U.S. Department of Transportation

Federal Highway Administration

HOT MIX ASPHALT CONSTRUCTION

PARTICIPANT MANUAL

JOINT AASHTO FHWA INDUSTRY TRAINING COMMITTEE ON ASPHALT

"Partners In Performance"

The Joint AASHTO/FHWA/INDUSTRY
Training Committee on Asphalt

Presents...

HOT MIX ASPHALT CONSTRUCTION

A three day program for field construction personnel

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Developed under the direction of
the American Association of State Highway and Transportation Officials,
the Federal Highway Administration,
and the HMA Industry
by:

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INTRODUCTION

Welcome! This training program is the result of a partnership between the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the Hot Mix Asphalt (HMA) Industry. It was developed through the cooperative efforts of the Joint AASHTO/FHWA/ INDUSTRY Training Committee on Asphalt. The National Asphalt Pavement Association served as the catalyst to develop these materials, and the joint committee reviewed and provided additional resources and input. The program is based on the HMA Paving Handbook, developed through a project of the Transportation Research Board.

The HMA Industry is changing and so are the people. It just isn't the status quo anymore, and you are dealing with different mixes, techniques, and specifications. What does this all mean? It means we are going to have to all work together to get the job done. The purpose of this program is to provide the tools to do so. So let's get started.

On the next page you will find an **Action Plan**. This is for the ideas and suggestions that you want to pursue when you return to work. It maybe a specific technique, application, or even a spin-off of what you are already doing. This program will provide the forum for many ideas. It is up to you to do something with them. The first step is to **write your ideas down so you don't forget them**. The second step is **try them out** and see if they work for you and your situation.

The program begins at Tab 1 with the Introduction. This unit also provides additional background on the program.

Schedule for HMA Construction Program

Course Introduction
Project Organization and Communication
Surface Preparation
HMA Delivery
HMA Placement
Joint Construction
Troubleshooting #1
Compaction
Troubleshooting #2
Quality Control / Quality Assurance
Troubleshooting #3
Final Exam

ACTION PLAN

Don't let a good idea go unused.

It's not how many ideas you receive but how many you implement that will make this program a success for you and give you the greatest return on your investment. When you use an idea within 24 hours of hearing it, you are more likely to integrate it and retain it permanently. You are encouraged throughout this program to write your ideas down and commit yourself to specific action. Make sure you do something as a result of your attendance in this program.

ACTION I WILL TAKE

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

1

HMA Construction Course

UNIT 1 Course Introduction (1/2 hour)

1.1 Introduction

1.1.1 Welcoming Remarks

Welcome. You are departing on a great adventure in the best industry around. Transportation is the one field that everything else relies on. It is needed to transport people, goods, and services like food, clothes, manufacturing products and the like. Where good roads go, a good economy follows. Your career in the construction industry is a crucial one. America is depending on every inch of the road you build or inspect to ensure its competitiveness in a global economy. In addition, it is paid by the taxes you and I pay. Where else can you determine how well your tax dollars are spent and have a direct impact on the economy?

The construction industry has always drawn a unique type of people to it. These people enjoy working outdoors for a living, don't mind getting their hands dirty, and like to see the fruits of their labor. It's people like you that make this industry. Your backgrounds are quite varied and so are your experiences. You have been places and seen things no one else has. You earned your degrees from the School of Hard Knocks and The Street University. On-the-job training has probably been your teacher. All these experiences have shaped and formed your opinions about the ways you believe your job must be done.

What you will be exposed to in the next two and a half days will hopefully confirm your experiences as being best practice. The information being presented has been generally accepted as best practice and should be followed as the rule, not the exception. As you already know, it takes an open mind to survive in this Industry. We ask that you keep an open mind during these sessions, and don't hesitate to challenge what you feel is right, we just might be wrong! So let's get started.

1.1.2 Purpose and History of Program

Background:

The construction industry is under increasing pressure to design, manufacture, and construct higher performance pavements faster and at lower costs. In addition, this industry is facing many new changes in personnel, equipment, and construction types. Personnel in the field (contractor and agency) must be able to make consistent, accurate decisions regarding material suitability, construction techniques, and other factors affecting the performance and cost of the final in-place product. The need is to produce technically competent decision-makers in the field to cope with these changes, and produce the highest quality Hot Mix Asphalt (HMA) pavements possible.

History:

This program was initiated by the National Asphalt Pavement Association through a meeting with American Association of State Highway and Transportation Officials (AASHTO) and Federal Highway Administration (FHWA). A joint resolution (AR-2-89)

was passed by AASHTO Standing Committee on Highways in June of 1989. The Joint AASHTO/FHWA/INDUSTRY Committee on Asphalt was formed during the fall and first met in December of 1989. The HMA Construction program was decided upon because it was felt that its initial impact would be the strongest. In addition, delays were faced waiting on the completion of the HMA Paving Handbook, upon which this course is based. The first pilot program was held in November of 1991 in Atlanta, Georgia and received good reviews. The debriefing meeting was held in April of 1992. The comments from the pilot program and debriefing meeting were reincorporated into a revised program which was piloted in November of 1992 with a debriefing meeting immediately following. The final corrections were made to the program and the final products were made available in 1993.

One of the biggest problems the committee faced was the timing of the pilot programs. They had to be held late in the Fall to be able to attract the target audience. The committee decided to make sure the program was right and spend a little more time in the process.

Goals and Objectives:

The main goal is to design, develop, and institute a National Training Program through the joint efforts of AASHTO, FHWA, and the INDUSTRY. The main objective is to produce technically competent decision-makers in the field through a series of technical training programs. These programs are designed to provide a uniform, consistent, practical knowledge of all aspects (design, materials, production, and construction) related to Hot Mix Asphalt Pavements. To ensure uniformity, the basic material for this course will be derived from the jointly sponsored HMA Paving Handbook.

Each individual program will be designed as a stand alone program. The overall program will cover the following topics:

1. Design, Rehabilitation, and Maintenance of HMA Pavements
2. HMA Materials and Mix Design
3. HMA Production
4. HMA Construction

The first program developed is HMA Construction.

HMA Construction Program:

The main goal of this program is to give the participant a working knowledge of the HMA Construction process and help them to understand the effects of construction on the final product. Other goals of this program include:

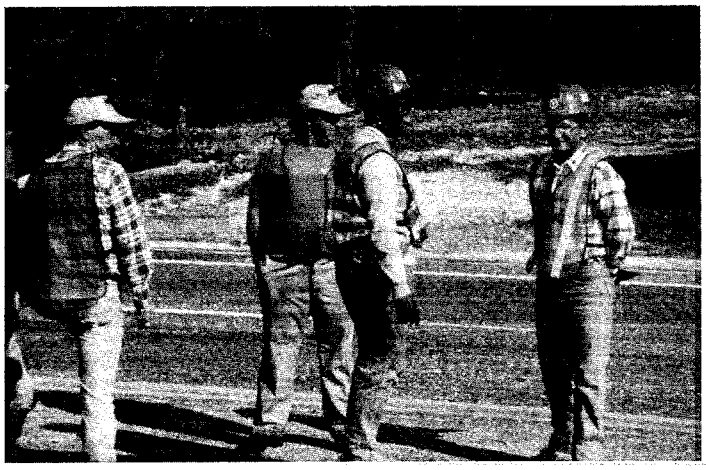
- Provide information, through hands-on exercises and reference materials, so that the participant can identify potential problems in the field and provide specific solutions.

- Recommend good practices and methods to set the job up right to minimize problems during construction.

- By exposing everyone to the same information, put the construction team (agency and contractors) on even ground to facilitate communication and cooperation.

1.1.3 Target Audience

The target audience for this program is defined as the decision-makers in the field that determine the ultimate success of the pavement being constructed. This includes: agency inspectors or technicians; contractor foremen and superintendents; consultants; or other personnel who would benefit from this information.



The program is written assuming a basic level of knowledge of HMA Construction, and focuses heavily on basic principles and concepts. Note: It is well known that understanding and applying the basic principles contained in the HMA Paving Handbook and this Training Program will eliminate the majority of paving-related problems.

1.2 Introductions

This group will be together for the next three days. There is a tremendous amount of talent and experience in this room and we want you to share that with the others here.

1.2.1 Instructors

The instructors will introduce themselves, and briefly provide some background information on themselves.

1.2.2 Participants

When called upon, please introduce and share a bit about yourself. Please answer the following questions:

What's your name?
Who do you work for?
What's your job responsibility?
How long have you been doing it?
What is the one question you want answered before you leave?

P.S. Please remember to wear your name tag for the entire program.

1.2.3 Team Selections

The participants will be divided into two-member teams.

1.3 Group Rules

For any society or group to function, some basic rules exist.

1) *Relax, and have a good time.*

You have a unique opportunity to meet other people in your line of work from all over. Talk with them, dine with them, socialize with them, ask them questions. More importantly, don't forget to listen to them.

2) *Don't be late.*

We start on time to finish on time. We have much to cover and little time to do it in.

3) *Attendance is a must.*

In order to complete this program you must attend all the sessions.

4) *Respect your neighbor.*

You don't have to agree with the other participants or instructors, but you should respect their opinions if you want yours to be respected.

5) *There are no dumb questions.*

You are free to ask questions anytime. The instructor may want to hold a question until a more appropriate time, but all questions will be answered.

6) *Participation is a must.*

You will get much more than you give by participating in this program. Remember, you don't get if you don't ask.

7) *No smoking in the classroom.*

Adequate breaks will be provided. If you can't wait, make your absence as short as possible.

1.3.1 Schedule

A copy of the detailed daily schedule for this program is enclosed. This program is full of information and resources to make your job easier and includes adequate time for discussions.

The layout of this program is designed to parallel the sequence of actual construction. Although you may be involved in some or all of these phases, it is important to cover them all so you can see the relationship between each of the units. The units are listed below along with how much time will be given to each of them.

Unit	Title	Duration in hours (Approx.)
Unit 1 -	Course Introduction	1/2
Unit 2 -	Project Organization and Communication	1
Unit 3 -	Surface Preparation	1
Unit 4 -	HMA Delivery	1
Unit 5 -	HMA Placement	4
Unit 6 -	Joint Construction	1
Unit 7 -	Troubleshooting #1	2
Unit 8 -	Compaction	4
Unit 9 -	Troubleshooting #2	1
Unit 10 -	Quality Control/Quality Assurance	2
Unit 11 -	Troubleshooting #3	1
Unit 12 -	Final Exam	1
	TOTAL	19.5 hours

1.4 Participant Manual

1.4.1 Layout

The participant manual, the one you are reading right now, is laid out to follow along with the course. Each unit is tabbed. Each page of each unit starts with the unit number, i.e. page 8 of the compaction unit would be numbered 8-8. There is also an appendix with a glossary of terms, examples of forms, and other reference materials.

About the text, you will notice several different fonts or type styles used in this manual. (The font that this sentence is written in is instructional and reference materials developed just for this course). *The font that this sentence is written in is text which comes directly from the Hot Mix Asphalt Paving Handbook, the black soft cover handbook that accompanies this manual.* Only selected sections have been taken from the handbook because of time and space restrictions. Therefore, it is recommended that you read the entire handbook for additional information.

The following section is a typical format that will be found at the beginning of each unit. It provides a brief explanation of the units' relevancy to you called "What's-in-it-for-me", followed by a brief overview of the units contents. It is followed by the KEYWORDS of the unit and the OBJECTIVES you should be able to complete by the end of this unit. In the METHODS section, we describe how this chapter will be presented, so you can know what to expect. Lastly, we describe what EVALUATION you will need to complete before leaving this unit.

Take a look at this example.

What's-in-it-for-me? Good Question. . . While pulling this program together, a state DOT employee said, "Not another training program!" It made us stop and think. Why we are doing this? The answer is that there is a need for both the agency and the contractor to have a uniform understanding of the processes involved in construction. Why? TO MAKE YOUR JOB EASIER!! That's why. For the first time we (meaning AASHTO, FHWA, and the INDUSTRY) have agreed to co-develop a training program aimed at the decision-makers in the field, namely the contractors' foremen/ superintendents and the agency's inspectors and project personnel. The members of the committee that organized the pilot all agree on several issues:

1. The workforce is changing (losing experienced personnel to retirements, cutbacks, etc.). Also, the new workforce that is entering this business is much more diverse than it used to be. Overall, we need to provide some uniform training on HMA Construction to ensure that we build quality pavements now and in the future.

2. The only way to really build a job right is to cooperate and use two-way communication. It is much easier to work with someone than against them, particularly if you have to work with them for weeks or months at a time.

OVERVIEW: During this introduction to the HMA Construction program, we will review what this program is for and why it came into existence. We will also begin to get to know each other by introducing ourselves and pairing up as two-member teams. We will then review the schedule and other details. Finally, you will be assigned some reading materials for some out-of-class reading, which will help reinforce this training experience.

KEYWORDS: Agency, Contractor, AASHTO, FHWA, Industry, Hot Mix Asphalt (HMA).

OBJECTIVES: At the end of this unit, you should be able to:
1. Understand why you are here;
2. Understand what will occur during this program.

METHODS: In this session, we will use lecture and several slides to emphasize the main points of this session. An out-of-class reading assignment will be given to help reinforce the materials covered in this program.

EVALUATION: At the end of most sessions, you will need to fill out an evaluation of the session and the instructors.

1.4.2 How to Best Utilize Contents

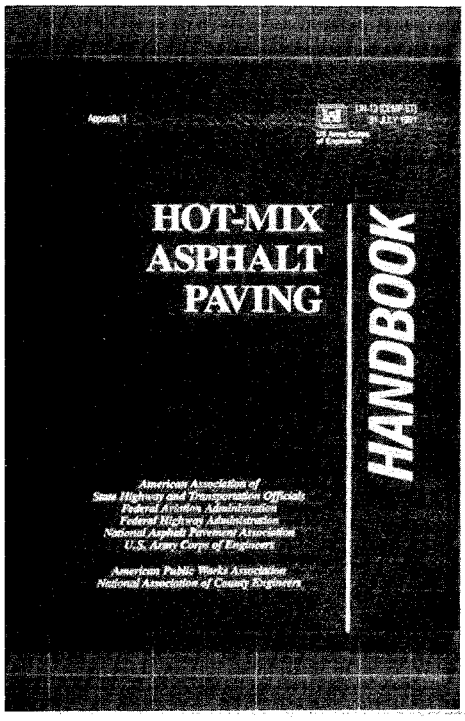
The way to get the most out of these materials is read them once prior to class, review them during class, and then re-review them in about a week. During class, mark & highlight the main points emphasized by the instructor, and feel free to write in

the columns. You will get more out of this program by making notes directly in the manual rather than on a separate pad. Taking notes this way keeps your thoughts organized and sequenced, and makes this manual a valuable reference tool.

1.4.3 Program Evaluation

You will be provided an evaluation form which we would like you to fill out as we complete each unit. This will be turned in on the last day before you leave. We encourage you to comment freely, we have thick skin and need to find out if these materials are effective for you and where we should make modifications. Thanks in advance.

1.5 HMA Paving Handbook



Each year, more than $20 billion is spent in the United States to construct asphalt pavements for highways and airports. Asphalt paving contractors, public agencies, and the pavement research community share concerns about the problems of properly constructing these pavements.

A working group of industry, government, and academic officials assembled by the Transportation Research Board (TRB) agreed that a step towards addressing some of these problems would be the development of an asphalt paving handbook, widely accepted by major segments of the paving industry. Field manuals and handbooks have been available from many agencies, but none has been adopted by all major industry segments; and, as a result, personnel from contractors and specifying agencies may be confused by conflicting recommended practices.

In 1988, the TRB Executive Committee accepted the recommendation for the preparation of such a handbook, and with financial support from the American Association of State Highway and Transportation Officials, the Federal Aviation Administration, the Federal Highway Administration, the National Asphalt Pavement Association, and the U.S. Army Corps of Engineers proceeded with its development. The handbook is being technically approved and distributed as a general guide for asphalt paving construction not only by its financial sponsors but also by the American Public Works Association and the National Association of County Engineers.

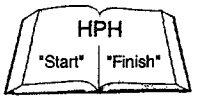
1.5.1 Layout

The Hot Mix Asphalt Paving Handbook is the best compilation of best construction practice available today. It is broken into three sections. The first section covers project organization and materials and mix design. The second section covers HMA facility operations. The third section covers HMA placement.

The bulk of this HMA Construction Program is taken from Section Three, but other information is pulled from Section One and Two. We recommend that you read the entire handbook, aim for a couple pages a day. Much of this course is taken directly out of this handbook and expanded upon. The information will be valuable to your career in this Industry. Remember, Knowledge is Power.

1.5.2 How to Best Utilize Contents

The best way to utilize the HMA Paving Handbook is to read it and keep it with you as you work. Keep it in your pickup or in your field office where you can have instant access to it. It should become a thumb worn old friend of yours. Highlight the information you need, use "Post-It's" to mark different sections, or just bend a dog-ear into a page.



1.6 Reading Assignments

You stand to gain the most out of this program if you could review the next day's materials the night before the presentation. However, since you didn't receive these materials before today, you won't have the chance to review what will be covered today. We do ask that you review them tonight after class to reinforce what occurred today. The program is designed to cover a lot of material in a short time, and a review will be helpful. At the beginning of each unit is an icon like shown on the left. It contains the pages of the HMA Paving Handbook referenced for that unit.

1.7 Terminology

Black top, asphalt, bituminous concrete, asphalt concrete, bituminous asphaltic concrete, hot mix, topping, the names go on and on. Language and terminology can be a big problem in this industry, although it does tend to have regional or local dialects that the locals can understand. Individual State DOT's have different names for mixes which change far too often to keep track of. Developing nationally accepted Hot Mix Asphalt Paving Handbook and a national training program on the same topic has met with it's share of terminology problems. For the sake of uniformity and consistency, this program will use a general set of terminology.

For this program, we have included a glossary of terms in the Tab 12 for your information. They have been compiled from the HMA Paving Handbook, the Construction Equipment Manufacturers Association (CIMA), the National Asphalt Pavement Association (NAPA), and the Asphalt Institute (AI). In addition, the terms "HMA Facility" and "Plant" will be used interchangeably in this program.

Communication is a very important part of this program and a uniform language helps eliminate confusion. Some of these terms may be new to you, some not, but we trust you understand the significance and importance of everyone being on the same page at the same time.

1.8 Review Objectives

Can you?

1. Understand why you are here;
2. Understand what will occur during this program.

2

HPH 1-5 1-9

UNIT 2 Project Organization and Communication (1 hour)

2.1 Introduction

2.1.1 Review Objectives of this Unit

What's-in-it-for-me? A better understanding of the roles and responsibilities of each person on the job is going to make your job easier. How many times have you asked someone to make a decision, only to find out they are the wrong person? Then, you have to keep asking the same questions over and over again until you finally get the right answer. The same is true for project documents, which may give conflicting instructions; you have to know which one supersedes the other and which one to go to get the right answer.

OVERVIEW: During this unit, we will look specifically at project documents, the pre-construction and pre-paving conferences, ongoing communication, and project records.

KEYWORDS: Project documents, plans, special provisions, specifications (standard & supplementary), daily diaries, reports (production & placement), AASHTO, ASTM, MUTCD, OSHA.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of project organization;
2. List four components of project documents, in order of authority;
3. Define the purpose of the pre-construction conference;
4. Describe what should occur at a pre-paving conference;
5. Identify what project records (diaries, estimates, reports, etc.) should contain.

METHODS: We will use a combination of video, slides, and lecture to emphasize the main points of the unit. In addition, the problem session will consist of a one-on-one situation where you and your partner will be required to work out an agreeable solution in a short time period...just like in the field.

EVALUATION: You will complete an evaluation of this unit.

Ensuring a cooperative spirit and excellent lines of communication on the jobsite should be your first priority. The days of the adversarial relationship between the agency and the contractor are over. We have entered into a new era of trust and cooperation. Partnering is a new practice that is proven and effective. It just isn't business as usual any more.

2.2 Video

2.2.1 Introduction

The following video tape is about several minutes long and stresses the importance of project organization and communication. The objectives of using video tape are: to relate the live action of your normal work environment into a classroom, show construction as a live process, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.

2.2.2 View Video Tape

2.2.3 Questions on Video

?

What did you see on this tape that is different from what you normally do?
How important is communication to you?
How many here have ever had any formal training in communication or listening?
Any other questions before we dive in?

2.3 Importance of Communication

The most essential part of project planning and organization is communication. The project documents are written instructions that describe in detail the requirements. The preconstruction conference initiates verbal communication between the representatives of the agency and the contractor personnel. It sets the tone for both the working relationship and direct communications during the execution of the project. It is difficult, if not impossible, to produce high-quality work if open lines of communication do not exist between the contractor's people and the agency's personnel. Likewise, safety on the job cannot be maintained if communication between all parties is inadequate.

2.3.1 Communication

Communication means sharing information. It requires the skills of speaking clearly, listening intently, and concentrating during the process. It is difficult to communicate in the noisy environment of a construction site, however, that isn't a reason not to try.

The quality of the work completed and the safety of those performing and inspecting the construction are directly related to the quality of the communication between the agency and the contractor. Communications should be oral and written. Much information can be communicated in oral form. Important information should be followed up in written form.

A Quality Assurance program is based on communication and the move towards these kinds of specifications underscores the importance of improving communication.

2.3.1.1 Two-Way Street

Asphalt paving projects, like many construction projects, are not always built as originally scheduled. When such changes do occur, it is important that they be communicated between the contractor and the agency and between the agency and the contractor. Communication is a two-way process. The informal meetings on a daily basis provide a forum for the exchange of such information.

2.3.1.2 Active Listening

Communication is a two-way street. It's as much listening as talking. One problem with communication is that we all hear things a little differently. We all use internal biases and personal experiences to filter out the bits and pieces of information we understand as part of the listening process. Many words have multiple meanings which further complicate matters.

The real key to communication is ensuring that the other person leaves with a clear understanding of what you are trying to convey. Whether they agree or not is a different matter. Communication, either verbal or written, is most successful when it is simple and concise. Big, fancy words may impress you, but rarely do they impress others.

2.3.2 Ideas for Improving Communications

Most people aren't trained in communications or listening. It is a skill that must be developed and practiced the rest of your life. Most problems are due to a problem in communication. It isn't the intent of this course to make expert communicators out of you, but to just let you know a problem may already exist. The best communicators are the best listeners and not the best talkers.

Listen carefully to words, facial and body expressions, and tone and level of someone's voice. FEEDBACK! Provide feedback to the person you are communicating with. Look for it; demand it; it is the only way to make sure what you said is what they heard. Mistakes made on the jobsite don't cost nickels and dimes, they cost thousands or tens of thousands of dollars. Summarize what the person said to you back to them to make sure the message came through. It requires a serious commitment to listen properly, and trying to pay close attention to someone on a busy construction site makes effective communication very difficult. However, that's no reason not to try your hardest to ensure what they hear and understand is what you meant.

2.4 Project Documents

Project documents illustrate and describe work to be done under the contract. Specific definitions of these and other terms that apply directly to a project are normally included in the first section of the governing standard specifications. A number of other documents are often incorporated by reference into the standard specifications, supplemental specifications, and special provisions. If there is a discrepancy between the instructions and specifications in any of the contract documents, a definite hierarchy exists among the four major forms of documents. The order of priority, from the highest to the lowest, for the contract documents is usually defined as the special provisions, the plans, the special or supplemental specifications, and, finally, the standard specifications. The plans and specifications need to be accurate and complete, and they should leave little room for assumptions or for later reinterpretation. In addition, the plans and specifications need to define the responsibilities of the representatives of the agency as well as the contractor personnel. Accurate and complete contract documents save many hours of later discussion between the agency's representatives and the contractor.

2.4.1 Special Provisions

Additions or revisions to the standard or supplemental specifications that are applicable only to an individual project.

?

Are you informed about special provisions in the contract before the job starts?

2.4.2 Plans

The drawings that show the location, character, dimensions, and details of the work to be done.

?

Do you normally get a set of plans for the project you're working on?

2.4.3 Supplementary Specifications

Approved additions and/or revisions to the standard specifications.

2.4.4 Standard Specifications

The directions, provisions, and requirements for performing the work illustrated and described in the plans. The items in the standard specifications relate to or illustrate the method and manner of performing the work or describe the qualities and quantities of materials and labor to be furnished under the contract. Material specifications and test procedures from the American Association of State Highway and Transportation Officials (AASHTO) and the American Society for Testing and Materials (ASTM) are often listed in the specifications and become part of the contract documents just as if the whole text were written into those specifications. Additional documents, such as the Manual on Uniform Traffic Control Devices (MUTCD) and the Occupational Safety and Health Administration (OSHA) regulations are also treated in the same manner when referenced in the specifications.

2.4.4.1 National Specifications (AASHTO, ASTM, MUTCD, OSHA)

?

Who uses the MUTCD manual already?

2.4.4.2 State and Other

Many specifications and test methods written by AASHTO or ASTM are modified for use under local conditions. Governmental agencies often publish their own material specifications and test methods. Inspection manuals or guidelines are normally for use by the agency's representatives and usually are not part of the contract documents.

?

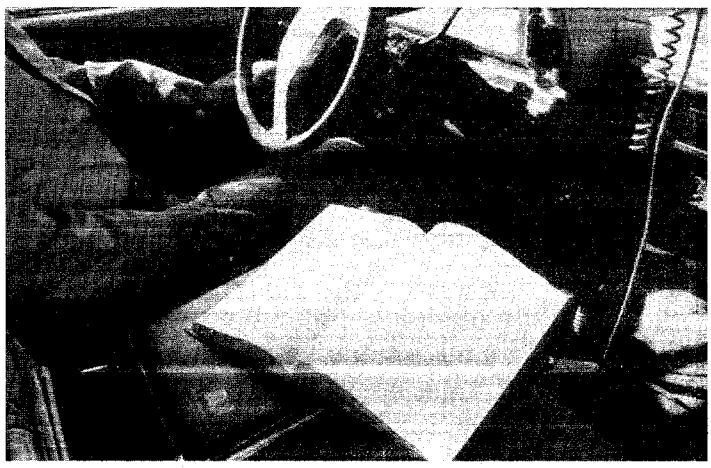
Is a set of supplementary and standard specifications available on your jobsite?

2.5 Project Records

It is important that accurate and complete records be kept for all construction projects. This is true for both the project engineer and staff and for the contractor's general superintendent, plant and paving superintendents, and all foremen. Trying to reconstruct events at a later time without written notes and complete test data is usually frustrating and often results in conflicting opinions as to exactly what happened. One procedure should constantly be followed: if in doubt about whether the information is important or beneficial, write it down.

2.5.1 Daily Diaries

All project supervisors, both agency personnel and contractor employees, should keep a detailed daily diary. It should be the place to report any different or unusual events that occur on the job. It can be used to document other events, such as a listing of visitors to the project. For the information in a diary to be accurate and meaningful, the data must be recorded in the book shortly after the events occur. If job conditions and schedules preclude making the midday entry, the events of the day should always be written down upon completion of each day's activities. The information contained in the diary must be detailed and complete. It should contain as much detailed information as possible. The importance of the information contained in each daily diary cannot be overemphasized. Many claims and lawsuits have been settled on the basis of information written in a diary.



?

Do you keep good notes and complete your diary daily?
If not, what keeps you from doing so?

2.5.2 Reports

If something happens that is important enough to remember later on, it is important enough to take the time to write it down immediately after it happens so that the information is accurate and complete.

2.5.2.1 Plant Reports

The results of all daily and periodic tests conducted at the asphalt plant should be recorded. Although different forms may be used, both the project inspection personnel and the contractor employees should collect essentially the same type of information. The data should include: (a) project number and location information, (b) weather conditions, (c) source of materials used on the project, (d) job-mix formula information, (e) aggregate gradation and asphalt content test data, (f) mix test results, (g) the amount of each material (aggregate, asphalt cement, and additives) used, (h) the number of tons of asphalt mix produced, and (i) location on pavement where daily production was placed. Any additional information required by agency specifications should also be reported on the form. It is important to record the date, time, and location of all samples taken, and the name of the individual taking the samples. Most forms should have a "Remarks" area. This portion of the form should be used to indicate any unusual occurrences or test results that took place during the day. Failing test results should be highlighted on the form. Any corrective action or changes to the mix materials, plant-operating parameters, or test procedures should be indicated. The results of those actions or changes should also be indicated on the form.

An example of this can be found in the Appendix (Form 2-1).

2.5.2.2 Pavement Reports

The data should include: (a) project number and location, (b) weather conditions, (c) the type and number of tons of each mix placed and the exact location of that mix--layer number, thickness, lane, and station number, (d) the type and make of equipment used by the contractor, (e) the density results obtained, and (f) the smoothness results obtained. Other data should be reported, such as the type, amount, and location of any tack coat material placed; the location (both transversely and longitudinally--station number) of any tests taken; and a running total of the tons of each mix laid on the project. All samples taken must be marked properly to indicate the location, the time and date of the sampling, the reason that the sample was taken, what quantity of material the sample represents, and the name of the person who took the sample. The "Remarks" are on the pavement report form and should be used to report any unusual conditions or test results that occur during the first day. Failing test results should be highlighted on the form and an explanation provided, as to both the cause of the deficiency and the steps taken to correct the problem. The result of the corrective action should also be given.

An example of this can be found in the Appendix (Form 2-2).

2.5.3 Pay Estimates

Pay estimates vary from state to state but their intent is to document work performed to date that has been accepted and that funds can be released to pay the contractor. It is important that these documents are accurate and the contractor is informed about what particular pay estimates contain.

2.5.4 Traffic Control Plan

Few new projects are built anymore and most all projects share the worksite with passenger and truck traffic. It is crucial that the traveling public get through your worksite safely and at the highest practical speed. Since lane closures, shifting lanes, and slow moving traffic are common, the motorist must have advanced warning that these hazards exist. The traffic control plan must meet the minimum standards spelled out in the MUTCD and/or the local regulations. The plan must be clear and leave no room for interpretation -- lives are at stake! All project personnel are responsible for reporting a problem with traffic control, although there is normally one person in charge. You can't be too safe out there, motorists show up in the weirdest places. And remember, you are probably very familiar with your site, but always assume the public is making their first drive through your worksite.

?

Do you drive your worksite daily and look at the traffic control devices?
Can the public understand what you are trying to tell them?

2.5.5 Change Orders

Rarely can a project team complete a project as originally planned. Invariably there is an overrun on one bid item and an underrun on another. Depending on the project, change orders can be a big issue or a small one. Since change orders modify the contract documents, it is important that all parties involved understand as soon as possible if a situation exists, especially if it requires an increase in the total contract amount. Early and constant communication is the key to avoiding a problem involving change orders.

?

Who signs change orders?

2.6 Pre-Construction Conference

A pre-construction conference is often held before work commences on a project. During this meeting, the overall tone is set for the job, preferably one of cooperation.

2.6.1 Agency Input

2.6.1.1 Review Scope of Project

It is generally the responsibility of the agency's representatives to outline the scope of the project and to discuss the information provided in the contract documents.

2.6.1.2 Unusual Aspects of Project

In addition, it is also the responsibility of the agency personnel to discuss any unusual aspects of the job—items that are not routine construction practices.

2.6.1.3 Key Agency Personnel

A list of personnel who will be assigned to the project should be provided to the contractor.

An example can be found in the Appendix (Form 2-3).

2.6.2 Contractor Input

The individuals representing the contractor should be familiar with the job and be able to speak with authority about what is to be accomplished. A progress schedule for the job should be presented and discussed with the agency's personnel.

2.6.2.1 Progress Schedule

Agreement is needed on the methods to be employed to complete the project on schedule, with a minimum of delays and change orders. The discussion should include material sources, plant production rates, haul distances and routes, paving widths and speed, and the type and operation of the compaction equipment.

2.6.2.2 Questions

Any questions about the information in the contract documents should be raised and clarification requested, if necessary.

2.6.2.3 Key Contractor Personnel

A listing of key contractor personnel who will be assigned to the project should be provided, with clear lines of authority established.

An example form can be found in the appendix (Form 2-4).

2.6.3 Project Personnel

The role of each person on the project, for both the agency and the contractor, should be discussed and made clear. This requires that the supervisory personnel define the tasks, authority, and responsibility of each of the key individuals to be involved in the work.

2.6.4 Testing

Sampling methods and frequencies should be discussed. Test methods to be used should be reviewed to assure that all individuals understand the purpose of each test, the location and the personnel who are to conduct the test, the time frame for the return and communication of the test results, and the procedures to be used if failing test results are obtained. If not adequately covered in the specifications, the use of duplicate or split samples (one for testing by the contractor and one for testing by the agency) needs to be considered, as well as procedures for retesting inadequate materials. The details of the quality control program, both on the part of the contractor and the agency, should be discussed so that everyone is aware of "who, what, why, when, and how."

2.6.5 Safety

One of the most important items to be discussed at the pre-construction conference is job safety. Safety is not only a legal and financial responsibility of all the people on the project but a moral responsibility as well. This topic should include not only the safety of those individuals working on the job (both contractor and agency personnel) but also the safety of the traveling public. Clear responsibility for maintenance of all traffic control devices such as signs, pavement markings, and flagging should be delineated.

2.6.5.1 Review Plan

The traffic control plan must be reviewed and understood by all parties involved. Remember, traffic control plans spell out the minimum requirements needed.

8. What the compaction sequence is.
9. Details on how the control (test) strip will be constructed.

The contractor should discuss any unusual aspects of the project that may require further clarification and action. A typical example is a situation where there may not appear to be enough HMA in the contract to construct a certain pavement section. This happens frequently in constructing leveling courses.

Don't wait until the heat of the battle to bring up an important issue. Do it now!

2.7.2.4 Other Items

Any other concerns, comments, ideas, or suggestions should be brought forth by the contractor now.

2.7.3 Agency Input

Communication is a two-way street and the agency needs to provide input into this as well to ensure the project works.

2.7.3.1 Explain Unusual Aspects of Paving

Are there any unusual aspects of the project that the contractor should be aware of or didn't mention in his presentation?

2.7.3.2 Agency Personnel's Roles and Responsibilities

1. Who is the key person in charge?
2. Is the same set of inspectors being used or are they new?
3. Who has what authority?
4. Who's responsible for quality assurance?

2.7.3.3 Review QC/QA Plan

Now is a great time to review the QC/QA plan and discuss sampling and testing of the finished product.

1. What is the proper line of communication?
2. Were there any problems on previous paving that need to be resolved?
3. Who is doing the testing?
4. Who will mark the test locations? Do they need any help?
5. Has everyone seen the test results from the previous day's paving?

2.7.3.4 Other Items

Any other concerns, comments, ideas, or suggestions should be brought forth by the agency now.

2.7.4 Discussion

After both parties explain their plans, it is crucial that a time be set aside for discussion of the big picture.

1. Does anyone have any ideas to make this job run smoother?
2. How can we make the final pavement our best project yet?
3. Is everyone committed to make this project an award winning pavement? This should be your goal on every project!

2.7.5 Meeting Minutes

All meetings should have minutes taken of who was present, what was discussed, and what action was decided upon. The minutes should be circulated for review to the key personnel, and they should sign off on them. A copy should be kept as part of the project records. This will help keep the communication lines open and avoid disputes later on.

2.7.6 Action Items

If an issue needs resolving, it should be given some priority, be assigned to a specific individual or team to solve, and given a deadline -- as short as possible.

There you have it, a fairly complete pre-paving conference that should inform everyone of what's going to happen and minimize any problems in the field. Again, these meetings may be long or short depending on the nature of the project, but it is best practice to have a meeting in any case.

The goal of these meetings should be **"NO SURPRISES."**

Now you're ready to get started.

2.8 Ongoing Communication

Ongoing communication is also part of the process.

2.8.1 Weekly Updates

At least weekly, the key project personnel should get together to review the process of the project or more frequently if conditions warrant. The tone of the meetings should be one of cooperation, not desperation. Remember, it is easier to work with someone than against them, and life is too short to go around angry.

2.8.2 At Major Events

Major events are also time for a meeting and should follow the same tone as established earlier. Major events may include switching traffic through a cross over, prior to starting the final surface course, etc.

What is a major event to you?

2.9 Safety

The old saying "Safety is Everyone's Business" is certainly true on an HMA paving project. From the contractor's superintendent, to the front-end loader operator at the asphalt plant, to the

truck driver, to the raker behind the paver, every individual who works for the contractor must be aware continuously of the need to practice safe work habits. Likewise, every person who works as a representative of the agency, from the project engineer, to the inspector at the plant, to the ticket taker at the paver, must be aware of safe work habits. Communication is one of the keys to a safe work environment. Every individual should know what is expected and know how to perform the assigned tasks. Occupational Safety and Health Administration regulations must be known, understood, and followed by each person involved in the construction project.

Safety talks are a good way to start the day for both contractor and agency personnel. People need to be reminded that they are operating in a potentially dangerous environment, both at the plant and the laydown site. Further, if an unsafe work practice is noticed, corrective action should be taken immediately, even if the paving operation has to be shut down until the unsafe practice is changed.

Constant care and vigilance is needed to prevent accidents and injury. The Occupational Safety and Health Administration, the National Asphalt Pavement Association, state DOTs, and others have published manuals that deal with safety at the asphalt production plant and around a paving operation. Safety is everyone's business on a construction project.

2.10 The Construction Team

Conflicts will arise in even the best-run projects; this is normal and even healthy. Your objective is to deal with these conflicts quickly, accurately, and completely. Left untended, conflicts will grow like a cancer and can affect everyone and the quality of the final project. Many states have gone to "partnering" to help solve conflicts.

2.10.1 Partnering

Partnering is growing in the construction industry and well-rooted in several states. Partnering treats the agency and contractor with equal respect. It establishes goals to complete the project on time, at cost, and with minimal conflicts. This is accomplished through regular progress meetings, empowering project personnel with decision-making authority, and establishing a team approach to building a project. Partnering works, is highly recommended, and is considered best practice for the construction of HMA pavements.

2.10.2 Decision-Making Authority

Construction is a fast paced environment. The contractor must get a certain amount of production each day to stay on track and meet the project deadlines. Problems do arise on projects which need immediate answers and decisions. These problems should be dealt with at the lowest possible level, which means decision-making authority needs to be placed in the hands of the people at this level. The project cannot tolerate a formal meeting every time a situation comes up. The best approach is to determine in the pre-construction conference who has which level of decision-making authority and have it agreed to beforehand. Simple items should be handled by the inspector and contractor foremen.

These may include deciding whether to continue paving when...

1. Inclement weather (rain, etc.) hits your site.
2. Mix arriving on the jobsite is obviously out-of-specification due to temperature, uniformity, etc.
3. An insufficient thickness or yield is noticed.
4. The measured surface tolerance is out-of-specification.

What other decisions can be made in your state at the jobsite level without going up the chain of command?

More complex problems will require the project superintendent and resident engineer to resolve. These problems may include:

1. How to deal with material overruns.
2. How to handle in-place material that has tested out-of-spec.
3. Re-testing to verify test results.
4. Pay adjustments.

What other decisions must be made at this level in your state?

The goal should be to empower personnel to make those responsible decisions at the lowest level possible. However, personnel must never overstep their decision-making authority.

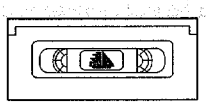
2.10.3 Response Time

All situations should be given deadlines for resolution. In some cases, the deadline may be five minutes; in others it may be two days. Partnering agreements establish specific response times based on the personnel level involved. Simple problems should have fast response times; more complicated problems may take longer, but everyone must know ahead of time how long that will be.

2.11 Communication Problem Session

This exercise is just one of several you will participate in during this program. You will team up with a partner and be given a situation written on a handout. Your partner will also be given some background information on the problem, which may differ from yours

since one of you will be the agency and the other one will be the contractor. You will have two minutes to read and study your information and eight minutes to make a decision, no longer. You should not let your partner read your information. Get to work, we need your decision in ten minutes.



2.12 Review Video Tape

2.13 Review Objectives

Can you?

1. State the objective of project organization;
2. List four components of project documents, in order of authority;
3. Define the purpose of the pre-construction conference;
4. Describe what should occur at the pre-paving conference.
5. Identify who is responsible for what information;
6. Identify what project records (diaries, estimates, reports, etc.) should contain.

2.14 Evaluation

Please complete the Unit 2 evaluation at this time. Thank you.

3

HPH 3-10 3-15

UNIT 3 Surface Preparation (1 hour)

3.1 Introduction

3.1.1 Review Objectives of this Unit

What's-in-it-for-me? So we spilled too much tack in a few locations, forgot a pothole here or there, left a patch too high, sealed the cracks to overflowing...It won't show through. Besides, we are all ready to pave and have ten trucks on the road. We can't stop now, can we?

Surface preparation, like many things, rarely gets the attention it needs. It often involves change orders because more problems are found by the time the job actually gets started, and it is time consuming to repair pavements. Besides, no one ever sees what you have done. So why bother? Proper preparation is viewed like traffic control is to many, a necessary evil. Let's just do enough to get by. It's going to be covered up (or removed) by the time the project is over anyway.

It's easy to cover some fault or problem up with hot mix, but rarely do those faults or problems go away. In fact, many times the entire situation becomes worse and is always more expensive to fix the second time around. Remember the old Fram Oil Filter commercial, "You can pay me now or pay me later." The same motto applies to pavement construction. Proper surface preparation means fewer problems you will have to come back to later and fix, and less time in the hot seat explaining why you didn't fix it when you had the chance.

OVERVIEW: During this unit, we will look at the steps involved in preparing bases and existing pavements for overlays with HMA. Also, we will go into detail on patching techniques for pavement repairs including selecting the proper technique, proper materials, and inspection of the process. In addition, we will look at milling existing pavements and placing leveling courses, and preparing PCC pavements.

KEYWORDS: Base, Overlay, Surface Preparation, Tack Coat, Prime Coat, Proof Rolling, Milling, Leveling.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of surface preparation;
2. Recognize proper techniques for base preparation;
3. Recognize proper techniques for overlay preparation;
4. Identify proper techniques, materials, and compaction for patching;
5. Recognize proper techniques for placing leveling courses;
6. Recognize proper techniques for milling existing surfaces.

METHODS: We will use a combination of video, slides, and lecture to emphasize the main points of this unit.

EVALUATION: You will complete an evaluation of this unit.

3.1.2 Importance of this topic

The performance of a hot-mix asphalt pavement under traffic is directly related to the condition of the surface on which the pavement layers are placed.

3.2 Video

3.2.1 Introduction

The following video tape is several minutes long and stresses the importance of proper surface preparation prior to overlaying with HMA. The objectives of using this video tape are: to relate the live action of your work environment into a classroom, show the real process of surface preparation, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.

3.2.2 View Video Tape

3.2.3 Questions on Video

?

How involved do you get in surface preparation?
What seems to be your biggest problem with surface preparation?

3.3 Preparation of a New Base

3.3.1 Preparation of subgrade/base course

3.3.1.1 Subgrade

If the asphalt pavement is to be placed directly on the subgrade soil, that subgrade material should meet all applicable requirements for moisture content, density, and smoothness. The subgrade should be able to support the weight of the haul traffic. If distortion of the subgrade soil occurs during the paving operation, the placement of the mix should be stopped until the condition of the soil can be corrected.

3.3.1.2 Base Course

If the asphalt layer is to be constructed directly on a new or existing untreated granular base layer, that material should meet all the requirements for moisture content, density, and smoothness.

3.3.2 Proof rolling

Proof rolling should be done, however, on top of the granular base material and the amount of deflection of the base and the amount of indentation of the truck wheels into the granular base course material noted. If the base material is stable and dry and does not deflect and indent significantly under the wheels of a loaded tandem axle truck, placement of the

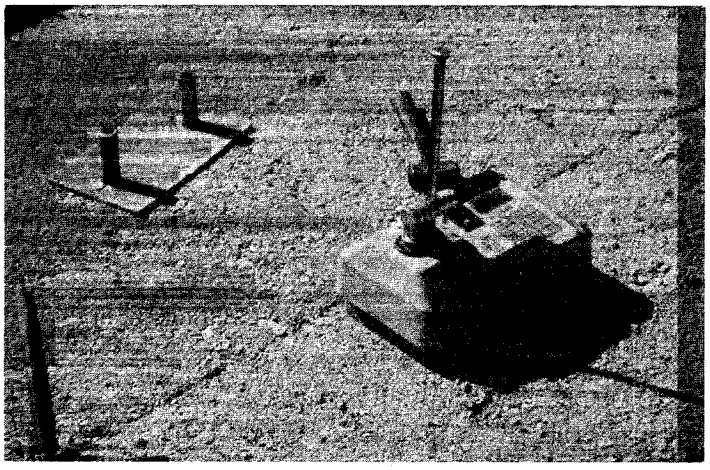
prime coat and/or the new asphalt mix should be permitted to start. If the condition of the granular material is not satisfactory, the base course should be reworked or stabilized.

LOCAL PRACTICE: The proof-rolling procedure in your state is as follows.

1. What equipment shall be used? _____
2. How is the test conducted? _____
3. What constitutes a passing test? _____
4. What is required of a failed area? _____
5. What is the maximum time duration allowed between proof rolling and placement of the next layer? _____
6. Who is responsible for maintaining a proof-rolled subgrade or base prior to overlay? _____
7. Other specific information: _____

_____

3.3.3 Density checks



Pavement materials must be compacted to perform, whether they are subgrade, aggregate base or HMA. Density testing should be standard practice prior to placing the next lift, and nuclear gauges make density testing quick and easy. Density checks coupled with proof rolling will tell you whether you are ready to pave or not.

LOCAL PRACTICE:
Subgrade should be compacted to _____% of _____.
Base Courses should be compacted to _____% of _____.

3.3.4 Prime coat

There is a considerable difference of opinion as to the benefits of a prime coat of asphalt material on a granular base course layer. Advocates feel that the material acts as a temporary waterproofing layer, allows the base course to be used for light traffic, binds together any dust on the surface of the granular base layer, promotes the bond between the base course material and the new asphalt overlay, and prevents slipping of thin pavement layers. In many cases, however, a prime coat is not needed on a granular base course layer. A prime coat does not add anything to the structural capacity of the pavement layers.

If the specifications require the application of a prime coat, the prime coat material should be applied with a pressure distributor to the base course at least 48 hours before paving is to begin. Typically a cutback asphalt (MC-30 or MC-70) is used. An asphalt emulsion is not normally used because it will not penetrate very far into the granular material, although some

inverted emulsions have been applied successfully. Typical application rates range from 0.15 gal/yd² (0.68 l/m²) *for a tight surface to 0.40 gal/yd²* (1.81 l/m²) *for an open surface. No more prime should be applied than can be absorbed completely by the granular base course in 24 hours. If not absorbed, the excess should be blotted with sand and removed.*

LOCAL PRACTICE:
Prime coats (are/are not) used in this state. If used, a typical type is _____ with an application rate of _____ for _____types of surfaces. The cure period is _____.

