CAT® PAVING PRODUCTS

GUIDE TO ASPHALT PAVING

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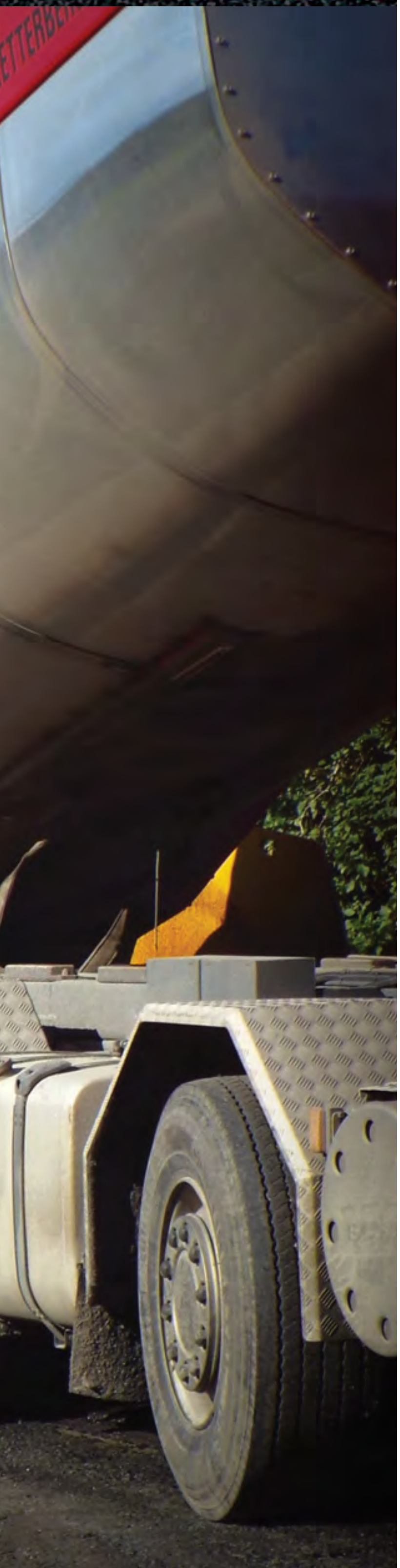

INTRODUCTION

The Cat Paving Products *Guide to Asphalt Paving* is intended to be a practical reference guide for the process of paving.

This guide deals with asphalt production only to the extent that production of asphalt affects the quality of the material being laid down on a project. Likewise, the design of the various types of bituminous material will be covered briefly in order to help develop an understanding of how mix design may affect the flow of material through a paver and under the paver's screed. The guide is not intended to be a reference for project design or asphalt selection.

The *Guide to Asphalt Paving* will be helpful to all personnel involved with the planning, preparation, and placement of asphalt. Certainly, the crewmembers who operate the paver should understand the information contained in the guide. Crew supervisors who help the operators and work on the planning steps will find the guide useful. Estimators, project managers and project superintendents can use the guide to help plan project efficiency and prepare to meet the requirements and specifications of various applications. Finally, quality control and quality assurance personnel will find valuable troubleshooting information in the guide.

Specific applications will be discussed in detail. However, due to the many variables in asphalt paving around the world, it is impossible to cover every situation in a reference guide such as this. Also, the terms used to describe paver components, asphalt mixes, and project variables are different around the world. When possible, for the purpose of clarity, terms will be explained or defined in different ways. For example, in this guide, the word "asphalt" will be used most often to describe what may be called "bituminous material" or "asphalt concrete" in some parts of the world.

No matter how the material being laid down by the paver is referred to, there are four basic elements to quality construction of asphalt layers. The information contained in this guide will consistently refer back to these four elements.

BASICS OF PAVING QUALITY

1. **Utilize fundamentals correctly every time.** When the crew violates certain asphalt paving fundamentals, defects in the asphalt layer usually appear.

   A crew that is well-trained in paving fundamentals and takes the time to control the fundamental aspects of paving will generally be successful. In Unit 3, "Fundamentals of Paving," these basic principles are described. They should be the foundation for all crew actions. In Unit 8, "Troubleshooting Guide," the guide demonstrates that adherence to these fundamental principles creates solutions to many common mat defects.

A well-trained crew has set up the feeder system to maintain the correct head of material.

2. **Pave efficiently.** To pave efficiently means to calculate and maintain a paving speed that consumes the mix in a steady manner and avoids long paver stops waiting for mix.

   A calculated paving speed should be used on any project that has long, uninterrupted paving segments such as a highway. Minimizing or eliminating paver stops helps to maintain smoothness and the consistency of layer temperature in front of the compaction process. Paving continuously for long periods on projects such as parking lots and city streets, is much more difficult, but striving for efficiency is still worthwhile. How to calculate paving speeds and plan for efficiency are covered in Unit 2, "Pre-project Planning."

Efficient paving means continuous paving on highway projects.

3. **Understand grade and slope requirements.** On many projects, automatic grade control and/or automatic slope control will be required to create the correct layer thickness (yield), improve smoothness, match the height of an existing structure, and/or to create profile (slope).

   Before starting to work, the project's requirements must be determined and grade and slope control must be set up to make the paver create the desired results. A paver is not set up to pave a parking lot the same way it is set up to pave an airport runway or a highway.

   Each project has different requirements and specifications. In Unit 6, "Automatic Grade and Slope Control," the basics of grade and slope control, as well as specific tips for controlling yield, smoothness, joint matching, and so forth are discussed.

Set up grade and slope control according to project requirements or specifications.

4. **Avoid big mistakes.** Big mistakes, like spills in front of the paver or running low on material in the auger chamber, cause big quality problems and often result in costly rework.

   Throughout this guide, examples of paving mistakes will be shown with suggestions for learning how to avoid them. Many times, lack of planning and poor preparation contribute to mistakes. The equipment may be used incorrectly. Or, the crew may be skipping set-up steps and violating paving fundamentals.

   Whatever the cause, big mistakes should be easy to identify and correct.

Spills on the grade in front of the paver are a big mistake and should be corrected.


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GRADE CONTROL

Unit 1
THE BASICS OF ASPHALT PRODUCTION

It is essential that all crewmembers know the basics of asphalt production and how different mix designs affect the paving process. Effective communications between the plant personnel and the paving crew are crucial, as the paving crew must be aware of changes in hourly production or mix formulation.

[BASICS OF ASPHALT PRODUCTION]

In general terms, asphalt is a combination of aggregates, fine material, and bitumen, also called asphalt cement. The aggregates, when moved into close contact during the compaction process, provide strength in the asphalt layer. The bitumen and fines fill the voids between the aggregates and act as the binder that helps bond the aggregates.

Depending on the specifications mandated by the project owner or by the desired end result, additives and modifiers are often included in the mix formula. Various types of recycled material, most commonly reclaimed asphalt pavement, may be included in the mix formula. In Unit 1, the basics of asphalt production and the types of asphalt mixes and their uses are covered.

[ASPHALT MANUFACTURING FACILITY]

An asphalt manufacturing facility consists of many elements: aggregate stockpiles, asphalt cement storage tanks, an aggregate feeder system, an aggregate drying system, a system to blend aggregate and asphalt cement, a production control system, dust collectors, surge and storage bins (silos), and a scale. The facility will often have a laboratory used for quality control and quality assurance. A location where trucks are cleaned out and a suitable release agent is applied to the bodies of the haul units is typical.

[AGGREGATE STOCKPILES]

Stockpiles usually consist of crushed aggregate in different sizes and sand (fine material), although there may also be stockpiles of what is commonly called river run, or uncrushed aggregate. Each stockpile should be clearly marked so the loader operator who transports material can easily identify aggregate type and size. Production of asphalt should not begin unless there is at least one day's supply of aggregate for each type scheduled to be used in the manufacturing process.

Stockpiles should be located in such a manner as to prevent contamination through contact with adjacent stockpiles. Barriers are commonly used to separate stockpiles.

Placing aggregates on paved surfaces is another way to minimize contamination of stockpiled material. The loader operator will not have to worry as much about introducing soil or other low-quality materials into the asphalt manufacturing process.

Reducing the moisture content of stockpiled material is another issue. When aggregates have high moisture content, additional drying time will be required, which is costly due to increased fuel consumption by the plant and a decrease in hourly production.

Protecting stockpiles with removable covers is a common practice. Another quality control step that is becoming increasingly popular is placement of stockpiles inside covered structures. The additional costs of these techniques can be justified when production costs go down and hourly production increases.

A well organized asphalt plant increases productivity and profitability.

Depending on the design of the asphalt manufacturing facility, stockpiles are usually created in three ways: with stationary conveyors, moving conveyors or dump trucks.

If the plant is located within a quarry and crushing operation, aggregates are stockpiled by discharging crushed material from stationary belt conveyors or from moving radial belt conveyors. The stationary conveyor creates a cone-shaped stockpile. The moving radial conveyor creates a fan-shaped stockpile. When aggregates are transported to a dedicated asphalt manufacturing facility, dump trucks are commonly used.

When discharging material from a conveyor or from a dump truck, material segregation may occur—even though the material is theoretically of a uniform size. The fine (smaller) material tends to flow toward the center of the stockpile, while larger material rolls toward the outer edges of the stockpile.

The loader operator who is transferring material from the stockpiles to the aggregate feeder system (cold feed bins) can help blend material. The loader operator should not take material from the same stockpile location in successive passes.

Instead, the loader operator should divide the face of the stockpile into three segments. Take each bucket from a different segment in an alternating sequence. Approach the stockpile with the loader bucket lowered to the ground, but not digging into the soil.

If the stockpile is not covered and there is moisture in the lower portion of the stockpile, raise the bucket 0.5 m to 1.0 m (18" to 36") off the ground when approaching. Slowly curl the bucket upward and back as it enters the stockpile. When dumping each load, slowly rotate the bucket from the lowest height possible and fill the appropriate feeder bin.

Visual observation of the stockpile will identify areas of segregation, if any exist. Samples of the mix produced at the plant will also help determine if the gradation of the mix is within specifications.

[ASPHALT CEMENT STORAGE TANKS]

Plants typically include multiple storage tanks that contain the various types of asphalt cement used in the production of different mix designs. Each tank should be clearly labeled, indicating the type of asphalt cement that is stored and the capacity of the tank. Tank piping used for loading and unloading should be clearly labeled as well.

Environmental regulations vary around the world, and permits for above-ground and in-ground asphalt cement storage tanks are frequently required. The permits spell out the maintenance requirements and necessary steps to prevent leaks and spills in the storage area.

Storage tanks for asphalt cement.

Asphalt cement storage tanks are insulated and include heating systems and often mixing systems, especially if the asphalt cement has been modified with polymers. For example, unmodified asphalt cement may be heated to 160° C (320° F) in the storage tank. Polymer-modified asphalt cement will be heated and stored at slightly higher temperatures.

The asphalt cement storage tank supplies the mixer with the specified amount of asphalt cement.

[AGGREGATE FEED SYSTEM]

A feed system supplies the mixer with aggregates of the correct size and in the correct amounts according to the gradation specified by the mix design.

The facility must have a sufficient number of feeder bins to supply the various mix elements. One feeder bin should not be used to supply two types or sizes of aggregates.

Feeder bins are normally open-top compartments with sloped sides and adjustable gate openings at the bottom for controlled discharge of material. It is the responsibility of the loader operator(s) to maintain adequate levels in the feeder bins.

During the mix manufacturing process, the feeder bins should not be allowed to run extremely low or completely out of material. Most control systems have a bin level detection system that automatically stops the flow of material to the dryer and mixer if one or more bins run out of material.

The feed system is designed to deliver a steady flow of aggregate to the mixer.

Material sizing screens are an integral part of the aggregate feeder system. The sizing screens prevent oversize aggregate from entering the dryer and mixer. The sizing screens have one-dimension openings. For example, if a base mixture is being manufactured, the screen openings may be 45 mm (1.75"). For the production of binder and surface mixes, screens will usually have an opening that is up to 6 mm (0.25") larger than the largest nominal aggregate size.

User Tip: *Oversize material that shows up in the asphalt layer is a common problem. There can be several causes. One is the asphalt manufacturing facility using the wrong size opening in the sizing screen. Or, it may be that the sizing screen has been damaged and has holes. When troubleshooting the appearance of oversize material in the asphalt layer, include an inspection of the sizing screens in the checklist.*

Aggregates flow out the discharge gates in a metered fashion, usually onto a moving conveyor belt. Scales, or load cells, weigh the contents of the belt. This information is sent to the facility's control system which regulates the speed of the conveyor belt according to the production needs of the dryer and mixer.

[DRUM MIXER]

Various types and sizes of drum mixers are available. Their operation can be summarized in the following manner: dry and heat the aggregates, introduce asphalt cement, blend the aggregates and asphalt cement, discharge the mixture, and provide an exhaust for gases and dust. These steps produce a continuous flow of mix into surge bins (silos) or storage bins.

Drum mixers are the most recent type of drying and mixing equipment. They can be permanent or portable. Hourly production rates are determined by drum length and diameter.

A drum mixer's spiral flighting continuously moves aggregate to the lower end.

Plants that utilize a drum mixing system are capable of high-output, continuous asphalt production.

The mixer's production rate is affected by the moisture content and the desired output temperature. Aggregate having high moisture content requires longer drying time resulting in lower hourly production. Likewise, certain mixes require higher output temperatures that vary according to the type of bitumen, the length of haul to the project, ambient conditions, and the compaction process.

User Tip: *It is important for the crew foreman or project superintendent to receive accurate hourly production rates. Hourly production is one determining factor for ordering trucks to haul mix to the project. Knowing hourly production also helps the supervisors and crewmembers calculate the working speed that promotes efficient paving. Remember, paving efficiently is a key quality element.*

Drum mixers are installed at a slight inclination. Aggregates enter the upper end of the drum mixer. A burner blower also extends into the upper end of the drum mixer. The burner blower provides the heat that dries the aggregates and brings their temperature to a specified level.

Spiral flighting inside the drum mixer continuously moves the aggregates toward the lower end of the drum mixer. It usually rotates at a rate of five to 10 revolutions per minute.

The line that discharges liquid, asphalt cement extends into the lower end of the drum mixer. As the aggregates move from the middle area of the drum mixer toward the lower end (discharge), they are coated with hot asphalt cement.

Some gases and dust are created inside the drum mixer during the drying and mixing process. An exhaust fan pulls the gases and dust out of the drum through a vent. The suction created by the exhaust fan also helps air induction at the blower burner end of the drum, leading to better combustion.

Hot mix flows out the bottom of the drum mixer's lower end, usually onto a drag slat conveyor that loads the mix into a surge or storage bin (silo).

[BATCH MANUFACTURING]

A batch manufacturing facility produces one quantity of mix at a time. A batch facility has many of the same components as a drum mix system. The aggregate stockpiles and feeder system operate in much the same manner as described in the section on drum mixers. The main difference between drum mixers and batch facilities is how the aggregates are heated and blended with asphalt cement.

In a batch facility, the various cold aggregates are delivered by a belt system to a rotary dryer. The aggregates enter the upper end of the rotary dryer, while the burner blower is at the lower end. Spiral flighting and gravity move the aggregates through the flame. The aggregates and hot gases inside the dryer move to the lower end. The hot aggregates then are discharged into an elevating system.

The bucket elevator, an enclosed container, transfers the hot aggregates to the top of the batch tower. While the aggregate proportions have been initially controlled by the cold feeder system, a more precise screening occurs at the top of the batch tower. A series of vibrating screens separates the aggregates by size and fills the hot aggregate bins. From the hot aggregate bins, the aggregates are transferred in measured amounts to the mixer, usually a twin-shaft pugmill.

User Tip: *The vibrating screens typically handle only a small amount of material. If a screen is overloaded, material that would normally pass through a given screen opening may run over into an adjacent hot bin. The gradation of the aggregates in the mix would, therefore, be incorrect. When troubleshooting mix conformance problems, it is important to sample the hot bins to assure that overloaded screens are not causing the problem.*

When the correct amounts of aggregates are transferred to the mixer, the container is closed. Hot aggregates are mixed for a specified time. A metered amount of hot asphalt cement is injected into the pugmill and the wet mixing cycle begins. It is important that the volume of material inside the mixing pugmill be maintained at the correct level to assure correct blending and aggregate coating.

At the end of the mixing cycle, the "batch" can be loaded directly into a haul unit, but is more commonly retained in a surge or storage bin (silo) for later loading.

[DUST COLLECTORS]

Dust collection systems are an important part of air quality control. There are two types of dust collection systems: a wet collector in the form of a high-pressure venturi or a fabric filter collector, commonly called a baghouse.

Wet collectors are less common because the collected dust is not available for use as a component in approved mix designs. Also, the water and dust mixture is a waste product that requires special handling and disposal.

Dry dust collectors force the dusty exhaust air produced during the manufacturing process (drum mixer or batch mixer) through a series of cloth bags. Dust clings to the outside of the bags and clean air exits from the baghouse through a filtered air outlet. The rows of bags receive periodic cleaning by means of air pulses and vibration. One row of bags is cleaned at a time. The dust falls into a hopper at the bottom of the baghouse.

To prevent contamination, many dust collection systems have an automatic shutoff feature that stops production when the collection hopper is full.

Dry dust collected by a baghouse has the potential to be returned to the mix.

Baghouse dust may be returned to the drum mixer or batch mixer, if the mix design permits inclusion of baghouse dust.

User Tip: *If clumps of dust appear in the mix, it may be a sign that bag cleaning is not being done properly. Be alert for dust balls or "fat spots," if the mix contains baghouse dust.*

[SURGE OR STORAGE BINS (SILOS)]

Surge or storage bins hold the material produced by the asphalt manufacturing facility until the mix is loaded into haul units and transported to the worksite.

By definition, a surge bin is intended as a temporary holding unit. The surge bin allows the production of mix to continue, even if there is an interruption in the availability of haul units. A batch facility is capable of suspending operation while waiting for haul units, if there is no surge bin. A drum mixer is designed for continuous operation and does not produce high quality material if the drum mixer stops and starts.

If a surge bin is used in conjunction with a batch facility, production of mix can begin prior to the scheduled arrival of haul units. Hauls units can quickly load from a surge bin without the need to wait for the completion of a batch cycle. Therefore, the cycle times of haul units are more predictable, and the task of ordering haul units should be less complicated because of the continuous flow.

Depending on the capacity of the surge bin, the batch mixer or drum mixer can cease production when there is enough surge capacity to fill the haul units that are scheduled for the remainder of the shift. The cost of a surge bin is repaid quickly by the reduction in facility operating costs and may reduce the number of required haul units.

Storage bins provide additional capacity for the manufacturing facility. An asphalt manufacturing facility may have multiple storage bins that permit the mixer to produce and store different types of mixes. The facility can simultaneously serve different customers and different projects.

Storage bins are heated and insulated. Mix may be stored for the duration of one paving shift in some storage bins. Other long-term storage silos can hold mix up to three days at 160°C (320° F).

The special silos have one outlet flap, which is sealed with oil to prevent air from entering through the flap and passing upward through the stored mix. Storage bins promote maximum production at the manufacturing facility because they can hold many hours of mixer output. The increased manufacturing production means increased paving production. Consider the following examples.

A drum mix asphalt plant with a surge bin and no storage bins is going to produce 200 tonnes (220 tons) per hour. A 3 m (10') paver with vibratory screed being supplied by a material transfer device is laying down the mix at an uncompacted depth of 65 mm (2.5") and a constant width of 5.5 m (18'). At a paving speed of 4.5 m per minute (14' per minute), the paver will consume the hourly mix production in an efficient manner. In 10 hours, for example, the paving crew will lay down 2 000 tonnes (2,200 tons). The paver, which theoretically can lay down 1 000 tonnes (1,100 tons) per hour, actually has unused capacity at this production rate.

Now, let's add 300 tonnes (330 tons) of storage capacity to the manufacturing facility. Mix production begins two hours before the arrival of haul units and the storage bin is filled before the start of paving.

Since the crew will work 10 hours, divide the storage capacity by 10. Add the result—30 tonnes (33 tons)—to the hourly production rate. Hourly paving production will be 230 tonnes (250 tons) per hour. Paving speed is increased to 5 m per minute (16' per minute) to consume the additional mix in an efficient manner.

At the plant, the facility operator loads trucks primarily from the surge bin to keep the mixer working continuously, and periodically from the storage bin in order to use the storage capacity by the end of the shift. Daily production is now 2 300 tonnes (2,500 tons) in the same 10-hour period. One or two additional haul units will be required.

User Tip: *While surge and storage bins have various designs, most have clam-type discharge gates and cones that are intended to minimize material segregation during truck loading and discharge. If any of the gates are malfunctioning, segregated material may appear in the haul units and in the asphalt layer. Likewise, if the level of mix in a bin goes below the top of the cone at the bottom of the bin, segregation may occur. Include bin inspection in the list of troubleshooting steps when trying to determine the cause of segregation.*

[SCALES]

The weight of the mix loaded into haul units at the manufacturing facility must be carefully controlled and documented. Haul units must not carry loads that exceed the rating of the haul unit or the maximum axle load specified by local public works departments.

Load-cell scales are common under or on the sides of surge and storage bins. They measure the empty and loaded weights of the haul unit. A computerized system calculates net load weight.

Some surge and storage bins measure the weight of the mix in the bin before and after discharge in order to control and document the loads carried by haul units.

The driver of the haul unit receives a load ticket that is delivered to a collector at the worksite. Usually the project owner receives a copy of each weight ticket and the contractor also keeps a copy. Weight tickets are the basis for payment on many projects. Analysis of weight tickets is helpful for calculating yield accuracy and for verifying a paving crew's hourly production rate.

Surge and storage bins help assure uninterrupted flow of material to the worksite.

User Tip: *Loading time is stamped on the weight ticket. Write the arrival time at the worksite on the ticket. Knowing the time it takes for the haul units to make the trip from the manufacturing facility to the worksite is useful when ordering haul units. This may help more accurately adjust the number of haul units throughout the shift to account for rush hour traffic and normal traffic flow in urban areas.*

[MANUFACTURING FACILITY CONTROLS]

Modern manufacturing facilities are controlled by complete computer systems with varying degrees of operational complexity. The control systems are housed in portable or stationary control houses.

Normally, control houses are positioned to provide the operator with a good view of the facility's operations. The control house contains the computer controls and a wraparound console with various computer screens. The facility operator can simultaneously monitor mix production, mix storage and truck scale operation.

The control system stores the data for various mix formulas and receives input from a variety of measuring devices, such as burner temperature sensors, aggregate feeder scales, and mix output temperature sensors. The system automatically adjusts conveyor belt speeds, burner temperature, asphalt cement flow rates and mixing times.

From the standpoint of the paving crew, plant operation has one primary goal—produce uniform, high-quality mix at the estimated hourly production rate. The operator of the manufacturing facility must have good communication with the paving crew. When something changes in the mix manufacturing process, the paving crew has to know what that change is and how it will affect the arrival of the material at the worksite.

[BITUMEN]

What is technically known as bitumen may also be called asphalt cement or asphalt binder in many parts of the world. Naturally occurring bitumens were the original binders used in the earliest production of bituminous mixtures used for paving. The supply of natural bitumens is limited and only accessible in a few locations. As the demand for bituminous paving material increased in the first half of the 20th century, other sources of bitumen had to be developed.

Today, the bitumen used in the production of paving material is produced by the distillation of crude oil during the refining process. At ambient temperature, bitumen is a semi-solid. Bitumens soften and eventually become liquid when sufficiently heated.

Bitumens are produced and classified based on their ability to satisfy project engineering requirements. Until the 1990s, bitumen specifications in Europe and North America relied primarily on mechanical tests for hardness and viscosity.

Heated bitumens added to the mix provide the required binder.

Penetration – The penetration test is used to measure the hardness of bitumens. A lower penetration number indicates greater hardness.

In the test, a container of bitumen is kept at 25° C (77° F). A steel needle is applied to the surface of the bitumen for five seconds under a load of 100 grams. The distance the needle penetrates, rated in tenths of a millimeter (dmm), is the penetration measurement.

Specifications for penetration-graded bitumens typically state the penetration range. On the basis of the penetration test, bitumens are classified into five standard grades from hardest to softest: 40-50, 60-70, 85-100, 120-150, and 200-300 dmm.

Viscosity – Viscosity is typically calculated using the time required for the bitumen to flow between two successive marks. The viscosity of a bitumen is graded in hundreds of poises (grams per centimeter per second) at 60° C (140° F).

User Tip: *From the standpoint of the paving crew, knowing the hardness and viscosity of the bitumen helps crewmembers understand how the mixture will flow under and support the screed. The harder or more viscous the bitumen, the stiffer the mixture will be. A stiffer mix tends to support the screed more easily and the crew may have to adjust accordingly. Those screed adjustments will be discussed in Unit 3, "Fundamentals of Paving."*

In the United States during the 1990s, the Strategic Highway Research Program introduced the performance-grade system to replace the penetration and viscosity grading systems. The performance-grade system is used to assess and designate the engineering properties of bitumens at temperatures that are representative of climatic conditions in which the bitumens will be used.

Performance grade is a two-number system where the first number represents the maximum pavement design temperature (C°), while the second number represents the minimum likely pavement design temperature (C°) that can be used without failure.

For example, performance grade 64-28 signifies maximum pavement temperature at 64° C (150° F) and minimum pavement temperature at -28° C (-20° F). A bitumen classed as 64-28 provides enough stiffness to prevent permanent deformation or rutting temperatures as high as 64° C (150° F). Yet, a 64-28 bitumen remains flexible enough to resist cracking at temperatures as low as -28° C (-20° F).

Most paving bitumens are classified as straight-run bitumens. They are usually produced from the residue of atmospheric distillation of petroleum crude oil. Additional classes include oxidized bitumens, cutback bitumens, and bitumen emulsions. These last three classes are not typically used for the production of high-temperature bituminous paving material.

Another class, known as modified bitumens, contains quantities of special additives such as polymers, crumb rubber, latex, sulfur, polyphosphoric acid and/or other products that modify their properties to meet specific engineering requirements. Modifiers typically represent 3 to 15 percent of the bitumen by weight.

User Tip: *Modifiers such as polymer and latex tend to make mixes stiffer. They are often produced at higher than normal temperatures to help the mixes flow under the screed and as an aid to the compaction process. Some modified mixes are very sticky. The frequency of cleaning and maintenance must be increased to avoid build-up of mix on the paver's feeder system and screed components.*

[AGGREGATES]

While bitumens serve as the binding agent in the bituminous mixture, aggregates serve as the load-bearing component of the bituminous layer. Various types of aggregates are used in bituminous paving mixtures. They are classified as sand, gravel, crushed stone, slag and mineral filler.

Sand – Sand is the fine granular material resulting from the natural disintegration of rock or the crushing of rock. There are many different types of sand, both naturally occurring and artificial. Each type of sand has its own characteristics. Sands often are blended to achieve the desired gradation for a particular mix formula.

Sands are classed by size range, often being between 0.05 and 2 mm (0.002 and 0.08") with 2 mm (0.08") being the opening of a #10 mesh sieve and 0.05 mm (0.002") being the opening of a #270 mesh sieve. Another common way to classify sands is material passing a #4, or 6 mm (0.25") sieve.

Sands help fill in voids between larger aggregates.

Gravel – Gravel is also produced by the natural disintegration of rock and is found around the world. Gravel is larger than sand, the dividing point being the #4 mesh sieve or 6 mm (0.25"). Gravel typically has rounded surfaces. To be included in a bituminous mixture, gravel is usually crushed, not just for sizing purposes, but also to create angular faces that are more desirable for building strength and stability in the bituminous layer.

There are two types of gravel: bank and river. Bank gravel is mined from deposits in areas defined by glacial activity. Bank gravel can be clay-like or sandy, depending on the proportion of fine to coarse material. Bank gravel must be thoroughly washed prior to stockpiling for use at an asphalt manufacturing facility.

River gravel is composed of small pieces of rounded stone, usually no larger than a large coin, harvested from a river bed. The stones are typically more rounded due to erosion caused by water flowing over them for many years.

Crushed Stone – Crushed stone results from the mechanical reduction of gravel, rock, and boulders by specially designed crushing equipment. During the crushing operation, oversized chunks are removed by a scalping screen. A series of vibrating screens can be used to further grade the crushed material.

Crushed sedimentary rock, formed from sediment in water or from wind-blown deposits is one type of aggregate. Sandstone, made up of mineral fragments compressed into layers over a long period of time, is an example of sedimentary rock. Limestone is a sedimentary rock made up of fossilized and compressed plants and animals. Gypsum is a sedimentary, layered rock that results from evaporation or a chemical process.

Sedimentary rocks are plentiful in some areas and are relatively easy to mine and crush. Some sedimentary rocks are fragile and can be damaged during the paving and compaction process.

Igneous rocks, a second class of crushed aggregates, are the result of cooling and hardening of hot molten materials originating beneath the surface of the earth.

Extrusive igneous rocks, like basalt, are those that cooled on the surface of the earth. Intrusive igneous rocks cooled and formed below the surface and were later exposed by erosion or movement of the earth's surface.

Consistent aggregate size and type are keys to setting up a paver to achieve best results.

Igneous rocks are harder than sedimentary rocks and more durable. The drawback to the use of crushed igneous rock is accelerated wear on paver and screed components due to the hardness of the aggregate.

Metamorphic rocks were formed from sedimentary and igneous rocks by prolonged exposure to pressure, high heat and/or chemicals. Metamorphic rocks like gneisses, schists and quartzites are hard, but brittle. They can be damaged by excessive impacts during compaction or excessive tamping force.

Slag – There are various types of slag, a nonmetallic byproduct of a blast furnace or coal combustion in a wet-bottom boiler. Quality requirements for the use of slag in bituminous mixtures vary considerably, but slag can be a good paving grade aggregate when properly sized.

Many slags are porous and absorb bitumen (asphalt cement) readily. Bitumen content is normally adjusted upward when slag is used.

Carefully metered aggregates, bitumen and filler materials produce consistent asphalt quality

Mineral Fillers – Mineral fillers, often referred to as fine materials, are defined as any materials that will pass a #200 mesh screen. The minerals fill in the very small voids in the bituminous layer and thus increase the stability of the layer.

Mineral fillers combine with the bitumen in some mix designs to create a mastic that helps bond the aggregates. Mineral fillers can be crusher dust, Portland cement, flyash, hydrated lime, or naturally occurring fine deposits such as loess. Mineral fillers have special storage containers at the asphalt manufacturing facility and are used in carefully metered amounts.

[TYPES OF BITUMINOUS MIXES]

Bituminous mixes are classified in two broad categories: hot mix asphalt (high-temperature asphalt) and warm mix asphalt (low-temperature asphalt).

Hot mix asphalt – Hot mix asphalt, or high-temperature asphalt, is the product originally produced by modern asphalt manufacturing facilities. In order to lower the viscosity of the straight-run or modified bitumen, the storage temperature of the bitumen will be in the range of 150° C to 175° C (300° F to 350° F).

The aggregates will be heated to the same temperatures prior to blending and coating with the bitumen. These elevated temperatures are necessary to assure proper coating of the aggregates by bitumen and to aid in the compaction process. Depending on the mixer output temperature, ambient conditions and length of haul, the bituminous material may pass under the screed at 150° C (300° F), for example.

Warm mix asphalt –The manufacture and installation of warm mix asphalt, or low-temperature asphalt, started during the 1990s in Europe. The goal of the early research was to find methods to manufacture bituminous material at significantly lower temperatures (using less fuel and creating fewer emissions) while maintaining workability, compaction and serviceability that are equal to or better than hot mix asphalt.

Warm mix asphalt is now accepted as a viable alternative to hot mix asphalt around the world, and the range of applications has grown to nearly universal acceptance.

The texture of the mat is influenced by the type and size of the aggregate.

Warm mix asphalts are produced by adding one of three additives to straight-run bitumens:

1. Water foamed asphalt with an application temperature of 129° C to 135° C (265° F to 275° F)
2. Organics or waxes.
3. Chemicals or surfactants. For wax or chemical additives, the temperature range is 116° C to 121° C (240° F to 250° F).

Dense-graded mix – Dense-graded mixes are produced with continuously graded aggregates. In other words, a variety of aggregate sizes are utilized in the design, along with fines and bitumen. Dense-graded bituminous material is used for many paving applications and may be installed as base layers, binder layers or surface layers. Dense-graded mixes can be further classed as coarse (harsh) mixes or fine (tender) mixes.

Coarse mixes have maximum nominal aggregate size of 19 mm (0.75") or larger in their designs. Coarse mixes tend to support the screed better than fine mixes, but coarse mixes are more prone to segregation.

User Tip: *When laying down a coarse mix, pay special attention to end-of-load segregation and segregation due to erratic feeder system operation. Minimize or discontinue cycling hopper wings to prevent segregation. Do not pave out the surge capacity in hopper inserts or material transfer vehicles when paving with large stone mixes. Adjust the feeder system to run continuously with auger speed in the range of 20 to 40 revolutions per minute.*

Fine mixes have maximum nominal aggregate size of 12 mm (0.5") or less and often a higher percentage of bitumen. Fine mixes are more easily deformed by the weight of the screed, but are usually less prone to segregation.

User Tip: *When laying down a fine mix, you may have to engage the screed counterbalance system to help the screed float correctly and to avoid deforming the asphalt layer during paver stops. If the paver is so equipped, engage the screed support system during paver stops to prevent deep marks.*

Open-graded mix – Open-graded mixes have relatively uniform-sized aggregate typified by an absence of intermediate-sized aggregates. Open-graded mixes are most often used as surface layers, but may also be used as permeable base layers.

Open-graded surface layers utilize small aggregates (usually less than 12 mm / 0.5") and are laid down in thin layers. Because thin layers of bituminous material can lose heat quickly, it is very important for the crew to maintain a speed that allows the compaction train to keep pace with the paver. Mixes like these typically do not have segregation issues. But, because there is a lot of stone-on-stone contact within the layer, watch for aggregate damage when using tamping screeds.

Layers of open-graded mixes lose heat rapidly so paving speed must be matched to the speed of the breakdown roller.

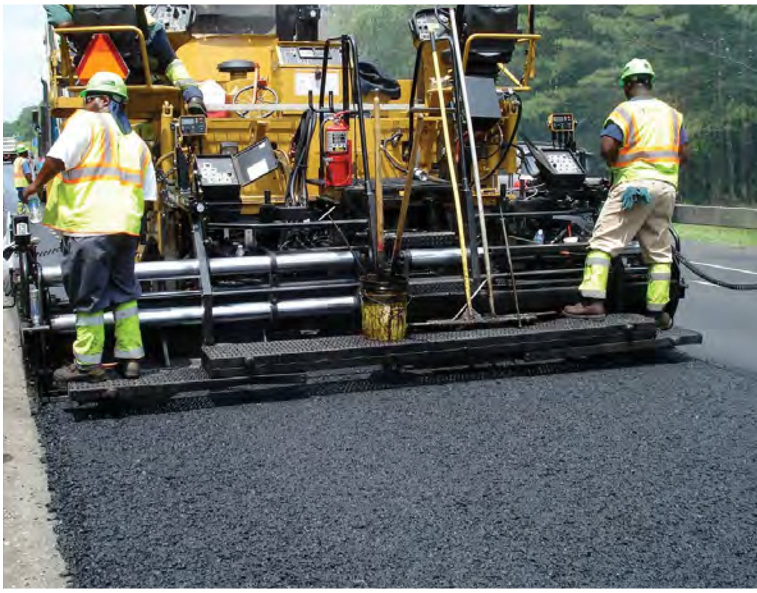
Gap-graded mix – Gap-graded mixes use an aggregate gradation with particles ranging from coarse to fine with intermediate sizes missing or present in small amounts. These mixes also have a high degree of stone-on-stone contact, meaning the same precautions must be observed as when paving with tamping screeds to avoid layer damage. Gap-graded mixes are also more permeable than dense-graded mixes.

Stone-matrix asphalt – Stone-matrix asphalt, like other open-graded mixes, will be missing intermediate aggregate sizes. Stone-matrix asphalt consists primarily of large aggregates and fines and is bound by modified bitumen. These types of mixes are very stiff because of the modified binder and are difficult to move by hand after passing under the screed.

Stone-matrix asphalt is usually very temperature sensitive and must be compacted at elevated temperatures. Therefore, this is another mix that requires the paving crew and the compaction crew to work at the same pace and keep the rollers in the same temperature zone.

Porous asphalt – Porous asphalt is a special mix design created to allow water to percolate through the bituminous layer and underlying aggregate base layer so the runoff water can be captured in a storage reservoir.

Porous asphalt has no fine material in its gradation. Air void content varies considerably according to the engineering requirements. Air voids may be as low as 15 percent or as high as 28 percent in other areas. Porous asphalt is a surface layer, usually laid down between 5-10 cm (2-4") thick. Porous asphalt is laid down using all types of screeds, with or without screed vibration and tamping forces.



Stone-matrix asphalt is a stiff mix that is difficult to rake and shovel.

[BITUMINOUS LAYERS]

Depending on the type of structure that is being built or maintained, as many as five consecutive bituminous layers over a base or sub-base may be placed. Or, may be placed just one layer of bituminous material on some sort of base material. Each layer has its own purpose, usually some sort of mix design unique to that particular layer, and a thickness that satisfies the requirements of that layer.

Let’s examine the layers that make up a highly-engineered highway project. Many such projects use a design known as perpetual pavement.

Bituminous base layer – The base layer of a highway project is laid down on a compacted granular base or stabilized sub-grade and base. In a perpetual pavement design, the base layer may be up to 30 cm (12") thick. The role of the base layer on a highway project is to resist the strain caused by heavy loading and prevent deformation of the underlying base and/or sub-grade.

The aggregates in the bituminous base layer are usually large—up to 38 mm (1.5"). It is common to pave these layers up to 15 cm (6") thick. The base layers are also the first step in creating a smooth longitudinal profile. Averaging skis are commonly used when paving base layers.

Bituminous binder layer – The primary role of the binder, or intermediate, layer of a highway project is to add strength. In this case, the strength is meant to prevent rutting that may occur over time in the surface layer from extending into the intermediate layer.

The mix used in the binder layer will usually have aggregate slightly smaller than the base layer, but is normally a high-quality, dense-graded mix, often using modified bitumen for stiffness. Averaging skis are frequently used when paving binder layers to make additional gains in smoothness. Binder layers often include about 15 cm (6") of bituminous material.

Bituminous surface layer – The surface layer, normally around 5 cm (2"), may have several roles. It may be an impermeable mix designed to keep moisture away from the layers below. Or, as previously discussed, the surface layer may be open-graded to allow moisture to percolate down and prevent puddles and hydroplaning.

The surface is usually the stiffest mix to help minimize rutting caused by heavy axle loading. It should have a skid-resistant texture and the correct transverse profile for drainage. The surface layer is normally the thinnest layer.

A bituminous layer may serve many functions, especially on lower-volume streets and roads. On many streets and parking lots, only two bituminous layers are used to provide strength. On some rural roads, only one bituminous layer is placed on a granular base. In these instances, the granular base or sub-grade provides the bulk of the structure's load-bearing capability. The bituminous layer(s) prevent moisture penetration and provide a durable, smooth surface.

Leveling layer – On some projects, especially cold plane and re-pave projects, a leveling layer, also called a shim layer, may be installed before the surface layer. The purpose of the leveling layer is to correct the transverse profile (slope) and to help improve the longitudinal profile (smoothness). A leveling layer is usually 5 cm (2") thick at the most.

User Tip: *If slope correction is required while paving a leveling layer, check the slope of the base prior to paving. Knowing the amount of slope corrections that will be required will help determine whether to pave slopes using automatic slope control or manual slope control. In Unit 6, the use of slope is discussed in greater detail.*

[SUMMARY]

Paving crewmembers need to know enough about mix designs and the production of bituminous material to help them plan the paving process and to troubleshoot problems on the job. Above all, the supervisor of the paving crew must stay in communication with the asphalt manufacturing facility. Any changes in hourly production will require changes to paving speed and compaction patterns.

Even minor changes in mix design, binder content and gradations can have a large impact on the quality of the bituminous layer and the compaction process.

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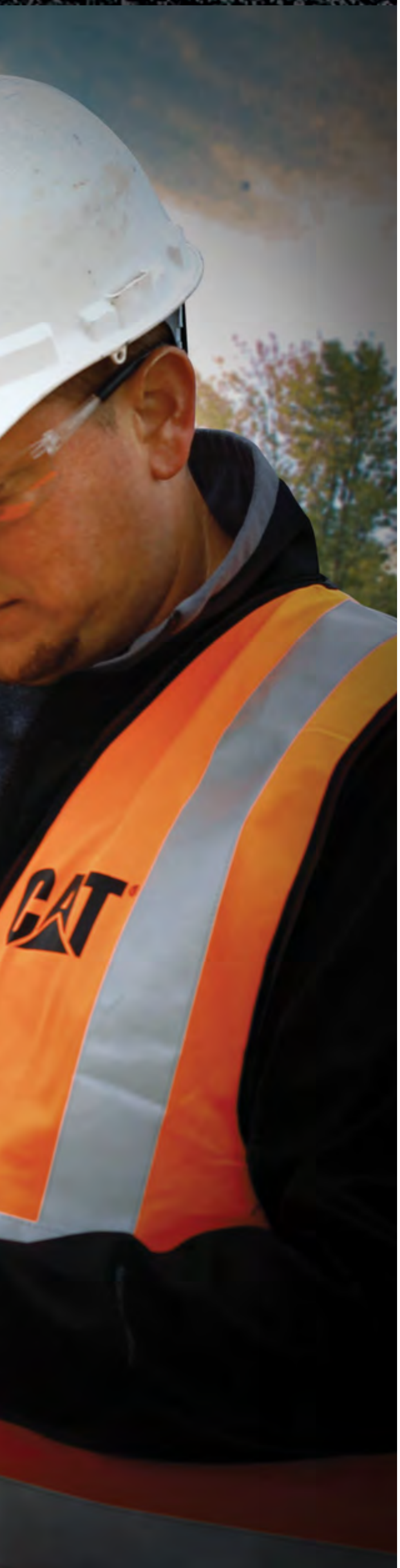


Unit 2
PRE-PROJECT PLANNING

Never underestimate the importance of pre-project planning. Plan early, and create a process to ensure all elements of the plan are in place and executed.

Many common quality problems disappear when proper planning is done before paving begins, and when good communications are in place with all those involved in the process.

The stages of pre-project planning vary, depending on the size and scope of the project. In some instances, planning includes a formal document that is written by the paving contractor and submitted to the project owner for approval.

In other cases, especially on small projects, planning is less formal. But in any situation, planning should not be left to the last minute. A pre-project checklist that is reviewed and approved before the crew arrives at the project should always be used.

A discussion at the start of the shift is a good idea but should not be substituted for thorough planning days or weeks before the project starts.

In this unit, a comprehensive checklist will be developed. Although some of the usual steps are missing, that is okay. Keep the steps in place on the project checklist. Likewise, not all the items mentioned in this unit will apply to every project.

Typically, a project manager is the primary planning coordinator. Depending on the size and structure of the organization, the role of the project manager may be delegated to several people, such as an owner, a superintendent, a crew supervisor or a quality control manager.

[ROLE OF THE PROJECT MANAGER]

The project manager is the link between the project owner, the engineering firm (if any), the general contractor (if any), subcontractors, suppliers and the various departments within the asphalt paving company. The project manager helps to create the plan and makes sure that all steps are followed by the asphalt manufacturing facility, the quality control team, subcontractors and the paving and compaction crewmembers.

[PRE-CONSTRUCTION MEETING]

Most large projects have formal pre-construction meetings that help to finalize the construction plan. The project manager is the primary representative for the paving contractor and may be assisted by a quality control manager and project superintendent. During the pre-construction meeting, many items in the plan are discussed, reviewed and agreed upon. Here is a typical list of points to be covered.

1. Describe the scope of the project.
2. Discuss project specifications to clarify any questionable aspects before starting construction.
3. List project personnel and establish clear lines of authority, as well as contact information.
4. Discuss sequencing, scheduling and methods for completing a quality project on schedule and within budget.
5. Provide a paving plan to include such items as stockpiling of material; plant production and operation; scale operations and procedures; haul units and routes; paving widths; speed of paving; and type and operation of equipment to be used.
6. Provide a plan for constructing a control strip (test section) of adequate size to simulate actual production paving rates and conditions.
7. Discuss sampling and testing frequency and locations, re-testing procedures and quality control and acceptance of program details.
8. Discuss safety goals and procedures to be used on the project: for example, weekly safety meetings with all project personnel.
9. Set up a means to have on-going communication with the owner's representatives and project representatives. Arrange weekly meetings to focus on schedule updates, personnel changes and use of different equipment or methods. Also discuss problems that have occurred or might occur.
10. Discuss traffic control and the best ways to keep the public aware of project progress and planned activities. Topics should include use of media, message boards, flyers to local businesses, local council meetings and more.

[SPECIFICATIONS AND REQUIREMENTS]

Method specifications – The public works agency, especially on highway projects, may write method specifications that determine what type(s) of equipment and construction techniques must be used, as well as any other special conditions that must be addressed. Here are some examples of typical method specifications.

Use of a material transfer vehicle is frequently written into the specifications on highway projects in North America.

