride treatment of gravel depresses the freezing point and helps bind the materials. In these ways, it helps decrease frost susceptibility.
9. Calcium Chloride treatment of gravel roads should take place at least one year prior to placement of an AST. The presence of concentrations of Calcium Chloride next to asphalt emulsions will make the emulsion break prematurely.
10. Asphalt Concrete Pavement should be considered for areas with over 2000 ADT.
11. Asphalt treated base course materials provide the benefit of reducing the thickness required for a wearing course if more than 50 mm (2”) thick. However, they greatly increase the cost of the base course.
12. Stone Mastic or Matrix Asphalt (SMA) is used to rehabilitate areas with premature rutting failure due to studded tire wear. These are generally in urban areas with greater than 10,000 ADT. It is used only as an overlay on previously laid Asphalt Concrete Pavement.
13. Applications for Superpave for needs somewhere between using Asphalt Concrete Pavement and SMA.
14. Life cycle cost analysis at the design level will provide an estimate of the most cost effective alternative to construct.
15. Use common sense!

# 16. Appendix I Like Night and Day

## Like Night and Day by John S. Ball III (Courtesy The Asphalt Contractor)

### 16.1 Nighttime paving is a whole new ballgame

Contractors are being asked to perform more nighttime paving these days. It used to be just a once-in-awhile job, but now it's an every night occurrence. High visibility is the name of the game when you're paving, but it is especially critical with night paving. When the traveling public comes down the road, what's the first thing they see to indicate there is work ahead, that they need to slow down and be cognizant of crew members standing in or near traffic? High visibility means not only that the crew can be seen, but also that the signing, cones, and barrels are up in the job zone, and that the proper indicators are positioned at intervals well ahead of the work zone. One of the most important steps in preparing for night paving is to alert the public of what's happening out there. The more we can inform the traveling public, the easier it will be to perform the work in progress for that night. And the earlier we can let them know, the better. This may happen 3 or 4 miles (5 or 6 k) before they get to the construction zone. It may seem like a long time to them, but it allows them sufficient time at different intervals to recognize they need to change their driving pattern.

### 16.2 A sign of the times

The number one factor in preparing drivers for nighttime paving is signage. Permanent signs are seen first. They are usually 4 x 4s on posts which indicate construction ahead for the next X miles, and they are considered permanent because the are installed in the ground. Message boards play a key role after permanent signs. They alert the driver to what kind of construction is going on down the road. Message boards might announce to the traveling public the dates of construction or what ramps they can expect to find closed or open. These types of signs can also indicate what's going to happen for not only the week but for the night as well as whether there's anything special drivers should be alerted to, such as an open joint down the center line or grooved pavement resulting in an uneven surface after milling. Next, drivers usually come upon an arrow board flashing left or right depending on what's closed, and this is also where the taper of cones starts. The length of the taper determines how many cones are placed and how far out those cones are spaced. Sometimes the job calls for placing barrels out on top of a drainage inlet. Other times, horse barricades are used. The direction in which the reflective tape is placed on the barricades determines the slope of the road, which way traffic will go.

In order to properly set signs and cones, you need a traffic coordinator as part of your paving crew. Because signs blow over, and cones get knocked over both in and out of the work zone, this person should be a rover. He should be like a traffic cop, roving up and down the road to make sure signs and cones and safety barriers are up and in place. He must be in a highly visible truck equipped with orange and white strobe lights and a flashing arrow attenuator so bright they make you immediately wonder what's going on.

In addition to strobe lights, more experienced companies who do nighttime paving will invest in break lights and four-way flashers to install on their flagging truck. The break lights will have strobe lights and the headlights will flash, like a cop pulling you over. They're called wigwag lights, and they work effectively to get the traveling public's attention.

### 16.3 Lights, camera, action!

Many drivers may go through the elaborate pattern of signs and directional tools you have installed, but they may not be paying attention. As they get to the lights of the construction sight all they may see is a huge white light in the middle of the road and that can be confusing if they haven't paid attention to the signs and cones and changed their driving pattern. That's why the contractor must make the work zone as highly visible as possible and make sure crew members are well lit with reflective vests and similar safety clothes. But he must also make sure the crewmembers can see the traffic all around the work zone, and that's where lighting comes into play.

Key to night paving is alerting the public, but also key is having the crewmembers know exactly what the game plan will be. Will the crew pave the road about a mile that night? What is the scope of the work? The crew foreman and supervisor must make sure the whole crew is informed because at night there is a limitation to the work scope. You can't look down the road and judge the distance, because you're faced with total darkness. The laborers, roller operator, paver operator, and back-end people are all affected by this situation, and that's why it's so important to discuss in detail the scope of work planned for the night. It's critical to line out the work you're going to do.

One of the most important factors is that everybody looks out for each other. As crewmembers, everybody has to know where everybody else is because once you step outside the light and into the shadows nobody knows where you've gone. The paver puts out a lot of light, but if you go outside that lit area, it's a danger zone. You want to make sure you tell somebody you're going to the pickup truck to get some paint if that's what you're going after. In the daytime you can take things like that for granted because everybody can see you're going for the paint. That's also why everyone wears a vest at night. Crewmembers used to wear reflective belts, but you can't see them at night, so they wear reflective vests.