3.3.5 Base Disturbance from Traffic

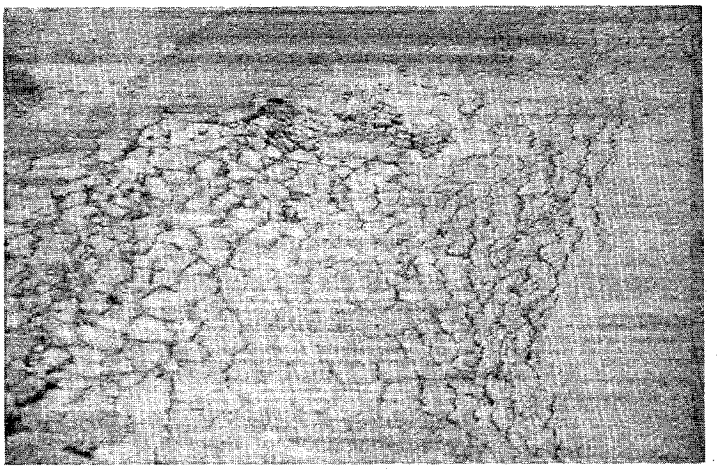
Construction traffic occasionally disturbs a base course before it can be covered up. The best practice is to fix it, even if you need to stop the operation to do so. The performance of the pavement is counting on every inch of stone or HMA being where it should be. Fix it now or pay for it later.

A checklist for base preparation can be found in the Appendix (Form 3-1).

3.4 Preparation of an Existing Surface

If an HMA overlay is to be placed on top of an existing asphalt pavement, the existing surface must be prepared properly before any mix is laid. At a minimum, the failed areas should be removed and replaced, the potholes properly patched, the cracks cleaned out and sealed, and the ruts filled in or, preferably, removed by cold milling.

3.4.1 Pavement Repair and Patching Techniques



To attempt to bridge failed areas with the new overlay material is usually foolish unless a very thick overlay is to be constructed.

It is important for the construction team to work together on pavement repairs to make sure the repairs will perform as intended. This includes marking, verifying depth and a stable base is reached, patching, compacting, testing, and working under traffic. The plans will detail the amount and type of patching called for on a project.

3.4.1.1 Matching technique to conditions

Removal and replacement should be carried out on all pavement areas on which severe load-related distress has occurred.

3.4.1.2 Materials

Patching materials come in all shapes and sizes, from cold mix to hot mix to special proprietary mixes. Hot mix is your best choice if it is available and it usually is for these kind of projects. The material used for repairing patches should meet or exceed the material requirements for what is already in place or what is called for in the contract. If the patch calls for patches deeper than 4-6 inches, a binder or base course HMA (with a larger top size aggregate) should be used.

3.4.1.3 Procedure

Subgrade distortion should be repaired by undercutting and replacement with suitable backfill material. Proper subsurface drainage should be installed as necessary. New granular base course material, stabilized base course layers, and/or asphalt mix should be placed in order to bring the strength of the pavement structure in the failed area to the same level as the surrounding good pavement layers. If asphalt concrete mix is used to patch a large area, the mix should be placed with a paver.

Localized failed areas should be patched properly. Each failed area should be cut back to sound pavement and squared up with the sides as vertical as possible, the loose material and water in the hole removed, a tack coat applied to the sides and bottom of the pothole, and the mix placed in the hole. If the pothole is deeper than 4 in. (100 mm), *the mix should be placed in layers and each layer compacted properly.*

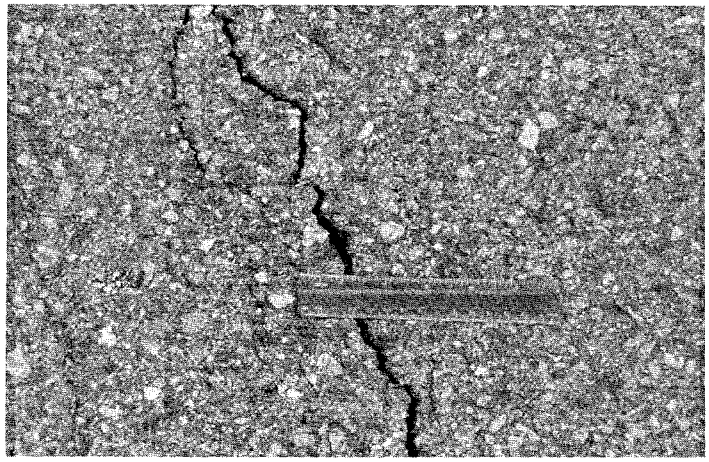
3.4.1.4 Compaction

Compaction is critical; this is not the place for Throw-And-Go. These patches become a permanent part of the pavement and must be as uniform and dense as the surrounding material, or else problems may surface later. Cores or nuclear density tests may be required and the material placed must meet the specifications, or else the pavement's performance will suffer.

compaction is often necessary in tight corners and hard-to-reach areas. Extra diligence is needed to ensure hand-compacted areas receive the same attention as machine compacted areas.

LOCAL PRACTICE:
Patches should be compacted to _____% of _____, and tested by nuclear/coring.

3.4.2 Crack Filling/Sealing



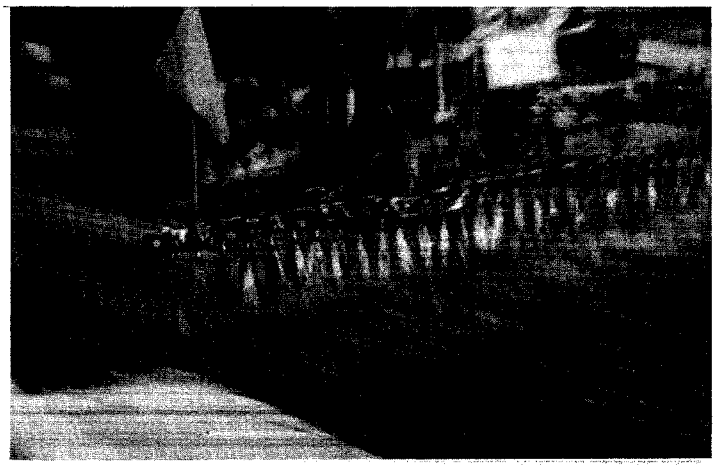
Badly cracked pavement sections are normally patched or replaced. The benefits of filling other cracks in the existing surface depend, in part, on the width of the cracks. If the cracks are narrow (less than 3/8 in. (10 mm) *in width), it is doubtful that the crack sealing material will actually enter the crack. If wider cracks are present, they should be cleaned of debris. The crack sealing material should be inserted when the cracks are clean and dry. The level of the crack filling material should be slightly lower than that of the surrounding pavement surface. The amount of reflective cracking that occurs in an overlay sometimes may be reduced by the use of a surface treatment on the existing pavement, depending on the cause of the cracking. Alternatively, a slurry seal consisting of a slow-setting emulsion, fine aggregate, and water may be used. Such a crack filler operation may be more economical than a standard crack sealing process, depending on the extent of the cracking.*

LOCAL PRACTICE:
Crack sealing (is/is not) routinely conducted prior to overlay. If it is conducted, the operation should fill all cracks greater than _____ wide. It should be conducted _____. Cracks should be cleaned by _____, filled to _____ the surrounding surface using a crack sealant material such as _____. The configuration/application of the operation will be _____.

3.4.3 Cleaning

The existing surface must be clean before the tack coat is placed. Usually this is accomplished with a power broom or street sweeper or some combination of the same. Dried caked mud and other foreign materials must be removed, spilled asphalt should be shoveled or picked up (especially if only a thin overlay is to be placed).

3.4.4 Tack Coat



The purpose of tack coat is to ensure a bond between the existing pavement surface and the new asphalt overlay. A good bond can increase the overall structural strenth of the pavement structure. It also has the potential to prevent intrusion of water between the layers and, thus, minimizing stripping near the interface. *If a good bond is not formed between the existing surface and the new overlay, a slippage or sliding-type failure can easily occur. The pavement surface must be completely clean before the tack coat is applied. The tack coat material, which is normally asphalt emulsion but can also be asphalt cement or cut back asphalt, should be heated to the proper temperature so that it is fluid enough to be sprayed from the nozzles instead of coming out in strings. If the correct amount of tack coat is sprayed on the surface, some of the existing surface will still be visible through the tack coat--not all of the existing pavement surface will be covered with the tack coat. The proper tack coat application will leave a residual asphalt cement content of approximately 0.04 to 0.06 gal/yd²* (0.18 l/m² to 0.27 l/m²) *on the roadway.*

The application of the tack coat material is essential when an overlay is being constructed on an existing pavement surface; either portland cement concrete, hot-mix asphalt, or surface treatment. A tack coat often is not needed, when a layer of new mix is being placed over another layer of asphalt pavement that has been laid within a few days.

Local Practice: A typical type of tack is _____ and is applied at a rate of _____ to leave a residual asphalt content of _____.

A checklist for existing surface preparation can be found in the Appendix (Form 3-2).

3.4.5 Leveling courses

Common practice in the past has been to place a leveling course on the existing pavement surface in order to improve the rideability of the pavement structure. This leveling course, sometimes also called a wedge and level course or a scratch course, was designed to fill in the low spots on the pavement surface. This leveling action was accomplished through the principle of the floating screed on the paver.

Normally, the area to be leveled is marked out and determination is made as to the amount of leveling course to be placed in the area, routinely measured in pounds per square yard (kilograms per square meter). The material is placed either by machine or hand and then compacted. Rubber tire rollers compact variable leveling courses more uniformly than steel wheel rollers and are recommended for leveling courses. Density is difficult to measure on variable depth leveling courses.

LOCAL PRACTICE:
Leveling courses are used for _____. The type of equipment used to place a leveling course is a _____ and _____ are used to compact the mix. Density tests are (required/not required) on leveling courses.

3.4.5.1 Differential compaction and density tests

The thicker mix, however, typically compacts more than the mix in thinner locations. This problem, called differential compaction, requires that multiple courses be constructed over a pavement surface that is badly out of shape before a smooth surface can be obtained.

3.4.6 Overlays on PCC pavements

The following is a general overview of PCC surface preparation. Any severely distressed areas in the PCC slabs should be cut out, removed, and replaced using full-depth slab-repair techniques with PCC or HMA. Corrective work should also be completed on the underlying subbase or subgrade material. Any severely spalled

areas at joints should be repaired using partial-depth slab-replacement methods. Rocking slabs must be stabilized.

Joints that are poorly sealed should be cleaned. The joints, when dry, should be resealed with appropriate joint seal material. Once the patching and resealing has been accomplished, the surface of the PCC pavement should be cleaned completely using mechanical brooms and air blowing and/or water flushing where needed.

3.5 Preparation of a Milled Surface

3.5.1 Milling equipment and techniques

Milling, also called cold planing, can be used in lieu of placing a leveling course (filling in the low spots) to remove the high points in the existing surface. Milling can be accomplished in any width necessary, from 6 in. (0.15 m) *to more than 13 ft.* (4 m).

3.5.2 Advantages/disadvantages

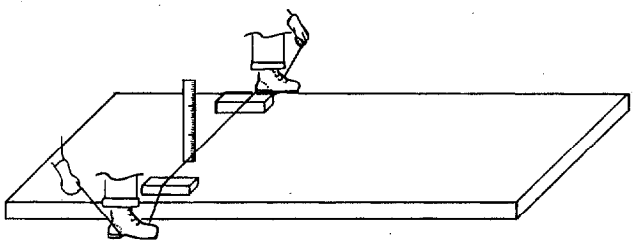
Equipped with automatic grade and slope controls similar to those used on an asphalt paver, the milling machine is capable of producing a level surface in one pass over the present roadway. The RAP produced by the milling process can be hauled back to the asphalt plant for future recycling. In addition, the texture of the milled surface enhances tack and bond and may reduce the possibility of slippage of an overlay over the existing surface.

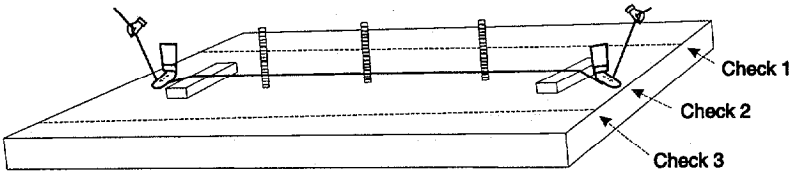
3.5.3 Pavement repair

Pavement repairs are even more important when milling and overlaying. Milling removes a portion of the structural capacity of the pavement. If no or poor repairs are made, the final structure will certainly suffer. Milling may uncover the additional problems not originally estimated and may require additional patching or repairs. Adequate time and resources should be planned between milling and overlay procedures to correct any problems uncovered.

3.5.4 Grade and slope of milled surface

Milling machines can leave a precisely controlled surface since they employ the same type of grade and slope control equipment a paving machine has. The final grade should be checked prior to paving to ensure the proper profile is obtained. A good practice is to check the surface with a level or stringline prior to paving. Milling on main highways done at night is more difficult than operations done during the day.





3.5.5 Cleaning

A pavement surface that has been milled typically is very dusty and dirty. Once the pavement has dried, multiple sweepings with a mechanical broom are usually needed. In some cases, it may be necessary to dampen the milled surface before sweeping or to air blow and/or flush the milled surface with water. Any dust and dirt left on the milled surface will greatly affect the bond between that course and the new asphalt overlay.

3.5.6 Tack coat

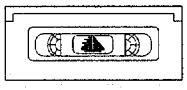
More tack coat material may be needed on a milled surface because of the increased surface area.

3.5.7 Crack Filling/Sealing

Crack filling and sealing on milled pavements should be performed in the same manner as discussed under conventional overlays.

3.6 Construction Traffic

Work of this nature typically requires many locations with construction vehicles frequently moving from one to another. Extreme caution must be stressed as accidents are more prone to happen in this situation.



3.7 Safety

Traffic control on surface preparation work is very difficult since work may be required at many locations. Traffic control must not compromised, especially in this situation. In fact, it may be even more important here by the very nature of the operation.

3.8 Summary

A good summary of the key points of surface preparation is found on page 3-15 of the HPH and is repeated in the handout entitled "Tips for Best Practice."

3.9 Review Video Tape

3.10 Review Objectives

Can You?

1. State the objective of surface preparation?
2. Recognize proper techniques for base preparation?
3. Recognize proper techniques for overlay preparation?
4. Identify proper techniques, materials, and compaction for patching?
5. Recognize proper techniques for placing leveling courses?
6. Recognize proper techniques for milling existing surfaces?
7. Recognize proper techniques for PCC preparation?

3.11 Evaluation

Please complete the Unit 3 evaluation at this time. Thank you.

4

HPH 3-1 3-9

UNIT 4 HMA Delivery (1 hour)

4.1 Introduction

The purpose of the haul vehicle is to transport the asphalt mixture from the asphalt plant to the laydown machine. This must be done without delay and without any change in the characteristics of the mix during the delivery process.

4.1.1 Review Objectives of Unit

What's-in-it-for-me? Making and placing hot mix is similar to manufacturing any product, be it newspapers, rubber bands, pickup trucks, or virtually anything you buy today: 1) sophisticated equipment is used, and 2) a continuous operation produces a better product at a lower cost per unit. The HMA Industry is no different. Our product (HMA) works best when it is planned and constructed as a **process**, and the **process** is allowed to run unimpeded as much as possible. Most of the problems arise when we fool with the process; i.e., slow it down, stop it, or speed it up. Your efforts should be aimed at keeping the process moving instead of spending your time trying to fix all the problems that occur when it changes.

A sign of a good paving operation is when the project personnel are calm and focused because everything was set up correctly to begin with, and it is running smoothly. Your goal is to think "PROCESS" and relate process to "LESS WORK." In most cases, ensuring an adequate delivery of HMA to the site and balancing all your production schedules will produce a better product with less work.

Continuous process = fewer problems = less work = better product...not a bad deal!

OVERVIEW: During this unit, we will look at the importance of looking at HMA construction as a continuous process as a means to reduce field problems and, to increase the quality of the product. Specifically, we will look at the delivery of HMA from the time it is loaded into the truck until it is unloaded at the jobsite.

KEYWORDS: Scheduling, Production Rates, Haul Trucks, Payload, Tarps, and Release Agents.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of HMA delivery.
2. List the four different production rates that need to be coordinated prior to paving.
3. Identify the types and capacities of haul vehicles used.
4. List advantages and disadvantages of each type of vehicle.
5. Identify proper loading of haul vehicles.
6. Describe proper haul vehicle operating techniques.
7. List important areas of vehicle maintenance.

METHODS: We will use a combination of video, slides, lecture, and a calculation problem.

EVALUATION: You will complete an evaluation of this unit.

4.2 Video

4.2.1 Introduction

The following video tape is several minutes long and stresses the importance of proper HMA Mix Delivery as part of the construction process. The objectives of using this video tape are: to relate the live action of your work environment into a classroom, show the real process of delivering HMA, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.

4.2.2 View Video Tape

4.2.3 Questions on Video

Why is the consistent delivery of HMA so important?
What problems do you face in keeping a consistent supply of mix coming to the paver?
Why?

4.3 Haul Trucks

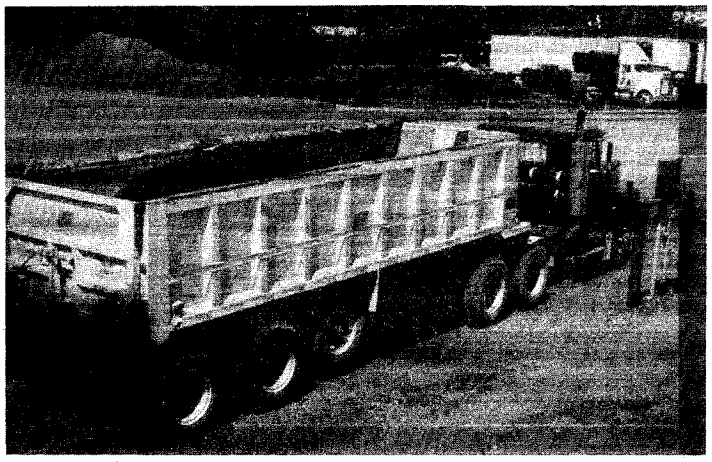
Three primary types of trucks are usually employed to transport the mix: end dump, bottom or belly dump, and live bottom (conveyor) trucks. All of these trucks are loaded in the same manner, either directly from the pugmill at a batch plant or from the surge silo at a batch or drum mix plant. The three types of vehicles differ in how each unloads the mix at the paver.

4.3.1 End Dump

An end dump truck delivers the mix directly into the hopper of the paver. When the bed is raised, it should not be in contact with the hopper and should not press down on or ride on the paver. End dump units may have 3 to 6 axles, and payloads can vary from 12 to 20+ tons (10.9 to 18± tonnes) depending on local regulations. They have the shortest wheel base and are the easiest to maneuver. The main drawback is their limited carrying capacity in many areas.

4.3.2 Semi-trailer

Contact between the truck bed and the paver can be a problem, however, when large semitractor trailer units are used as haul vehicles, particularly when the truck bed is extended to its highest point. When the weight of the truck is being carried by the paver, the laydown machine may lose its ability to operate properly.

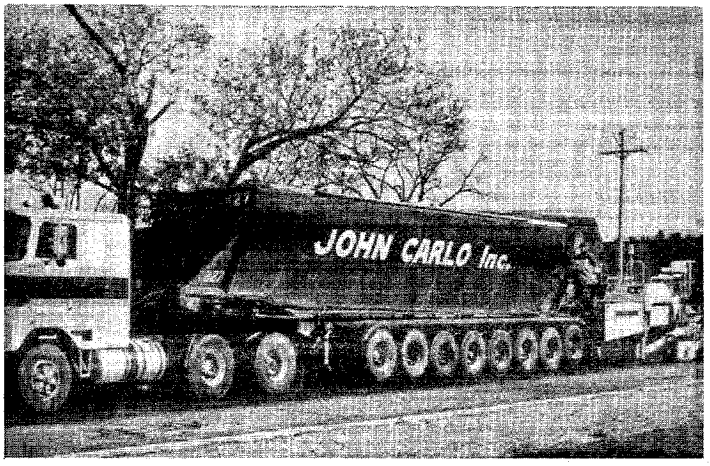


Semi-trailer units typically haul more than single units and typically carry the maximum legal gross load. The payload depends on number of axles, local regulations, and the empty weight of the vehicle. Normally, these trailers carry between 20 and 25 tons (18 to 23 tonnes) of mix. The disadvantages include more skill required to maneuver these units around the jobsite, overhead obstructions (wires, bridges) when the bed is raised, and a potential for segregation when loading.

4.3.3 Bottom Dump

A bottom or belly dump truck delivers its load from underneath the truck bed into a windrow. It is important that the correct amount of mix be placed in the windrow to assure that the paver hopper does not run out of mix or become overloaded with too much mix. Continuous operation of the paver, which must be equipped with a pickup machine (windrow elevator), can only be accomplished if a continuous and consistent supply of mix is available. The ability of the paver to place a smooth layer of mix will be affected by the uniformity of the windrow. Keeping the size of the windrow constant is easier than correcting the problem of too little or too much mix in the paver hopper. Bottom dump units also can carry the legal limit. The payload is dependent on the same factors as semi-trailers. The advantage is increased carrying capacity over end dump units, but greater operator skill in conjunction with greater dump person skill is needed to adequately size the windrow.

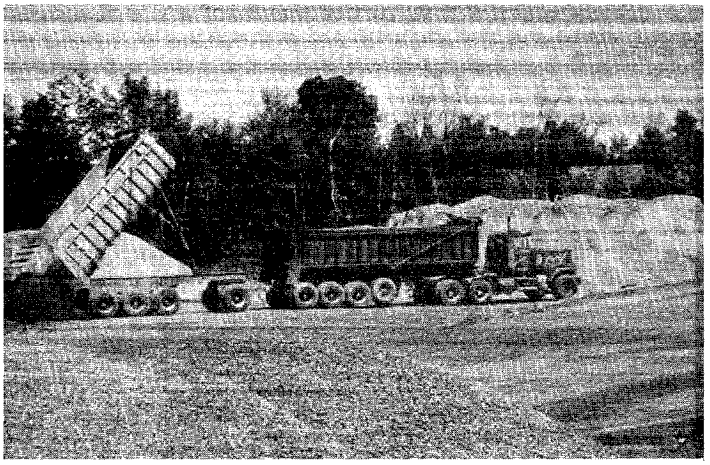
4.3.4 Horizontal Discharge



A live bottom truck employs a conveyor belt or slat conveyor in the bottom of the truck bed to discharge the mix without the need to raise the bed, and deposits the mix directly into the hopper of the paver as does an end dump truck.

Horizontal discharge units also can carry the legal limit. The payload is dependent on the same factors as semi-trailers. The advantage here is that the unit can discharge directly into the paver. The disadvantages include an increased skill level required of the operator. The unit shown in the inset illustrates a unit common only to the State of Michigan which uses 11 axles and carries a payload of approximately 50 tons (45 tonnes). Other states which use this type of unit use a five or six axle design carrying the legal limit.

4.3.5 Double Trailer Combinations



Double trailer combination haul trucks have localized usage around the country. They can haul more material with less trips, but require greater operator skill to do so. The units may be end dump or bottom dump combinations.

LOCAL PRACTICE:
In this area, the typical types of haul vehicles used and their net tonnage are:

Type	Capacity

4.3.6 Maintenance

4.3.6.1 Mechanical

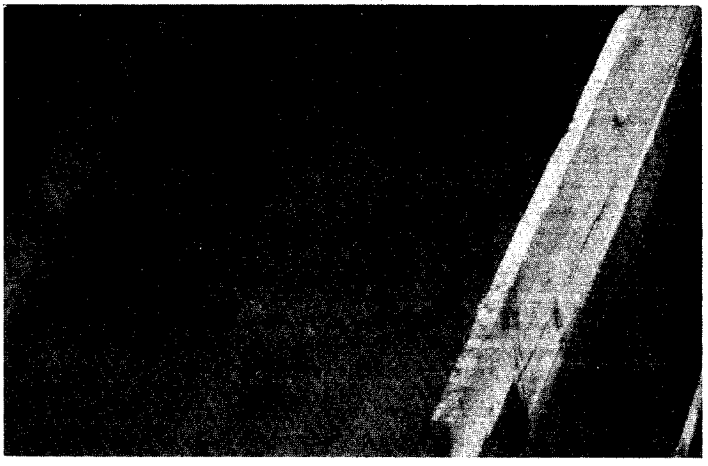
Haul Trucks must be in mechanically sound condition. This includes the engine, drive train, hydraulic system, brakes, and lights. The driver should be responsible for maintaining the vehicle. If anyone else notices a potential problem with the vehicle, such as broken tail lights, it should be brought to the attention of the driver. Vehicles determined to be unsafe should be parked immediately and not be allowed on public roads.

4.3.6.2 Hydraulic

The hydraulic system must be checked by the driver daily. Hydraulics are used to raise the truck bed, and a failure in this system could prove dangerous. Leaks in this system will spill fluids that are detrimental to HMA pavements.

4.3.6.3 Truck Bed

4.3.6.3.1 Cleaning



The bed of the haul truck, whether an end dump, bottom dump, or live bottom truck, should be free of all deleterious materials before mix is placed in it. The bed should be reasonably smooth and free from any major indentations or depressions where the truck bed release agent and the HMA can accumulate.

4.3.6.3.2 Insulation

If environmental conditions warrant it, the sides and bottoms of the truck bed should be insulated. The insulation should be tight against the body of the bed; there should not be any gaps between the side of the truck and the insulation through which wind could enter.

4.3.6.4 Cleaning the Undercarriage

Most haul trucks are used to haul a variety of different products in varying terrain. Mud, sand, stone, or old HMA can build up on the undercarriage of the unit and fall off onto the paving surface, or worse yet, onto the road at highway speeds creating a potential hazard to other vehicles. The truck driver is responsible for maintaining the vehicle, and should be alerted if such a condition exists.

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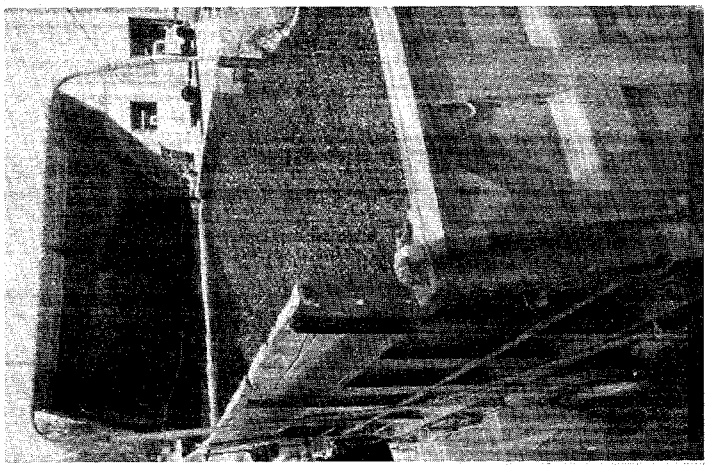
Look for loose rock and dirt near the truck's tail lights. Will this fall on your mat? What effect will it have on the pavement?
Will it shake loose and break a window or cause an accident?

4.3.7 Tarps



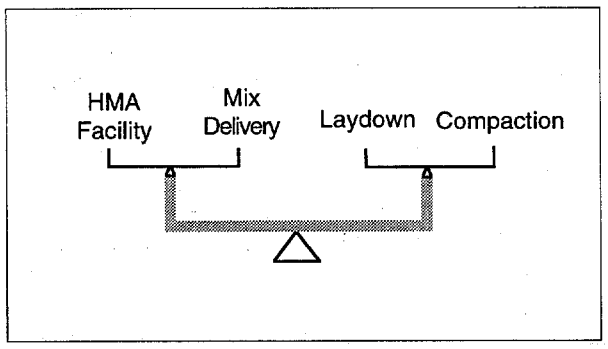
Every haul truck should be equipped with a tarpaulin, which can be employed as needed to protect the mix in case of inclement weather. The tarp should be made of water-repellent material, should be of sufficient weight and strength to resist tearing, should be in good condition, and should not have any holes or tears in it. For safety reasons, it is desirable to use tarps that can be extended by mechanical means over the bed of the truck without the driver having to climb up on the sides of the vehicle to unroll the tarp.

If there is any water on the tarp when the truck is ready to discharge mix into the paver hopper, the water should first be removed from the tarp by raising the bed of the truck and letting the water run off before the truck backs into the hopper.

Tarps are not normally necessary in warm weather and with relatively short haul distances between the plant and the paver.

LOCAL PRACTICE:
In this area, haul trucks (are/are not) required to have a tarp;
1. that is constructed of_____.
2. that covers the bed _____.
3. that is used to cover the load _____.

4.4 Determining Production Rates



Paving is a constant balancing act. The contractor must continually balance facility production, mix delivery, laydown, and compaction production rates to ensure a high quality mat is produced.

4.4.1 Facility Production

HMA facilities range in production rates from 200 to 700 tons per hour (182 to 636 tonnes), and many of these facilities are equipped with storage silos to hold additional tonnage to keep up with the demand. However, the facility providing HMA to a specific project may also be providing mix to several jobs at the same time. The contractor is responsible for knowing what production rate they will be allotted on a given day or at a given time, and the other rates should be adjusted to match.

4.4.2 Mix Delivery

Haul trucks and mix delivery are usually the most uncertain forces that must be balanced. Adequate trucks should be assigned to the job to handle the facility production rate allocated. Traffic delays must be dealt with. Also, there is a tendency for drivers to want to stay in a pack. This practice should be discouraged as constant supply of HMA is needed to keep the paver moving.

4.4.3 Laydown Production

Laydown production rates depend on the width and depth of the mat being placed, the speed of the paver, and type of project. Mainline paving requires higher rates than does paving turnouts. Paver speed must be balanced with the other forces. This will be discussed in more detail later.

4.4.4 Compaction Production

Compaction production rates depend on the size and type of rollers used, the width of mat being placed, and the number of coverages required to achieve density. This must also be balanced, and will be discussed in more detail later.

4.4.5 Dealing with Extenuating Circumstances

The best laid plan will always have to deal with extenuating circumstances. Rain, equipment breakdowns, and traffic delays all can ruin a well-intentioned paving plan. Alternative plans should be considered, spare equipment may need to be available, and night paving may need to be considered, depending on the nature of the project.

?

What kind of situations have you experienced?

4.4.5.1 Rain Delays

When rain occurs at the paving site and mix is still in the trucks waiting to be unloaded, judgment is needed. If the rain is relatively light and appears to be going to continue for some time, and if the pavement surface has been tacked and does not contain puddled water, the trucks can be unloaded as quickly as possible and the rollers brought up directly behind the paver to compact the mix before it cools completely.

If the rain appears to be of short duration--a passing shower--the mix should be held in the haul truck. Once the rain has stopped and any puddles of water have been swept from the roadway surface, the mix can be unloaded from the waiting trucks into the paver and laid down. As long as chunks of mix do not appear behind

the screed and the rollers can densify the mix adequately, little harm is done in holding the mix in the haul trucks.

4.4.5.2 Equipment Breakdown

It always happens when you least expect it, but equipment will break down from time to time. If it is a truck, others can fill in, and you can adjust your process. If it is a paver or roller, you have a big problem. Unless a spare is available, a choice will need to be made. Keeping equipment maintained will reduce this problem, but not eliminate it. The best way to deal with this is to always keep a back-up plan in mind.

4.4.5.3 Traffic Delays

Since trucking dictates production more than other processes, it is important to know the routes and conditions they will be able to take. What may be a ten minute drive under normal conditions may be a 40 minute trip under heavy traffic or with lane closures. Accidents are another problem which can shut down a job because the mix cannot get to the paver. Alternate routes should be planned, if possible, and communication via C.B. radio will keep one in contact with the trucks.

4.4.6 Scheduling Problem

On the following page is an example form which can be used to calculate the number of trucks needed for a particular situation. An additional copy is available in the appendix for your use.

?

How do you determine the number of trucks needed on a job?

MIX DELIVERY PRODUCTION CALCULATION FORM:

Date:_____ Project #: _____

Project:_____

Tons scheduled to be placed today (MIX): _____ tons

Hours of paving scheduled (TIME): _____hours

Rate of mix needed to be delivered to jobsite (H-RATE):
= MIX ÷ TIME = _____ ÷ _____ = _____ tph

Rate of mix available from HMA facility (F-RATE): = _____ tph

STOP: Is the H-RATE slightly greater than or equal to the F-RATE?

Average Truck Capacity (SIZE):_____net tons

Total Truck Trips Needed (TRIPS):
= MIX ÷ SIZE = _____ ÷ _____ = _____ trips = TRIPS

Truck Cycle (in minutes):

Delay at Facility :_____
Load Time :_____
Ticket & Tarp :_____
Haul to Job :_____
Delay on site :_____
Dump/clean up :_____
Return Haul :_____
==========
Total cycle in minutes = _____ ÷ 60 min/hr
= **Truck Cycle (CYCLE):** _____ hours/trip

Number of Trips per Truck (LOADS):
= TIME ÷ CYCLE
= _____ ÷ _____ = (Round down) _____ trips/truck = LOADS

Number of Trucks Needed (TRUCKS):
= TRIPS ÷ LOADS
= _____ ÷ _____ = (Round up) _____ total trucks = TRUCKS

Is TRUCKS x LOADS ≥ TRIPS? (_____) x (_____) = (_____) ≥ (_____)

4.5 Operating Techniques

The truck drivers must be made part of the construction team from the beginning. The trucking supervisor or representatives of the trucking subcontractor should be invited to key meetings to help coordinate hauling activities and foster a team spirit. Truck drivers should be adequately trained to understand their function and purpose in the paving team. A good refresher is the NAPA Truck Driving Techniques Manual available from NAPA.

4.5.1 Safety Considerations

Safety is paramount. Haul trucks are constantly entering and leaving the jobsite and must operate safely and obey the law. Adequate traffic control devices, and flaggers if needed, must be present to allow safe passage for the haul trucks.

4.5.2 Pre-loading Inspection of Bed

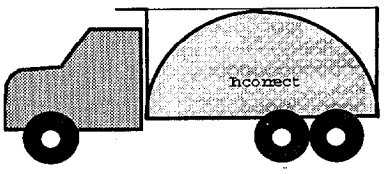
The bed of the haul truck, whether an end dump, bottom dump, or live bottom truck, should be free of all deleterious materials before mix is placed in it. The bed should be reasonably smooth and free from any major indentations or depressions where the truck bed release agent and the HMA can accumulate.

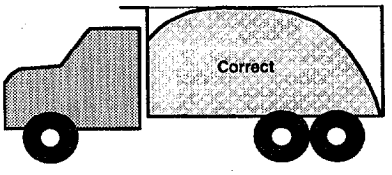
4.5.3 Release Agents

Once the bed is clean, it should be coated with a release agent. Nonpetroleum-based materials, such as lime water or one of a variety of commercial products, should be sprayed uniformly over the sides and bottom of the truck bed and should be used in the minimum quantity necessary to cover the surface area of the bed without runoff. Diesel fuel should not be used as a lubricant for the truck bed. Diesel fuel can cause changes in the properties of the asphalt mix material with which it comes in contact. Diesel fuel can contribute to environmental problems as it evaporates or if it soaks into the ground.

4.5.4 Axle Weights vs. Load Distribution

Most haul trucks need to be loaded with the load slightly forward in the truck bed to comply with axle weights and load distribution regulations.





4.5.5 Loading Sequence

One objective of the truck-loading operation is to get the vehicle filled with mix and on its way to the paver as quickly as possible. This objective must be balanced, however, with the need to minimize segregation of the mix that occurs during the loading process.

Some mixes are more prone to segregation than others and special care must be taken to ensure the mix load is as uniform as possible. Some mixes are not prone to segregation and conventional load out procedures work fine. There is no one correct way to load a truck. The method will depend on the mix type, truck type, and a host of other factors. Use the method that will minimize the potential for segregation to occur during the loading. This loading plan should be discussed and agreed upon at the pre-construction conference. The following scenarios assume the mix being loaded has a tendency to segregate and multiple drops are needed.

4.5.5.1 From Pugmill

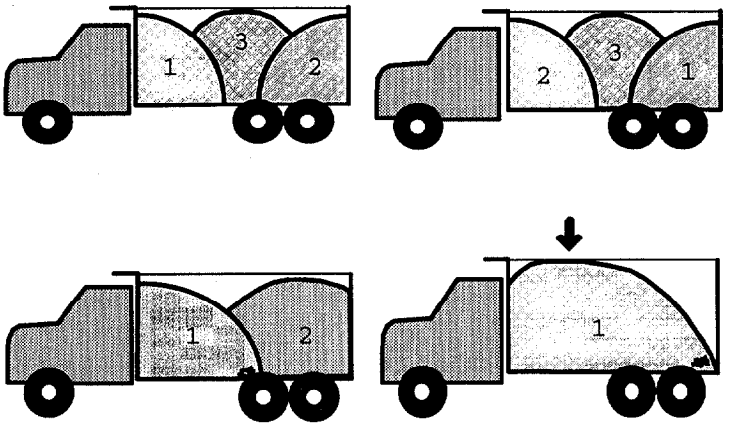
If it takes three batches of mix to reach the capacity of the haul truck, one pugmill batch should be loaded into the front of the truck bed. The truck should then be moved forward and the second batch of mix should be discharged into the rear of the truck, just in front of the tailgate. The third batch of material should be delivered into the center of the bed.

4.5.5.2 From Silo

Segregation of the mix can occur when mix discharged from the surge silo is deposited into the haul truck in a single drop. This segregation problem can be minimized by loading the truck in multiple drops of mix from the silo, similar to the procedure used for loading from the batch plant pugmill. The number of drops used depends on the length and capacity of the truck.

4.5.5.3 Example for End Dump Types

For other numbers of batches, multiple drops of mix should also be used, with the first batch delivered to the front of the truck bed, the second batch deposited at the tailgate end of the bed, and the remaining drops of mix placed evenly in between the first two. Such a loading sequence will minimize the distance the coarse aggregate particles can roll and thus minimize the amount of segregation that is produced in the mix.

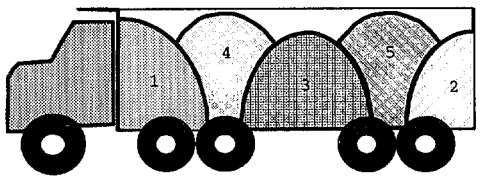


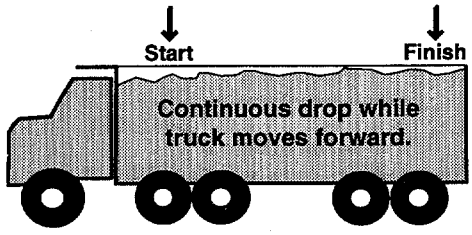
Not recommended for segregation prone mixes.

Some states have reversed this order. The first drop is placed at the tail gate, the second placed at the front, and the third placed in the middle.

4.5.5.4 Example for Semi-Trailer Types

When a semitractor trailer truck is to be loaded, at least five and probably seven different discharges of mix should be made before the truck capacity is reached. In every case, the mix should first be deposited at the front of the bed and then at the tailgate of the truck. The space in between the first two drops should be filled in with small, separate piles of mix placed between the initial "batches" of mix. The use of multiple drops of mix is slower than loading the truck in a single discharge of material from the silo.





4.5.6 Topping Off

There is a tendency for the plant operator to fill the truck to its legal capacity to reduce haul costs, particularly if the truck is sitting on a scale under the silo. Although this is good economic practice, it should not be accomplished by dribbling mix into the truck from the silo after the majority of the mix is already in the truck. The discharge of small amounts of mix from the silo greatly increases the chance for segregation of the mix.

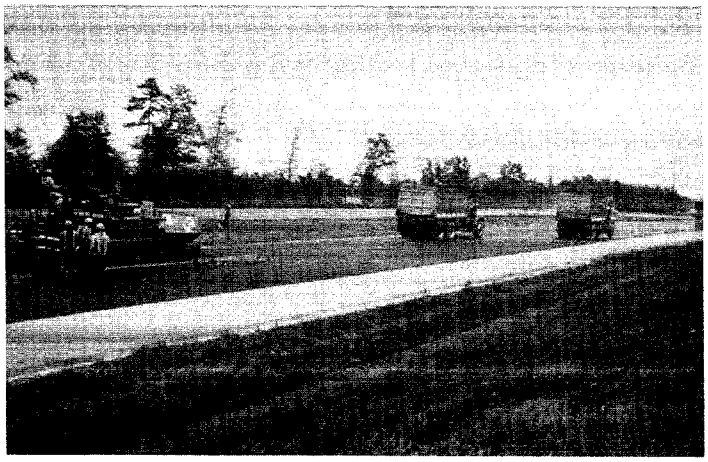
4.5.7 Overloading

Overloading is not recommended as it is illegal, dangerous, and can cause extreme stresses in pavements. Modern electronic weight out equipment and printed tickets have help to eliminate this.

4.5.8 Hauling to Jobsite

Once loaded, ticketed, and tarped if necessary, the haul truck should proceed immediately to the jobsite. The practice of trucks traveling in convoys should be discouraged.

4.5.9 Waiting On Site



Haul trucks should park in designated areas and attempt to minimize tracking of tack coats. Trucks should stay far enough ahead of the paving train as to not interfere with operations, but close enough to back to the paver to keep the operation moving. Communication is again the key. Drivers should be informed about the paving plan.

4.5.10 Backing

When an end dump or a live bottom truck is used to deliver mix to the paver, the truck driver should back the truck up to the laydown machine but stop just short of the push rollers on the front of the paver. It is very important that the truck be centered before the paver contacts it. Off-center positioning can push the paver out of alignment, create problems as the mix floods the hopper, and cause the truck bed to contact and damage the hopper wings. In addition, project personnel tend to tune out back-up alarms and are vulnerable while walking in the driver's blind spot. This is the area between the tailgate and the paver hopper. Too many accidents occur in this area.

Have you ever had a close call?

4.5.11 Truck Hitches/Contact/Configuration

Once the truck has come to a halt and the driver has released the brakes on the vehicle, the paver operator should start the machine moving forward, picking up the stopped truck. The key to this process is that the paver picks up the truck instead of the truck backing into and bumping the paver. Use of the proper procedure will reduce the incidence of screed marks and roughness in the mat.

4.5.12 Dumping

Prior to dumping into the hopper, the ticket must be examined to ensure the truck contains the right mix for the job. Several mixes may be in use at a jobsite at once, and it is important that the right mix go where it was intended.

Stop and check the ticket before the tail gate release gets pulled!

4.5.12.1 Into Hopper

4.5.12.1.1 Raising Bed

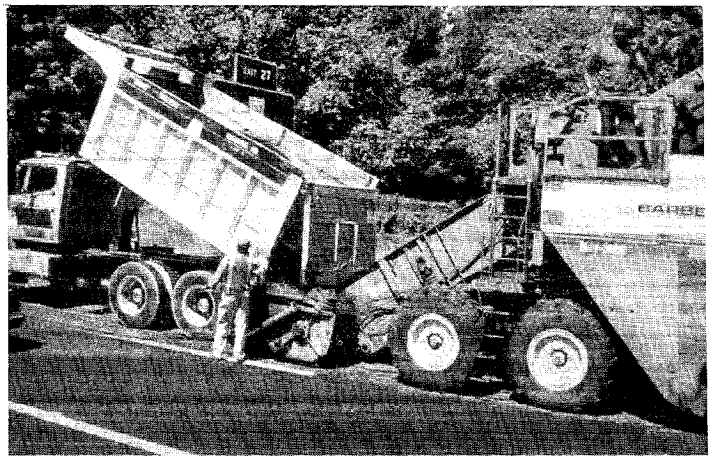
If an end dump truck is used and the mix has a tendency to segregate, the bed of the truck should be raised a short distance in order to allow the mix in the bed to slide against the tailgate before the tailgate is opened.

4.5.12.1.2 Popping Gate and Flooding Hopper

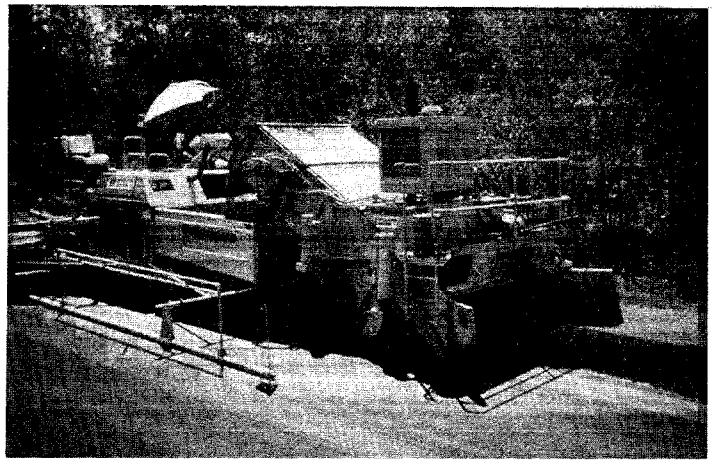
Once the tailgate is opened, the mix is discharged from the truck in a mass and floods the hopper of the paver, reducing the possibility of segregation behind the paver screed. The same procedure should be employed, if possible, when a live bottom truck is used to transport the mix.

4.5.12.2 Into a Material Transfer Vehicle (MTV)

This piece of equipment is basically a surge bin on wheels. Asphalt mix is deposited into the hopper on the front of the vehicle. The mix is transported from the hopper to a conveyor, which delivers the mix to the extended hopper on the paver. The material transfer vehicle also allows the paver to be operated almost continuously if a continuous supply of mix is available from the asphalt plant. This provides for a smoother mat behind the paver screed by permitting the paver operator to keep the head of material in front of the screed constant. The equipment also eliminates the problem of the haul trucks bumping the paver and truck drivers holding the brakes on the truck when being pushed by the paver. Because of the weight of this piece of equipment when it is full of mix, it must be determined ahead of time that the pavement over which this machinery will be running can support the weight of the device without being over stressed and damaged.



4.5.12.3 Into a Windrow



The windrow can be formed in one of two ways. A spreader box (windrow sizer) can be employed. The mix is deposited into the box and is uniformly metered out onto the roadway as the truck moves forward. This procedure provides the most accurate means of keeping a constant supply of mix in front of the paver.