The use of material transfer vehicles and their functional capabilities is specified on some highway projects. Those capabilities may include a minimum surge capacity and a type of remixing or blending system. The intent of this specification is to promote continuous paving by separating the paver from the haul units. (See Unit 7 for more information about material transfer vehicles.)

Sometimes the type and size of compaction equipment is controlled by a written method specification that varies depending on the type of bituminous material, layer thickness, and layer purpose.

To promote the construction of durable longitudinal joints, some highway owners require staggered or echelon paving. Staggered paving requires two or more pavers in a style that creates a hot-on-hot longitudinal joint. Staggered paving requires careful planning for haul unit operation, material transfer vehicle usage, and paving speeds. (See Unit 7 for more information about echelon paving.)

An example of a mandatory special condition is the requirement to use attachments that create a wedge joint or notched wedge joint at the unconfined edge of a paving line. These specialty joints require installation of joint formers at the outer end of the screed.

In each of the previous examples, the project manager has to communicate the needs to the equipment manager or equipment dispatcher to assure that the right equipment is available for the project.

End result specifications – End-result specifications typically describe some sort of measurement or testing to verify the quality of the finished product. End-result specifications often dictate how the crew will set up and operate the equipment and, therefore, must be understood by the crew before they begin working.

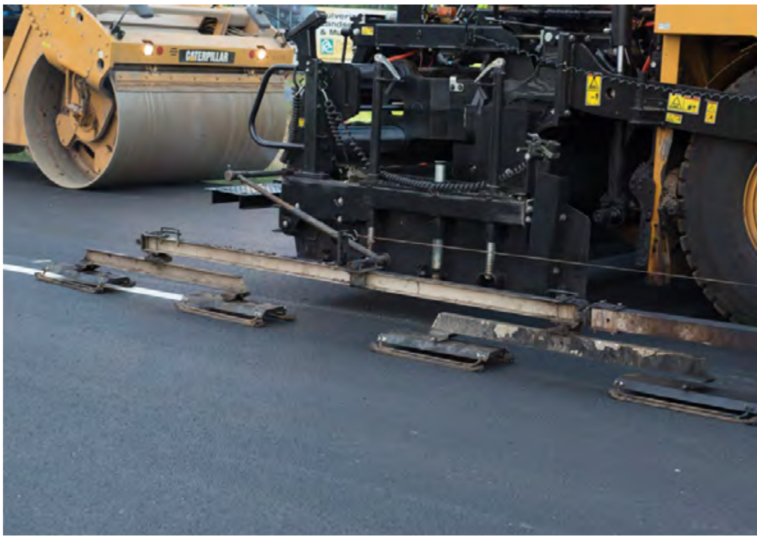
A notched wedge joint is mandatory on this project.

Highway projects may have a performance pay factor, or some acceptance factor, based on the smoothness of the bituminous layer. Common ride quality measurement systems used today are the International Roughness Index, Profile Index, and Ride Number.

In each case, a target will be set for ride quality. Depending on the public works department's policy, the contractor may earn an adjustment in pay per ton (either upward or downward), or may have to perform corrective action to reach a minimum target for ride quality. On projects with a ride-quality specification, use of averaging skis is common. (See Unit 6 for more information about paving with averaging skis.)

Most projects have some sort of end-result specification for in-place density. Depending on the type of mix and the difficulty of the specification, the project manager may have to order additional compaction equipment or specialized compaction equipment. An airport project, for example, requires more planning than a street project because there typically is a higher risk factor associated with creating the specified densities.

Another requirement that is written with increasing frequency measures the uniformity of the temperature of the bituminous layer behind the paver and prior to compaction. Quality control personnel have to know how to document the temperatures to satisfy the specification. The paving crew has to know how to control the temperature of the layer and how to take corrective action when temperatures vary too much. In this example, the project manager will probably order the use of a material transfer vehicle and set a paving speed to establish non-stop paving.



Mechanical averaging skis are often used to help meet ride quality specifications.

Requirements – Job requirements may not be written specifications. The requirements can simply be the most important results to the owner. If the crew talks about and understands these requirements, they can usually set up and operate the paver to achieve the results.

In a parking lot, the most important concerns are usually drainage and appearance. Before paving, the crew should check the slope of the base to determine if the drainage created by the base prep crew is correct. If the slopes are correct, the paver can be set up to lay down the specified thickness and water will drain appropriately.

If the base slopes are incorrect, the crew may decide to set up the paver using automatic slope control. If the slopes are significantly wrong, the crew that installed the base should be brought back to correct the defects.

User Tip: *Remember, when slope control is used, the layer thickness will vary and yields can be adversely affected. Always try to correct slopes prior to paving. Use slope control to make minor slope corrections. (See Unit 6 for more information about slope control.)*

To improve the appearance of a parking lot surface, the crew should lay out the project to maximize the creation of hot-on-hot longitudinal joints or warm-on-hot joints. The compaction pattern is then planned to overlap the joints immediately for best appearance.

In another application, height match to an existing structure such as a concrete gutter may be the most important requirement. In that situation, the crew will need a grade control sensor and the necessary mounting equipment. Prior to paving, check the condition of the gutter to verify that it is suitable to use as a grade reference.

Drainage and appearance are important to the owners of parking lots.

On airport projects, elevations and yield are often the most critical requirements.

On some projects, yield or layer thickness, is the priority to the owner of the bituminous structure. The crew needs to know beforehand when a project has been bid as a "yield" project. They will set up the paver to maintain a uniform layer thickness and typically will not be using averaging skis to control yield.

In summary, specifications and requirements have to be understood by managers, crew supervisors, quality control staff and crewmembers.

[MOBILIZATION AREAS]

The equipment that is going to be used has to be delivered to the project, unloaded and parked at a pre-arranged location. Normally, these areas are referred to as mobilization, or staging areas.

The project manager may have to rent space to park equipment between shifts, if the work will continue for an extended time. The manager will have to find several parking locations if it's a highway project that covers a significant length in terms of kilometers or miles paved.

The mobilization area may include space for crew parking, or the project manager may have to organize transportation for crewmembers. The mobilization area may include space for equipment cleaning. In that case, the crew must be aware of local regulations that control the placement, clean-up and salvage of excess bituminous material. The equipment manager and dispatcher must be informed about the locations of all mobilization sites.

[TRAFFIC CONTROL]

Traffic control affects the safety of the motorists and the workers on the project. An approved traffic control plan should be in place. The plan must conform to local regulations concerning lane closures, detours and time available for work on any given day.

Following is a list of questions that may need to be answered. There may also be special considerations in the local area. Always check with local law enforcement and/or the public works department to resolve any questions.

1. Can newspapers, radio or television be used to give the public advance notice of delays and detours?
2. Can message boards be used to alert motorists in advance of the project? Do the motorists have enough time to react to instructions?
3. Can motorists understand what they need to do?
4. Are a speed detecting radar device and message board available?
5. Are road closures possible, instead of lane closures, to keep traffic away from the work zone?
6. Are adequate barriers, cones and barrels in place to clearly guide traffic away from work areas?
7. Do traffic control personnel have the proper communication devices?
8. Are local law enforcement officials available to assist with traffic control?
9. Are provisions made for changing lane closures?
10. Has someone planned for temporary striping?
11. Is a plan in place for maintenance of warning devices such as message boards and flashing lights?

Lane closures on major highways require planning and good communication for the motorists and crewmembers.

12. Are intersections properly controlled?
13. Are provisions in place for helping haul units enter and depart the work zone?
14. Are provisions made to relieve flaggers and drivers of pilot vehicles?
15. Are all personnel equipped with reflective personal protective gear?
16. Is the proper lighting arranged for night projects?

A great deal of the work for traffic control may be done by a subcontractor, but ultimately the project manager is responsible for ensuring that the traffic control plan is understood by all and continuously monitored.

[HAUL UNIT CLEANING SITE]

Before returning to the asphalt plant, haul units must be cleaned to prevent spilling bituminous material on roadways. Whenever project layout permits, locations should be designated where haul units can be cleaned. These locations should be indicated on the approved haul unit route and given to each driver.

There are several reasons why clean-out areas should be used. First, if haul units are cleaned out directly in front of the paver, the piles of material will lose heat and will show up as cold spots in the paved layer when the screed passes over or through the piles.

Second, the piles may be run over by the tires of the next haul unit, thus creating high spots in the grade being paved. The screed may then drag over the high spots, creating blemishes and areas of open texture.

Finally, requiring a crew to clean spills will stop the paver and that may contribute to deformation and inconsistent temperature of the layer.

The best practice is to have haul units clean out at a designated area and then salvage that material at the end of the shift.

On this project, drivers use the emergency lane as a designated area for vehicle cleaning. Material will be salvaged at the end of the shift.

[GRADE CONDITIONS]

It is extremely important that grade conditions be checked and corrected prior to paving. No matter what type of grade is in front of the paver—crushed aggregate base, reclaimed bituminous base, milled surface, existing bituminous surface, or concrete—defects in the grade can cause defects in the bituminous layer.

Substandard base, like this weak area, must be identified and repaired prior to paving.

Aggregate or reclaimed bituminous base – The preparation of the base may be done by a subcontractor or by a division of the paving contractor. The base crew has the responsibility to meet the specifications, and stringent quality control should be in place. Prior to paving, here are some items to verify.

1. Has the base been inspected and accepted? Who signed off on the quality of the base? Is the inspector available for consultation if any issues need to be discussed?
2. Has the base been proof rolled? Is a proof roller (usually a pneumatic compactor) still available on the project?
3. Is a motor grader available to make corrections if needed? Is a compactor available to work behind the motor grader?
4. Is a water truck available for dust control and/or to add water for additional compaction?
5. Has the slope of the grade been checked in numerous locations to verify that the transverse profile conforms to plan drawings? If the paver's slope control is needed to correct slopes, has the project inspector been notified that yields may be adversely affected?
6. Are super-elevations, if any, clearly marked so screed operators can see where transitions are required?
7. Is a prime coat required on the aggregate base? Is the application rate correct? How much time is needed for the prime coat to cure?

Milled surface – Milled surfaces require inspection before paving. The milling contractor often performs the inspection, and it is the project manager's responsibility to ensure that step has been taken. Paving should not proceed until the quality of milled surfaces has been verified.

1. Are the elevations left by the cold planer correct? In other words, has the correct amount of material been removed? This is important when there are height clearance issues on the project or when there is a need to match the height of adjacent structures such as curbs and gutters.
2. Is the transverse profile (slope) correct? Remember, a cold planer can be set up to control slope just like a paver.
3. Is the surface texture acceptable? There are different types of cutter drums. A project may require micro-milling produced by a cutter with closely spaced tools. Also, excessive milling speed can cause the tool spacing pattern to be incorrect.
4. Has the cold planer created a rough ride or has the cold planer improved ride quality? It is a good idea to verify the ride quality of the milled surface when the cold planer starts to work on a project. If there is a high degree of roughness, the operation of the cold planer should be changed (install averaging ski, slow down, increase tool maintenance, for example) to improve the smoothness of the milled surface.

If the milled surface has areas of delamination, the milling depth may need adjustment.

5. Are there areas of delamination? When the depth of the cut is just above the intersection of two bituminous layers, a portion of the upper layer may lose its bond with the lower layer and break off in thin chunks. Paving over delaminated areas creates variable thickness with resulting loss of smoothness and variations in density. The project manager may ask for a change in the planned cutting depth to reduce delamination.
6. Has the surface been properly swept, flushed and cleared of all debris? Paving should not begin until all loose material is removed from the milled surface.

Overlay – Paving over existing pavement layers has many of the same issues as paving over a milled surface. For example, the crew should verify the slopes and have a good idea of what needs to be done to improve smoothness. Following are other considerations:

1. Have all badly deteriorated areas, such as block cracking, been corrected?
2. Have all potholes been patched or filled?
3. Have all high and/or low spots been removed or pre-leveled?
4. Have cracks been sealed or filled? Some types of crack sealant tend to expand once hot bituminous material has been placed over them. Be careful not to use too much crack sealant, and to use one that does not react to hot mix.
5. Have all existing joints and tie-ins been cut to create a straight vertical face?
6. Has the surface been swept and cleaned?
7. Is the tack distributor properly calibrated to apply the correct amount of tack?
8. How much curing time is required before paving over the tack being applied?
9. Has an approved release agent been applied to structures such as manhole covers and water valves?

[PROJECT LAYOUT]

Prior to paving, analyze the project to determine the most efficient way to complete the job. Some projects are straightforward in their design and only need a brief review with crew supervisors and crewmembers. Other projects, like large parking lots, must be carefully planned and laid out. Following are some items to consider when laying out the project.

1. Lay out the project with the fewest number of passes possible to minimize the number of longitudinal joints.
2. Designate crew and allow time for the crew to paint paving width guides or to install string to determine paving widths.
3. Check the specifications to determine how to stagger longitudinal joints on multiple lift projects.
4. If the screed will not reach the widest planned width, be sure to order bolt-on screed extensions or, if a larger paver is available, order the larger paver.

User Tip: *Most pavers can be ordered with wide-width paving kits. The kits contain bolt-on screed extensions, auger extensions, auger support systems, and mainframe (tunnel) extensions. Always install the appropriate auger and mainframe extensions to facilitate the movement of material to the outer edges of the paving width. (See Unit 3 for more information.)*

Order the necessary extensions for screeds, augers and mainframes when preparing for wide-width paving.

1. Plan for constant paving widths whenever possible. It is especially important to avoid changing width while paving on projects with ride quality specifications. For most commercial projects, moving hydraulic screed extenders in and out is unavoidable and is usually acceptable.
2. Pave emergency lanes (shoulders) at the same time as driving lanes when possible. If the emergency lane has a different slope, use the screed extender to create the desired slope.
3. If the emergency lane must be paved separately, pave it first whenever possible. The emergency lane will serve as a grade reference for the adjacent traffic lane, and also can serve as a place to stop and reverse compactors, and to park compactors when refilling water spray systems.
4. Order cutoff shoes when the paving width is less than the basic width of the main screed. An example would be when using a 3 m (10') paver to pave a 2.5 m (8') emergency lane.
5. Plan the setbacks for each shift. On some multi-lane projects, exposed longitudinal joints cannot be left. That requires backing up and matching each lane that is paved during the shift. The setbacks take time and should be included in calculations for paving speed and daily production.

Paving the emergency lane first provides a better reference for the grade control system when paving the adjacent driving lane.

6. Pave the primary driving lanes prior to paving intersection approaches, tie-ins, turning lanes, tapers and ramps. This is especially important when the project has ride quality specifications. Designate a second crew to pave the small areas and do not interrupt the high-production work of the mainline crew.
7. Select grade controls that match the project layout. For example, if paving in one lane in one direction (no setbacks) for the entire shift, a mechanical ski will likely work best. Be sure to have the correct ski installation hardware. Or, the project may include obstacles such as catch basins that prevent use of a mechanical ski. In that case, a non-contact ski that requires different mounting hardware will likely be selected.

User Tip: *Be careful not to create a situation where haul units must back up a long distance to reach the paver that is doing setback paving. This can cause a steep drop in production. Avoiding this situation is usually easier on highway projects than parking lots and city streets.*

[ORDERING HAUL UNITS]

Ordering the correct number of haul units has a major affect on hourly production and the working speed of the paver. The number of haul units should be sufficient to permit continuous, maximum operation of the asphalt manufacturing facility and, thus, maximum hourly production. The hourly plant production is one of the inputs needed to calculate the working speed of the paver.

The project manager usually delegates ordering haul units to the project superintendent or to the crew supervisor. Calculate how many haul units are needed by gathering the following information:

Planned hourly output of the asphalt manufacturing facility. The maximum production rate of the asphalt plant is a known factor, but remember the production rate can be affected by moisture content in the aggregates and other variables.

Plan amount of material held in storage silos at the start of the shift. For example, if the plant can produce 200 tonnes (220 tons) per hour, and the plant is going to start production an hour before haul units are scheduled, then 200 tonnes (220 tons) will be stored.

Cycle time for a haul unit to make a round trip from the plant to the job and back. The cycle times may vary depending on traffic volumes, especially if the haul route is in an urban area. The number of haul units may have to be increased or decreased to account for peak-hour traffic conditions.

Average haul unit load. If all the haul units have basically the same capacity, the average load is easy to determine. If the capacities are different, some extra calculations will be required to find the average load carried by the haul units and determine the appropriate arrival sequence at the worksite.

Having haul units with different capacities scheduled for a project complicates ordering the correct number of haul units.

Example One, No Storage – For this project, the asphalt manufacturing facility is going to produce 200 tonnes (220 tons) per hour. There are no storage bins. The cycle time for haul units is 90 minutes (1.5 hours). The average load for the haul units is 24 tonnes (26.5 tons).

200 tonnes per hour ÷ 24 tonnes = 8.33 trucks per hour

8.33 trucks per hour x 1.5 hours = 12.5 trucks

In other words, 13 trucks would be needed to have adequate capacity to match plant output under these conditions.

To calculate the number of haul units:

1. Tons per hour production ÷ average load = trucks per hour
2. Trucks per hour x cycle time in hours = total trucks needed

Example Two, Storage Bins – Next, add storage bins to the calculation. Assume 250 tonnes (275 tons) in storage at the start of the shift. Assume that the crew is scheduled to work for 10 hours during this shift. Make the calculation to use a portion of the storage each hour so the combined hourly production with stored material will be used uniformly by the end of the shift.

250 tonnes ÷ 10 hours = 25 tons per hour added production

Therefore, hourly production is increased to 225 tonnes (250 tons) per hour. Calculate the haul unit requirement again using the new production figure.

225 tonnes per hour ÷ 24 tonnes = 9.38 trucks

9.38 trucks x 1.5 hours = 14 trucks

To transport the additional hourly production, order at least one more haul unit.

Example Three, Variable Capacity – Assume that two different types of haul units are available for the project described in Example Two. The paving company owns haul units that carry 24 tonnes (26.5 tons). There will be eight of those haul units assigned to the project. Other haul units will be hired, but they transport an average of 20 tonnes (22 tons). How many of the smaller haul units are needed?

First, calculate how many tonnes the eight larger trucks can transport when they all complete a round trip and then divide by the cycle time.

8 trucks x 24 tonnes ÷ 1.5 hours = 128 tonnes/hour

Next, subtract the weight carried by the larger trucks from the total hourly production.

225 tonnes minus 128 tonnes = 97 tonnes per hour remaining

Finally, revert to the original formula.

97 tonnes per hour ÷ 20 tonnes = 4.85 trucks

4.85 trucks x 1.5 hours = 7.3 trucks

Therefore, eight of the smaller haul units would be hired to complement the eight larger company owned units.

Example Four, Variable Traffic – In the previous examples, the cycle time—1.5 hours—has been constant. Now, assume that the haul units carrying 24 tonnes (26.5 tons) will be traveling through peak traffic for two hours at the start of the shift and for two hours at the end of the shift. During peak traffic hours, the cycle time will increase to 2.2 hours. Use the formula to determine the correct number of haul units.

For the period 0700 to 0900 21 trucks would be hired. Between 0900 and 1500, seven trucks would be assigned to hauling aggregates or working with a cold planer, for example. Then, direct the seven trucks to return to the paving project to work from 1500 to 1700.

The task of making these calculations is simpler using software like the Paving Production Calculator. This software is available as an App from the appropriate App stores. Shown below are the previous examples as calculated using the Paving Production Calculator.

225 tonnes per hour ÷ 24 tonnes = 9.38 trucks

9.38 trucks x 2.2 hours = 21 trucks

During off-peak traffic hours, the cycle time reverts to 1.5 hours.

225 tonnes per hour ÷ 24 tonnes = 9.38 trucks

9.38 trucks x 1.5 hours = 14 trucks

Example 1, No storage — For this project, the asphalt manufacturing facility is going to produce 200 tonnes (220 tons) per hour. There are no storage bins. The cycle time for haul units is 90 minutes (1.5 hours). The average load for the haul units is 24 tonnes (26.5 tons).

TRUCKING CALCULATOR

Trucking

Paver Speed

Compaction

Windrow

Yield

Slope

Thickness

Job Summary

Legal

Exit

General Inputs

	Imperial Units	*Metric Units*
Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Multiple Silo Plants: Initial Storage	[0] *tons*	[0] *tonnes*
Paving Hours:	[0.0] *hrs*	[0.0] *hrs*
Truck Capacity (size):	[26.5] *net tons*	[24.0] *net tonnes*

Truck Cycle Times *(minutes)*

Load Time and Ticket:	[6]
Tarp:	[4]
Haul to Job:	[35]
Time on Site:	[2]
Dump / Clean:	[8]
Return Haul:	[35]

Truck Cycle Factor *(total time in hours)*	[1.5]
Number of Trucks Needed:	[12.5]

Example Two, Storage Bins – Next, add storage bins to the calculation. Assume 250 tonnes (275 tons) in storage at the start of the shift. Assume that the crew is scheduled to work for 10 hours during this shift. The calculation is made to use a portion of the storage each hour, so hourly production will be combined with stored material to use the material uniformly by the end of the shift.

250 tonnes ÷ 10 hours =
25 tonnes per hour added production

Therefore, hourly production is increased to 225 tonnes (250 tons) per hour. Calculate the haul unit requirement again using the new production figure.

TRUCKING CALCULATOR

- **Trucking**
- **Paver Speed**
- **Compaction**
- **Windrow**
- **Yield**
- **Slope**
- **Thickness**
- **Job Summary**
- **Legal**
- **Exit**

General Inputs	*Imperial Units*	*Metric Units*
Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Multiple Silo Plants: Initial Storage	[276] *tons*	[250] *tonnes*
Paving Hours:	[10.0] *hrs*	[10.0] *hrs*
Truck Capacity (size):	[26.5] *net tons*	[24.0] *net tonnes*

Truck Cycle Times *(minutes)*	
Load Time and Ticket:	[6]
Tarp:	[4]
Haul to Job:	[35]
Time on Site:	[2]
Dump / Clean:	[8]
Return Haul:	[35]

Truck Cycle Factor *(total time in hours)*	[1.5]
Number of Trucks Needed:	[14.0]

Example Three, Variable Capacity – Assume that two different types of haul units are available for the project described in Example Two. The paving company owns haul units that carry 24 tonnes (26.5 tons). There will be eight of those haul units assigned to the project. Other haul units will be hired, but they transport an average of 20 tonnes (22 tons). How many of the smaller haul units are needed?

First, calculate how many tonnes the eight larger trucks can transport when they all complete a round trip and then divide by the cycle time.

8 trucks x 24 tonnes ÷ 1.5 hours = 128 tonnes/hour

Next, subtract the weight carried by the larger trucks from the total hourly production.

225 tonnes minus 128 tonnes = 97 tonnes per hour remaining

TRUCKING CALCULATOR (LARGE UNITS)

Menu	General Inputs	Imperial Units	Metric Units
Trucking	Production Rate of Hot Plant:	[141] *tons/hr*	[128] *tonnes/hr*
Paver Speed	Multiple Silo Plants: Initial Storage	[1] *tons*	[0] *tonnes*
Compaction	Paving Hours:	[0.0] *hrs*	[0.0] *hrs*
Windrow	Truck Capacity (size):	[26.5] *net tons*	[24.0] *net tonnes*
Yield	**Truck Cycle Times** *(minutes)*		
Slope	Load Time and Ticket:	[6]	
Thickness	Tarp:	[4]	
Job Summary	Haul to Job:	[35]	
Legal	Time on Site:	[2]	
	Dump / Clean:	[8]	
	Return Haul:	[35]	
Exit	**Truck Cycle Factor** *(total time in hours)*	[1.5]	
	Number of Trucks Needed:	[8.0]	

TRUCKING CALCULATOR (SMALL UNITS)

Menu	General Inputs	Imperial Units	Metric Units
Trucking	Production Rate of Hot Plant:	[107] *tons/hr*	[97] *tonnes/hr*
Paver Speed	Multiple Silo Plants: Initial Storage	[0] *tons*	[0] *tonnes*
Compaction	Paving Hours:	[0.0] *hrs*	[0.0] *hrs*
Windrow	Truck Capacity (size):	[22.0] *net tons*	[20.0] *net tonnes*
Yield	**Truck Cycle Times** *(minutes)*		
Slope	Load Time and Ticket:	[6]	
Thickness	Tarp:	[4]	
Job Summary	Haul to Job:	[35]	
Legal	Time on Site:	[2]	
	Dump / Clean:	[8]	
	Return Haul:	[35]	
Exit	**Truck Cycle Factor** *(total time in hours)*	[1.5]	
	Number of Trucks Needed:	[7.3]	

Example Four, variable traffic – In the previous examples, the cycle time—1.5 hours—has been constant. Now, assume that the haul units (all carrying 24 tonnes / 26.5 tons) will be traveling through peak traffic for two hours at the start of the shift and for two hours at the end of the shift. During peak traffic hours, the cycle time will increase to 2.2 hours.

TRUCKING CALCULATOR

Trucking
Paver Speed
Compaction
Windrow
Yield
Slope
Thickness
Job Summary
Legal
Exit

General Inputs	*Imperial Units*	*Metric Units*
Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Multiple Silo Plants: Initial Storage	[276] *tons*	[250] *tonnes*
Paving Hours:	[10.0] *hrs*	[10.0] *hrs*
Truck Capacity (size):	[26.5] *net tons*	[24.0] *net tonnes*

Truck Cycle Times *(minutes)*	
Load Time and Ticket:	[6]
Tarp:	[4]
Haul to Job:	[55]
Time on Site:	[2]
Dump / Clean:	[8]
Return Haul:	[55]
Truck Cycle Factor *(total time in hours)*	[2.2]
Number of Trucks Needed:	[20.6]

[CALCULATING PAVING SPEED]

Calculating the correct paving speed is necessary to ensure efficient paving—one of the basic principles of quality paving. Unless the project has many short pulls and lots of areas where the crew will be doing handwork, the paving speed should be established to develop at least 75 percent efficiency. That is to say, the paver is laying down mix at least 45 minutes out of every hour and stopped for truck exchanges or waiting for mix no more than 15 minutes out of every hour. On a highway project with long pulls and using a transfer vehicle, the paver can approach 100 percent efficiency with careful planning.

Continuous paving at a constant speed is the goal when smoothness is desired. Uniform layer temperatures are also more likely when the paver makes only a few short stops during the shift.

Calculate the paving speed, communicate the paving speed, and stay with the paving speed unless something changes to affect the hourly production rate. Normally, the paving superintendent or the crew supervisor calculates the paving speed and tells the paver operator what speed to maintain.

Paving speed can be calculated if the following information is known:

- Planned hourly output of the asphalt manufacturing facility, including storage bins
- Paving width
- Paving thickness (loose or compacted)
- Weight of the material (loose or compacted). The weight of the material can be obtained from the operator of the asphalt manufacturing facility or from the quality control staff.

To calculate the paving speed manually:

Metric Units

$$\text{tons / hour} \times \frac{1000\text{ kg}}{60\text{ min}} (16.67) \div \text{width (m)}$$
$$\div \text{ depth (m)} \div \text{kg / m}^3 = \text{m / min}$$

The paving speed that results from this formula is at 100% efficiency. The paving speed may have to be multiplied by an efficiency factor to account for truck exchanges and stops waiting for mix.

For example, an 85% efficiency factor may be used. The calculated paving speed would then be multiplied by 0.85.

Imperial Units

$$\text{tons / hour} \times \frac{2000\text{ lb}}{60\text{ min}} (33.33) \div \text{width (ft)}$$
$$\div \text{ depth (ft)} \div \text{lb / ft}^3 = \text{ft / min}$$

The second page of the Paving Production Calculator provides a faster way of calculating paving speed than doing a manual computation.

Again, the Paving Production Calculator is available through Cat dealers or as an App from the appropriate App stores.

Example One – On this project, the hourly production rate is 200 tonnes (220 tons) per hour. The uncompacted paving depth is 75 mm (3").

The paving width is 5.5 m (18'). The weight of the uncompacted material is 2162 kg/ m³ (135 lb/ft³).

PAVER SPEED CALCULATOR

Trucking | **Paver Speed** | Compaction | Windrow | Yield | Slope | Thickness | Job Summary | Legal | Exit

General Inputs	Imperial Units		Metric Units	
Paving Thickness:	[2.95]	in	[75]	mm
Paving Width:	[18.00]	feet	[5.486]	meter
Material Density Uncompacted:	[135]	lbs/ft³	[2162]	kg/m³
Paver Speed @ Given Production Rate				
Production Rate of Hot Plant:	[220]	tons/hr	[200]	tonnes/hr
Calculated Paving Speed - 100% Efficiency:	[12.3]	ft/min	[3.75]	m/min
Calculated Paving Speed - 95% Efficiency:	[12.9]	ft/min	[3.94]	m/min
Calculated Paving Speed - 90% Efficiency:	[13.5]	ft/min	[4.12]	m/min
Calculated Paving Speed - 85% Efficiency:	[14.1]	ft/min	[4.31]	m/min
Calculated Paving Speed - 80% Efficiency:	[14.8]	ft/min	[4.50]	m/min
Calculated Paving Speed - 75% Efficiency:	[15.4]	ft/min	[4.69]	m/min
Effective Paving Speed:	[12.3]	ft/min	[3.75]	m/min

The Paver Speed Calculator provides paving speeds based on six efficiency factors.

100% efficiency: 3.75 m/min (12.3'/min) – Theoretically, using a material transfer vehicle, the paver can pave continuously without stopping or changing the paving speed. It is usually unrealistic to expect the paver to work at one continuous speed for an entire shift. Events happen to cause slight delays in trucking, for example. So, normally, a lower efficiency is selected.

95% efficiency: 3.94 m/min (12.9'/min) – If a 95% efficiency factor is selected, the actual working speed will be slightly higher than the actual speed at 100% efficiency. The higher working speed is used to make up for a few short stops during that hour. The effective speed is still 3.75 m/min (12.3'/min).

90% efficiency factor: 4.12 m/min (13.5'/min) – Planning for lower efficiency factors, the actual working speed continues to increase little by little while the effective paving speed stays the same. Realistically, a 90% to 95% efficiency factor would probably be selected when using a material transfer device.

85% efficiency factor: 4.31 m/min (14.1'/min) – If material is transferred directly from haul units to the hopper of the paver, the efficiency factor selected will continue to decrease. The approximated maximum that can be achieved without a transfer device is 85%.

80% efficiency factor: 4.5 m/min (14.8'/min) – Lower efficiency factor equals higher actual speed. The effective paving speed remains the same.

75% efficiency factor: 4.7 m/min (15.4'/min) – In general, on projects that have mostly long pulls with the paver, the minimum efficiency factor that is consistent with quality results is 75%. If less than 75% efficient, there are too many long paver stops. The paving speed will have to be slowed to reduce the amount of time the paver is stopped. Or, perhaps, a way can be found to shorten the truck exchange time.

Example Two – Assume that all factors remain the same as in Example One, except that the paving width is now 3.7 m (12'). Enter the factors into the Paving Production Calculator.

PAVER SPEED CALCULATOR

Menu			Imperial Units	Metric Units
Trucking	**General Inputs**			
Paver Speed		Paving Thickness:	[2.95] *in*	[74.9] *mm*
Compaction		Paving Width:	[12.00] *feet*	[3.658] *meter*
Windrow		Material Density Uncompacted:	[135] *lbs/ft³*	[2162] *kg/m³*
Yield	**Paver Speed @ Given Production Rate**			
Slope		Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Thickness		Calculated Paving Speed - 100% Efficiency:	[18.4] *ft/min*	[5.61] *m/min*
Job Summary		Calculated Paving Speed - 95% Efficiency:	[19.3] *ft/min*	[5.89] *m/min*
Legal		Calculated Paving Speed - 90% Efficiency:	[20.2] *ft/min*	[6.17] *m/min*
		Calculated Paving Speed - 85% Efficiency:	[21.2] *ft/min*	[6.45] *m/min*
		Calculated Paving Speed - 80% Efficiency:	[22.1] *ft/min*	[6.73] *m/min*
		Calculated Paving Speed - 75% Efficiency:	[23.0] *ft/min*	[7.01] *m/min*
Exit		**Effective Paving Speed**:	[18.4] *ft/min*	[5.61] *m/min*

Because the paving width is narrower in Example Two, the paving speed increases to consume the tonnes delivered to the worksite each hour. The effective paving speed, or 100% efficiency factor, is 5.6 m/min (18.4'/min). At 75% efficiency, the actual paving speed increases to 7 m/min (23'/min).

Assuming that this is a binder (intermediate) course and that the wearing (surface) course will be thinner, calculate a speed for the wearing course shown in Example Three.

Example Three – Hourly production remains at 200 tonnes (220 tons) per hour. The weight of the uncompacted material is the same. Using the 3.66 m (12') paving width, enter 50 mm (2") paving thickness and calculate the paving speed.

PAVER SPEED CALCULATOR

Trucking	**General Inputs**	*Imperial Units*	*Metric Units*
Paver Speed	Paving Thickness:	[1.97] *in*	[50] *mm*
Compaction	Paving Width:	[12.00] *feet*	[3.658] *meter*
Windrow	Material Density Uncompacted:	[135] *lbs/ft³*	[2162] *kg/m³*
Yield	**Paver Speed @ Given Production Rate**		
Slope	Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Thickness	Calculated Paving Speed - 100% Efficiency:	[27.6] *ft/min*	[8.42] *m/min*
Job Summary	Calculated Paving Speed - 95% Efficiency:	[29.0] *ft/min*	[8.84] *m/min*
Legal	Calculated Paving Speed - 90% Efficiency:	[30.4] *ft/min*	[9.26] *m/min*
	Calculated Paving Speed - 85% Efficiency:	[31.7] *ft/min*	[9.68] *m/min*
	Calculated Paving Speed - 80% Efficiency:	[33.1] *ft/min*	[10.10] *m/min*
	Calculated Paving Speed - 75% Efficiency:	[34.5] *ft/min*	[10.53] *m/min*
Exit	**Effective Paving Speed**:	[27.6] *ft/min*	[8.42] *m/min*

In Example Three, the paving thickness is less, so the paving speed increases to maintain the same production rate. As the paving speed begins to increase, three factors need to be considered.

1. Can the compaction process keep up with the paving speed? Notice that the Production Calculator includes a tab for calculating compactor working speed. Use that tab to verify that the correct compaction equipment will be available.

   To calculate compactor speed these factors must be known:

   - Drum width
   - Vibratory system frequency
   - Repeat passes to reach target density

The Paving Production Calculator verifies that a vibratory compactor with 170 cm (67") wide drums operating in the first compaction phase behind the paver and set in high frequency, 3 800 vibrations per minute, and making three repeat passes can match the paving speed.

The actual roller working speed is set at 89 m/min (292'/min). The pattern has a total of nine passes so the effective roller speed is 9 m/min (29'/min), a pace that exactly matches the paver's progress. Note that the efficiency factor is 85%. The efficiency factor compensates for water refill stops and non-vibratory, pattern-reverse times.

Pre-project planning should always include verification of the production match between the paver and the first phase compactor(s).

COMPACTION CALCULATOR

Trucking	Roller Model:	[*Click to Select Another Model*]	[CB54]
Paver Speed	**General Inputs**	*Imperial Units*	*Metric Units*
Compaction	Paving Width:	[12.00] *feet*	[3.658] *meter*
Windrow	Actual Drum Width:	[67] *in*	[170.18] *cm*
Yield	Amount of Overlap:	[5.9] *in*	[15.0] *cm*
Slope	Speed of Vibrator:	[3800] *VPM*	[3800] *VPM*
Thickness	Impacts (recommended):	[13] *per ft*	[43] *per m*
Job Summary	**Number of Passes to Cover Mat Width Once:**		[3]
Legal	Number of Repeated Passes (from test strips):		[3]
	Total Number of Passes:		[9]
	Roller Efficiency Rate (recommended 75 to 85%):		[85] *%*

		Imperial Units	*Metric Units*	*Effective Paver Speed*
	Actual Roller Speed:	[292] *fpm*	[89] *mpm*	[27.6] *ft/min*
Exit	**Effective Roller Speed*:**	[28] *fpm*	[9] *mpm*	[8.42] *m/min*

** Effective Roller Speed should be at least 100% but no more than 115% of the Effective Paver Speed.* [% = 104]

2. Will a vibrating and tamping screed be able to perform properly at the calculated speed? Screeds with tamper bars are usually limited to slower working speeds, when compared to screeds that employ only vibration. The tamper bar must deliver a certain amount of energy into the bituminous layer in order to create the relatively high screed-laid density that is required for some applications.

To deliver high energy and avoid creating ripples in the layer, the tamper bar needs to hit the surface between 1.5-4 times per linear centimeter. Depending on the frequency of the tamping system, the width of the tamping foot, and stiffness of the material, working speed may have to be adjusted to obtain the desired density and impact overlap.

3. If automatic grade and slope control are used, can the system react quickly enough to match the paving speed? High-speed paving—in excess of 18 m/min (60'/min)—is a difficult proposition. Mistakes happen quickly. And certainly, a tamping screed cannot function properly at that high speed.

However, there are times when laying down a relatively thin layer (less than 5 cm (2") the supply will be 225 tonnes (250 tons) per hour or more. Then paving speed will approach the limitations of automatic grade and slope control. For high-speed paving—any application in excess of 18 m/min (60'/min)—Caterpillar recommends paving that layer manually, without use of grade and slope control systems.

[SUMMARY]

Do not overlook the importance of pre-project planning, whether creating a formal project plan or simply creating a checklist. Once approved, be sure to communicate the plan to the appropriate personnel. Delegate authority to supervisors and crewmembers, so they can prepare for their responsibilities. Have a method in place to verify that all elements of the plan are in place before work begins.

Do not put off planning until the last minute. Good planning will prevent many time-consuming and costly errors that are common on poorly planned paving projects.


CAT
AP1055F
GRADE CONTROL
SE10

Unit 3
FUNDAMENTALS OF PAVING

Each paving crew member should understand how the paver works, and the basic theories of paving. That knowledge helps with quality control and on-the-job problem solving.

Proper fundamentals are one of the four principles of quality paving. When the crew takes shortcuts or loses focus on fundamentals, defects invariably appear in the layer of bituminous material.

First, crewmembers must know how to correctly use all paver controls. That means the crew must study and refer to the Operation and Maintenance Manual that is shipped with the paver. Controls and features vary on different paver models. A procedure or technique used on one paver may not be appropriate for another. Always set up and operate the paver in the manner described in the manufacturer's manual.

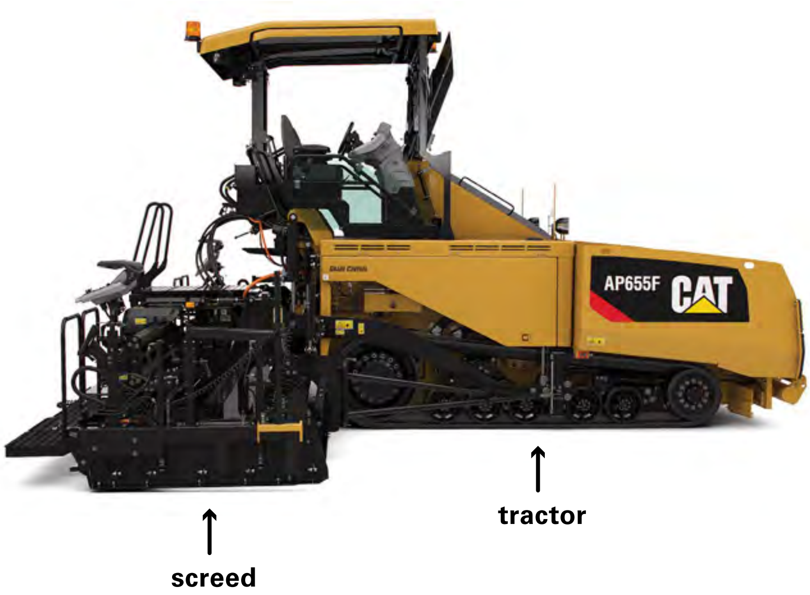
Second, crewmembers have to fully understand the concept of the free-floating screed. This concept is basically the same for all pavers. The material supports the screed, which is towed by the tractor. When all the factors that influence how the screed floats on the material are properly controlled and constant, then the screed is said to be at equilibrium and will maintain its vertical position.

Finally, the crewmembers must know all factors that influence how the screed floats. These include paving speed, the material feed system, screed adjustments, temperature of the bituminous material, and type of bituminous material. The crew is expected to control the first three factors: speed, material feed system and screed adjustments. The crew does not control mix temperature or mix design, but the crew needs to know how to react to variations in those factors.

[HOW THE PAVER WORKS]

An paver has two basic elements, the tractor and the screed. The tractor provides power to tow the screed. The tractor receives the material from haul units or transfer devices and moves the material to the rear of the tractor, where it is placed in front of the screed. The tractor can be equipped with one or two operating stations having controls for steering, the propel system, and parts of the material feed system.

The screed is connected to both sides of the tractor at the tow-point connections. From the tow-points, tow arms extend back and connect to the front of the screed. The screed controls the width and depth of paving. It also provides the initial density and texture of the bituminous layer.



[TRACTOR]

Two push rollers are located at the front of the tractor. When the mix is transferred directly from the haul unit to the tractor hopper, the push rollers contact the rear wheels of the haul unit. The push rollers turn as the wheels turn. The truck driver must maintain light pressure on the brakes to prevent it from rolling away and creating a spill in front of the paver. (See Unit 7 for more information about the truck exchange procedure.)

Two push rollers contact the rear tires of the haul unit as the paver pushes the haul unit.

User Tip: *Periodically clean the push rollers to avoid material build-up. If build-up occurs, irregular impacts between the paver and haul unit can lead to mat defects.*

A truck hitch is an option on many pavers. It provides a solid connection between the paver and the haul unit. The paver operator controls the truck hitch with a console switch. When the truck hitch is open, the truck backs up and stops just before contacting the push rollers. The paver moves forward slightly and contacts the rear tires of the haul unit. The operator then closes the truck hitch and the rollers on the two truck-hitch arms contact the wheel rims.

When the load is fully discharged, the operator opens the truck hitch to permit the empty haul unit to depart. Truck hitches help avoid large spills in front of the paver that are caused when a truck inadvertently loses contact with the push rollers.

Material from haul units can be discharged directly into the paver hopper or can be moved into the hopper using a transfer device. The hopper provides a limited amount of storage for bituminous material, so the paver can continue to operate for some period of time between haul units.

Flashing at the front of the hopper helps retain material. Hopper inserts are commonly installed when the crew is using a material transfer device. The hopper insert increases the storage capacity of the paver and makes it easier to pave continuously at normal paving speeds without stops between haul units.

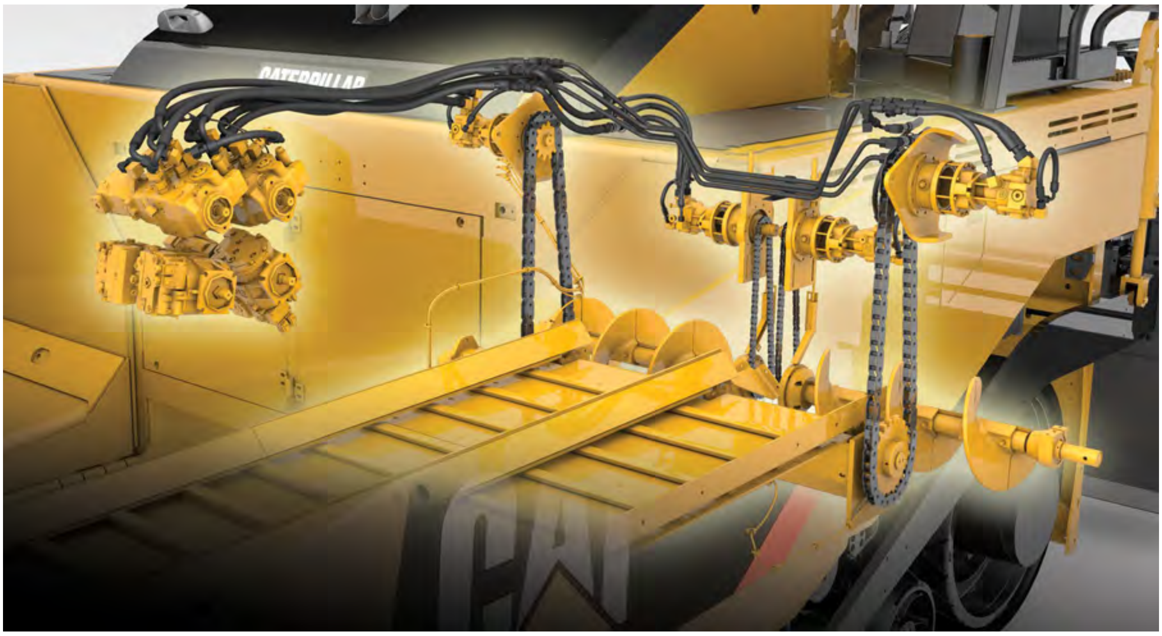
The optional truck hitch helps provide a secure connection between the front of the paver and the haul unit.

The sides of the hopper can be raised one at a time or simultaneously to use the material that has flowed to the sides. Local regulations sometimes prohibit raising hopper sides because doing so can cause material segregation.

Some pavers are equipped with an optional fold-up section at the front of the hopper. Folding helps prevent spills over the flashing when the sides of the hopper are raised.