Some states are now writing a light package into their specs. They don't specify how to put the lights on, but how many lumens are needed on the paver and the roller. The wattage determines how many lumens you need. Paver manufacturers leave it up to the buyer to set up his lighting system. There are many types of lights available to the contractor. You may have two spotlights that shine into the auger section and a couple by the hopper, but that's about all most pavers are equipped with. However, paver manufacturers do offer a generator that fits on the paver and is operated hydraulically so you don't have gas cans to worry about. It runs off the hydraulic pumps and turns out 9,000 watts, so it turns out a pretty good amount of light when you need it. On a recent job in Erie, Pa., we had a rather unique light package for a nighttime paving job. We used three different kinds of lights on the paver. We mounted fluorescent lights over the operator's head to shine directly into the auger area. This clearly illuminates the augers as they turn, the head of material and the feeder paddles. This worked most effectively back there because fluorescent is soft light, and doesn't produce a lot of shadows.

The contractor made a light stand 8 feet (2.5 m) high above the paver. The higher up you go with the lights, the more radiance you achieve. On top of this light stand, we used six 500-watt floodlights. Spotlights were used most often for this situation, but they create beams of light. Floodlights have a broader illumination area. And, because the light package is so high, we usually have two floodlights shining on the back of the mat when the mix comes out, and two others mounted on the edge of the pole of the light frame so light is shed on the edgers. Two others in the middle shine on the hopper. Usually, contractors use floodlights to light up the equipment and the work zone. Very few use fluorescent lights because they're fragile and have to be mounted in a plastic tube for safety factors. The light package frame isn't that rigid, so if you go over something rough it will protect the fluorescent lights. They're 4-foot fluorescent tubes and are usually mounted in-groups of four. They offer a beautiful ray of light. Floodlights are harsh and very bright. If you stand in a floodlight it shadows. Fluorescent light doesn't cast as much shadow.

The best light of all, in my opinion, is the average streetlight. We mounted a street light on a pole in the middle of the paver and the hopper. It is unique because it works with a 500-watt floodlight, and it illuminates the whole hopper and surrounding area so when the truck backs up there is no light beaming in the driver's mirror. it beautifully illuminates the width of the hopper so the truck and paver can meet nicely.

On this particular job, though, we had a troublesome spot. The guy operating the paver could not see his guide bar very well by the push roller. So, using some ingenuity, we had a mechanic come up with another 500-watt light, which he mounted onto a magnet. Because the whole paver is all-metal he just stuck it to the side of the hopper to illuminate that area perfectly.

## 16.4 Shedding light on safety

Matching the joint is another hot spot you have to tackle strategically when you're paving at night. We could see the head of material, but we couldn't quite see how it came out from underneath the screed. So, we had another magnetic light mounted to the edger plate. It was a good engineering solution.

If you're using automatics, often they will provide they're own lights. On this particular night paving job, the contractor used the Topcon system, and the numbers and gauges were all lit up, so we had no problem seeing the automation. We ran them off a ski, so with all those lights on, the ski was illuminated, and we were able to see the joint matcher.

Another area, which it is critical to have well illuminated, is the operator's pedal on the paver. The operator must be able to see his instrument panels. The pedestals for the back of the paver must also be well lit so the screed operator can see the controls he or she has to use. You just can't put enough lights on a paver to allow your crew a good view of everything.

When we talk about nighttime paving, it's not just the scope of the work we're going to accomplish, but how safely we can do it, and whether everybody on the job is well protected. That applies to the traveling public as well. Do they understand what we're doing when they come upon us and do our people understand how dangerous it is out there? Their vision isn't as clear as it is in the daytime.

## 16.5 Like night and day

A unique thing happens at night when you pave. As you pave in the daytime, you're paving along, and you're looking at the traffic, people zipping by, tooting their horns at you, and you wave back at people. At night it's a totally different world. You don't have this background activity, because no one is around. You work a little harder at night because the scope of work you accomplish is different. There's no room for fooling around at night, and there are no distractions because of the sight limitations.

Also, there's no second-guessing anything at night, and that means the equipment has to be on the ready at all times. Everything is all fueled up, all watered up, and operators know exactly how much water is in your roller. They're more alert at work because they can't stop for a breakdown. Usually, the equipment used at night is well maintained. The mechanic won't send you a questionable piece of equipment, because you can't afford to have any breakdowns at night. There is no one to fix the equipment. You don't have the luxury of having places open for that, so you have to make sure your equipment is well maintained. Usually a mechanic stays with you at night because normally the job is big enough to require it. The mechanic will often help out operating a roller or second paver so he fills his time when he isn't fixing a breakdown. And, supervisors are more in tune to the ways of the operators at night. They make the work situation better to achieve more production. They decide what they can do to make it easier for the operators to emphasize the quality of work. Supervisors recognize the need to do the little extras they don't have to do on daytime jobs.

For instance, we made use of the paver generator and kept our people awake at the same time on this particular nighttime job. We had a 50-cup coffeepot on board the paver to keep everybody awake. Crewmembers could have coffee whenever they wanted it. That kind of catering to the employee is good because in "the twilight zone" sleepiness sets in between 3 a.m. and 4:30 a.m. Your body starts to wonder what's happening, and thinks it's time to shut down. You kind of walk around like you're in a daze. Having coffee on board helps tremendously.

Nighttime paving crews look at one another and check on each other about that time. They'll spot their partners, and allow each other to sit down a little bit. The best part of the night, many crewmembers say, is right around 4:45 a.m. when it starts to get light out and the sun starts to come up. If you've never paved at night, it may look like a horror show out there on the mat because the lights show every dimple, every wrinkle, every stop mark in the mat. That emphasizes everything, but if you stick to the right procedures, when daylight hits, the finished product is never as bad as you think.

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