The second, and more common, method is to control the amount of mix discharged by the width of the gate opening under the truck and the speed of the truck. Manual control of the discharge requires constant attention of the "dump person" to assure that neither too little mix nor too much is being fed into the paver hopper. For both of these methods, the amount of mix delivered is dependent on the width and the thickness of the layer being placed. Thus, a different gate opening in the windrow sizer or the truck bed is needed for each set of project conditions and truck speed.

If a windrow elevator is used to gather mix from a windrow on the roadway and deliver the mix to the paver hopper, the slat conveyor should pick up all of the mix that is in the windrow without leaving any mix on the existing surface.

The windrow should be sized so that the hopper on the paver is from 25 percent to 75 percent full. The paver hopper should contain enough mix so that the slat conveyors are not visible on the bottom of the hopper, and the hopper should not be so full that mix runs out the front of the hopper.

4.5.12.4 Dealing With Crusted Mix

There is no set limit as to how far a load of HMA can be transported. The key factors are the workability of the mix while it is passing through the paver and the ability to get the mix compacted. Both of these factors are highly dependent on the temperature of the mix.

The slight crust thickness that does form during transport should be able to be broken up completely as the mix is discharged from the haul vehicle into the paver, is carried by the slat conveyors back to the augers, and is passed under the paver screed. As long as chunks of asphalt mix do not affect the quality of the mat behind the paver, the crust that forms on top of the mix during delivery will not be detrimental to the long-term performance of the mix.

4.5.13 Paving

4.5.13.1 Steering

While paving, the driver must focus not only on the dump person but in front of the truck also. The driver is responsible for steering within the "pull" of the paver, and keeping a slight pressure on the brakes to maintain contact with the paver and rollers.

4.5.13.2 Braking

Too much braking force from the haul truck may cause the paver to slip and affect the mat.

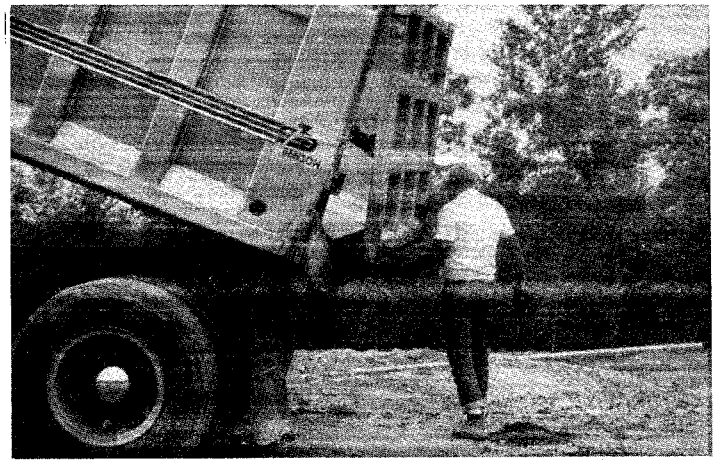
?

Ever have to shovel two tons of HMA out from the front of the paver because the driver didn't keep his foot on the brake?

4.5.14 Pulling Away

Once the final hot mix has exited the truck bed, the bed should be lowered so the apron can clear the hopper guards. The truck should immediately depart from the area to a clean up station, and let the next truck back up.

4.5.15 On Site Clean Up



The contractor should designate a clean up area for the drivers to clean the remaining mix from their trucks, the tail gate, and the apron.

4.5.15.1 "Banging the Gate"

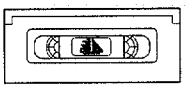
A common practice to leave the truck bed up, speed up and stop quickly to bang the tail gate to expel any remaining mix should be discouraged.

4.5.15.2 Spillage on Pavement

"Banging the gate" and some other practices tend to drop small piles of mix on the roadway which are subsequently rolled over by other trucks. If these piles are not removed, they can affect the quality of the finished mat. If a spill occurs, the mix should be removed.

4.5.16 Back Haul to Facility

Once the truck has completed the on-site clean up, it should immediately return to the facility for the next load. The truck drivers should not delay departure or else the entire operation will be affected.



4.6 Summary

A good summary of HMA delivery techniques is found on page 3-9 of the HPH and is repeated in the handout entitled "Tips for Best Practice."

4.7 Review Video Tape

4.8 Review Objectives

Can you...

1. State the objective of HMA delivery?
2. List the four different production rates that need to be coordinated prior to paving?
3. Identify the types and capacities of haul vehicles used in your area?
4. List advantages and disadvantages of each type of vehicle?
5. Identify proper loading of haul vehicles?
6. Describe proper haul vehicle operating techniques?
7. List important areas of vehicle maintenance?

4.9 Evaluation

Please complete the Unit 4 evaluation at this time. Thank you.

5

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UNIT 5 HMA Placement (4 hours)

5.1 Introduction

5.1.1 Review Objectives of Unit

What's-in-it-for-me? When the construction team understands what they have to work with, and what the equipment can and can't do, it will definitely make the project run easier, and produce a better pavement.

Placing hot mix can best be described as a balancing act. Many forces and variables must be balanced together to produce a mat that is uniform, dense, and smooth. The screed's operation is very simple in theory and, therefore, should be fairly simple in practice. However, a lack of understanding of the forces on the screed complicate the scene. Difficulties arise in trying to continually adjust a system that is continually trying to balance itself out.

One of the best examples of this battle of the forces is an attempt to meet specifications of yield, thickness, and smoothness when placing a thin lift over an uneven surface.

Proper operation of the paver involves more than just the mechanics of how the machine works. It also has to do with how the machine is used, what the dimensions of the final mat are, and how efficient the process is. It is in the contractors' and the agencies' best interests to pave as wide as possible (given the circumstances) for several reasons: wider paving means fewer pulls with the paver, fewer lane closures, and fewer longitudinal joints.

However, each paving project is slightly different. Each requires a slightly different paving plan to optimize the efforts expended. Paving equipment is designed for flexibility in paving width and application, and if used and maintained properly, does a very fine job.

The operation of the paver requires careful attention to detail to ensure that the quality of the final mat meets or exceeds the specifications. There is a Standard Operating Procedure for starting up paving operations regardless of the type of paving being scheduled. In addition to a start up plan, there are specific practices that, if followed, will ensure the highest probability of success for the paving process. The objective is to place the highest quality pavement at the lowest cost per ton.

OVERVIEW: During this unit, we will look specifically at the components of the tractor unit and the screed unit, how they function, and how they work together. Next, we will look specifically at the forces that affect the operation of the screed unit. We will look at how the screed can be adjusted either manually or automatically, and when to use either method. Next, we will look at the different types of paving available to accommodate a wide variety of paving demands. In addition, we will look at the importance of maintaining the paver. Finally, we will look specifically at the operation of the paving machine from start up to concluding operations.

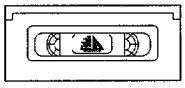
KEYWORDS: Tractor, Screed, Hopper, Conveyor, Conveyor Flow Gates, Augers, Screed Plate, Crown, Screed Arm, Screed Extensions, Head of Material, Angle of Attack, Yield, Thickness, Smoothness, Grade Control, Slope Control.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of HMA placement;
2. Identify main components and functions of the tractor unit;
3. Identify main components and functions of the screed unit.
4. Describe how the screed works;
5. List the major forces acting on the screed;
6. Identify types and functions of grade and slope control systems;
7. List the capabilities of the grade and slope control systems;
8. Recognize the relationship between yield, thickness, and smoothness.
9. List paving types and when to use them;
10. Layout a paving job to keep the longitudinal joints out of the wheel paths;
11. Describe the factors involved in night paving;
12. Identify important areas of paver maintenance.
13. Describe how to properly place HMA (include transportation, start up, beginning paving, during paving, and concluding paving operations).

METHODS: We will use a combination of video, slides, and lecture to emphasize the main points of this unit. In addition, a problem session will consist of a scheduling problem.

EVALUATION: You will complete an evaluation of this unit.



5.2 Video

5.2.1 Introduction

The following video tape is several minutes long and stresses the importance of proper paving when constructing HMA pavements. The objectives of using this video tape are: to relate the live action of your work environment into a classroom, show the real process of placing HMA, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.

5.2.2 View Video Tape

5.2.3 Questions on Video

?

Did you see anything being done differently than you do?
How do your paving procedures differ from what you saw here?

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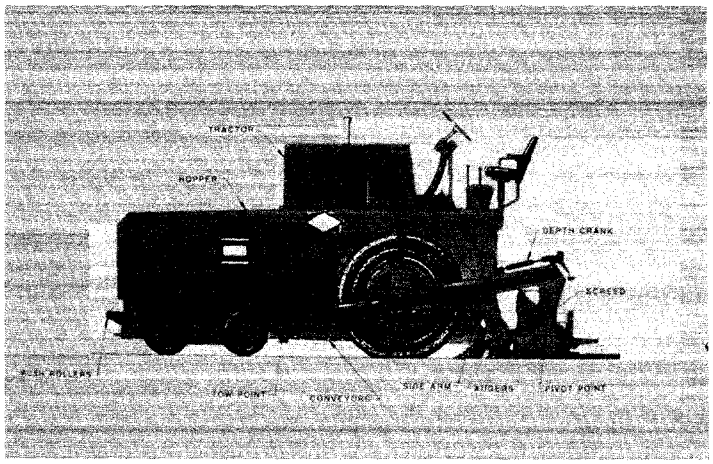
5.3 Tractor Unit (Review of Equipment and Function)

The purpose of the paver is to place the hot-mix asphalt to the desired width and thickness and to produce a satisfactory mat texture. The paver consists of two primary parts: the tractor unit and the screed unit. The tractor unit provides the motive power to the paver and transfers the asphalt mixture from the receiving hopper on the front of the machine to the spreading screws at the back of the paver.

The tractor unit fulfills all of the functions necessary to receive the asphalt mix from the haul trucks, carry that material back to the spreading screws, and distribute the mix across the width of the screed. It is composed of several major components including the truck push rollers, mix-receiving hopper, material flow gates, twin slat conveyors, and a pair of screw conveyors or augers.

5.3.1 Drive System



5.3.1.1 Purpose

The tractor unit is powered by its own engine and provides the required propulsion energy to move the machine forward, either on rubber tires or crawler tracks.

5.3.1.2 Rubber Tire

If the paver is moved regularly under its own power between paving locations, the rubber tire machine is normally used because its travel speed is much greater than that of the crawler track paver.

5.3.1.2.1 Tire Size Versus Inflation Pressure

Different sizes and types of tires are used on rubber tired pavers. Inflation pressures vary between 35 psi to 85 psi (241 kPa to 586 kPa).

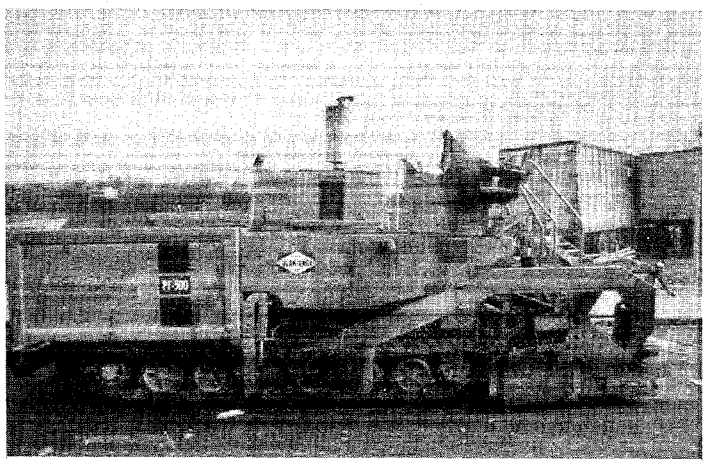
5.3.1.2.2 Tire Size Versus Ballast Load

Rubber tires are ballasted with a calcium chloride solution to reduce bounce in the paver. Amounts vary upon tire size and range from 466 gallons to 1000 gallons per tire (1764 litres to 3785 litres).

5.3.1.2.3 Front Wheel Assist

Many paver manufactures offer front wheel assist as an option on new pavers. This unit consists of a planetary drive motor mounted on the rear set of steering or bogie wheels. Depending on the size of the paver and manufacturer, the drives can increase the tractive power of the paver by 50 percent.

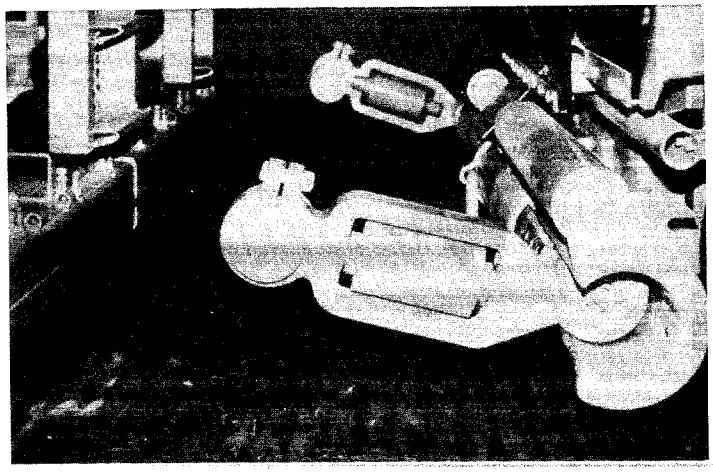
5.3.1.3 Track



The crawler tracks could be all steel, steel equipped with rubber pads, or flexible bands with steel shoes and rubber pads. If the paver is used on top of a yielding surface,

the crawler track system will provide an increased area over which to spread and support the weight of the paver.

5.3.2 Push Rollers and Truck Hitches



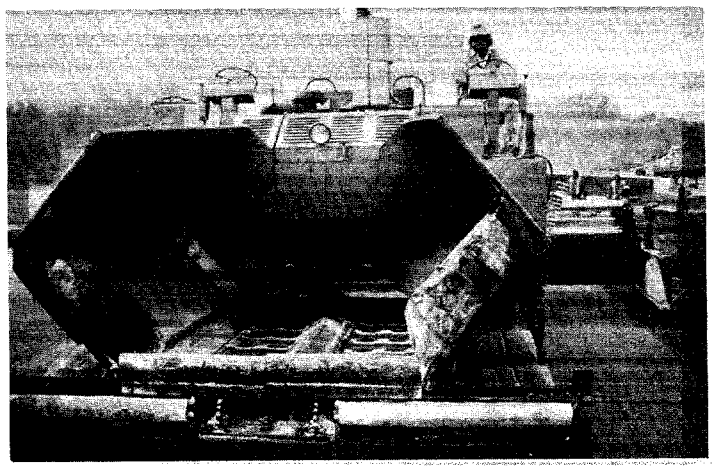
The push rollers, located on the front of the paver hopper, are used to maintain contact with the tires of the haul truck and to push that truck ahead of the paver. The rollers must be clean and free to rotate to allow smooth forward travel of the paver. If the push rollers are not cleaned periodically and do not rotate freely, the truck tires will slide on the rollers and increase the load on the paver. The purpose of the hitch is to keep the truck in contact with the paver and prevent the truck driver from pulling away from the paver and inadvertently dumping mix on the pavement in front of the paver. The hitch, controlled by the paver operator, comes in contact with the rear wheels of the truck on each side of the truck.

5.3.3 Hopper

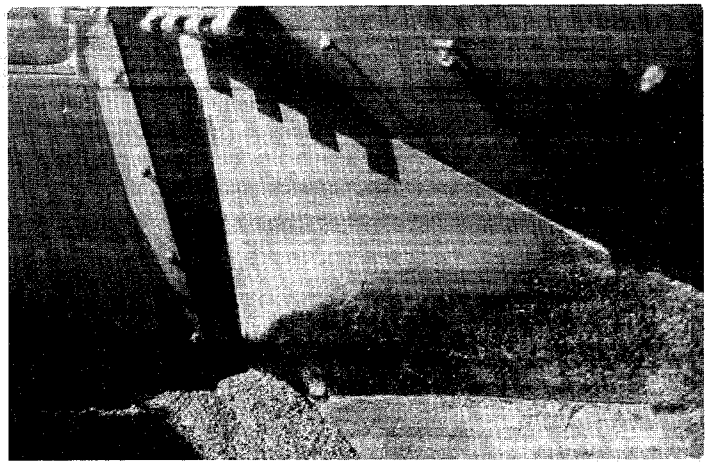
5.3.3.1 Purpose

The paver hopper is used to receive and temporarily hold the asphalt mix from the haul vehicle or the pickup machine.

5.3.3.2 Shape, Capacity, Wings

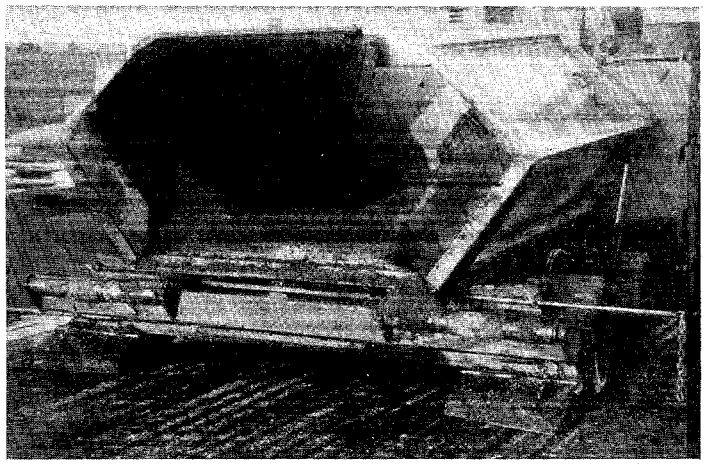


The hopper must be wide enough to allow the body of the haul truck to fit inside of it. In addition, particularly for smaller pavers, the hopper must be low enough to permit the truck bed to be raised without the bed placing excessive weight on the front of the hopper.



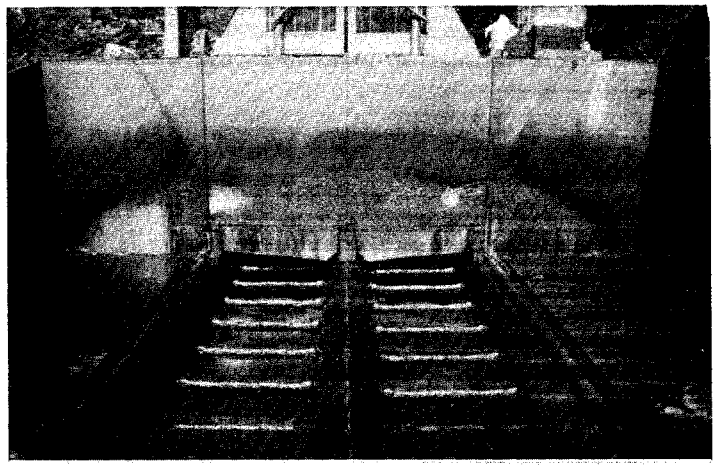
Some contractors weld a diagonal wedge into the back corners of the hoppers to redirect the mix into the center of the hopper.

5.3.3.3 Flexible Guards (overflow guards, hopper flashing)



The front of the hopper must be designed in a way to minimize the spillage of mix out of the hopper during the dumping of the hopper wings. This is normally accomplished by using rubber belts or flaps attached to the wings.

5.3.4 Conveyor (slat conveyor)



At the bottom of the paver hopper is a set of slat conveyors. These devices are used to carry the asphalt mix from the hopper through the tunnel on the paver and back to the spreading screws. The slat conveyor on one side of the paver operates independently from the movement of the slat conveyor on the other side of the machine. This allows the paver operator to feed more or less material to one side of the paver or the other in order to pave ramps, mail box turnouts, and tapers.

5.3.5 Conveyor Flow Gates (hopper gates)

At the back of the paver hopper is a set of flow gates. These gates, one over each of the two slat conveyors, are used to regulate the amount of mix that can be delivered by the conveyors to the augers. The gates move vertically, either by manual manipulation or mechanically. The flow gates should be adjusted to provide a uniform head of material (at a level at or just above the center of the auger shaft) in front of the screed.

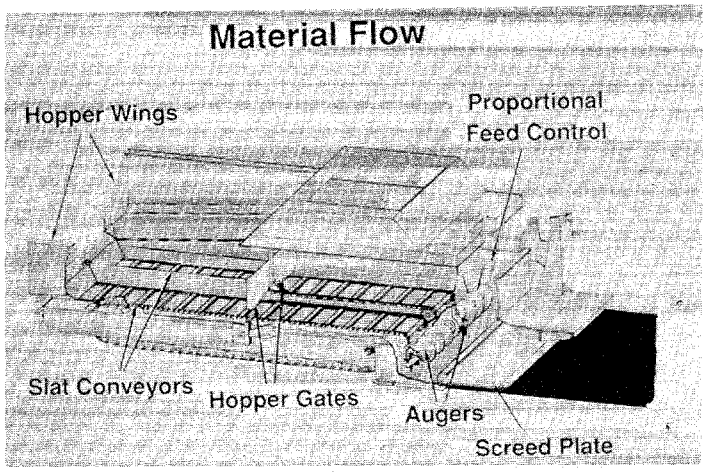
5.3.6 Augers

The amount of mix carried in the auger chamber should be as constant as possible. The proper depth of material on the augers should be at the center of the auger shaft. The level of material carried in front of the screed should not be so little as to expose the lower half of the screw conveyor flights. Further, the level of mix delivered to the screed should never be so great as to cover the upper portion of the auger, as shown in this same figure.

5.3.6.1 Purpose

The mix that is carried to the back of the tractor unit by the slat conveyors is deposited in front of the screw conveyors or augers. Just as the two slat conveyors operate independently of each other, the augers on each side of the paver are run separately from one another. The mix placed in the auger chamber from the slat conveyors is distributed across the width of the paver screed by the movement of the augers. At the junction of the two augers in the center of the paver, adjacent to the auger gear box, there typically is a different-shaped auger (reverse auger or paddle) to tuck mix under the gear box and assure that the mix placement at this location is the same as that across the rest of the width of the mix being laid. It is important that the augers carry a consistent amount of mix across the front of the screed so that the pressure (head of material) on the screed is kept as constant as possible.

5.3.7 Material Feed System



If the feed system is set and operating properly, the slat conveyor and augers on each side of the paver will rarely shut off. This continuous action of the conveyors and augers is accomplished by setting the proper position for the hopper flow gates and determining the correct speed setting for the slat and screw conveyors. ***The primary key to the placement of a smooth pavement layer is the***

use of the material feed system to keep the head (level) of material in front of the screed constant, primarily by keeping the slat conveyor and augers running as close to 100 percent of the time as possible.

5.3.7.1 Manual Control - Constant Speed

On older pavers, in the manual mode, the slat conveyor and the auger speed are constant. The paver operator can only control the amount of mix being carried back to the screed by adjusting the height of the flow gates. If the gates are set too high, the material feed system will provide a "slug" of asphalt mix to the augers whenever the slat conveyors and the augers are operated. If the gates are set too low, the material feed system will not be able to deliver enough material to the augers, thus reducing the head of mix in front of the screed and the force pushing on the screed. The flow gates and feeder on-off switches must be set at a position that requires the slat conveyors and augers on each side of the machine to run as close to 100 percent of the time as possible.

5.3.7.2 Manual Control - Variable Speed

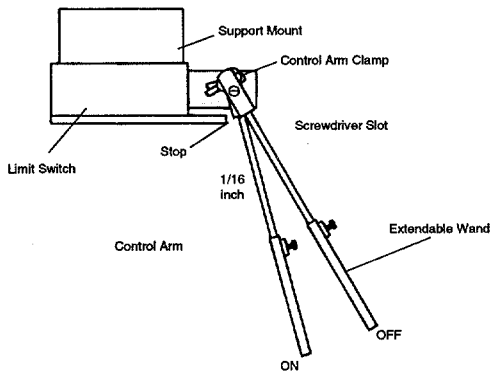
Some pavers are designed so that in the manual mode the paver operator can select one of several speeds for the slat conveyor, each essentially a percentage of the maximum speed of the conveyor. Once the conveyor speed is selected, the speed of the auger is proportioned to the speed of the slat conveyor. The operator is responsible for controlling the slat conveyor and augers in order to keep a constant level of asphalt mix in front of the paver screed. The flow of material to the screed essentially is regulated by the height of the hopper flow gates and by the starting and stopping of the slat conveyor and auger on each side of the paver.

5.3.7.3 Automatic Control

5.3.7.3.1 Sensor Types and Location

For the automatic feed control system to function properly, the feed sensor control arm should be located as close to the outside end of the augers as possible. If rigid paver screed extensions are used, as discussed later, the control arm should be mounted beyond the end of the augers, just inside the end gate on the paver screed.

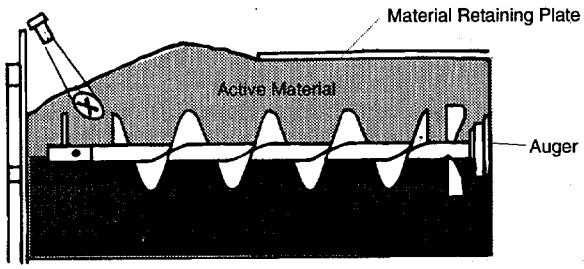
5.3.7.3.1.1 Material Feed Sensor

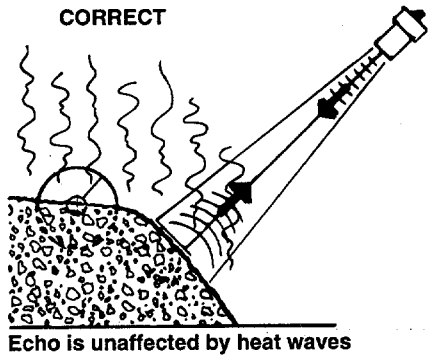


For this system, a feed control sensor (a type of limit switch) is used to determine the amount of mix in the auger chamber. If the volume of mix available in front of the screed falls below the desired amount, the feed control sensor will move enough to engage the slat conveyor and auger system, pulling more mix back to the screed area. As the material is distributed in front of the screed, the feed control sensor will rise and disengage

the feed system. This action will maintain the preselected head of material in front of the screed. This sequence repeats itself, continuously maintaining a consistent head of mix as long as material is available in the hopper. On some pavers, a variable-speed (potentiometer-type) feed system is used to control the amount of material in front of the screed. Instead of an on-off system, the speed of the delivery system is increased when more mix is needed and the speed of the slat conveyor and auger system (on each side of the paver) is decreased when the head of material in front of the screed is too great.

5.3.7.3.1.2 Ultrasonic

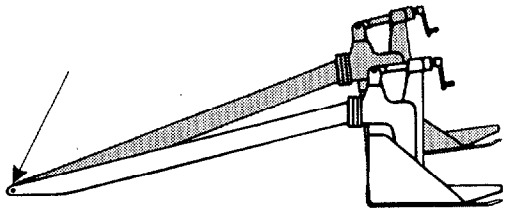




Echo is unaffected by heat waves

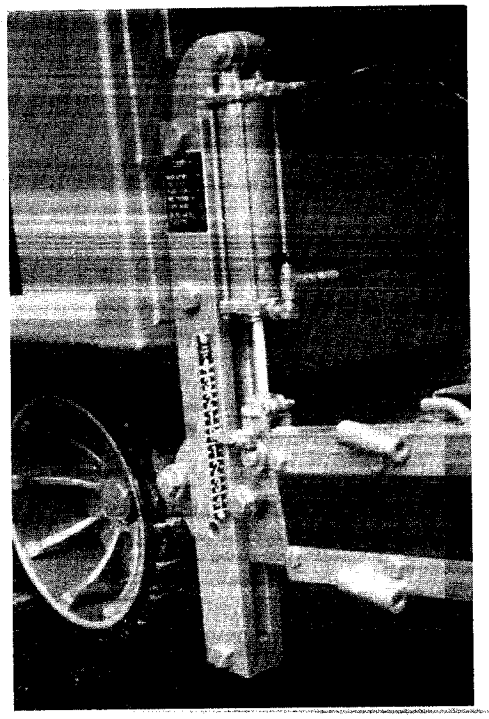
In addition to these limit switch-type and variable-speed systems, both ultrasound and infrared sensing devices can be used to determine the amount of mix in the auger chamber. These two types of systems operate on the same basis as the limit switch system; measuring the amount of mix in front of the screed and controlling the slat conveyor and auger feed system to maintain a constant head of mix at the screed.

5.3.8 Tow Points



The screed unit is attached to the tractor unit at only one point on each side of the paver. This point is called the tow point or the pull point by the different paver manufacturers. The tow point is really a pin-type connection that allows the leveling arms (also called side arms or pull arms) of the screed to rotate or pivot around that point. This pin connection reduces the transmission of movement between the tractor unit and the screed unit.

5.3.8.1 Cylinders



The cylinders that drive the tow points are normal hydraulically adjustable cylinders. They can be adjusted manually or automatically with a grade and slope control systems. The pin connection is usually centered in the middle of the cylinders when paving begins, but may be set differently depending on the paving type and conditions.

5.3.9 Maintenance

If the paver stops, the whole operation comes to a grinding halt. Routine maintenance plays a big part in the success of the final pavement. Worn or loose parts will affect the quality of the mat. Maintenance records of the paver may be helpful when troubleshooting paver related mat problems.

5.3.9.1 "Washing Down" and Use of Solvents

Pavers must be clean to operate properly. HMA will stick to metal surfaces when cold and is difficult to remove. Therefore, it is best practice to clean pavers while the machine is still warm and the HMA can be removed. Kerosene is normally used to remove excess mix. However, the excess can

drip off the paver posing a potential hazard. The minimum amount should be used to get the job done. Any excess fluids spilled on the ground should be removed and disposed of properly.

5.3.9.2 "Wear Check" Procedures

Most paver manufactures can supply "wear check" manuals on various components of the paver that will wear during use. Sprockets, chains, plate steel, augers, and other components subject to wear should be checked per the manufacturers recommendations. Worn parts can affect the ability of the paver to place a quality mat, and can break suddenly. The best defense against these potential problems is a good program of preventative maintenance.

5.3.9.3 Storage of Electronic Equipment

Electronic "boxes" for grade and slope control need to be properly stored to prevent accidental damage. Spare parts are a good idea when the job requires close tolerances not able to be achieved running manually.

5.3.9.4 Checklists

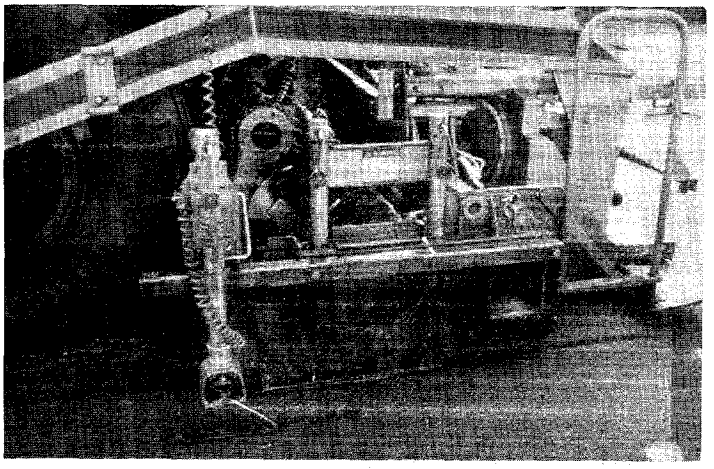
A checklist for paver maintenance can be found in the Appendix (Form 5-1).

HPH 3-25 | 3-37

5.4 Screed Unit (Review of Equipment and Function)

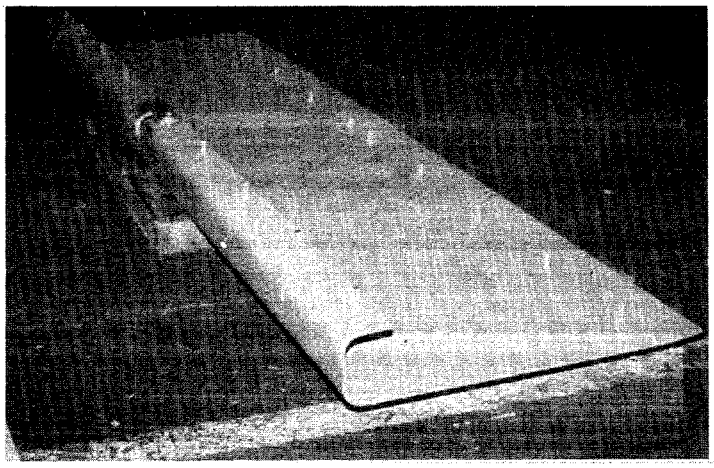
The second unit consists of the paver screed. This leveling device is attached to the tractor unit at only one point on each side of the paver and is able to "float" on the asphalt mix and provide initial texture and compaction to that material as it passes out from under the screed.

5.4.1 Purpose



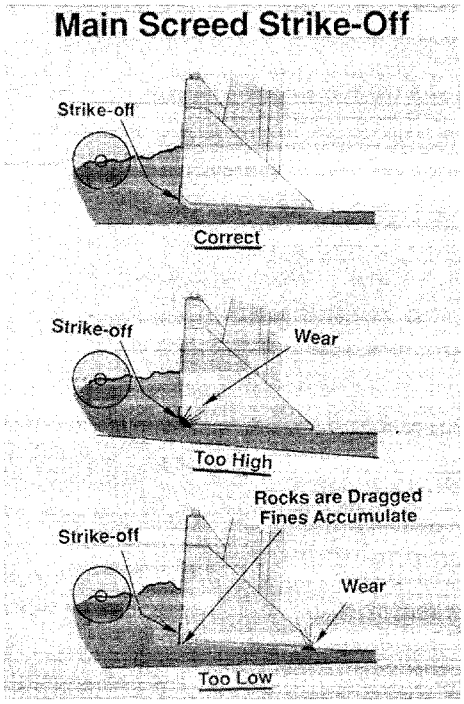
The screed unit, which is towed by the tractor unit, establishes the thickness of the asphalt layer and provides the initial texture to the new surface. In addition, the screed imparts some level of density to the material being placed through the vibratory or combination tamping and vibratory action of the screed. The principle of the free-floating paver screed was developed in the early 1930s. That concept allows the paver screed, which is attached to the tractor unit at only one point on each side of the machine (the tow or pull point), to average out changes in grade that are experienced by the wheelbase (rubber tires or crawler tracks) of the tractor unit. The floating-screed principle is employed on all of the modern asphalt pavers in use today.

5.4.2 Screed Plate



The screed plate is a formed piece of steel that bolts to the bottom of the screed. The screed plate is the only portion of the screed that develops the initial texture of the mat and can be adjusted. The center of the leading edge of a rigid screed has grooves cut into it to allow the screed to be flexed or warped.

5.4.3 Strike Off (Pre-Strike Off)

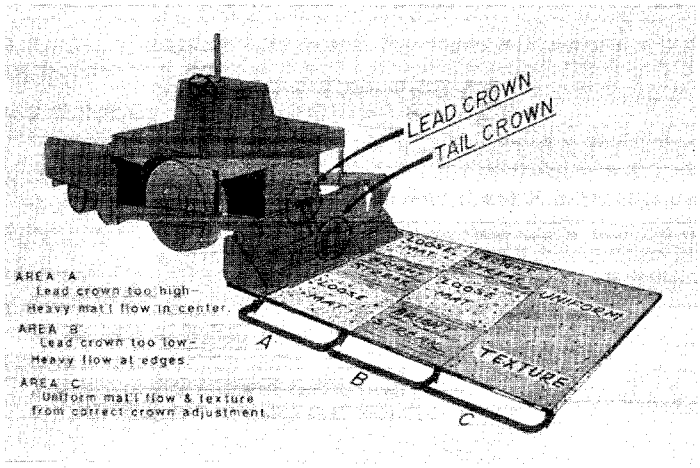


The screed may be equipped with a device on its front edge that is called a strike-off by some manufacturers and a prestrike-off by others. The purpose of this device is to control the feed of the asphalt mix under the paver screed, thereby regulating the amount of mix that reaches the nose of the screed plate. Further, the strike-off or prestrike-off is used to reduce the wear on the leading edge of the screed.

When the strike-off is attached to the front of the screed, its position becomes important relative to the ability of the screed to handle the asphalt mix properly. If the strike-off is set too high, extra material will be fed under the screed. This action will cause the screed to rise. The resulting increase in the mat thickness will be overcome by manually reducing the angle of attack of the screed, using the thickness-control cranks. This, in turn, will cause the screed to pivot around its hinge point and ride on its nose. Rapid wear of the nose plate will result. In addition, the screed will settle when the paver is stopped between truckloads of mix because the weight of the screed is carried only on the front part of the screed.

When the strike-off is set too low, the thickness of the lift will be reduced because of the lack of mix being fed under the screed. In order to maintain the proper thickness, the angle of attack of the screed must be altered, causing the screed to ride on its tail. This increases the wear on the back of the screed and also causes the screed to settle whenever the paver is stopped because of the concentration of weight of the screed on a smaller surface area.

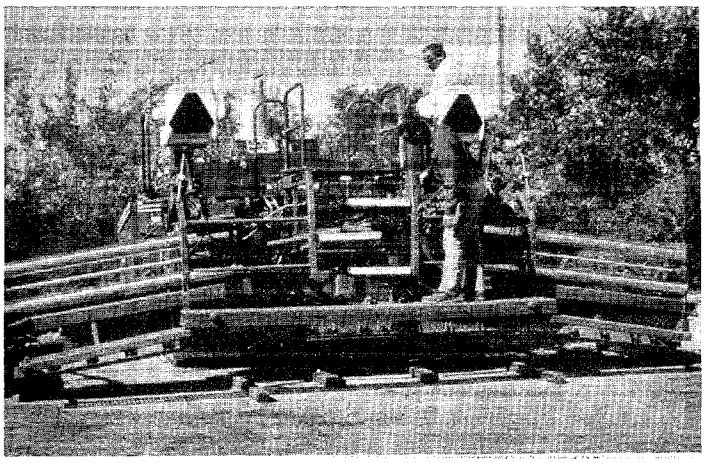
5.4.4 Crown Control



The screed on the paver can be angled at its center to provide for positive or negative crown. The amount of crown that can be introduced into the screed varies. The adjustment of the crown is typically done using a turnbuckle device to flex the bottom of the screed and impart the desired degree of crown. Normally the lead crown setting is 1/32 in. to 3/16 in. (0.8 to 5 mm) *greater than the tail crown position, with 1/8 in.* (3 mm) *being the average difference in the crown settings.*

5.4.5 Screed Extensions and End plates

5.4.5.1 Hydraulically extendable



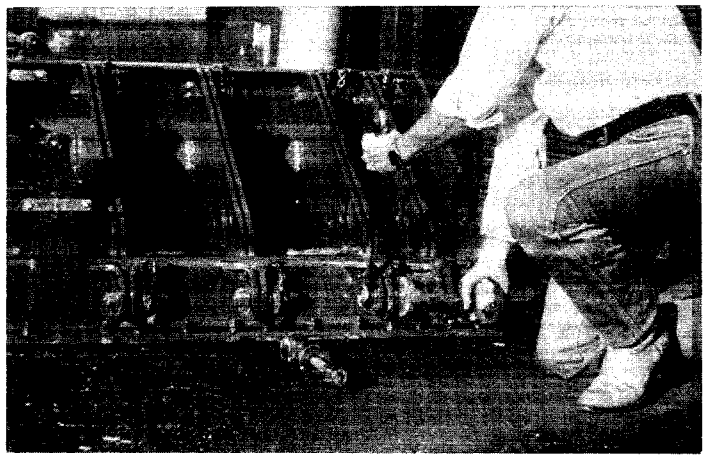
Most paver manufacturers have developed hydraulically extendable paver screeds that trail the primary or basic screed on the paver. One make of pavers, however, is equipped with a power extendable screed that places the extendable portion of the screed in front of the main screed.

For all hydraulically extendable screeds, it is very important that the angle of attack for the extendable screeds is the same as the basic screed.

If the extensions on the extendable portion of the screed are not properly aligned with the main screed, a longitudinal mark or ridge will occur in the surface of the mix at the junction between the two screeds. In addition to the longitudinal mark, a mismatch in the elevation between the two screeds can also result in a possible difference in surface texture in the mix. Finally, the lack of proper alignment between the two screeds can cause a difference in the degree of compaction that is obtained in the mix under the extendable screed.

In addition, proper placement of material feed sensor in the auger area is important to avoid segregation problems.

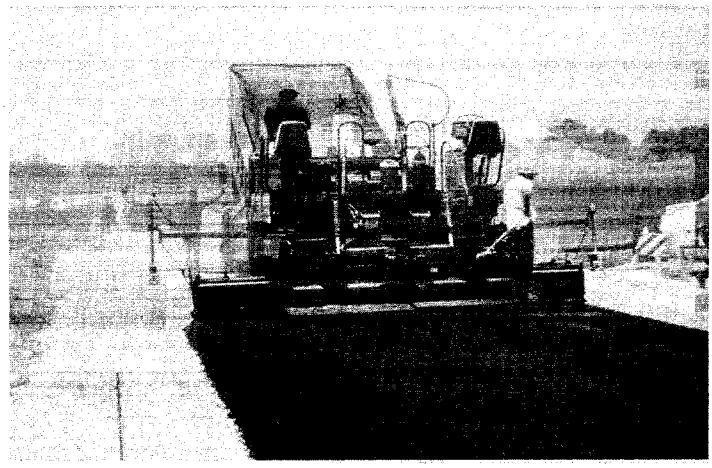
5.4.5.2 Rigid Screed extension



When the basic width of the paver screed (8 ft (2.4 m) *for small pavers and 10 ft* (3 m) *for the larger machines) needs to be changed to accommodate increased paving widths, rigid screed extensions can be employed. These extensions come in several widths, usually 6-in., 1-ft, 2-ft, 3-ft, and 5-ft sections* (.15, .3, .6, .9, and 1.5 m). *Further, it is very important that the extension be set at the same elevation and angle as the basic screed to prevent the presence of a transition line or ridge at the intersection of the main screed and the extension or between different sections of extension.*

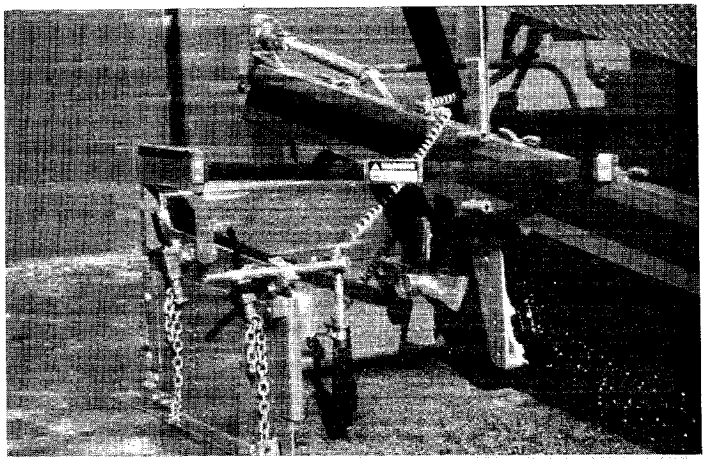
Whenever a rigid screed extension is employed on the basic paver screed, auger extensions and the accompanying auger tunnel extensions should also be added. The length of all the auger and tunnel extensions should, in general, be the same length as the added screed extensions to allow room between the end of the auger and the end plate of the screed. Typically the distance between the end of the auger extension and the end plate should be about 18 in (0.45 m).

5.4.5.3 Hydraulic Strike-Off



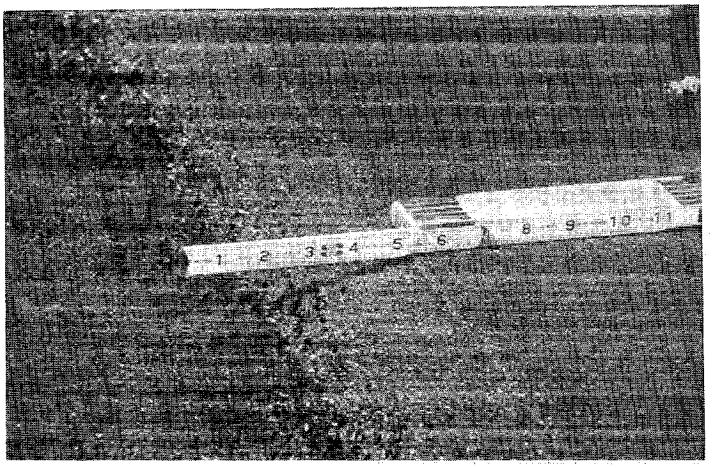
The hydraulic strike off is an option for most screeds and allows the screed to be extended for brief periods to form turns outs, ramps, etc. Either a strike-off or a mini screed (approx. 6 inches (0.15 m)) is available to impart initial texture and compaction to the mix that passes under it. However, this texture and compactive effort are normally different from that which develops under the screed. In addition, the mix will need to be left higher than the screed placed mix. The use of hydraulic strike-offs to place mainline paving instead of adding rigid extensions is not considered best practice.

5.4.5.4 End Plate (end gate)



An end plate (or end gate or edger plate) is attached to the end of the screed to restrict the outward movement of the mix around the end of the screed. In typical operating mode, however, the end plate is positioned tight to the surface being paved to retain the mix and control the width of material being placed.

5.4.5.5 Beveled or Shaped Guide Plates, Jointers

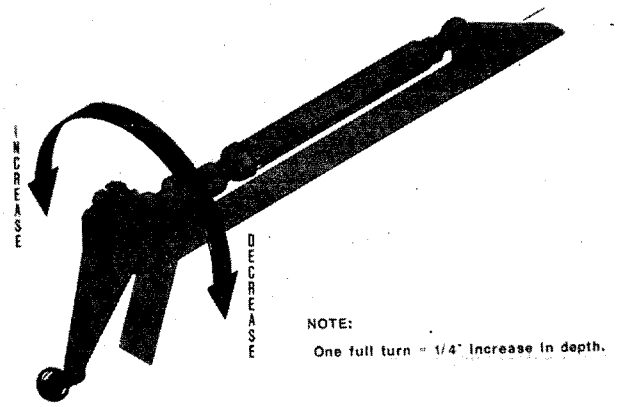


Some manufacturers offer different shaped or beveled edge plates to form longitudinal joints. The most common will leave a wedge shaped joint as shown here.