Inside the hopper, two drag-slat conveyors move the material from the hopper, through tunnels under the operator's platform, and deposit the material in front of the screed. On modern pavers, the left and right conveyors are driven independently to meet the demands for material in front of the screed. For example, if the left side of the screed is set at a wider width than the right side of the screed, then the left feed system conveyor will run faster than the right conveyor.

The operator can raise the sides of the hopper, if desired and permissible, to move mix from the sides of the hopper to the feed system conveyors.



Left and right feed system conveyors move material to the front of the screed. Left and right augers move material out to the full paving width.

At the rear of the tractor, two augers move the material in the auger chamber out to the paving width. The left and right augers also feature individual controls to regulate their rotation speeds.

The material feed system has several types of sensors to help automatically regulate the material feed system. Either sonic or mechanical feeder sensors are located at the rear of the left and right conveyors and/or near the ends of the left and right augers.

The tractor can be equipped with one or two console equipped operating stations. The controls regulate propel speed, tractor steering, some material feed system controls, lights and some screed controls. The operator selects the station that provides the best visibility for steering or slides the station to the side of the tractor with the best visibility.

The paver operator's primary responsibilities are to help coordinate transfer of material to the hopper, guide the machine, and control speed. The operator is also responsible for setting some feed system controls.

Tractor undercarriages include wheel, rubber track, and steel track designs.

Before the introduction of the rubber track undercarriage, there was clear distinction in applications for the track-type and rubber-tire undercarriages.

Track-type systems were preferred for extra traction and flotation on soft base materials. Rubber-tire systems were preferred for worksite mobility and for projects where smoothness of the wearing course was very important. Rubber track undercarriage now combines traction, high travel speed and smoothness and is very common in some regions today.

Tow-point connections are located between the screed and the tractor near the center of the tractor on both sides.

A hydraulic cylinder is attached to the tow arm. The front of the tow arm extends through a vertical slide compartment. At the end of the tow arm is a roller that contacts the slide compartment. The screed or paver operators can adjust the height of the tow-point connection to meet application requirements. A scale shows the operators the height of the tow-point. The tow-points are the only physical connections between the screed and the tractor and they play an important role in how the screed floats.

The tow-point connection features a height scale that enables the tractor or screed operators to set and check the position of the connection.

[SCREED]

Screeds are classified into two primary types—fixed-width and hydraulically extendable, each having several variations.

Extendable screeds can have extenders that are in front of the main screed (called a front-mount screed) or are behind the main screed (called a rear-mount screed). There are vibratory screeds and tamping screeds with vibration.

Each screed has its own relative merits that fit certain applications better than others. In some areas, there may be method specifications that mandate the use of a particular type of screed. This guide will not debate the benefits of one screed type over another, but will seek to explain how to best set up and use any type of screed.

A fixed-width screed consists of one screed frame and screed plate. Typical fixed-width screeds are 2.5 m (8') or 3 m (10') wide. To increase the paving width, the crew must add bolt-on screed extensions. Fixed-width screeds are preferred for some applications, because they tend to make it easier to create uniform layer density from edge to edge, and they tend to resist flexing when paving at wide widths.

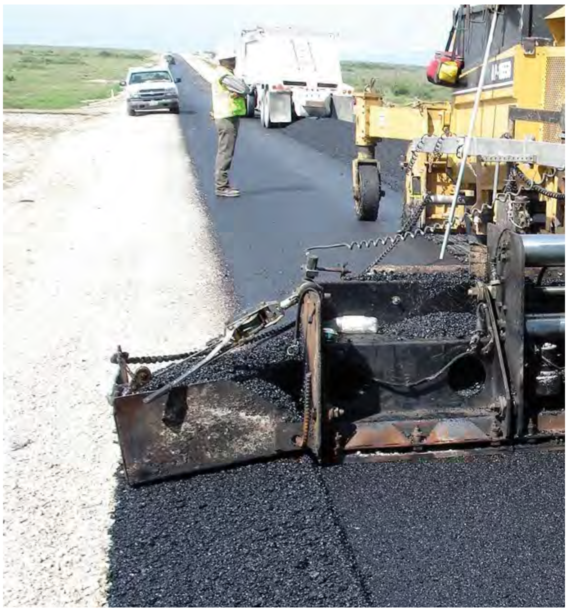
A hydraulically extendable screed consists of a main frame with screed plate plus right and left extender frames with plates. Typical main screeds are 2.5 m (8') or 3 m (10') wide, just like the fixed-width screeds. To increase paving width beyond the basic width, the operators use control switches to move the extenders.

Left and right hydraulically extendable screed extenders simplify the task of changing paving width.

Depending on the particular screed arrangement, the total width of the screed can be increased to twice the width of the main screed by moving the extenders to their capacity. Those screeds are commonly referred to as “double-extending” screeds. Other hydraulically extendable screeds can be opened up to slightly less than twice the width of the main screed.

User Tip: *If possible, use equal-extension widths on both sides of the main screed, whether using bolt-on or hydraulic extenders. Equal-extension widths make it easier to control steering and balance material flow.*

Extendable screeds are nearly unlimited in their setup capabilities. Their versatility is why extendable screeds are most commonly used around the world. For example, an extender can be sloped to an angle that is different than the main screed plate when the application calls for paving an emergency lane with one slope, while paving the driving lane with another slope.



To meet the requirements of some applications, the crew must install bolt-on screed extensions and specialty attachments to the left and/or right screed extenders.

There are two types of extendable screeds. They include screeds with front-mount extenders and screeds with rear-mount extenders. The front-mount screed is equipped with extenders that move in and out in front of the main screed. In general, it is easier to retract front-mount extenders because the material brought in by the end gates is unrestricted. For this reason, front-mount screeds are often preferred by crews that pave urban-type projects where frequent width changes are required.

Front-mount screeds have extenders that move in and out in front of the main screed.

User Tip: *If using an extendable screed with front-mount extenders, and the paving width will constantly extend at least 60 cm (2') outside the main screed width, be sure to add auger and mainframe extensions. Remember, the material must flow straight out from the auger chamber to reach the end gates. Failure to add on auger and mainframe extensions will make it difficult for the crew to adjust the feeder system.*

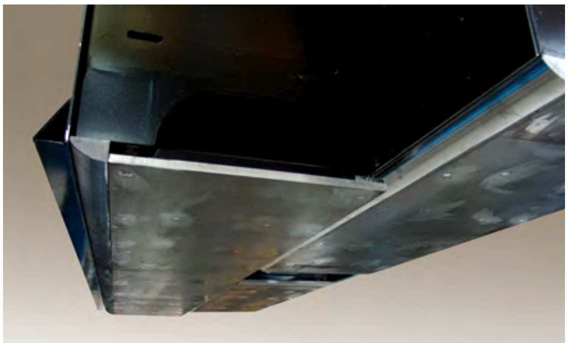
Rear-mount screeds have extenders that are located behind the main screed. In general, rear-mount screeds are preferred by crews that pave mainline and highway projects, requiring fewer paving-width changes.

User Tip: *When using an extendable screed with rear-mount extenders and the paving width will constantly be at least 1 m (3') outside the main screed width, be sure to add auger and mainframe extensions. Rear-mount screeds provide a little leeway compared to front-mount screeds. The material exits the auger chamber and has time to flow out and back to fill in the area in front of the extenders. Failure to add on auger and mainframe extensions make it difficult to adjust the feeder system.*

Rear-mount extendable screeds have extenders that move in and out behind the main screed.

Vibratory screeds have small, external eccentric weight shafts installed over each screed plate. The rotation of the eccentric weights causes the screed plates to vibrate when the vibratory system is activated. Vibrating plates increase the density of the layer by an additional one or two percentage points.

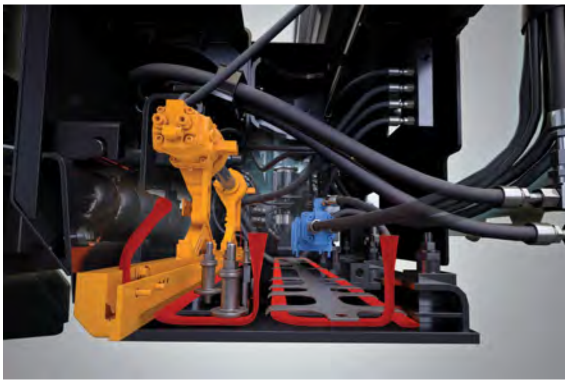
For example, if a non-vibratory screed produces an asphalt layer that is at 84 percent of maximum theoretical density, that number will increase to 85-86 percent if the vibratory system is activated—all other factors being equal. Screed vibration also helps bring the fine mix particles to the surface and improves mat appearance.



View of the screed plates on a rear-mount, vibratory, extendable screed.

User Tip: *Adjust the frequency of the screed vibratory system while the paver is moving at normal operating speed. The goal is to deliver the maximum vibration energy into the bituminous layer without causing excessive vibration of screed components. A common technique is to place a coin or metal washer on any flat screed surface. Increase vibratory frequency until the coin begins to bounce. Reduce frequency until the coin just stops bouncing. If the paving speed is changed, adjust the vibratory frequency.*

Tamper screeds supplement vibration energy with the energy of one or two tamper bars. Tamper bars are located in front of the main screed and the screed extenders. The tamper bars are connected to an eccentric drive shaft that produces rapid vertical movement of the tamper bars. The movement helps material, especially stiff mixes with large aggregates, flow under the screed nose. The extra help means that the screed can float on the layer using a relatively small planing angle (angle of attack).

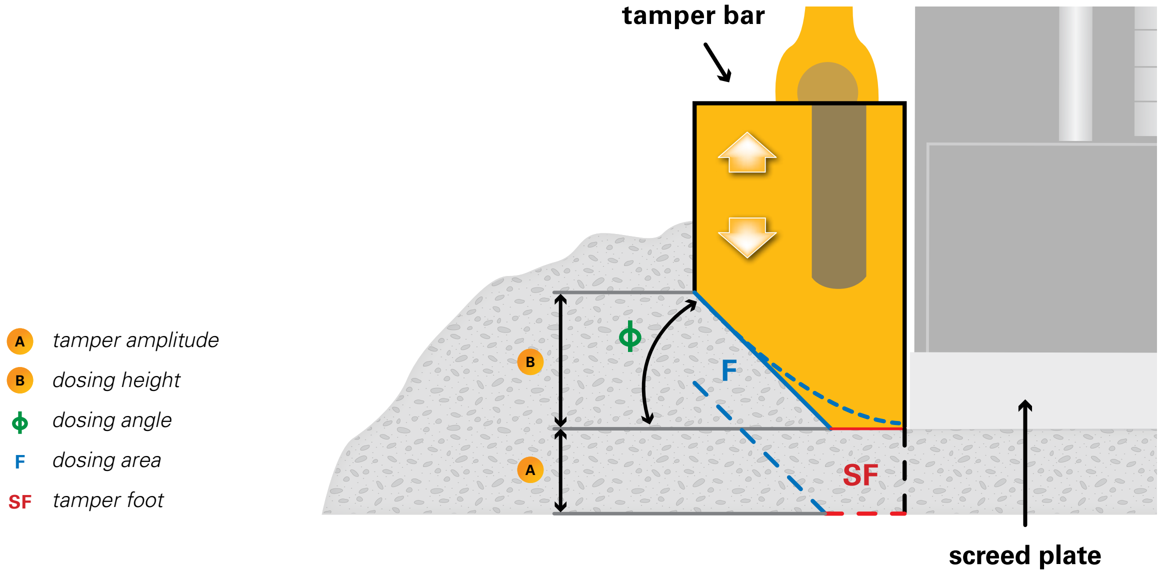


View of rear mount, extendable screed with vibration and tamper bars.

The distance the tamper bar moves and the frequency (rotations per minute) of movement depend on the screed model. For example, the tamper bar movement up and down may be 8 mm (0.3") at a maximum frequency of 2000 rotations per minute. The effect of the tamper bar energy will be to increase the density of the layer laid down by the paver beyond the results from vibration only.

For example, if the density of the layer is 86 percent of maximum theoretical density using only vibration, density may increase to 90 percent after activating the tamper bar system.

The working speed, the frequency of the tamper bar and the width of the tamper foot are factors that affect the results. The tamper foot (bottom of the tamper bar) is 25 mm (1") wide when new. The tamper foot must impact the surface of the layer in a closely spaced manner to create an overlap of about 6 mm (0.25") for each stroke of the tamper bar. In general, the maximum working speed is around 8 meters per minute (26' per minute) when paving with a tamper bar screed. Excessive working speed can cause ripples in the surface of the bituminous layer.



User Tip: *As the tamper bar accumulates use, the dosing angle changes and the area of the tamper foot becomes smaller. Therefore, the overlap between tamper strokes is harder to maintain. Regularly inspect the tamper foot and replace it when the wear affects smoothness or reduces production. As abrasion reduces the size of the tamper foot, the paving speed must be reduced to avoid creating ripples in the surface of the bituminous layer and to achieve the desired pre-compaction layer density.*

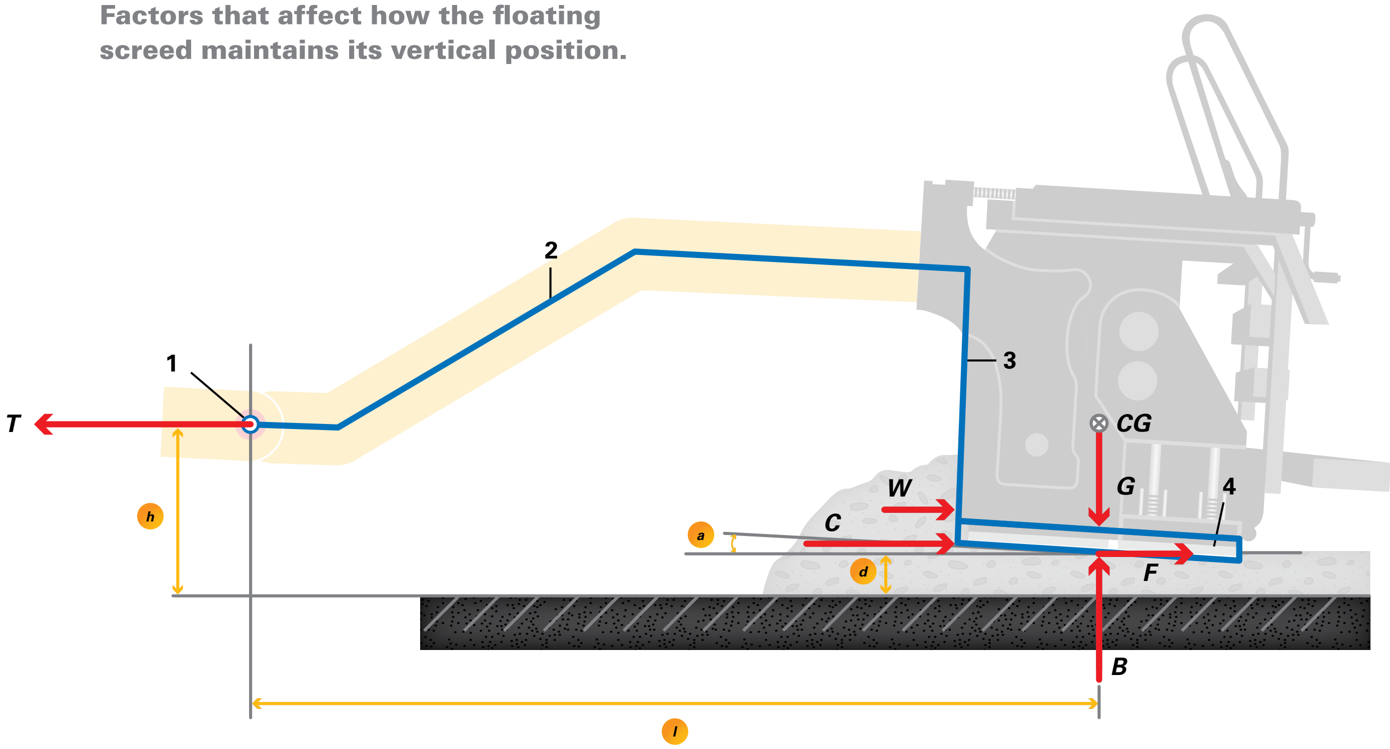
[PRINCIPLE OF THE FLOATING SCREED]

All screeds share one common principle: They float on the bituminous material that passes under the nose of the screed. When the paver operator lowers the screed to the starting reference, the operator positions the screed Raise / Lower / Float switch in the Float position. While the paver is moving, the bituminous material supports the screed.

Depending on the weight of the screed and the stiffness of the material, the operator may elect to put some upward hydraulic pressure in the screed lift cylinders to help the screed float at the proper angle. Also, the operator may choose to hold the screed in position during stops to prevent leaving indentations in the uncompacted layer. (More information about these systems is provided near the end of this unit.)

Both vibratory screeds and vibratory / tamping screeds float on the material. Their characteristics are somewhat different, but the factors that impact how they float on the material are basically the same. These factors are best explained in a diagram.

Factors that affect how the floating screed maintains its vertical position.



1 *tow-point connection (rotary joint)*
2 *tow arm (beam)*
3 *front panel*
4 *screed plate*
T *traction force*
W *weight of material in front of the screed*
C *cutting force (shear force)*
G *gravitational pull (weight of the screed)*
B *buoyant force*
F *frictional force*

h *height of the tow-point*
l *projected length*
d *depth of the layer (mat thickness)*
a *angle of attack*

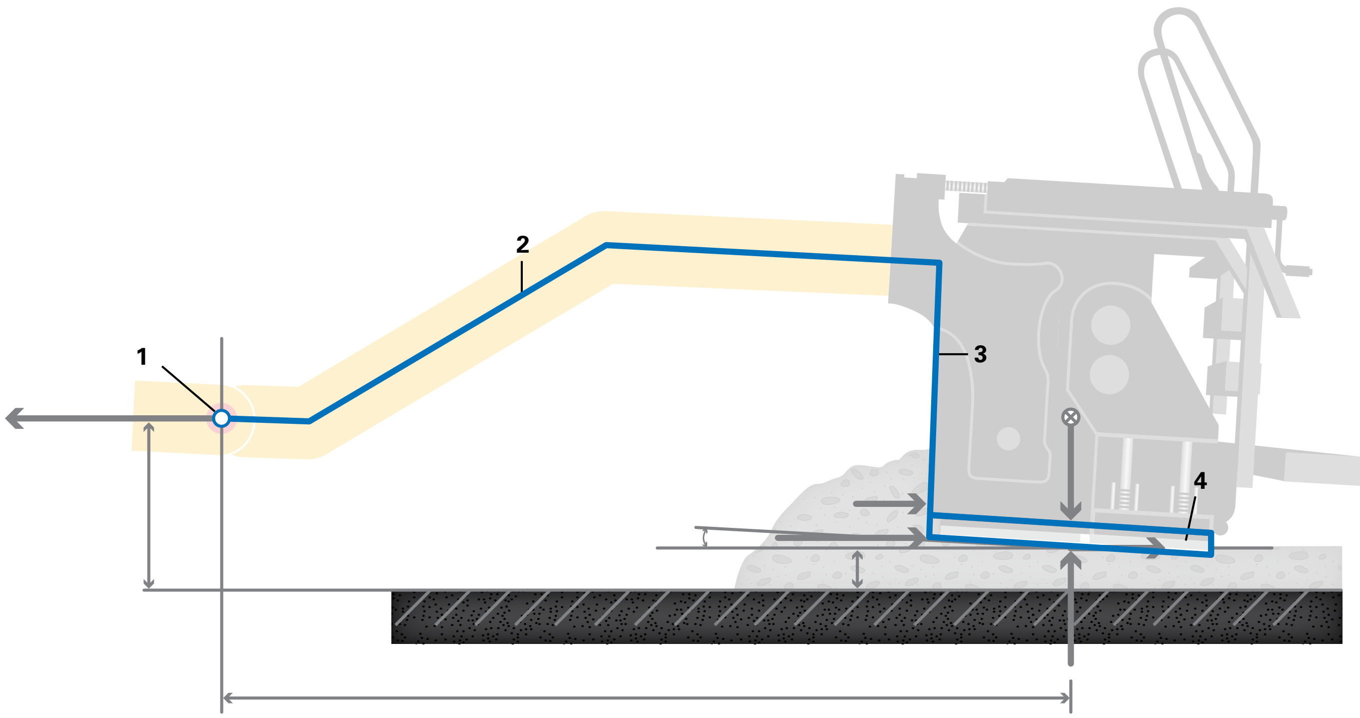
First, let's identify the main components in the diagram.

Number 1 is the tow-point connection (rotary joint). There are connections on each side of the paver. The height of the tow-point connections is adjustable. (See Units 4 and 5 for information about setting the tow-point height.) Changing the height of a tow-point connection affects the main screed angle of attack and thereby the vertical position of the screed.

Number 2 is the tow arm (beam) that extends between the tow-point connection and the front of the screed. There are identical tow arms on each side of the paver.

Number 3 is the front panel of the screed. This panel confines the material in the auger chamber. A certain amount of material is pushed in front of the panel, while a certain amount flows under the front panel.

Number 4 is the screed plate, which floats on material that is sheared off by the front panel. In conjunction with the tamper bar (if equipped) and screed vibration (if engaged), the screed plate develops an additional amount of mat density as the mat is being laid down. The screed plate also affects the texture of the mat surface.



1 *tow-point connection (rotary joint)*

2 *tow arm (beam)*

3 *front panel*

4 *screed plate*

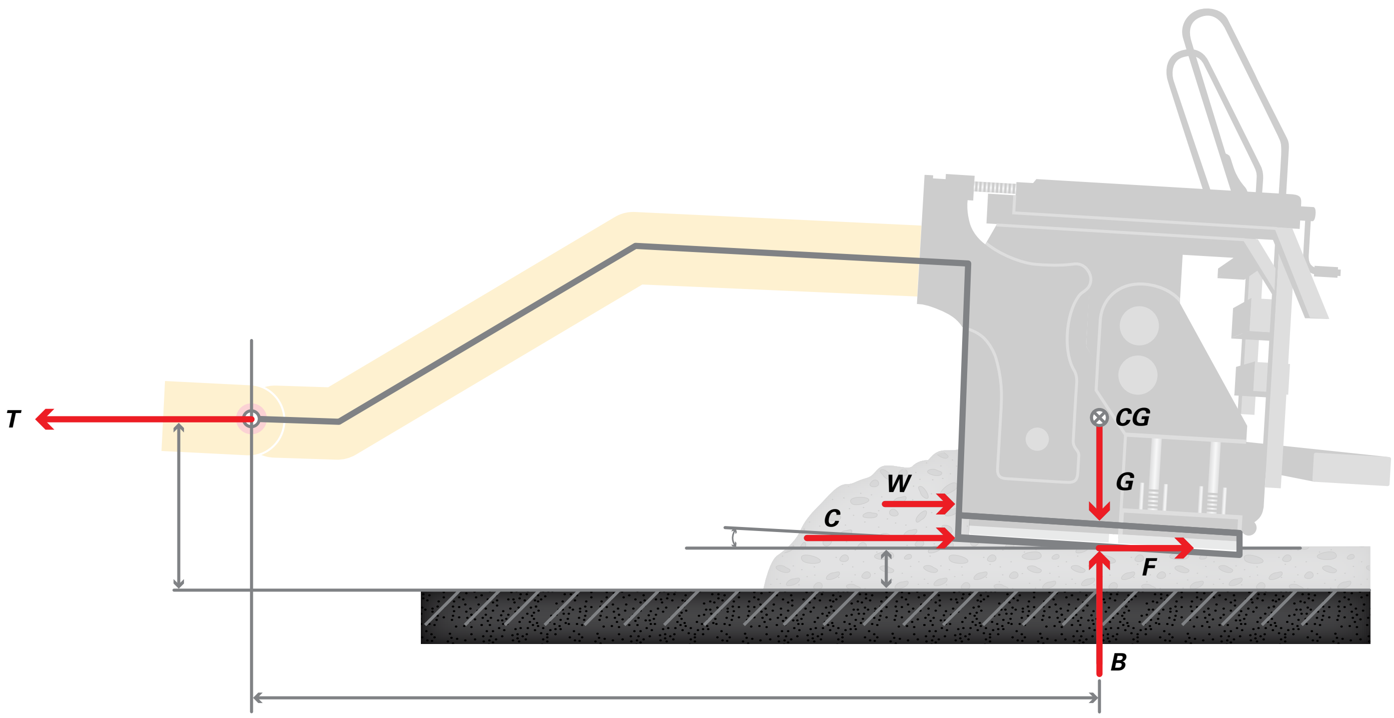
Next, are the forces that act on the screed.

Force *T*: traction force. The traction force is controlled primarily by the speed of the paver. The paving speed provides the energy that enables the screed to shear a portion of the material in the auger chamber. Uniform paving speed contributes to screed equilibrium and, therefore, a uniform layer thickness and smoothness.

Force *W*: weight of material in front of the screed. This weight, or force, creates resistance. Weight is affected primarily by the material height in front of the screed, also called the head of material. The higher the head of material, the heavier the weight. The heavier the weight, the greater the resistance felt by the screed—and the more the screed wants to climb onto the head of material.

Conversely, the lower the head of material, the lower the resistance, and the screed pushes more material in front while allowing less to pass under the front of the screed. When the head of material remains uniform, the screed is more likely to float at equilibrium.

Resistance felt by the screed also depends on the action of the augers. When the augers rotate very slowly or stop rotating altogether, the material compresses against the front of the screed and its weight increases. Consequently, the screed will tend to ride up and thickness increases. Uniform auger rotation in the range of 20 to 40 revolutions per minute helps the screed maintain equilibrium.



T *traction force*

W *weight of material in front of the screed*

C *cutting force (shear force)*

G *gravitational pull (weight of the screed)*

B *buoyant force*

F *frictional force*

Note for tamper screeds: *If the paving speed is increased and the tamper and vibration speed remains constant, the distance between tamper impacts increases. Less material will be consolidated under the screed and the thickness will decrease. To maintain the correct layer thickness at higher working speeds, tamper and vibration speeds must be increased accordingly.*

The opposite effect occurs when working speed is decreased. Impacts delivered by the tamper bar are closer together and more mix passes under the screed. To restore the balance between working speed and tamper forces, the speed of the tamper bar will have to be decreased.

Force *C* : cutting force (shear force). The cutting or shear force is the screed's ability to pass a certain amount of mix under the front of the screed, while pushing the remainder of the material in the auger chamber forward. The shear force is affected by paving speed, head of material, resistance of material influenced by rotation of the auger, and angle of attack.

Force *G* : gravitational pull (weight of the screed). The weight of the screed acts to compress the layer as material passes under the screed. If all other factors are equal, a heavier screed wants to compact the material to a greater extent. The crew members may have to adjust to make a heavy screed reach a stable equilibrium point. If the width of the screed remains unchanged, the weight force remains nearly the same.

If the width of the screed is changed significantly while paving, the force changes and the crew will have to make adjustments to maintain the correct depth. For example, if extenders are brought out, the weight felt by the material is less and the screed will rise.

Force *B* : buoyant force. This is the hydrodynamic lifting force that is created by the material passing under the screed. Mix designs that contain large aggregates (19 mm / 0.75" or greater) and high viscosity with modified asphalt cement tend to have larger lifting forces than fine-grained mixes with conventional asphalt cement. This lifting, or supporting force, remains nearly constant once the screed has reached equilibrium and the thickness of the bituminous layer and the mix design remain the same.

Force *F* : frictional force. The frictional force that is created between the screed plate and the mix passing under the screed plate is generally fairly small. As long as the mix formula and temperature remain the same, the frictional force stays constant and screed equilibrium is not affected.

Colder-than-normal mix tends to create less drag, or friction, on the screed plate. Under this condition, the screed will tend to fall. The larger the temperature loss in the mix, the more the screed will fall.

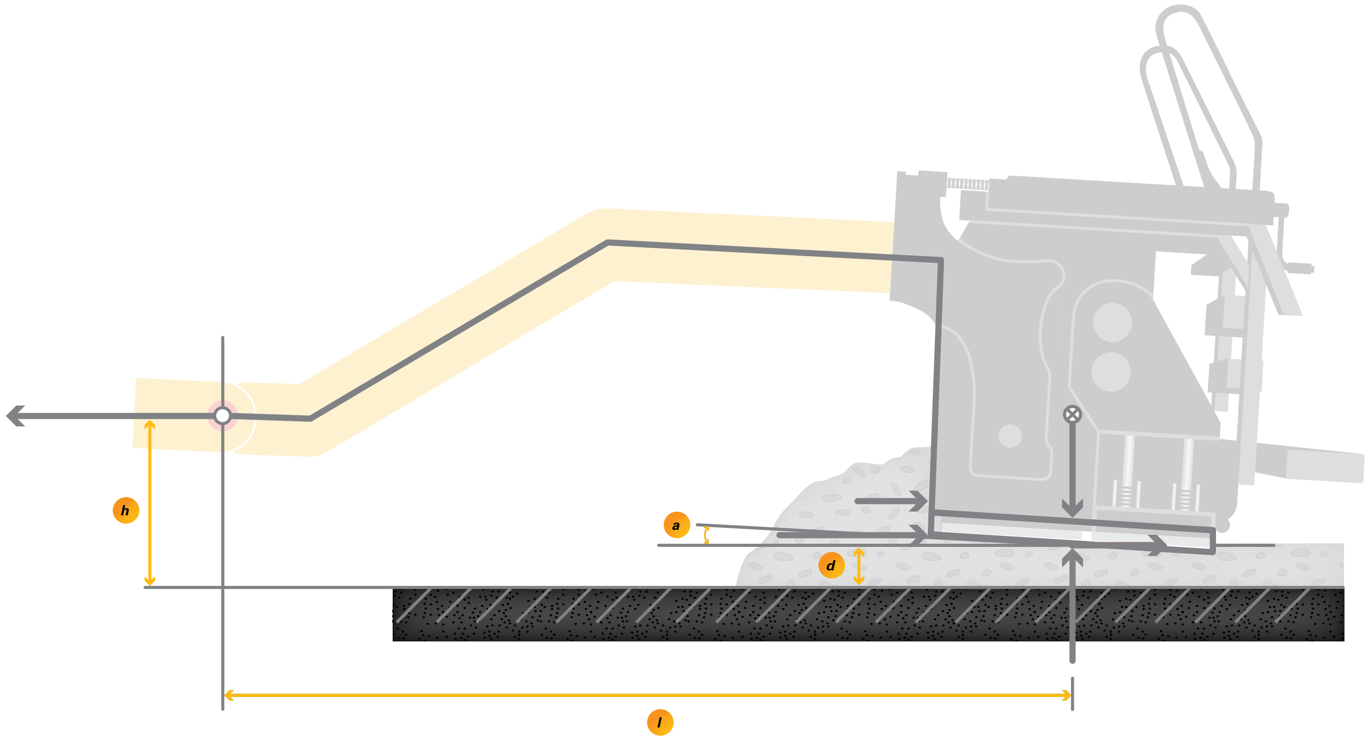
Next, let's examine the dimensional characteristics in the diagram.

Dimension *h*: height of the tow-point. The height of the tow-point connection affects the traction angle, or line of pull. The traction angle is the relationship between the height of the tow-point connection and the pivot point of the screed.

Before starting to pave, position both tow-point connections at the height that is appropriate for the planned layer thickness. (See Unit 4 for more information about setting the tow-point height for vibratory screeds. See Unit 5 for more information about setting the tow-point height for tamper screeds.)

The traction angle that is formed by the height of the tow-point connection affects the main screed angle of attack. On tamper screeds, this is the normal way to change the angle of attack. On vibratory screeds, crews use either the tow-point or manual depth cranks to change the angle of attack.

Increasing the traction angle increases the angle of attack and the screed will climb. Decreasing the traction angle decreases the angle of attack and the screed will go down. Screed operators can change the height of the tow-point connection manually using control switches or automatically using a grade control system.



- **h** *height of the tow-point*
- **l** *projected length*
- **d** *depth of the layer (mat thickness)*
- **a** *angle of attack*

User Note: *When paving manually (not using automatic grade and slope controls), the leveling characteristic of the free-floating screed can produce up to 50 percent improvement in smoothness when paving over a moderately to severely rough grade. The screed at equilibrium tends to remain at a given height, while filling in low spots in the grade and leveling off high spots.*

Dimension *l* : projected length. The projected length of the paver is the distance between the tow-point connection and the screed's center of gravity (indicated as CG on the page 70 diagram), or the screed pivot point. The projected length is often referred to as the paver's leveling distance. When the paver is moving and the screed is at equilibrium, the leveling distance creates a smooth surface—even when paving over an irregular grade.

Dimension *d* : depth of the layer (mat thickness). Layer depth is the distance between the bottom of the screed plate and the grade. Layer depth affects where the crew should position the tow-point in order to create the ideal traction angle (line of pull) and the ideal angle of attack for the main screed. Specifically, when the paving depth is 15 cm (6") or greater, the crew will have to supplement the traction angle with increased angle of attack to help the screed float in a stable condition.

Dimension *a* : angle of attack. The angle of attack is also referred to as the planing angle. Angle of attack can be thought of in several ways. It can be described as the angle between the nose of the screed plate and the grade over which the screed is paving. Or, it can be described as the relationship between the nose and the trailing edge of the screed plate. In general, the best screed stability and best appearance of the bituminous layer occur when the angle of attack is between 3 mm (0.125") and 6 mm (0.25").

The primary influence on main screed angle of attack for tamping screeds is the height of the tow-point connection. The angle of attack on vibratory screeds can be set or altered in two ways: turning the depth crank or changing the height of the tow-point connection.

Summary. The forces that affect the screed are interrelated. If one factor is changed, one or more other factors may need adjusting to create the conditions necessary for screed equilibrium. Therefore, the crew should strive for uniform performance at all times.

However, even with the best planning and preparation, it is virtually impossible to keep all forces constant. Setting up the screed properly can minimize the negative effects of fluctuations in the forces that affect the screed. Pay attention to the traction angle (line of pull) and the angle of attack that is created at the start of paving. Having the screed in the most stable condition will help reduce the screed's reactions to changing forces.

[CONTROLLING THE FACTORS THAT AFFECT THE SCREED]

The screed will float at the same position as long as all factors that affect the screed remain unchanged.

A floating screed is towed by the tractor portion of the paver and supported by the bituminous material that passes under the screed nose. When the paver takes off from the starting reference, reaches the planned speed and develops uniform operation of the material feed system, the screed will float at that position unless one of the factors is changed.

Paving Speed. As described in the previous section, the speed of the paver affects how the screed floats. The screed can reach its planing angle and its equilibrium point at any speed. As long as the speed remains the same, the screed maintains its vertical position. When the speed changes, the screed reacts because the shear factor also changes.

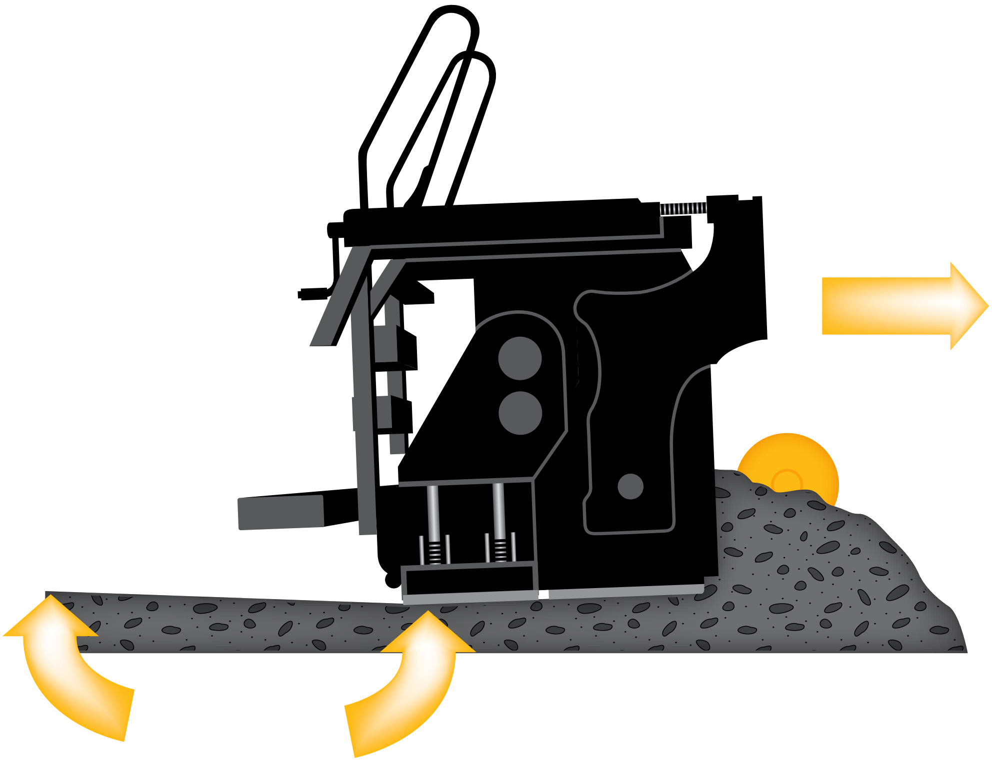
Factors that affect the screed:

1. **Paving Speed**
2. **Head of Material**
3. **Screed Adjustments**
4. **Type of Mix**
5. **Temperature of Mix**
6. **Grade Conditions**

***User Tip:** A common time for the operator to increase the paving speed is when haul units begin to accumulate in front of the paver. Or, the operator may increase the paving speed at the end of a pull when the last truck is being paved out. Caterpillar recommends paving at a continuous, calculated speed with the understanding that there may be times when several haul units accumulate in front of the paver. Resist the temptation to pave faster. High-speed paving will not increase production. The paver will simply stop more often waiting for mix, and quality will suffer.*

Increasing the paving speed will cause the screed to drop.

When the paving speed is increased, more energy is available to push the head of material in front of the screed. Less material flows under the nose of the screed and layer thickness decreases. If the automatic grade control system is in use, the system will detect the change in layer thickness and call for a correction. Still, there will be a dip in the bituminous layer, resulting in increased roughness.

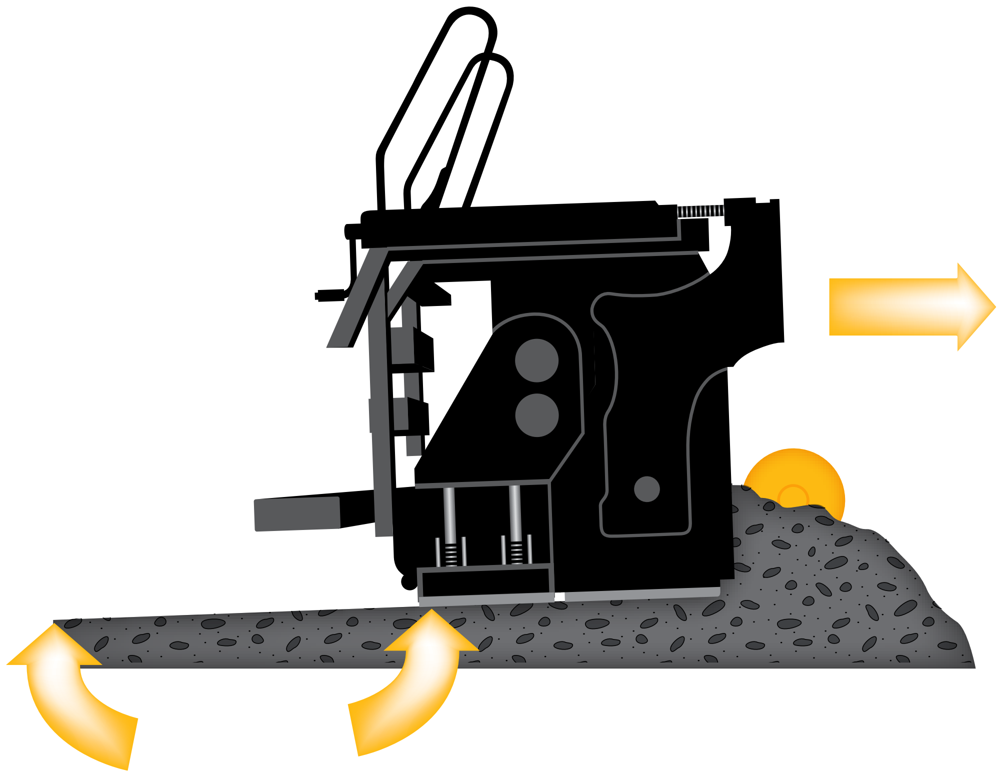


***Note for tamper screeds:** If the paving speed increases and the tamper and vibration speeds remain constant, the distance between tamper impacts increases. Less material will be consolidated under the screed and the thickness will decrease. To maintain the correct layer thickness at a higher working speed, increase the tamper and vibration speeds accordingly.*

Decreasing the paving speed will cause the screed to climb.

When the paving speed is decreased, less energy is available to push the material in the auger chamber. The screed has a tendency to ride up the head of material and more mix passes under the screed.

Note for tamper screeds: *When working speed is decreased, impacts delivered by the tamper bar are closer together and more mix passes under the screed. To restore the balance between working speed and tamper forces, the speed of the tamper bar must be decreased.*



User Tip: *A common time for the operator to decrease the paving speed is when there is only one truck in front of the paver and no more in sight. Or, the operator may decrease the paving speed during truck exchanges to avoid running low on material in the hopper while continuing to pave. Short stops during truck exchanges or waiting for more material are not necessarily bad events. But, many operators have been trained to avoid, as much as possible, stopping the paver. Caterpillar recommends paving at a continuous, calculated speed with the understanding that short stops are often unavoidable.*

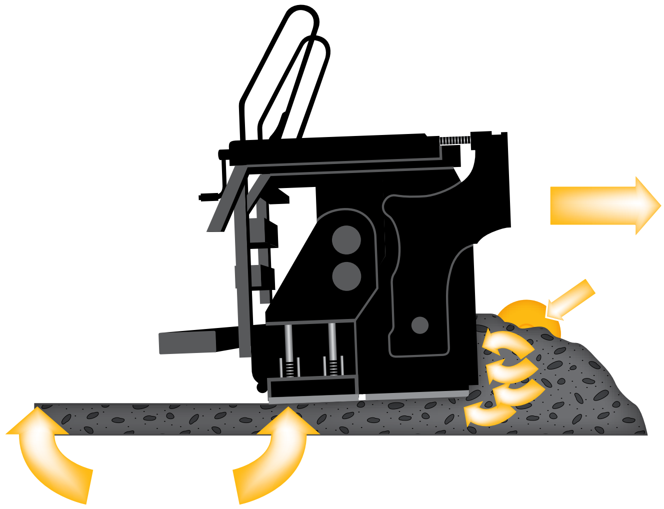
Material Feed System. Another factor that affects how the screed floats is the operation of the material feed system. The goal of the paving crew is to adjust the material feed system to create a continuous flow at uniform speed through the paver and in front of the screed.

The head of material in the auger chamber should cover one half, or slightly more than one half, of the augers.

The target for the paver operator and screed operators is to cover one half, to slightly more than one half, of the augers. Once the correct head of material is created, the crew must maintain it. Remember, the head of material in the auger chamber is the weight, or resistance, felt by the screed.

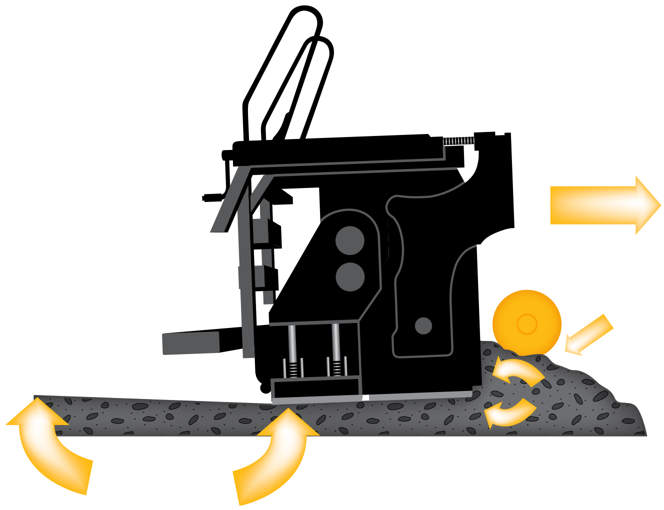
When the resistance to paving energy stays the same, then the screed stays at equilibrium and maintains its vertical position. Ride quality will be improved and the appearance of the bituminous layer enhanced.

Covering about half of the augers with material enables the mix to move efficiently toward the end gates at the full paving width. If the augers are overloaded, the material begins to compact in the auger chamber by its own weight and does not move as well. Auger overloading also requires more power and increases wear on the auger segments.



The screed height drops when the head of material decreases.