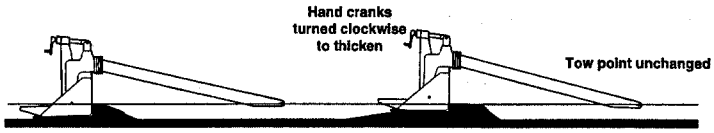
5.4.5.6 Cut-Off Shoes

Cut-off shoes can be used, if necessary, to reduce the width of mix placed to a width that is less than the basic main screed width. Typically the cutoff shoes come in widths of 1 ft or 2 ft (0.3 m or 0.6 m), *and are adjustable in increments of 1 1/2 in. or 3 in.* (38 mm or 75 mm), *depending on the manufacturer.*

5.4.6 Thickness Control Screws

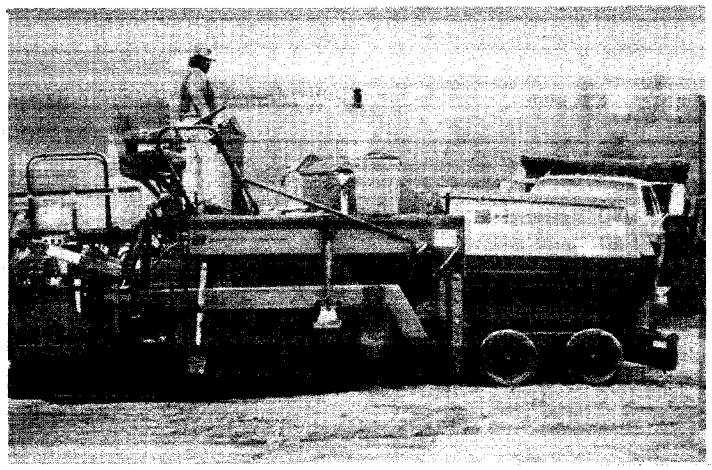


The thickness-control mechanism, usually either a crank or a handle, allows the screed to be moved or rotated around the pivot point. As the mix passes under the screed plate, the screed floats on the mix, determining the mat thickness and the texture of the material as well as providing the initial compaction of the asphalt mix.



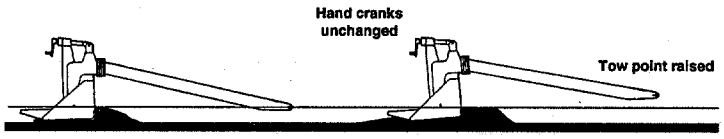
For a constant position of the tow point (the tractor unit running on a level surface and without automatic screed controls), altering the setting of the thickness-control devices changes the attitude (angle of attack) of the screed and changes the forces acting on the screed. This, in turn, causes the screed to move up to, or down to, a new elevation as the paver moves forward, and thus alters the thickness of the mat being placed. The reaction of the screed to changes in the position of the thickness-control settings, however, is not instantaneous.

5.4.7 Screed Arm (tow arm)



The screed is attached to the leveling or tow arms on each side of the paver through a hinge or pivot point.

The pivot point is located at the center of the wheelbase of the tractor. This allows the screed to use the tractor as a leveling device, much like a ski.



5.4.8 Pre-Compaction Systems

5.4.8.1 Vibrators

Early pavers were equipped with tamper bars that were located on the leading edge of the paver screed. These tamper bars were used to tuck the asphalt mix under the screed and to provide some degree of initial compaction to the mix as it passed under the screed. The tamper bar system was replaced by the more efficient vibratory screed system.

Two factors within the screed itself also contribute to the degree of compaction. The first is the frequency of vibration and the second is the amplitude of the compactive effort.

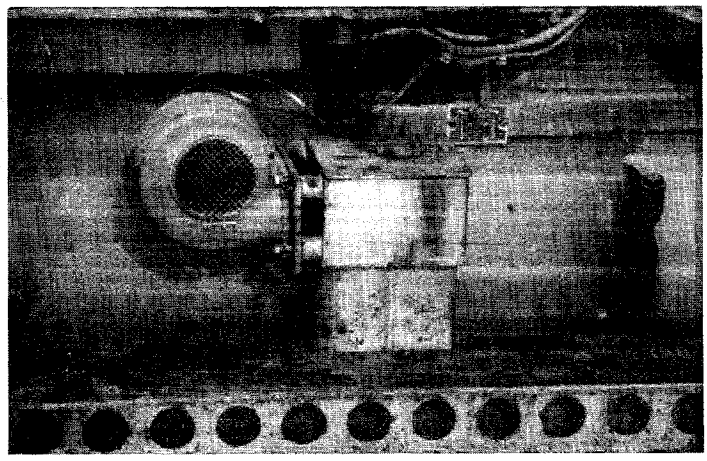
The frequency of vibration is controlled by the rotary speed of the vibrator shaft. Increasing the revolutions per minute of the shaft will increase the frequency of the vibration. The applied amplitude is determined by the location of the eccentric weights that are located on the shaft. The position of the eccentric weights can be altered to increase or decrease the amount of compactive effort applied to the mix by the screed. In general, the vibrators should be used near the maximum possible frequency. On screeds where it is possible to change the amplitude of the applied vibrational force, the amplitude setting selected is related to the thickness of the mat being placed; lower amplitude for thinner lifts and higher amplitude for thicker lifts.

The amount of density obtained by the paver screed is also a function of the speed of the paver. The faster the paver moves, the less time the screed sits over any particular point in the new mat, and, thus, the amount of compactive effort applied by the screed decreases. For asphalt concrete mixes, it can be expected that approximately 70 to 80 percent of the theoretical maximum density of the mix will be realized in the mix when it passes out from under the paver screed.

5.4.8.2 Other

A few of the most recent pavers (and many pavers used in other countries) are equipped with combination screeds—both tamper bars and a vibratory screed.

5.4.9 Heating Systems



The screed is equipped with heaters or burners, the primary purpose of which is to increase the temperature of a cold bottom screed plate to approximately 300 °F (149 °C). It is necessary for the screed to be at the same temperature as the asphalt material passing under it in order to assure that the mix does not stick to the screed plate and tear, providing a

rough texture to the mat. A properly heated screed, particularly at the start of the day's paving operations or after any extended shutdown of the laydown process, provides for a more uniform mat surface texture.

The screed heaters cannot be used to increase the temperature of the mix being placed because the amount of time that the mix is actually under the screed is much too short to accomplish any temperature rise in the mix.

5.4.10 Maintenance

The biggest maintenance area with screeds is uneven wear on the screed plate. Templates are available to measure the wear on the screed plate. When properly adjusted, the wear should be uniform.

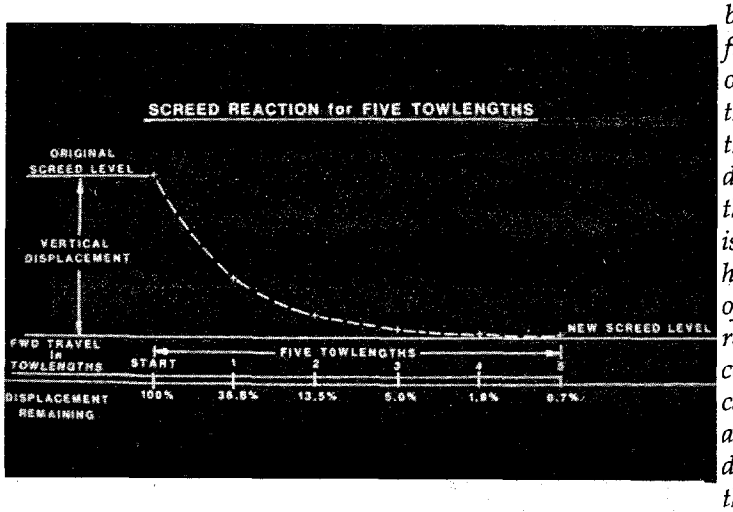
5.5 Operational Principles of the Screed

5.5.1 Self-Leveling Concepts

As a roadway is being paved without the use of automatic grade and slope controls, the tractor unit moves upward and downward in response to the grade of the underlying material. The fact that it takes five times the length of the leveling arm before the screed completely reacts to a change in the location of the tow point allows the screed to reduce the thickness of the asphalt mix being placed over the high places in the existing surface and to place more mix in the low spots on the present roadway. It is this averaging or leveling action that forms the basis for the floating screed principle of the asphalt paver.

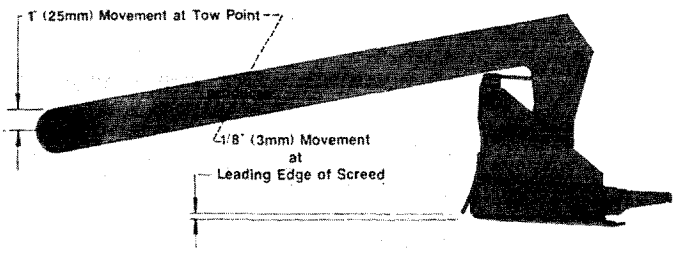
The use of automatic paver controls allows the paver to construct a smoother pavement by keeping the location of the screed pull or tow point constant relative to a predetermined reference as the tractor unit moves up and down vertically in response to small changes in the grade of the underlying pavement surface. This allows the screed to carry out the leveling action needed over a longer reference length in order to reduce the roughness of the existing surface through the application of the new asphalt layer.

5.5.2 Screed Response Versus Distance Traveled



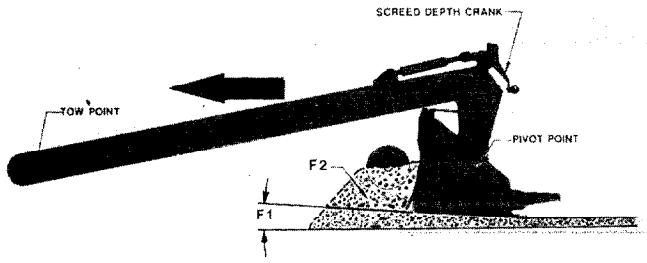
After the tow or pull point has been raised it takes approximately five times the length of the leveling or tow arms on the paver screed for the screed to complete 99 percent of the change, up or down, to the desired new elevation. This means that if the length of the leveling arm is 9 ft (2.7 m)*, the paver would have to move forward for a distance of at least 45 ft* (13.7 m) *before the required input to the thickness-control device was completely carried out by the paver screed. As an example, assume that it is desired to increase the thickness of the mat being placed from 1 in. to 1-1/2 in.* (25 mm to 38 mm).

Approximately 63 percent of the thickness change is accomplished after the paver has moved forward a distance equal to one leveling arm length, or 9 ft (2.7 m) *in this example. As the paver moves forward another 9 ft* (2.7 m)*, about 87 percent of the desired thickness change has been completed. Approximately 95 percent of the elevation change is done by the time a distance of 27 ft* (8.2m) *has been traveled (three leveling arm lengths of 9 ft* (2.7 m) *each). It is not until the paver has moved down the roadway a distance equal to at least five leveling arm lengths, however, that some 99+ percent of the thickness change has been completed. The same exercise holds for a reduction in the thickness-control settings at the screed.*



The same principle applies to a change in the location of the tow point or pull point of the screed leveling arm where it is attached to the tractor unit. If the tow point is displaced, the change in elevation of the tow point is translated to a change in the angle of attack of the paver screed. The paver must still move forward for a distance of approximately five times the length of the leveling arm on the machine for the screed to react to the change in the location of the tow point and move up to or down to the new elevation.

5.5.3 Forces Acting on Screed



5.5.3.1 Speed of Paver

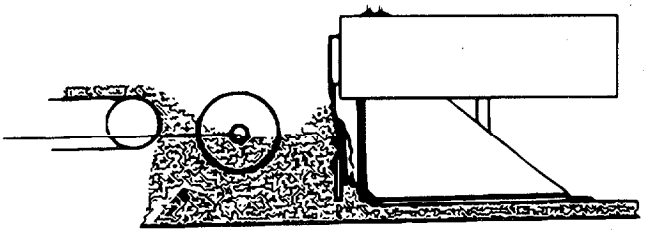
The first force acting on the screed is the towing force of the tractor. This force varies as the speed of the tractor unit increases and decreases.

Because the speed of the paver has a major effect on the angle of attack of the paver screed, it is good paving practice to keep the speed of the paver as consistent as possible during laydown operations. Under manual material flow control and screed control, if the forces on the screed remain constant except for the change in paver speed, an increase in the speed of the paver will cause the thickness of the asphalt layer being placed to decrease. Similarly, a decrease in the speed of the tractor unit will cause an increase of the thickness of the mat being laid. This will only occur, however, as long as no other changes are made in the system; the location of the pull points (tow points) of the screed remain at a constant level and the rate of feed of mix to the augers remains constant. As paver speed increases, if no additional mix is delivered by the slat conveyors to the augers, less mix is available to pass under the screed and the thickness of the layer would be reduced.

Under automatic material flow control, however, the volume of mix delivered to the augers would increase as the paver speed increased, maintaining a constant head of mix in front of the screed. In this latter case, the forces against the screed would remain balanced at the new speed and the thickness of the layer would be unchanged even as the paver speed was increased. Thus, through the use of automatic material-control devices on the paver, the head of material can be maintained at a constant level regardless of paver speed, and the layer thickness placed will remain constant.

5.5.3.2 Head of Material

The second force on the screed is the head of material pushing against the screed. As the amount of asphalt material in the auger chamber that pushes against the screed changes, the net force acting on the screed also changes.



The head of material is the most important force acting on the screed. Some paving experts maintain that 90-95 percent of paver-related problems can be solved by maintaining a uniform head of material during paving operations.

5.5.3.3 Angle of Attack

If the volume of mix in the auger chamber is increased, the force on the screed will also increase, causing the screed to rise. This action will then cause the angle of attack of the screed to decrease until a new equilibrium position is reached. If the amount of material being carried on the augers is decreased, the thickness of the mat will be reduced, all other factors being equal, as the screed falls. This results in an increase in the angle of attack of the screed until the forces on the screed are once again in equilibrium.

There is a potential for the head of material to be affected each time the slat conveyors and augers are turned off and on. This is true particularly if the head of material is not properly set initially. For this reason, the use of a proportional automatic feed-control system is very important, because this device keeps the slat conveyors and augers running as much of the time as possible, provided the flow gates are properly set. This, in turn, keeps the head of material relatively constant and allows the screed to place a mat of consistent thickness. A constant head of material against the paver screed reduces the occurrence of ripples and auger shadows.

5.5.3.4 Pre-Compaction Force

Screeds in the U.S. are almost exclusively use a vibratory system to impart initial compaction into the mix. The force will vary with the settings of amplitude and frequency along with the speed of the paver. Another drawback in speeding up the paver is that the pre-compactive force from the screed will decrease. This will require additional compactive effort from the rollers to achieve the specified density.

5.5.3.5 Screed Weight

Hydraulically extendable screeds weigh more than rigid screeds. On average a rigid, 'wedge lock' screed weighs about 3000 pounds (1.36 tonnes) and a hydraulically extendable screed weighs about 5000 pounds (2.27 tonnes). As the extensions are extended the weight is transmitted over a larger area and the contact pressure approaches the same as a rigid screed.

A heavier screed may aid in pre-compaction force, but may require a different initial settings than a rigid screed to place the same mat.

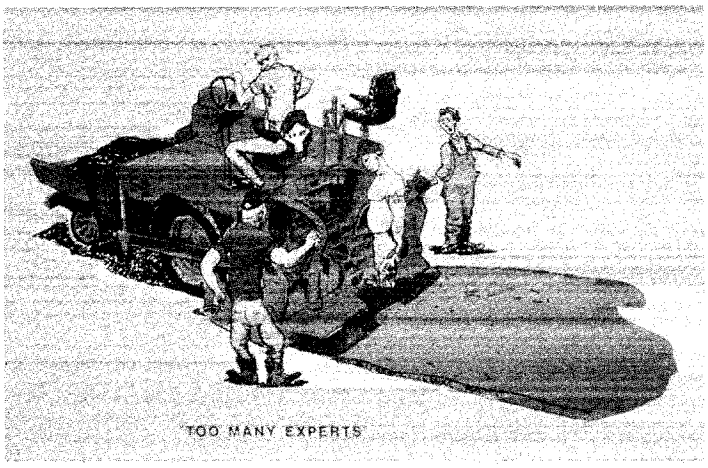
In summary, the three main forces acting on the screed are speed of the paver, head of material, and angle of attack. The head of material is the most important force. It is the result of balancing material feed systems, truck exchanges, and speed of the paver and will significantly affect the smoothness of the mat. Therefore, KEEP THE HEAD OF MATERIAL UNIFORM!

5.6 Screed Control Systems

If the paver always moved over a level grade, the forces on the screed would be constant as long as the paver was moving at a constant speed. The towing force on the screed would be stable and the head of material in front of the screed would be consistent as long as the feed-control system was set to operate as much of the time (close to 100 percent) as possible. Under these conditions, a very smooth asphalt mat could be obtained from behind the paver without a screed operator ever changing the setting of the thickness-control cranks on the back of the screed. Indeed, once the angle of attack of the screed is set when the paver starts up in the morning, no changes would ever need to be made to the setting of the thickness-control handles.

In the real world, however, the tractor unit operates on a grade that is variable. As the elevation of the existing surface moves up and down, the wheelbase of the tractor unit (either crawler or rubber tire) follows that grade. This vertical movement of the tractor as it moves forward causes the elevation of the tow or pull point on the tractor to change in direct relation to the movement of the tractor unit. As the location of the tow point is altered by the movement of the tractor, the angle of attack of the screed is changed.

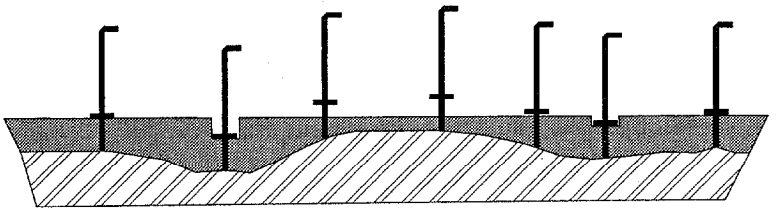
5.6.1 Who's responsible for changes?



The screed operator. This is not a toy. Only those authorized to make changes to the mat should touch these screws. If changes are induced by other than the screed operator, they should be told immediately.

5.6.2 Sticking the mat

On many projects, particularly those involving the resurfacing of an existing pavement, the screed operator is forced by the job specifications to maintain a certain yield of asphalt mix



per square yard or per station (per square metre). *It is not uncommon to watch a screed operator continually check the thickness of the mat being placed by the paver and then adjust the setting of the thickness-control cranks to increase or decrease the amount of mix being placed. This change in the setting of the thickness-control system is done without regard to the changes being made at the same time to the screed as the elevation of the tow point changes while the tractor unit moves forward over the variable grade.*

Two inputs, then, are being introduced into the self-leveling system at the same time. The first input is the vertical movement of the tow point of the screed, which reacts to changes in the movement of the wheelbase of the paver. The second input is the manual changing of the thickness-control cranks by the screed operator. The input from the movement of the tow point and the input from the change in setting of the thickness-control device may be in the same direction as one another or they may be opposite to one another, even canceling each other out.

Sticking the mat is useful for training to understand screed response versus distance traveled, and occasionally to verify mat thickness. It is best practice to refrain from continually sticking of the mat during normal paving operations.

Note: Always allow adequate screed response time after changing thickness control screws or tow point position before making additional changes.

5.6.3 Manual Controls

When a paver is being operated manually, it is very important for the screed operator to realize that the reaction to a change in the setting of the thickness-control crank is not immediate. The paver must move forward at least one leveling arm length before 63 percent of the thickness change is completed. If a second change is made in the setting of the thickness-control crank before the first change is accomplished, the first change will never be completed. It will still take an additional five times the length of the leveling arm for the second thickness change to be carried out. For this reason, continual changes in the setting of the thickness-control devices are usually detrimental to the development of a smooth mat.

As the tractor follows the grade of the existing pavement surface with the rubber tires or crawler tracks, the length of the wheelbase of the paver becomes the reference for the screed. Because of the reaction time of the screed, as discussed in the previous section, the screed will react more slowly to changes in grade than will the tractor. Thus, under manual screed control, the screed will average out deviations in the roughness of the present pavement layer, placing more mix in the low spots and less mix over the high points in the underlying pavement.

5.6.3.1 Grade Control Adjustment

Under manual screed operation, the ability of the screed operator to produce a consistently smooth asphalt layer is dependent on a number of factors. The first is

the frequency at which the operator feels the need to adjust the setting of the thickness-control cranks: The more the screed operator changes the angle of attack of the screed, the more uneven the resulting asphalt pavement will be. The second factor is the roughness of the existing pavement surface: The more the screed operator tries to assist the self-leveling action of the screed, the rougher the resulting pavement surface will be.

5.6.3.1.1 Rotation and Depth Increase with Single Turn

On thickness control screws, most manufacturers use a clockwise pitch to increase depth of mat. Normally, one turn will equal 1/4 inch (6 mm) in mat thickness once that screed has re-balanced. The standard screws on Blaw Knox pavers use a counter clockwise pitch to increase depth, although the other pitch is available.

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5.6.4 Automatic Controls

The primary purpose of automatic screed controls is to produce a smoother asphalt pavement layer; smoother than the paver can accomplish by itself and smoother than a screed operator can accomplish by continually changing the setting of the thickness-control cranks.

The automatic screed control functions by maintaining the elevation of the screed tow points in relation to a reference other than that of the wheelbase of the paver itself.

The elevation of the tow point is kept at a constant elevation in relation to a given grade reference. The automatic system does not permit the relative position of the tow or pull point to change even though the tractor unit is moving up and down vertically in response to the roughness of the surface over which it is traveling. Thus, by maintaining the tow point at a constant elevation, the angle of attack of the screed is also maintained at a constant setting. This allows the screed to ride at a consistent angle, permitting the screed to do an even better job of reducing the quantity of mix placed over the high spots in the existing pavement surface and increasing the amount of mix laid in the low spots.

Automatic screed controls are employed to keep the elevation of the tow points on the paver at a more constant elevation relative to the reference being used. Deviations in the pavement surface are averaged out over the length of the reference (either a preset stringline or a long mobile ski). As the tractor unit moves up and down over the existing grade, the elevation of the tow point moves over a smaller range of elevations than if the relatively short wheelbase of the tractor provided the reference. Keeping the elevation of the tow points constant permits the screed to maintain a more consistent angle of attack. This provides for a smoother mat behind the screed.

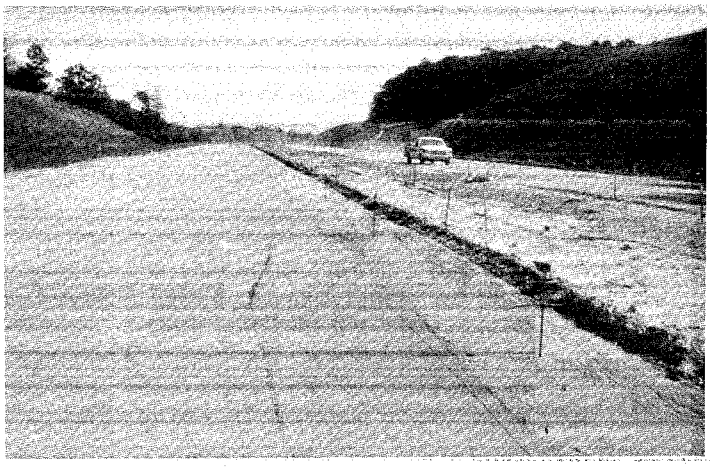
5.6.4.1 Grade Control

5.6.4.1.1 Types of Grade Reference

Grade sensors are used to monitor the elevation of the existing pavement surface in a longitudinal direction. There are three basic types of grade references that can be employed to maintain the elevation of the screed tow point: (a) the erected stringline, (b) the mobile reference, and (c) the joint matching shoe.

Each type of grade control can be used alone on either side of the paver. Grade sensors can also be employed on both sides of the paver at the same time. This use of the references will average out the variations in the grade of the existing pavement surface on both sides of the lane being paved. The same type of grade reference can be used on both sides of the machine or a different type of grade reference can be mounted on each side of the paver; a preset stringline on one side and a mobile reference on the other side, for example. Use of double grade references generally will not produce a uniform cross-slope for the new asphalt layer except if a preset stringline is used on both sides of the laydown machine. When a grade reference is used in conjunction with a slope-control device, the grade sensor is typically positioned on the centerline side of the paver, with the slope controller determining the depth of the mat on the outside edge of the pavement.

5.6.4.1.1.1 Stringline

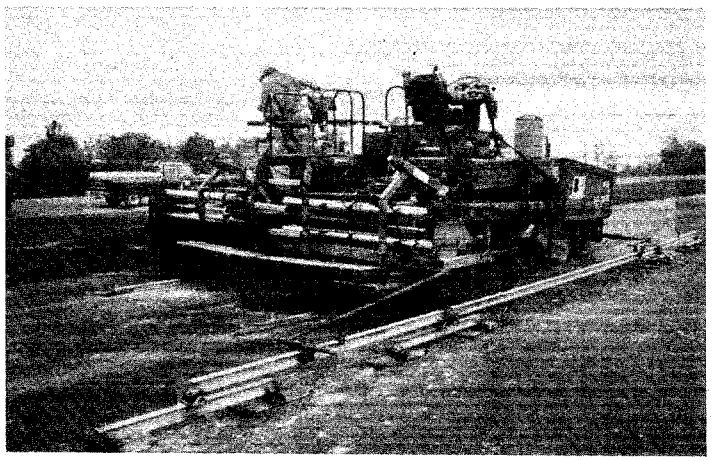


Theoretically, the use of an erected stringline should allow for the smoothest possible asphalt mat behind the paver screed. This method of supplying an elevation input provides the most consistent reference for the paver tow point. Thus, its principal advantage is that a predetermined grade can be matched very accurately if the controls are used properly. Practically, however, the use of the erected stringline has a number of drawbacks that may offset the theoretical increase in smoothness obtained by its use. The elevation of the erected stringline must be set by a surveying crew. On horizontal curves, it is very difficult to use an erected stringline to control the grade of the new pavement layer. The string cannot be set in a curve, and therefore a series of chords must be used around the radius of the curve. If the string is not stretched tightly, the sensor wand on the paver, which can run either on the top or below the stringline, will react to the sags in the line and duplicate those sags in the new pavement surface. Another disadvantage of the erected stringline is the fact that the haul trucks and all paving personnel must keep away from the line and not disturb it in any way. With a properly set and maintained stringline, the mat placed by a paver equipped with automatic screed controls can be very smooth and at the correct elevation. Unless smoothness, or compliance with a predetermined grade reference, is an extremely important criterion on a paving project, however, it is questionable that the added price of erecting and maintaining the stringline is cost-effective for the typical hot-mix

asphalt highway-paving job. Thus, for the vast majority of the highway-paving projects, an erected stringline is not used.

5.6.4.1.1.2 Mobile reference

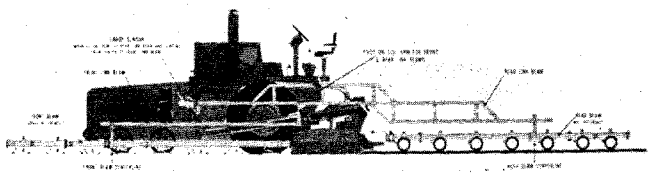
Different paver manufacturers use different types of mobile reference devices to extend the relative wheelbase for the automatic screed-control system. The operation of these reference systems, however, is essentially the same. One paver manufacturer offers a semirigid tubular grade reference (pipe) that is 20, 30, or 40 ft (6.1 m, 9.2 m, or 12.2 m) *in length. For one version, the pipe or tube rides directly on the existing pavement surface. A spring-loaded wire is stretched between the quarter points of the ski, on top of the pipe. The grade sensor that inputs the electrical signal to the paver tow point rides on top of the wire. The second variation employs the same semi-rigid tubular grade reference pipe with the spring-loaded wire, but it is equipped with numerous spring-loaded wheel assemblies attached to the pipe at 2 1/2-ft* (0.76 m) *intervals. This version is similar to a floating beam.*



Another paver manufacturer provides a floating beam. A series of feet or shoes are attached to the bottom of the floating beam. The grade sensor usually rides directly on the beam at its midpoint.

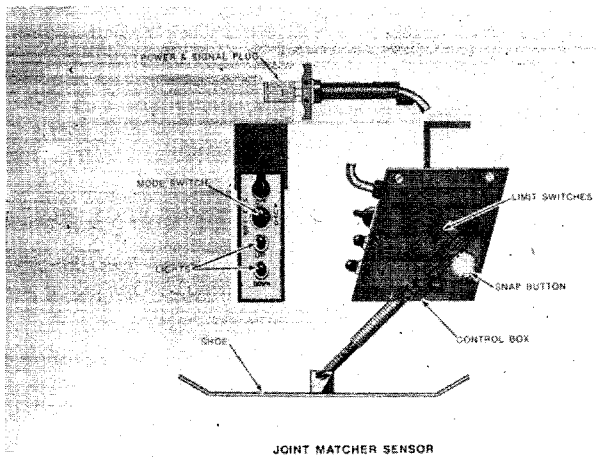
A third paver distributor also supplies a floating-beam type of mobile reference system. The beam is normally 30 or 40 ft (9.2 m or 12.2 m) *in length. Instead of multiple feet spread out along the length of the beam, however, a series of shoes is placed at each end of the beam.*

Of the three types of mobile reference devices described above, the floating-beam type reference that uses multiple feet or shoes typically results in a smoother pavement compared with the mat placed with the rigid tubular grade-control device. The beam will typically provide a reference for the paver that will ignore isolated deviations in grade (a rock on the roadway) and provide a smoother layer behind the paver.



One paver manufacturer has produced a mobile reference ski that is 55 ft (16.8 m) *in length from front to back. Part of the reference beam is located in front of the paver screed. This portion of the reference system senses the grade of the existing pavement surface. To the rear of the screed, riding on a series of spring-loaded wheels, is another floating beam that is used to reference the grade of the newly placed asphalt mix. A set of intermediate bridge beams, which go up and over the screed, are used to join the two parts of the floating beam together. The grade sensor rides on one of the intermediate bridge beams and transmits the average grade of the front and back beam to the paver tow point to control its elevation.*

5.6.4.1.1.3 Joint Shoe



JOINT MATCHER SENSOR

The third type of reference is the joint matching shoe. This device consists of a short (approximately 1-ft-long (0.3 m)*) shoe or ski that is used to reference the grade of an adjacent piece of pavement or curb.*

Because of its short length, the joint matching shoe will not remove any major variations that occur in the pavement surface. Indeed, the purpose of the shoe is to duplicate the grade of the adjacent surface.

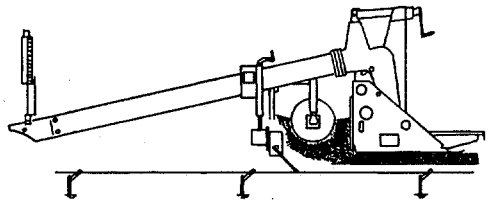
When placing the second lane of a base course or a binder course layer, it may be better to use a longer mobile reference (a 30-ft-long (9.2 m) *ski) instead of the joint matching shoe. The mobile reference will provide the input needed to construct a smoother pavement surface than will the joint matching shoe. For the surface course layer, however, the joint matching shoe may be used to assure that the elevation of the mix on both sides of the longitudinal joint is the same, although the use of a longer mobile reference is still better paving practice.*

5.6.4.1.1.4 Other

Laser technology has been used successfully on a number of paving projects. Additional care must be exercised when using this equipment.

5.6.4.1.2 Location of Grade Controller

Correct sensor position for string line is just ahead of augers.

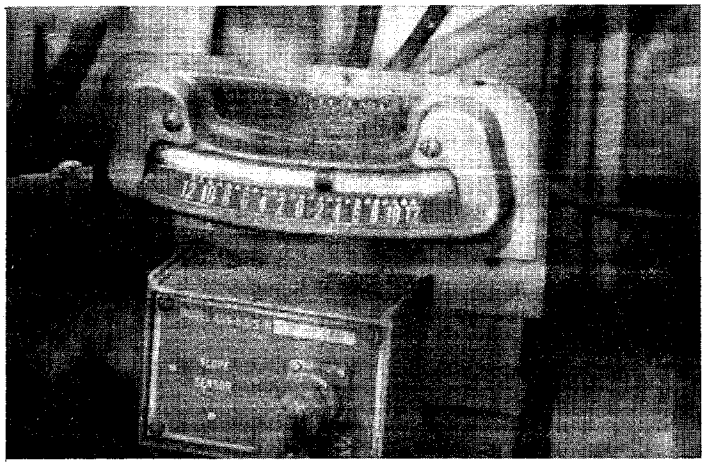


Different paver manufacturers have different recommendations for the placement of the grade reference-control sensors. Occasionally the grade sensor will be mounted adjacent to the tow point on the paver. The grade sensor is sometimes located at various positions on the leveling arm. This side-mounting position typically is recommended when it is desired to correct long vertical deviations in the present pavement surface. When located on the leveling arm, the reaction time to changes in grade is short and the angle of attack of the screed is altered quickly. On some occasions, and particularly for wide-width paving, the grade sensor is mounted near or on the paver screed. To function properly, the grade sensor must be located in front of the pivot or hinge point of the screed.

If no information is available about the suggested location for the sensor for a particular paving operation, it is recommended that the sensor be hung on the leveling arm, at a point between one-third and two-thirds of the length of the arm between the tow point and the screed.

The operation of the grade-control sensor should be checked regularly. When the paver is moving, the up and down lights on the grade sensor should either blink occasionally or blink constantly but change in intensity, both top and bottom, to indicate that a signal is being sent to the tow point actuator. If the grade sensor uses a meter instead of lights, the reading on the meter should change when the sensor wand is moved as well as when the paver is placing mix on the roadway. In addition, the elevation of the tow point should change occasionally, depending on the amount of roughness of the existing pavement surface, in order for the angle of attack of the screed to remain constant as the tractor unit follows the underlying pavement grade. The change in elevation, however, should be smooth; the screed should not be moving up and down rapidly and constantly.

5.6.4.2 Slope Control



In most cases, paving that is done with automatic screed controls is accomplished with a combination of grade control on one side of the paver and slope control to determine the grade on the other side of the machine. The slope control operates through a slope sensor that is located on a cross-beam between the two side arms of the screed. One side of the paver screed is controlled by the grade sensor. The other side of the screed is controlled by the slope controller.

When slope control is used, the thickness of the mat on the side of the machine (usually the outside edge of the roadway) that is controlled by the slope sensor could be variable in depth, depending on the condition of the existing pavement surface. The desired degree of cross-slope is dialed into the slope controller. Without regard to the grade of the existing pavement, the slope controller maintains a constant cross-slope regardless of the resulting thickness of the asphalt layer placed. If there is a high point in the present pavement surface, the slope controller will place less material over that location. If there is a low point in the existing pavement, the slope controller will allow the screed to deposit more mix in that location.

5.6.4.2.1 Adjustments

Adjustments in slope control must be done gradually and only while the paver is moving. When dialing in and out of a superelevation, a good practice is to supply the screed operator with a list of station numbers and cross slopes, or have them visibly marked on the grade stakes.

5.6.4.2.2 Transitions

If automatic controls are being used on the paver, the screed operator should not try to change the angle of attack of the screed manually by turning the thickness-control cranks. If this is done while the machine is moving, the automatic grade and slope controls will attempt to compensate for the manual input by changing the elevation of the tow point. Manual input will be needed, however, if the tow point actuator has reached the limit of its travel—the tow point hydraulic ram is at its upper or lower limit. In this case the paver should be stopped and the tow arm reset at the centerpoint of its travel. The screed should be nulled, the proper angle of attack input to the screed, and paving restarted again.

In addition, when a superelevated curve is being paved that requires a change from the existing cross-slope, it is necessary to run the grade sensor on

one side of the paver automatically and the slope sensor on the other side of the paver manually. This process will permit changes to be made in the amount of superelevation and provide the required degree of cross-slope.

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5.7 Yield Versus Thickness Versus Smoothness

The paving specifications for hot-mix asphalt overlay projects are written in a variety of ways.

5.7.1 Base Condition

The amount of extra thickness depends on the roughness of the existing pavement: The more uneven the pavement being paved, the greater will be the volume of mix needed to assure compliance with the minimum thickness requirement.

5.7.2 Minimum Thickness

In some cases, the specifications call for a minimum thickness of mix to be placed. For this type of requirement, it is usually necessary for the paver to place a mat thickness that is greater than the minimum depth required in the contract.

5.7.3 Yield

The second type of specification calls for the placement of a given amount of mix, in terms of pounds of mix per square yard, over the pavement surface area. In this case, the thickness requirement is an average depth, not a minimum depth. If the specifications for a project called for the placement of 110 lb of mix/yd^2 (60 kg/m^2) *(approximately 1 in.* (25 mm) *of compacted thickness for an asphalt concrete mixture), the angle of attack of the paver screed would not have to be set at as great an angle in order to place the mix an average depth of 1 in.* (25 mm) *(compacted) compared with a minimum specification thickness of 1 in* (25 mm).

The paver screed, left to operate without human intervention on the thickness-control cranks and run either with or without automatic controls, will typically overyield mix. This means that the paver will require more material than generally expected in order to react to variations in the grade of the existing pavement and to shave off the high spots and fill in the low spots in that surface. In order to meet the yield requirement, therefore, it is usually necessary to reduce the thickness of the mat being placed slightly in order to comply with the yield requirement. An additional problem with a yield-type specification is the longitudinal distance used to determine the yield value. In some cases, yield is checked after every truckload of mix. This frequency of checking often leads to continual changes in the thickness-control cranks on the paver. Yield should only be checked periodically: the tons of mix placed over a distance of 1000 ft (305 mm) *or more than an hour's duration of paving.*

5.7.4 Smoothness

The third type of specification is one that requires a certain degree of smoothness for the finished pavement surface. Many different smoothness specifications exist. Most are related to the amount of deviation permitted from a straightedge of a given length or to a certain maximum number of inches of roughness per unit of length, typically a mile or some part of a mile. Although it is normally possible to meet such smoothness specifications through the use of automatic screed controls, the ultimate success in making the requirements depends on the amount of mix available to be placed, the condition of the existing pavement, and the number of layers of mix to be laid. The amount of mix necessary to meet a smoothness requirement will usually be greater than the amount needed to meet a given yield requirement.

5.7.5 Controlling Yield vs. Controlling Thickness or Smoothness

The problem comes when it is desired to meet some specified yield requirement and *to meet a minimum thickness or smoothness requirement at the same time. Because of the principle of the floating screed, it generally is not possible to accomplish both of the specifications at the same time on the same project, depending on the smoothness of the pavement being overlaid. Particularly for thin overlays, the paver is normally not capable of meeting a minimum thickness and/or a smoothness specification at the same time as a yield type requirement. The governing criteria (yield, minimum thickness, or smoothness) should be determined at the time the job is designed and verified to the contractor before paving commences (during the preconstruction meeting).*

5.8 Types of Paving

5.8.1 Planning Layout of Pulls (optimal joint placement)

Planning is an important part of paving and should be done well before work is ready to begin. The paving plan should be reviewed in the pre-paving meeting and should focus on paving as wide as practical and keeping longitudinal joints out of the wheel paths the traffic will eventually travel in.

Optimal joint spacing will place the final surface course joint in the center of the 4-inch lane strip or slightly to the side. Temporary striping should also be placed as close to the final stripe location as possible.

Who decides how to layout the paving?
When is this decision made?

?

5.8.2 Main Line Paving

Main line paving is typically 12 ft (3.7 m) wide, although wider widths are used to minimize joints.

5.8.2.1 Use of Hydraulic Strike-Off

It is not best practice to use a hydraulic strike off to place main line paving, unless the texture and density are acceptable to the agency representative.

5.8.2.2 Combined Mainline and Shoulder

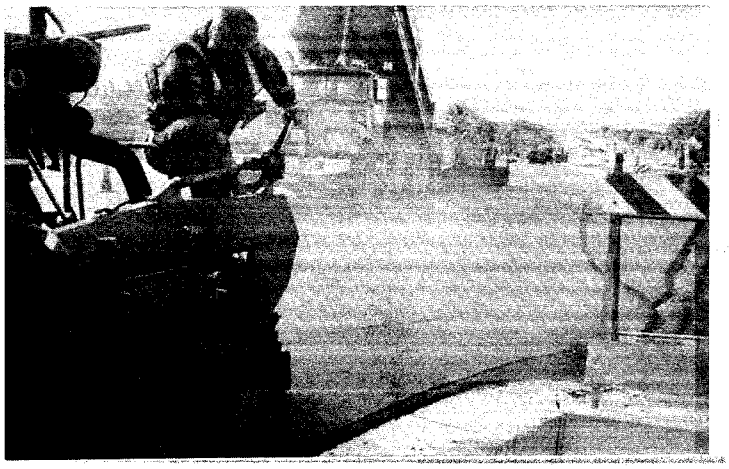
It is more common to see a paving mainline and shoulder combined, especially with the adjustable hydraulically extendable screeds. One screed extension can be used to place the shoulder and be set at a different cross slope than the main screed and the other extensions. When possible, this is good practice. It also eliminates another paver pass to pull the shoulder at a later date.

Caution: If a combination mainline shoulder pull is used, careful attention must be given to the layout of the temporary and permanent striping.

5.8.3 Variable Width Paving

If paving requires frequent changes in the width of paving, this will affect the forces on the screed. This should be kept in mind when adjusting the width of paving "on-the-fly."

5.8.3.1 Tapers, Turnouts



In most cases, only one paver is available on a given project. Main line pulls should be placed first and tapers and turn outs placed later, unless a safety hazard exists. This way, the smoothness and density of the mainline will remain uniform. Tapers and turn outs typically require handwork and take longer to construct, and would throw the entire operation out of balance.

If two pavers are available, the turn outs can be paved in echelon.

5.8.3.2 Use of Hydraulic Strike-Off

The hydraulic strike off may be used in variable width paving as long as the mat texture and smoothness are acceptable. If it would replace handwork, it should be considered.

5.8.4 Transitions

Transitions into and out of superelevated sections should be thoroughly planned and rehearsed before attempting. Grade elevations may need to be shot and painted on the previous pavement layer to assist.

5.8.5 Temporary Ramps and Cross-Overs

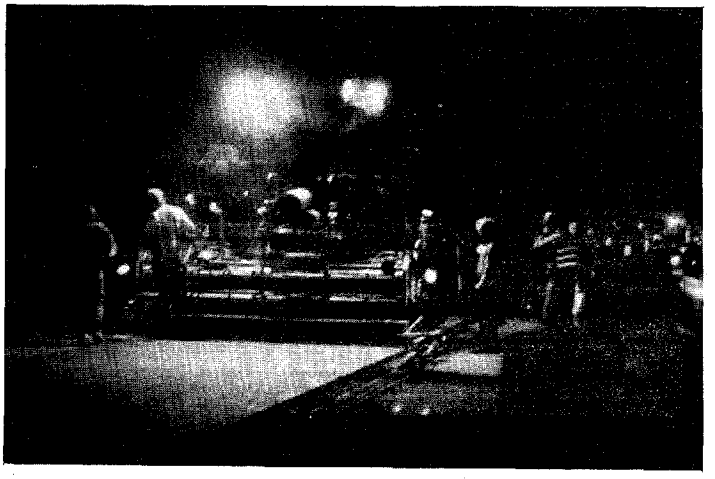
Temporary ramps and cross-overs need to be constructed to the same if not tighter tolerances for grade and slope. Traffic often exceeds posted construction zone limits and these structures often have sharper curves and slopes than that normally found on highways. Motorists may have more difficulty maintaining control in these areas.

5.8.6 Echelon Paving

If echelon paving (two pavers running next to each other) is used, the construction of the longitudinal joint is essentially similar to the building of a joint against a cold, compacted pavement layer. No raking of the joint need be accomplished. Properly lapped and properly compacted, it is usually difficult to see the longitudinal joint produced by the echelon paving process. In addition, use of this technique will normally result in the density of the longitudinal joint being equal to the density of the adjacent mat.

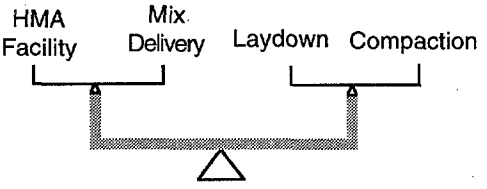
5.8.7 Night Paving

Night paving is commonplace in many urban areas. Additional attention to details is required at night for a number of reasons. Limited visibility, cooler weather, different crews and trucking personnel may be involved, and a host of other problems. A new mat looks different at night than during the day and may cause undo concern for inexperienced personnel. Safety is a big issue and all personnel must wear required safety vests. Construction equipment must be equipped with adequate supplemental lighting, especially the paver and rollers. Testing personnel need to be extra careful at night.



5.9 Operating Techniques

5.9.1 Determining paver speed



The first order in running a balanced process is determining the speed and capacities of the paver. Calculating paver production rate and speed is important. Making sure all the operators know at what speeds they are to operate at is even more important. The key is balance.

5.9.1.1 Example Problem and Calculation

On the following page is a form we will use to calculate paver production rates. You may use a different technique in your daily operations, but for consistency sake, we will use this one. You may also want to check your method against this one and see how close they match.

Important: Schedule ahead of time to balance plant, hauling, paving, and compaction production rates. Understanding the variables that can affect each production rate is the key to be able to adjust when one rate changes -- and they will change! Balancing these rates may be a continual process, but will lead to a better pavement, and more production.

This procedure was developed as a mainline paving operation. A paving operation with very short pulls, many transverse joints, and/or great deal of handwork will significantly reduce the tons per hour production estimates. However, it is just as important to set up a schedule with these operations as a mainline operation.

PAVING PRODUCTION CALCULATION FORM:

Date:_____ Project #: _____

Project:_____

Tons scheduled to be placed today (T-MIX): _____ tons

Hours of Paving Scheduled (P-TIME): _____hours

Mix Delivery Rate (H-RATE):
= T-MIX ÷ P-TIME
= _____ ÷ _____ = _____ tph

Paving Width (WIDTH): _____ ft

Paving Thickness (THICK): _____inches ÷ 12 in/ft = _____ft

Compacted Mix Density (DENSITY):

Specification limits for density: Minimum = _____; Maximum = _____
The in-place target density should be above the Minimum: Target = _____

DENSITY = Reference Density x % Target Density
= _____ pcf x _____
= _____ pcf

33.33 = Conversion factor (tons to pounds & hours to minutes)

Actual Paver Production Rate (P-RATE):

= MIX RATE x 33.33 ÷ WIDTH ÷ THICK ÷ DENSITY

= _____ x 33.33 ÷ _____ ÷ _____ ÷ _____

P-RATE = _____ fpm

Paving Efficiency Factor (EFF1): _____ (recommended: 0.75 - 0.85)

Actual Paver Speed (PAVER):

PAVER = P-RATE ÷ EFF1 = _____ ÷ _____ = _____ fpm

5.9.2 Warming Up Paver and Screed

The tractor must be warmed up and the screed must be heated prior to paving. It is a good time to give everything a last once-over to make sure you are ready.

5.9.3 Positioning on Joint

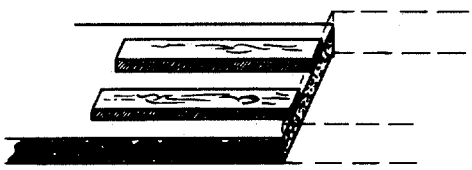
After the temporary joint is removed, cleaned, and tacked, the screed can be positioned. It is best practice to straightedge a cold joint in the longitudinal direction to ensure the new joint will be level with the previous mat.

5.9.3.1 Overlap on Cold Joint

As the screed is positioned on the joint, it should be placed far enough back so that the strike off is on the cold joint.

5.9.3.2 Starting Blocks

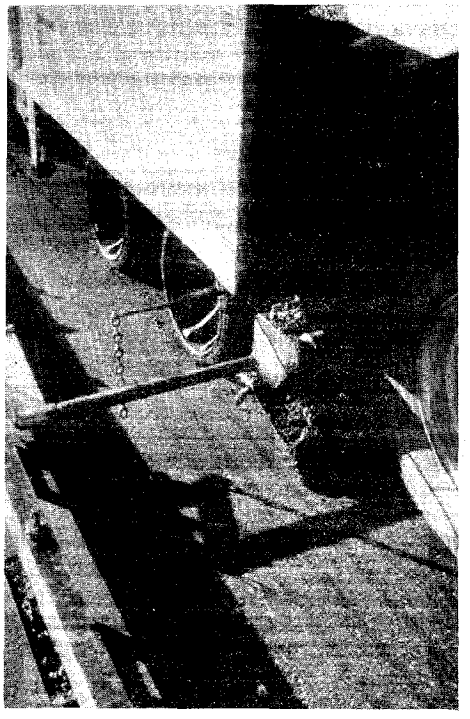
Place boards or lath that equal the compaction rate of the material from thickness of the joint.



Starting blocks should be used and placed underneath the screed. The thickness of the blocks should be as thick as the roll down of the mix. A good rule of thumb is to start with 20 percent thicker than the lift being placed to allow for roll down, then adjust for particular mixes. For a 1-1/2" (38 mm) compact mat, a good starting point would be to use a 3/8" (10 mm) starting block. This will be discussed more in Unit 6: Joint Construction.

5.9.3.3 Aligning the Machine

It is very important that the paver be aligned prior to the start of paving. Both transverse and longitudinal directions should be checked. Keeping the paver aligned during paving will also improve the joints (longitudinal and transverse).



5.9.3.3.1 Steering Guide

Pavers come with steering guides which help keep the paver in a straight line. Often, they are painted with orange paint to increase visibility. The guide should be positioned so the paver operator can clearly see the guide, the reference on the pavement, and a distance down the mat.

5.9.3.3.2 Stringline

The layout of the first pass of the paver will determine the layout of all subsequent passes. It is good practice to use a string line, paint mark, or some type of reference to use as a reference for the steering guide. This is one case where a little effort up front will save a lot of headaches down the road. On subsequent passes, the reference may be the edge of the previously placed mat or a curb line.

5.9.3.4 Screed Width Versus Mat Width

The width of the screed must equal the width of the mat. For wider paving, this is easier for hydraulically extendable screeds, but may require extensions on a rigid type screed. On both screeds, however, the extensions must correspond to the main screed settings or else the mat will show a line or texture problem.

5.9.4 Nulling the Screed

The screed is nulled as per the manufacturer's instructions. It usually is accomplished by rotating the thickness control screws both directions until the screw exhibits some free play. This must be done on both screws, then each re-checked, as freeing up one side may induce some force in the other side.

5.9.5 Initial Screed Settings

5.9.5.1 Angle of Attack

The initial angle of attack is induced in the screed by turning the thickness control screws to increase the depth approximately one turn. This must be accomplished on both sides of the screed. Extensions will also need to be adjusted.

5.9.5.2 Screed Strike-off

In general, the strike-off is located in the range of 3/16 in. to 1/2 in. (5 to 12 mm) *above the bottom plane of the main screed plate. No compaction of the mix occurs under the strike-off.*

Location is determined by screed type, mix type, and experience. When in doubt, use the manufacturer's recommendations.

5.9.5.3 Lead & Tail crown

When rigid extensions are used in conjunction with the main or basic screed, the crown being placed in the pavement by the paver can usually also be altered at any of the points where the extensions are joined. If a hydraulically extendable screed is being used with the paver, the crown can be introduced not only in the center of the main screed but also at the points between the basic screed and the hydraulic extensions.

Normally the lead crown setting is 1/32 in. to 3/16 in. (0.8 to 5 mm) *greater than the tail crown position, with 1/8 in.* (3 mm) *being the average difference in the crown settings.*

5.9.5.4 Material Feed Sensor Location/Adjustment

For the automatic feed control system to function properly, the feed sensor control arm should be located as close to the outside end of the augers as possible. If rigid paver screed extensions are used, as discussed later, the control arm should be mounted beyond the end of the augers, just inside the end gate on the paver screed.

The primary key to the placement of a smooth pavement layer is the use of the material feed system to keep the head (level) of material in front of the screed constant, primarily by keeping the slat conveyor and augers running as close to 100 percent of the time as possible.

5.9.5.5 Grade and Slope Controls and Settings

The grade controller and reference system, usually a ski, are attached to the paver. As mentioned earlier, the location of the sensor will vary but is normally one-third to two-thirds of the distance of the leveling arm forward of the screed. When paving wide, the sensor is often mounted on the screed, forward of the leading edge, to minimize vibration to the sensor. After the screed is charged, the sensors are switched from standby to on, the two-point cylinder valves are open, and screed lift cylnders are not engaged.

5.9.5.6 Position of Tow Arm

The tow points are adjusted to the starting position, usually in the middle of the stroke of the cylinder, or as needed for the project. If the project calls for the mat to start thin and taper to a thicker section, the tow point should be positioned lower. If running manually, the tow points are pinned in place, and mat thickness adjustments are made with the thickness control screws.

5.9.6 Charging the Hopper, Tunnels, and Screed

Once all initial settings have been made, the paving is almost ready to begin. The first truck should be backed into place and dumped into the paver. Some use the second or third load of mix first because it may be hotter. The hopper should be flooded and the slat conveyors started to pull the mix to the augers. Enough mix should be run back to provide a uniform head of material across the width of the

screed and just up to the auger shafts. Using too much or too little mix to form the head of material will cause problems later. If extensions are used, some shoveling may be needed to move mix into the extreme corners of the end plates. Remember, the key is to create a uniform head of material and keep it constant.

5.9.7 Pulling-off Joint

After the screed is charged, the sensors are switched from standby to on, the tow point cylinder valves are opened, and screed lift cylinders are checked. Pull off the joint once the screed is charged and all settings are in place. This should start fairly rapidly and then move quickly to paving speeds.

Some time will be needed to properly construct and compact the transverse joint. The procedure that builds the best joint, with minimal disruption to the team should be used.

5.9.8 Re-checking Settings

Once the paver has moved away from the joint and the screed is balanced, the settings must be checked. If settings need to be changed, they should be made while the paver is moving.

5.9.8.1 Grade and Slope of Mat

Is the thickness adequate?
Is the cross slope right?

Remember, don't stick and turn, stick and turn. Adjustments take time to be fully realized in the mat.

5.9.8.2 Screed Lead and Tail Crown Adjustment

How is the mat texture?
Does the lead or tail crown need to be adjusted?

5.9.8.3 Screed Extension Adjustment

Is there a mark or a texture difference between screed extensions?

5.9.9 Truck Exchanges

When changing trucks, it would be best if the transfer could be done without slowing down or stopping the paver. At relatively slow paving speeds, it might be possible to make the truck exchange while keeping the head of material in front of the screed constant. This would require, however, that the level of mix in the hopper be kept at a level at least even with the bottom of the flow gates at all times. Use of a windrow elevator or a material transfer device eliminates this problem.

If the normal paving speed is fast enough or the truck exchange is slow enough that the proper amount of mix cannot be maintained in the hopper (on the slat conveyors and on the augers) between loads, it would be better to stop the paver when the transfer of trucks occurs. As soon as one truck is emptied, it should pull away from the paver. The paver should be brought from paving speed to a stop as quickly and smoothly as possible without jerking the machine. The next truck should then be backed toward the paver, stopping short of the paver, 1 or 2 ft (0.3 to 0.6 m) *away. For a dump truck, the bed should be raised in the air, without releasing the tailgate, so that some mix can slide against the tailgate. The paver should be started and brought back to the preselected paving speed as quickly and smoothly as possible. The tailgate on the truck should be released as soon as the push rollers on the paver make contact with the vehicle tires, and the mix should be delivered to the paver hopper before the level of mix in the hopper drops below the level of the bottom of the flow gates. This procedure of stopping and restarting the paver quickly will minimize the change in the forces acting on the screed and will allow a near-constant mat thickness to be placed.*

If dump-type haul trucks are used, however, a smoother-riding pavement can be constructed by quickly reducing the speed of the paver and then stopping the paver when a truckload of mix is depleted instead of by keeping the paver creeping along until the next truck arrives at the hopper.

5.9.10 Speed of Paver

Paver speed should be predetermined and set. A marker should be placed on the speed control to ensure the speed is maintained. The paver speed should be checked occasionally by marking, timing, and measuring on the pavement edge. Remember that the key to a good operation is balance. Speeding up to empty a bunch of trucks does not help the situation. Remember, the roller operator may not be able to get density. TEAMWORK.

5.9.11 Checking Yield

An additional problem with a yield-type specification is the longitudinal distance used to determine the yield value. In some cases, yield is checked after every truckload of mix. This frequency of checking often leads to continual changes in the thickness-control cranks on the paver. Yield should only be checked periodically: the tons of mix placed over a distance of 1000 ft (305 m) *or more than an hour's duration of paving.*

5.9.12 Folding Hopper Wings

The sides, or wings, of the hopper are movable. Mix, if left to stand for a long period of time in the corners of the hopper, will cool and may appear as chunks of mix back of the screed when it passes through the paver. Thus, the mix is periodically moved from the sides of the hopper into the middle of the hopper by folding the wings (sides) and allowing the mix to be deposited into the area of the slat conveyors.

To minimize segregation, the paver operator should fold the wings as seldom as possible. The frequency at which the wings are dumped depends on the rate of delivery of the mix to the paver, the temperature of the mix, and the environmental conditions. The wings should be emptied before the mix that collects in the corners of the hopper cools so much that chunks are formed that cannot be broken up as that mix moves through the paver to the augers and under the screed. On colder days, the hopper wings will need to be dumped more frequently than on warmer days.

In all cases, the paver hopper should be at least partially full at the time that the wings are dumped into the center of the hopper; the amount of mix in the hopper should be approximately at the level of the bottom of the flow gates at the back of the hopper. The slat conveyors should not be visible at the time that the wings are raised. Keeping the hopper relatively full between truckloads of mix, keeps the head of asphalt mix in front of the paver screed constant and also reduces any segregation that might be present in the mix. In addition, the wings should not be "banged" repeatedly as they are emptied.

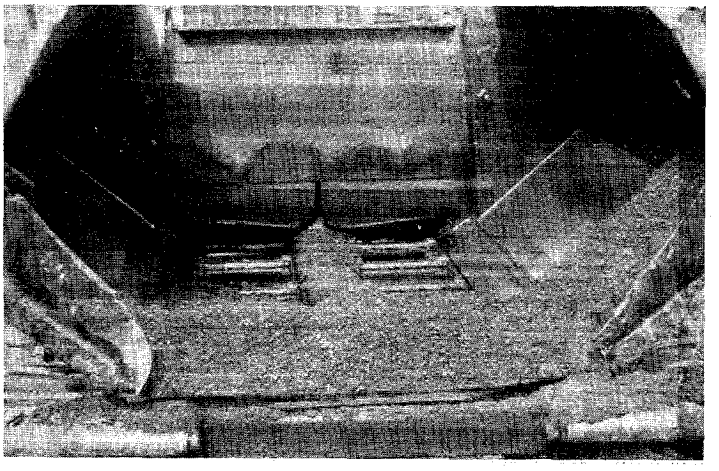
5.9.13 HMA Level in Hopper

The mix level in the hopper should always keep the tunnels buried above conveyor flow gate openings between truckloads. Don't run the tunnels empty!

5.9.14 Auger Operation

Auger operation and conveyor operation should be adjusted to keep them running as close to 100 percent of the time as possible. If they need adjustment, check the location of the material feed sensor and/or the sensitivity setting.

5.9.15 Conveyor Flow Gate Position (Hopper Gate)



Adjustment may be needed to keep the augers and conveyors moving.

5.9.16 Raking/Luting

The sign of a well run operation is not a bunch of flying rakes or lutes. If the operation is set up properly, the transverse joints will need only minimal attention, and longitudinal joints will require at most only a slight bumping action. This will be discussed in more detail in the next unit.

Some paving requires a great deal of handwork, i.e., many manhole covers, turnouts, etc. These take some time to do and the production schedule should account for this.

5.9.17 Traffic Control

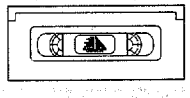
Traffic control and safety is everyone's business. A good paving operation has a good traffic control plan that maximizes the safety of those working in or passing through the work zone.

5.9.18 Concluding Paving

The end of all paving results in a transverse joint of some sort which will be discussed in the next unit. The paver should be parked in a secure, safe area and cleaned of accumulated mix. It should be greased while hot and checked for wear and loose parts.

5.10 Summary

A good summary of key points related to paving is found on page 3-37 and 3-52 of the HPH and is repeated in the small handout entitled "Tips for Best Practice."



5.11 Review Video Tape

5.12 Review Objectives

Can you...

1. State the objective of HMA placement?
2. Identify main components and functions of the tractor unit?
3. Identify main components and functions of the screed unit?
4. Describe how the screed works?
5. List the major forces acting on the screed?
6. Identify types and functions of grade and slope control systems?
7. List the capabilities of the grade and slope control systems?
8. Recognize the relationship between yield, thickness, and smoothness?
9. List paving types and when to use them?
10. Layout a paving job to keep the longitudinal joints out of the wheel paths?
11. Describe the factors involved in night paving?
12. Identify important areas of paver maintenance?
13. Describe how to properly place HMA?

5.13 Evaluation

Please complete the Unit 5 evaluation at this time. Thank you.

6

HPH 3-53 | 3-69

UNIT 6 Joint Construction (1 hour)

6.1 Introduction

6.1.1 Review Objectives of This Unit

What's-in-it-for-me? All pavements have one internal weakness...joints. Whether concrete or asphalt, joints probably cause more problems than any other. However, it is difficult, if not impossible, to construct a pavement without any joints. Therefore, the real trick is to make as few joints as possible and to construct them carefully and properly. Also, the appearance and quality of the joints determines the overall appearance and quality of the finished mat. Fortunately, it is normally easier and quicker to construct a good joint than a bad one. What's in it for me? ANSWER: more pride in the quality of the finished job because it looks better and will last longer. Joints done properly require less work, but require teamwork.

OVERVIEW: During this unit, we will look specifically at transverse and longitudinal joint construction and how to make them right the first time.

KEYWORDS: Transverse, Tapered Joint, Butt Joint, Longitudinal Joint.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of joint construction;
2. Describe the two types of joints and when they are used;
3. List and describe the types of transverse joint construction methods available;
4. List and describe the types of longitudinal joint construction methods available; and
5. Identify proper joint raking techniques.

METHODS: We will use a combination of video, slides, and lecture to emphasize the main points of this unit.

EVALUATION: You will complete an evaluation of this unit.

6.2 Video

6.2.1 Introduction

The following video tape is several minutes long and stresses the importance of proper joint construction when constructing HMA pavements. The objectives of using this video tape are: to relate the live action of your work environment into a classroom, show the real process of joint construction, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.

6.2.2 View Video Tape

6.2.3 Questions on Video

?

How to you build your joints?
Do you have many joint-related failures in your state?
What is your biggest problem with constructing joints?
Which is easier to build, transverse or longitudinal?

6.3 Transverse Joints

6.3.1 Purpose

When the placement of the asphalt mix is to be suspended for a period of time, it is necessary to construct a transverse joint across the pavement being placed. This is accomplished in one of several ways, depending primarily on whether traffic is to travel over the asphalt mix between the time the paving is stopped and it is started again.

If traffic is not going to pass over the end of the paving, a vertical butt joint can be constructed. If traffic will be permitted to travel over the transverse joint, a tapered joint will be necessary.

6.3.2 End of Paving

It is very important that the paver be run in normal fashion right up to the point at which the transverse joint is constructed. This means that the head of material carried in front of the screed should be as consistent as possible at the location of the joint. This requirement permits the forces acting on the screed to be constant and maintains the angle of attack for the paver screed. The result of such a paving operation is a uniform mat thickness at the joint, the same thickness as for the previously placed mix.

It is a common but incorrect practice, however, to empty out the paver hopper whenever a transverse joint is to be built. It is a much better practice to locate the transverse joint at the point where the amount of material in front of the screed is normal.

6.3.2.1 Butt Joints

For a butt joint, a vertical face is constructed by hand methods across the width being paved. This operation consists of raking, shoveling, and then removing the mix that is located downstream of the selected joint location. The asphalt mix that is in place upstream of the joint is not touched in any manner. The mix that is removed from the downstream side of the joint is then recycled or discarded.

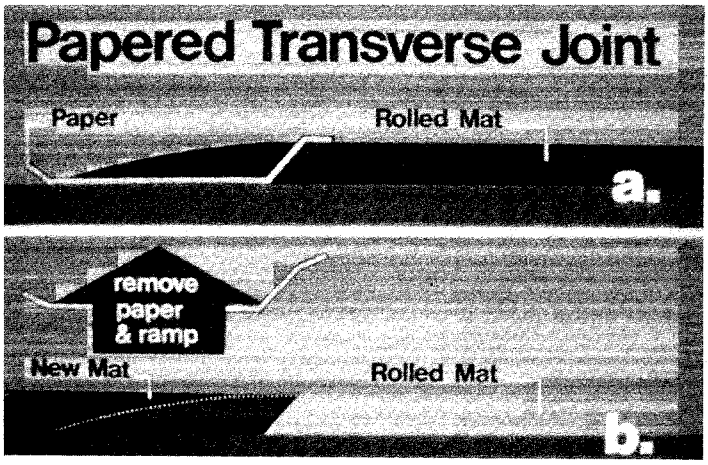
Compaction of the mix on the upstream side of the joint is accomplished in normal fashion. It is necessary, however, for the rollers to compact the mix immediately adjacent to the joint. For this to be done properly, runoff boards must be placed next to the joint.

Passing the rollers over the edge of the transverse joint, without having any boards beyond the edge to support the weight of the rollers, will cause rounding of the edge of the joint. This latter type of joint construction results in two problems. First, the rounding of the edge of the butt joint prevents the construction of a proper vertical joint when paving is restarted. Second, the amount of compactive effort applied to the asphalt mix adjacent to the joint is typically not adequate.

6.3.2.2 Tapered Joints

If traffic is to be carried over the transverse joint, it is necessary to build a tapered joint. For this type of joint, as for the butt joint, it is proper for the paver operator to keep the head of material in front of the paver screed as consistent as possible up to the point that the joint is to be built. This process assures that the thickness of the mix being placed is uniform up to the joint. There is more opportunity for this to be done in practice with tapered joint construction than with butt joint construction because the mix left in the paver hopper can be used to build the taper.

At the point of the transverse joint, the asphalt mix downstream of the joint is temporarily pushed aside. A vertical edge is formed at the upstream face of the mix. If the tapered joint is to be only temporary, treated paper or other similar material is then placed downstream of the joint directly on the existing pavement surface. This paper is used because the asphalt mix will not stick to it. The length of the paper is dependent on the thickness of the course just placed but is typically about 3 or 4 ft long (1 or 1.3 m) *and the width of the lane being paved.*



Once the paper is in place, the asphalt mix is shoveled back over the paper and a ramp is formed in this mix with a lute or rake. Any asphalt mix that is not used to construct the ramp or taper is

discarded. If the joint is to be left in place permanently, the taper is constructed in the same manner except that the treated paper is not used.

Constructing a temporary tapered transverse joint using sand or dirt as the bond-breaking medium is not an acceptable paving practice.

A third type of tapered joint is the nonformed, sawed joint. For this type of joint, the paver operator keeps the paver operating normally until there is no more mix in the hopper or in the auger chamber. At the point where the mix becomes nonuniform across the width of the lane being paved, a ramp is constructed with the "left-over" mix. No vertical face is formed, and the mix is merely tapered from the proper layer thickness to the level of the adjacent existing pavement. Any mix not needed to make the ramp is removed.

One advantage of the tapered joint is the fact that the compaction equipment can run over the edge of the transverse joint and down the ramp without rounding the joint. Because the rollers can pass over the end of the mat easily, the compaction of the mix upstream of the joint is usually superior to the mix adjacent to the butt-type joint. A second advantage is that there generally is less mix to shovel from the joint, because some of the extra mix is used to make the ramp or taper. The disadvantage of this kind of joint is that this mix must eventually be removed before paving commences downstream of the transverse joint.

6.3.3 Tying In

In areas where the new hot-mix asphalt layer abuts an existing structure, such as a bridge deck, it is often necessary to place the mix adjacent to the joint by hand. The mix that is needed to complete the joint is deposited in the area to be paved either by the paver or by being dumped from a haul truck. In order to avoid overworking the mix and possibly causing segregation, the mix should be placed as close as feasible to its final location. The mix is then spread by hand methods, normally using rakes or lutes.

In addition, the mix must be "left high" in order to allow for the compression of the material by the compaction equipment. Because the mix is being placed by hand, it will not be as dense as it would be if it were laid by the paver. Thus the 1/4 in./1 in. rule of thumb usually used will not be valid for hand-spread mix. To permit proper compaction of the mix and have the mix end up at the proper elevation to match the adjacent structure, the level of the mix should be approximately 3/8 in. higher than the surrounding pavement for each 1 in. of compacted layer thickness. (Note: 1/4 in./1 in. = 6 mm/25 mm, 3/8 in. = 9 mm)

Note: The loose to compacted thickness varies by mix type and is determined by experience.

The hand work area must be rolled by the compaction equipment as soon as possible after the mix is in the proper location. Because of the time necessary to place the mix, rolling will be delayed and the mix will be cooling during the placement process. In order to achieve the required density, extra rolling may be needed.

6.3.4 Start of Paving

6.3.4.1 Squaring Up

A straightedge should be used to determine the condition of the transverse joint before paving begins. If the mix upstream of the joint is level, the location of the transverse joint is fine. If the straightedge indicates that the previously placed mix is not level, the location of the transverse joint should be moved to a point where the proper thickness and smoothness of the pavement layer exists. The mix downstream of the new joint location should be removed and recycled.

6.3.4.2 Removal of Material

If a tapered joint has been constructed at the transverse joint, the mix in the ramp or taper must be removed before the paving can be started. For a taper built with treated paper, there is no bond between the mix in the ramp and the underlying pavement. The paper and mix are readily removed and returned for recycling. A vertical face is left at the upstream edge of the joint.

For a taper constructed with the board and a ramp of asphalt mix, the material downstream of the board will be partially bonded to the existing pavement surface. A front-end loader typically is used to pry up the mix in the taper. This can be very difficult to do, depending on the amount of traffic that has passed over the transverse joint and the environmental conditions at the site. Once the mix has been removed, the board is then removed, exposing the vertical face of the joint.

If a nonformed tapered transverse joint is used, it is necessary first to saw a transverse joint in the asphalt mat. It can be placed far enough back from the taper to assure that the thickness of the layer is constant. Once the joint is cut completely through the asphalt mat, a front-end loader is used to pry up the mix that is downstream of the saw cut. As with the tapered joint that uses the board, one disadvantage of this type of joint is that it is often very difficult to remove the mix downstream of the saw cut from the existing roadway. As an alternative, a cold-milling machine can be used both to form the vertical edge of the transverse joint and to remove the mix in the taper.

6.3.4.3 Cleaning and Tacking

After the existing joint materials are removed it is important to thoroughly clean the area exposed and properly tack the surfaces. It requires little work and is good practice to tack the vertical edge of the joint before paving resumes.

6.3.4.4 Starting Blocks

The asphalt mix that passes out the back of the paver screed still must be compacted. As a rule of thumb, an asphalt concrete is expected to densify approximately 20 percent under the action of the compaction equipment. This means that the mix must be placed about 1 1/4 in. thick in order to produce a compacted mix that is 1 in. thick. (31 mm to produce a 25 mm mat)

Note: The loose to compacted thickness will vary by mix type. Place the mix at a loose thickness which will result in the proper final thickness after compaction.

Proper paving practice requires that the paver screed be placed on a set of starting blocks on the upstream side of the transverse joint. The thickness of the blocks, or strips of wood, should allow the additional thickness of the layer to be placed, which will be compacted to the required asphalt thickness.

If the paver is starting out at a new location where there is no old mat on which to set the starting blocks and screed, the thickness of the starting blocks must be increased to compensate for the lack of mix on the upstream side of the joint.

6.3.4.5 Pulling Off the Joint

Once the paver screed has been set on starting blocks of the proper thickness, the screed should be nulled. An angle of attack should then be set into the screed. Before the paver pulls off of the starting blocks, the material feed system on the machine is activated and mix is deposited in the auger chamber in front of the screed. The amount of mix delivered should be enough to cover the augers up to the center of the auger shaft. This will provide the proper head of material against the screed. Once the auger chamber is properly filled, the paver is started, the screed is pulled off of the starting blocks, and the paver is brought up to the desired laydown speed as quickly as feasible. The angle of attack of the screed is adjusted, as needed, as the paver moves down the roadway, in order to provide the proper thickness of the asphalt mat. If the paver screed is nulled and the angle of attack set correctly while the screed is on the starting blocks, the amount of adjustment necessary to the screed should be minimal.

6.3.4.5.1 Manual Method vs. Automatic Controls

Whether to pull off the joint using manual grade or automatic grade controls is subject to debate. However, the main goal is to ensure a smooth and uniform transition between the old and new pavements. There is no reason to have to pull off using manual controls then switch to automatic, but some contractors prefer this method. The method that gives the desired end performance is the one that should be used.

6.3.5 Raking/Luting the Joint

If the transverse joint is constructed properly up to this point, the amount of raking that needs to be done also is minimal. If the paver screed starts out on blocks and if the head of material against the screed is constant, the thickness of the mat downstream of the joint will be correct. Very little mix, if any, will need to be brushed back from the joint. There is never any reason to rake a transverse joint excessively.

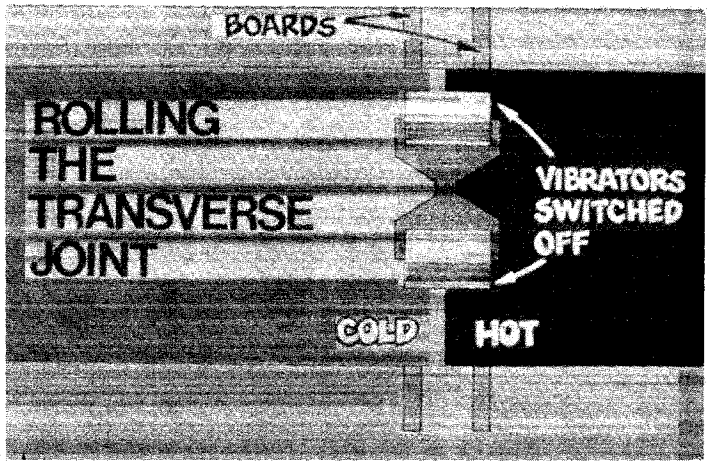
It is considered good practice to shovel up and recycle any coarse aggregate that remains after luting a surface course. The appearance of the final surface is very important and should be as uniform as possible.

6.3.6 Initial Straightedge Check

Before the material on the downstream side of the joint is compacted, it should be determined if the joint is smooth by running a straightedge across the joint. The straightedge should rest on the uncompacted mat and extend over the already compacted mix. The distance between the bottom of the straightedge and the top of the compacted mat should be equal to the amount of rolldown that will occur during the compaction process...

6.3.7 Compacting

Ideally, a transverse joint should be compacted transversely. If the rolling is done transversely, wood boards must be used to support the roller as it moves beyond the longitudinal edge of the pavement. If the roller cannot compact the joint in the transverse direction because of site restrictions (adjacent guardrail or steep side slope, for example) or traffic in the next lane, the transverse joint will have to be rolled in the longitudinal direction. The initial (breakdown) rolling should be accomplished, however, as quickly as possible after the paver has moved off of the joint. The roller should pass slowly and completely over the joint before the machine is reversed. If the joint has



been constructed properly, the compaction process is no different from the application of ordinary compactive effort on any other part of the asphalt mixture.

6.3.8 Final Straightedge Check

The straightedge should be used again to check the level of the joint once the compaction process has been completed.

6.4 Longitudinal Joints

6.4.1 Purpose

The longitudinal joint occurs when one lane of asphalt mix is constructed adjacent to a previously placed lane of mix.

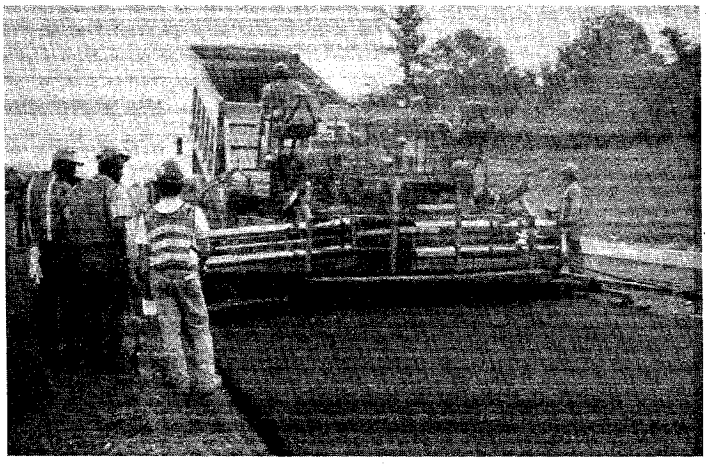
The first pull of a paver almost always leaves at least one unsupported longitudinal edge in the mat. This joint will be a potential weakness in the finished pavement and must be handled carefully to minimize this potential.

When placing multiple layers of HMA, longitudinal joints should be staggered so a single vertical joint does not run the depth of the pavement.

6.4.2 Building an Unsupported Joint

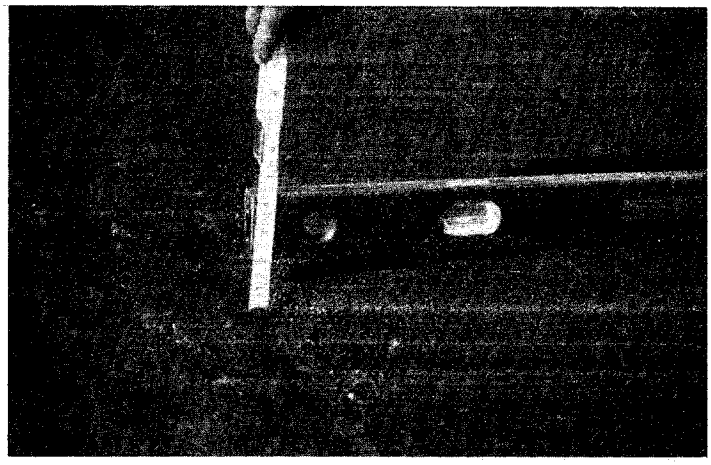
6.4.2.1 Conventional Unconfined

A conventional unconfined longitudinal joint is most common. The edge of the material is extruded through the screed and restrained by the edge plate. The material is compacted from the top down and is unconfined on one edge. Therefore, there is a tendency for the edge of the mat to have a lower density than say the middle of the mat which has adequate mix confinement all around.



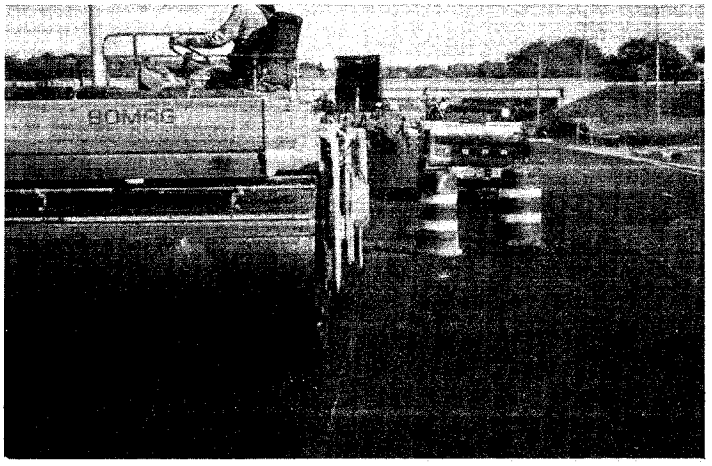
All longitudinal joints should be constructed as cleanly and as straight as possible. This joint matching process has a much higher success rate than a joint that isn't cleaned and meanders side to side.

6.4.2.2 Formed Taper



Some states have started to specify a tapered joint for several reasons. Some believe a taper provides more of an area for the new hot mat to bond to the previously placed cold mat. Some believe there is a smaller chance of the joint splitting open in the future. Others believe traffic can easily pass over a tapered joint at highway speeds without less possibility of losing control. Michigan and New Jersey are examples of states that use this type of joint.

6.4.2.3 Compaction of Unsupported Joints



Longitudinal joints can be compacted in a variety of ways. During the initial construction of an unsupported or wedge joint, the roller should hang the edge of the roller drum approximately 6 inches (150 mm) over the unsupported edge to provide some confinement. On thicker lifts, another technique is to hold the first pass of the roller approximately 1 foot (0.3 m) inside of the outside edge, then compact the strip of mix in a subsequent pass. Compaction will be covered in greater detail in Unit 8 - Compaction.

6.4.3 Preparing a Cold Joint

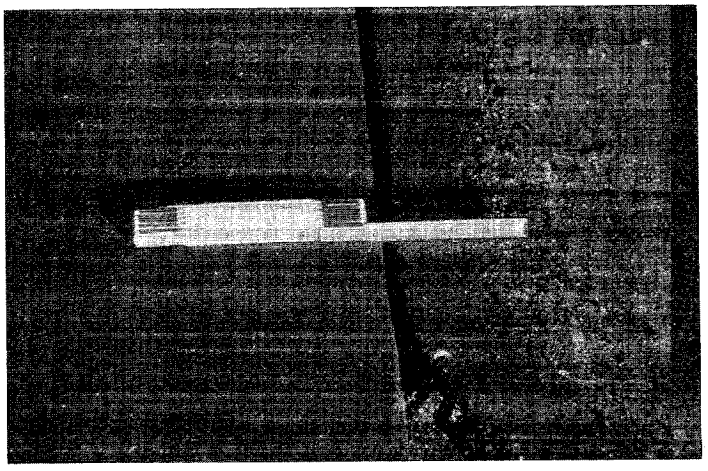
6.4.3.1 Cleaning

The edge of the longitudinal joint may contain loose materials after being exposed to traffic and should be swept before a new mat is placed along side.

6.4.3.2 Tacking

If the joint is not cut back and the mix along the joint is clean, a tack coat is not normally needed.

6.4.3.3 "Cutting Back"



Some specifications require the use of this technique to prepare a longitudinal joint.

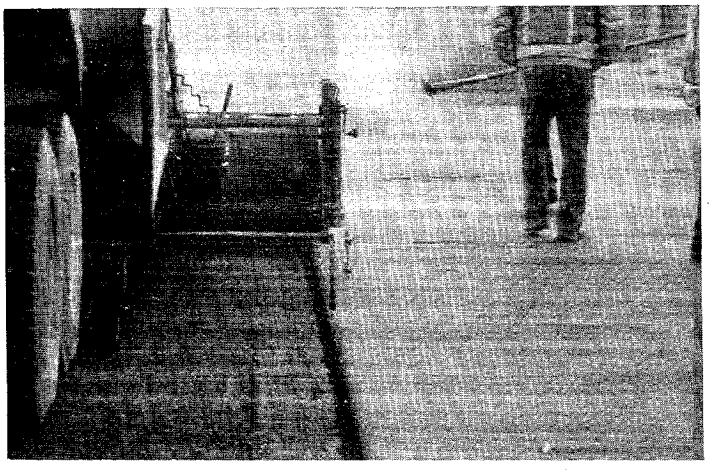
In some cases, before the longitudinal joint between two adjacent lanes of pavement is constructed, the longitudinal edge of the previously placed mix is cut back for a distance of 1 to 2 in. (25-50 mm) *This is accomplished with a saw or with a cutting wheel attached to a grader or front-end loader. The purpose of this operation is to remove that portion of the mix at the longitudinal joint that may have a lower density than the main portion of the mat because of the lack of confinement of the mix during the compaction process. If this is done, a tack coat should be placed on the newly exposed face of the longitudinal joint.*

If traffic will not pass over the joint before matching the joint, cutting the joint while the mix is still warm will require less effort.

6.4.4 Paving a Longitudinal Joint

6.4.4.1 Overlapping the Joint

The key to the construction of a good longitudinal joint between lanes of asphalt mix is the amount of overlap between the new mat and the previously placed mat. This amount of overlap provides just enough material on top of the joint to allow for proper compaction without having extra mix, which must be pushed back from the joint by a raker.



Overlap a sufficient amount to produce a tight joint and allow for the steering tolerance of the paver. This distance varies, but 1 to 1-1/2" inches (25-38 mm) has worked successfully in many cases. The end gate should be in full contact with surface and leave a tight edge.

One major problem with longitudinal joint construction is an excessive amount of overlap of the paver screed over the previously placed mat. (This may be caused, in part, by a ragged or wavy longitudinal edge on the first paver pass. Use of a string to guide the paver operator as the first lane is placed will usually reduce this problem greatly.) Because this extra asphalt mix cannot be pushed into the compacted mat, the material is raked or luted onto the new mat. If the longitudinal edge of the first lane is straight and if the correct amount of overlap is used, the amount of raking that must be done will be minimal.

6.4.4.2 Luting the Joint

If the amount of overlap of the new mix on the old lane is 1 to 1 1/2 in. (25-38 mm), *any raking that is done should be used merely to "bump" the joint, pushing the mix off of the old lane and onto the new mat directly over the joint. If the adjacent lane is overlapped too far and too much mix is deposited on the old mat, the excess material should be pulled away from the new mat instead of being pushed onto the new mix. The mix should not be broadcast across the new lane. The excess mix should be picked up and recycled.*

Excellent longitudinal joints can be constructed without raking the joint at all. If the proper amount of overlap of the new mix on the previously placed mat has been done, raking of the longitudinal joint can be eliminated. It is recommended that raking of this joint be deleted if proper overlap and compaction can be obtained.

6.4.4.3 Compacting the Joint

If the level of the new, uncompacted mix is even with or below the level of the compacted mix in the adjacent lane, the compaction equipment will not be able to densify the mix along the joint properly. Whether the first pass of the roller is on the cold side of the joint or on the hot side of the joint, part of the weight of the roller will be supported on the previously compacted mat. This means that the compaction equipment will bridge the mix in the joint, leaving it essentially uncompacted or only partially compacted. (Use of an intermediate pneumatic tire roller instead of a steel wheel roller—static or vibratory—will reduce this problem.) The level of the mix at the longitudinal joint must be above the elevation of the compacted mix, by an amount equal to approximately 1/4 in. for each 1 in. (6 mm per 25 mm) *of compacted pavement, if proper compaction of the mix at the joint is to be accomplished.*

6.5 Summary

A good summary of joint construction techniques is found on page 3-69 of the HPH and is repeated in the handout entitled "Tips for Best Practice."

6.6 Review Video Tape

6.7 Review Objectives

Can you?

1. State the objective of joint construction;
2. Describe the two types of joints and when they are used;
3. List and describe the types of transverse joint construction methods available;
4. List and describe the types of longitudinal joint construction methods available; and
5. Identify proper joint raking techniques.

6.8 Evaluation

Please complete the Unit 6 evaluation at this time. Thank you.

7

UNIT 7 Troubleshooting #1 (2 hours)

7.1 Introduction

7.1.1 Review Objectives of this Unit

What's-in-it-for-me? Your main job (agency or contractor) is to make things work and get the job done right. Whether you are directing paving operations or inspecting them, you will ultimately determine if these pavements will perform or not. With the authority to construct and inspect these pavements comes the responsibility to do the best job possible. In many respects, you are paying your own salary because the money to build these projects comes from taxes you pay (federal, state, and local taxes).

When you are spending your own money on something, be it a stereo, golf clubs, or a fishing pole, you want the best your money can buy. The same must be true for pavements. If you are paying for them and building them, *you have the unique opportunity* to guarantee the best job is being done (within practical limits, of course). Your ability to think on your feet (particularly at 40 feet per minute), communicate clearly under extreme pressure, and make knowledgeable decisions quickly is what makes your career so challenging. Good troubleshooting skills and experience will enable you to identify problems quickly, pinpoint the source of the problem, and recommend proper action which will solve the problem and minimize delays. Why do you have to shut down the job, call a meeting, and lose two days of production in order to determine the source of a problem when you can pinpoint it in the field with some basic troubleshooting techniques?

OVERVIEW: During this unit, we will develop a systematic approach to rationally troubleshoot a problem, then look at several case studies in which you will be responsible for identifying the problem, and developing a course of action to solve them.

OBJECTIVES: At the end of this unit, you should be able to:
1. State the objective of effective troubleshooting;
2. List the steps needed to effectively troubleshoot;
3. Analyze situations and recommend action to be taken.

METHODS: We will use a set of handouts containing background materials to present a series of situations requiring action. You will work in your assigned teams to troubleshoot these case studies.

EVALUATION: At the end of each case study, we will discuss your solution and recommendations as to what you would do in such a situation. In addition, you will need to complete an evaluation of the unit.

7.2 How to Troubleshoot

Troubleshooting skills are always in demand. They make you a more valuable asset to your company and to those you work with. A systematic approach to problem solving can be applied in every situation. The key to this is to work in a system and not get

sidetracked. To effectively troubleshoot a situation or failure requires you to use all your senses and puzzle solving abilities. There are several steps you should take whenever you are called to troubleshoot. These apply to any situation, be it a paving project or a car repair. This is a skill that must be developed and you can use for the rest of your life. The more you do, the better you will get at it. Follow these steps.

1. **Stop, step back, look at the big picture, and identify the problem.**

   You must be objective and open-minded throughout the process. Don't draw conclusions too early and don't let your emotions cloud your judgement. This is why it is sometimes better to have someone else come in and look at a problem because they are detached from the problem, physically and emotionally. They don't have tunnel vision and may be able to provide an answer quicker to your problem.

2. **Break the problem into small, definable elements.**

   This is difficult sometimes because many things interrelate. Still, you need to break it down. A segregation problem can be normally broken into the following areas: Mix, Production, Load Out, Dumping, and Paver Operation. You could break paver operation into smaller pieces like: Hopper Operation, Slat Conveyor Operation, Auger Operation, Screed Operation, and Raking/Luting.

3. **Eliminate the obvious.**

   Once you have seen the big picture, start narrowing on the problem. If it is a segregation problem, you can pretty much eliminate traffic control and compaction as culprits. It may sound silly but covering all your bases isn't.

4. **Analyze each element. Determine if it could contribute to the problem.**

   The goal here is to see if any of your elements could contribute to the problem. It may not seem like a big problem with any particular element, but when combined together, they may show what the real problem is. Still, you have to identify each possible cause. If segregation or other process-related problem is your problem, you will need to be placing mix to analyze the system. It is virtually impossible to fix something when it isn't running.

   It may be helpful for you to ***try some visualization to help determine the cause.*** For example, if segregation in a base course mix is your problem, shrink yourself down to the size of 1-1/2" rock and follow it from the stockpile to the mat. Follow it as it is loaded into the truck, dumped into the hopper, and as it makes its way through the hopper gates and out across the augers. Looking at it from this perspective may help identify the root cause of your problem.

   Interview persons present and any available test data. Did you see, hear, or feel anything different today than yesterday? Have you changed any key people lately? These and other questions like them will help you refine your search. If test data is available it should be plotted on process control charts to look for trends and relationships.

5. **Recombine the pieces.**

   Now comes the interesting part. Step-by-step, pull the elements together starting at the beginning of the process. Sometimes a problem will be isolated into one part of the process, like running the tunnels empty between loads. Sometimes the problem may have many contributing factors that alone would not result in the problem.

6. **Develop your recommendations based on the available facts.**

   You've done a lot of work to get to this point, don't stop now. Your gut instinct may or may not be right, but facts are more defendable. This is especially true if the answer requires a process to be changed, or major equipment modification or repair.

7. **Make changes ONE-AT-A-TIME, evaluate, and feedback.**

   A common mistake is to make a bunch of changes to an operation all at once in order to fix a situation quickly. Taking this road will only complicate matters worse. Your best bet is to fix one item at a time and check the process. Normally, if the process improves, the change was valid. Move sequentially and change one operation at a time, determining if the change was valid before moving on. This way you have validated your troubleshooting skills and only fixed the problem, not created another.

   This process of making changes, evaluating the change, and feeding back information about the results is a simple step-by-step system. It is used to ensure the right changes are made, the problem is solved, and make sure another problem isn't created. Again, if it is process-related, the process will have to be running in order to observe the results.

   Changing auger flights, adding extensions, changing loadout, dumping, and hopper operations all at once may solve the problem, but what if it was only due to the hopper operation? If so, you have wasted time, effort, and money fixing something that was not broken. Make one change, evaluate it, and feedback the results.

8. **Make some notes.**

   Your final step should be to make some written notes somewhere to refer to in the future. You may think you will remember what you did, but it is unlikely that you will remember every detail. Often, the details make the difference. Share your findings with someone else, they may run into the same problem someday when you are not around.

   Congratulations. You did it!

7.3 Troubleshooting Charts

Lucky for many of us, some paving industry experts have combined their years of field experience and developed some simple-to-use troubleshooting guides, flow diagrams, and booklets. These tools can be very valuable in your own troubleshooting, but remember they are only tools. A chart can't simulate the exact conditions that are creating your problem. Therefore, you still need to go through the process; the charts do speed up the process and help you look at the big picture.