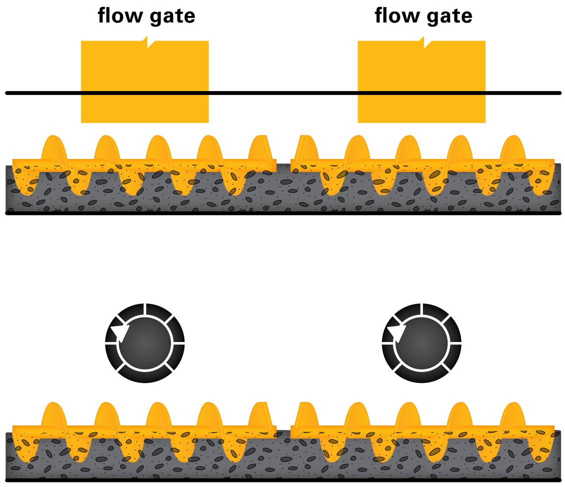
The screed will dive if the head of material in the auger chamber decreases. The loss of layer thickness happens very quickly and the screed may begin to drag aggregates. Many times the crew does not have to see this happening. They can hear the feeder system hydraulics begin to rapidly turn the augers as the feeder sensors detect the drop in material. Running low on mix in the auger chamber is considered a big mistake—one of the factors that has a big affect on quality.



User Tip: *There are several times that the head of material can diminish while paving. One is when paving under automatic slope control, because the screed will continue producing the correct slope at the surface of the layer. The screed may be laying a very thin layer or very thick layer if it is correcting for slope errors in the base. A very thick mat requires more material and can temporarily create a low head of material, until the feeder system catches up. The second possibility for running low on mix in the auger chamber is paving during truck exchanges. Some operators are trained to never stop between haul units. If the haul unit with a fresh supply of material is slow to position itself in front of the paver, the material in the hopper will run low, the conveyors will run low, and the head of material will run low.*

Controlling the head of material in the auger chamber and delivering a continuous flow of material through the paver requires coordination by the paver and the screed operators.

The paver operator has primary control of material delivery from the hopper through the tunnels and into the auger chamber. The material that drops off the conveyors into the auger chamber can be regulated in two ways, depending on the type of paver.



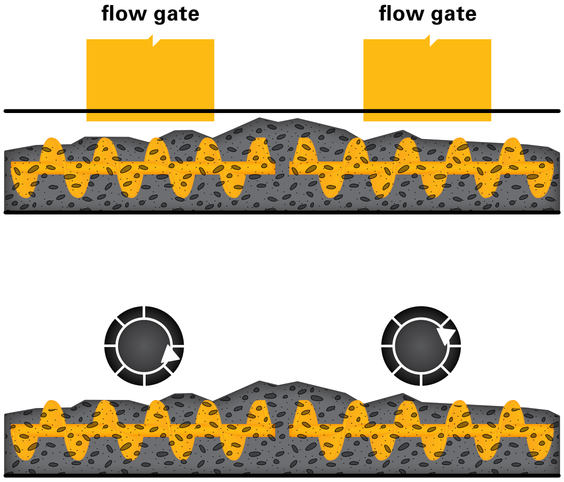
The position of the flow gates or the setting of the ratio control dials determines the level of material in the center of the auger chamber.

Some pavers have flow gates that are located over the left and right conveyor tunnels, on the rear wall of the hopper. Flow gates are strike-off devices used to meter the amount of material that flows back to the auger chamber. The height of each flow gate is independently adjustable.

Other pavers do not have flow gates, so the right and left conveyor tunnels are completely open. Those pavers have ratio control dials at the operator's station. Adjusting the ratio control dials regulates the speed of the conveyors.

Both flow gates and ratio control dials have the same affect on the material feed system. They control the volume of material that enters the auger chamber and, thus, they control the head of material in the center of the auger chamber.

If the operator raises the flow gates too high or turns up the ratio control dials too much, the auger chamber will be flooded and the head of material in the center of the auger will be too high. When there is too much material coming back on the conveyors, the rotational speed of the left and right augers will decrease. The augers may stop completely or run too slowly. The augers should not stop or operate in an ON / OFF mode during normal paving operations. Lower the flow gates or turn down the ratio control dials to speed up the rotation of the augers.

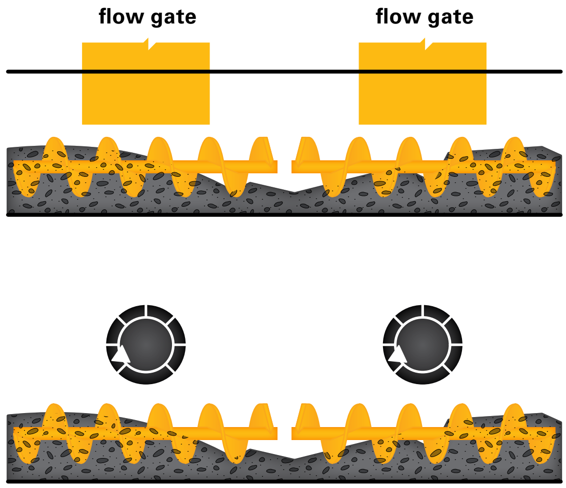


The head of material in the center of the auger will be too high if the flow gates are open too high, or the ratio control dials are set too high.

Conversely, if the flow gates are lowered too much or the ratio control dials are set too low, the center of the auger chamber will run low on mix and the head of material will be too low. When there is not enough material flowing back on the conveyors, the rotation of the augers will be too high.

The ideal range for auger speed is between 20 and 40 rotations per minute. If the auger speed is too high, continuous stripes of segregated aggregates may appear in the bituminous layer. If the auger speed is too slow or ON and OFF, random patches of segregated aggregates may appear. (More information about causes of stripe segregation and patch segregation are found in Unit 8.)

In addition to the appearance of various types of segregation, incorrect auger speed can also cause variations in the pre-compaction of mix in the auger chamber. Maintaining the correct auger speed takes teamwork on the part of the paver operator and the screed operator(s).



The head of material in the center of the auger will be too low if the flow gates are lowered too much, or the ratio control dials are set too low.

User Tip: *On most pavers, controls for flow gate height and conveyor speed (ratio control dials) are found at the operator's station on top of the paver. It is the paver operator who has the ultimate responsibility for controlling the volume of material coming into the auger chamber and, therefore, ultimate control of auger speed. The controls available for the screed operators can temporarily affect auger speed. The crew must understand this relationship.*

Screed operators control the head of material at the outer end of the auger shafts by adjusting the mix height dials at the screed control panels. To increase the head of material at the end of the auger shafts, turn the mix height dial clockwise. To decrease the head of material at the end of the auger shafts, turn the dial counter-clockwise. Adjusting the mix height dial affects the sensitivity of the material feed sensors that are aimed at the material emerging from the auger chamber.

Mix height dials at the screed control panels regulate the head of material at the ends of the auger shafts.

There are two types of feeder sensors: mechanical and sonic. Mechanical sensors contact the head of material as it flows through the auger chamber. As the material pushes against the paddle, the paddle turns a rheostat-type switch. As the paddle rotates outward, the sensor begins to slow the feeder system. As the paddle rotates inward, the sensor speeds the delivery of material. Adjusting the mix height dial controls where the sensor starts to slow the feeder system, or the point at which the system is shut off.

Mechanical feeder sensors contact the material as it flows out of the auger chamber.

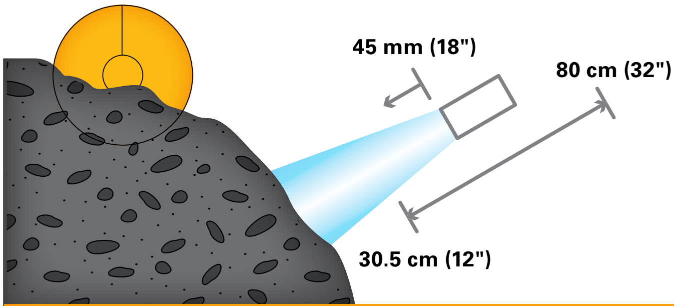
User Tip: *Mixes that include modified asphalt cement are often sticky. Mix can build up on the tractor bulkhead and can interfere with the motion of a mechanical feeder sensor. The crew needs to periodically clean the tractor bulkhead to avoid erratic feeder system operation.*

The other type of feeder sensor is a sonic-type sensor. This sensor emits sound pulses. Echoes bounce off the material coming out of the auger chamber. The sonic sensor monitors the time it takes for the echoes to return to measure the distance between the sensor and the target. There are several principles that are important to know about sonic feeder sensors.

The working range for a sonic feeder sensor is between 30-80 cm (12-32"). If the target is closer than 30 cm (12"), the feeder system for that side of the paver will shut off. If the target for a sonic feeder sensor is beyond 80 cm (32"), then the feeder system for that side of the paver will run at full speed. The recommended distance from the target for sonic feeder sensors is 45 cm (18").

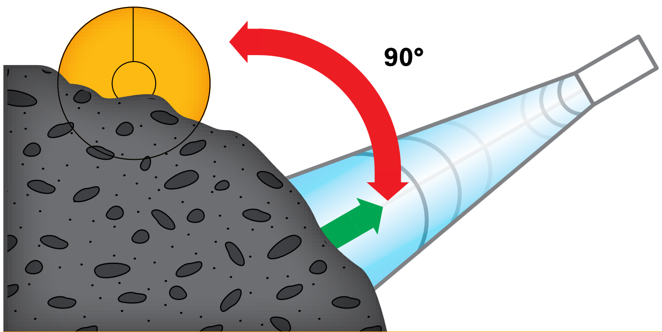
Sonic feeder sensors emit sound pulses that rebound off the material coming out the auger chamber and back to the sensor.

Aiming a sonic feeder sensor is extremely important. It emits a given number of sound pulses per second. In order to be accurate as a measurement device, the sensor must receive the same number of returning echoes. If the sensor is aimed at an incorrect angle, some of the echoes will not return to the sensor and the feeder system will operate erratically.



Sonic feeder sensors must be positioned the correct distance away from the intended target.

User Tip: *If difficulty is encountered getting the feeder system to run smoothly at the desired speed and desired head of material, the first troubleshooting step should be to re-aim the sonic sensor until the system operates properly. As an aid to aiming the sensor, use a tape measure or folding ruler extended to 45 cm (18"). Hold the ruler on the end of the sensor and see what the ruler is contacting at that distance. Check the angle and make sure that the sensor is pointed directly at the target.*

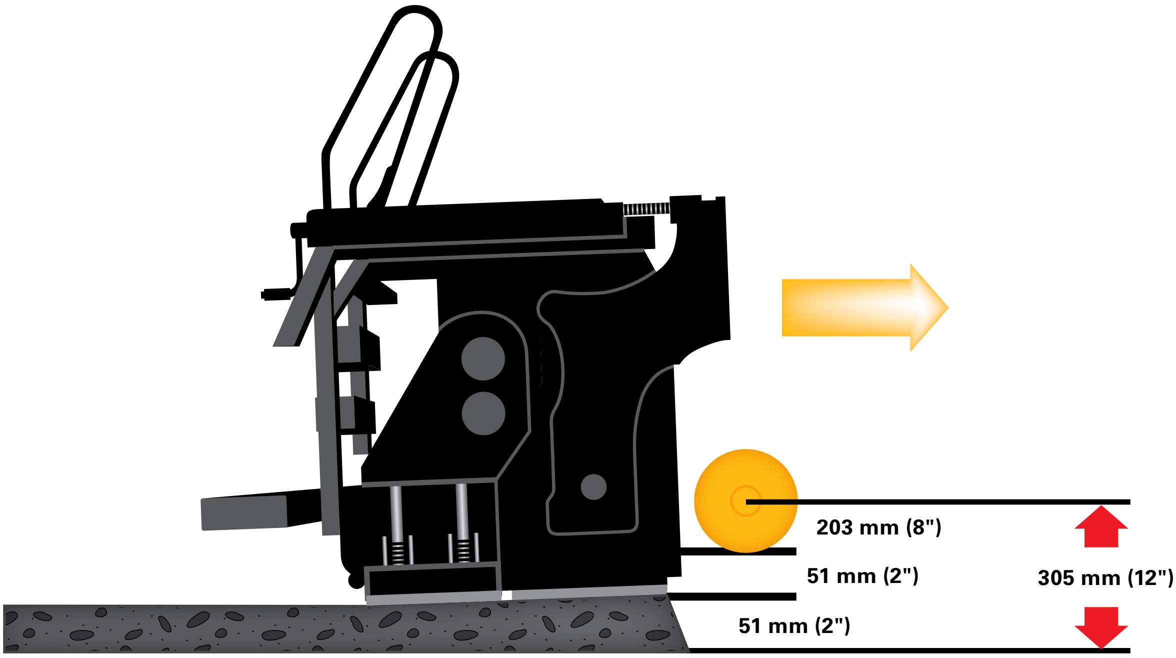


Sonic feeder sensors must be aimed perpendicular to the intended target.

Selecting the best target is another key to smooth feeder system operation when using sonic feeder sensors. Ideally, the sensor should be aimed at the material coming off the front side of the auger shaft. This material is moving toward the screed end gate, which is the outer edge of the bituminous layer. If this material is targeted, the mix height dial will help control how the material flows out and where it contacts the end gate. Do not aim the sensor at the grade or too far back on material that is stagnant. Always aim the sensor at moving material.

The target for the sonic sensor should be the active head of material coming off the front side of the auger shaft.

User Tip: *One of the most difficult applications when using a sonic feeder sensor is paving at a width that is the same as the basic screed width. In other words, the end gate at the screed extender is drawn all the way in, and no material is flowing from the auger chamber. In that situation, the sensor will have to be aimed straight down. Try to keep the sensor at least 30 cm (12") away from the target. Or, if mechanical sensors are available, install them. Mechanical sensors make it easier to control the feeder system at narrow paving widths.*



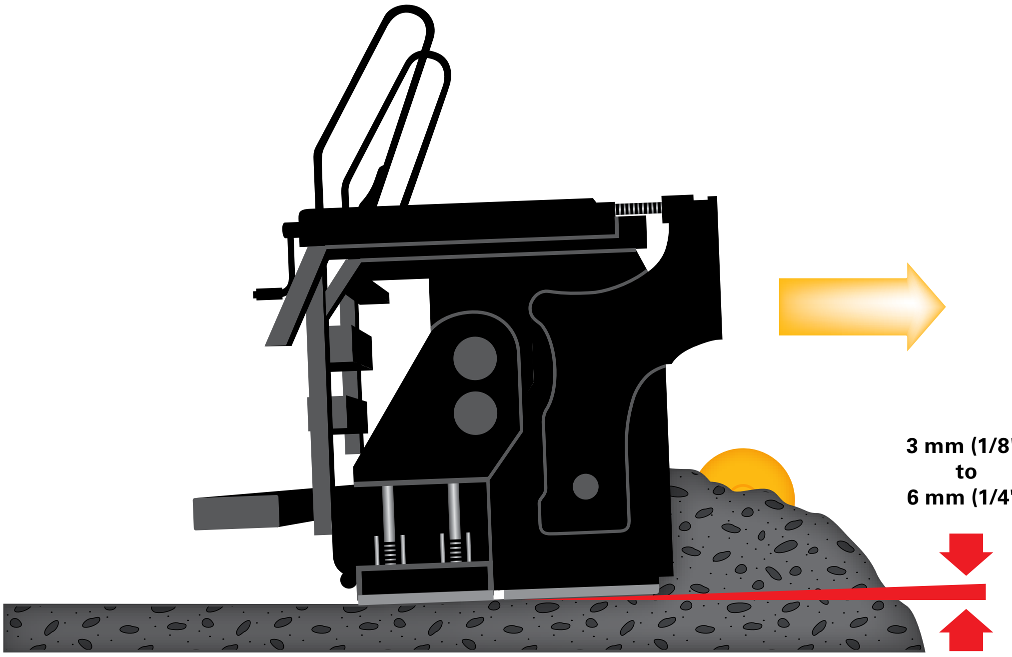
Adjust auger height to avoid creating auger shadows in the surface of the bituminous layer.

On many pavers, the height of the auger shaft is adjustable. When preparing the paver for operation, lower the augers until they are about 5 cm (2") above the surface of the layer for mixes with a maximum aggregate size of 13 mm (0.5") or smaller. For mix designs with aggregates 19 mm (0.75") or larger, position the augers 8 cm (3") above the layer.

If the augers are too low, they will leave dark shadows in the surface of the bituminous layer. The layer will appear tight in the center and will have open texture (shadows) on either side of center, the same length as the left and right auger shafts. Then, the layer will appear tight again at the edges. If this texture pattern develops, gradually raise the augers until the appearance of the layer is uniform.

User Tip: *Here's an easy way to measure auger height. Assume that the augers are 40 cm (16") in diameter. The center of the auger shaft will be 20 cm (8") above the bottom of the augers. The bottom of the augers should be 5 cm (2") above the layer. Assume that the layer is 5 cm (2") thick. Lower the augers before filling the auger chamber. Measure from the center of the auger shaft to the grade. When the distance is 30 cm (12"), the auger height is correct for that layer thickness. Add 2.5 cm (1") to auger height when using a large-stone mix.*

Screed Adjustments – The third crew-controlled factor that affects how the screed floats is screed setup and adjustment. The first setup step is establishing the correct angle of attack.



At equilibrium, the screed should float at a slight nose-up attitude.

All screeds are designed to produce the best results when the screed reaches equilibrium and floats at a slight nose-up attitude. The front of the screed plate should be between 3-6 mm (0.125-0.25") higher than the trailing edge of the screed plate. That angle of attack (also called the planing angle) allows material to pass under the nose of the screed and provide the support that floats the screed. At the correct angle of attack, the entire surface of the screed plate is used to help provide pre-compaction and the surface texture of the bituminous layer.

Texture stripes in the surface of the bituminous layer are usually caused by variations in the angle of attack across the width of the screed.

When the angle of attack for the main screed plate or an extender screed plate is too high, a smaller portion of the screed is in contact with the bituminous layer. The smaller contact area exerts more force on the surface of the layer and will create a tight, shiny appearance at the surface.

When the angle of attack is too low or when the screed is running nose down, the surface looks open or torn, and short waves can be seen. Note that the surface of the layer in the photo is open behind the left extension (right side of photo) and tighter behind the main screed. If the density is checked at different locations across the width of the layer, you will find that the pre-compaction density will be variable, too.

The angle of attack on screed extensions should be adjusted while the paver is moving.

The angle of attack at the main screed extenders are set at the start of paving and is adjusted to change the layer depth. The angle of attack at the screed extensions is fixed when screed plates are installed. When paving starts, it is common to adjust the extender angle of attack to make the surface texture uniform.

On many screeds, there is a series of adjusters on the trailing edges of the extenders. Turn the adjusters clockwise to increase the angle of attack. Per the example shown in the photo above, the screed operator is gradually increasing the angle of attack on the left extender to tighten the surface of the layer.

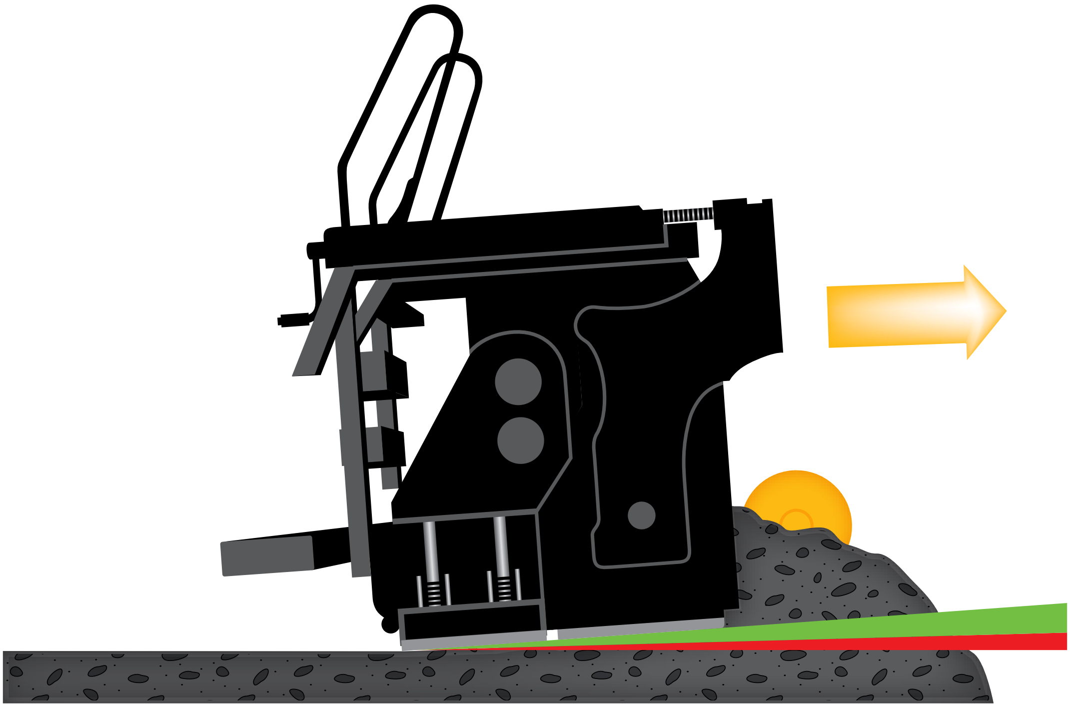
When the planing angles are the same on the main screed and the screed extenders, the texture of the surface is uniform.

The surface of the bituminous layer should have a uniform appearance from edge to edge. Remember, texture is affected by angle of attack. Material segregation and other defects have other causes. (For more information about defects and problems, see Unit 8.)

User Tip: *There are several other ways to determine if the screed is consistently running with the wrong angle of attack. If the angle is too high, there will be excessive and premature wear on the trailing edge of the screed plate when compared to the nose bar and the front of the screed plate. If the angle of attack is too low, or if the screed is running nose down, the wear will be concentrated around the nose bar. Also, lock the screed when raising it at the end of a pass, and look at the bottom of the plates. The screed was tilted back and running with too much angle of attack during that pass if the screed plates are clean and shiny at the rear half, and have fines adhering to the front half.*

In review, a few noteworthy principles affect the angle of attack on the main screed.

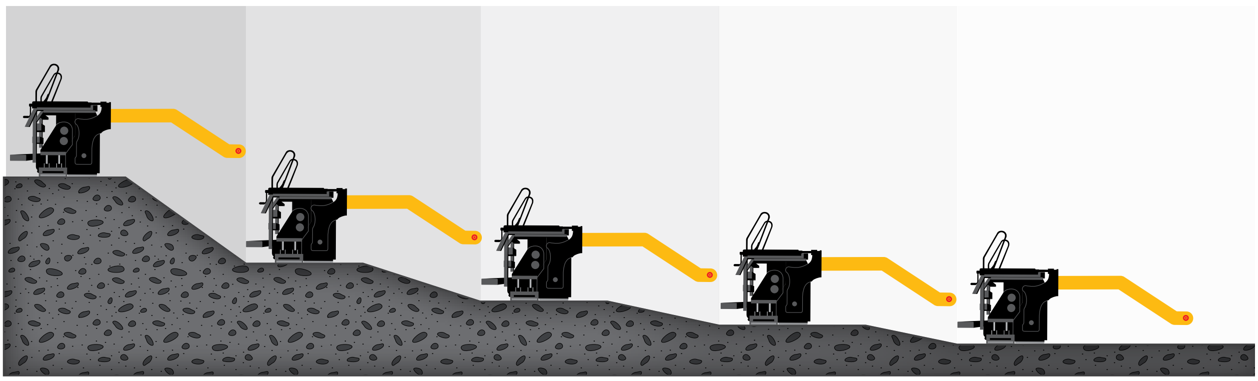
Every time the screed is lowered on a starting reference and prepared for paving, adjustments must be made that create the angle of attack for the main screed. Those adjustments are covered in detail in Units 4 and 5. For starters, assume that the main screed has the correct angle of attack—3-6 mm (0.125-0.25").



While paving, the screed operator can increase or decrease the angle of attack.

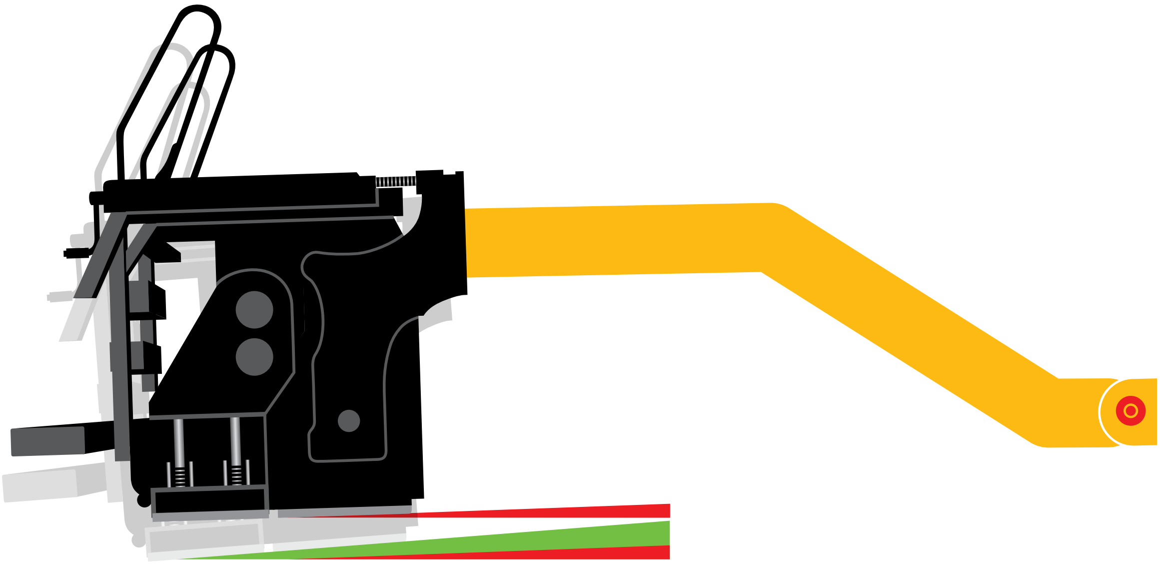
There are two ways a screed operator can change the angle of attack while paving. On a vibratory screed, the operator can turn the depth-control screws located on the left and right sides of the screed. Or, the operator can adjust the tow-point height up or down manually, or by using automatic grade and slope control. On a tamper bar screed, the operator normally uses only the tow-point height as a means to change the main screed angle of attack.

User Tip: *If the paver is equipped with depth control screws and those screws have conventional thread spacing, one rotation of the screw will cause about 6 mm (0.25") of screed movement. If the depth control screws have coarse threads, one rotation of the screw will cause about 13 mm (0.5") of screed movement.*



The change in layer thickness occurs over a distance equal to five tow arm lengths.

When a depth-control screw is turned or when the tow-point height is adjusted, the angle of attack changes and the screed immediately begins to move up or down. Most of the change in layer thickness, about 65 percent, occurs in the first tow-arm length. Another 65 percent of the remainder occurs in the next tow-arm length. The thickness change occurs progressively until the change is complete in five tow lengths. This phenomenon is the leveling effect that is common to all floating screeds. The gradual change in layer thickness improves the smoothness of the layer.

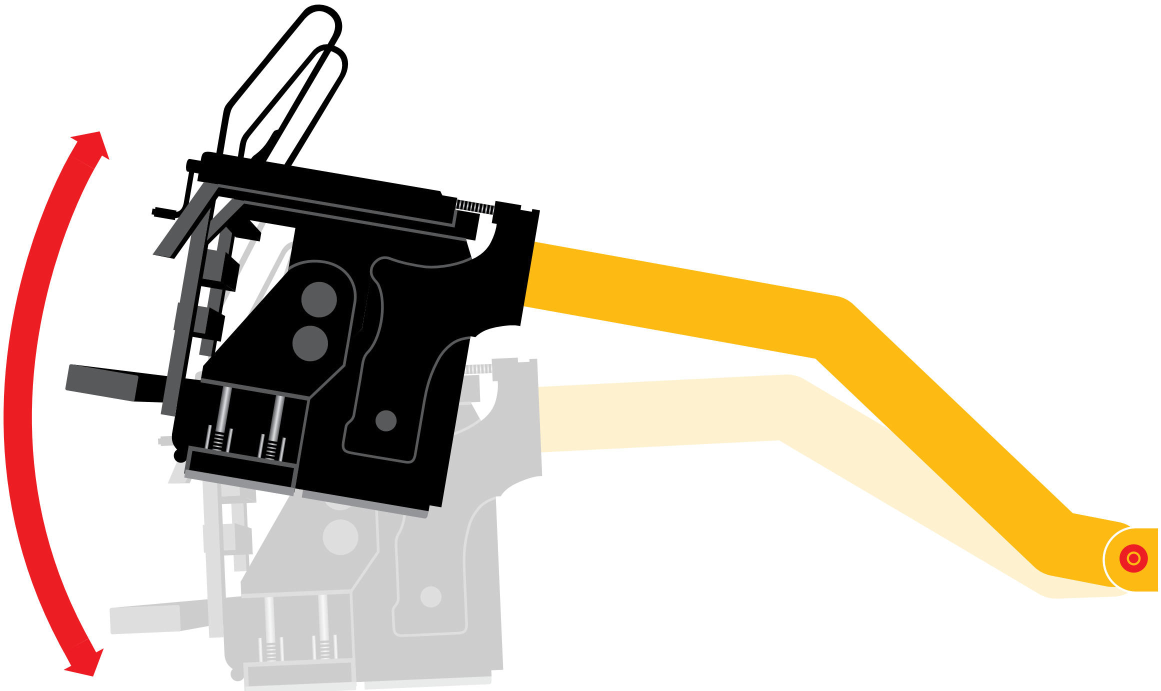


When the thickness change is complete, the screed has returned to its original angle of attack.

The thickness change is complete at the end of five tow-arm lengths. The main screed has returned to its original angle of attack and resumed its equilibrium point where it is floating at an unchanging vertical position.

The screed operator should wait until the screed has resumed its original angle of attack (reached equilibrium) before checking layer thickness. If the screed has depth-control screws, the operator can check the tension on the depth-control screw.

When the thickness change has completely occurred, the depth-control screw should have no tension—indicative of the floating screed. If there is still tension on the depth-control screw, the screed is still moving and has not returned to the original angle of attack.



The screed moves in an arc as it changes layer thickness.

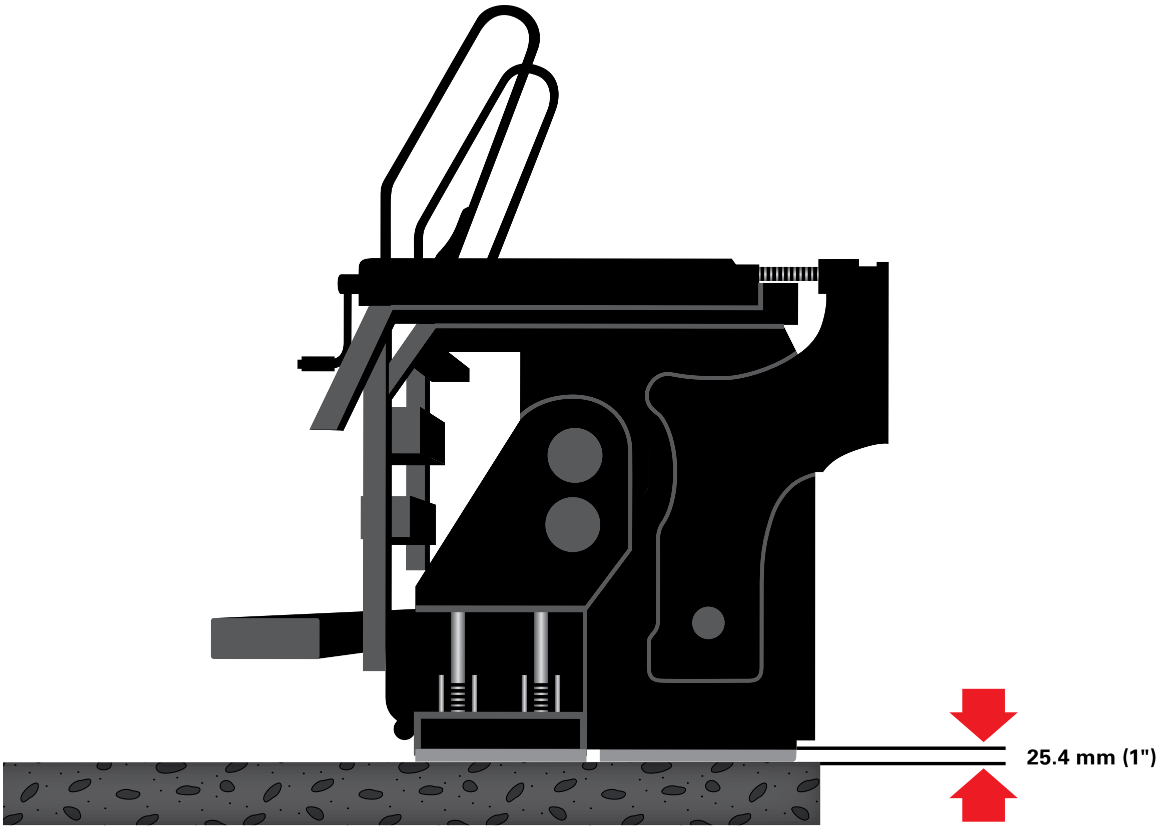
Understanding how the screed moves up and down is key to understanding why the screed always returns to the angle of attack that the crew created at the start of paving.

Remember, the screed is attached to the paver on both sides at the tow-arm connections. Think of that connection as the center of a circle. The length of the tow arm where it attaches to the front of the screed is a radius. The length of the tow arm plus the screed itself forms a longer radius. Since the tow arm is pinned to the tow-point connection, the screed actually rotates around that pin connection as it moves.

The front of the screed, which has a shorter radius, moves in a smaller arc, not straight up and down. The rear of the screed, which has a longer radius, moves in a larger arc compared to the screed nose. Therefore, the rear of the screed moves a little farther and a little faster than the nose of the screed. The change in angle of attack at the front of the screed is gradually canceled by the fact that the rear of the screed is moving to return the screed to equilibrium—the original angle of attack.

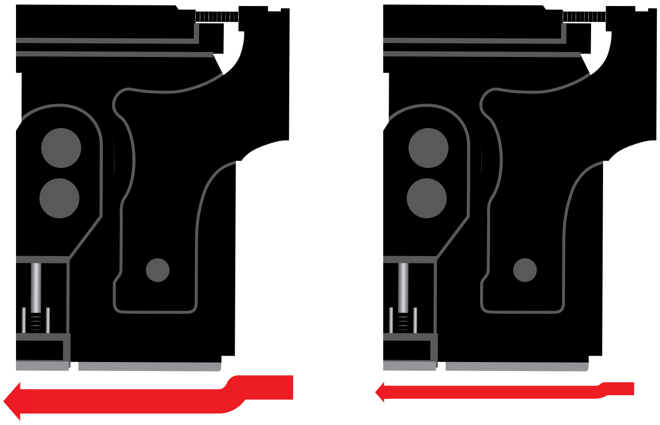
Units 4 and 5,contain information about the procedure to set the correct angle of attack at the start of paving. Correctly setting the angle of attack at the start is critical, because the screed always returns to that position after every thickness correction.

Several other screed adjustments should also be considered.



Adjustable strike-offs on some screeds control the exposure of the nose bar.

Some vibratory screeds have an adjustable strike-off on the front wall of the main screed. The strike-off height controls the amount of the rounded nose bar that is exposed. The factory height is 25 mm (1") above the screed plate, so the entire nose bar is exposed. For many mix designs, the nose bar should be fully exposed to aid material flow.



Lowering the strike-off reduces the flow of material under the nose bar.

When the strike-off is lowered, it's harder for material to flow under the rounded nose bar. Caterpillar recommends lowering the strike-off to counteract the effects of paving with mixes that contain large aggregate sizes.

Some base layer mixes have aggregates up to 38 mm (1.5"). Those large aggregates tend to float the screed easily and create too much lift. It becomes difficult to control layer thickness without reducing the angle of attack too much. The screed runs flat or nose down. The surface or the bituminous layer looks open, torn or scuffed because the angle of attack is incorrect. Closing off some of the nose bar reduces the lifting forces exerted by mixes containing large aggregates and helps the screed float at the correct angle of attack.

The screed counterbalance system is another feature that affects screed performance. When the counterbalance system is activated, it exerts a small amount of upward hydraulic pressure (lift) through the screed lift cylinders. Its purpose is to help reduce screed settlement marks when the paver is stopped. It is most useful when working with sandy or tender mixes.

Screed counterbalance is a standard feature on Cat Pavers.

On newer Cat Pavers with vibratory screeds, counterbalance pressure can be viewed and adjusted via the Advisor display. Older Cat Pavers or Cat Pavers with tamping screeds are equipped with a pressure gauge and adjustment dial.

When the paver stops on the fresh bituminous material, it may leave an impression of the screed in the surface of the layer.

The screed will dent the fresh bituminous material to a certain extent—depending on the mix type, the length of the paver stop, and the screed weight. The marking will be most apparent when paving with tender mixes, which have smaller aggregates, and straight-run asphalt cement. The mark will be less apparent when paving with stiff mixes, especially those with modified asphalt cement.

Examine the surface of the layer after the initial-phase compactor has completed a pass over the screed indentation.

After paving starts again, wait for the initial-phase compactor to make a pass over the area where the paver stopped. The screed mark should no longer be visible. In other words, the compaction process will completely eliminate the marks and they will not affect ride quality. If the marks remain visible after the initial-phase compactor has completed its passes, activate the screed counterbalance system or, if the system is already in use, increase the pressure.

On pavers with vibratory screeds, the factory setting is 3.4 bar (50 psi). If counterbalance is required, reduce the pressure to the lowest possible setting to achieve the desired results, never to exceed 10.3 bar (150 psi).

On pavers with tamping screeds, set the system pressure between 0 and 5 bar (0 and 73 psi) for the Paving mode and 15 bar (218 psi) for the Standby mode. Adjust the Standby pressure as required to eliminate deep screed settlement marks.

Cat Pavers with tamping screeds are equipped with a screed lower lock function.

When screed lower lock is engaged, the screed is put in the Hold position when the paver controls are in the Standby mode. Therefore, the screed is virtually weightless when the paver is stopped, which minimizes indentations. When paving resumes, the Standby mode is terminated and the screed lower lock disengages after a preset time.

[SUMMARY]

Understanding how a paver works and what factors impact the concept of the free-floating screed is critical to achieving high quality results when laying down bituminous material. Each crewmember should know the theory that is behind the process, not just the steps in the paving process. If every member of the crew, including supervisors and quality control personnel, can explain theory, they will be better equipped to troubleshoot problems when they occur.

Caterpillar recommends continuous training that includes a review of fundamentals and principles of paving. Even the most experienced operators and supervisors will benefit from exposure to basic training. A thorough knowledge of the basics lays the foundation for advanced study.


AP655F
CAT
GRADE CONTROL

Unit 4
PREPARING TO PAVE WITH VIBRATORY SCREEDS

Among the most crucial steps during takeoff are setting the angle of attack; filling the auger chamber slowly, one side at a time; and paving with a calculated speed.

Before pulling off the starting joint, the crew must heat the screed plates to prevent hot mix from sticking to them.

Unit 4 describes how to prepare a paver to pull off a starting reference when utilizing a vibratory screed. The process for getting ready to pave with a tamping and vibrating screed is different and will be covered in Unit 5. To prepare the paver, Caterpillar recommends using a step-by-step procedure that helps crewmembers work together through all of the required steps.

Pulling away from a starting reference can be a frustrating process for even the most experienced paving crew. Sometimes the screed drops after pulling off the starting reference. Sometimes the screed climbs during the takeoff. Sometimes the takeoff is perfect. While there is no way to guarantee perfect takeoffs every time, the crew can create more predictable results when they work together to follow a logical sequence.

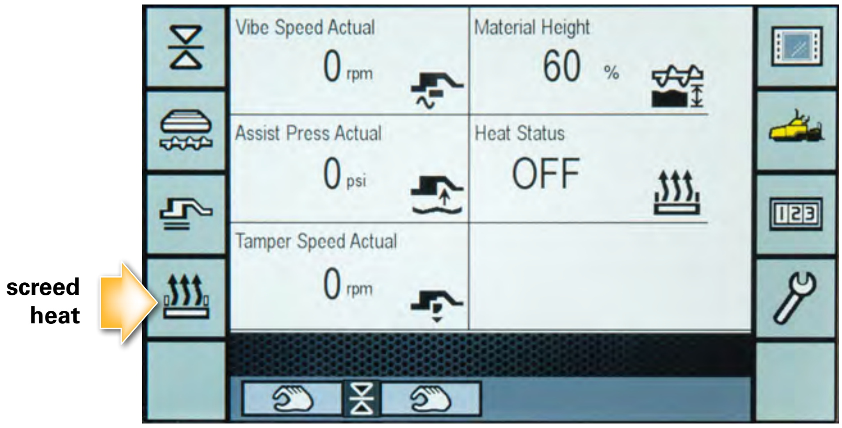
Note: *Some of the steps described in this unit apply specifically to certain Cat Pavers equipped with vibratory screeds. Some procedures may be different for older Cat Paver models. Other steps are general in their application and are appropriate for any paver model. Always consult the specific instructions in the Operation and Maintenance Manual for the pavers used on the worksite.*

[1. HEAT THE SCREED]

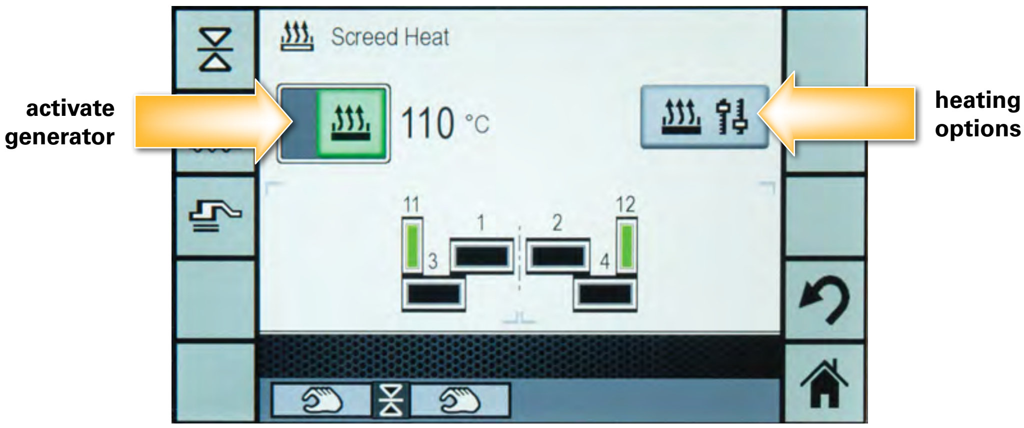
The first step is heating the screed plates prior to pulling off the starting reference. If the screed plates are not close to the temperature of the material passing under the screed, the hot mix will adhere to the bottom of the screed plates. Drag marks will appear in the surface of the bituminous layer, and the screed will dive after pulling off the starting reference.

Before heating the screed, position the screed approximately 25-75 mm (1-3") off the ground. If the screed is in the fully raised position, wind can affect the performance of the heating system. If the screed is in the fully lowered position, the ground temperature affects the performance of the heating system. In both cases, the heating system will take longer to bring the screed plates up to the desired temperature.

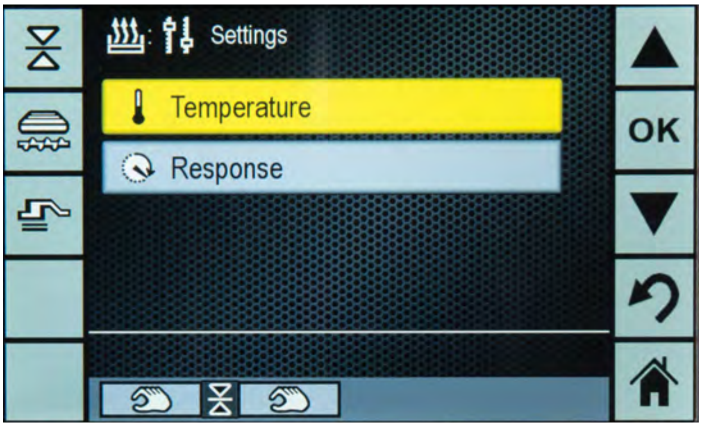
Two types of screed heating systems are available on Cat Pavers. One is electric screed heat.



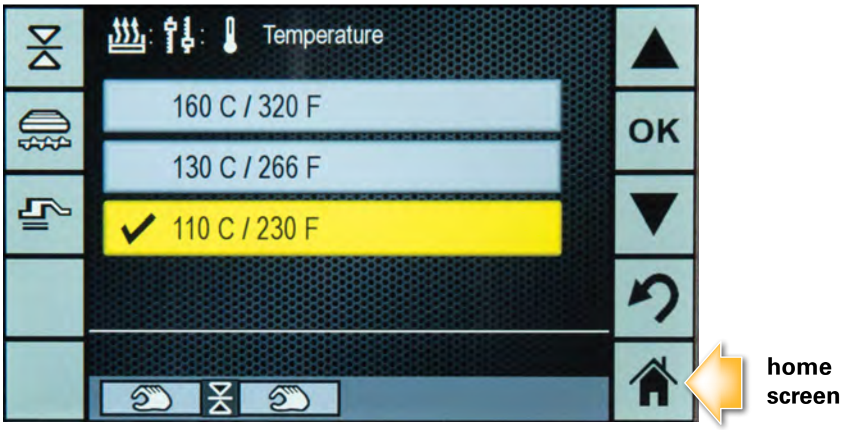
Use the display at either tractor operating station or either screed operating station to start the screed heating system. To start electric screed heat, first touch the screed heat icon on the display screen.



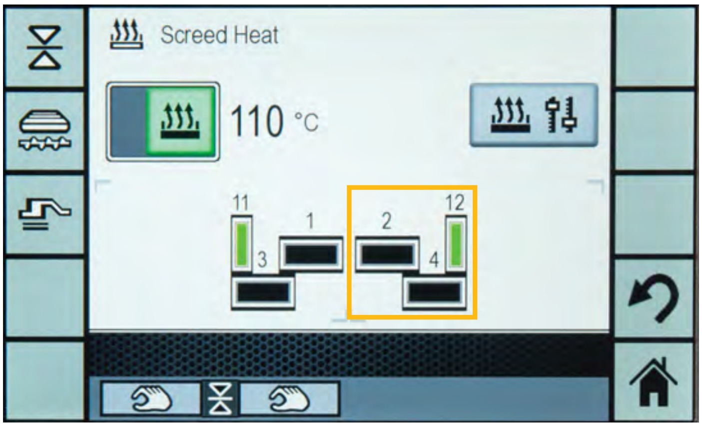
The screed-heat screen will appear. The generator icon is located on the left side. Touch the generator icon and slide to the right. When activated, the icon will turn green, the engine rpm will increase to 1300 rpm, and the generator will be activated. Choose the temperature set-point by selecting the heating option icon on the right side of the screen.



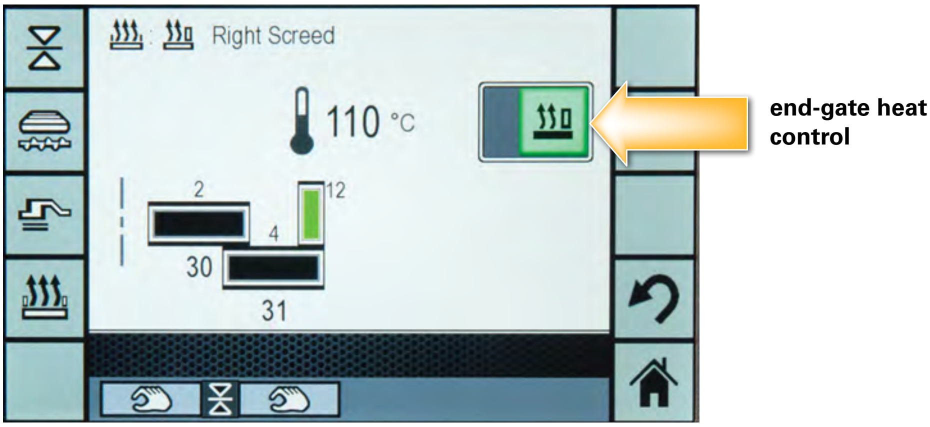
The heating options menu appears next in the display. Touch the temperature option.



The screen then shows three choices for set-point temperature. Select either low range, where the set-point temperature will be 110° C (230° F); the mid range, where the set-point temperature will be 130° C (266° F); or the high range, where the set-point temperature will be 160° C (320° F). Once the temperature range has been selected, touch the Home screen.



Check the status of the screed heat system while the screed plates are heating. The screed heat screen shows the four standard heating elements—two on the main screed plate and one on each extender screed plate. When equipped, optional end gate heating elements will also be displayed. There are two zones in the display. One zone (shown above) includes the right half of the main screed plate, the right extender screed plate, and the right end gate (if equipped). The other zone includes the comparable left side heating elements, simply touch the zone to display screed plate temperatures.



The heating elements in the right zones appear. In this view, the optional end-gate and end-gate heat icon have been activated as indicated by the green color. The right half of the main screed and the right extender are still heating, as indicated by the black color. When all the screed plates are green, the preset temperature has been reached. Following is a list of the temperature ranges for each temperature set-point and the coloration shown on the screen.

Set Point	Black	Gray	Green
Low	0–59° C (32-138°F)	60-109° C (140°-228°F)	110° C+ (230°F+)
Medium	0-79° C (32-174°F)	80-129° C (176-264°F)	130° C+ (266°F+)
High	0-109° C (32-228°F)	110-159° C (230-318°F)	160° C+(320°F+)

User Tip: *Many crews, especially those doing commercial work with frequent restarts, leave the generator on and let the screed re-heat automatically. When the temperature of any portion of the screed plates drops below the set-point temperature, that heating element will automatically energize and reheat the screed. The screed operators do not have to remember to heat the screed after picking up the screed and moving, if they leave the system activated.*

The second type of screed heating system uses liquid propane. Before activating the propane heating system, open the valve on the liquid propane cylinder.

To activate the automatic ignition sequence, depress the AUTO / OFF pad **(1)**. The propane burners will begin to ignite. As the burners ignite, the yellow indicators **(2)** illuminate to confirm that heating has started for that portion of the screed plate. If a burner does not ignite, the indicator light will be red. To ignite that burner, depress the number **(3)** of the burner to be ignited. Then, depress the AUTO / OFF pad again. Verify that the yellow ignition indicator light has illuminated.

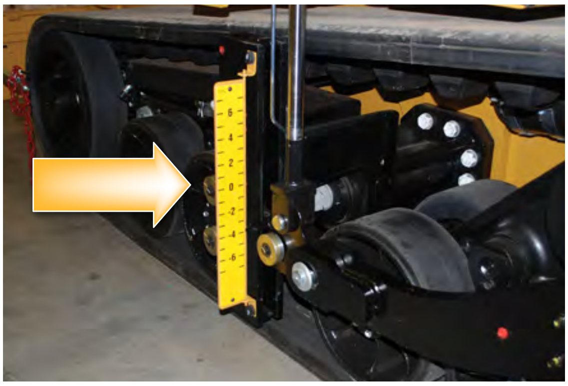
To change the temperature of any burner, depress the pad **(1)** that corresponds to the number of that burner. The set point temperature for the selected burner shows on the display **(2)**. Depress the UP or DOWN arrows **(3)** until the desired set-point temperature appears in the display. Repeat the sequence for other burners, if needed.

When a portion of the screed plate is close to the set-point temperature, the corresponding green and yellow indicators illuminate. When the set-point temperature has been reached, the yellow indicator goes dark, and the green indicator remains illuminated. When all four green indicators are illuminated, the screed is ready for paving.

As long as the AUTO / OFF control is in the AUTO position, the appropriate burners will reignite when any of the screed plate temperatures drop below the set-point temperatures.

[2. POSITION TOW-ARM CYLINDERS]

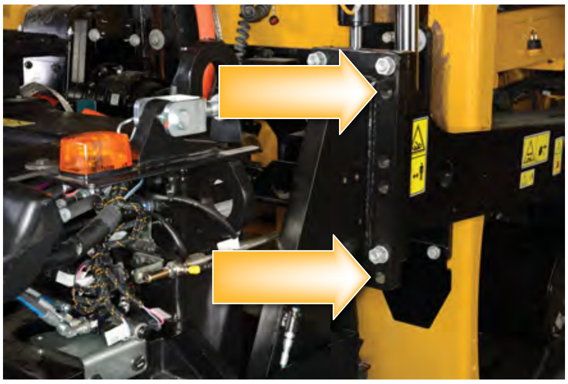
With the screed above the starting reference, adjust the height of the tow arms on both sides of the paver. The height of the tow arms affects the line of pull (traction angle) between the tow-arm connection and the pivot point of the screed.



Set the tow-arm position to create the correct line of pull.

The position of the tow-points is dependent on the paver model and height scale that are adjacent to the tow-arm connection. Always consult the Operation and Maintenance Manual for the paver being used.

In this view, the tow arm is set at the "zero" position. The center, or zero position, is correct for laying down an asphalt layer up to 7.5 cm (3") thick. This tow-arm position will create a line of pull that is approximately parallel to the grade. When the layer is greater than 7.5 cm (3") thick, raise the tow arm above zero a distance equal to the amount above 7.5 cm (3"). For example, when laying down a layer that is 10 cm (4") thick, position the tow arm 2.5 cm (1") above the zero mark.



The connection between the tow arm and screed drop arm should be changed for deep-depth paving applications.

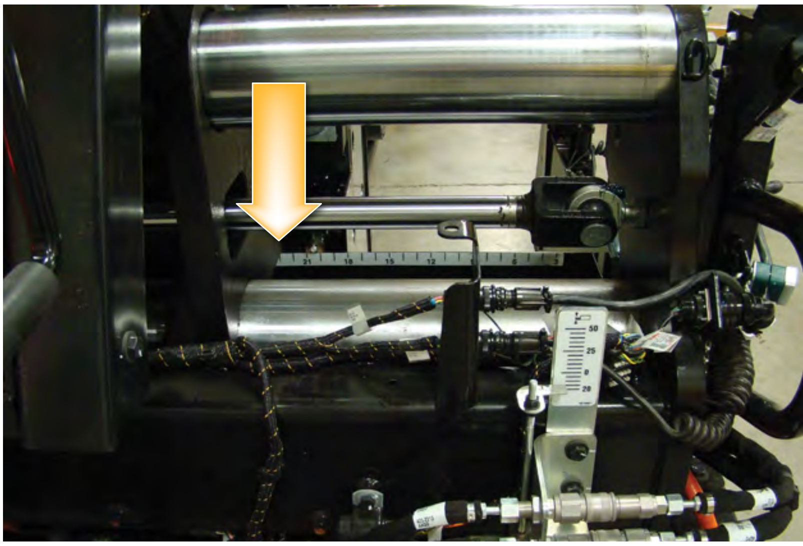
When paving 18 cm to 30 cm (7" to 12") deep, Caterpillar recommends changing the connection between the tow arm and the drop arm of the screed. Remove the bolts at the connections on each side. Lower the drop arms and install the bolts in the lower holes of the drop arms. The zero mark on the height scale will now be the correct tow-arm position for paving depths between 18 cm and 23 cm (7" and 9"). Raise the tow arm above the zero mark for paving deeper than 23 cm (9").

User Tip: *The tow-point height scales use metric dimensions. The numbers refer to centimeters. The metric dimensions confuse some crews. Converting the scale to inches may avoid confusion and mistakes.*

[3. SET THE PAVING WIDTH]

With the screed still above the starting reference, set the paving width. When utilizing a fixed width screed, bolt on extensions may be required. Most of the time, the screed will have hydraulic power extenders. Using the scale that is facing the back of the screed, move the extender out the desired amount. It is good practice to have equal extenders on both sides of the screed, whenever possible. For example, if the paving width is 3.6 m (12') and the paver is equipped with a 3 m (10') screed, then bring each extender out 30 cm (1').

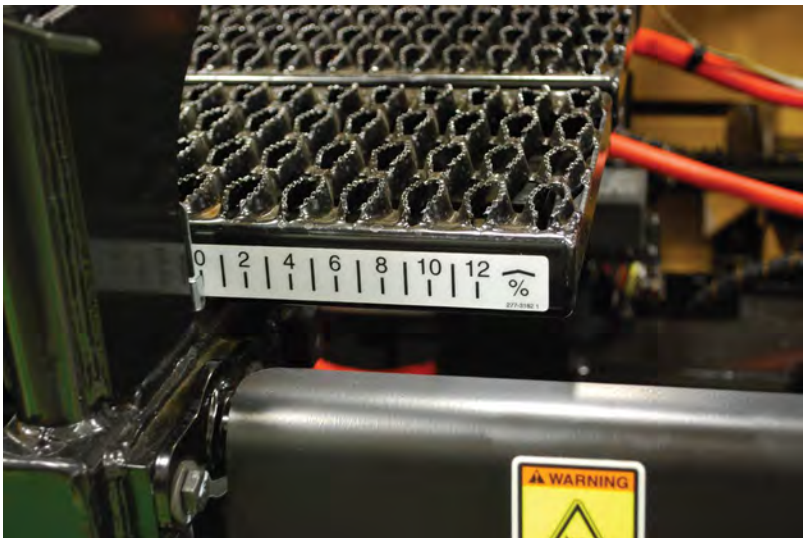
For some applications, the extender is used to pave the emergency lane in addition to the driving lane. The emergency lane may have a different slope than the driving lane, and therefore extender widths will be unequal for that application.



User Tip: *Remember the guidelines for adding auger extensions and mainframe extensions when planning the paving width. Add auger and mainframe extensions when paving with a front-mount screed to keep the end of the auger within 60 cm (2'), or closer, of the end gate. Add auger and mainframe extensions when paving with a rear-mount screed to keep the end of the auger within 1 m (3'), or closer, of the end gate.*

[4. SET MAIN SCREED CROWN]

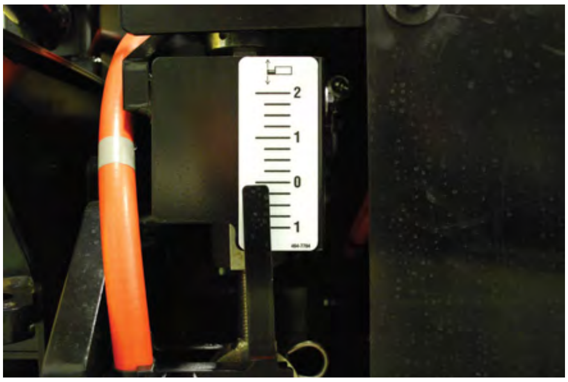
Next, set the crown of the main screed according to the project specifications. The scale for the main screed crown is in the center of the screed. Use the power crown switch to adjust the crown. Most of the time, the crown should be set at zero. In other words, the screed is flat. A positive or negative crown can be created. The crown scale shows percent of slope from the center of the screed.



User Tip: *Caterpillar recommends verifying the accuracy of all scales on the screed. To set the crown scale, raise the screed and lock it in the raised position. Use a string or straight edge to verify that there is no crown in the screed. Use the crown switch if necessary to flatten the screed. Then, check the crown scale. Move the indicator to point at zero if necessary. The crew should not have to "string the screed" at the beginning of every shift, if they periodically check the accuracy of the crown scale.*

[5. SET EXTENDER HEIGHT]

Screed extenders have power height adjustments. Push-buttons for left and right screed extenders are located on the respective screed control boxes. The scales that show extender height are installed near the ends of the extenders.



During this step, the screed operators set the height of the extender, so they are in the same plane as the main screed. To create a height match between the main screed and the screed extenders, set the height of the extenders 5 mm (0.2") above zero on the height scale, when paving with rear-mount screeds.

To create a height match between the main screed and the screed extenders, set the height of the extenders 5 mm (0.2") below zero on the height scale, when paving with front-mount screeds.

[6. SET EXTENDER SLOPE]

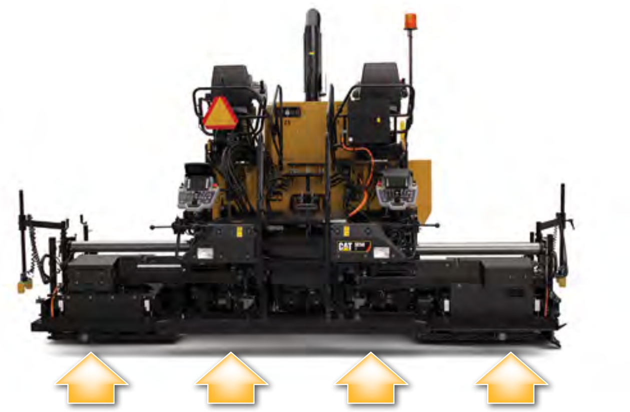
Screed extenders have power slope adjustments. Push buttons for the slope of the left and right screed extenders are located on the respective screed control boxes. The scales that show extender slope are located on the main screed next to the screed control boxes.

Using the slope scale as a guide, set the slope of the extender. If the plan specifies a flat screed, set the indicator at zero.

User Tip: *The scale may not always be calibrated exactly to the slope of the extender. Always check the slope of the layer directly behind the extender after pulling off the starting reference. Use the slope switch to make adjustments to the slope of the extender, if necessary.*

[7. LOWER THE SCREED ON THE STARTING REFERENCE]

Before lowering the screed, raise the end gates to ensure that the screed, not the end gates, rests on the starting reference. Make sure the starting reference is correct. When using starter boards, use at least two. Position the starter boards directly beneath the depth control screws. In that position, the boards will support both the main screed and the screed extenders. If a screed extender has been pushed out more than half its maximum width, use another starter board to support that extender.

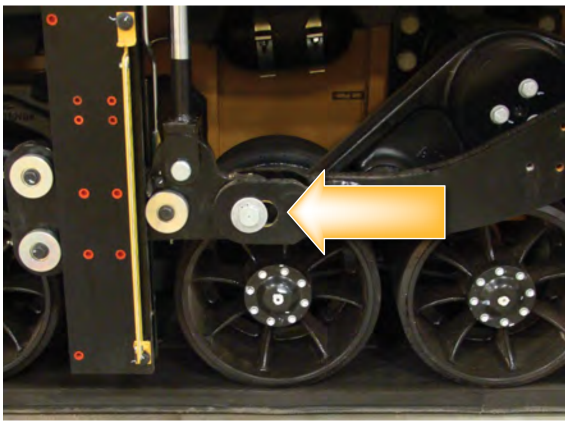


Boards should be placed at the outer edge of the main screed (behind the tractor) and outer edges of the extenders.

Note: *Starter boards must be long enough to support the entire width of the main screed and the screed extender. For example, if both the main screed plate and the screed extenders are 45 cm (18") long, then starter boards that are at least 90 cm (36") long will be needed.*

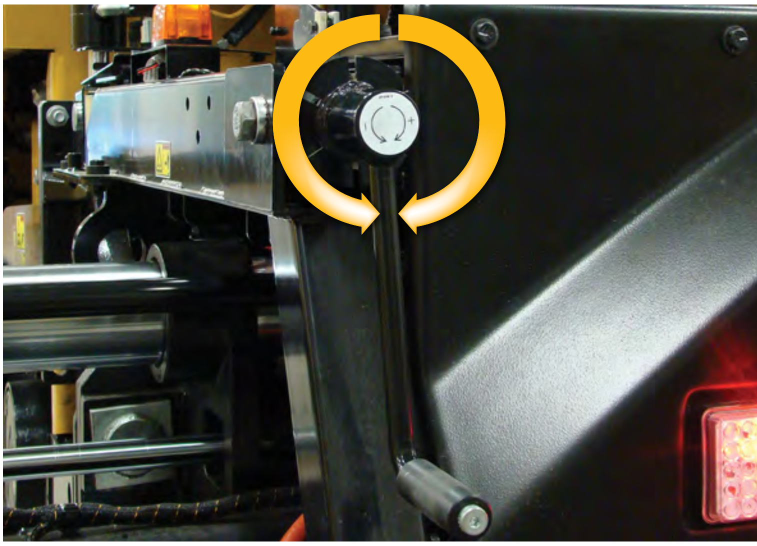
Lower the screed to the starting reference. Activate screed float. “Float” position.

With the screed resting on the starting reference, move the paver ahead slightly to take the slack out of the tow-arm connection. The roller on the end of the tow arm must be in contact with the tow-point slide assembly before the paver starts to pave. If there is a gap between the tow-arm roller and the slide, the screed will dive off the starting reference.



[8. NULL THE SCREED]

Nulling the screed means taking all tension out of the depth-control screws. It is very important that screed operators null the screed one side at a time. For example, start with the left side of the screed. Turn the depth-control screw in either direction until there is no resistance. This is the null position. Next, null the right depth-control screw in the same manner. Return to the left depth-control screw and verify that this screw is still in the null position. Now, the screed is totally "relaxed."



***Note:** At this time, the screed should be setting with a slight nose-up angle of attack. Remember, in step five, the extender height was set at 5 mm (0.2") above the main screed for rear-mount screeds and 5 mm (0.2") below the main screed for screeds with front-mount extenders.*

When the rear-mount screed was lowered, the first component to touch the starting reference was the main screed plate due to the extender being 5 mm (0.2") higher. When the screed was nulled, it rocked back around the pivot point to allow the extender to touch the starting point. The nose of the screed assumed the nose-up position at the correct angle. The same result occurs with front mount screeds. In that situation, the extender touched the starting reference first, and the main screed rocks back during the nulling process.

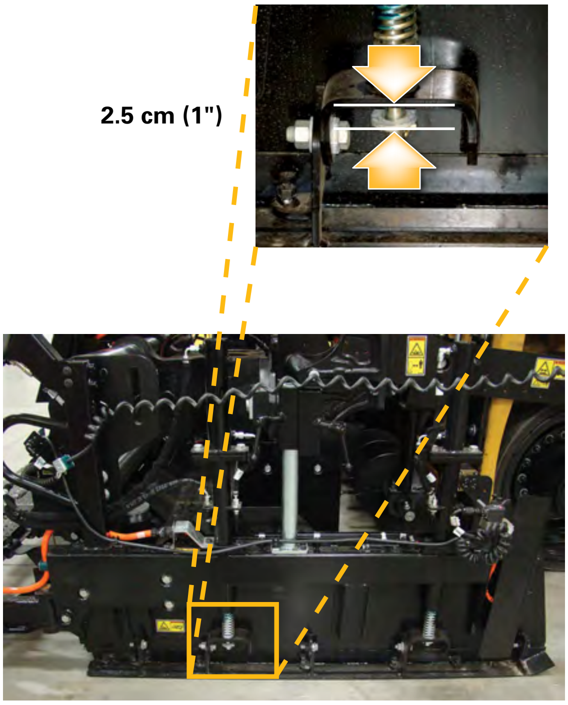
To hold the screed at the correct angle of attack during takeoff, turn each depth-control screw in the direction of "depth increase" until there is resistance in the depth-control screw. In other words, remove all slack from the depth-control screws and create slight tension.

***User Tip:** Older screed models required several rotations of the depth-control screws to set the angle of attack. Crews may be accustomed to putting several rotations into the screws. On new Cat Vibratory Screeds, it should not be necessary to utilize these rotations. In fact, the added rotations of the depth-control screws will increase the angle of attack, and make the screed run with too much nose-up attitude. Screed plates will show excessive, premature wear on the trailing edge. The texture of the bituminous layer will be tight and shiny.*

[9. POSITION END GATES]

End gates on both ends of the screed retain material at the proper width. Position the end gates in a manner that is appropriate for the application. Caterpillar recommends that the end gates be lowered, so the end-gate ski floats on the grade when creating unconfined edges. First, lower the end gate until it touches the grade. On manual gates, raise or lower the spring tension to create a 2.5 cm (1") space between the washer and bracket that enables the end gates to move up and down over any grade irregularities. On hydraulic power end gates, lower them to the grade and press the "auto" button or raise them even with the bottom of the extender plate depending on the requirements.

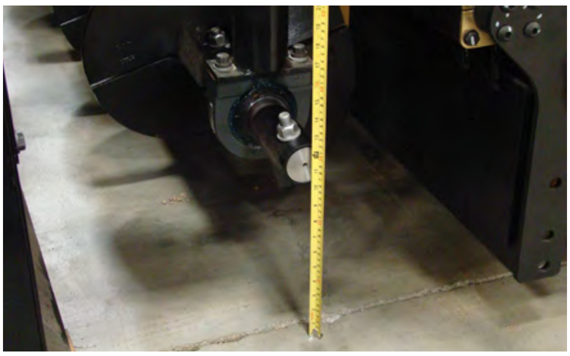
In other situations, the end-gate ski will be positioned at the same height as the screed plate. For example, when creating a height match to an adjacent layer or to an existing gutter, bring the end gate up to the same level as the screed plate.



User Tip: *Always perform end-gate maintenance at the end of each shift or more frequently when paving with polymer-modified asphalt cement. The slide area is a narrow opening. Fines and small aggregates can lodge in the slide area. The end gate is difficult to adjust when the slide area is dirty. Clean the slide area between the outer and inner frame members by lowering the end gate all the way and spraying with an approved release agent.*

[10. SET HEIGHT OF AUGERS]

Using the push buttons at the paver operator's stations or at the screed operator's stations, set the height of the augers in relation to the surface of the uncompacted bituminous layer. As a general rule, set the augers so the bottom of the auger segments are 5 cm (2") above the surface of the layer. Increase the gap between the bottom of the augers and the layer to 8 cm (3") when paving with a mix that has aggregates 25 mm (1") or larger. Make final adjustments to auger height at the start of paving. If there is open texture in the layer directly in line with the auger shafts, the augers are too low. Gradually increase the height of the augers until the texture of the bituminous layer is acceptable.



[11. POSITION FEEDER SENSORS]

There are two types of feeder system sensors: mechanical and sonic. Each type should be carefully positioned prior to the start of paving.

To position a mechanical sensor, use a tape measure or folding ruler. Rotate the paddle arm that extends out of the sensor box to a 45-degree angle. Measure back to the last auger segment. The tip of the paddle should be about 45 cm (18") away from the last auger segment. If necessary, slide the sensor on the sensor support arm to the correct position. The tip of the paddle should also be in line with the center of the auger shaft when it is rotated to a 45-degree angle. Adjust the height of the paddle arm until it is even with the center of the auger shaft.

When swung out to a 45-degree angle, the tip of the paddle should be about 45 cm (18") away from the last auger segment.

Aim sonic sensors at the active head of material coming out at the front of the auger chamber. Ideally, this target area should be about 45 cm (18") away from the end of the sonic sensors. They should be aimed perpendicular to the target so the echoes from the sound pulses will reflect back to the sensors.

When using sonic feeder sensors, it may be easier to make the final adjustments and aim the sensors after paving has started. Extend the measuring device out 45 cm (18") along one side of the sensor to show where the sensor is aimed. Reposition the sensor, if necessary.

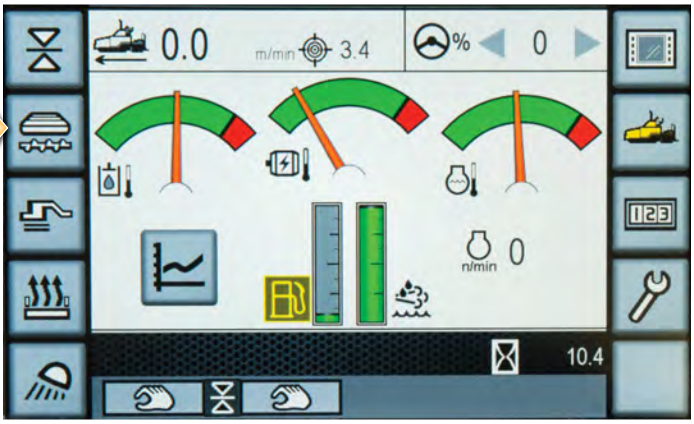
Sonic feeder sensors should be aimed at the active head of material coming out of the auger chamber.

[12. SET FEEDER SYSTEM CONTROLS]

Before starting to pave, it is important to set the feeder system controls for the operation of the left and right conveyors and the left and right material height dials.

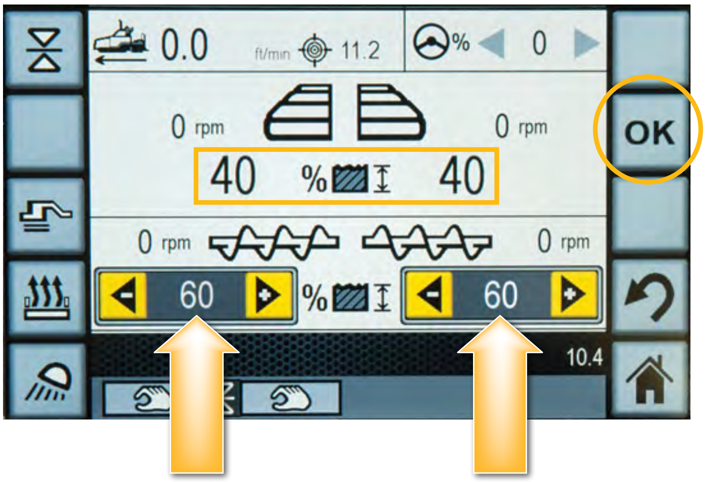
MATERIAL FEED ICON

material feed adjustments



To access the feeder control screen, touch the Material Feed icon that is on the left side of the tractor control panel.

MATERIAL FEED CONTROL SCREEN



mix height adjustment LEFT

mix height adjustment RIGHT

Using the multi-function dial on the control panel, set the conveyor speed to 40 percent for each conveyor. Adjust the mix height to 60 percent using the arrows on the touch screen. After adjusting mix height, push the OK icon on the touchpad to accept the setting. This is a starting point for the feeder system. The tractor operator or screed operator can fine tune these settings when paving begins.

[13. FILL THE AUGER CHAMBER]

Filling the auger chamber to the correct level is extremely important. The most common mistake is overfilling the auger chamber. Remember, the material in the auger chamber is weight, or resistance, felt by the screed. If there is too much resistance, the screed will climb at the takeoff and create a high spot at the transverse starting joint.

Fill the auger chamber in front of the screed until the material covers one half the auger.

Fill the auger chamber one side at a time, alternating between the conveyor and auger. This helps prevent material from being pulled under the machine and overfilling the chambers. The goal is to fill the auger chamber evenly on both sides.

NOTE: *Do not fill the chamber using the conveyor and auger switches together or by using the feeder override switches located on the screed. This will overfill the chamber and cause a bump on take off.*

Use one manual conveyor switch at a time to move material out until it just touches the auger shaft.

User Tip: *Always fill the auger chamber with the engine at low idle speed. At low idle, the hydraulic drive for the feeder system operates slowly. It is easier for the operator to control the flow of material on the conveyors back to the auger chamber and across the auger chamber using the left and right augers. The slower conveyor speed minimizes the amount of material that gets pushed under the tractor. Also, slower auger speed minimizes segregation when paving with a mix containing large-size aggregates.*

Then, use the manual auger switch to move material to the end of the screed. The correct head of material covers one half of the augers.

Always fill the auger chamber using the manual mode at low idle and be careful not to overfill.

Overfilling the auger chamber will result in a bump when starting off the transverse joint.

Use a shovel to move material out to the end gates whenever the extenders are moved out more than 30 cm (1') away from the last auger segment or whenever special attachments are added to the end of the screed. Using the auger to force mix out to a wide paving width will create an overload in the center of the auger chamber and the screed will climb during takeoff. Do not fill in the area adjacent to the main screed. This area will be filled in when the paver takes off from the starting reference.

When the auger chamber has been filled to half full—no more, no less—put the conveyors and augers in "AUTO" mode. Either push the automatic conveyor and auger button or press individual automatic buttons for both the conveyor and auger. Verify that all four automatic system indicators are illuminated.

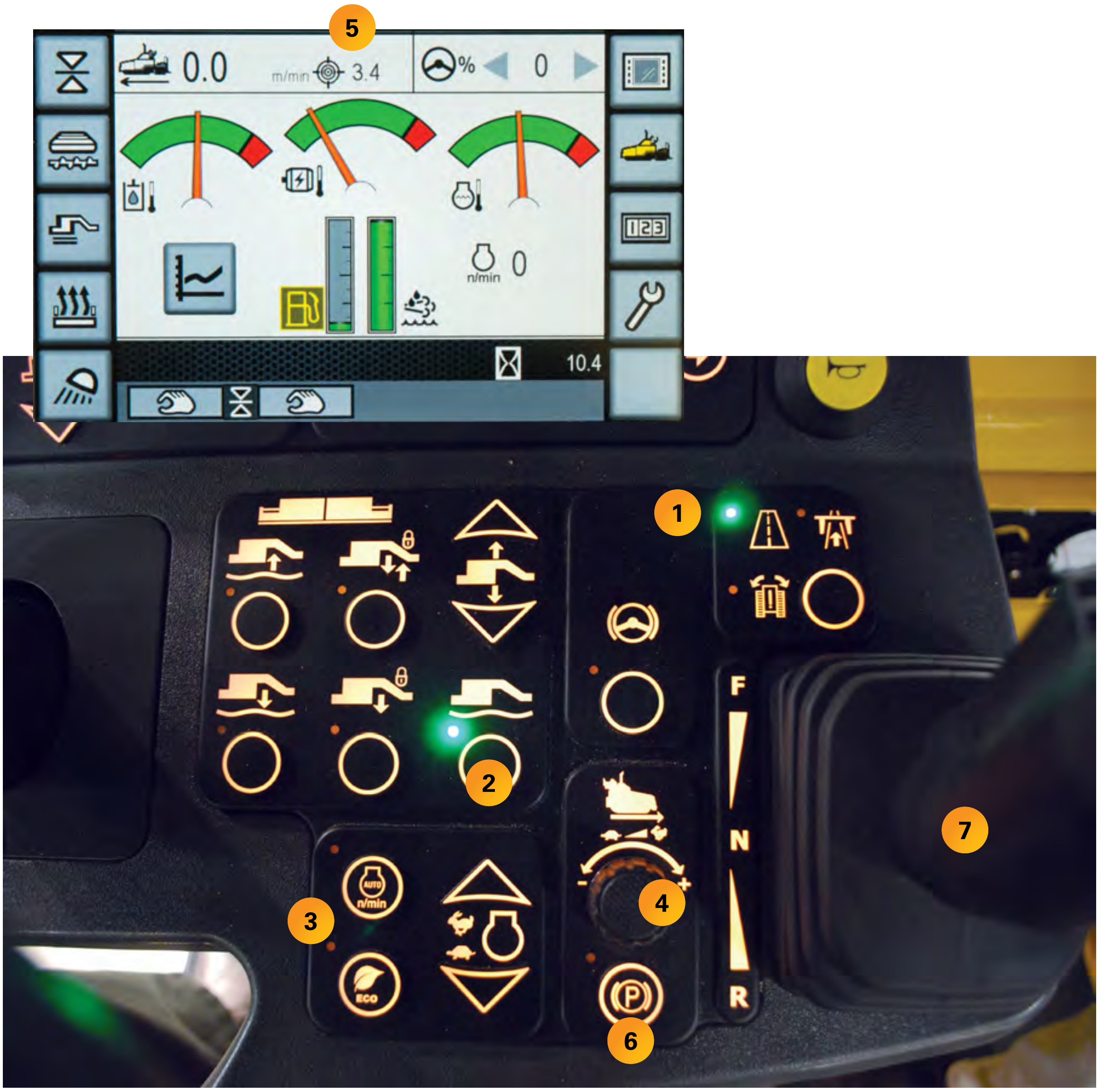
As soon as the propel lever is moved from the Neutral position, the feeder sensors begin to automatically control the operation of the feeder system.

[14. SET ACCESSORY FUNCTIONS]

Caterpillar recommends that final grade and slope control adjustments, if any are required, be made after all the other tractor and screed preparations have been completed. If the crewmembers follow the same steps and the same sequence every time they prepare to pave, they are less likely to make mistakes. They are also more likely to work together and not skip steps.

At this time, the crew can also make adjustments to accessory systems like the screed counterbalance pressure, friction steering and system time delays.

[15. PULL OFF THE STARTING REFERENCE]



*At this point, the paver is ready to pull off the starting reference. Make sure the gear selector is in the PAVE mode **(1)**, the screed is in float **(2)**, and the engine throttle is set at the chosen speed (ECO or high idle) **(3)**. Then, turn the speed control dial **(4)** clockwise until the calculated paving speed is displayed in the target speed area of the display **(5)**. Release the parking brake **(6)**. Propel the machine by squeezing the trigger and stroking the propel lever **(7)** fully forward in one quick, smooth motion.*

User Tip: *When the calculated target speed is reached, use the propel lever to stop and start the machine using the same quick, smooth motion as before. Slowly stroking the propel lever will result in a more uneven head of material and have an adverse effect on mat smoothness.*

As the paver reaches the calculated paving speed, the screed operators should check the operation of the feeder system.

The left and right screed operators should be looking to the area at the end of the auger shaft, and in front of the extender. Their primary responsibility at the start of paving is to make sure enough material is coming out of the auger chamber and flowing to the end gate. The screed operators can adjust the mix height dial to set the head of material at the end of the auger shaft and to set the flow of material in front of the extender.

The screed operators' first responsibility is to make sure there is enough material in front of the extenders.

Next, check the material level in the center of the auger chamber. The left or right ratio control dials are used to adjust the head of material. Once the head of material is correct across the full width of the auger chamber, check the auger rotational speed.

The paver operator checks the head of material in the center of the auger chamber.

User Tip: *On newer Cat Pavers, the speed of the left and right augers can be monitored on the LCD display at the screed control boxes. On older pavers without auger speed gauges, the operator can simply monitor the rotation of the auger shafts by watching the rotation of the last auger segment. The last auger segment is a split segment. As the tip of the segment rotates, count how long it takes for one complete revolution. A two-second revolution equals 30 revolutions per minute. Remember, the ideal range for auger speed is 20 to 40 revolutions per minute.*

[16. OPERATIONAL ADJUSTMENTS]

To speed up the auger rotation, turn the ratio control dial counterclockwise. This slows the speed of the affected conveyor and reduces the volume of material in the auger chamber. Hence, the sensor will signal for an increase and the augers will rotate more quickly. To slow the auger rotation, turn the ratio-control dial clockwise.

Once the paving speed has stabilized and the feeder system is operating at a uniform speed with the correct head of material, the screed will be at its equilibrium point. All forces acting on the screed are in balance, and the screed is now floating at a constant level. Check and adjust thickness and slope of the layer. Also check mat appearance. The texture of the surface should be uniform from edge to edge.

Extender height is too high.

Sometimes there may be a slight mismatch between the height of the extenders and the height of the main screed. The difference in height will cause a straight line to appear longitudinally in the surface of the layer. If the line is directly behind the end of the main screed, then the extender is too high. While continuing to pave, hold down the extender-height switch until the line disappears.

Extender height is too low

If the line is directly behind the inside edge of the extender, then the extender is too low. Activate the extender height raise switch until the line disappears.

[SUMMARY]

The proper takeoff from the starting reference sets the tone for the length of the pass. The crew should take the time to implement all 15 steps correctly in the proper sequence.

Two of the steps are particularly important. The first is setting the main screed angle of attack. Be sure the crew knows the characteristics of the screed with which they're working. What they learned on one screed may be different than what is needed on another screed. Remember, the angle of attack that is installed while the screed is setting on the starting reference is the angle of attack the screed returns to for the length of that pass.

Second, fill the auger chamber slowly one side at a time. It is very common for the crew to overfill the auger chamber at the starting point. Always fill the auger chamber with the engine at low idle. It takes a few minutes longer to slowly fill the auger chamber, but it results in smoother transverse joints.

Finally, be sure the crew is paving with a calculated paving speed whenever possible. If the speed changes for some reason, the crew must adjust the feeder system to match the new demand for material.


AP600F
CAT

Unit 5

PREPARING TO PAVE USING TAMPING SCREEDS WITH VIBRATION

Utilization of tamping screeds with vibration requires different take-off techniques. Crews need to be well trained in the processes that apply to these screeds.

Unit 5 describes how to prepare a paver to pull off a starting reference when utilizing a tamper-bar screed. The process for preparing to pave with a vibratory screed is different and is described in Unit 4. Caterpillar recommends using a step-by-step procedure to prepare the paver, one that helps crewmembers work together and includes all steps.

Pulling away from a starting reference can be a frustrating experience for the paving crew.

Sometimes, the screed drops after pulling off the starting reference. Sometimes the screed climbs during the take-off. Sometimes the take-off is perfect. While there is no way to guarantee perfect take-offs every time, the crew can create more predictable results when they follow a logical sequence and stay together.

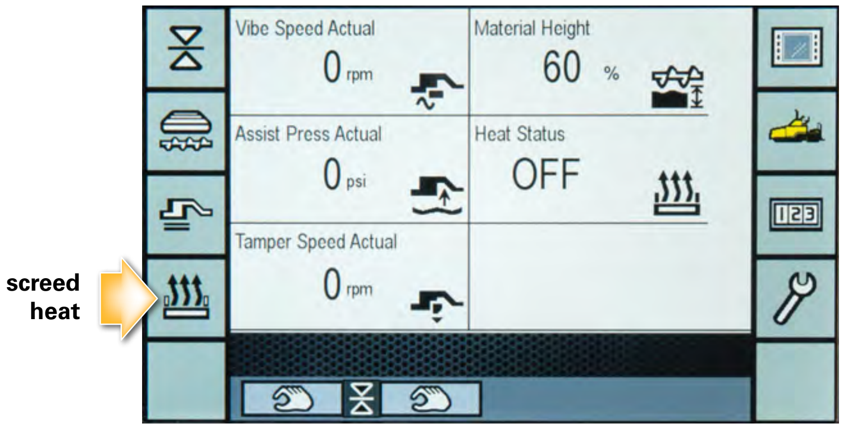
Note: *Some of the steps described in this unit apply specifically to Cat Pavers. Other steps are general in their application. Always consult the specific instructions in the Operation and Maintenance Manual for the paver that is being used.*

[1. HEAT THE SCREED]

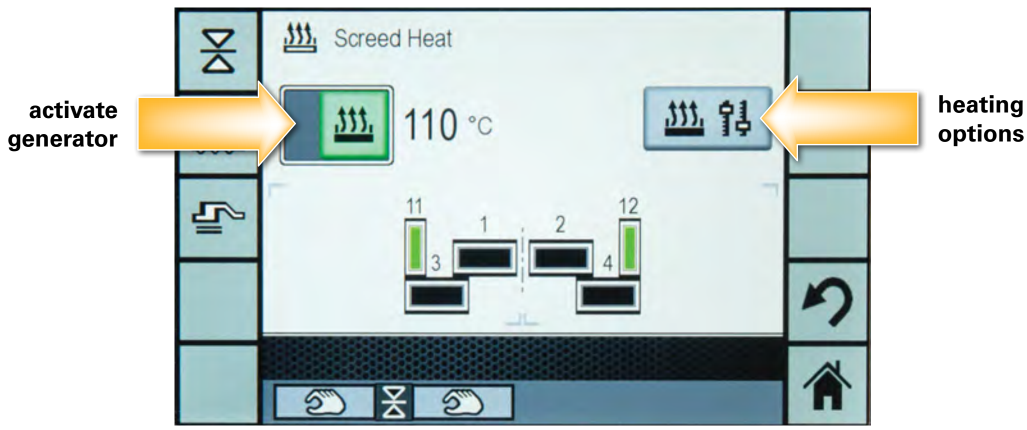
The first step is heating the screed plates prior to pulling off the starting reference. If the screed plates are not close to the temperature of the material passing under the screed, the hot mix will adhere to the bottom of the screed plates. Drag marks will appear in the surface of the bituminous layer, and the screed will dive after pulling off the starting reference.

Before pulling off the starting joint, the crew must heat the screed plates to prevent hot bituminous material from sticking to them.

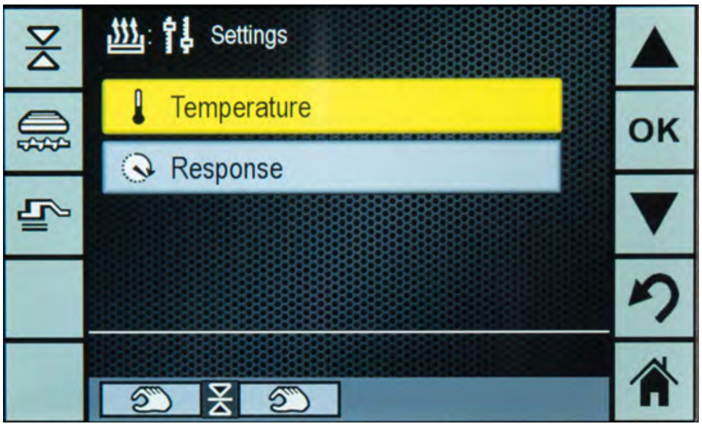
Several types of screed heating systems are available on Cat Pavers. One is electric screed heat. Start with the screed approximately 25-75 mm (1-3") above the ground. If the screed is at maximum height, wind can affect the performance of the heaters. Also if the screed is on the ground, the ground acts as a heat sink, and it will take longer for the screed to reach temperature.



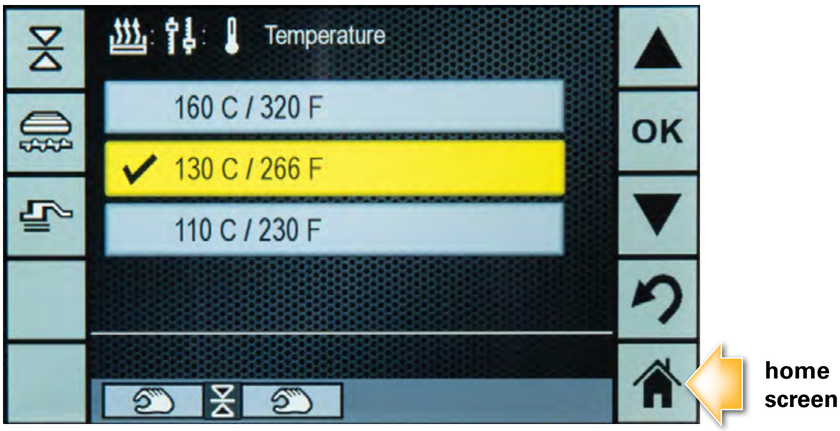
Activate the electric screed-heat system from either the left or right operator station on the tractor or the left or right operator station on the screed. Touch the screed heat icon. Electric screed heat can be activated from any of the four operator station screens.



When the screed-heat screen appears, the operator can activate the generator by touching the heat icon and sliding the icon to the right. The icon will illuminate green, the engine speed will increase to 1300 revolutions per minute and the generator will provide power to the screed heat system. The operator can choose the temperature set-point by touching the heating option icon on the right side of the screen.