7.3.1 HPH-BG Charts

The first chart was developed by Barber Greene and can be found in Figure 101 on page 3-90 of the HPH.

For example, assume the agency personnel is not pleased with the surface texture of the final wearing course being placed.

Under the "Problem" column, find the "Mat Texture - Non-uniform" and look to the right at the possible causes. They could be the following:

- Fluctuating Head of Material
- Feeder Screws (Augers) Overloaded
- Finisher Speed Too Fast
- Screed Riding on Lift Cylinders
- Screed Plates Worn Out or Warped
- Screed Plate Not Tight
- Cold Screed
- Running Hopper Empty Between Loads
- Screed Extensions Installed Incorrectly
- Vibrators Running Too Slow
- Sitting Long Periods Between Loads
- Improper Mat Thickness for Max. Agg. Size
- Improper Base Preparation
- Improper Mix Design (Aggregate)
- Improper Mix Design (Asphalt)
- Mix Segregation
- Variation in Mix Temperature
- Cold Mix Temperature

That's 18 possible causes for non-uniform mat texture! This is how these charts work. Your mission would be to analyze each of these possible causes and determine if they are valid or not, then suggest the appropriate change. In addition, it is a fact that many states are moving to coarser surface course mixes that just don't look as black, sticky, and tight as the older mixes that were placed for years. Therefore, these mixes will not "look" as uniform as some finer mixes. Just something to think about.

7.3.2 ASTEC Flow Diagrams

The other type of troubleshooting tool is a diagnostic flow chart. Astec Industries developed several types of these charts.

The chart uses a logical step-by-step diagram to lead you through a problem. Again this is just a tool, but can be very helpful.

7.3.3 HMA Paving Handbook

The HMA Paving Handbook has an excellent section on equipment and mat problems (Section 3 pgs. 3-89 to 3-107) which you should become familiar with.

HPH 3-89 | 3-107

7.4 Case Study #7-1: Pavement Preparation -- See Handout.

This case study is a situation regarding pavement preparation where you and your partner represent the agency and the contractor. You choose who will be who, but you may learn more by taking on the role of the opposite, e.g., agency becomes contractor, contractor becomes agency.

You will each be given a handout with certain information pertaining to this situation. You need to read the material, formulate your position, and come to some conclusion with your partner.

7.5 Case Study #7-2: Hauling Problems -- See Handout.

You will each be given a handout with certain information pertaining to this situation. You need to read the material, formulate your position, and come to some conclusion with your partner.

7.6 Case Study #7-3: Placing Problems -- See Handout.

You will each be given a handout with certain information pertaining to this situation. You need to read the material, formulate your position, and come to some conclusion with your partner.

HPH
3-104 | 3-106

7.7 Case Study #7-4: Segregation -- See Handout.

You will each be given a handout with certain information pertaining to this situation. You need to read the material, formulate your position, and come to some conclusion with your partner.

7.8 Summary

To review the troubleshooting process:

1. Stop, step back and look at the big picture.
2. Break the problem into small, definable pieces.
3. Eliminate the obvious.
4. Analyze each piece. Determine if it is a potential contributor.
5. Recombine the pieces.
6. Develop your recommendations based on the available facts.
7. Make changes to the process, ONE-AT-A-TIME.
8. Make some notes.

?

7.9 Review Objectives

1. State the objective of effective troubleshooting;
2. List the steps needed to effectively troubleshoot;
3. Analyze situations and recommend action to be taken.

STOP

7.10 Evaluation

Please complete the Unit 7 Evaluation at this time. Thank you.

8

HPH 3-70 | 3-87

UNIT 8 Compaction (4 hours)

8.1 Introduction

8.1.1 Review Objectives of this Unit

What's-in-it-for-me? The compaction process, which must be closely controlled to achieve a quality pavement, is the last chance you will have to make or break a job. The best pavement design, the latest mix design, and the most sophisticated HMA facility don't stand a chance unless you compact the mix (while it is hot) to the specified density. Compaction determines the ultimate performance of the mix and pavement. Compaction, although simple in concept, is often very difficult to achieve in the field because of a number of variables that affect the ability of the rollers to densify the mix. You must understand what these variables are, and how to control them, in order to ensure that you can achieve density under a variety of conditions.

Which type of rollers are best for overlays? Which are best for leveling? Which are most efficient? How do you select the right roller for the job? With the many types, sizes, and configurations available (of compaction equipment), these questions are not always easy to answer. Because of economics, contractors purchase equipment that they believe will do the best job within a variety of conditions. The real key is to recognize the advantages and disadvantages of each type of roller when selecting one for a project.

Setting up the rolling pattern takes some thought and time to do, and involves much more effort on the part of the operator to maintain consistency over the period of a day. Slow and steady is the right way to do it.

OVERVIEW: During this unit, we will look specifically at what compaction does for a mix design and for a pavement. Also, we will look at the variables and factors that affect the compaction process. Next, we will look specifically at the types of rollers or compaction equipment available and how to pick the best roller for the job. Finally, we will look specifically at the variables facing the compaction process and the importance of keeping rollers maintained.

KEYWORDS: Compaction, Density, Air Voids, Pass, Coverage, Aggregates, Asphalt Cement, Static, Pneumatic, Vibratory, Frequency, Amplitude, Impact Spacing, Contact Pressure, Test Strip, Rolling Pattern, Rolling Zone, Roller Speed.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of compaction;
2. List five engineering properties related to compaction;
3. Identify material and mix properties affecting compaction;
4. List the types of compaction equipment and equipment considerations;
5. Pick the right roller for the job;
6. Identify compaction variables;

7. Identify the main components of compaction equipment maintenance;
8. Calculate roller productivity;
9. Describe proper compaction operating procedures.

METHODS: We will use a combination of video, slides, and lecture to emphasize the main points of this unit. In addition, the problem session will consist of calculating roller productivity.

EVALUATION: You will complete an evaluation of this unit.

8.2 Video

8.2.1 Introduction

The following video tape is several minutes long and stresses the importance of proper compaction when constructing HMA pavements. The objectives of using this video tape are: to relate the live action of your work environment into a classroom, show the real process of compaction, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.

8.2.2 View Video Tape

8.2.3 Questions on Video

Did you see anything wrong with the compaction processes shown in this video?
What seems to be your biggest problem with compaction?
How many rollers do you normally see in a roller train?

8.3 Definitions

8.3.1 Density "A Measurement"

The density of a material is simply the weight of the material that occupies a certain volume of space. For example, an asphalt concrete mixture containing limestone aggregate might have a compacted density of 147 lb/ft^3 (2.36 tonnes/m^3). *This density, or unit weight, is an indication of the degree of compaction of the mixture.*

8.3.2 Compaction "A Process"

Compaction is the process through which the asphalt mix is compressed and reduced in volume. Compaction permits the unit weight or density of the mix to be increased by placing more materials in a given volume of space or by taking a given amount of material and compressing it into a smaller space or volume. As a result of the compaction process, the asphalt-coated aggregates in the mix are forced closer together, which increases aggregate interlock and interparticle friction and reduces the air void content in the mix. The maximum

theoretical density of a mix can be determined from a laboratory test (the Rice procedure, ASTM Test Method D 2041), which is the recommended procedure.

8.3.3 Pass

A pass is defined as the entire roller moving over one point in the mat one time.

8.3.4 Coverage

A coverage is defined as the roller moving over the entire width of the mat one time.

8.3.5 Time Available for Compaction (TAC)

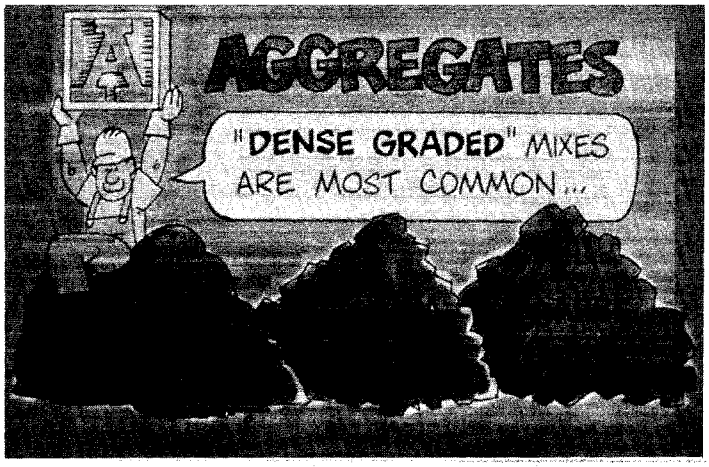
The time available for compaction is the time (in minutes) that a particular mix is at the right temperature range for efficient compaction. Ideally, there is a TAC for breakdown, intermediate, and finish rolling.

8.4 Importance of Compaction

Compaction is the single most important factor that affects the ultimate performance of a hot-mix asphalt pavement. Adequate compaction of the mix increases the fatigue life, decreases permanent deformation (rutting), reduces oxidation or aging, decreases moisture damage, increases strength and stability, and decreases low-temperature cracking. An asphalt mixture that has all the desirable mix design characteristics will perform poorly under traffic if that mix is not compacted to the proper density level.

8.5 Factors Affecting Compaction

8.5.1 Properties of the Materials



8.5.1.1 Aggregates *"The Rock Carries the Load"*

Three properties of the coarse aggregate particles used in an asphalt mixture that can affect the ability to obtain the proper level of density are the particle shape of the aggregate, the number of fractured faces, and the surface texture. As the crushed

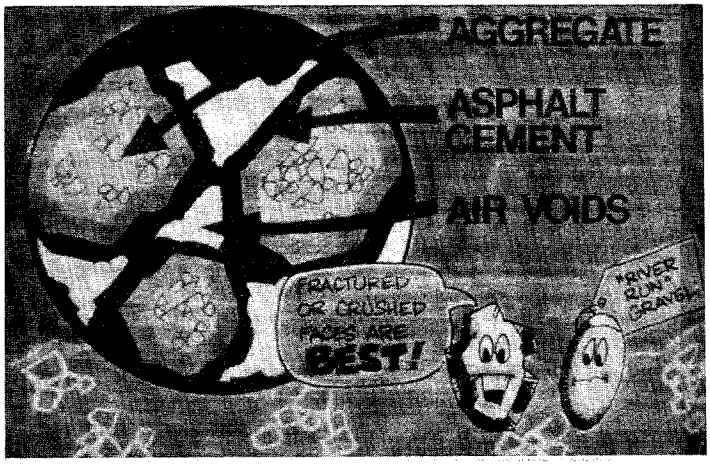
content of the coarse aggregate increases, as the nominal maximum size of the aggregate increases, and as the hardness of the aggregate (granite compared with limestone, for example) increases, the compactive effort needed to obtain a specific level of density also increases. Angular particles offer more resistance to manipulation than do rounded aggregate particles. The compactive effort is also affected by the shape of the aggregate, with a cubical or block-shaped aggregate needing a greater degree of manipulation than a rounded particle shape before achieving a given density level.

A continuously graded (dense-graded) aggregate, from coarse to fine, may be easier to compact than a mixture with any other aggregate gradation. A harsh mix typically requires a significant increase in compactive effort to obtain the desired level of density. An oversanded or finely graded mix, on the other hand, tends to be extremely workable. It still might be difficult to achieve density on such a mix, however, because of the inherent tender nature of such an oversanded mix. A mix designed with a high dust content will generally be more difficult to compact than a mix designed with a lower dust content.

8.5.1.2 Asphalt Cement *"Binds the Rock Together"*

The grade and amount of asphalt cement used in the mix affects the ability to densify the mix. An asphalt cement that is higher in viscosity or lower in penetration will generally provide for a stiffer mix at a given mix temperature and therefore require a greater compactive effort. The degree of hardening that occurs in the asphalt cement during the manufacture of the mix affects the compactibility of that material. The asphalt cement content of the mix influences its compactibility. In general, a mix with too little asphalt cement may be stiff and require an increase in compactive effort, whereas a mix with too much asphalt cement may shove under the rollers.

8.5.1.3 Mix Properties



A mix that is placed at a higher temperature will be easier to compact than will a mix that is lower in temperature when it is laid. The workability of the mix is affected by the temperature susceptibility of the asphalt cement. The fluids content of the mix, not just the asphalt content, affects the compactive effort needed. Fluids content is the sum of the asphalt cement content and the moisture content of the mix. The moisture content of the mix should be less than 0.5 percent, by weight of mix, when the mix is discharged from the plant.

8.5.2 Environmental Variables

Research work completed in the early 1970s determined the time available for compaction of various asphalt concrete mixes. The time available for compaction was defined as the time, in minutes, it took for a mix to cool from laydown temperature to a minimum compaction temperature. Laydown temperature is the mix temperature when the paver screed passes over the mix. Minimum compaction temperature for this study was set at 175°F. Below this temperature, it was found that the internal friction and cohesion of the mix increases to the point that little density gain is achieved with the application of additional compactive effort.

Six variables were found to have an effect on the rate of cooling (and, therefore, on the possibility of obtaining a required level of density) of a layer of asphalt placed on top of another existing layer of the same type of material. Those variables are: layer thickness, air temperature, base temperature, mix temperature, wind velocity, and solar flux.

A series of "cooling curves" for asphalt concrete mixtures illustrate the amount of time available for compaction under different combinations of variables. For these two figures, it is assumed that the material being compacted is a dense-graded asphalt concrete mix. Ambient air temperature is assumed to be equal to the surface temperature of the base. A constant wind velocity of 10 knots (about 11.1 miles/hr) and a constant degree of solar radiation (solar flux of 50 BTU/ft²/hr) is also used to generate the graphs. The curves then provide the time, in minutes, for the mix to cool from the laydown temperature to the minimum compaction temperature (175°F) for different compacted layer thicknesses.

Note: The charts listed below and following discussion use the inches and degrees Farenheit. To convert to s.i. units, refer to the charts in the "TIPS" booklet.

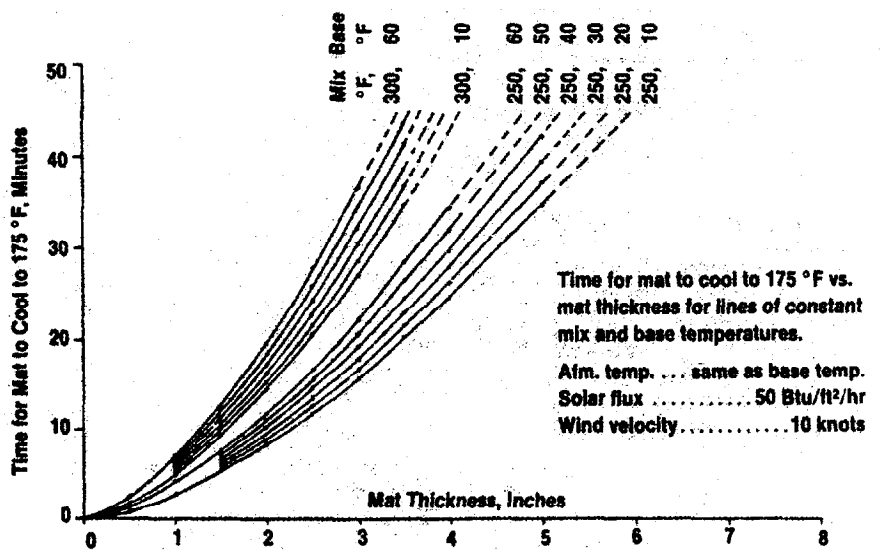


Figure 3-89. Time for mat to cool to 175°F vs. mat thickness for lines of constant mix and base temperatures (225°F or 275°F behind paver) *(Dickson and Corlew; AAPT 1970)*.

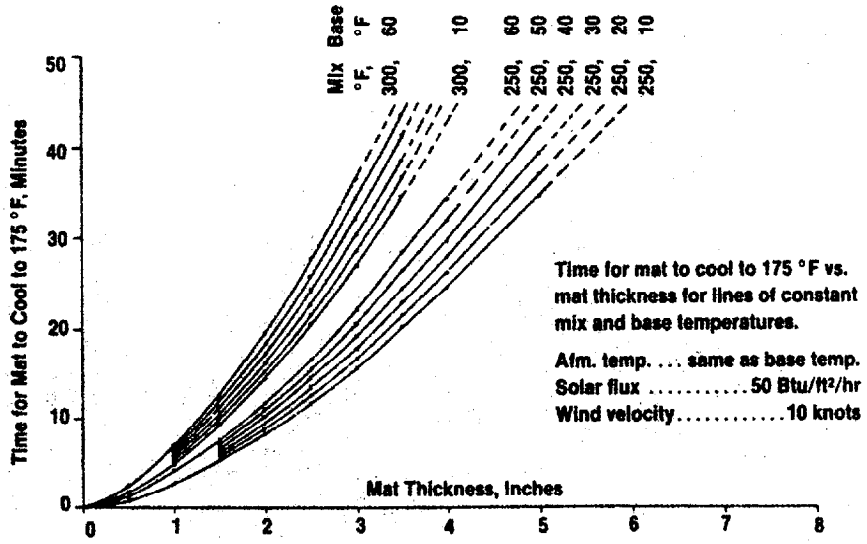


Figure 3-89. Time for mat to cool to 175°F vs. mat thickness for lines of constant mix and base temperatures (225°F or 275°F behind paver) *(Dickson and Corlew; AAPT 1970).*

8.5.2.1 Layer Thickness *"Thickness ↑ = TAC ↑ "*

Layer thickness is probably the single most important variable in the rate of cooling of asphalt mixtures, especially for thin lifts. It is very difficult to obtain the desired density on thin lifts of mix in cool weather because of the rapid loss in temperature in the mix. For example, for a mix laydown temperature of 250°F and a base of 40°F, a 1-in.-thick mat will cool from that 250°F temperature to the 175°F compaction cutoff point in less than 4 min. For a 2-in.-thick layer, under the same mix and base temperature conditions, it will take about 10 min for the material to cool to 175°F.

8.5.2.2 Air and Base Temperature *"Temperature ↑ = TAC ↑ "*

A portion of the heat in the asphalt layer is lost to the air. All other factors being equal, an increase in the ambient air temperature decreases the rate of cooling of the mix. Heat in the mix is also lost to the layer on which the new material is placed. There usually is more rapid cooling of the mix downward to the base than upward into the air. Base temperature is actually more important than air temperature in determining the time available for compaction. It is often assumed that air and base temperature are the same. This is not necessarily true, particularly in cool weather. A moist base layer significantly increases the cooling rate of the new overlying asphalt layer. Heat is lost from the mix to the moisture, turning water into steam and increasing the rate of heat transfer.

8.5.2.3 Mix Laydown Temperature *"Temperature ↑ = TAC ↑ "*

Asphalt mixes are usually produced at temperatures between 270 °F and 325 °F. Depending on environmental conditions and the length of haul, the mixture can lose between 5 °F and 25 °F from the plant to the paver. As the temperature of the hot-mix asphalt being placed is increased, the time available for compaction is greater.

For a lift thickness of 2 in. and a base/air temperature of 40°F, the time to cool to 175°F increases from 9 min. to 16 min. as the placement temperature increases from 250°F to 300°F. For a 4-in. course thickness and a 60°F base/air temperature, a change in laydown temperature from 300°F to 250°F reduces the time available for compaction from 36 min. to 21 min. The effect of mat laydown temperature is more significant at lesser mat thicknesses and lower base temperatures.

8.5.2.4 Wind Speed *"Wind Speed ↑ = TAC ↓"*

A thin layer of mix will cool more quickly in a strong wind than when there is little or no wind. Wind has a greater effect at the surface of the mix than within the mix, and can cause the surface to cool so rapidly that a crust will form.

8.5.2.5 Solar Flux *"Sunny Day = TAC ↑"*

The amount of radiant energy available from the sun (solar flux) is a function of many variables, including the position of the sun above the horizon, the distance above sea level of the paving project, the amount of turbidity in the air, and the degree of cloud cover. A mix will cool more slowly on a sunny day compared with a cloudy one. The amount of solar flux is more important in its effect on base temperature than its effect on mix temperature.

8.5.3 Laydown Site Conditions

A number of factors at the laydown site directly affect the ability of the compaction equipment to gain the required level of pavement density. The relationship between lift thickness and nominal maximum aggregate size in the mix is another variable that affects the amount of density that can be obtained. The uniformity of the lift thickness is another factor to be considered. It is much easier to obtain a required level of density in an asphalt layer that has a constant thickness compared with a course that varies in depth. Asphalt leveling courses that, by their very nature and purpose, are nonuniform in thickness, are often difficult to densify to a given air void content uniformly, especially when placed over a rutted or wavy road.

8.6 Types of Rollers

The type of equipment used to compact the asphalt mix obviously has a significant effect on the degree of density that can be obtained in a given number of passes of a particular roller. Three types of self-propelled compaction equipment are currently being used: static steel wheel rollers, pneumatic tire rollers, and vibratory rollers.

8.6.1 How Do Rollers Compact?

Rollers compact by applying their weight over the area of the drum/tires that touch the mat (contact pressure). The process packs the aggregate particles together and removes most of the air voids. Each roller type applies contact pressure slightly differently, but the concept is the same.

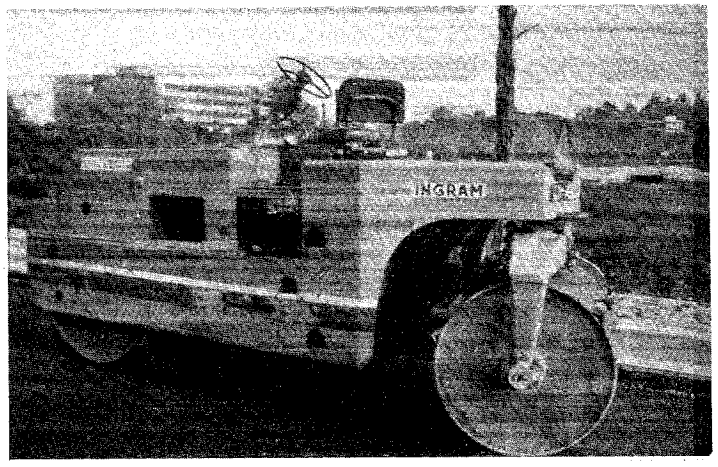
At the beginning of the compaction process, mixes have relatively low bearing capacity because the aggregate particles are not yet in contact due to the significant amount of air voids that exist. For example: if you walk across a new mat (not recommended) you will sink in because you exert a higher contact pressure (your weight divided by the area of the sole of your boots) than bearing capacity of the mix.

As the roller passes over the mix repeatedly, the aggregate particles are packed closer together, the excess air is removed, the asphalt cement cools and acts more like a glue than a lubricant, and the bearing capacity of the mix increases.

When the bearing capacity of the mix equals the contact pressure exerted by the roller, the roller has "walked-out" of the mix. Further roller coverages may be necessary to further increase the mix density, orient the aggregate particles, seal the surface, and finally, "iron" out the roller marks.

In theory, that is how rollers compact. In practice, it isn't quite so simple because of the many compaction variables involved. In addition, most high-type asphalt concrete mixes are difficult to compact and new techniques and methods are constantly being tried to achieve the specified density. Nothing is set in stone anymore!

8.6.2 Static Steel Wheel Roller



Static steel wheel rollers normally range in weight from 3 to 14 tons (2.7 to 12.7 tonnes) *and have compression drums or rolls that vary in diameter from approximately 40 in. to more than 60 in.* (1.0 to 1.5 m) *The gross weight of the roller can usually be altered by adding ballast to the roller, but this adjustment cannot be made while the roller is operating, and is not normally changed during the term of a paving project.*

8.6.2.1 Pounds Per Linear Inch

Static rollers are often specified having a certain pound per linear inch of roller width or p.l.i. (the p.l.i. rating is the contact pressure (psi) at a contact arc of one inch). However, the weight is not equally distributed on both drums.

Example: a 12-ton roller with two, 50-inch wide drums. In this case, 60% of the weight is on the drive drum and 40% is on the guide drum. This varies between manufacturers.

☞ Your turn! Calculate what the p.l.i. should be.

Drive drum = 12 tons x 2000 lbs/ton x .60 ÷ 50 inches = _____ p.l.i.
Guide drum = 12 tons x 2000 lbs/ton x .40 ÷ 50 inches = _____ p.l.i.

The old standard 3-wheel roller (two large-diameter drive drums and one small-diameter steering drum) have very different p.l.i. ratings. Between the drums, this produces an uneven density profile across the width of the entire drum. The full width of this roller is not truly available for calculating compaction production rates, and would be less efficient than a narrower roller with a uniform p.l.i.

8.6.2.2 Contact Pressure

Effective weight or contact pressure, in terms of pounds per square inch of contact area, is the key variable for this type of equipment and is dependent on the depth of the penetration of the rolls into the mix. The greater the depth of penetration, the greater the contact area and thus the less the contact pressure.

The table below illustrates how the roller contact pressure increases as the mix's internal strength increases during the compaction process. Look at a typical 12-ton roller. As the roller makes its first pass, the contact pressure may range from 46 to 36 psi as the drum sinks in 1/2 to 3/4 of an inch, depending on the initial stiffness of the mix. As additional passes are made, the mix becomes stiffer as the aggregate is packed together and the air voids are reduced. The drum eventually "walks out" of the mix and the contact pressure becomes extremely high. At 1/16" penetration, the contact pressure reaches 132 psi (a 266 percent increase over an original contact pressure at 3/4 inch penetration)!

Roller Contact Pressure at Penetration Depths

In Pounds Per Square Inch

STATIC ROLLER TYPE	1/16"	1/8"	3/16"	1/4"	1/2"	3/4"
Two Axle Tandem 270 p.l.i. - Drive 190 p.l.i. - Guide						
8.5 ton (less ballast)	96	64	53	45	33	26
12 ton (with ballast)	132	88	74	63	46	36

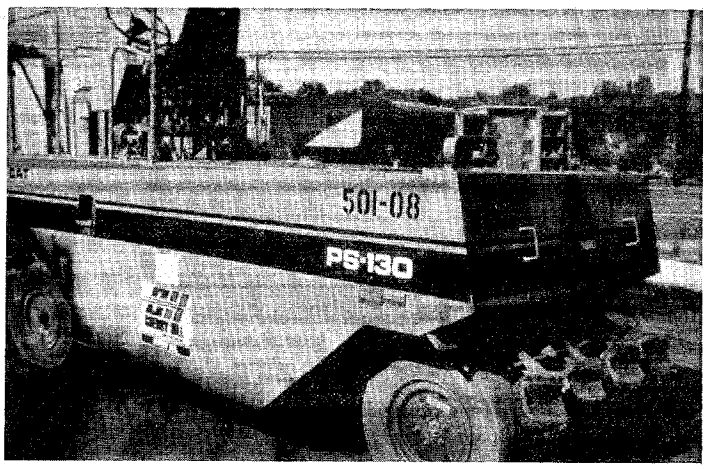
Note: To convert to kPa; multiply psi x 6.8946. (Ref. NAPA)

8.6.2.2 Operation

Drawbar pull is defined as the horizontal force required to move the roller forward. Rollers with large-diameter rolls have lower drawbar pull (rolling resistance) because they do not tend to penetrate as far into the mix as does a roller with smaller-diameter rolls.

Once the size and weight of a static steel wheel roller is selected, the variables under the control of the roller operator are the speed of the roller, the position of the roller on the mat in relation to the paver, operation with the drive wheel toward the paver, and the number of passes made with the roller.

8.6.3 Pneumatic (Rubber Tire or Traffic) Roller



Most pneumatic rollers are operated in the intermediate roller position, behind a vibratory or static steel wheel breakdown roller and in front of a static steel wheel finish roller. These rollers are sometimes used, however, for initial rolling of the mix as well as occasionally for finish rolling.

8.6.3.1 Tire Inflation Pressure Versus Ground Contact Pressure

For this type of roller, the compactive effort applied to the mix is a function of the wheel load of the machine, the tire pressure, the tire design (tire size and ply rating), and the depth of penetration of the tires into the mix. All of the tires on the roller should be the same size, ply, and tire pressure. The area of each tire footprint and the wheel load of the roller are the primary factors in judging the effectiveness of a rubber tire roller. The greater the contact pressure between the tire and the mix, the greater the compactive effort applied by the roller.

8.6.3.2 Tire Pressure

The tire pressure used depends in part on the number of plies used in the tires. If the mix is tender, a lower tire pressure will displace the mix less than will a higher pressure in the tires. For a stiff mix, a higher tire pressure can be used, because the mix will be stable enough to support the weight of the roller without the mix shoving laterally under the tires. Tire pressure is normally kept constant for a particular project, but the level selected should be dependent on the properties of the mix being compacted and the position of the roller on the mat. The tire pressure should not necessarily be the same if the pneumatic tire roller is used in the breakdown position compared with the intermediate position in the roller train.

The compactive effectiveness of pneumatic rollers can be varied by adjusting the tire inflation pressure and/or ballast on the roller. The following examples illustrate this point.

Inflation Pressure and Ground Contact Pressure at Various Wheel Loads and Ply Ratings (7:50 x 15 Tire)

Example	Ply Rating	Wheel Load (pounds)	Tire Pressure (psi)	Contact Area (in^2)	Ground Contact Pressure (psi)
A	14	1250	130 (max)	16	78
	14	2800	130 (max)	30	92
B	14	2300	35 (min)	41	56
	14	2300	130 (max)	26	88
C	10	2800	90 (max)	38	73
	14	2800	130 (max)	30	92

Note: To convert to kPa, multiply psi x 6.8946 (Ref. HYSTER)

Example A: Changing wheel loading. Increasing the wheel load from 1250 pounds per tire to 2000 pounds per tire, while keeping the inflation pressure constant, will increase the contact pressure of the tire from 78 psi to 92 psi (a 18 percent increase from the original).

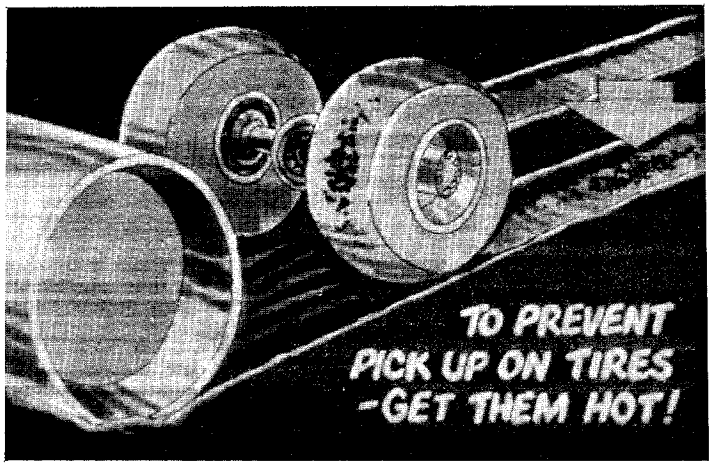
Example B: Changing inflation pressure. Increasing the inflation pressure from 35 psi to 110 psi, while maintaining a constant load of 2300 pounds per tire, will increase the contact pressure from 56 psi to 88 psi (a 57 percent increase from the original).

Example C: Changing 1 ply rating. Increasing the ply rating (changing tires) from a 10 ply tire to a 14 ply tire and inflating them to the maximum inflation pressure will increase the contact pressure from 73 to 92 psi, a 26 percent increase.

In general, if the contact pressure of the pneumatic roller is to be adjusted during paving, it is adjusted by varying the inflation pressure in the tires. It is important to **keep all the tires at the same inflation pressure**, and check them daily.

8.6.3.3 Mix Pick-Up

The tires on the pneumatic roller will often pick up the mix when an oversanded surface course mix or a mix with some particular additives is being compacted. Many times attempts are made to eliminate this pickup problem by spraying water or a release agent on the tires during the rolling process. This does not always solve the problem. A better solution is to allow the tires on the roller to reach the same temperature as the mix being compacted without adding water or release agent to the tires. Skirts are sometimes hung down from the sides of the roller around the tires for the purpose of shielding the tires from the wind and keeping them hotter.



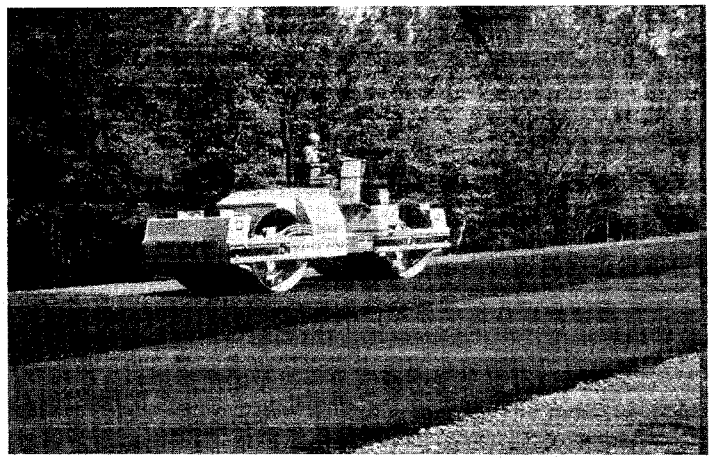
8.6.3.4 Operation

Once the size of the pneumatic tire roller and the tire pressure to be used are selected, the only variables that can be controlled easily by the operator are the rolling speed, the location of the roller with respect to the paver, and the number of roller passes over each point in the pavement surface. If the compactive effort applied by the pneumatic tire roller is not adequate, the operator should alter the wheel load on the tires and/or change the inflation pressure in the tires.

Pneumatic rollers are ideally suited for compacting leveling courses of mix laid on an uneven base. The independent action of each wheel aids in producing a uniform density on this type of surface. A steel drum may bridge over an area, leaving some areas at a lower density.

The key to using a pneumatic tire roller is to **get the tires hot and keep them hot** by keeping the roller moving.

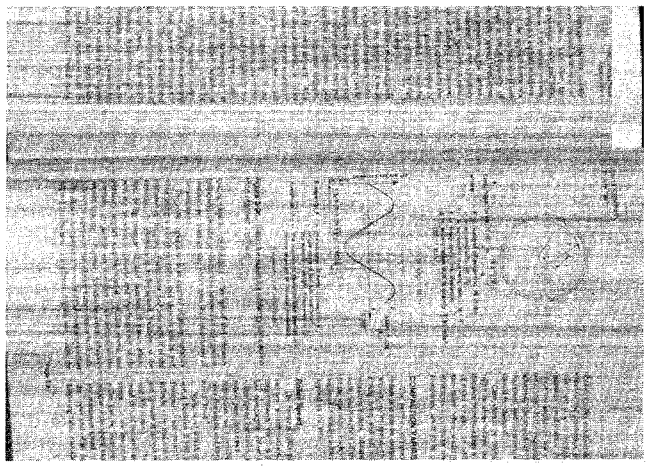
8.6.4 Vibratory Roller



Vibratory rollers come in a variety of configurations. Single-drum vibratory rollers are manufactured with both a rigid frame and an articulated frame. Double-drum vibratory rollers come in rigid-frame, single-articulated-frame, and double-articulated-frame models. These rollers can be operated in any one of three modes: static (with the vibrators off), with one drum vibrating and one drum static, and with both drums vibrating.

These rollers thus have two types of compactive force that is applied to the hot-mix asphalt: static weight and dynamic (impact) force. The compactive effort derived from the static weight of the roller is caused by the weight of the rolls and frame. The compactive effort derived from the impact force is produced by a rotating eccentric weight located inside the drum (or drums). As the eccentric weight rotates about the shaft inside the drum, a dynamic force is produced. Changing the eccentric moment arm or adjusting the eccentric mass has a directly proportional effect on the dynamic force.

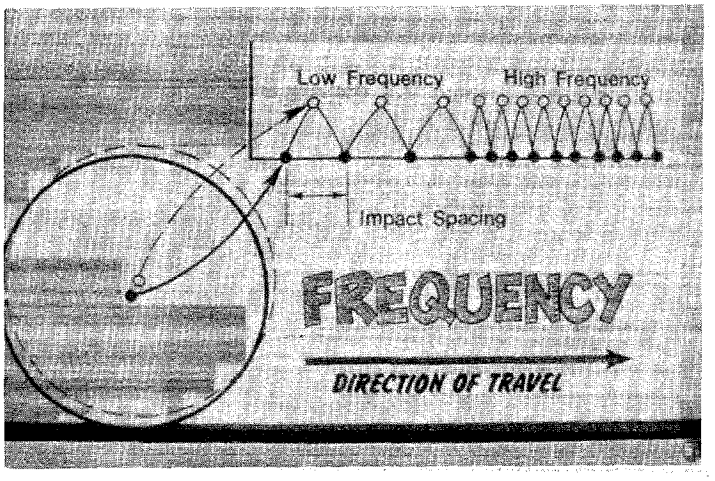
8.6.4.1 Amplitude *"How High"*



The elements of comparison for the dynamic component of a vibratory roller are the magnitude of the centrifugal force, its vibrating frequency, the nominal amplitude, and the ratio of the vibrating and nonvibrating masses acting on the drum. The nominal amplitude is defined as equal to the weight of the drum divided by the eccentric moment of the rotating weight and is a function of the weight of the drum and the location of the eccentrics. Normal values of nominal amplitude range from 0.01 to 0.04 in. (0.25 to 1.0 mm) *Some rollers can operate at only one fixed amplitude. Other rollers have "high" and "low" amplitude positions.*

Still other rollers have 3 amplitude settings.

8.6.4.2 Frequency *"How Often"*



As the layer thickness increases, it is often advantageous to increase the nominal amplitude applied to the asphalt mix. Unless "high" amplitude is needed to achieve a particular density level, the vibratory roller should be operated in "low" amplitude. The frequency of vibration is the number of complete cycles that the eccentrics rotate per minute. The faster the rotation of the eccentrics, the greater the frequency of vibration. Some vibratory rollers can operate at only one frequency or have a very limited selection of frequencies. Other vibratory rollers can alter the frequency of the applied load between 1600 and 3000 vibrations/min. Frequencies below 2000 vibrations/min are not normally acceptable to compact asphalt mixtures.

Typical Data for Vibratory Tandem Rollers

Vibratory Steel Tandem	oper. wt. (lbs.)	drum diam. (in.)	drum width (in.)	static drum (p.l.i.)	dynamic drum (p.l.i.)	vpm	nom. amp. (in.)
6-8 ton	14700	41.5	56.5	130	260	2900	.025
9 1/2-11 ton	20500	48	66	155	380	2600	.030
> 13 ton	30000	59	84	185	420	2400	.030

(Ref. NAPA)

8.6.4.3 Impact Spacing

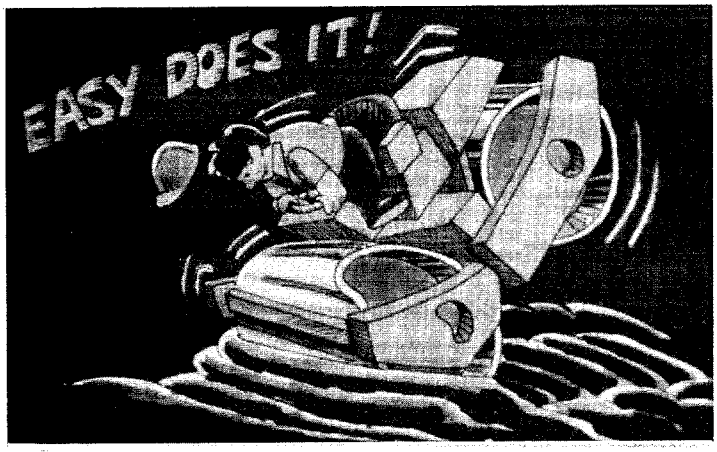
The spacing of the impacts of the applied force is a function of the frequency of the vibration and the travel speed of the roller. A smaller impact spacing (a greater number of impacts per foot) is thus usually preferred.

A recent survey of major roller manufacturers recommended the following impact spacings. The impact spacing should be in the range of 10 to 12 impacts per foot (1.2 to 1.0 inches between impacts (30 to 25 mm)) to ensure

the highest efficiency of the vibratory rollers and reduce the possibility of leaving ripples in the finished pavement.

Remember: The combination of proper impact spacing (frequency and speed) and amplitude settings is the key to maximizing the efficiency of the specific vibratory roller.

In general, the vibratory roller should be operated at as high a frequency as possible. The use of the highest possible frequency of vibration increases the number of impacts per foot at a given roller speed.



8.6.4.4 Operation

The roller operator is in control of more variables when using a vibratory roller and thus should be well educated in the proper selection and interaction of the variables. In addition to roller speed, location on the layer being compacted, and number of passes made, both the nominal amplitude and the frequency of the vibratory impact can be varied. Roller speed and vibratory frequency are combined to determine the impact spacing. Further, for double-drum vibratory rollers, the operator can vibrate either one or both rolls. Care should be taken when operating a vibratory roller in areas where buildings are nearby. In addition, the use of vibration on the roller when underground utilities and drainage structures are directly under the pavement layer being compacted needs to be considered carefully.

8.6.5 Maintenance

8.6.5.1 Water Systems

The water system is designed to keep the mix from sticking to the drums or tires. It must be fully operational and well maintained at all times. The water system is typically the highest maintenance item on a roller.

Whether gravity feed or pressure feed, only enough water should be used to keep the drum wet. Any more water is wasteful and will require the roller to be out-of-service more frequently while re-watering. For pressure fed systems without a gravity flow backup, keeping an additional water pump available is a good idea.

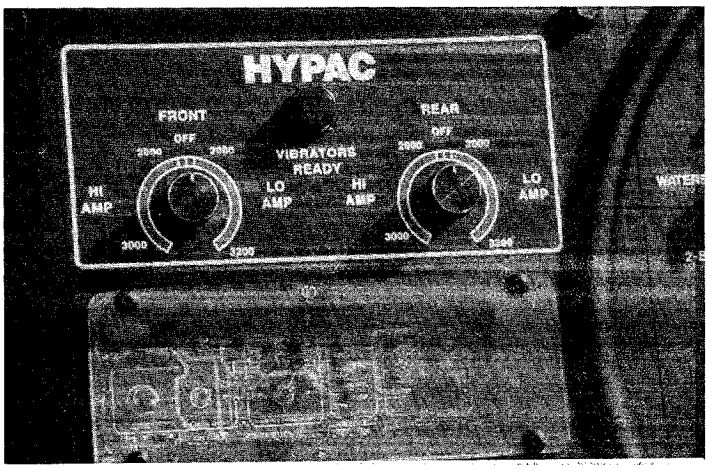
8.6.5.2 Hydraulic Systems

Most rollers operate extensively by hydraulics and the importance of keeping these well maintained is vital. Consider the hydraulic fluid the life blood that keeps rollers running. If a heart attack (damaged hydraulic pump), blockage (dirty filter), or rupture (broken line or fitting) occurs, the roller is down. If a roller is placed out of service, either a back up roller must be available or the production rates must be changed.

8.6.5.3 Mechanical Systems

A broken roller is no roller. Again, proper maintenance will minimize down time.

8.6.5.4 Vibratory Systems



Vibratory rollers are a different animal compared to other rollers. The vibration that is imparted into the mat is not without cost. Increased maintenance, particularly at vibration isolation points, and a potential for more wear and tear because the machine is vibrating, are concerns. The VPM should be monitored over time because internal wear can effectively reduce the VPM.

A vibrating reed-type tachometer shown here is an excellent tool to verify the performance of a vibratory roller system. For under $300, it is an inexpensive investment, especially when working with difficult to compact mixes. Other types are available and some rollers have a tachometer mounted directly on the roller.

8.6.5.5 Rolls, Tires, Pads, Scrapers

Rolls should be inspected for wear or damage. Tires must be inflated properly. Pads do wear out and need to be replaced periodically. It is a good idea to have spares, especially with pneumatic rollers. Scrapers wear down and need to be replaced. Replacement scrapers should be made of softer material than the drums or tires or else they may gouge the surface.

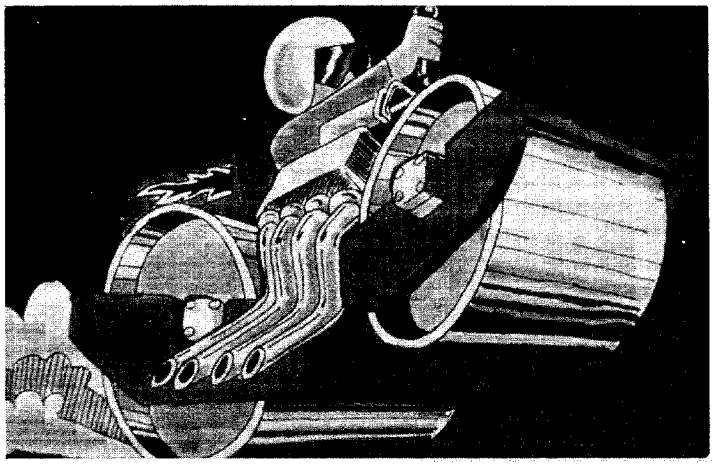
8.6.5.6 Checklists

A checklist for roller maintenance can be found in the Appendix (Form 8-1).

8.7 Compaction Variables

The primary compaction variables for all types of rollers that can be controlled during the rolling process are: (a) roller speed, (b) number of roller passes, (c) rolling zone, and (d) roller pattern. In addition, for vibratory rollers, vibration frequency, vibration amplitude, and direction of travel are also under the control of the operator. Each of these factors has an effect on the level of density achieved under the compactive effort applied to the mix.

8.7.1 Roller Speed



The faster a roller passes over a particular point in the new asphalt surface, the less time the weight of the roller "dwells" on that point. This in turn means that less compactive effort is applied to the mixture. As roller speed increases, the density achieved with each roller pass decreases. The roller speed selected is dependent on a combination of factors: productivity, layer thickness, and the position of the equipment in the roller "train."