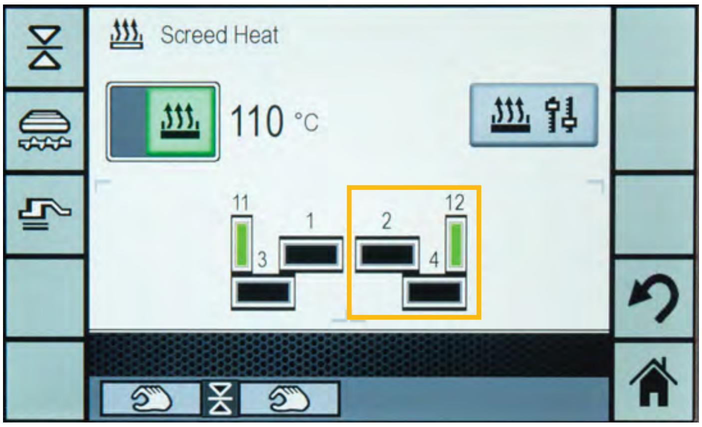


The heating options menu appears next in the display. Select the temperature option.

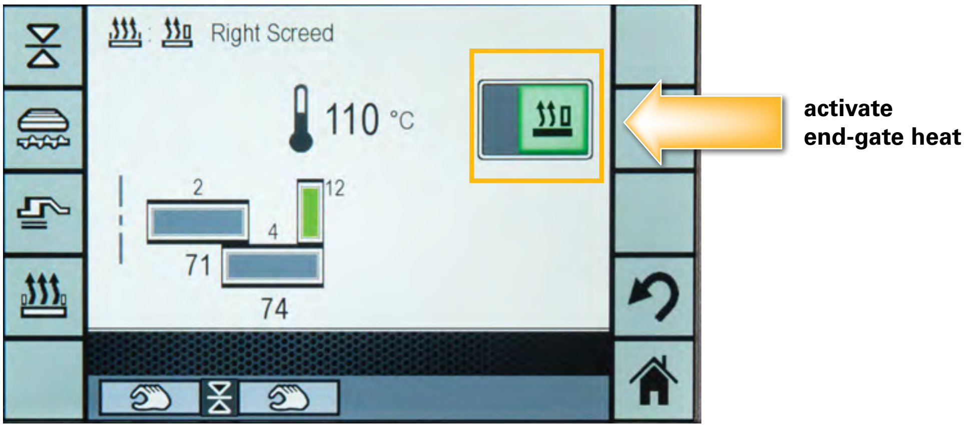


The screen then provides three choices for set-point temperature. Select either low range, where the set-point temperature will be 110° C (230° F); the mid range, where the set-point temperature will be 130° C (266° F); or the high range, where the set-point temperature will be 160° C (320° F). Touch the Home icon (lower right) to return to the normal operating screen and continue preparing the screed to start paving. The screed heat sequence takes 15 to 20 minutes under normal conditions.

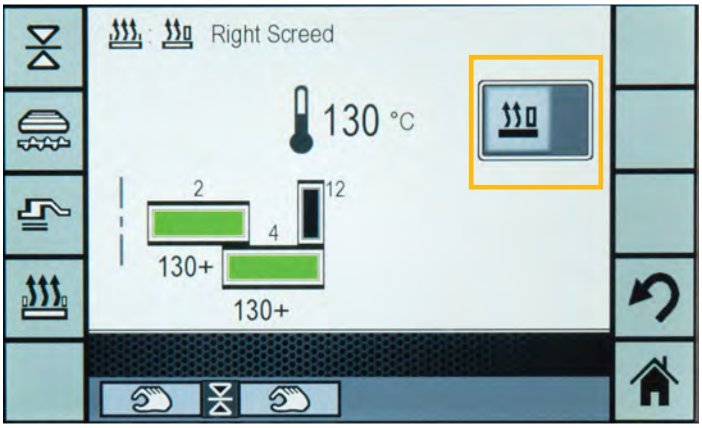
View 1



View 2



View 3



Returning to the Screed Heat screen shows the status of the various heating elements.

Check the status of the screed-heat system by touching the Screed Heat icon at any time.

On Cat extendable-type screeds, each screed frame section has a heating element. There is one for each screed extender and there are two for the main screed. The left and right end-gate skis may also have heating elements.

The heating elements are grouped in two zones. One zone includes the elements in the right end-gate ski, the right screed extender and the right half of the main screed plate. ***(view 1)****. The other zone includes the heating elements in the left end-gate ski, the left screed extender and the left half of the main screed plate. Touch one of the zones to view the status of the heating elements.*

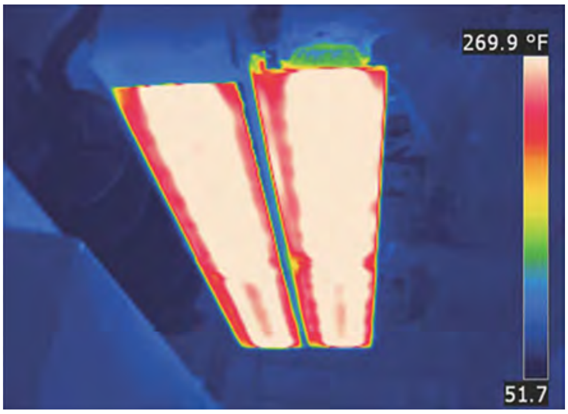
When the optional end-gate heat has been activated, the end-gate heat icon and the end-gate will be green. The screed plates shown here in gray have not yet reached their preset temperature ***(view 2)****. When the end-gate heat has been deactivated, the end-gate heat icon will be gray and the end-gate will be black* ***(view 3)****.*

The various heating elements appear as green, gray or black depending on their current temperatures. The following chart explains what the colors mean for each set point temperature.

Set Point	Black	Gray	Green
Low	0–59° C (32-138°F)	60-109° C (140°-228°F)	110° C+ (230°F+)
Medium	0-79° C (32-174°F)	80-129° C (176-264°F)	130° C+ (266°F+)
High	0-109° C (32-228°F)	110-159° C (230-318°F)	160° C+(320°F+)

The temperature sensors that provide input to the screed heat controller are located along the outer edges of the screed plates. In the infrared image, notice that the edges are slightly cooler than the inner portion. When the set-point temperature is sensed by the temperature sensors around the outer edges, the temperature in most of the screed plate is actually higher.

When the screed plate around any of the heating elements reaches the set-point temperature, the icon for that portion of the screed will turn green. That heating element will de-energize. When all the icons are green, the screed is hot enough to begin paving.



Infrared image of screed plates heating with electric screed heat

User Tip: *Many crews, especially working in urban applications with frequent re-starts, leave the generator on and let the screed re-heat automatically. When the temperature for any portion of the screed plates drops below the set point temperature, that heating element will automatically energize and reheat the screed. The screed operators do not have to remember to heat up the screed after picking up the screed and moving, if they leave the system activated.*

The second type of screed heating system uses liquid propane. Before activating the propane heating system, open the valve on the liquid propane cylinder.

To activate the automatic ignition sequence, depress the AUTO / OFF pad **(1)**. The propane burners will begin to ignite. As the burners ignite, the yellow indicators **(2)** illuminate to confirm that heating has started for that portion of the screed plate. If a burner does not ignite, the indicator light will be red. To ignite that burner, depress the number **(3)** of the burner to be ignited. Then, depress the AUTO / OFF pad again. Verify that the yellow ignition indicator light has illuminated.

To change the temperature of any burner, depress the pad **(1)** that corresponds to the number of that burner. The set point temperature for the selected burner shows on the display **(2)**. Depress the UP or DOWN arrows **(3)** until the desired set-point temperature appears in the display. Repeat the sequence for other burners, if needed.

When a portion of the screed plate is close to the set-point temperature, the corresponding green and yellow indicators illuminate. When the set-point temperature has been reached, the yellow indicator goes dark and the green indicator remains illuminated. When all four green indicators are illuminated, the screed is ready for paving.

As long as the AUTO / OFF control is in the AUTO position, the appropriate burners will reignite if the screed plate temperature drops below the set-point temperature.

[2. POSITION TOW-ARM CYLINDERS]

With the screed above the starting reference, adjust the height of the tow-points on both sides of the paver. The height of the tow-points affects the line of pull (traction angle) between the tow-point connection and the pivot point of the screed.

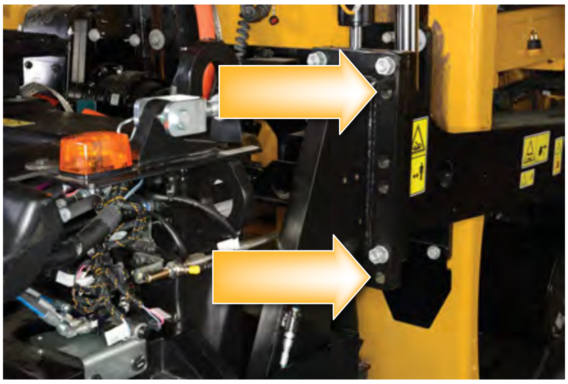
After the screed has heated, adjust both tow-points to the same height. Use the tow-point height controls located on the screed control boxes or on the operating consoles. There are two tow-point height scales. One is located adjacent to the tow-point connection. The other is above the tow-point connection at the front of the tractor.

Align the pointer to the zero mark. Then raise the tow-point indicator above zero a distance equal to 1.5 times the thickness of the layer passing under the screed. For example, if the planned uncompacted layer thickness is 5 cm (2"), then position the pointer 7.5 cm (3") above the zero mark on the scale.

Set the tow-point height to create the correct line of pull.

User Tip: *The tow-point height scales use metric units. Each mark is two centimeters. Depending on the preferred units of measure, the scale can be converted to inches to avoid confusion and mistakes.*

Cat Pavers can be set up to pave at deep depths. To facilitate deep-depth paving, reposition the tow-arm attachment on the drop arm to the bottom set of holes. Change the tow-arm position when paving between 18 cm (7") and 30 cm (12"). Then, set the tow-point height according to the paving depth.

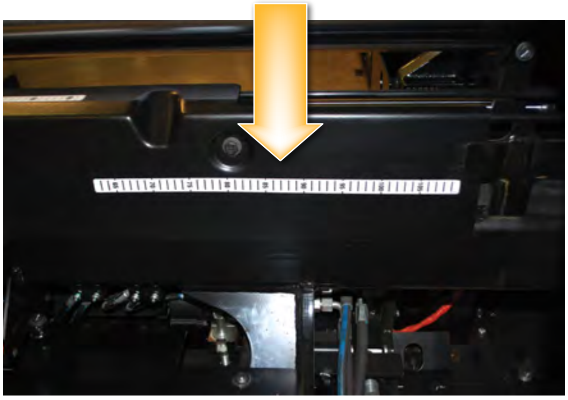


Change the tow-arm position for deep-depth paving.

[3. SET THE PAVING WIDTH]

With the screed still above the starting reference, set the paving width. If utilizing a fixed width screed, extensions may need to be added, and the screed extensions will have to be bolted on. Typically, the screed will have hydraulic-power extenders. Using the scale that is facing the back of the screed, move the extender out to the desired setting. It is good practice to have equal extender on both sides of the screed, whenever possible. For example, if the paving width is 3.6 m (12') and the paver is equipped with a 3 m (10') screed, bring each extender out 30 cm (1').

For some applications, the extender may be used to pave the emergency lane in addition to the driving lane. The emergency lane may have a different slope than the driving lane, and therefore, extender widths will be unequal for that application.



Based on main screed width, set extender width according to the project requirements.

User Tip: *Remember the guidelines for adding auger extensions and mainframe extensions when planning the paving width. Add auger and mainframe extensions when paving with a front-mount screed to keep the end of the auger within 60 cm (2'), or closer, of the end gate. Add auger and mainframe extensions when paving with a rear-mount screed to keep the end of the auger within 1 m (3'), or closer, of the end gate.*

[4. SET MAIN SCREED CROWN]

Next, set the crown of the main screed according to project specifications. The crown indicator scale is located on the right side of the screed. Use the power crown controls on the right or left screed control panel to create the desired positive or negative crown. The crown should normally be set at zero. In other words, the screed is flat. The crown scale shows percent of slope from the center of the screed.

Some projects may require crown of the main screed.

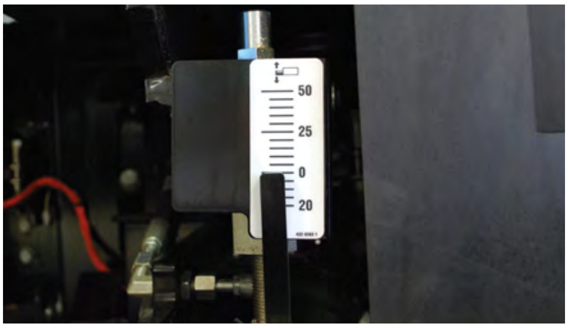
User Tip: *Caterpillar recommends verifying the accuracy of all scales on the screed. To set the crown scale, raise the screed and lock it in position. Use a string or straight edge to verify that there is no crown. Use the crown adjustment controls if it is necessary to flatten the screed. Then, check the crown scale. Move the indicator to zero. The crew should not have to “string the screed” at the beginning of every shift, if they periodically check the accuracy of the crown scale.*

[5. SET EXTENDER HEIGHT]

Screed extenders have adjustable height. Set the height of the extenders so they match the height of the main screed. When the height of the extenders is correct, there are no transition marks in the surface of the bituminous layer.

On Cat Screeds, there are height scales on the inner edge of each extender. Adjust extender height using controls on the right and left screed consoles. To help create the desired 5 mm (0.2") angle of attack in the main screed, set the height on both screed extenders 5 mm (0.2") above the zero mark on the scale.

Again, it is good practice to periodically verify that the height scales are calibrated to give an accurate measurement of extender height.



Set the extender height before lowering the screed to the starting reference.

[6. LOWER THE SCREED ON THE STARTING REFERENCE]

Before lowering the screed, raise the end gates to the proper position to ensure that the screed rests on the starting reference and not the end gates. Next, make sure the starting reference is correct. Use a starting reference with a thickness that matches the uncompacted mat depth that will be placed by the screed. Normally, the mat will compact about 6 mm (0.25 per inch) per 25 mm (1") of mat depth. For example, to achieve a 50 mm (2") compacted mat, use a starting reference that is 64 mm (2.5") thick. Use two references. Position them so they are under the pivot of the extender and completely supporting both the main screed and the screed extender from front to back.

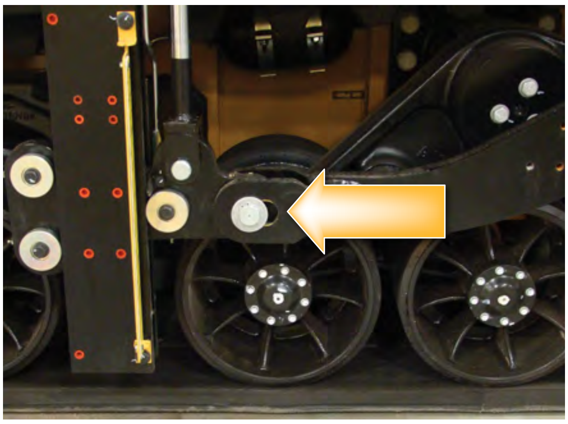
If starter boards are used, utilize at least two. Position the starter boards so they will support both the main screed and the extender. If a screed extender has been extended more than half its maximum width, use another starter board to support that extender.

Boards should be placed at the outer edge of the main screed (behind the tractor) and outer edges of the extenders.

User Tip: *Starter boards must be long enough to support the entire width of the main screed and the extender. For example, if both the main screed plate and the extender are 45 cm (18") long, then starter boards that are at least 90 cm (36") long will be needed.*

Lower the screed to the starting reference. The screed operator must be sure to leave the screed Raise / Lower switch in the "Lower" or "Float" position.

With the screed resting on the starting reference, move the paver ahead slightly to remove slack from the tow-point connection. The roller on the end of the tow arm must be in contact with the tow-point frame before the paver starts to pave. Removing the slack from the tow-point connection puts light tension on the screed frame, helping the screed float at the correct height when paving starts. If there is a gap between the tow-arm roller and the frame, the screed will dive off the starting reference.



Move the paver forward to remove slack from the tow-point connection.

[7. ADJUST THICKNESS SCREWS]

Thickness screws on both sides of the screed need to be adjusted to establish the angle of attack for the main screed. When laying down mats up to 10 cm (4") thick, adjust both screws so the indicators on the thickness control scales are aligned with zero. The main screed angle of attack will be approximately 6 mm (0.25") when the thickness screws are set at zero and the tow-point height is set at the correct distance above zero on the tow-point height scale.

When laying mats that are between 10 cm (4") and 30 cm (12"), adjust the screws to move the indicator progressively further into the plus range. Increasing the thickness-screw setting increases the main screed angle of attack. The thickness gauge must be at two marks positive or more for mats 20 cm (8") thick or thicker.

Thickness control scales are located on both sides of the screed.

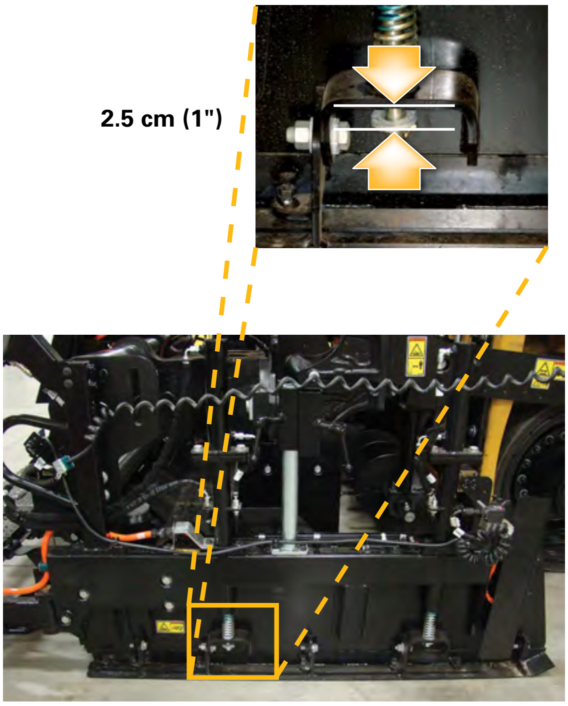
Note: *Thickness screw adjustment is dependent of mix type and other factors. The previously referenced numbers are a starting point and may have to be increased or decreased depending on mix type.*

[8. POSITION END GATES]

End gates on both ends of the screed retain material at the proper width. They float on the grade.

First, lower the end gate until it touches the grade. On manual gates, raise or lower the spring tension to create 2.5 cm (1") space between washer and bracket to allow the end gates to move up and down over any grade irregularities.

In certain situations, the end-gate ski may need to be positioned at the same height as the screed plate. For example, when creating a height match to an adjacent layer or to an existing gutter, adjust the end gate up to the same level as the screed plate.



Position the end gates in a manner that is appropriate for the application.

Note: Always perform end-gate maintenance at the end of the shift, or more frequently when paving with polymer-modified asphalt cement. Pay particular attention to the slide area. It is a narrow opening where fines and aggregates often become trapped. The end gate is difficult to adjust when the slide area is dirty. Clean the slide area between the outer and inner frame members by completely lowering the end gate and spraying with an approved release agent.

[9. SET AUGER HEIGHT]

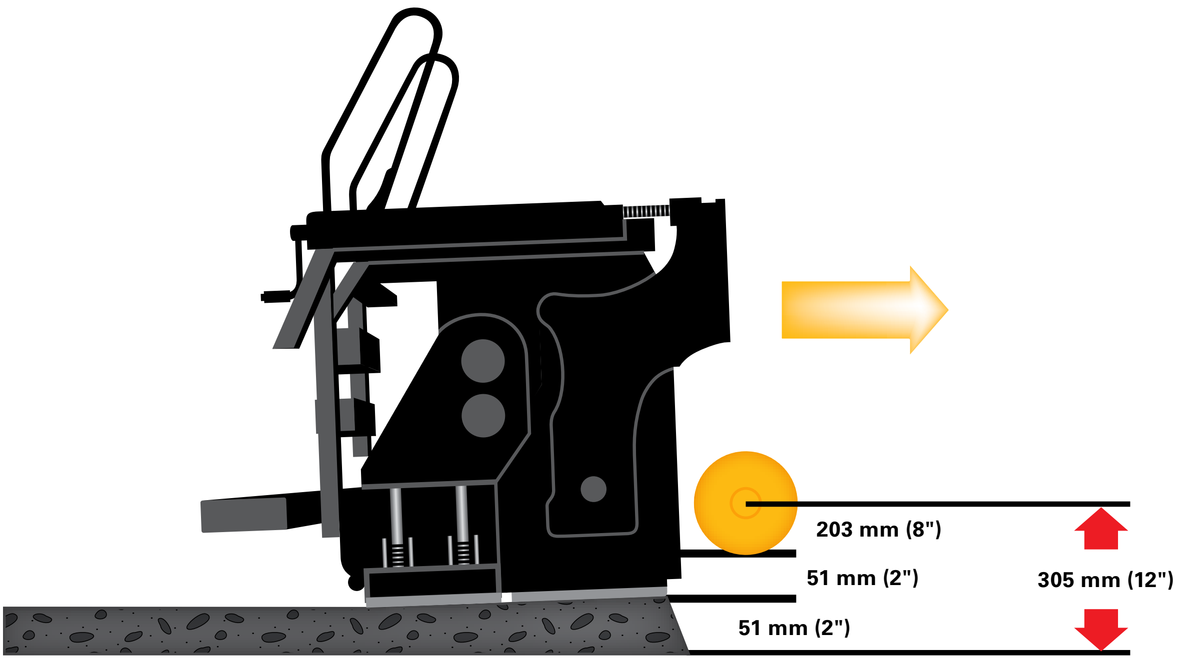
The height of the augers in relation to the depth of the uncompacted mat has an impact on the texture and finish of the mat.

If the augers are too low, open texture and material segregation may appear. If the augers are too high, the head of material will likely be too high, which will cause the screed to climb. Various mix designs react differently to auger height adjustment. As a rule, with aggregate size below 16 mm (0.6"), set the auger height at least 5 cm (2") above the height of the uncompacted mat. With aggregate size above 16 mm (0.6"), set the auger height at least 8 cm (3") above the height of the uncompacted mat.

The distance from the bottom of the auger to the center of the auger shaft is 200 mm (8"). Now add 50 mm (2") or 80 mm (3") to that. Then add the thickness of the mat to be paved. The total is the distance from the centerline of the auger shaft to the grade. Adjust the auger up or down until the dimension is reached.

If the mix is very coarse or very tender, fine-tune the auger height after paving starts.

The augers are too low, if open texture is evident in the layer directly in line with the auger shafts. Gradually increase the height of the augers until the texture of the bituminous layer is acceptable.



[10. POSITION FEEDER SENSORS]

Depending on user preference, Cat Pavers may be equipped with mechanical, paddle-type feeder sensors or with sonic feeder sensors. Both types must be positioned correctly for uniform material flow from the auger chamber to the end gates.

Paddle sensors contact material that is flowing out of the auger chamber. They are mounted to an adjustable shaft at the front of the auger chamber.

Position the paddle-type feeder sensors so they are detecting the active pile of material about 46 cm (18") away from the last auger segment. The paddle arm should be at a 45-degree angle at the 46 cm (18") distance.

Paddle sensors provide accurate control and are easy to adjust with a measuring device.

Position the sonic sensors installed on the end gates, so they point at the moving head of material that comes out the front of the auger chamber. Ideally, this target area should be about 45 cm (18") away from the end of the sonic sensor. The sensor should be positioned perpendicular to the target so the echoes from the sound pulses reflect back to the sensor.

It may be easier to make the final adjustments and position the sensors after paving has started when using sonic feeder sensors. Extend a measuring device out 45 cm (18") and put the measuring device along one side of the sensor to show exactly where the sensor is aimed. Reposition the sensor if necessary.

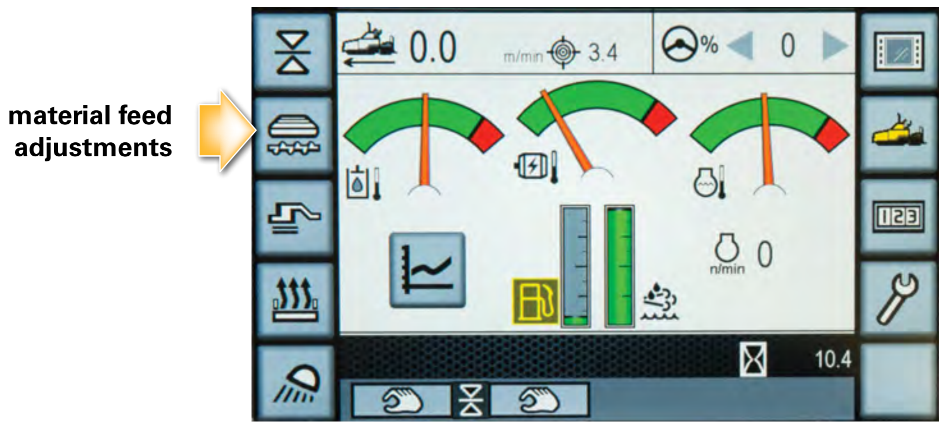
Sonic sensors should be positioned perpendicular to the moving head of material.

[11. ADJUST FEEDER SYSTEM CONTROLS]

Set the feeder control system before paving begins. Sometimes, it doesn't need to be adjusted when making a new pass—specifically, when making a new pass at the same width. However, if the paving width has changed or this is the first pass of the shift, start with the feeder controls at the recommended starting positions.

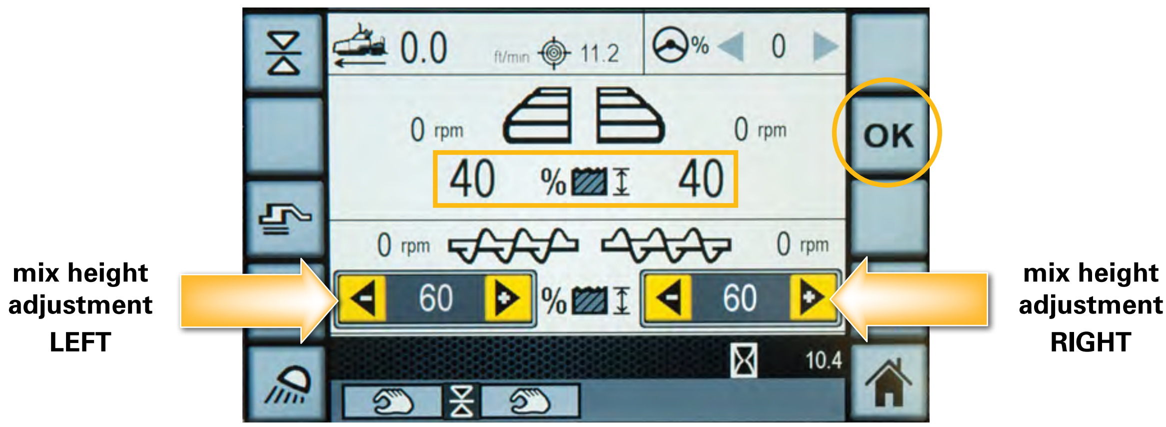
Use the control panels to set feeder system controls.

MATERIAL FEED ICON



Select the material feed adjustment icon on the left side of the tractor control panel touch screen.

MATERIAL FEED CONTROL SCREEN

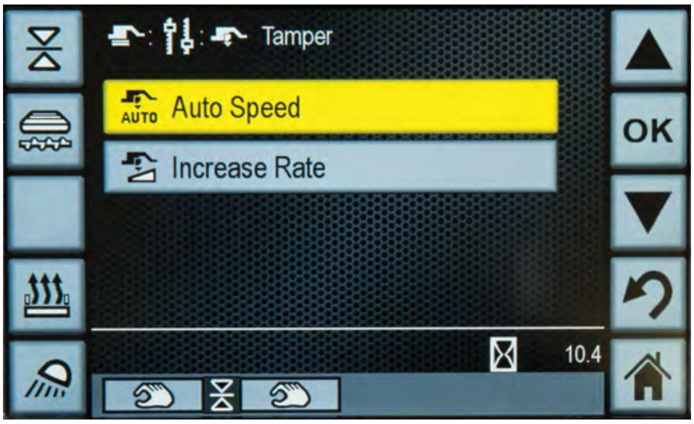


The feeder control sets conveyor speed and mix height.

Using the multi-function dial on the control panel, set the conveyor speed to 40 percent for each conveyor. Adjust the mix height to 60 percent using the arrows on the touch screen. After adjusting mix height, push the OK icon on the touchpad to accept the setting. This is a starting point for the feeder system. The tractor operator or screed operator can fine tune these settings when paving begins.

Use the screed control panel to set tamper and vibration speeds.

On the main screed control panel, set the tamper bar speed to 1200 RPM using the multifunction dial. Set the tamper bar ramp time control to the minimum position. Set the vibration frequency control to 1500 RPM.



Depending on the type of mix and the paving speed, adjust each control when paving starts. The objectives are to achieve the target density for pre-compaction by the screed and to produce a mat with consistent texture and smoothness. As a rule, a higher paving speed requires a higher tamper speed and higher vibration frequency. The tamper ramp time is normally adjusted when using stabilized material for base. When laying down bituminous material, the tamper ramp time is set at "Minimum," so that it starts immediately when paving begins.

[12. FILL THE AUGER CHAMBER]

Filling the auger chamber to the correct level is extremely important. The most common mistake is overfilling the auger chamber. Remember, the material in the auger chamber is weight, or resistance, felt by the screed. If there is too much resistance, the screed will climb at take-off and create a high spot at the transverse starting joint.

Fill the auger chamber using manual conveyor and auger controls.

Use the left and right conveyor controls at the operator station to fill the auger chamber.

User Tip: *Always fill the auger chamber with the engine at low idle speed. At low idle, the hydraulic drive for the feeder system operates slowly. The slower conveyor speed minimizes the amount of material that gets pushed under the tractor. Also, slower auger speed minimizes segregation when paving with a mix containing large-size aggregates. It is easier for the operator to control the flow of material across the entire auger chamber using the left and right augers.*

Start with either the left or right conveyor. Hold the manual control down and slowly fill the auger chamber behind that conveyor until the material covers the augers in the center.

Manual auger controls are located below the conveyor controls.

Select the manual auger control for that side and depress the control until all material has been moved out as far as possible.

Alternately, use the manual conveyor control and the manual auger control to fill the auger chamber and to create a head of material that covers one half of the auger shaft or slightly more. Repeat the procedure for the other side of the auger chamber.

Use a shovel to move material out to the end gate whenever the extender is beyond 30 cm (1') away from the last auger segment or whenever special attachments are added to the end of the screed. Using the auger to force mix out to a wide paving width will create an overload in the center of the auger chamber and the screed will climb during takeoff.

Do not fill in the area adjacent to the main screed and directly in front of the screed extender. This area will be filled by material as the paver pulls forward off the starting reference.

Use a shovel to move material out to the end gate.

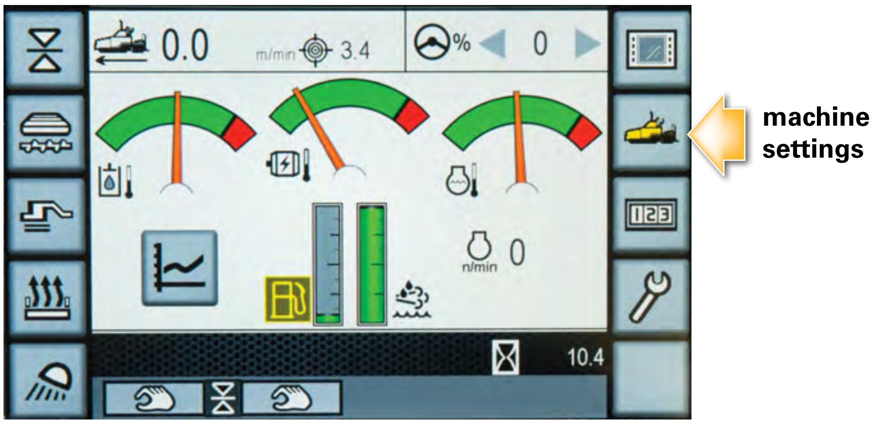
Put feeder controls in the Automatic mode.

When the auger chamber has been filled half full—no more, no less—set the conveyor and auger mode controls on the console to Auto. Either push the automatic conveyor and auger button or press individual automatic buttons for both the conveyor and auger. Verify that all four automatic system indicators are illuminated. If the controls remain in the Manual mode, neither the conveyors nor the augers will operate when paving operation begins.

[13. SET ACCESSORY FUNCTIONS]

Refer to the Operations and Maintenance Manual to review the list of available accessory functions. Access the accessory functions by touching the Machine Functions icon. Some of the accessory functions available are:

- Friction Steer
- Vibrator System On/Off and Speed
- Screed Assist System
- Timers
- Propel Hill Hold
- Automatic Engine Speed Control



Before pulling off the starting reference, set accessory functions.

Set the Grade Control system before pulling off the starting reference.

Automatic grade and slope controls are considered accessory controls. Set them according to the job specifications. Install any averaging devices and/or grade sensors as required. Select either single-side screen display or dual-side screen display per operator preference.

[14. PULL OFF THE STARTING REFERENCE]

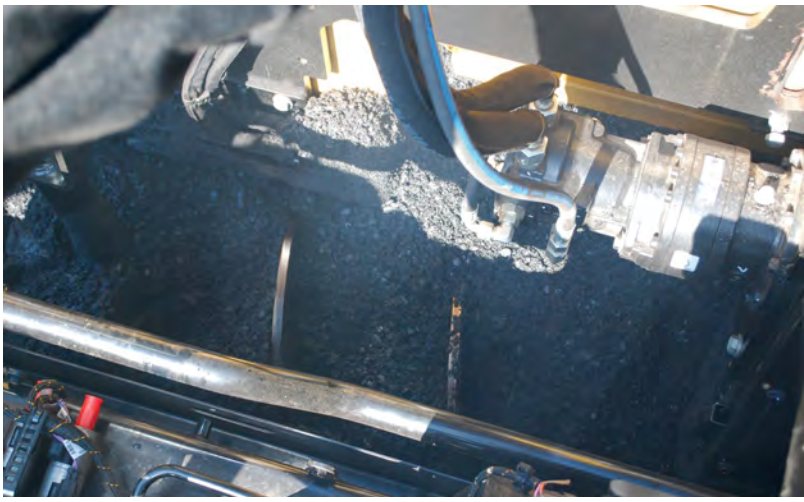
*Make sure the gear selector is in the PAVE mode **(1)**, the screed is in float **(2)**, and the engine throttle is set at the chosen idle speed (ECO or high idle) **(3)**. Then, turn the speed control dial **(4)** clockwise until the calculated paving speed is displayed in the target speed area of the display **(5)** and release the parking brake **(6)**. Propel the machine by squeezing the trigger and stroking the propel lever **(7)** fully forward in one quick, smooth motion.*

***Note:** When the calculated target speed is reached, use the propel lever to stop and start the machine using the same quick, smooth motion as before. Slowly stroking the propel lever will result in a more uneven head of material and have an adverse effect on mat smoothness.*

The left and right screed operators should be monitoring the area at the end of the auger shaft and in front of the extender. The primary responsibility at the start of paving is to ensure that there is enough material coming out of the auger chamber to flow to the end gate. The screed operator can adjust the mix height dial to set the head of material at the end of the auger shaft and to set the flow of material in front of the extender.

The screed operators are responsible for making sure enough material flows to the front of the extenders.

Next, the paver operator checks the level of material in the center of the auger chamber. Use the left or right ratio control dials to adjust the head of material. Once the head of material is correct across the full width of the auger chamber, the auger rotational speed must be monitored and adjusted if necessary.



Observe the head of material in the center of the auger chamber.

User Tip: *On many Cat Pavers, the speed of the left and right augers is shown on the LCD displays. On older pavers without auger speed indicators, the operator can simply monitor the rotation of the last auger segment. The last auger segment is a split segment. As the tip of the segment rotates, count how long it takes for one complete revolution. A two-second revolution equals 30 revolutions per minute. Remember, the ideal range for auger speed is 20 to 40 revolutions per minute.*

To increase auger speed, turn the ratio control dial counterclockwise. This slows the speed of the affected conveyor and reduces the volume of material in the auger chamber. Hence, the sensor will signal for an increase and the augers will rotate more quickly. To slow the auger rotation, turn the ratio control dial clockwise.

[15. OPERATIONAL ADJUSTMENTS]

A good takeoff should result in uniform appearance of the asphalt layer.

The screed will be at its equilibrium point when the paving speed has stabilized and the feeder system is operating at a uniform speed with the correct head of material. Forces acting on the screed are in balance and the screed is now floating at a constant level. Check and adjust layer thickness and slope and also check the appearance of the layer. If screed height, angle of attack and slope are correct, the mat should have a uniform texture across the full width of the mat, and no longitudinal lines should be present.

Extender height too high

If an extender is set too high, a longitudinal transition mark in line with the outer edge of the main screed will appear. The mat will be thicker behind the screed extender. First try decreasing the tamper speed. This will cause the screed to lower, decreasing mat thickness. The tow-points are then adjusted up increasing the angle of attack returning to the original mat thickness. When the angle of attack is increased, the separation marks will decrease. Continue to adjust the tamper speed until the marks disappear.

Lower the extender until the transition marks are eliminated.

Note: *If the extenders were not calibrated to the main screed, mechanical adjustments may be required to completely remove the separation marks.*

Extender height too low

If a slight mismatch occurs between the height of the extender and the height of the main screed a line will appear longitudinally in the surface of the layer.

If an extender is set too low, a longitudinal transition mark in line with the inner edge of the screed extender will appear. A thinner mat behind the screed extender will be evident. First try increasing the tamper speed. This will cause the screed to lift, increasing mat thickness. The tow-points are then adjusted down, decreasing the angle of attack returning to the original mat thickness. When the angle of attack is decreased, the separation mark will decrease. Continue to adjust the tamper speed until the mark disappears.

Lower the extender until the transition marks are eliminated.

Note: *If the extenders were not calibrated to the main screed, mechanical adjustments may be required to completely remove the separation marks.*

Two of the most important fundamentals of smooth paving are maintaining a consistent paving speed and a constant head of material.

Normally, the paver can pave smoothly at any speed that matches the delivery of mix to the worksite. The important thing is to keep the speed constant.

If the paving speed is changed drastically, the screed will either rise or fall, and mat smoothness will suffer.

Also, if paving speed changes, the demands on the feeder system also change and the feeder system must be adjusted to match the new material demands.

For quality paving results, always follow the basic fundamentals of paver set-up and keep the operation consistent.

[SUMMARY]

The proper takeoff from the starting reference sets the tone for the length of the pass. The crew should take the time to do every startup step correctly and in the proper sequence.

Two steps are particularly important. The first is setting the main screed angle of attack. Be sure the crew knows the characteristics of the screed with which they're working. What they learned on one screed may be different than what is needed on another screed. Remember, the angle of attack that is installed while the screed is setting on the starting reference is the angle of attack the screed returns to for the length of the pass.

Second, fill the auger chamber slowly, one side at a time. It is very common for the crew to overfill the auger chamber at the starting point. Always fill with the engine at low idle. It takes a few minutes longer to slowly fill the auger chamber, but it pays off in smoother transverse joints.

Finally, be sure the crew is paving with a calculated paving speed whenever possible. If the speed changes, adjust the feeder system to match the new demand for material.


GRADE CONTROL
AP555F
CAT

Unit 6
AUTOMATIC GRADE AND SLOPE CONTROL

Automatic grade and slope control is designed to make the crew’s jobs easier and improve the quality of the final product. A crew that is well-trained in the uses of grade and slope control can set the paver up to maximize productivity and paving efficiency in a wide range of applications.

Unit 6 provides information about automatic grade and slope control, one of the four basic elements to quality construction of asphalt layers. Several types of grade and slope systems are available on pavers. The components shown in this unit are primarily from the Cat Grade Control System and the Trimble Paving Control Systems. Other systems may differ, however, the basics of grade and slope setup and operation are the same for all systems.

Grade control can be thought of in several ways. On some projects, it can be considered the control for thickness of the layer being placed. Many projects require the layer thickness to remain constant so the yield (the number of tons calculated for a project versus the number of tons actually laid down) is exactly what has been planned.

On other projects, grade control may be thought of as the control for elevation of the layer that is being placed. On that type of project—airport runways, for example—the layer thickness can vary in the quest to create exact elevations.

Grade control can be used to improve the longitudinal profile (smoothness or ride quality) of the bituminous structure. In the case of paving for best ride quality, grade control ignores thickness and elevation and concentrates on eliminating roughness. These applications will be reviewed in detail in this unit and in Unit 7.

Slope control creates the specified transverse profile (slope). When selecting automatic slope control on one side of the paver, thickness and ride quality may be compromised.

Automatic grade and slope control will not correct mistakes that the crew makes. Automation can make the crewmembers' jobs easier, but the crew must always follow the fundamentals of paving and use best practices whether they are paving manually or using automation.

[GRADE AND SLOPE COMPONENTS]

Grade and slope control systems consist of one or more grade sensors, a slope sensor, a control module, and display units. Main system power cables, grade sensor cables and slope sensor cables are also utilized. On some pavers, many of the components are built into the tractor and screed and stay on the paver at all times. On other pavers, most grade and slope components are installed on the paver at the start of every shift and removed for storage at the end of the shift. Always follow the manufacturer's guidelines for installation and storage of grade and slope system components.

User Tip: *The main power cable from the tractor to the control panel or to the system display carries 24 volts. Before connecting the power cable to the control panel or to the display, be sure to have the paver key switch in the OFF position. If there is power in the cable, it is possible to cause damage to the cable or to the control panel or display when connecting the cable.*

[SONIC GRADE SENSORS]

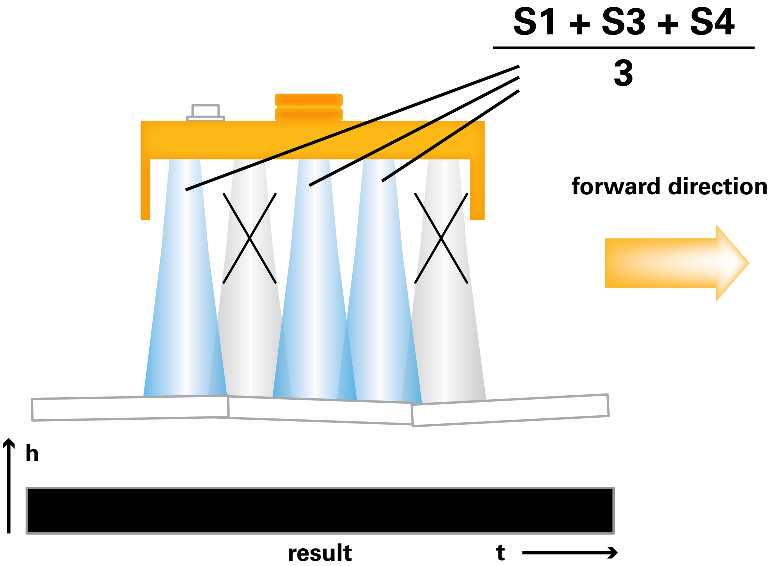
Grade sensors are either sonic or mechanical.

Sonic sensors do not touch the grade reference. Instead, sonic sensors emit sound pulses. The sound pulses travel from the sensor to the grade target. The grade target can be an existing roadway surface, a milled surface, an adjacent bituminous layer, a gutter, or a string. The sound pulses rebound from the grade reference back to the sensor.

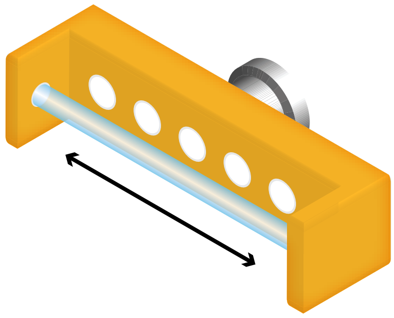
Sonic sensors use sound pulses to measure the profile of the grade over which the bituminous layer is being placed.

When the grade sensor emits a sound pulse, a timer starts. When the echo returns to the sensor, the timer stops and this information is continuously sent to the control panel or to the system controller. The speed of sound is a known factor. The controller uses the time it takes for the sound pulses to rebound back to the sensor to calculate the distance between the sensor and the grade target.

Some sonic sensors have a single transducer that emits one set of sound pulses. Cat Sonic Sensors have five transducers.



The Cat Sonic Sensor makes five grade measurements.



On Cat grade sensors, a transducer emits horizontal sound pulses to detect rapid air temperature changes.

When using a Cat Sonic Sensor to read any grade reference other than a stringline, install the sensor so it is parallel to the direction of paving with the cable connection toward the rear of the paver. The five transducers make five separate measurements. The system ignores the two measurements that have the most deviation from the benchmark distance. The other three measurements are averaged. The average of the three best measurements is sent to the control module.

Sound pulses travel faster through hot air than through cooler air. The grade sensor senses ambient temperature and corrects the distance measurements it sends to the controller based on the ambient air temperature.