Static steel wheel rollers can normally operate at a speed between 2 and 5 miles/hr (176 and 440 ft/min). *Pneumatic tire rollers typically run between 2 and 7 miles/hr* (176 and 616 ft/min), *whereas vibratory rollers can operate at speeds between 2*

and 3 1/2 miles/hr (176 and 308 ft/min) (3.2 to 5.6 km/hr). *The following table provides an indication of the range of roller speed for three different types of rollers and three different operating positions:*

Typical Range of Roller Speeds, in Miles Per Hour

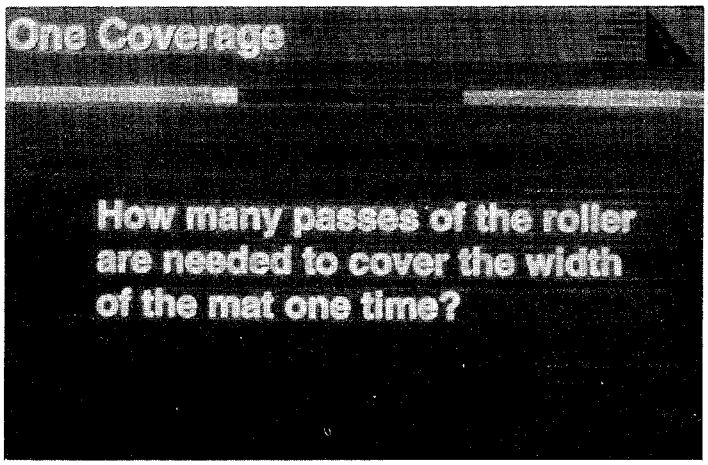
Type of Roller	Breakdown	Intermediate	Finish
Static Steel Wheel	2 to 3-1/2	2-1/2 to 4	3 to 5
Pneumatic	2 to 3-1/2	2-1/2 to 4	4 to 7
Vibratory	2 to 3	2-1/2 to 3-1/2	-----

Note: To convert mph to kilometer per hour, multiply by 1.61.

Compactive effort is significantly improved at slower roller speeds. Roller speed will also be governed by the lateral displacement or tenderness of the asphalt mix. If the mixture moves excessively under the rollers, the speed of the compaction equipment should be reduced. In addition, for vibratory compactors, roller speed also affects the impact spacing. Roller speed is usually established by the speed of the paver. Varying the speed of the compaction equipment merely causes variations in density. "Slow and steady" is the key to proper compaction.

8.7.2 Number of Coverages

To obtain the target air void content and uniform density in an asphalt mixture, it is necessary to roll over each point in the pavement mat a certain number of times. The actual number of passes depends on many variables. The type of compaction equipment is one very important consideration. The capabilities of each type of roller vary, however, with mat thickness, mix temperature, mix design (asphalt content and aggregate characteristics) and environmental conditions. In addition, the number of passes required depends on the position of the rollers in the roller train. To determine the minimum number of roller passes needed to achieve proper density levels, a test strip should be constructed at the start of any major paving project. A number of different combinations of rollers and roller patterns should be tried to determine the "optimum" combination of compactive efforts to achieve the required density level as efficiently as possible. Rarely will the first combination of rollers, roller passes, and rolling zones tried provide the most economical rolling sequence unless the mix is one with which the contractor is thoroughly familiar.



A nuclear density gauge can be employed to determine the optimum number of roller passes necessary to obtain the required density level. If this piece of equipment is used, however, a proper correlation to the actual density of the asphalt pavement layer, measured by cores, must be completed to assure that the density measured by the nuclear gauge is equal to or greater than the specifications requirements.

8.7.3 Rolling Zone

Compaction must be achieved while the viscosity of the asphalt cement in the mix and the stiffness of the mix is low enough to allow for reorientation of the aggregate particles under the action of the rollers. In other words, the mat must still be hot for effective compaction. The rule of thumb commonly used is that the proper level of air voids should be obtained before the mix cools from laydown temperature to 175 °F (80 °C).

To reach the required density level the quickest, initial compaction should occur directly behind the laydown machine. If the stability of the asphalt mixture is high enough, breakdown rolling can be carried out very close to the paver, while the mat temperature is still high. More density is obtained with one pass when the mix temperature is 250 °F (121 ºC) *than with a similar pass when the mat is at 220 °F* (104 °C).

Sometimes when a tender mix is placed, the initial rolling is delayed (the rolling zone is lengthened) to avoid excessive shoving or checking of the mix by the rollers. Depending on the characteristics of the mix, it is still often possible to obtain the required level of density of the mix as long as the proper combination of rollers and compactive effort is applied to the mix. In some cases, however, the mix is so tender that rolling must be delayed to the point that the desired density level cannot be achieved. In this case, other solutions need to be tried.

A method estimating how long this zone should be is discussed later, but in general it is about 250 feet (76 m).

8.7.4 Rolling Pattern

Rollers are "busy" most of the time on a paving project. The question is whether they operate correctly and effectively. Generally, compaction is applied, but not necessarily in the right place. Numerous compaction studies have shown that the middle of the width of the paver pass typically receives more compactive effort than the edges of the pavement. This is unfortunate, because traffic uses the wheelpath areas and travels near the edge of the pavement more often than in the center of a lane.

8.8 Operating Techniques

8.8.1 Transportation

Equipment must be transported safely and in accordance with manufacturers recommendations. Some states do not allow steel drum rollers to travel on bridge decks. In this case, adequate transportation must be in place to move rollers as the project requires.

8.8.2 Test Strip Construction

The actual rolling pattern to be used to compact the mix on a paving project should be determined at the start of the project through the construction of a roller test strip. This strip should be located at a convenient point where the pavement layer placed will remain as part of the final pavement structure. The mix should be representative of the material to be produced for the project; generally the plant should produce mix for a short period of time before mix is made for the compaction test section. The thickness of the layer compacted should be the same as that to be used for the rest of that particular layer, and the length of the test strip should be at least 300 ft (92 m). *The condition of the underlying layers should be representative of that on the rest of the project.*

After the rolling pattern is established, a control strip is then utilized by some specifications to establish a correlation between nuclear and core density as discussed in Unit 10.

8.8.2.1 Simulating Actual Production Conditions

Due consideration should be given to the selection of rollers that are to be employed to densify the pavement layer. The combination of rollers used on a previous project might not be the most cost-efficient or effective for the variables involved in the present job. Although vibratory rollers are usually used for breakdown rolling and pneumatic tire rollers for intermediate rolling, a greater degree of density with a lesser number of total roller passes might be obtained on some mixes (e.g., when a large pneumatic tire roller is used in the breakdown position with the vibratory roller following in the intermediate position). Determination of the "optimum" combination of rollers and roller patterns might require the construction of two or more test sections.

8.8.2.2 Establishing Roller Pattern

Different mixes may require considerably different levels of compactive effort and thus different compaction equipment and rolling procedures. An asphalt mix containing large aggregate, for example, may need different types of rollers to achieve a required level of density than an asphalt concrete mix made with smaller-size coarse aggregate.

8.8.2.2.1 Selecting Compaction Equipment

For each roller employed on a project, the mat width can be divided by the width of the compaction rolls to determine the number of passes needed to cover each transverse point in the surface. A pass is defined as one trip of the roller in one direction over any one spot. Multiple passes are needed to completely compact the transverse width of the lane being paved as well as over each point in the pavement surface to assure attainment of the required level of density.

If a large pneumatic tire roller is used in the breakdown position, it is generally difficult to determine the degree of density obtained in the mat through the use of a nuclear gauge because of the rough texture of the mat after the first several passes of the pneumatic tires. Nuclear readings must be taken after the mix has been smoothed out with the intermediate roller.

Roller Types by Application Mode

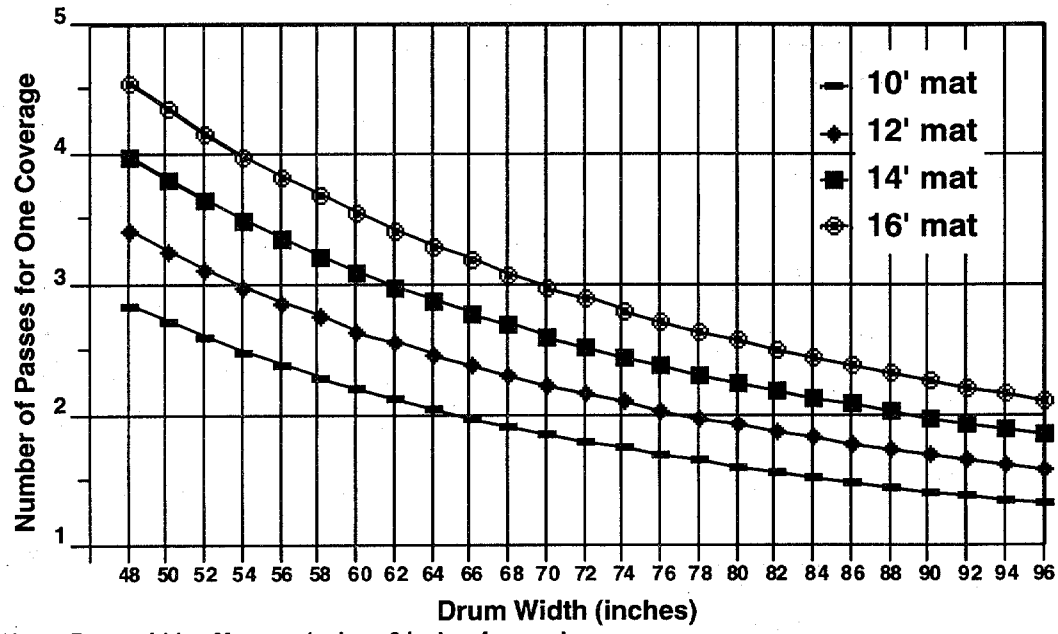
Breakdown Types	Intermediate Types	Finish Types
3 Wheel Static	3 Wheel Static	3 Wheel Static
Tandem Static 8-10-1/2 ton 8-12 ton 10-14 ton	Tandem Static 8-12 ton 10-14 ton	Tandem Static 8-10-1/2 ton 8-12 ton 10-14 ton
Pneumatic Rollers 20" rim 24" rim	Pneumatic Rollers 15" rim 20" rim 24" rim	Pneumatic Rollers 15" rim 20" rim 24" rim
Vibratory Tandem 10-11 ton > 12-1/2 ton 6-8 ton	Vibratory Tandem 6-8 ton 10-11 ton > 12-1/2 ton	Vibratory Tandem: Static Mode 6-8 ton 10-11 ton > 12-1/2 ton
Single Drum 6-8 ton 10-11 ton	Single Drum 6-8 ton 10-11 ton	

Note: To convert short tons to metric tonnes, multiply tons x 0.909 (Ref. NAPA)

8.8.2.2.2 Width of Paving

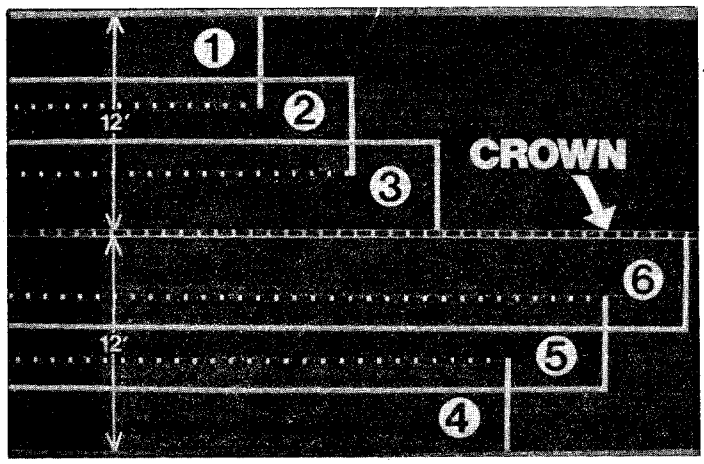
Standard paving widths of 10, 12, 14, and sometimes 16 ft (3.1, 3.7, 4.3, 4.0 m) can affect the efficiency of certain rollers. Ideally, the roller that can cover the width of paving with the fewest number of passes will be the most efficient. Other smaller width rollers are routinely used, but the number of total passes will increase. For example, look at the following graph.

Drum Width vs. Lane Width



Note: Drum width = Measured minus 6 inches for overlap

8.8.2.2.3 Width of Roller



If the width of the roller drums (or tires) is 84 in. (7 ft), only two passes of the roller are needed to cover the 12-ft-wide lane, including a 6-in.-wide overhang at each edge of pavement. A roller that is 72 in. (6 ft) wide cannot cover the complete 12-ft lane width in only two passes. Three passes of the 72-in.-wide roller would be necessary to properly compact the lane, as shown in the third line of the figure. If the roller had drums or tires that were 60 in. (5 ft) in width, three passes of the roller would be required, similar to the roller with the 72-in.-wide drums. A roller with drums that are 54 in. would need to make four passes across the width of a 12-ft lane in order to completely cover the lane width.

8.8.2.2.4 Number of Repeat Coverages to Achieve Density

The number of roller passes needed over each point on the pavement surface is a function of a large number of variables. One of the most important variables is the level of density required in the pavement layer. If a certain percentage of

laboratory density or theoretical maximum density is needed, the higher the required percentage, the more compactive effort that will have to be applied to the pavement layer.

8.8.2.2.5 Monitoring with a Nuclear Density Gauge

The most common method for monitoring changes in density with roller passes is through the use of a nuclear density gauge. Density is estimated by transmitting gamma rays into the mix and measuring the amount of radiation reflected back to the device in a given amount of time. The count data that are obtained can be related to the relative density of the layer. Nuclear gauge readings should be taken after each pass of each roller, and the rate of increase in density after each pass determined. When no appreciable increase in density is obtained with the application of additional roller passes, the maximum relative density for that mix has been obtained. When a pneumatic tire roller is used in the compaction process, particularly in the breakdown mode, it is often very difficult to obtain an accurate density reading with a nuclear gauge. One or more passes with a steel wheel roller may be necessary before a valid nuclear gauge reading can be obtained.

The density value determined with the nuclear gauge is relative and is generally not the same as the density value obtained from cores cut from the pavement. Thus a correlation must be developed between the nuclear density reading and the actual unit weight of the pavement. That unit weight must be compared to the maximum theoretical unit weight of the mix in order to calculate the actual in-place air void content of the layer.

8.8.2.2.6 Your Friend, the Thermometer

If you are monitoring compaction, one of the most important tools you should have at your side is a thermometer, preferable several. In addition, you should know how and when to use it, and finally you should use it!

8.8.2.2.6.1 Types of Thermometers

There are several types of thermometers available but all do the same thing... they measure temperature. The more expensive ones tend to do it faster. Whichever model you decide, make sure it reads the range you need for compaction (say 50 to 350 °F), and the increments are reasonable (no more than 5 °F intervals); this translates to 10 to 177 °C in 2 °C intervals. Just about every laboratory supply store sells these. Don't just buy one, buy them by the dozen.

For less than $15, you can buy a 1 inch diameter x 5 inch analog dial thermometer that clips to your pocket. They range from 50-500 °F in 5 °F increments (0 to 250 °C ± 2 °C). They are easy to handle and give you a reasonable measurement (this isn't rocket science -- you don't need it to two decimal points). Also <u>when</u> they break, get crushed, or disappear you don't have to mortgage your house to get a new one.

For less than $20, you can buy a 2 inch diameter x 8 inch analog type. They are slightly bigger, have about the same range & precision, and are easier to read, but where to put them becomes a problem.

For about $30, you can buy a surface-type unit. This is useful for measuring surface temperatures for early or late season paving. It is hard to use a probe thermometer to take surface measurements.

For about $40, you can buy a inexpensive, digital, hand-held thermometer with a probe and a connecting cable. They run on batteries, are more precise (± 1 °F), and seem to command a bit more respect than the small dial style (i.e. they tend to last longer).

Over $40 and the sky is the limit. You can get real heavy-duty, analog dial thermometers ($40+), or digital-type with multiple probes ($100+), or even infrared ones ($300+). All have advantages and disadvantages.

The point here is thermometers are cheap compared to what the paving operation is worth, and it is best practice to have several thermometers available on the paving site at all times.

8.8.2.2.6.2 Using a Thermometer

How? Using a thermometer is pretty easy... stick it in, wait, and read it (or point it for infrared types). If you have a probe-type thermometer, it has to go into the mix and stay long enough to equalize (which maybe 20-30 seconds or more). Infrared units are fast and expensive, and growing in popularity. Turn it on, point, shoot, and read the measurement. Infrared units measure surface temperature (which is normally cooler than the rest of the mix) but can take many measurements in a short period of time.

Where? (1) Insert into the unsupported edge of the new mat so you can measure how the mix cools over time (great for measuring time available for compaction (TAC)). Using several of these, one at each end of a rolling zone, will help you to determine if the compaction process is being performed in the right temperature range for the mix. (2) When taking nuclear measurements during the test strip construction or during paving, it is also helpful to take quick temperature measurements after each test, to make sure you are still in the proper range. (3) Use them to check base and air temperatures, especially during critical conditions. (4) Use them to checking loads of HMA before they get dumped into the paver (if the mix is cooling significantly

between the HMA facility and the jobsite, you may have moisture problems). The list goes on.

When? Take enough readings to develop a comfort index with the specific conditions you are working in. What's the temperature of the mix behind the screed? Is it the same all day? What's the temperature 100 feet back? 250 feet? 500 feet? 1000 feet? (31 m, 76 m, 153 m, or 305 m) How long in minutes does the mix take to cool to 175 °F? Take more readings when needed; early in the morning, when the weather changes, when you are paving at the temperature limits, or when the mix is difficult to compact.

8.8.2.2.6.3 Potential Problems

The problem with the inexpensive dial thermometers is that the calibrating adjustment is a nut on the back of the dial. With typical rough use, these nuts can work loose and the temperature calibration is lost. They can be re-calibrated if they are not damaged too severely, and it is good practice to check these often.

The problem with the infrared-type is they will normally display a consistently lower temperature than a probe-type. You may need to correlate them to get a true measurement of the mix.

8.8.2.2.6.4 Calibrating Thermometers

Never completely trust a single thermometer, especially if you don't know where it's been... run a couple quick checks. For a precision check, insert several probe thermometers into the center of a pile of hot mix (a shovel-full will do) and wait a minute -- they should all read the same temperature. If you are using a infrared unit, aim it at the same pile and compare the probe measurements to the infrared. This will allow you to develop a simple correlation between surface and depth temperatures.

For a quick accuracy check, place them in a pan of boiling water, you should get 212 °F (100 °C).

8.8.2.2.6.5 Actually Using the Thermometer

Now you know the types of thermometers available and how to use them, the big question is, Will you? Measuring the temperature of HMA is not glamorous or exciting, but it sure can tell you a great deal about the mix and conditions you are working in. Since mixes have been changing so much the last few years, it is can be considered best practice to use this inexpensive tool to improve your chances of achieving density and producing a high performance pavement.

Safety, Safety, Safety. Watch out when bending over taking readings, make sure the roller operator and others know where you are at all times. Be careful when working on the side of the mat, especially if traffic is traveling close by.

8.8.2.3 Effective Roller Speed

The first calculation needed concerns the amount of mix to be produced by the plant, the width of the pavement lane, and the depth of the mix. Once the typical speed of the paver is known, the maximum speed of the rollers should be selected. The actual speed selected for each roller will depend on the type of roller and its width as well as its position in the rolling sequence. It will also depend on the ability of the roller to achieve a balance between achieving density, smoothness, and an unblemished pavement surface.

The next calculation that must be made concerns a comparison of the width of the layer being placed and the width of the rollers to be used in order to determine the number of transverse roller lanes needed to cover the whole width of the pavement. (A pass is defined as one trip of the roller in one direction over any point on the pavement surface.) With the paver speed, the roller speed, and the number of transverse lanes needed to obtain full-width coverage of the roadway surface, the number of passes that each roller can place over each point in the pavement and still keep up with the paver can be determined. The number of passes, however, must be matched to the plant production rate and to the speed of the paver.

8.8.2.3.1 Example Problem and Calculation

COMPACTION PRODUCTION CALCULATION FORM:

Date:_____ Project #: _____

Project:_____

Recommended Breakdown Rolling Speeds:

Static: 2 to 3-1/2 mph; **Pneumatic:** 2 to 3-1/2: **Vibratory:** 2 to 3[A]

Actual Speed fpm (mph)	Reversal Factor	Effective SPEED fpm (mph)
176 (2.0)	-10%	158 (1.8)
220 (2.5)	-10%	198 (2.3)
264 (3.0)	-10%	238 (2.7)
308 (3.5)	-10%	277 (3.1)
352 (4.0)	-10%	317 (3.6)

[A] Actual Speed for vibratory rollers can be based on the roller's operating frequency and an impact spacing of 10-12 impacts/ft. Use the following two lines to calculate these values.

ACTUAL SPEED = VPM (_____) ÷ (_____) impacts/ft = _____ fpm ÷ 88 = _____ mph
EFF-SPEED = Actual - 10% = (_____) - 10% (_____) = _____ fpm ÷ 88 = _____ mph

Actual Roller Drum Width (DRUM): _____inches

Effective Drum Width (EFF-DRUM): To account for drum overlap, 6 inches is normally used.

EFF-DRUM = DRUM - 6 inches ÷ 12 in./ft = _____ - _____ ÷ 12 in./ft = _____ ft

Paving Width (WIDTH): _____ft

# of Passes to Cover Mat Width Once (PASS): = WIDTH ÷ EFF-DRUM
PASS = _____ ÷_____ = (Round up to whole number) _____

# of Repeat Coverages to Achieve Density (COVERAGE): _____ (From test strip)

Total # of Passes (T-PASS): = PASS x COVERAGE = _____ x _____ = _____
(Note: If T-PASS is an even number, add 1 to T-PASS for make up pass)
Is T-PASS an even number? If Yes >>>>>> New T-PASS = T-PASS + 1 = _____

Roller Efficiency Factor (EFF2): _____ (recommended 0.75 - 0.80)

Effective Compaction Production Rate (C-RATE):

C-RATE = EFF-SPEED x EFF2 ÷ T-PASS = _____ x _____ ÷ _____ = _____ fpm

Compare: F-RATE (____tph) to H-RATE (____tph): P-RATE (____fpm) to C-RATE (____fpm)

8.8.2.3.2 Balancing Production Rates

Although fairly simple to calculate on paper, balancing production rates in real life is much more difficult, due to the number of complicating factors that arise daily. Trucks tend to bunch up and arrive all at once, the paver speed can vary, and rollers do need to be re-watered. The best way to deal with this is to buffer the operation with a slightly higher roller production rate. This will enable you to deal with these situations as they arise. Setting up a paving operation with too low a compaction production rate is not recommended.

8.8.3 Breakdown Rolling

Breakdown rolling is the first interaction between the roller and the mat. It can be a friendly or a troublesome meeting. Most contractors use steel drums to breakdown the mix, increase the mat density, and establish the mat smoothness. Some use rubber tired rollers for breakdown of HMA.

Rollers should always stop and start slowly on uncompacted mix and angle the drum when stopping to reverse. The majority of the density is obtained during breakdown rolling so it is important to keep this roller moving as much as possible. When the roller does stop, it is best practice to park on a cold mat. Parking on the hot mat, especially near the paver, will leave roller marks that are difficult to remove.

8.8.3.1 Determining the Rolling Zone

As discussed, the rolling zone is that area of the mat which is at the right temperature range to be most efficiently compacted. This will vary by mix type and the other compaction variables already discussed. In addition, <u>each</u> roller in the rolling train will have its own rolling zone, whether it be in the breakdown, intermediate, or finish rolling stage.

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How long should the rolling zone be?

A commonly accepted rolling zone length is approximately 250 feet (76 m) for normal paving operations (standard paving width, standard overlay thicknesses, and summer weather conditions). However, this length should be considered an estimate which depends on many factors and should be checked during production. The rolling zone length should be the maximum length which ensures uniform density across and down the mat at all times.

The second way is to use the available information you have to estimate it, then adjust it based on experience from the specific paving project. Since you already have calculated the effective compaction production rate (C-RATE) of the roller, and you can estimate the Time Available for Compaction (TAC). Multiply the C-RATE by the TAC and you will have an estimate of the rolling zone in feet. This is the distance the roller travels down the mat before reversing direction.

Step 1 Determine the Effective Compaction Production Rate (C-RATE) of the roller.

For example, the C-RATE from 8.8.2.3.1 was ____ fpm.

Step 2 Estimate the Time Available for Compaction (TAC).

For example: given the mix thickness of ___ inches, and estimating the project temperatures (Mix = _____, Base = _____), use the charts on Page 8-5 and 8-6. Based on this information, the TAC would be approximately _____ minutes. This assumes density can still be effectively attained at 175 °F. For many high-type mixes, this minimum temperature may actually be higher.

Step 3 Multiply the C-RATE times the TAC.

Rolling Zone ≅ (_____ fpm) x (_____minutes)
≅ _____ feet
CAUTION: This is an estimate only!

The actual time available for efficient compaction might be different. Each mix will have an optimum temperature range (a maximum temperature minus a minimum temperature) where it is compacted most efficiently, and must be determined in the field by trial.

You can determine a more accurate TAC during production by measuring the time it takes the mat to cool to a minimum temperature. Insert a thermometer inside the mat behind the screed and measure the time the mix takes to cool to a specific temperature. Use this value instead of the value from the temperature cessation tables.

The rolling zone will also vary as compaction variables vary. For example, the rolling zone would typically be shorter on a 60 °F day than a 95 °F day, or when the mix lift was 1.5 inches versus 4.0 inches.

8.8.4 Compacting Transverse Joints

Good practice is to make an initial breakdown pass and then check the joint with a straightedge. In case the new mat is too high, the mix can still be reworked and then recompacted. It is important to understand that the first pass will still leave the mat slightly high, but experience will determine if it is too high. The goal is to produce a transverse joint that rides as smooth as the rest of the mat.

8.8.4.1 Transverse Rolling

As discussed in the Joint Construction unit, ideally it is best to compact transverse joints in the transverse direction. However, it is not always possible.

If rolling in the transverse direction, run-off boards the thickness of the mat may be needed to keep the roller level. The drum should overlap the

new mat with most of the drum on the cold mat and pinch the joint. Some contractors use multiple passes, each pass placing more of the drum on the hot mat. Again, the method that produces a dense, level joint most efficiently is the one to use.

8.8.4.2 Longitudinal Rolling

If a transverse joint is to be compacted in the longitudinal direction, it is important the first passes of the roller be made at very slow speeds. Higher speeds may force the new mix away from the joint creating a void or weakness. Some only roll in with one drum on the new mat and then reverse back. Angling the drum while entering the new mix can be effective also.

Summary: There is no one right way to roll a transverse joint; the method that works most efficiently and consistently is the one to use.

8.8.5 Compacting Longitudinal Joints

There are three main methods to compact a longitudinal joint. Each method can produce similar densities. The best practice is to compact a joint consistently and efficiently.

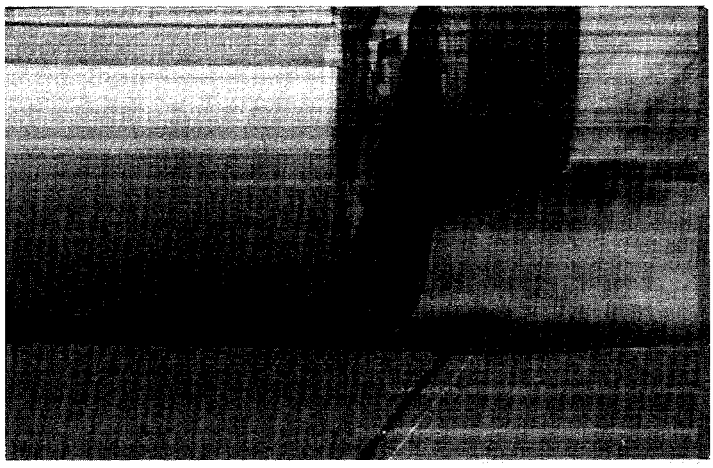
8.8.5.1 Rolling from the Cold Side

The oldest method is to roll the joint from the cold side with most of the drum on the previously placed mat, overlapping approximately six to twelve inches. The problem is that this is the most inefficient method since most of a roller pass is wasted. Vibratory rollers should not operate in the vibratory mode on this first pass. Of the three methods, this one produces the lowest density on the joint.

8.8.5.2 Rolling from the Hot Side - "Normal Overlap"

Rolling from the hot side places most of the roll on the hot mat and overlapping approximately six inches on the cold mat is the most efficient method. Vibratory rollers, in the vibratory mode, can be used in this mode since the drum will not impact on the cold mat.

8.8.5.3 Rolling from the Hot Side - "The Modified Pinch"



An additional method that can be tried is to roll from the hot side but hold the drum away from the joint about six inches, leaving a ribbon of uncompacted material. A subsequent pass will be made to compact this ribbon with an attempt to force more mix into the joint area and allow the mix to remain in contact with the joint longer prior to compacting. However, this method does require an additional pass and is not as efficient as rolling from the hot side.

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How do you roll longitudinal joints?

8.8.6 Intermediate Rolling

Intermediate rolling may or may not be required on a project. If adequate density cannot be achieved with the breakdown roller, an intermediate roller may be needed. Some states require an intermediate roller, typically a pneumatic tire for surface texture and kneeding action. Intermediate rollers can typically be operated at higher speeds than a roller in a breakdown mode. Intermediate rollers should follow a roller pattern and not concentrate on running down the middle of the mat.

8.8.7 Finish Rolling

Finish rolling is the last step of the operation and is normally used to "iron" out any roller marks left by a breakdown or intermediate roller. This roller is typically a static steel wheel roller, or a vibratory roller operating in a static mode. Some contractors equip the finish roller operator with an infrared thermometer so that finish rolling can occur within a range of temperatures. Finish rolling is not the place to bet on obtaining additional density. It is a cosmetic process.

Since this roller is normally well behind the paving operation, it is operating alone most of the time. Traffic safety devices must remain until finish rolling is finished. The operator and any additional personnel, performing a coring or nuclear density operation for example, must be careful of stray traffic entering the site. The traveling public may not see a lone roller or technician bent over a nuclear gauge until it is too late.

8.8.8 Re-watering During Paving

Rollers must re-water periodically during paving. Maintaining a spray system that uses the minimum amount of water will reduce these stops, but not eliminate them. It is best to re-water during a temporary lull in paving, and refill a half empty tank, than wait until production is peaking and run out of water. If this cannot be avoided, and the mix is cooling too rapidly to wait, the intermediate or finish roller should be moved to the breakdown position until the original breakdown roller is available.

8.8.9 Concluding Operations

Rollers are the last equipment on and off the pavement. The last section of a pavement placed must receive the same attention to detail and compactive effort as the first section. Rollers should be checked, and maintained at the end of each day. If something needs repair, repair it now.

8.8.10 Opening to Traffic

If the mix hasn't cooled below a mix-specific temperature before opening to traffic, additional densification can occur in the mix, primarily in the wheel paths. It is possible that heavy traffic could over-densify the mix and cause rutting. Therefore, agreement should be reached in the pre-construction meeting as to the minimum temperature (surface or internal) before the pavement is opened to traffic. Intersections, night paving, and ramps are key areas. In some areas, a water truck has been used to cool the pavement temperature.

8.9 Summary

A good summary of key points related to compaction is found on page 3-87 of the HPH and is repeated in the small handout entitled "Tips for Best Practice."

8.10 Review Video Tape

8.11 Review Objectives

Can you?

1. State the objective of compaction;
2. List five engineering properties related to compaction;
3. Identify material and mix properties affecting compaction;
4. List the types of compaction equipment and equipment considerations;
5. Pick the right roller for the job;
6. Identify compaction variables;
7. Identify the main components of compaction equipment maintenance;
8. Calculate roller productivity;
9. Describe proper compaction operating procedures.

8.12 Evaluation

Please complete the Unit 8 evaluation at this time. Thank you.

9

UNIT 9 Troubleshooting #2 (1 hour)

9.1 Introduction

9.1.1 Review Objectives of this Unit

What's-in-it-for-me? Troubleshooting skills are developed, not inherited. Many of the problems you will need to troubleshoot are complex because of the number of factors involved and the amount of information available. Your job is to sort through this information and extract the relevant. The effective use of these skills can make you invaluable to your organization.

OVERVIEW: During this unit, we will look at several case studies in which you will be responsible for identifying the problem, and developing a course of action to solve them.

OBJECTIVES: At the end of this unit, you should be able to:
1. Analyze situations and recommend action to be taken.

METHODS: We will use a set of handouts containing background materials to present a series of situations requiring action. You will work in your assigned teams to troubleshoot these case studies.

EVALUATION: At the end of each case study, you will discuss your recommendations as to what you would do in such a situation. In addition, you will need to complete an evaluation of the unit.

9.2 Case Study #9-1: Checking

9.3 Case Study #9-2: Bleeding

9.4 Case Study #9-3: Test Strip

9.5 Case Study #9-4: Compaction

This is a challenging case study that brings most all of what has been covered to date together. There are a lot of facts available, not all are applicable. Your project is to answer the questions. Work with your partner and look for the small details that will open this problem up.

9.6 Summary

STOP

9.7 Evaluation

Please complete the Unit 9 Evaluation at this time. Thank you.

10

UNIT 10 Quality Control/Quality Assurance (2 hours)

10.1 Introduction

10.1.1 Review objectives of this unit

What's-in-it-for-me? Whenever you purchase a product, you have a certain level of expectation. If you buy a cola, you want it to taste like cola, not like root beer. If the can says it contains 12 ounces, you expect 12 full ounces. Getting shortchanged means not getting what you expected: it breaks easily, it does not last as long as you think it should, or it is a continuing source of costly problems (like a used car). This is where quality control and quality assurance come into play.

All manufacturing processes must have a process Quality Control (QC) system to measure its ability to produce a consistent product. In addition, the buyer of the product should have some system to assure they will get what they pay for. The system should be fair to both parties. In the HMA Industry, we are rapidly moving into formal Quality Assurance programs, although many have been active for years.

Quality Assurance (QA) in its broadest context is the total system of activities which are concerned with making sure the quality of a product is what it should be.

OVERVIEW: During this unit, we will look specifically at what QA is, and how it applies to the HMA Industry. We will look at: different types of specifications, basic statistical tools, terms and definitions, how to sample and test in an unbiased manner, and the individual elements of QA.

Also, we will look specifically at density and smoothness tests, covering equipment, procedures, and test variation. In addition, we will look at an easy way to chart individual test results to compare them against each other and against the job specifications.

KEYWORDS: Buyer, Seller, Quality Assurance, Quality Control, Mean, Standard Deviation, Range, Precision, Bias, Density, Core, Nuclear Gauge, Profilograph, Mays Meter, Profilometer, Straightedge, and Control Chart.

OBJECTIVES: At the end of this unit, you should be able to:

1. State the objective of QA;
2. State the objective of the QC;
3. Describe the four types of specifications;
4. Define population, lot, sample, specimen;
5. Define and construct random sampling and testing plans;
6. Calculate the compacted density of a sample;

7. Calculate basic statistical functions;
8. Construct control charts;
9. List applicable QA/QC tests (basic equipment, procedures, and variables).

METHODS: We will use a combination of video, slides, calculations, graphing problems, and lecture to emphasize the main points of this unit.

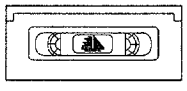
EVALUATION: You will complete an evaluation of this unit.

Note: This section borrows heavily from NHI Course No. 13123, Highway Materials Engineering, Module I, Materials Control and Acceptance - Quality Assurance. *Text from this manual is denoted in this font type.*

10.2 Video

10.2.1 Introduction

The following video tape is several minutes long and stresses the importance of Quality Control and Quality Assurance when constructing HMA pavements. The objectives of using this video tape are: to relate the live action of your work environment into a classroom, show the real process of QA, and provide a basis for discussion. Look with detail at this tape and see if you can determine what is being done properly, and if anything is being done improperly based on your experiences. We will take a second look at this same video at the end of this unit to serve as a review.



10.2.2 View Video Tape

10.2.3 Questions on Video

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Who is responsible for Quality Control in your state?
Who is responsible for Quality Assurance in your state?
What role do you play in QA? In QC?

10.3 Types of Specifications

The following is a brief comparison of the major specification types which discuss the evolution of specifications over the last 30 years. There are four principal types of specifications used today.

10.3.1 Method - Recipe

The method specification, which was widely used in the 1940's and 1950's, puts maximum control and responsibility in the hands of the specifying agency. A method or recipe type specification spells out exactly the equipment, methods, materials, and techniques a contractor is supposed to use. In effect, the agency rents the contractor's personnel and equipment. This type of specification did not allow the contractor to

be innovative or be rewarded for providing a higher quality product than called for in the specifications.

In the early use of method specifications, little or no testing was done. The specifying agency based acceptance primarily on inspection. This type of specification is still used, but usually is accompanied by a greater degree of testing than in the 1950's.

10.3.2 End-Result

In 1958, the construction of the AASHTO Road Test provided the first step toward end-result specifications. This type of specification stressed testing, as opposed to inspection, as the main measure of contract compliance. The development of the acceptance limits used on the AASHTO Road Test came from a panel of engineers who used their expertise to provide limits that they thought could be met by the contractor and which would lead to the desired product. The testing program undertaken at the AASHTO Road Test proved that the limits generally could not be met consistently. Some Marshall test properties were met with a relatively high frequency, while others were rarely met.

End-result is a term that defines the desired quality of the finished product. Most of the specifications specify the standard controlling mix properties, yield or thickness, density, and/or smoothness. The problem with this specification is determining reasonable levels of acceptance, and determining the relationships between the controlling mix properties. Many states are experimenting with end-result specifications.

10.3.3 Quality Assurance

As shrinking budgets depleted personnel reserves, agencies moved more of the responsibility for the day-to-day process quality control to the contractor. The contractor is required to perform tests at specified frequencies and make the data available to the agency. The agency may use the contractor's data as part of the acceptance plan, which usually calls for the agency to make a certain number of acceptance tests to assure the quality of the product and to check the contractor's test results. Testing equipment, methods, and personnel must be uniform in this system to minimize variability. QA specifications are characterized by a division of responsibility between contractor and agency and that the sampling and testing requirements are statistically-based. Some agencies use a combination of method and QA specifications.

As QA specifications have evolved, it has been found that inspection is still an essential function. All things cannot be evaluated by testing after-the-fact. There are certain properties and construction activities that require inspection during the process. Inspection and good engineering practice must be applied.

10.3.4 Performance-Based

A true performance-based specification does not yet exist. In the true sense, the agency is concerned with the performance of the final, in-place product and not how it was built. The problem with this specification is that performance-based test methods have not been fully developed. Further development and validation of

performance-based tests are currently under way in the SHRP Asphalt Research Program.

10.3.5 Summary

At present, a spectrum of specifications exists. On one end of the scale are the method specifications, with only inspection. Next are method specifications with indirect end-result testing. Next are end-result specifications using intuitively derived acceptance limits and sometimes containing equipment requirements. On the other end of the scale are end-result specifications requiring contractor process control, using mathematically derived limits for acceptance, and specifying the degree of independent assurance. Ideally, the specification should be related to performance.

?

What type of specifications do you currently use?

10.4 Quality Assurance System

Within the highway construction industry, this system of activities can be broken into three principal elements. These elements are: **Process Quality Control**; **Acceptance Sampling**, **Testing**, and **Inspection**; and **Independent Assurance**.

10.4.1 Process Quality Control

Process Quality Control covers all production processes and tasks associated with meeting specification requirements. Such tasks as maintenance of equipment, equipment calibration, stockpiling and materials handling, construction procedures, as well as, sampling and testing of component materials and product are included. *The party doing the work is in the best position to exercise process quality control. For this reason, as well as, to avoid legal problems; most QA type specifications assign responsibility for process quality control to the contractor.*

10.4.2 Acceptance Sampling, Testing, and Inspection

The functions involved in acceptance of a product include in-process inspection, monitoring of the contractor's or supplier's process control, and acceptance testing. **Acceptance Testing** is the most important function of both an end-result and a quality assurance specification. It is performed to provide the specifying agency with the information that relates the product to the specification limit(s).

10.4.3 Independent Assurance

The third function, **Independent Assurance (IA)** encompasses the actions and considerations included in both process quality control and acceptance sampling, testing, and inspection. **IA** is a management tool that requires a third party, not directly responsible for process control or acceptance, to provide an independent assessment of the product.

10.5 Process Quality Control

Process quality control as defined earlier covers all production processes and tasks associated with meeting specification requirements. It is one of the essential elements of a balanced Quality Assurance System and covers all tasks including sampling and testing that are associated with controlling the production/construction processes.

Process Quality Control is the process of making tests and observations, monitoring these, and making adjustments to the production and laydown processes to ensure that the finished pavement will have a high level of compliance with the buyer's specifications. It includes testing and observing the quality of the aggregates purchased at the pits and quarries, so that uniformity is maintained. It includes setting the proportions at the cold feed, setting the hot bin weights, adding the correct amount of asphalt cement, measuring the volumetric properties of the HMA, and determining the mixing times and techniques. It also includes determination of correct laydown and proper rolling techniques. More important, it involves constant testing and evaluation of test results to determine if production is in control. Quality control also includes the actions of other facility personnel in making the changes and adjustments necessary in day-to-day operations.

10.5.1 Process Quality Control Responsibilities

The specifications must be clear as to which party has responsibility for process quality control. In the past, the highway agency has often assumed this responsibility. This can lead to legal problems if the material or work does not meet specification requirements. The party that does the work is generally in the best position to control the production/construction processes. For this reason, most QA specifications call for the contractor to be responsible for process quality control.

10.5.2 Process Quality Control Plan

*Some specifications require the contractor to submit a **process quality control plan** to the highway agency for review or approval prior to the beginning of work. The plan must outline the details of how many tests are to be run, the frequency of the testing, and the action that will be taken to put a process back in control if it goes out. Other factors that might be addressed in a process control plan include amount and frequency of plant inspections, verifications of calibrations, equipment maintenance, and type and amount of documentation that will be maintained.*

10.5.3 Process Quality Control Charts

Process quality control charts, particularly **statistical control charts** are powerful tools for monitoring and deciding when to make adjustments to the production/construction processes. These charts provide a means of verifying that a process is in control, as well as, an effective warning mechanism to alert the contractor or material supplier that they should look for possible problems with the process. They do not get or keep a process under control.

10.5.4 Total Construction Variability

It is important to understand that the Total Construction Variability of a particular material is a sum of several definable variabilities. These are sampling, testing, production, and actual material variability. What is important is actual material variability. Variation of construction materials is inevitable and unavoidable. *Control charts do not eliminate variability, but help distinguish between the inherent or **chance causes** of variability and **assignable causes** of variability.*

10.5.4.1 Chance Causes of Variability

Duplicate measurements will not always be identical. Every process has some inherent variability that can possibly be reduced by changing the process. Due to this variability, individual results can not be accurately predicted. However, groups from a constant process tend to be predictable.

10.5.4.2 Assignable Causes

*The second cause of variation, **assignable causes, can be eliminated if they can be identified.** Examples of assignable causes might be when the gradation for an aggregate goes out of specification due to a hole in one of the screens or because the cold feed conveyor setting is out of adjustment.*

10.6 Statistics - An Important Tool for Quality Assurance

A basic understanding of statistics is the first step in understanding how to use this tool in Quality Assurance and the materials testing associated with this program. *Statistics is the science that deals with the treatment and analysis of numerical data.*

There are four principal topics that must be understood to properly use the tool of statistics. These are sampling, testing, analysis of data, and interpretation of data.

10.6.1 Definitions

*Materials testing for both process control and acceptance involves sampling to determine the characteristics (asphalt content, void properties, density, etc.) of a larger quantity of material, commonly known as a **lot** or **population**. Since it is impractical to evaluate the entire lot of material, a portion of the lot (called sample) is taken and tested in order to make decisions about the lot.*

*The word **sample** can be used to refer to a **sample** of aggregate or HMA that is collected for testing to evaluate the quality of the material. **Sample** also has another meaning when used in a statistical application. To distinguish between these uses, in this unit, the term **specimen** is used to refer to the material obtained for testing.*

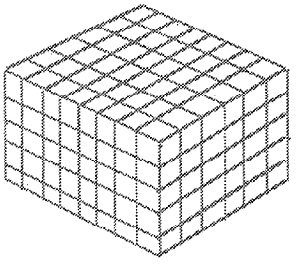
10.6.1.1 ***Population** or **Lot** is defined as all the measurements or counts that is obtainable from all the objects which possess common specified characteristics. A common definition of a lot is an isolated quantity of material produced essentially by the same process.* Example: One day's production or 1500 ton.

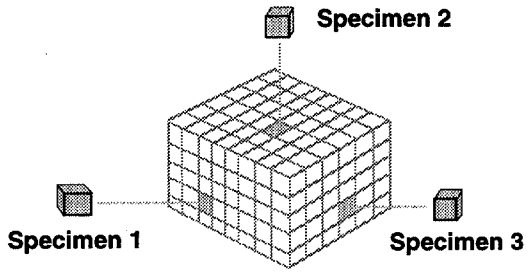
10.6.1.2 ***A Sample** is a set of measurements or counts that constitute a part or all of the population.* Example: The **sample** is a set of five density sets (five **specimens**) representing the day's production or lot.

10.6.1.3 ***Data** are the factual information (such as test results, measurements, or statistics) used as a basis for reasoning, discussion, or decision making.* Example: The **results** of the five density test specimens for the day's production.

10.6.2 Sampling

*A large cube-shaped object can be thought of as a **lot** consisting of smaller cube-shaped blocks which represent potential **specimens**. Assume that the cube represents a lot of hot mix and that we wish to know the density of the hot mix in the lot. Obviously, to determine the "best" estimate of the density, every bit of material in the lot must be tested (**complete enumeration**).*





Since complete enumeration is not feasible (the entire lot would be destroyed if cores are taken) ***sampling*** *is the practical solution. A* ***sample*** *can be selected from the lot of material, and* ***data*** *from the sample can be used to estimate the density of the hot mix in the lot in order to make a* ***decision*** *regarding its acceptability.*

The relationship between the properties of the sample and the properties of the population is an important aspect of statistical theory and practice since "good" estimates of the properties of a population require valid samples. Two concepts that are of particular importance for ensuring sample validity are random sampling and controlled conditions. Obtaining valid samples is not automatic. Random sampling is necessary.

10.6.2.1 ***Random Sampling*** *is a sampling procedure where any specimen in the population has an equal chance of being sampled.*

If the collected data is to be useful for generalization to the lot or population, it is essential that they are obtained under ***controlled conditions****. This includes the requirement that the set of data to be treated as a single group should represent homogeneous data (i.e., measurements or counts made under the same testing situation and that represent construction material produced under essentially the same conditions).*

Sampling is the most effective means for estimating the acceptability of a lot or population. However, how many specimens (1, 2, 3, etc.) should comprise the sample to arrive at a sound estimate? Getting samples which represent the population is the objective of any sampling plan.

The idea persists that a test on a single specimen shows the "true" quality of the material, and that if any test result is not within some limit, there is something wrong with the material, construction, sampling, or testing. Thus, terms such as investigational, check, and referee specimens are in common use to either confirm or document these "failures." Nature dislikes uniformity; variation is the rule. Therefore, any acceptance or process control sampling must account for variability of materials and construction. Multiple sampling and a procedure for identifying outliers helps accomplish this objective.