However, the grade sensor may be exposed to rapid changes in air temperature on a project. Therefore, grade sensors are also equipped with devices to detect rapid changes in air temperature.

Cat grade sensors have a built-in system to detect rapid air temperature changes. A transducer is built into a tab that extends about 10 cm (4") below the transducers that emit the grade-sensing sound pulses. That transducer emits horizontal pulses that rebound off the tab on the other side of the grade sensor. The speed of the sound pulses across this known distance is used to compensate for rapid air temperature changes. Other grade sensors use detachable temperature bails that serve the same purpose.

Sound pulses rebound back to the grade sensor off the first item that is within the range of the sound pulses. Therefore, the crew should take precautions to keep the grade reference area free of all objects.

User Tip: *When using grade sensors with detachable temperature bails, never use a sensor without the temperature bail. Be sure the temperature bail is in good condition and attaches firmly to the grade sensor. It is a good idea to have some spare temperature bails in the storage box for the grade sensors.*

Material spilling over the hopper sides is a common way that the target area for the grade sensor is contaminated. The grade sensor is an extremely sensitive measuring device and will detect even small aggregate particles. Find a way to prevent spills. Do not continue to operate with grade control unless a suitable grade target is consistently available.

Other things that may interfere with the sensor target area include laborers who are working around the paver, debris that may be knocked from overhanging trees, and spills from haul units as they pull away from the paver.

The height of the grade sensors above the grade reference should be checked while setting up the grade control system. The farther the grade sensor is from the reference, the larger the target area becomes.

Spills over the hopper sides may end up in the target area of the grade sensor.

Cat grade sensors are functional from 20-100 cm (8-39") above the target grade reference. If the distance from the target is outside that range, the grade control system will not function. Caterpillar recommends positioning grade sensors, so they are 40-46 cm (16-18") above the target.

Note: The functional range of other types of grade sensors may be different. Always follow manufacturers' guidelines. However, the 40-46 cm (16-18") height recommendation is usually applicable to other types of grade sensors.

The recommended height above the grade reference is 40 to 46 cm (16-18").

User Tip: *When a sonic averaging ski is installed, multiple grade sensors will be on the ski. Try to set all sensors within the recommended height range. The sensors do not have to be exactly the same height. However, try to install the ski, so it is parallel to the grade and the sensors do not have significant height differential.*

Caterpillar also recommends that the grade sensors be positioned as close to the edge of the paving width as possible. The location of the sensor becomes the control point for all thickness changes. It is especially important to position the grade sensor close to the paving width, if one side of the screed is under grade control and the other side is under slope control. The sensor can be positioned just outside the paving width or just inside the paving width, depending on the paving application and the suitability of the grade reference.

[MECHANICAL GRADE SENSORS]

Mechanical grade sensors, also referred to as contact-type sensors, touch the grade reference. Mechanical grade sensors are not subject to variations related to air temperature changes. Mechanical sensors are often installed on pavers that vent the engine cooling system on the side of the paver or when there are very windy conditions.

A mechanical sensor uses a rotary sensor. An arm extends from the rotary sensor. The arm can have a matching shoe that rides on the grade that is the reference or the arm can have a wand that contacts a stringline. The arm should run at about a 45 degree angle, always trailing behind the sensor. As the matching shoe or wand traces deviations in the grade reference, the rotary sensor detects changes in the angle of the trailing arm. The changes in the angle of the sensor arm are converted to distances and these measurements are sent to the control panel or control module.

Cat contact-type grade sensor equipped with joint-matching shoe.

The pressure on the wand is adjustable. Set the arm pressure so the wand stays in contact with the string, but does not deflect the string. The Cat rotary contact sensor can be set up to trace the top of the string or can be set up to ride underneath the string.

The mechanical sensor can be equipped with a wand that traces a stringline over an averaging ski.

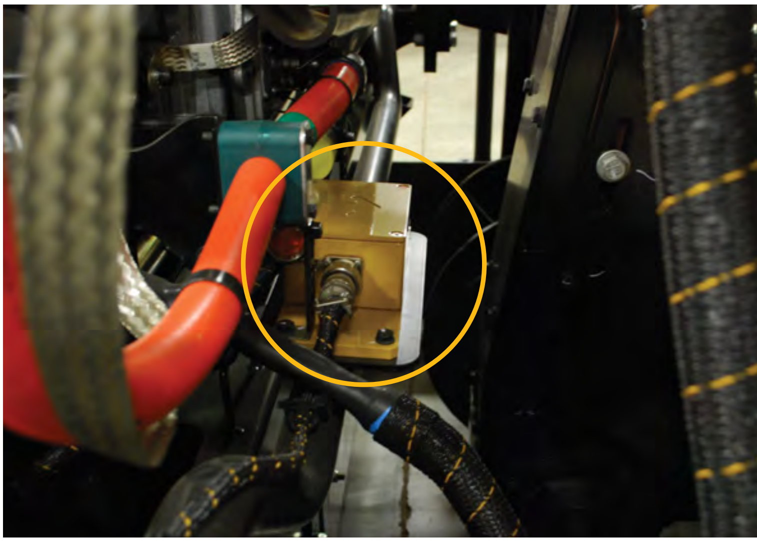
[SLOPE SENSOR]

The slope sensor is installed on a transverse beam that spans the width of the screed directly above the front of the main screed.

The slope sensor functions like a precision carpenter's level. It is a sealed sensor that remains on the paver and does not need to be removed and stored at the end of the shift. The angle sensor reads the slope of the screed and sends that reading to the control panel or control module. The slope sensor allows the crew to maintain slope from right to left or from left to right. Slope is measured in percent. Up to 10 percent positive or negative slope is possible when using automatic slope control.

The slope sensor is connected to the left and right control panels or display units. Only one side of the screed can be under slope control at one time.

Calibrate electronic slope sensors by using a mechanical or electronic level to measure the slope of the grade that the screed is resting on. Then, edit the slope value displayed on the control panel or display unit.



The Cat slope sensor is an electronic slope sensor.

Note: *Some systems still use hydraulic angle sensors with a pendulum suspended in oil. Calibrate hydraulic sensors according to the manufacturer's guidelines.*

[DISPLAY UNITS AND CONTROL PANELS]

Cat Pavers can be equipped with different types of grade and slope control systems. Some systems use control panels that combine displays and control modules into one device. The Cat Grade Control system has separate displays and a separate control module. Most of the information about system operation and many of the visuals in this unit cover the Cat Grade system on Cat F-Series Pavers.

Cat Grade Control on F-Series Paver.

Note: *Some Cat Pavers have grade and slope control that is installed at the factory. Those pavers use the screed control module for the grade and slope system. Other Cat Pavers have grade and slope systems that are installed by Cat dealers or by equipment users. Those pavers have a dedicated control module for grade and slope control. Always read and follow the guidelines contained in each grade and slope system's Operation and Maintenance Manual.*

Home Menu screen on the Cat SE-Series screed control box display.

When the key switch is in the ON position, the displays at the operator's stations and on both sides of the screed will illuminate and show the Home Menu screen.

An operator can select the grade and slope screen by depressing the button adjacent to the grade / slope icon at the upper left of the display housing.

The screed operator(s) can elect to work with single screen display or with dual screen display.

grade control menu

Grade Control display showing single screen mode for right side of the screed.

In the Operator Settings menu, an operator can set single screen or dual screen display.

To select the display mode touch the grade control menu and select operator settings. Select main screen and touch the 2D guidance screen mode.

After the change to the display screen mode is accepted, select the grade control icon (lower right) to return to the normal operating screen.

Dual screen mode showing elevation (grade) control right side and slope control left side

This illustration shows the Cat Grade Control display set in single screen mode on the right side of the screed. Functional areas are grouped for ease of understanding.

1. Grade indicators are on the far right side of the display. The green bars illuminate when the grade or slope system is within the dead band. This condition is usually referred to as being "on grade." The up and down arrows flash when the measured grade or slope value is outside of the dead band.

2 Adjustment and selection buttons are also on the right side of the display. Depressing the buttons adjacent to the up-and-down arrows enable the system to make grade or slope changes while paving in the Auto mode.

3. Set the benchmark (null) by depressing button adjacent to the bench key.

4. Switch between the Auto mode and the Manual mode by depressing the button adjacent to the Auto symbol.

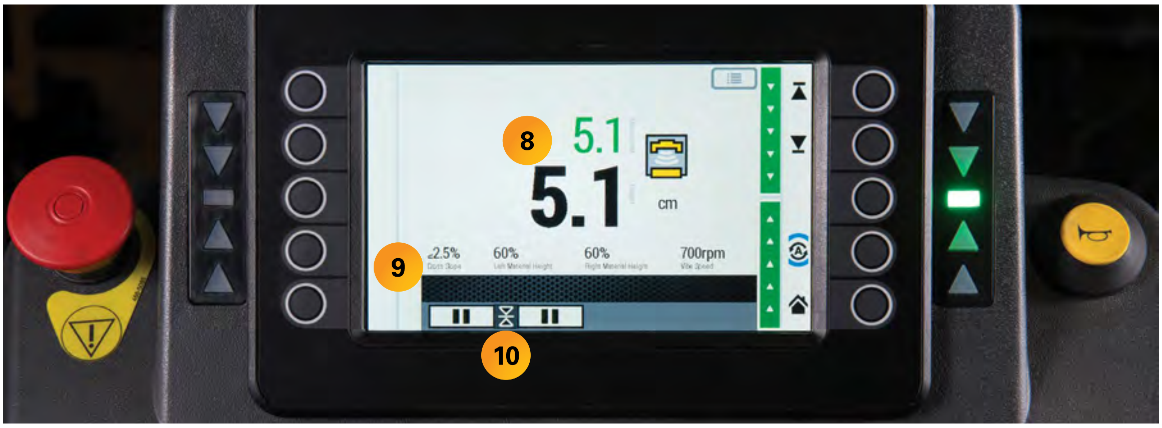
5. The Grade Control menu is located in the upper right portion of the screen. Select this touch-screen button to change units of measure, control system beepers, and other preferences for the grade control system.

6. The Sensor Selection icon is in the right center of the screen. Select this touch-screen icon to see what sensors are available and to select a different sensor.

7. Finally, depress the button adjacent to the Home icon to return to the Home screen

Once the sub-menu for Sensor Selection displays, select the icon for the sensor to be used. The sensor will highlight. Depress the button adjacent to the OK symbol to accept the change.

Touching the Sensor Selection icon opens the sub-menu of available sensors.



8. The measured reference number (smaller green) and the target reference number (larger black) are in the center of the screen. The measured number is the value sent to the display by the selected sensor. While the paver is moving, the number will usually be changing slightly as the measured grade or measured slope changes. The target reference number is a value selected by the operator and usually refers to the desired thickness or desired slope. The reference number stays the same unless the operator uses the up or down arrows to change thickness or slope. Edit the target number by tapping the touch screen value. Use the sub-menu to change the target value and move the system to a new position or target value.

9. The operator can choose to include a text bar at the bottom of the screen. A number of values are available for viewing. For example, the operator may wish to monitor certain feeder system functions, while using the grade control screen. Or, the operator may wish to view the slope of the screed, while operating in grade control. To use the text bar, select the grade control menu. Select operator settings and text slider bar to "customize" information that is available to view.

10. The bottom section of the display indicates the state of the system. When the "hand" symbol shows in this area, the control system is in the Manual mode. When the word "AUTO" shows in this area, the system is in the Automatic mode. When the Pause symbol (two vertical lines) shows in this area, the system is momentarily paused from the Auto mode. The pause symbol will appear when the operator moves the propel lever to the Neutral position, for example.

Selecting Type of Sensor

Dual screen display with single sensor grade control left and slope control right.

To select the type of sensor or averaging ski set-up, tap the sensor selection icon on the touch-screen display. The sub-menu for sensor selection will show each sensor or ski configuration that is available.


sonic over a string line


sonic over a hard surface


sonic in center of averaging beam


sonic in front and rear of averaging beam


all 3 sensors on averaging beam


contact sensor


cross slope sensor

3D slope sensor

3D elevation sensor

Select the icon for the sensor or configuration to be used. Depress the button adjacent to the OK symbol and then return to the desired display screen. The selected sensor icon(s) will appear on the Grade Control display.

When a sonic sensor over a string line is selected, the icon on the display guides the paver operator to keep the sensor centered over the stringline. The Cat grade sensor uses the center three transducers to measure the distance to the stringline. The Cat grade sensor uses the outer two transducers as centering guides. If the sensor is centered over the string, there will be a green circle around the string on the icon. If the sensor is offset to the left of center, there will be a red arrow pointing to the right. If the sensor is offset to the right, there will be a red arrow pointing to the left.

sonic tracer centered over string line

sonic tracer offset to the left of the string line

sonic tracer offset to the right of the string line

User Tip: *If the grade sensor is set up to measure a string over the body of a mechanical averaging ski as its grade reference, position the string 10 cm (4") above the body of the ski. If the grade sensor moves away from the target string, the grade control system will lock to grade and the tow-point will not move. The lock-to-grade feature activates anytime there is a sudden change in the grade reference in excess of 5 cm (2").*

Note: *When using a sonic grade sensor over a stringline and an icon for stringline guidance is not displayed, then the grade sensor is not tracking the stringline. For proper guidance, the sensor connector must be on the left side when viewing from the back of the paver.*

Benchmarking or Nulling the System

Once the paver and screed have been setup to pave using "Paving by the Numbers" and the Grade Control sensor/sensors have been installed, the system can be bench-marked or nulled.

Establishing a benchmark (nulling the system) creates a reference for the grade sensor or for the slope sensor. In the case of a grade sensor, the benchmark is the distance from the sensor to the grade reference. In the case of a slope sensor, the benchmark is the percentage of slope from right to left or from left to right.

To benchmark the system, depress and hold the left or right Bench button (middle button) for longer then two seconds. If the audio function is activated, the operator will hear three beeps, and the middle on-grade bar will illuminate as a green color.

When benchmarking the system under grade control, the value in the Measured value area is converted to the number shown in the Target value area. Benchmarking the system under slope control will convert the measured value to the target value.

The green on-grade bar illuminates when the system is benchmarked.

Selecting Automatic Mode

After benchmarking the system, depress and release the button adjacent to the AUTO symbol, the Mode Select button (second from bottom). The word "AUTO" will appear in the system status area. While the paver is placing material, AUTO will show continuously in the system status area.

When the paver is stopped, the grade and slope control system is temporarily in the Standby mode and the Pause symbol will alternate with the word Auto in the system status area. When the propel lever is moved out of the Neutral position, the system returns to the Auto mode and the word Auto will appear constantly in the system status area.

When paving in automatic mode, the control module will send signals to the tow-point valve. When a change in elevation or slope is required, the left or right tow-point valve will send hydraulic oil to the head end or rod end of the appropriate tow-point cylinder. The tow-point will move up or down to change the elevation or the slope to within the tolerance for grade and slope. The grade control system has a default tolerance (dead band) of 3 mm (0.125"). The slope control system has a default tolerance of 0.05%. Grade and slope tolerances can be adjusted, if desired.

The word "AUTO" appears when the automatic mode is selected.

The Pause symbol will alternate with the word Auto when the propel lever is in the Neutral position.

Editing the Measured Value

The value in the measured area is a reference for the operator. It is a good practice to edit that value, so it corresponds with the desired thickness of the bituminous layer or with the specified slope of the bituminous layer. To edit this value, select the measured value on the touch-screen display.

When the measured value is selected, a keypad will display. The desired value is entered on the keypad, either for grade sensor distance (elevation control) or for slope percentage.

A keypad displays when the measured value is selected.

The value entered will display at the top of the keypad. The value will be expressed in the selected unit of measure for the grade control system. To accept the change, depress the button adjacent to the OK symbol.

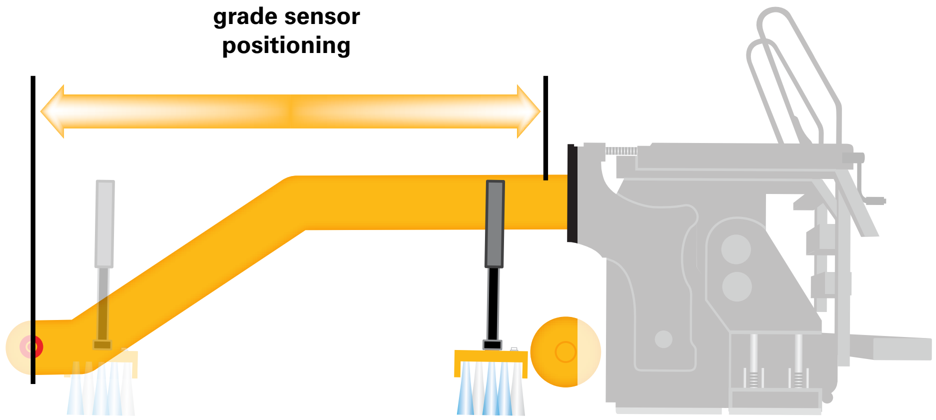
After returning to the grade control display, bench the system by depressing the left or right benchmark button (center button) for more than two seconds. Three beeps will be heard, and the target value will convert to the measured value that was just entered.

Keypad showing 2.5 inches entered as the measured value.

Bench the system and the target value will match the measured value.

[HOW SENSOR POSITION AFFECTS SCREED REACTION]

The position of a single grade sensor in relation to the tow-point connection or to the auger shaft affects how quickly the screed reacts to changes or corrections made by automatic grade control. Remember, when automatic grade and slope control is being used, the system automatically makes grade or slope changes by sending hydraulic oil through the tow-point valves to the tow-point cylinders. How far the tow-points move up and down determines the amount that the main screed angle of attack changes and, consequently how far and how fast the screed changes its elevation. Operators must understand these relationships in order to set up the paver properly for different paving applications.



Never position a single sensor in front of the tow-point connection.

A single grade sensor may be positioned anywhere between the tow-point connection and the center of the auger shaft when paving with a vibratory screed.

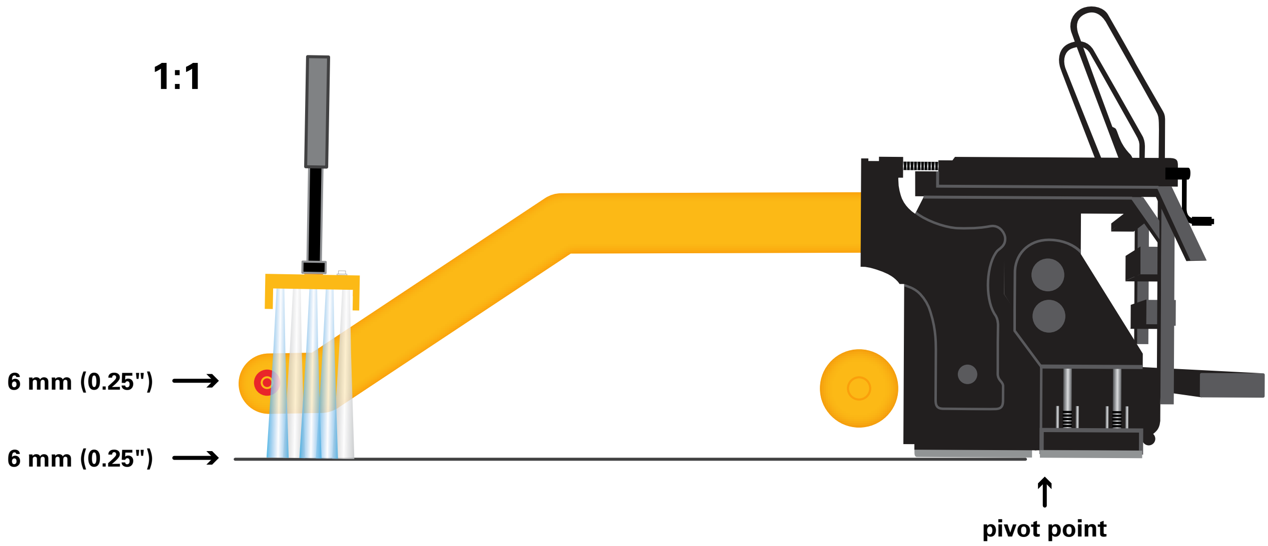
Note: *When paving with a tamping screed, a sensor may be positioned as far back as even with the tamper bar.*

Assume a single grade sensor is installed in front of the tow-point and the sensor detects a change in the grade elevation. If the change is a depression in the grade, the control module will signal the tow-point cylinder to move up. Conversely, if the grade sensor detects a high spot in the grade, the control module will signal the tow-point cylinder to move down. In other words, all grade corrections are the opposite of what is required when the grade sensor is ahead of the tow-point connection.

User Tip: *The Cat Grade Control System recognizes when a non-contact averaging ski is installed on the side of the paver. There are three sensors on the ski and, when three-sensor or two-sensor operation is shown in the Sensor Selection area, the system averages the measurements from the sensors. Don't worry that one of the sensors is in front of the tow-point connection. The system recognizes and accounts for that condition. However, if one-sensor operation of the non-contact averaging ski is selected, make sure that the middle sensor is behind the tow-point connection. The beam may have to be moved toward the rear to place the middle grade sensor in an acceptable position.*

Next, assume that a single sensor is behind the auger shaft or behind the tamper bar, and the sensor detects a change in grade elevation. By the time the system responds, it will probably be too late. The change in elevation will occur after the screed has passed the point where the deviation is located, and extreme roughness will be evident in the mat.

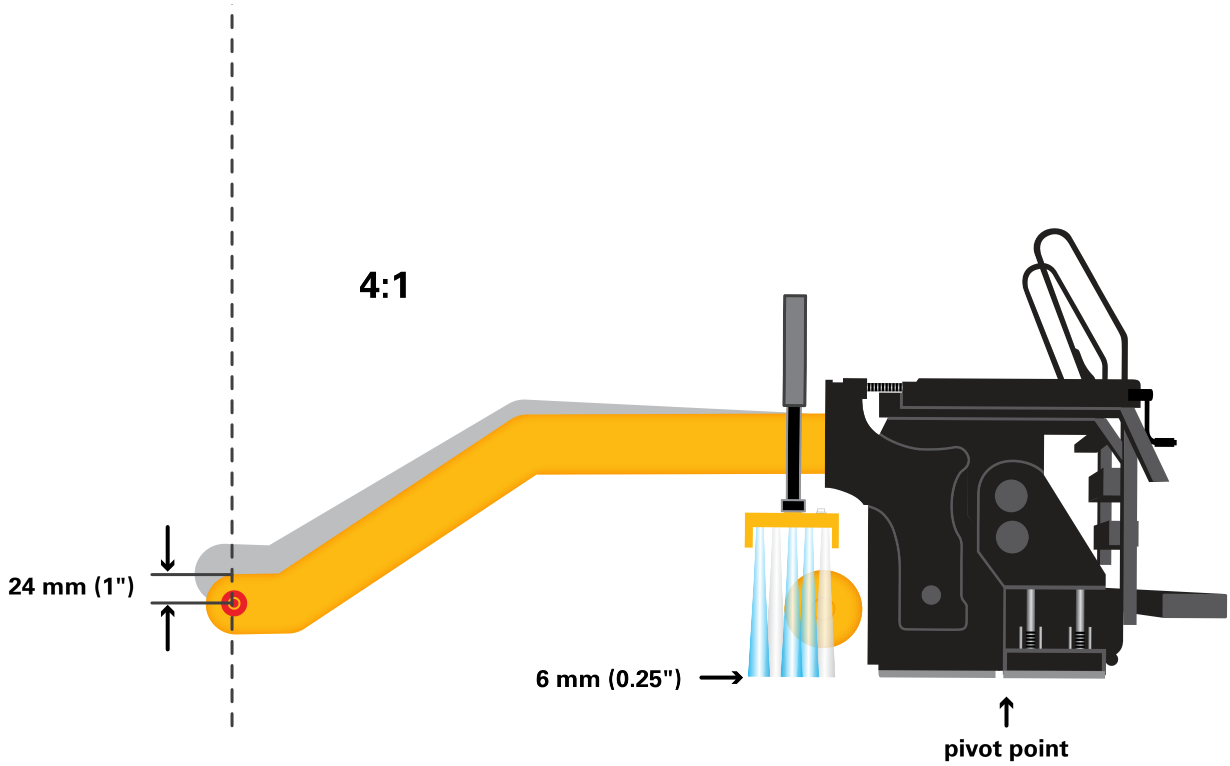
Always verify that the sensor is located correctly and that it will create the desired screed response.



Sensor position for slow screed reaction.

To create a screed that reacts slowly to grade changes, position the grade sensor just behind the tow-point connection. This sensor position creates a 1:1 ratio between the amount of grade deviation and the distance the tow-point moves. For example, if the sensor in this forward position detects a grade deviation that is 6 mm (0.25"), the grade control system will cause the tow-point to move 6 mm (0.25").

The main screed angle of attack changes slightly and the screed will climb or fall slowly. The change in elevation will occur gradually over a distance of approximately five tow-arm lengths. The bituminous layer will tend to fill in low spots in the grade and trim off high spots on the grade with the sensor close to the tow-point. Select this sensor position when it is important to improve the ride quality of the grade.



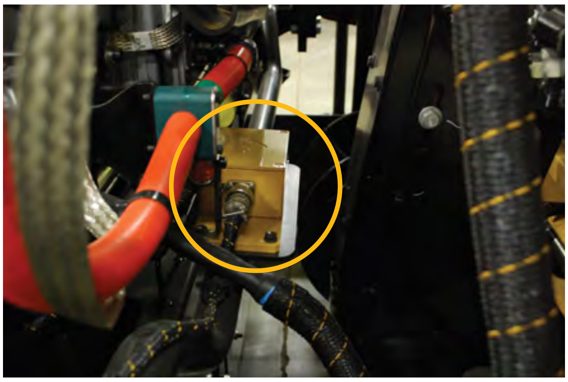
Sensor position for fast screed reaction.

To create a screed that reacts quickly to grade changes, position the grade sensor in line with the center of the auger shaft or even with the tamper bar. This sensor position creates a 4:1 ratio between the amount of grade deviation and the distance the tow-point moves. For example, if the sensor in this position detects a grade deviation that is 6 mm (0.25"), the grade control system will cause the tow-point to move 24 mm (1").

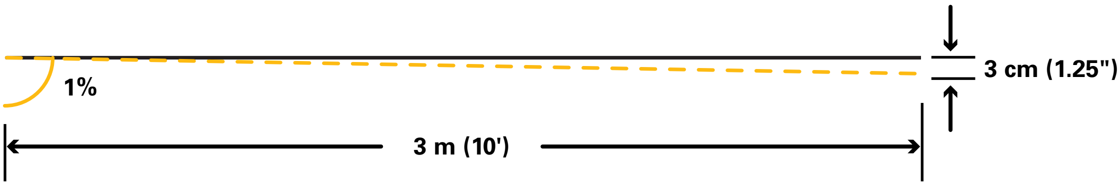
The main screed angle of attack changes significantly and the screed will climb or fall quickly. The change in elevation will occur almost instantly, and the bituminous layer will exactly match the change in elevation where the change occurs. The bituminous layer will tend to follow low spots or high spots in the grade with the sensor close to the auger shaft. The thickness of the layer will be very uniform, but smoothness may be sacrificed. Select this sensor position when it is important to have precise yield control or exact height match to a longitudinal joint or gutter.

Position the grade sensor ahead of the auger shaft or the tamper bar to begin to slow screed reaction. This will create a layer with an acceptable yield and profile while improving the smoothness at the same time.

The slope sensor is mounted on a transverse beam that spans the width of the main screed just ahead of the nose of the screed. In this position, the slope sensor also creates a 4:1 ratio between the distance that the tow-point moves in order to create the elevation change needed to maintain the specified slope. It is important for operators to understand how automatic slope control operates. First, the relationship between slope correction and elevation changes must be understood.

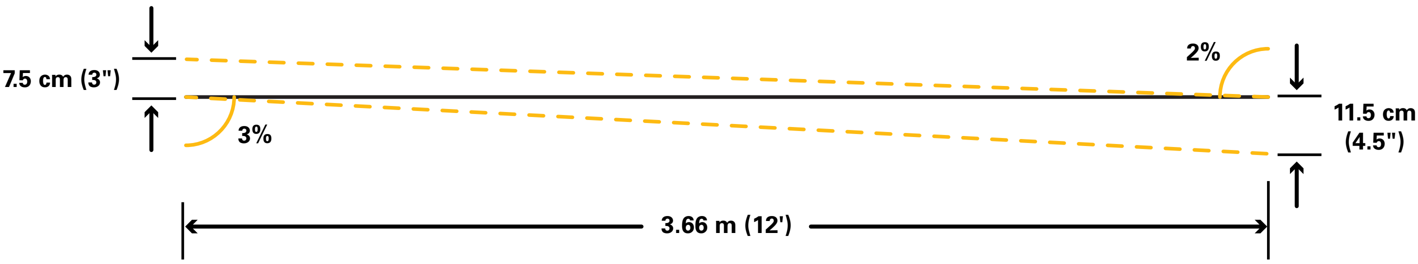


The position of the slope sensor also creates a fast screed reaction.

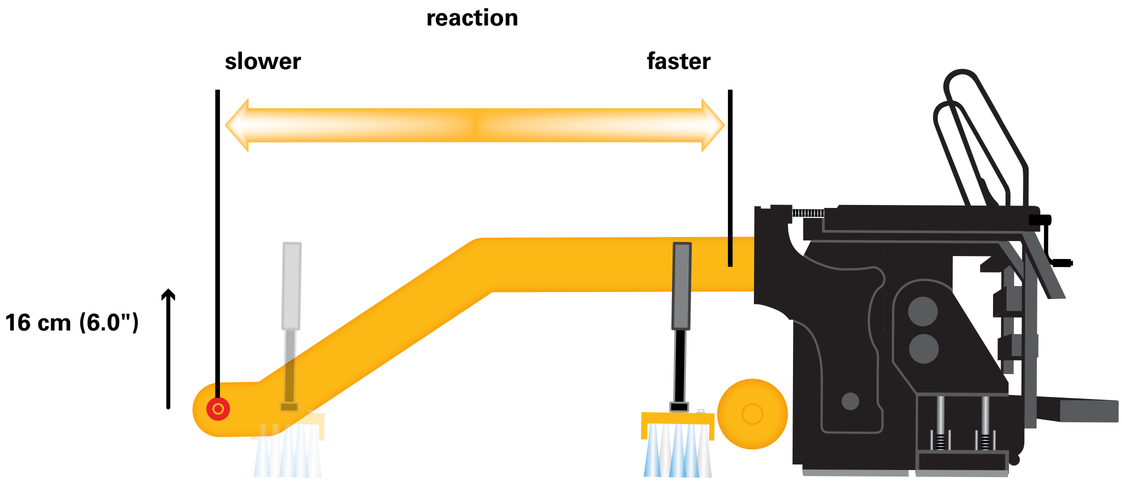


Assume that a structure needs to have a 1 percent slope from left to right. Starting at the left edge of the structure, the elevation of the layer must decrease by 1 cm per meter, or 0.125" per foot. If the width of the structure is 3 m (10'), then the elevation change will be 3 cm (1.25").

In practical terms, consider the following example. The slope of a compacted granular base is up to 3 percent from left to right in some areas. The plan specifies 2 percent slope. The paving crew needs to correct the slope to 2 percent in all areas, while paving the base layer. The width of the layer is 3.66 m (12'). The uncompacted depth of the layer is supposed to be 7.5 cm (3"). In those areas where the slope of the granular base is 3 percent, what will be the thickness of the layer at the right edge of paving?



In this example, the layer thickness has to increase by 4 cm (1.5") in order to create the specified slope. The crew will need to maintain the layer thickness at the left edge of paving. That is the only place where the operator can check layer thickness. The depth of the layer will increase as the layer extends from left to right. At the right edge, the layer thickness should be 11.5 cm (4.5") in order to correct the slope to 2 percent. How much will the right tow-point move in order to create the correct slope in this situation?



Because the slope sensor is located close to the front of the screed, the tow-point movement is a 4:1 ratio with the elevation change. Therefore, to create the 1 percent slope correction in a timely manner for this example, the tow-point will move up 16 cm (6").

Automatic slope control can create significant variations in layer thickness and, consequently, variations in yield. Automatic slope control can also create roughness in the bituminous layer.

User Tip: *When using automatic slope control to correct the transverse profile, it is a good idea to discuss the possible outcomes with the project owner and the on-site inspection personnel. Be sure to inform them that yields may be variable. If the inspection team is accustomed to checking yields truck by truck or over short distances, they may be surprised with the yield results, unless they have been prepared for the variations. It may be a good idea to use a slope board or slope meter to show the inspector where the corrections will occur.*

User Tip: *When using automatic slope control to correct the transverse profile, the demand for material passing under the screed will vary as the thickness of the layer varies. The paver and screed operators will have to be ready to adjust the feeder system frequently. They should pay particular attention to the area in front of the extender where the head of material will disappear the fastest. Auger speed will vary according to the demand for material, and stripe segregation may occur.*

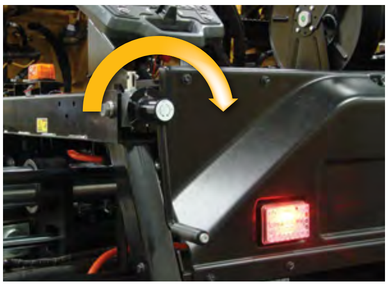
[RESTORING TOW-POINT HEIGHT]

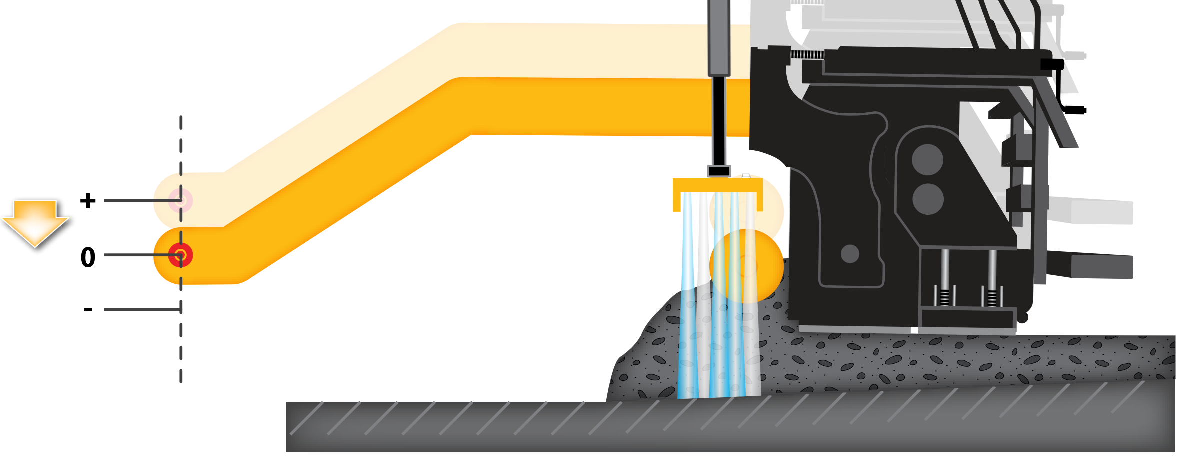
As discussed in previous sections of this guidebook, the height of the tow-points affects the line of pull and the main screed angle of attack. The tow-point height is set at the start of paving based on the planned thickness of the bituminous layer.

An operator can manually change tow-point height while paving in order to increase or decrease layer thickness. Or, an operator can use the grade and slope control system in the automatic mode to change tow-point height and layer thickness automatically.

The previous section described, how sensor position affects tow-point movement and screed reaction. Grade sensors positioned close to the nose of the screed can create large tow-point movements. Slope sensors, due to their fixed position close to the nose of the screed, can also create large tow-point movements.

Depending on the amount of grade deviation that is being corrected or the amount of slope correction, the tow-point cylinder may reach the end of its stroke, while the grade and slope control system is still signaling for additional movement. When that happens, the operator should employ a technique to "gain back" the tow-point cylinder to restore normal operation.



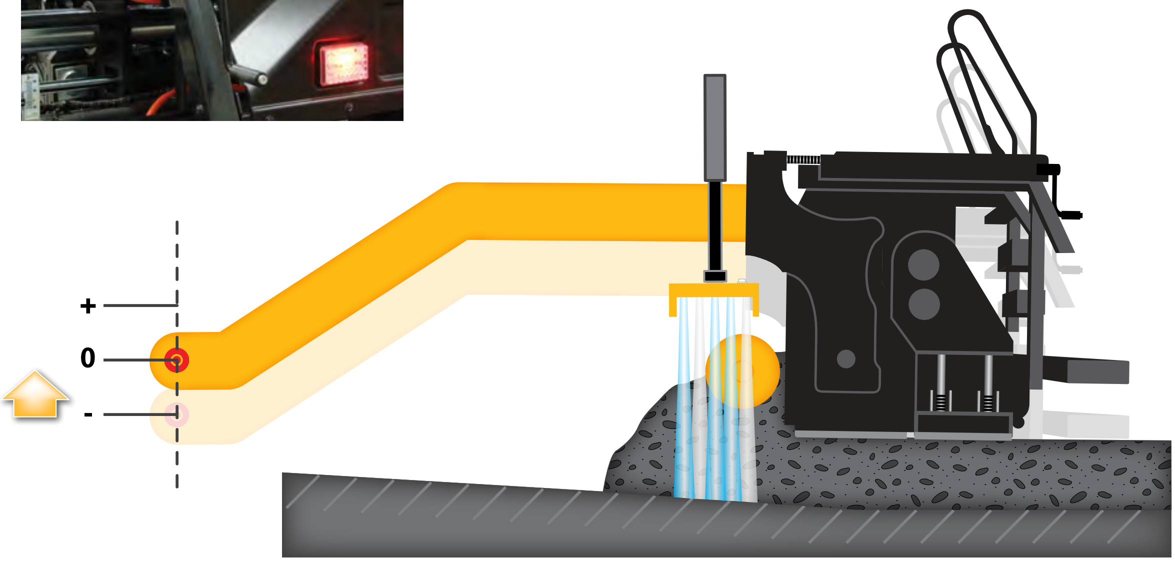


If additional thickness is required when the tow-point is fully raised and a single sensor Grade Control system is being utilized, Leave the system in the AUTO mode. On vibratory screeds, unlock the manual depth screw. Turn the screw slowly in the direction that increases layer thickness. Watch the tow-point height indicator. When the height indicator begins to move down, stop turning the manual depth screw. Allow the tow-point cylinder to stabilize. Make additional adjustments if needed. Once the desired tow-point position has been achieved, lock the depth control screw.

Note: *On tamper bar screeds, use the thickness screws to change the angle of attack on the main screed and start the tow-point height correction. Turn the screw toward positive marks to lower the tow-point. Turn the screw toward zero or negative marks to raise the tow-point.*

If the tow-point is too low, turn the manual depth screw or thickness screw in the direction that decreases layer thickness. Stop turning when the tow-point connection begins moving up. Allow the tow-point cylinder to stabilize. If additional adjustment is needed, continue to slowly turn the manual depth screw. Stop when the desired tow-point position has been achieved.

At times when paving with automatic grade control, the tow-point cylinder may run out of adjustment. Use the aforementioned technique to alter the tow-point height or to adjust the line of pull while paving.



User Tip: *It is virtually impossible to "gain back" cylinder stroke when using an averaging ski or if a single sensor is installed close to the tow-point connection. Remember, any changes in screed elevation occur over a long distance when using an averaging ski or when the sensor is close to the tow-point connection. Normally, the tow-point moves very small distances when a ski is used and manual tow-point adjustment isn't required.*

[CALIBRATING TOW-POINT CYLINDER VALVES]

No matter what type of grade and slope control system is being used, the tow-point cylinder valves must be calibrated on each side of the paver. Calibrating the tow-point cylinder valves assures that the tow-points move up and down smoothly and in the correct timeframe in response to signals from the grade and slope control module.

Each tow-point cylinder valve is calibrated independently. The calibration data for each tow-point cylinder valve is stored in the control module of the Cat Grade Control System. On other systems, data for the left tow-point cylinder valve is stored in the left control box. Data for the right tow-point cylinder valve is stored in the right control box. Clearly mark the right and left control boxes, so they are always installed on the correct side of the screed.

Most modern pavers, have proportional tow-point cylinder valves. When calibrating a proportional tow-point cylinder valve, set the amount of current that is necessary to move the valve spool enough to send a small amount of hydraulic oil to the head end or rod end of the tow-point cylinder. It should move a small distance and stop in a short period of time.

If the tow-point cylinder moves too far or too fast, the screed will create roughness in the bituminous layer. If the tow-point cylinder takes too long to respond, the screed will not place the correct thickness.

Note: *Instructions for calibration of tow-point cylinder valves when using the Cat Grade System are in the Operation and Maintenance Manual. Always follow the instructions for the paver model and the type of grade and slope control being utilized.*

To perform tow-point valve calibration, start with the display in the Grade Control mode. Select the menu icon on the touch-screen display. Then, select the Installation bar. There are separate bars for left and right valve calibration. Select the side to be calibrated.

Display showing the start of calibration for the left tow-point valve.

The Cat Grade System uses an "Auto Valve Calibration" process. Be sure to select either the right or left valve and calibrate one side of the paver at a time. Enter the Installation menu and follow the prompts that are shown on the display.

Display with instruction to center the tow-point.

The prompts on the screen provide instructions for completing tasks such as centering the tow-points and setting the upper and lower limits of tow-point travel. Once all of the manual requirements for tow-point valve calibration are completed, the system will perform an automatic self-calibration. When the calibration has been successfully completed, a message on the display indicates it's time to depress the button adjacent to the OK icon.

Display with instruction to set the lower limit of tow-point travel.

When calibrating the tow-point cylinder valves for any type of grade and slope condition, follow these guidelines to assure accurate calibration.

- Hydraulic oil at normal operating temperature
- Paver parked on a flat and level surface
- Tow-points centered
- Screed in float mode
- Slack removed from the tow-point connections
- Screed nulled
- Transmission in Pave mode
- Parking brake set
- Propel lever fully forward
- Speed control dial turned up halfway

Calibration of tow-point cylinder valves is not part of a scheduled maintenance program. Initial calibration of the tow-point valves is required when installing Grade Control systems. Once the system has been calibrated and performance has been verified, recalibration is unnecessary unless:

1. The grade control system is moved to another paver, or

2. The tow-point cylinder or tow-point valve have been replaced.

There may be times when it is suitable to recalibrate the grade control system. Examples are when the paver comes out of storage after sitting idle for a long period of time or before starting a project with a reward or risk associated with ride quality.

[AVERAGING SKIS]

Averaging skis are commonly used on projects where an improvement in the longitudinal profile (smoothness) of the structure is needed. An averaging ski is designed to provide either a physical reference that ignores high spots or low spots in the grade that is being paved or to electronically average three or four measurements taken by grade sensors over a given distance.

Two types of averaging skis are commonly used: mechanical, contact-type skis or electronic, non-contact skis. Each type has its own specific advantages.

Electronic non-contact skis

Electronic, non-contact skis have three or four equally spaced grade sensors along the length of the beam that carries the sensors. Typical beam length is 9 meters (30'). There are also skis with 12-meter (40') beams or longer. Non-contact skis can be set up to read a reference outside of the paving width or inside of the paving width.

Two mounting arms, either single or scissor-type, attached to the tow arm carry the non-contact ski.

It is important for the crew to have the correct mounting arms in order to install a non-contact ski. Two single arms are adequate to carry a ski that will be installed inside the paving width, or outside the paving width if the paving width is relatively narrow—say 3.6 meters (12'). The crew will need longer scissor-type mounting arms in order to install the ski to reference the grade outside the paving width for wider paving—say 4.9 meters (16').

Cat non-contact averaging ski installed to reference grade outside the paving width.

Install the non-contact ski so the center of the beam (balance point) is located somewhere between the center of the tow arm and the tow-point connection. The closer the balance point is to the tow-point connection, the slower the screed reaction will be.

The Cat non-contact ski has three vertically adjustable poles that carry the grade sensors. Measure the height of each sensor above the grade reference. They do not have to be exactly the same height, but they all should be within the recommended range of 40 to 46 cm (16" to 18"). When benchmarking (nulling) the grade control system on that side of the paver, each sensor will be measuring the grade based on its own benchmark.

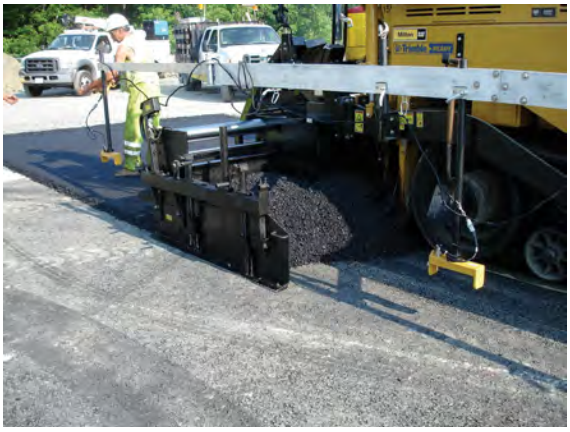
Follow these installation guidelines for all types of electronic, non-contact skis.

All three grade sensors on the Cat non-contact ski should be parallel to the direction of paving with the cable connection on the sensor toward the rear of the paver.

Cat non-contact ski setup to reference grade inside the paving width.