The selection of the sampling locations within the lot must be entirely random. "Random" does not mean "haphazard"; it means that the sample is selected without bias. Biased sampling often results when the technician uses his or her "judgement" regarding where to take the sample. In practice it may be difficult to train technicians who have been accustomed to inspection to randomly select samples without regard to quality. their tendency is to make sure that defective materials are represented in the sample, thus unconsciously biasing the sample. Random sampling is a must when using a statistically-based procedure, like Quality Assurance.

10.6.2.2 Random Number Tables

The most common method for determining when or where to obtain samples is through the use of a ***random number table****.*

A random number table is a collection of random digits. Random number tables come in many forms - some are short, some long, some grouped by pairs of digits, some with as many as 5 digits per group. when using a random number table, the key is ***bias must be avoided****.*

Random Number Table

0.74	0.60	0.01	0.27	0.43
0.29	0.21	0.78	0.01	0.43
0.28	0.37	0.00	0.49	0.97
0.73	0.08	0.87	0.32	0.97
0.72	0.14	0.09	0.70	0.41

An example of a random number table is shown here. The random numbers are presented in pairs of digits.

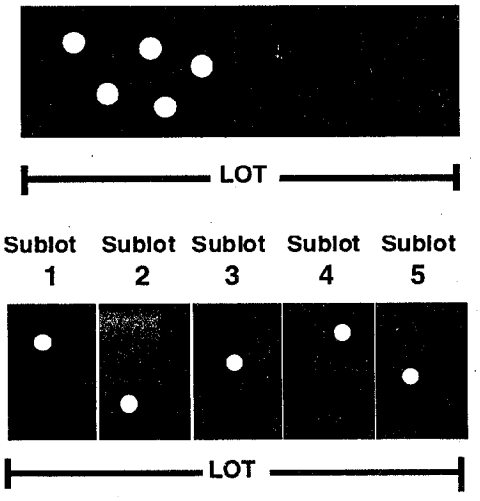
Sampling locations can be determined on the basis of time, tonnage, volume, distance, area, etc. The only other necessary information is the size of the lot to be sampled and the number of specimens to comprise the sample.

When selecting a group of random numbers, one can enter the table at any point (but never at the same point twice) and select the required amount of numbers. The numbers can be selected by columns or rows, by going left or right, up or down, selecting alternate numbers or any other pattern desired.

In addition to using tables, random numbers can be generated either by computer or some pocket calculators.

10.6.2.3 Stratified Random Sampling

Random sampling ensures that each specimen in a lot has the same chance of being selected for the sample. Stratified random sampling additionally involves the selection of two or more defined sublots of a given lot. Stratified random sampling is used to ensure that the specimens for the sample are obtained from throughout the lot, and are not concentrated in one portion or sublot of the lot.



The next two figures illustrate the basic principle of stratified random sampling. The large rectangle represents a lot, perhaps one day's paving form which cores (specimens) are to be obtained. Using a random number table, it is possible (but not necessarily likely) that all of the cores could be selected within the first half of the lot.

To avoid this possibility, the lot can be stratified into a number of sublots equal to the sample size to be selected from the lot. One core (specimen) is then randomly selected from within each sublot. This ensures that each portion of the lot has the same chance of being selected while, at the same time, ensuring that the sample is spread out over the entire lot.

An example will help to illustrate the use of random number tables and stratified random sampling.

10.6.2.4 Example Problem - Sampling

You are to determine the in-place density of a section of HMA placed today. *For this example, the specifications state that the lot size shall be 5,000 linear feet of pavement, and that the sample consists of 5 density tests per lot. If we assume that the pavement width is 12 feet and the lot begins at station 100+00, use a random number table to select the sampling locations.*

Sublot Size *The lot begins at station 100+00 and ends at station 150+00 (i.e., 5,000 feet in length). Five equal sublots are required, so the sublot length is 5,000/5 = 1,000 feet. The sublot locations are shown in the example.*

Now that the sublot boundaries have been identified, the location of the core within each sublot must be determined. To accomplish this, the location must be randomized in the longitudinal as well as the transverse direction.

A random number table can be used to determine both the transverse and longitudinal locations for the cores. Two sets (columns, rows, etc.) of random numbers are selected, one for the transverse position, the other for the longitudinal position.

Random Number Table

X →	0.74	0.60	0.01	0.27	0.43
Y →	0.29	0.21	0.78	0.01	0.43
	0.28	0.37	0.00	0.49	0.97
	0.73	0.08	0.87	0.32	0.97
	0.72	0.14	0.09	0.70	0.41

A set of 5 random numbers for the longitudinal (X) position and 5 random numbers for the transverse (Y) position of the sample may be chosen by using the second block of numbers from the table.

These X and Y random numbers are multiplied by the sublot length and paving width, respectively, as shown in the example below:

Sublot #1 *(start at station 100+00)*

Coordinate X = 0.74 x 1,000 = 740 ft.
Coordinate Y = 0.29 x 12 = 3.5 ft.

Sublot #2 *(start at station 110+00)*

Coordinate X = 0.60 x 1,000 = 600 ft.
Coordinate Y = 0.21 x 12 = 2.5 ft.

Your turn! Calculate the remaining sublot locations.

Sublot #3 (Start at station 120+00)

Coordinate X =_____ x 1,000 =_____ ft.
Coordinate Y =_____ x 12 =_____ ft.

Sublot #4 (start at station 130+00)

Coordinate X =_____ x 1,000 =_____ ft.
Coordinate Y =_____ x 12 =_____ ft.

Sublot #5 (Start at station 140+00)

Coordinate X =_____ x 1,000 =_____ ft.
Coordinate Y =_____ x 12 =_____ ft

The longitudinal distance (X) is added to the beginning station of the sublot and companion transverse distance (Y) is measured from a selected edge of pavement (assume the right edge for this example).

Sublot #1

Sta 100+00 + 740 ft. = Sta 107+40
@ 3.5 ft. from right edge.

Sublot #2

Sta 110+00 + 600 ft. = Sta 116+00
@ 2.5 ft. from right edge.

Your turn! Determine the sample remaining locations.

Sublot #3

Sta 120+00 + _____ ft. = Sta _____
@ _____ ft. from right edge.

Sublot #4

Sta 130+00 + _____ ft. = Sta _____
@ _____ ft. from right edge.

Sublot #5

Sta 120+00 + _____ ft. = Sta _____
@ _____ ft. from right edge.

Sublot	X Longitudinal	Y Transverse
1	107 + 40	3.5
2	116 + 00	2.5
3		
4		
5		

These locations would be the randomly selected locations to take your density tests.

10.6.3 Density Testing

Consistency is the key to testing. Following the established test methods is an absolute must. **Take no shortcuts when it comes to sampling or testing.** Error due to sampling and testing creates more problems and causes acceptable material to appear unacceptable.

Density tests are the most routine of the quality control and quality assurance tests. The in-place density of the material measures the air voids of the pavement and helps determine the probability of success of the pavement. Other tests such as smoothness (covered in 10.10) may be used, and the same principles of statistics apply.

10.6.3.1 Coring

The most traditional test in the field is the density test. It is done by sawing and removing section of the pavement and testing the sample. The bulk specific gravity of the sample is calculated and then compared to a reference density, either a percentage of laboratory compacted density or percentage of maximum theoretical specific gravity (Rice density).

Extreme care must taken when prying loose and removing cored specimens from the pavement, especially in hot weather. A small amount of damage to a core's surface can significantly affect the unit weight of the sample.

10.6.3.2 Nuclear

The most common method for monitoring changes in density with roller passes is through the use of a nuclear density gauge. Density is estimated by transmitting gamma rays into the mix and measuring the amount of radiation reflected back to the device in a given amount of time. The count data that are obtained can be related to the relative density of the layer. Nuclear gauge readings should be taken after each pass of each roller, and the rate of increase in density after each pass determined. When no appreciable increase in density is obtained with the application of additional roller passes, the maximum relative density for that mix has been obtained. When a pneumatic tire roller is used in the compaction process, particularly in the breakdown mode, it is often very difficult to obtain an accurate density reading with a nuclear gauge. One or more passes with a steel wheel roller may be necessary before a valid nuclear gauge reading can be obtained.

The density value determined with the nuclear gauge is relative and is generally not the same as the density value obtained from cores cut from the pavement. Thus a correlation must be developed between the nuclear density reading and the actual unit weight of the pavement.

The nuclear density gauge has become an excellent quality control tool and is used for quality assurance in some states.

10.6.3.3 Example Calculation

Given:

A specimen density (d) = 136.4 pcf and a reference density (D) = 147.1 pcf

What is the density of the specimen?

$$\text{Percent Density} = \frac{d}{D} \times 100$$

$$= \frac{136.4}{147.1} \times 100 = ____\%$$

What is the percentage of air voids in the specimen?

$$\text{Air Voids} = \frac{(D - d)}{D} \times 100$$

$$= \frac{(147.1 - 136.4)}{147.1} \times 100 = _____$$

or let reference density be 100 and subtract the density
100 - _____ =_____

10.6.4 Analysis of Data

*The next phase of statistical procedures is the quantitative **analysis of data.** This phase involves the calculation of two parameters used to estimate the properties of the total population. These parameters are the **central tendency** and the **dispersion.***

The central tendency, sometimes called the expected value, is simply the arithmetic mean (often denoted as an X with a bar over it (X) and called X-bar) or average determined as shown. Many pocket calculators have an average function.

*The second parameter necessary to define the population is a measure of dispersion or variability. One common and simple measure is the **Range (R).** The range is the difference between the largest and smallest values. However, because of its simplistic nature, the range does not provide the best estimate of the variability. Since it uses only two values, it does not take into account the other values that may be available for estimating variability.*

*A better measure of variability is the **Standard Deviation (s or s).** It is common practice to use **s** when dealing with a **sample** standard deviation and s when dealing with a **population** standard deviation.*

*The **standard deviation** is the root mean square of the deviation from the mean and s is determined in accordance with the following formula:*

$$\sigma = \frac{\sqrt{\Sigma(X_i - \bar{X})^2}}{n} \qquad s = \frac{\sqrt{\Sigma(X_i - \bar{X})^2}}{n-1}$$

$\bar{X}$ = Mean X_i = individual measurement n = Number of measurements

Many hand calculators also contain a standard deviation function.

Notice that the denominator in the sample standard deviation uses a term, n-1. This is called the degrees of freedom and is the number of independent observations available. A simple analogy for remembering the relationship between n and n-1 is that with a single value, n, an estimate of the average (although a poor one) can be obtained. However, for an estimate of variability, at least two values are needed; thus n-1 in this case is 2-1= 1.

10.6.4.1 **Example** (Continuing on from Problem 10.6.2.4)

For example: Three lots of hot mix (each lot consisting of 5000 linear feet of paving) have been evaluated by stratified random sampling into 5 sublots each and tested for density. The density test results are as follows: (listed in percent of maximum theoretical density)

		Lot #1	Lot #2	Lot #3
Sublot #1:		96.1	95.6	93.2
Sublot #2:		92.9	93.6	93.8
Sublot #3:		95.7	94.2	91.8
Sublot #4:		93.6	95.1	93.4
Sublot #5:		95.0	94.7	93.5
Mean $\bar{X}$	=	94.7	_____	_____
Std. Dev. (s)	=	1.37	0.78	0.78
Range (R)	=	3.2	_____	_____

Mean

The mean is the average of the sample being evaluated and gives you an indication of the sample's measure of central tendency. Simply, the mean (average) of a sample (set of numbers) is equal to the sum of the numbers divided by the total number of specimens.

Calculate the mean of the data in Lot #1:
(96.1 + 92.9 + 95.7 + 93.6 + 95.0) ÷ 5 = 94.7

☞ Your turn! Calculate the mean for Lot 2 and 3.

Lot 2: $\bar{X}$ = (95.6 + 93.2 + 94.2 + 95.1 + 94.7) ÷ 5 = _____

Lot 3: $\bar{X}$ = (93.2 + 93.8 + 91.8 + 93.4 + 93.5) ÷ 5 = _____

Standard Deviation
The standard deviation is easily calculated by most scientific calculators and gives an indication of the samples variability or measure of dispersion. If you use a calculator, make sure the standard deviation function supplies the sample standard deviation (s). Do not confuse (s) and (σ) values, the sample (s) is what you need to use.

Range
The range is easy, it is the difference between the largest value in a set from the smallest. Using the data from Lot #1, 96.1 pcf - 92.9 pcf = 3.2 pcf.

☞ Your turn! Calculate the range for Lot 2 and 3.
Lot #2: R = _____ - _____ = _____
Lot #3: R = _____ - _____ = _____

Some states have specifications that limit the range of a set of data.

?

Which lot has the highest variability?

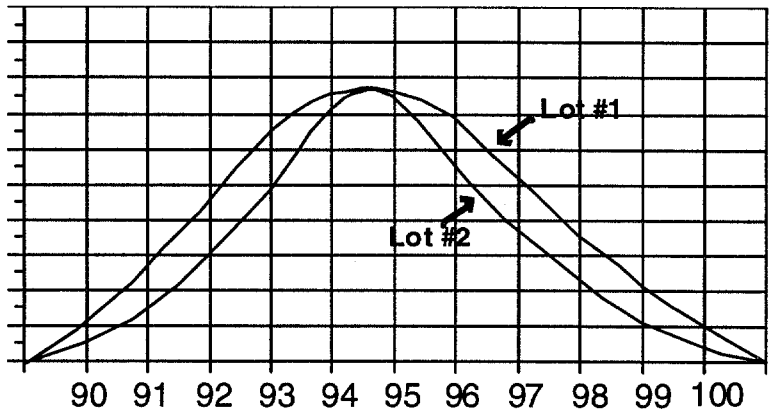
10.6.5 Interpretation of Data

*It is even more important to understand how the information provided by the sample data is used to generalize about the **population** or **lot** from which the sample data were obtained. From extensive research, it has been concluded that numerous measurements that occur in highway construction, and in nature in general, distribute themselves about some average value with the majority of the measurements grouped near the mean and with progressively fewer results recorded as one proceeds away from the mean.*

10.6.5.1 Normal Distribution

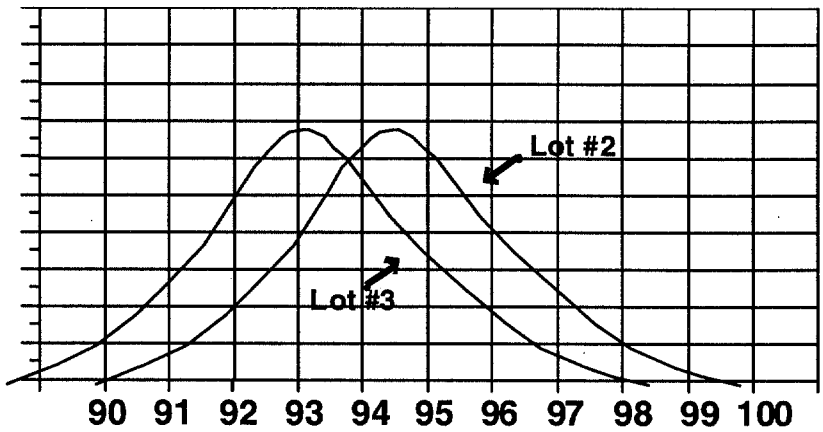
*In statistical analysis procedures, this symmetrical grouping of data around the mean is defined as the **normal distribution**. The normal distribution is depicted by a bell shaped curve with a single peak in the center of the distribution. This bell shaped curve is defined by the parameters of **mean** and **standard deviation** and is represented by a basic mathematical formula. As a result there is no one normal distribution, but a family of distributions with the same general bell shape. You can see that the **normal distribution** becomes a very powerful statistical tool.*

Since a particular normal distribution is uniquely and completely described by the mean and standard deviation, a different normal distribution is created whenever the value of either the mean or standard deviation is changed. This is illustrated in the following examples:



(Not to scale)

Normal distributions with the same mean but different variability (standard deviation). Lot 1 and Lot 2 have the same mean but Lot 1 is more variable than Lot 2.



(Not to scale)

Normal distributions with different means but same variability (standard deviation). Lot 2 and Lot 3 have the same variability but Lot 2 has a higher (average) mean density.

Since each normal curve is symmetrical about its mean value, the area under the curve is equal to one. Furthermore, provided the average and standard deviation have been determined, the area, or proportion of sample values, falling within any interval under the curve can be determined. It also follows that fifty percent of the values fall below the mean and fifty percent fall

above the mean. In addition, it is characteristic of the normal curve to have 66 percent of the area of the curve (or data values) fall between plus and minus one standard deviation of the mean, 95 percent of the area fall between plus and minus two standard deviations of the mean, and 99.7 percent or essentially all the area fall within plus and minus three standard deviations of the mean.

Example: Using the Density Values We Obtained

Lot	$\overline{X}$	s	$\overline{X} \pm 1s$ (66% of Data)	$\overline{X} \pm 2s$ (95% of Data)	$\overline{X} \pm 3s$ (99.7% of Data)	Spec Limits
1	94.7	1.37	93.3 to 96.1	92.0 to 97.4	90.6 to 98.8	92.0 to 97.0
2	94.6	0.78	93.8 to 95.4	93.0 to 96.2	92.3 to 96.9	92.0 to 97.0
3	93.1	0.78	92.3 to 93.9	91.5 to 94.7	90.8 to 95.4	92.0 to 97.0
Lot 1 + 2 + 3	94.1	1.19	92.9 to 95.3	91.7 to 96.5	90.5 to 97.7	92.0 to 97.0

It isn't the intent of this course to make you experts at statistics, only to enable you to be able to understand and calculate the basics. Additional courses are available through the National Highway Institute (NHI) that cover this subject in depth.

10.6.5.2 Outliers

Every so often you will obtain a test value that just seems out-of-place or looks strange. However, in a statistically-based program, you can't just arbitrarily throw out a number. There is a procedure to deal with extreme values and determine if it should be considered part of the sample. This procedure is ASTM Method (E178) but will not be covered in detail in this program. However, do keep in mind that there is a procedure to handle an extreme value.

10.7 Control Charts

Many types of control charts can be used to analyze data. *Control charts have been used in the manufacturing industry for years and have been successfully used in construction materials applications. Some of the benefits that are early detection of trouble, decreased variability of materials, establish process capability, reduced price adjustment costs, decreased inspection frequency, basis for modifying specification limits, permanent record of quality, provide a basis for acceptance, and instill a quality awareness.*

10.7.1 Types of Control Charts

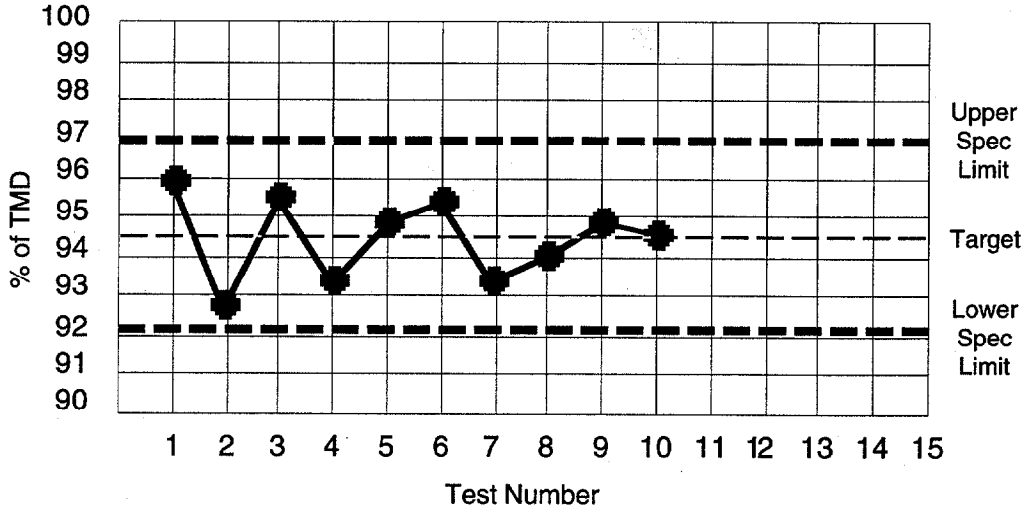
The simplest type is the **process control.** These charts show the specification limits with individual test results plotted chronologically. Plots of this type can show trends as they develop. This can give early warning of a process beginning to produce non-specification materials or work and trigger corrective action to be taken.

10.7.1.1 Process Control Charts

The following is an example of a simple "process control" chart.

Your turn! Given the data from the density problem, plot the last five data points on the process control chart below.

	Lot #1	Lot #2	Lot #3
Sublot #1:	(1) 96.1	(6) 95.6	(11) 93.2
Sublot #2:	(2) 92.9	(7) 93.6	(12) 93.8
Sublot #3:	(3) 95.7	(8) 94.2	(13) 91.8
Sublot #4:	(4) 93.6	(9) 95.1	(14) 93.4
Sublot #5:	(5) 95.0	(10) 94.7	(15) 93.5



How do you interpret these charts? There are four main trends you should watch out for:

1. *A singe point outside the upper or lower specification limits.*
2. *Two consecutive points near the upper or lower limits.*
3. *Five consecutive points on one side (above or below) the average or target value.*
4. *A sudden change in the direction of the results.*

Now, looking at the chart on the previous page, answer these questions.

What does this data tell you?
Could you see this trend just by looking at the raw data?
What trends does this data show?
Based on what you see, what action do you recommend be taken?

When any of these are noted, it is time to look at the process... Has anything changed? However, don't panic and make changes based on a single test result! Look at the results, check the calculations, and its normally a good idea to take another test(s) to verify this result. Remember, this is quality control. Once you have good evidence to support a change, make the change and check the result.

Process control type charts are very easy to construct and provide an easy-to-understand quick picture of the process. Any measurement can be plotted this way and it is a good idea to graph all key quality control tests. Since so many results are interrelated (gradation to asphalt content to void properties), these charts will help provide clues to any specific process related problems. For example, if the gradation is finer than the target, the AC content will normally be higher. A high minus 200 content and/or a high AC content will probably decrease air voids.

10.7.1.2 Statistical Quality Control Charts

The music bar charts are based on a sample size of one, therefore, they fail to address variability in the sample or process. These type of charts do not provide the capability to distinguish chance causes from assignable causes. Statistical quality control charts must be used to accomplish this. They reveal trends better than single point charts.

There are various types of statistical control charts. The two most useful for construction materials are the **control chart for means (X-bar Chart)** and the **control chart for ranges (R-Chart).**

The key element in the use of statistical control charts is the proper designation of the ***Control limits*** *that are set for a given process. These control limits are not necessarily the same as the tolerance limits of the specifications. The control limits are established by the process capabilities (i.e., the variability of the process which includes sampling, testing, production, and material variability). If the control limits are not within the allowable specification limits, then it will be necessary to modify the process to reduce variability in order to bring the process into control (i.e., the control limits are within the specification limits).*

It is beyond the scope of this program to go into detail about these types of charts, but let's take a quick look at the X-bar Chart and the R Chart.

Statistical control charts are based on the population of the material in question. However, we normally don't have the mean and standard deviation of the population, but we can estimate it based on past-production or early

production data on a project. We can determine where the control limits for the process are which will help determine assignable causes (discussed earlier) for process-related problems.

Let's look at our density tests again. In the previous examples you calculated values from only three Lots of HMA. With just a few values to look at, you would be taking a big risk if you used those to estimate your population. The more the better. Suppose, we had data from 20 Lots of material from previous paving of the same mix on the same project. We could take the mean of all the means (called X-double bar) and the mean of all the ranges (called R-bar) and use that to estimate the population. In this case the values were calculated to be X-double bar = 94.2% of TMD and R-bar = 2.46. Using the data form the chart below and the given formulas, we calculate the upper control limits (UCL) and lower control limits (LCL) for this process.

Factors for Control Charts

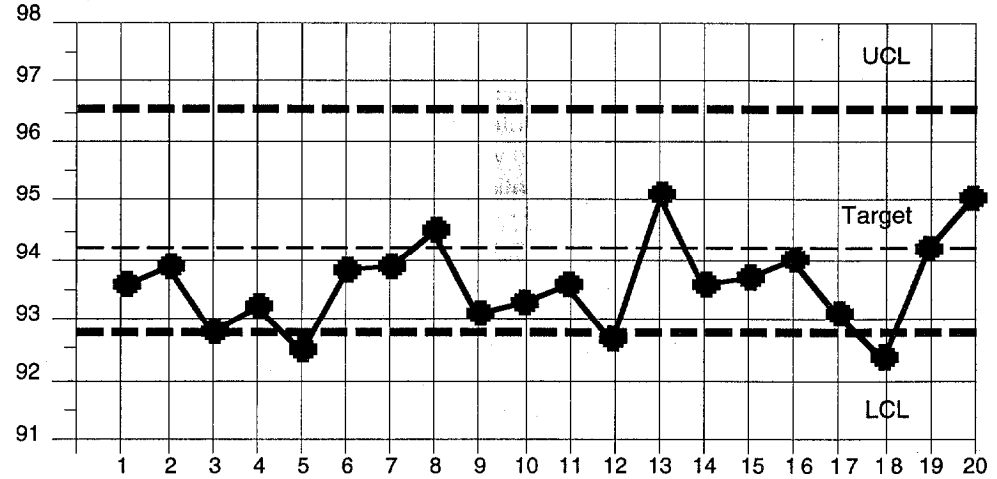
n	A_2	D_3	D_4
2	1.88	0	3.27
3	1.02	0	2.58
4	0.73	0	2.28
5	0.58	0	2.12
6	0.48	0	2.00
7	0.42	0.08	1.92

Remember, we used an average of 5 tests per lot, so n = 5. Note: You will have to take our word on these numbers and formulas, we just don't have time to explain their origin in this program.

To construct an X-bar Chart, we use the following formulas.

UCL	= X-dble bar + (A_2 x R-bar)	LCL = X-dble bar - (A_2 x R-bar)
UCL	= 94.2 + (0.58 x 2.46)	LCL = 94.2 - (0.58 x 2.46)
UCL	= 95.6 % of TMD	LCL = 92.7 % of TMD

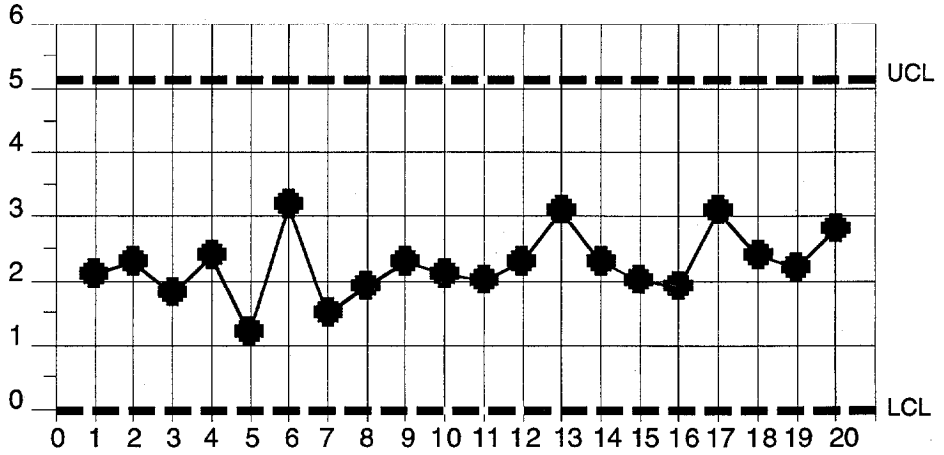
Below is an X-bar Chart using these values and 20 new Lots of material.



To construct an R Chart, we use the following formulas.

UCL	= D_4 x R-bar	LCL	= D_3 x R-bar
UCL	= 2.12 x 2.46	LCL	= 0 x 2.46
UCL	= 5.22 % of TMD	LCL	= 0 % of TMD

Below is an R Chart using these values and 20 new Lots of material.



To interpret these graphs, look for shifts or trends in the data. *Sudden shifts in mean or range may indicate a material change. Gradual shifts may indicate equipment (manufacturing and/or testing) wear. Erratic shifts might indicate over-control (making too many changes to the process).*

10.7.1.3 Summary

The biggest advantage to these charts (either process or statistical type) is that they can tell you when the process is heading in the wrong direction

before it gets out-of spec. Making a small change at this point to get the process back on the straight-and-narrow is much more efficient than waiting until the process is out-of-spec and then having to deal with a shut-down, or large penalty.

10.8 Acceptance Sampling, Testing, and Inspection

The functions involved in acceptance of a product or item of work include in-process inspection, monitoring of the contractor's process control, and acceptance testing. **Acceptance Sampling, Testing, and Inspection (AST&I)** is the function of the specifying agency and serves as the basis of acceptance of the material or work item. The details of the acceptance procedures must be clearly stated in the specification requirements including the frequency of testing, the points of acceptance sampling, the type of test to be used and the acceptance limits including what is to be done when there is non-specification material or work.

The specifying agency must determine what specification criteria is essential to good performance and what are the limits within which the material or work can be produced to assure good performance over the design life of the pavement. For asphalt concrete pavements the two principal field properties that can be measured relatively easy and are critical to good pavement performance are the density of the compacted pavement and its smoothness. As with process quality control, statistical procedures can be gainfully used to assure that a quality product is being produced. The **mean** and **standard deviation** for the density and smoothness properties of well-performing asphalt concrete pavements need to be determined. Once this is done reasonable and practical specification limits can then be established.

10.9 Independent Assurance

The third function, **Independent Assurance (IA),** encompasses the action and considerations included in both process quality control and acceptance sampling, testing and inspection. **IA** is a management tool that requires a third party, not directly responsible for either process quality control or acceptance sampling, testing, and inspection; to provide an independent assessment of the product.

10.9.1 Independent Assurance Program

The IA program can provide data for study and statistical analyses that can be used to modify specification requirements, refine process controls, and assess performance. The most recognized form for an IA program is that which the FHWA requires of state highway agencies on Federal-aid funded construction projects. The requirements of this program are more restrictive and better defined than the broader concepts mentioned above.

FHWA's regulations covering IA require that independent samples and tests and other procedures be performed by state personnel who do not normally have direct responsibility for process control or acceptance sampling and testing. These procedures are used to make independent checks on the reliability of the results obtained in acceptance sampling and testing and <u>are not used</u> to make a determination of the quality and acceptability of the materials or work.

The FHWA Technical Advisory T5080.11 "Acceptance of Materials" has suggested testing frequencies for all three elements of Quality Assurance: process control, acceptance, and independent assurance.

10.9.2 Independent Assurance Program: Techniques

There are many different techniques that can be used for IA programs. Typically, the samples for IA are taken at, or at nearly, the same time as the samples for acceptance testing. The results of the IA tests are then compared with the acceptance test results.

Due to the variability associated with sampling, splitting samples is suggested, particularly if direct comparisons are to be made between the acceptance and IA testing results. The reason that individual comparisons of paired samples are used is to provide timely comparison of results and follow up on any testing or test equipment errors.

To improve the utility of the IA program some specifying agencies have developed statistical tests to compare the mean and standard deviation of the IA tests with those of the acceptance tests. While these statistical tests are beyond the scope of this module, it is important to know that they exist. Such tests can be conducted continuously, thus, resulting in greater reliability and accuracy. This is a different concept from that contained in FHWA's IA program.

If the IA samples indicate that a significant difference exists between the IA results and the acceptance tests, the reason for the difference must be determined. This not always a simple task. There are many sources of error, including laboratory, operator, testing equipment, sampling procedure, etc.

10.9.3 Independent Assurance Program: Responsibility

For the IA program to be effective, inspectors and testers who witness or obtain samples for purposes of IA should make a strong effort to maintain good rapport with those responsible for acceptance testing. It is not the purpose of IA to find things being performed incorrectly, but rather to verify that procedures are proper. However, for the IA program to be effective, all variations from specified procedures and significant differences between acceptance tests and IA tests must be reported. In addition, those responsible for IA must be knowledgeable on all sampling and testing procedures so they can recommend corrective measures to be taken while on the project.

10.10 Smoothness Tests

Smoothness is another characteristic of the finished mat that will effect its' performance. A smoother mat provides a smoother ride and results in less damage to the pavement, from the dynamic effects of trucks impacting the pavement. Smoothness is measured in a variety of ways and is becoming a pay factor in many states.

10.10.1 Straight edge

Oldest way to measure a component of smoothness is with a straightedge. These are usually 10 feet long and some have been adapted with wheels and devices to normally measure deviations greater than 1/4 inch.

10.10.2 Profilograph

The most popular is the "California-style" profilograph. It uses a 25 foot long aluminum truss that rides on a set of 6 hard rubber wheels a each end. It has a center mounted bicycle-type recording wheel that measures the road surface and outputs to a recording device. As the profilograph travels the recording wheel picks up any upward or downward movements within the 25 ft reference plane. The recorder uses a horizontal scale of 1 in = 25 ft, and measures vertical distance (or roughness) on a 1 to 1 basis. The standard testing distance is 1/10 of a mile (528 ft). A blanking band is used to pavement roughness denoted in inches per mile, with the lower numbers indicating a higher degree of smoothness. Older versions produced paper trace which had to be manually interpolated. Newer versions use the same profilograph and a computer to interpret the road surface and automatically output the result. These devices are normally pushed by hand.

Many states that have implemented smoothness specs are based on this method, and many contractors have purchased this type of machine.

10.10.3 Mays Meter

The Mays meter is a towed device that measure smoothness and is used in several states.

10.10.4 Profilometer

The profilometer is a self-contained instrumented truck or trailer that uses accelerometers and distance measuring equipment to measure the pavement profile. The data collected is processed through a computer program and outputs a value. The biggest advantage is that it can 'profile' a pavement at highway speeds. The net cost per tested mile is less expensive over the long run, although the initial investment is higher than the other methods. Some agencies believe it provides the most accurate measurement of road smoothness.

10.10.5 Comparing Smoothness Results

Since each method measures a slightly different value or uses a different technique, attempts have been made to correlate the results. The values produced by each of these methods have yet produced a correlation formula with a high degree of precision.

10.11 Summary

For a **Quality Assurance System** to work properly, the three elements of **process quality control; acceptance sampling, testing, and inspection: and independent assurance** must be in place and working.

The process quality control function can take many different forms. But, experience has shown that it works best if the state highway agency specifies at least minimum process control requirements be established in the contractor's quality control plan. It is important that contractor personnel as well as those from the specifying agency realize how warning and control limits work. Otherwise, over reaction and over correction can create problems that may be more severe than not reacting at all.

Even when things appear to be going well, there is still a **need for inspection.** If obviously defective material is brought to the job site, it must be rejected or corrected. This statement may seem ridiculously obvious, but one argument that is often used against QA type specifications is that obviously defective material cannot be rejected if it is not part of the random sample. The fact that the random sampling procedure did not result in sampling of an obviously defective quantity of material does not mean that it should be accepted.

Quality Control and Quality Assurance are partners that help measure the process of HMA Construction. They provide tangible values that are used as indicators of how well the pavement will perform, and provide a basis for payment. QC/QA is considered best practice as long as it is done right.

10.12 Review Video Tape

10.13 Review Objectives

Can you?

1. State the objective of QA;
2. State the objective of the QC;
3. Describe the four types of specifications;
4. Define population, lot, sample, specimen;
5. Define and construct random sampling and testing plans;
6. Calculate the compacted density of a sample;
7. Calculate basic statistical functions;
8. Construct control charts;
9. List applicable QA/QC tests (basic equipment, procedures, and variables).

10.14 Evaluation

Please complete the evaluation for Unit 10 at this time. Thank you.

References:

Burati, J. L., Jr., and Hughes, C.S. **Highway Materials Engineering, Module I: Materials Control and Acceptance - Quality Assistance**, National Highway Institute Course No. 13123, February 1990.

Willenbrock, J.H. **A Manual for Statistical Quality Center of Highway Construction**, National Highway Institute, January 1976.

Correspondence with Doyt Bolling, Federal Highway Administration

Correspondence with Gale Page, Florida Department of Transportation

11

Unit 11 Troubleshooting #3

11.1 Introduction

11.1.1 Review objectives of this unit.

What's-in-it-for-me? This is the last unti of this program and instead of lecturing, it is time to spend some time answering any questions or working on any problems you have run into. You may wish to share some of your insights and experiences with the other partcipants.

OVERVIEW: This unit is intended to be an open discussion forum for questions and answers.

OBJECTIVES: At the end of this unit you should have had the opportunity to get answers to any remaining questions you had regarding this course and materials.

METHODS: The methods used to facilitate this unit are left to the discretion of the instructors and particpants.

EVALUATION: You will complete an evaluation of this unit and a general evaluation of the HMA Construction program. After completing your evaluations and turning them in, you will receive any last instructions and then your final exam.

11.2 General Discussion and Problem Session.

11.3 Closing Remarks by Instructors.

11.4 Evaluation

Some quotes to ponder:

"*Things that are taught in schools are not an education, but the means of education.*"
Ralph Emerson

"*Education's purpose is to replace an empty mind with an open one.*"
Malcom S. Forbes

12

MIX DELIVERY PRODUCTION CALCULATION FORM:

Date:_____ Project #: _____

Project:_____

Tons scheduled to be placed today (MIX): _____ tons

Hours of paving scheduled (TIME): _____hours

Rate of mix needed to be delivered to jobsite (H-RATE):
= MIX ÷ TIME = _____ ÷ _____ = _____ tph

Rate of mix available from HMA facility (F-RATE): = _____ tph

STOP: Is the H-RATE slightly greater than or equal to the F-RATE?

Average Truck Capacity (SIZE):_____net tons

Total Truck Trips Needed (TRIPS):
= MIX ÷ SIZE = _____ ÷ _____ = _____ trips = TRIPS

Truck Cycle (in minutes):

Delay at Facility :_____
Load Time :_____
Ticket & Tarp :_____
Haul to Job :_____
Delay on site :_____
Dump/clean up :_____
Return Haul :_____
==========
Total cycle in minutes = _____ ÷ 60 min/hr
= **Truck Cycle (CYCLE):** _____ hours/trip

Number of Trips per Truck (LOADS):
= TIME ÷ CYCLE
= _____ ÷ _____ = (Round down) _____ trips/truck = LOADS

Number of Trucks Needed (TRUCKS):
= TRIPS ÷ LOADS
= _____ ÷ _____ = (Round up) _____ total trucks = TRUCKS

Is TRUCKS x LOADS ≥ TRIPS? (_____) x (_____) = (_____) ≥ (_____)

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PAVING PRODUCTION CALCULATION FORM:

Date:_____ Project #: _____

Project:_____

Tons scheduled to be placed today (T-MIX): _____ tons

Hours of Paving Scheduled (P-TIME): _____hours

Mix Delivery Rate (H-RATE):

= T-MIX ÷ P-TIME

= _____ ÷ _____ = _____ tph

Paving Width (WIDTH): _____ ft

Paving Thickness (THICK): _____inches ÷ 12 in/ft = _____ft

Compacted Mix Density (DENSITY):

Specification limits for density: Minimum = _____; Maximum = _____

The in-place target density should be above the Minimum: Target = _____

DENSITY = Reference Density x % Target Density

= _____ pcf x _____

= _____ pcf

33.33 = Conversion factor (tons to pounds & hours to minutes)

Actual Paver Production Rate (P-RATE):

= MIX RATE x 33.33 ÷ WIDTH ÷ THICK ÷ DENSITY

= _____ x 33.33 ÷ _____ ÷ _____ ÷ _____

P-RATE = _____ fpm

Paving Efficiency Factor (EFF1): _____ (recommended: 0.75 - 0.85)

Actual Paver Speed (PAVER):

PAVER = P-RATE ÷ EFF1 = _____ ÷ _____ = _____ fpm

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COMPACTION PRODUCTION CALCULATION FORM:

Date:_____ Project #: _____

Project:_____

Recommended Breakdown Rolling Speeds:

Static: 2 to 3-1/2 mph; **Pneumatic:** 2 to 3-1/2: **Vibratory:** 2 to 3[A]

Actual Speed fpm (mph)	Reversal Factor	Effective SPEED fpm (mph)
176 (2.0)	-10%	158 (1.8)
220 (2.5)	-10%	198 (2.3)
264 (3.0)	-10%	238 (2.7)
308 (3.5)	-10%	277 (3.1)
352 (4.0)	-10%	317 (3.6)

[A] Actual Speed for vibratory rollers can be based on the roller's operating frequency and an impact spacing of 10-12 impacts/ft. Use the following two lines to calculate these values.

ACTUAL SPEED = VPM (_____) ÷ (_____) impacts/ft = _____ fpm ÷ 88 = _____ mph
EFF-SPEED = Actual - 10% = (_____) - 10% (_____) = _____ fpm ÷ 88 = _____ mph

Actual Roller Drum Width (DRUM): _____inches

Effective Drum Width (EFF-DRUM): To account for drum overlap, 6 inches is normally used.

EFF-DRUM = DRUM - 6 inches ÷ 12 in./ft = _____ - _____ ÷ 12 in./ft = _____ ft

Paving Width (WIDTH): _____ft

# of Passes to Cover Mat Width Once (PASS): = WIDTH ÷ EFF-DRUM
PASS = _____ ÷_____ = (Round up to whole number) _____

# of Repeat Coverages to Achieve Density (COVERAGE): _____ (From test strip)

Total # of Passes (T-PASS): = PASS x COVERAGE = _____ x _____ = _____
(Note: If T-PASS is an even number, add 1 to T-PASS for make up pass)
Is T-PASS an even number? If Yes >>>>>> New T-PASS = T-PASS + 1 = _____

Roller Efficiency Factor (EFF2): _____ (recommended 0.75 - 0.80)

Effective Compaction Production Rate (C-RATE):

C-RATE = EFF-SPEED x EFF2 ÷ T-PASS = _____ x _____ ÷ _____ = _____ fpm

Compare: F-RATE (____tph) to H-RATE (____tph): P-RATE (____fpm) to C-RATE (____fpm)

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FORM 2-1 DAILY HMA PRODUCTION REPORT

Date:_____ Time started:_____ Time Finished:_____
Project #: _____ Project: _____
HMA Facility: _____

Air temp._____F; Sunny/ Ptly. Cloudy/ Mstly Cloudy; Wind_____
Precipitation: Time started:_____ Time ended:_____ Remarks:_____
_____

Types & Sources of Materials Used: Mix Type: _____

Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;
Type:_____; Source:_____; Moisture:_____%; Percentage Used:_____;

Gradation Test Results

Sieve (mm)	JMF	Toler.	Test 1	Test 2	Test 3	Test 4	Average
3.0" (75.0)							
2.5" (63.0)							
2.0" (50.0)							
1.5" (37.5)							
1.0" (25.0)							
3/4" (19.0)							
1/2" (12.5)							
3/8" (9.5)							
#4 (4.75)							
#8 (2.36) /#10 (2.00)							
#16 (1.18) /#20 (0.850)							
#30 (0.600) /#40 (0.425)							
#50 (0.300) /#80 (0.180)							
#100 (0.150)							
#200 (0.075)							
Sample Time:	==========						=======
Sample Location:	==========						=======
Sample Temperature:	==========						=======

Random Temperature Checks:
High:_____; Low:_____; Range:_____; Average:_____; Std. Deviation:_____;

Mix Property Test Results

AC Content: Ext./ Nuc.							
Avg. Voids / Density							
Avg. Stability							
Avg. Flow							
_____							
_____							
_____							

Tons Made _____; Tons Shipped _____, Agg. Tons _____; AC Tons _____, _____ _____

REMARKS: _____
_____
_____
_____

Submitted by: _____ Date: _____

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FORM 2-2 DAILY HMA CONSTRUCTION REPORT

Date:_____ Time started:_____ Time Finished:_____
Project #: _____ Project: _____

Air temp.:_____F; Surface temp.:_____F; Sunny/ Ptly. Cloudy/ Mostly Cloudy; Wind_____
Precipitation: Time started:_____ Time ended:_____ Remarks:_____

Summary of Work Completed This Date

Item	Location	Tons/ S.Y.	Tons/day S.Y./day	Total to Date	Calculations

Field Test Results

Equipment Type: _____ ID #:_____ Calibration Information:_____ OK to Use?___

Time/Test#/ Sample ID #	Location (Station: Offset)	Data	Final Results	Spec. Limits	Calculations

REMARKS: _____

Submitted by: _____ Date: _____

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FORM 2-3 PROJECT PERSONNEL: AGENCY

PROJECT NAME: _____

PROJECT #: _____

LOCATION: _____

PROJECT INFORMATION: _____

ITEM	DESCRIPTION	QUANTITY	ITEM	DESCRIPTION	QUANTITY

KEY PROJECT PERSONNEL

Title	Name	Office/Field Telephone	Mobile (Car/Beeper) Telephone	Home Telephone
Resident Engineer				
Lead Inspector				
Inspector				
Inspector				
Inspector				
Construction Eng.				
Bituminous Eng.				
Materials Eng.				
District Mat'ls Lab				
Field Materials Lab				
Safety Engineer				
Local Police				
State Police				
Local Fire				
Ambulance				

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FORM 2-4 PROJECT PERSONNEL: CONTRACTOR

PROJECT NAME: _____

PROJECT #: _____

LOCATION: _____

PROJECT INFORMATION: _____

_____

_____

KEY PROJECT PERSONNEL

Title	Name	Office/Field Telephone	Mobile (Car/Beeper) Telephone	Home Telephone
Project Manager/ Engineer				
Project Superintendent				
Paving Foreman				
Paving Foreman				
QC Supervisor				
QC Field Tech.				
QC Lab Tech.				
QC Technician				
Facility Operator				
Traffic Control Supervisor				
Safety Director				
NRC Contact				
Haz-Mat. Resp.				

REMARKS: _____

_____

_____

_____

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FORM 2-5 **TRAFFIC CONTROL CHECKLIST**

Date:_____ Project #: _____
Project:_____

Location of area:
Station _____ to _____; Offset _____;
Other _____

- ☐ Are warning signs properly mounted and in place?
- ☐ Is the beginning taper proper length and in place?
- ☐ Is arrow board correct? (message, location, Illumination for day/night)
- ☐ Are channelizing devices in place? (Type)_____ Spacing _____ft
- ☐ Are side roads properly signed?
- ☐ Is the ending taper in place

Prior to beginning work, drive through your work zone and ask these questions about the basic requirements of a Traffic Control Setup (TCS):

1. Does this TCS Fulfill a Need?
2. Does this TCS Convey a Simple Message?
3. Does this TCS Command Respect of the Motorists?
4. Does this TCS Give Adequate Time for Response?
5. Does this TCS Meet All Applicable Specifications?