User Tip: *On some types of non-contact skis, the cable connections that attach to the sensors are numbered. The cable connection labeled as number one should be attached to the sensor closest to the front of the beam. The other cable connections attach to the sensors in numerical order, front to back. If the crew attaches the connections to the sensors in reverse order, the grade control system may act erratically. Caterpillar recommends clearly labeling each cable end, so the crew always installs the cable connections in the correct sequence.*

When a non-contact averaging ski extends over the screed, the last grade sensor will use the surface of the new bituminous layer as the grade reference. This reference will probably provide the most uniform grade measurement of all the sensor signals sent to the control module. Therefore, the averaging factor is improved and the ride quality of the layer will be enhanced. Caterpillar recommends, whenever possible, that the non-contact ski be setup to have the last grade sensor over the new bituminous layer.



The last sensor on the Cat non-contact ski is set to reference the surface of the layer directly behind the screed.

User Tip: *Some sonic grade sensors have foil transducers that emit sound pulses. Foil transducers can be affected by extreme heat and asphalt fumes. When setting up a sonic sensor with a foil transducer over the hot bituminous layer, be sure to inspect that sensor at the end of the shift. Look for wrinkles or the accumulation of an oily film on the transducer. Be prepared to replace the damaged transducer.*

User Tip: *When using any type of averaging ski, Caterpillar recommends taking off from the starting reference in the manual mode. Establish layer thickness manually, then benchmark the ski and enter the Auto mode for grade control. Remember, making depth changes when using an averaging ski takes a long time. It's easier to make depth changes manually and let the ski do the work of improving smoothness.*

Cat non-contact averaging ski with end sections folded and set up to use only the center sensor for a single sensor application.

As pointed out earlier in this unit, the number of sensors that are active on the Cat non-contact ski can be selected by using the Sensor Select function on the display.

When utilizing the Sensor Select function to choose one active sensor on the non-contact averaging ski, the center sensor measures the grade reference and sends a signal to the control module. It is not necessary to remove the ski. It may be necessary to position the mounting arms in a location that allows the center sensor to provide the best screed response. The remaining sensors may need to be disconnected in order to eliminate feedback by the active sensor.

Non-contact averaging skis are preferred for some applications rather than mechanical, contact-type averaging skis. Some of the reasons may include:

- Time constraints. Since the non-contact ski is attached to the side of the paver and is independent of the grade, it remains on the paver when the crew relocates to a new position on the project. Saving time is especially critical during night shifts when there is a need to reopen a roadway to traffic at a certain time.
- Obstacles in the grade. On some projects, obstacles may be encountered like drain inlets or utility boxes. Contact-type skis are affected by these obstacles. Non-contact skis can pass over these obstacles easily.
- Grade reference is acceptable. Electronic averaging skis do not have as much averaging capability as mechanical skis. However, if the grade reference (milled surface, for example) does not have extreme roughness, an electronic averaging ski is adequate and will be preferred because of its convenience compared to a mechanical ski.
- Smoothness specification is moderate. There are many smoothness measurement systems. Profile Index, which was the most common system for many years, is being replaced in many areas by the International Roughness Index. Other areas use a system referred to as Ride Number. Each Public Works Department chooses the system it prefers and then sets standards for the contractor to meet. If those standards are somewhat easy to satisfy, then an electronic averaging ski will be preferred because of its set-up convenience.

Mechanical, contact-type skis

Mechanical averaging skis have been in use since at least the 1950s. Their development was based on the need to improve ride quality even more than what can be accomplished by the floating screed. Remember, the floating screed tends to minimize grade deviations based on the distance from the tow-point connection to the front of the main screed. A mechanical averaging ski doubles or triples that length. A mechanical ski also tends to isolate the tractor portion of the paver from grade deviations.

Numerous references are used with mechanical skis. Some of the first were traveling stringlines and solid beams. Those types of averaging devises provided a grade reference for a sensor that was a 50 percent improvement. In other words, if there is a 25 mm (1") bump in the grade, that deviation will be 12.5 mm (0.5") at the center of the averaging device.

Modern mechanical skis provide a reduction of grade deviations that is approximately 88%. In other words, if there is a 25 mm (1") bump in the grade, that deviation will be 3 mm (0.125") at the center of the averaging device.

Like the electronic, non-contact skis, typical mechanical skis are 9 m (30') long. Longer 12 m (40') versions are also available.

Two basic types of mechanical skis are used: skis that ride outside the paving width and skis that ride inside the paving width.

The Cat 9-meter (30') multi-articulated outboard leveler reads a grade reference outside the paving width. This mechanical averaging ski is also available in the 12 m (40') length. The 9-meter (30') outboard leveler consists of three 2.5 m (8') aluminum sections that are bolted together after transportation to the worksite. Each section carries two shorter beams (about 1 meter / 3 feet long) through articulated connections. Each short beam carries two short contact runners (about 30 cm / 12" long), also through articulated connections.

The 9 meter (30') ski will bridge, or fill in, a depression up to 9 m (30') long. The 12 meter (40') version extends that bridging capability

The outboard leveler is extremely good at reducing roughness in the grade being referenced. When a contact runner goes over a bump, that bump is reduced by 50 percent at the articulation connection between the contact runner and the short beam. The deviation undergoes another 50 percent reduction at the articulation connection between the short beam and the main beam section. Another 50 percent reduction of the remainder of the deviation occurs at the center of the leveler. The three reductions in roughness represent an 88 percent improvement at the center of the leveler where the grade sensor should be located.

Cat 9-meter (30') multi-articulated outboard leveler averaging adjacent layer, while matching the longitudinal joint.

Whenever possible, Caterpillar recommends the use of mechanical skis when encountering a high degree of roughness in the base to be paved. When using a mechanical ski and best paving practices, a 60 percent to 70 percent improvement in ride quality measurements should be realized when initial roughness is high. More information about paving techniques for smoothness is contained in Unit 7.

9-meter (30') multi-articulated, outboard leveler used to improve an extremely rough grade.

The Cat Fore 'N Aft Leveler is frequently installed when there is no suitable grade reference outside the paving width or when the paving width is so great that an outboard leveler cannot be installed. The Fore 'N Aft Leveler consists of one 2.5 m (8') aluminum beam with two articulated short beams. Each of the short beams has two articulated contact runners. So the front section is very similar to the outboard leveler. A post extends from the center of the main beam. A string extends from the post on the front section over the screed and connects to a post on a following beam behind the screed.

Cat 9-meter (30') Fore 'N Aft Leveler provides averaging capability inside the paving width.

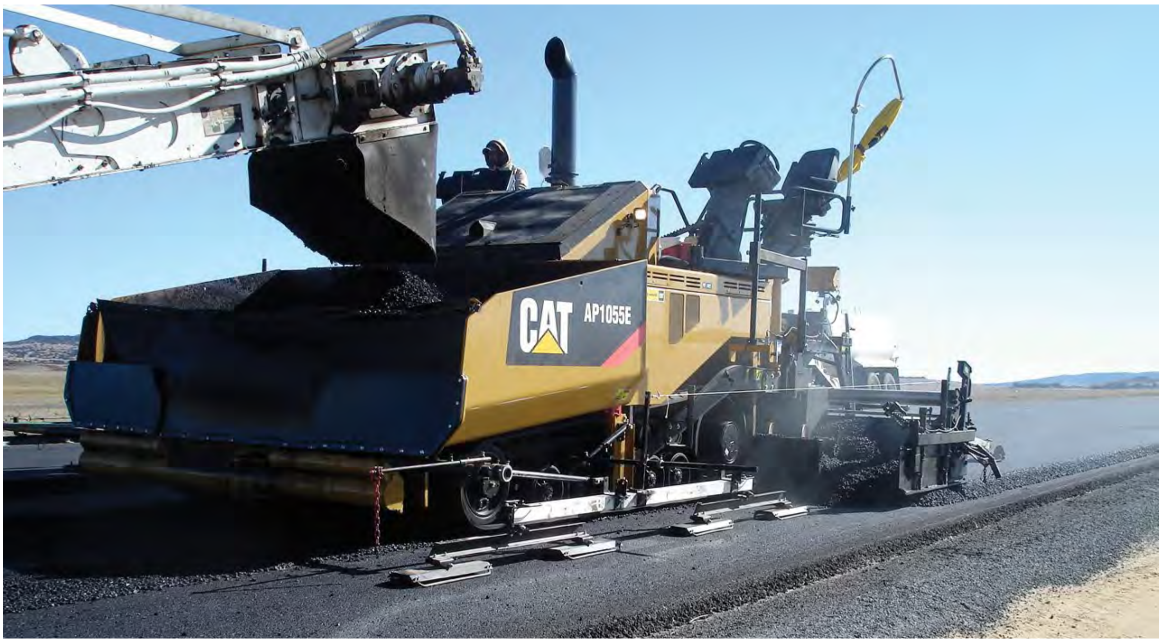
The following beam with string post has an articulated pan that rides on the new bituminous layer. The string that extends between the two posts is 9 m (30') long. The center of the string has a roughness reduction factor similar to the outboard leveler.

The rear section of the Fore 'N Aft Leveler rides on the new bituminous layer.

User Tip: *While heating the main screed plate and the extender screed plate, heat the drag pan on the trailing beam. Most crews use charcoal to heat the pan so it won't stick to the hot bituminous material. A propane torch can also be used for faster heating.*

Both types of Cat mechanical skis are towed by the tractor portion of the paver. The front tow arm has a collar that pivots around a shaft extending from the tractor steering guide arrangement. The tow arm always tows the ski; it never pushes the ski. The tow arm should be nearly parallel, or slightly nose up, to the beam of the ski.

The rear section of the Fore 'N Aft Leveler is attached to a shaft extending off the tractor frame. The rear section of the Outboard Leveler is attached to a shaft extending off the back of the screed. These connections are guide mechanisms that help keep the levelers straight.



The tractor tows the mechanical averaging ski.

The center of the stringline that spans the leveling devices is the point of maximum averaging. The most improvement in ride quality occurs when the center of the string is just behind the tow-point connection and the sensor is located above the center of the stringline.

The string itself should be multi-strand at least 3 mm (0.125") in diameter when using a sonic sensor. Do not use monofilament line or wire. They are poor targets for sonic sound pulses.

The string must be taut, especially when using a mechanical grade sensor. The sensor wand will always exert some downward or upward pressure on the string. The string has to be taut to avoid being bowed by the wand pressure.

The string should be at least 10 cm (4") above the body of the ski. If the sonic sensor loses the string as its target or if the mechanical sensor wand slips off the stringline, the Cat Grade Control System will lock to grade. That is to say, the system will ignore any sudden grade deviation that is in excess of 5 cm (2").

Mechanical or sonic sensors have equal accuracy using the ski stringline as a guide.

Cat sonic grade sensors are oriented horizontally when reading a stringline.

Use the Sensor Select function on the display to select the sonic sensor with stringline or mechanical sensor. Turn the sonic sensor horizontally to the stringline and center the sensor over the stringline. Always have the sensor cable connection on the left side of the sensor. Having the cable on the left side enables the outer transducers to act as guides for sensor location over the string. The display will indicate to the operator if the sonic sensor is drifting right or left over the stringline.

Mechanical, contact-type averaging skis are preferred for some applications rather than electronic, non-contact averaging skis. Some of the reasons to choose mechanical averaging skis are:

- **Maximum averaging needed.** A mechanical ski is the better choice when there is a high degree of roughness in the grade to be paved. Remember, a mechanical ski like the multi-articulated outboard leveler has a predictable averaging factor of 88 percent.
- **No time constraints.** When there are no time restrictions on a project, mechanical skis can be used. Typically, those projects have long passes in one direction without the need to set back and restart. Those projects are typically day shifts in rural areas.
- **Difficult specifications.** When the threshold for earning the highest level of ride quality incentive compensation is difficult to attain, choose mechanical averaging skis whenever possible. An example would be whenever there is a need to be under 0.6 meters per kilometer (40" per mile) using the International Roughness Index. Or, when using Profile Index with zero blanking band and there is a need to be under 16 centimeters per kilometer (10" per mile).

Mechanical ski is the better choice when there is a high degree of roughness in the grade to be paved.

Cat Paver equipped with Trimble three-dimensional guidance system.

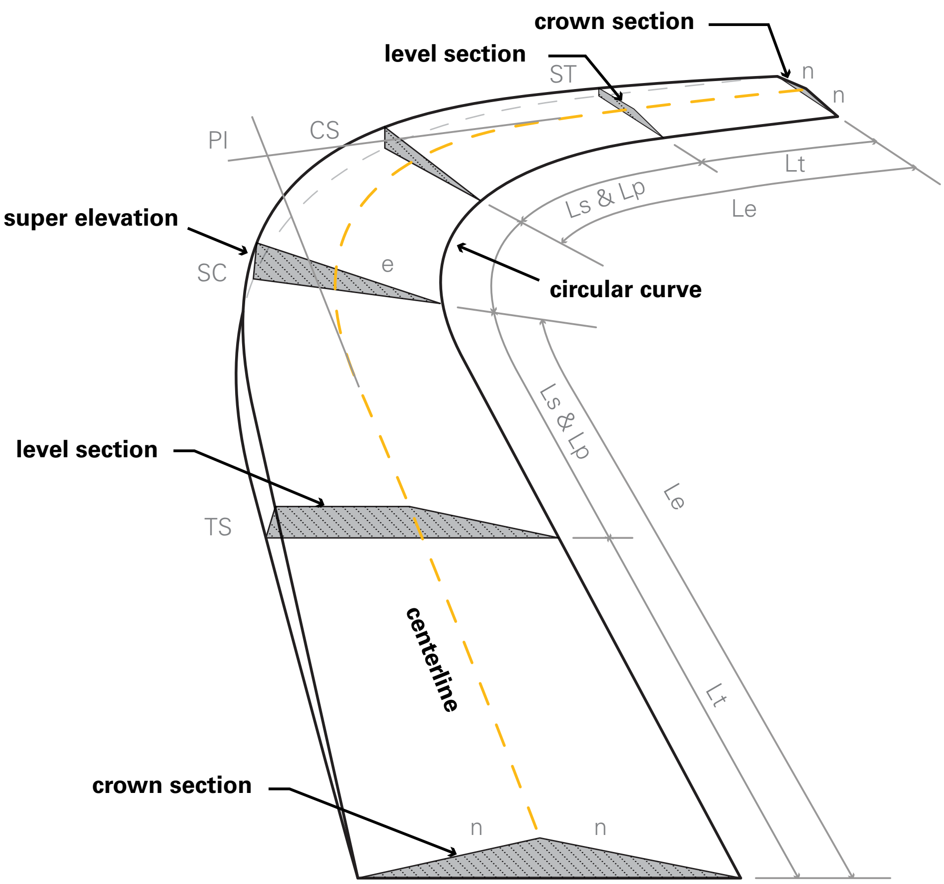
[THREE DIMENSIONAL PAVING]

The material in Unit 6 to this point has referred to on-machine grade and slope control. These types of guidance systems are sometimes referred to as two-dimensional systems. They control the screed based on measurements of the grade or slope as paving progresses. Another type of guidance system is available. Systems referred to as three-dimensional receive the input that controls screed reaction from sources that are independent of the paver.

A wide range of construction equipment uses three-dimensional guidance systems. This list of applications ranges from initial phases of surveying, clearing and earthwork to the preparation and compaction of the final aggregate base to paving and finally to pavement maintenance.

On a Cat Paver, the Trimble PCS900 provides an upgrade to Trimble or Cat control systems already in place on the paver.

A Universal Total Station provides off-machine guidance feedback for the paver.



Universal Total Stations perform stake-less surveys and can create complicated designs.

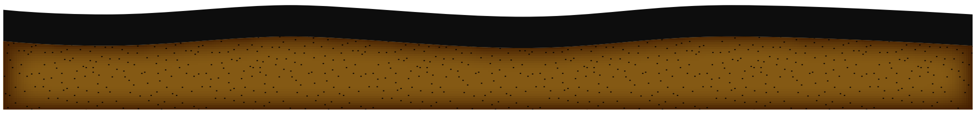
To provide the off-machine guidance that is necessary for three-dimensional paving, there must be at least one Universal Total Station on the project. For extreme accuracy (+/- 1.75 mm / 0.07"), stations should be within 350 m (1,150') of the paver. They provide continuous design feedback to receivers on the paver. The information can relate to a design that was created through original surveys done by the station or to a map of the existing structure that was created by a cold planer, for example.

Design information created and stored by the three-dimensional system can be transmitted to construction equipment during every phase of the project. From a paving standpoint, off-machine control simplifies working on difficult segments of a project—areas like super-elevations. The responsibility for looking ahead and reacting to slope changes on grade stakes is taken away from the operators and is done according to the design data and measurements transmitted by the Universal Total Station. Additionally, if all phases of earthwork and base preparation have been done using equipment under three-dimensional guidance, the final step, paving with expensive bituminous material will be done to precise yield calculations.

Machine targets are attached to masts that extend above the paver. The position of the targets is an indication of the position of the screed. This information is continuously sent to the control module. The control module signals the tow-point cylinder valves to move up or down to keep the screed at the design elevation and slope. The ability to integrate existing grade conditions with the design criteria gives three-dimensional guidance systems a significant advantage over two-dimensional systems. That advantage is the ability to create a layer that compensates for the rate of compaction in the layer.

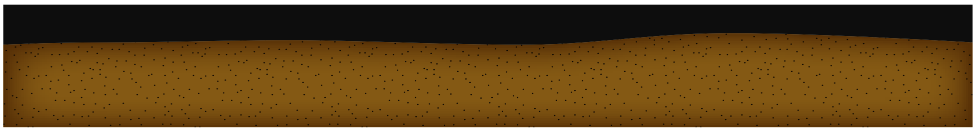
Machine targets on the paver are tracked by the Universal Total Stations.

ORIGINAL SURFACE (LONG LONGITUDINAL ROADWAVES)



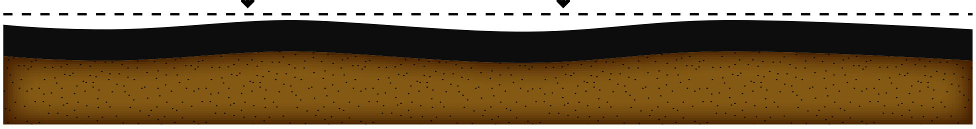
SURFACE AFTER PAVING TO DESIGN OR WITH A 2D SYSTEM

mat before rolling



SURFACE AFTER ROLLING

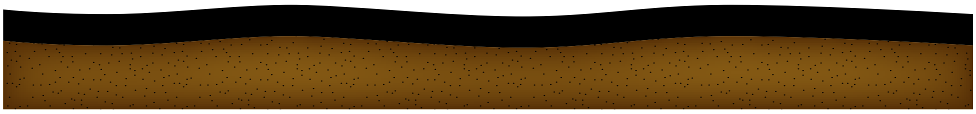
mat before rolling ↓ **mat after rolling ↓**



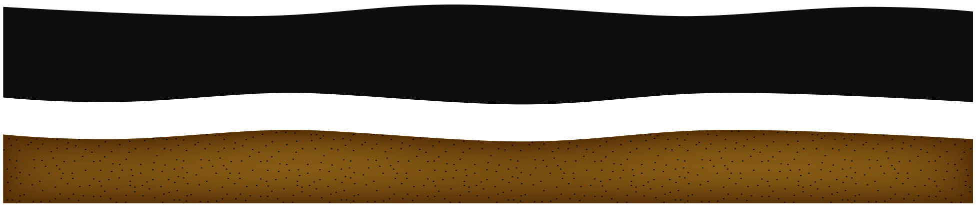
Using conventional two-dimensional guidance systems, it is possible to create an extremely smooth surface on a layer that is placed over an irregular grade. Using averaging skis especially, it is common to fill in low spots and level off high spots in the grade being paved. A wavy road can be made smooth by screed-laid material. However, due to the compaction rate – about 6 mm per 25 mm (0.25" per inch)—the layer with variable thickness experiences a variable compaction rate.

Consequently, the roughness of the original grade returns to a certain extent after compaction. The surface is smoother, but it can be even better.

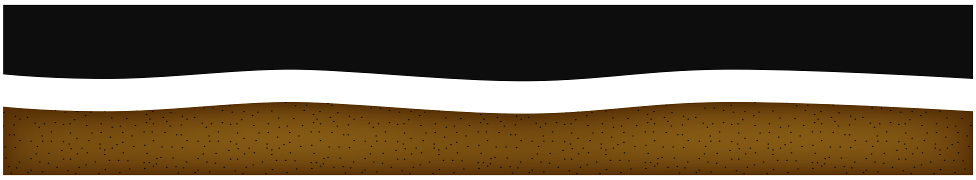
ORIGINAL SURFACE (LONG LONGITUDINAL ROADWAVES)



3D PAVED SURFACE (USING THE DIFFERENTIAL DESIGN)



3D PAVED AND COMPACTED SURFACE (DIFFERENTIAL DESIGN)



A three-dimensional control system can accept the compaction factor (in this case 1.25) and plan for the compaction factor in the design. The screed will be directed to increase thickness even more when paving over low spots and to decrease thickness when paving over high spots in the grade. In this example, the differential compaction will produce a smoother, more level surface.

Many types of projects are candidates for three-dimensional paving. Airport runways and aprons that need precise elevation control are already being completed with three-dimensional guidance systems. Large highway projects, both new construction and repair, benefit from close control of yields and improved smoothness. Contractors doing large site development projects are finding that survey work and machine control with three-dimensional systems save time and reduce costs.

[SUMMARY]

Automatic grade and slope control on pavers is an option designed to make the crew's jobs easier and to improve the quality of the final product. A crew that is well-trained in the uses of grade and slope control can set up the paver to be successful on all applications. Crewmembers must know the important considerations on any given project, and then should be able to decide what type of screed response is needed for the application. They should know how sensor position affects screed reaction. They should be able to select and install averaging skis that are correct for the application.

Remember, the use of grade and slope control cannot overcome defects caused by the crew violating fundamental paving practices or by making big mistakes. Make sure the fundamentals are done correctly every time and do not take shortcuts.


CAT
AP1055F
1096
GRADE CONTROL

Unit 7
PAVING APPLICATIONS

While each application presents its own challenges, paving fundamentals typically remain constant. The use of automatic grade and slope control is one of the few key success factors that changes with almost every application. Grade Control and other technological advances have helped contractors become more successful while handling challenging worksites and major applications.

Unit 7 focuses on successful techniques used in a variety of paving applications. Each application presents its own challenges and some require the use of special options or equipment. In general, however, the fundamentals of paving are the same for every application. Likewise, the need to be efficient and to avoid mistakes is the same for every paving application. However, one important factor that changes with almost every application is the use of automatic grade and slope control. Therefore, setting up and using grade and slope control systems are focal points covered in this unit.

Not every paving application or variable can be addressed in a publication on paving. As much as possible, this unit will cover the major applications, as well as those that typically are the most challenging. The general topics that are found in this unit include:

- Butt joint preparation
- Paving for yield (thicknesss)
- Paving for smoothness
- Paving for transverse profile (slope)
- Paving to elevations
- Longitudinal joint construction
- Paving super-elevations
- Truck exchange procedures
- Windrow paving techniques
- Paving with material transfer vehicles
- Balancing production (paving speeds)
- Echelon (staggered) paving
- Roller compacted concrete
- Paving aggregate base

[BUTT JOINT PREPARATION]

A butt joint is commonly defined as the transverse intersection of a previously laid and compacted bituminous layer with a new layer of hot or warm bituminous material. Butt joints, usually in conjunction with some sort of thin boards or metal strips are often the starting point of a paving pass. Too frequently, the transverse butt joint is an area of significant roughness and isolated bumps that requires grinding to meet smoothness or bump-control guidelines. The ultimate goal of transverse joint construction and compaction is to build a joint that is smooth and durable.

A large part of proper transverse joint construction is preparing the paver. Unit 4 covers preparing to pave with a vibratory screed. Unit 5 covers preparing to pave with a tamping and vibratory screed.

Following are other steps that will help assure that the butt joint is ready to be part of the starting reference for the paver.

The end of a pass is prepared, so creating a butt joint is easy when paving resumes.

When the crew completes the paving pass at the end of a shift or at the end of a designated distance, leaving enough material in the auger chamber is a good practice, so the screed maintains its elevation until the paver is stopped. When the operator picks up the screed and pulls forward, the head of material that was in the auger chamber should be uniform in size across the width of the layer. The crew should then put down some non-stick material and rake out the remaining asphalt over the ground cover, building a tapered ramp for the compaction equipment and for traffic, if any.

If the crew has a habit of using most of the material in the auger chamber before stopping at the end of the pass, the screed will lose elevation. The surface of the bituminous layer at the end of the pass will have a downward slant. If the butt joint is located within the area of downward slant, the screed will take off with a downward direction and the layer will be too thin.

Mark the location of the butt joint where the layer is flat and not slanting downward.

Check the condition of the compacted layer with a slope board or electronic slope meter when preparing to pave. Find a location where the layer is flat and mark that location. Remove the material in front of that mark.

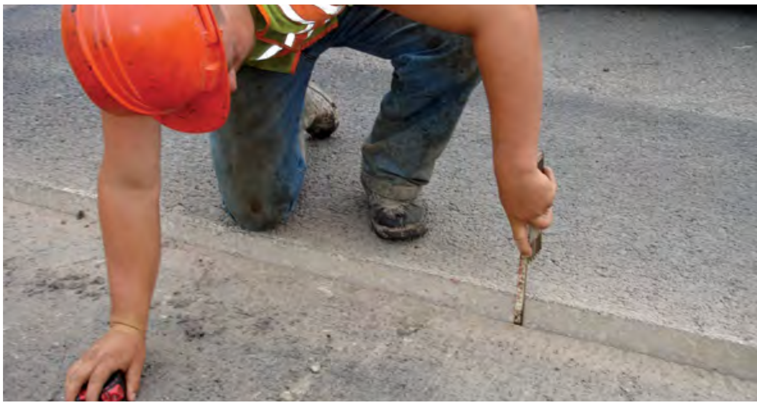
User Tip: *One way to help find where the layer starts to slant downward at the end of the pass is to paint a mark on the layer at the point where the crew switches the feeder system from Auto mode to Manual mode. Screed operators commonly use manual feed to control the material in front of the screed at the end of the pass. As soon as they switch to the Manual mode, the forces in front of the screed begin to change and screed elevation becomes variable.*

Cut a straight face for the butt joint. A rotary saw with adjustable depth control is the most common device. Use a skid steer or small loader to remove the material in front of the butt joint. Sweep the area in front of the butt joint and a short distance back from the butt joint.

A butt joint should have a straight, vertical face.

Note: *Never take off from a joint having a rounded face. In some applications, a cold planer works immediately in front of the paver. After the cold planer makes its plunge cut, the face of the butt joint forms an arc. Take the time to vertically cut the face with a saw before paving resumes.*

Most crews use some sort of thin wooden boards or metal strips to create the correct pre-compaction height at the transverse joint. For mats laid by a vibratory screed, the rule of thumb is 6 mm (0.25") compaction for every 25 mm (1") of uncompacted thickness. For mats laid by a tamping screed, the assumption is 1 cm (0.4") compaction for every 5 cm (2") of uncompacted thickness. Those guidelines are fairly accurate, but are affected by the type of bituminous material being placed, the temperature of the material, and the type of screed being used. To be even more precise when selecting the thickness of the starter boards, measure the height of the vertical joint. Subtract that dimension from the thickness of the intended layer. The difference between those two dimensions is the compaction rate and the exact thickness of the required starter boards.



Measure the height of the butt joint to help select the correct starter board thickness.

Some crews are successful starting with the screed sitting directly on the bituminous layer about 1 m (3') behind the face of the butt joint and bringing the screed up slightly as the paver begins to pave to create the correct pre-compaction thickness at the transverse joint. Caterpillar recommends use of this technique only for relatively thin layers—no more than 5 cm (2") thick. Thicker layers require the assistance of starter boards at the butt joint.

Pay special attention to tack on the face of the vertical butt joint and the area just in front of the transverse joint. The tack truck with spray bar may not be able to coat the face of the joint completely. When using a spray wand or hand applicator, be sure the butt joint is thoroughly coated with tack before locating the paver over the joint.

If the crew has prepared the joint and the paver properly, the joint should need only minimal handwork prior to compaction.

Use a spray wand or hand applicator to apply tack to the face of the butt joint.

A properly built transverse butt joint requires minimal handwork prior to compaction.

[PAVING FOR YIELD]

Yield is the ratio of the weight of the actual material being placed versus the weight of material that has been estimated in a bid or contract based on length, width and depth. For example, if a project bid called for installation of 5 000 tonnes (5,500 tons) of material and the actual usage is 5 200 tonnes (5,720 tons), the calculated yield is:

$$\frac{5200\,T}{5000\,T} = 104\%\ \text{Yield}$$

Another common way to think of yield is in terms of length that can be paved by a certain amount of material when the weight of the material is known, as well as the planned paving width and paving depth. In that case, yield is the ratio of the distance actually paved over the calculated paving distance.

Consider this example. The compacted weight of the material is 2450 kg/m^3 (153 lb/ft^3). The compacted depth is 5 cm (2") at a width of 3.66 m (12'). If the average haul unit carries 18 tonnes (19.8 tons) and the distance covered by one truckload is 41 m (135'), what is the yield of that truckload of material? This calculation is more complicated. The simplest way to handle this calculation is to use the Paving Production Calculator or similar software.

YIELD CALCULATOR

- Trucking
- Paver Speed
- Compaction
- Windrow
- **Yield**
- Slope
- Thickness
- Job Summary
- Legal
- Exit

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[1.97] *in*	[50.0] *mm*
Paving Width:	[12.00] *feet*	[3.658] *meter*
Material Density Uncompacted:	[153] *lbs/ft³*	[2450] *kg/m³*
Truck Capacity or Total Tonnage:	[19.8] *ton*	[18.0] *tonnes*
Length of Mat at 100% Yield:	[131.38] *feet*	[40] *meter*
Actual Length of Mat produced:	[134.51] *feet*	[41] *meter*
% Yield for given truck load or tonnage:		[102]

Thickness:	[1.97] *in*	[50.0] *mm*
Length of Mat produced:	[134.51] *feet*	[41] *meters*
Width:	[12] *feet*	[3.658] *meters*

Using the Paving Production Calculator, yield can be calculated for the distance that one truckload of material will cover.

In this example, the actual distance covered by one average truckload of material is 41 m (135'). The calculated distance is 40 m (131'). The yield is 102 percent in this example. The same yield calculation can be prepared for the distance covered in one shift.

YIELD CALCULATOR

Trucking
Paver Speed
Compaction
Windrow
Yield
Slope
Thickness
Job Summary
Legal
Exit

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[1.97] *in*	[50.0] *mm*
Paving Width:	[12.00] *feet*	[3.658] *meter*
Material Density Uncompacted:	[153] *lbs/ft³*	[2450] *kg/m³*
Truck Capacity or Total Tonnage:	[2204.6] *ton*	[2000.0] *tonnes*
Length of Mat at 100% Yield:	[14628.58] *feet*	[4459] *meter*
Actual Length of Mat produced:	[14435.70] *feet*	[4400] *meter*
% Yield for given truck load or tonnage:	[80]	[99]

Thickness:	[1.97] *in*	[50.0] *mm*
Length of Mat produced:	[14435.70] *feet*	[4400] *meters*
Width:	[12] *feet*	[3.658] *meters*

Yield can be calculated based on the weight of material being placed in one complete shift.

Substitute total tonnes placed during the shift for tons carried by one haul unit. In one shift, for example, the crew has installed 2 000 tonnes (2,200 tons) of bituminous material. That weight should cover a distance of 4 459 meters (14,629'). That weight actually covered only 4 400 meters (14,435'). Therefore, the yield is 99 percent for that shift.

Length of paving and width of paving are easily controlled on most projects. The variable that most often affects yield is paving thickness. In most situations, the thickness of the bituminous layer must be closely controlled, if meeting precise yield goals is required.

In order to closely control the thickness of the bituminous layer, the crew has to consider several variables. First, is the transverse profile (slope) correct? If the slope is not correct and the crew is responsible for correcting the transverse profile, then it is very likely that yields will be incorrect. This is a very important point.

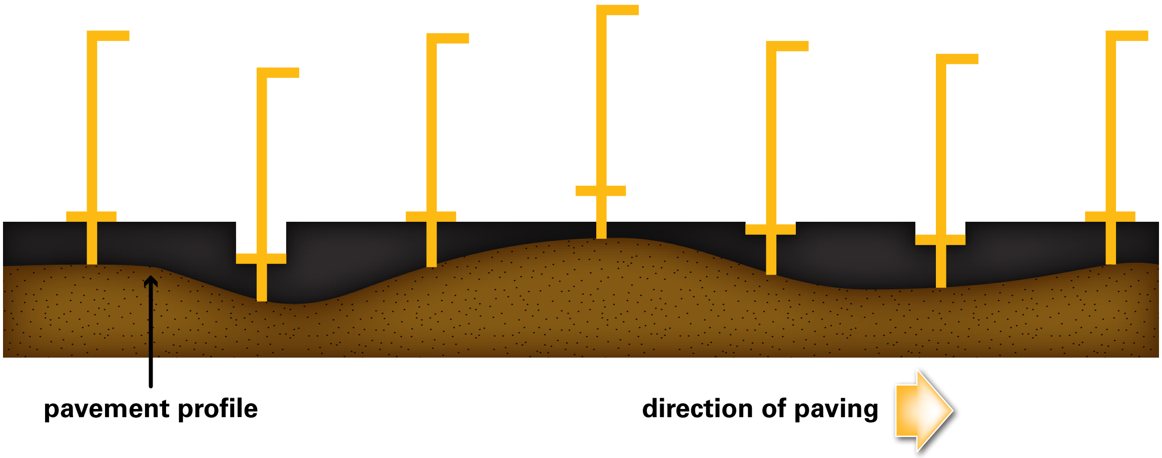
Paving with automatic slope control to correct the transverse profile created a thin layer of material on the right edge, resulting in incorrect yields.

Note: *Anytime that the transverse profile is being corrected by the paver, the project owner should be informed that yields will probably be incorrect.*

On another project, assume that the transverse profile is correct. There is, however, roughness in the grade to be paved, and the crew is being asked to improve ride quality. In that situation, the crew has decided to install averaging skis.

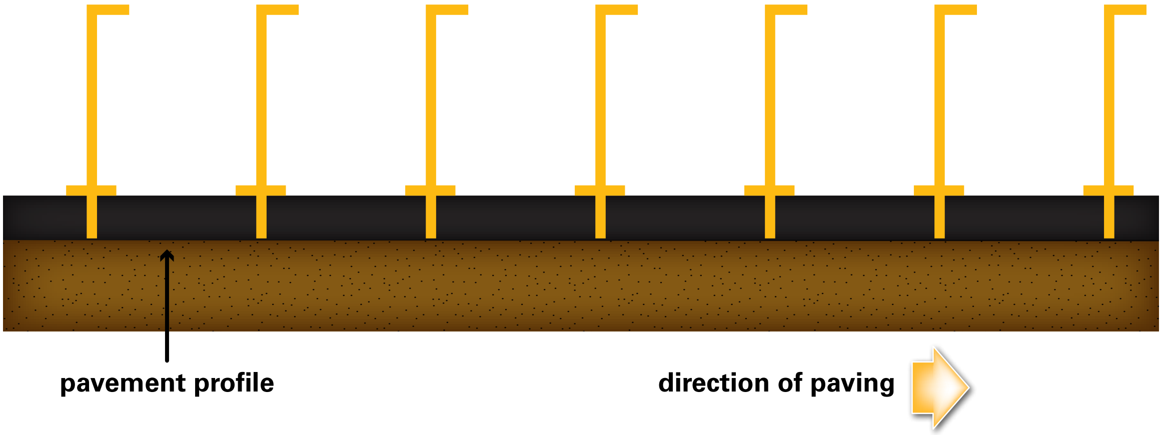
If averaging skis are making substantial improvements in the ride quality of the structure, there will be some yield variation. However, it is possible that at the end of a shift, the high spots and low spots will average out and the daily yield may be close to the calculated yield. The same can be said when the crew controls the thickness of the layer manually.

When averaging skis are used, the screed tends to fill in low spots and level off high spots with yields varying accordingly.



A series of depth measurements may show considerable variation when the screed is being controlled manually or if an averaging ski is installed.

Remember, the floating screed by its nature does not follow deviations in the grade. Rather, the floating screed, even without input from an averaging ski fills in the low spots and levels off the high spots. A series of depth measurements may show the thickness is too great in some areas and not thick enough in other areas. Do not make adjustments to thickness based on this series of measurements. Only make corrections when the layer is consistently thick or thin.

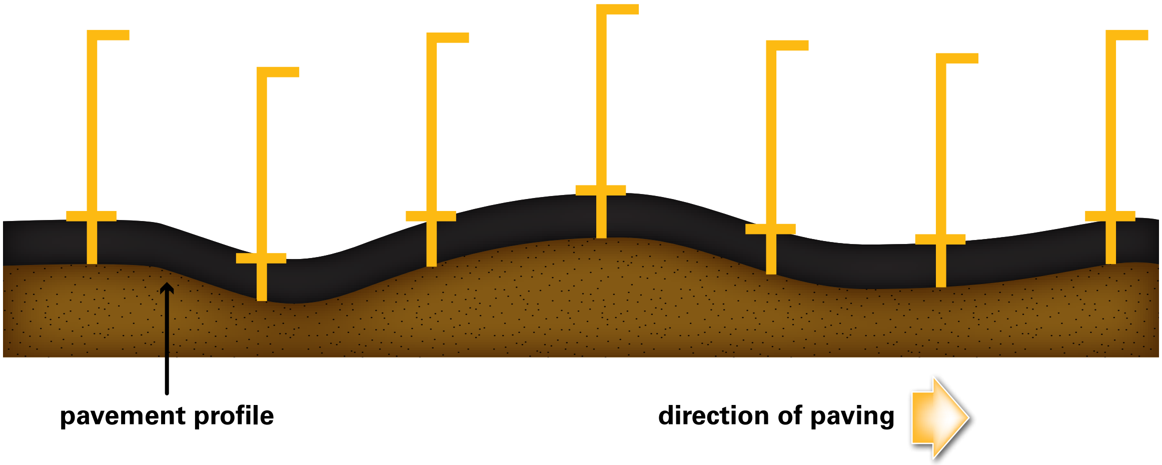


When the longitudinal profile is flat, it is easier to create a layer with uniform thickness.

If the grade is consistent over the bituminous layer being placed, it is easy to control thickness and yield. However, if the base has variations, there is only one way to control yield—pave with automatic grade control and a single sensor.

A single grade sensor installed close to the auger chamber provides the best control of layer thickness and yield.

The principles of Grade and Slope control are detailed in Unit 6. One of the principles dealt with how sensor position affects screed reaction. In order for the screed to follow the contours of the grade, position a single grade sensor adjacent to the auger chamber. Any grade deviation measured by the grade sensor will be transferred as a movement by the tow-point that is four times greater than the size of the grade deviation. The screed will react quickly. The layer thickness will change at exactly the location of the deviation—not good for smoothness, but great for yield.



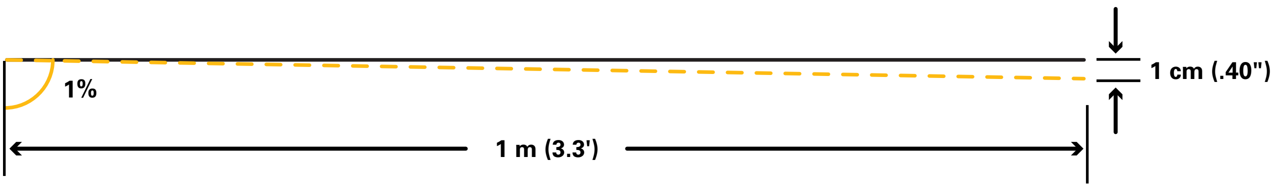
A screed that reacts quickly to grade deviations will create precise layer thickness and yield control.

The drawback to focusing on yield may be poor ride quality. If the longitudinal profile is rough and the Grade Controls are setup to control thickness, it is likely that longitudinal roughness will continue. If yield and layer thickness are the most important factors on a project, other factors may suffer.

[CREATING TRANSVERSE PROFILE (SLOPE)]

On many projects, the transverse profile or surface slope, of the bituminous layer is an important consideration. The slope of the structure accomplishes two important factors. One, slope controls the flow of water in the correct direction and to drain inlets, so moisture does not accumulate on the surface. Two, the transverse profile improves safety on curves (super-elevations).

If the longitudinal profile is rough and the Grade Controls are setup to control thickness, it is likely that longitudinal roughness will continue. The formula for calculating thickness changes when slope control is used to correct the transverse profile as described in Unit 6.



If the surface of the bituminous layer has a different slope than the base, the thickness of the layer will vary across the width of the layer. For every 1 percent of slope correction, thickness varies 1 centimeter per meter (0.125" per foot). To determine if the crew will use slope control and to determine whether slope will be controlled manually or automatically, check the slope of the base at numerous locations on the project.

Verifying transverse profile before paving helps the crew understand how to set up the paver.

If the application is placing the first base layer on granular material, check the transverse profile closely. Even if the grade trimmer or motor grader that finished the granular base material used some sort of automatic slope control, never assume that the slopes are correct. If discrepancies are found, notify the project owner or the engineer. They may want to correct the granular base before placing the more costly bituminous material. If discrepancies are found and paving must continue, notify the owner or engineer that the yields may be incorrect due to variable layer thickness caused by slope corrections.

Note: *In some areas, the use of slope control on the paver is required during installation of the first base layer on granular material. It is still a good idea to determine the accuracy of the transverse profile prior to paving.*

If the slope inspection reveals that slope corrections will be limited to 1 percent or less, automatic slope control can be used with confidence.

Set up the Cat Grade Control System for automatic operation after completing the steps to prepare the paver at the starting reference. To select slope control, tap the system status icon on the interactive display. The list of available sensors will show on the display. Tap the slope icon and depress the OK button.

Select slope control for the appropriate side of the paver.

Benchmark (null) the slope sensor by pressing and holding the Benchmark button (middle button) until the green “On Grade” light is illuminated. The system is in the manual mode at this time. Press and release the Mode Select button (second from bottom) and the word “AUTO” will appear in the system status area.

The slope value and slope direction shown on the display may or may not be correct at this time.

Check the slope of the screed while the screed is resting on the starting reference. Or, check the slope of the bituminous layer after the paver has pulled off the starting reference and the screed has reached equilibrium.

Verify the actual slope of the screed.

To calibrate the slope sensor, select the target slope value on the interactive display. Using the pop-up screen, enter the just measured slope value and slope direction. Depress the OK button to accept the value change and to return to the normal operating display.

By moving the appropriate tow-point cylinder up or down, automatic slope control will keep the slope of the layer within 0.05 percent of the benchmark value, if the deadband tolerance is not changed. The deadband can be set as low as 0.01 percent or as high as 0.50 percent.

To increase or decrease the slope benchmark while paving, depress the Up or Down arrow keys. Depressing and releasing an Up or Down arrow key changes the slope by 0.10 percent each time.

Calibrate the slope sensor with the measured slope.

Note: *The unit of measure for slope control can be changed to 0.01 percent, if desired.*

***Note:** The Cat Grade Control System has a unique feature called "cross coupling." When the cross coupling feature is set at the default value of 100 percent, the grade-side tow-point and the slope-side tow-point move at the same time for extremely accurate slope creation. If the default value is lowered, the slope sensor must sense the slope change and signal the tow-point valve independent of the grade-side tow-point. Caterpillar recommends keeping the default value for cross coupling unless the grade sensor is referencing an extremely rough surface.*

Some applications may require slope corrections that are greater than 1 percent. For those applications, it may be beneficial to control slope manually. Remember, the thickness of the layer changes as the difference between the desired slope of surface and the actual slope of the grade becomes larger or smaller. Since the tow-point makes large moves when automatic slope control is active, it is likely that the tow-point cylinder will be fully extended or fully retracted before the slope correction is complete. When the tow-point cylinder has no more stroke available, the screed operator has to "gain back cylinder." (See pages 167 and 168 in Unit 6.) If large tow-point movements are expected, manual slope corrections can be made to avoid losing tow-point cylinder movement.

The display serves as a slope monitoring system at all times.

The display used in the Cat Grade Control System constantly shows the actual slope value in Measured Values area when slope is selected. Slope is also shown in the text bar at the bottom of the display when the text bar is configured to show slope. Slope shows on the text bar no matter what other machine conditions have been selected, as long as the slope sensor is connected. Grade control can be used on either side in the AUTO or MANUAL mode. The slope value will not be affected and serves as a constant reference for manual slope control. Be sure to verify that the slope sensor is calibrated.

The most common way to control slope manually is to use the depth control screws that are features of vibratory screeds.

***Note:** Other grade and slope control systems have similar capability to monitor slope. Consult instructions included with other types of grade and slope control systems.*

MANUALLY DECREASING SLOPE

Assume that the system has been set up to control grade on the left side of the screed and that slope is to be maintained manually from left to right between 1.8 and 2.2 percent. Monitor slope using the right display. If the slope value on the display goes above 2.2 percent, layer thickness will need to be increased on the right side. Slowly turn the right depth-control screw in the direction of increase. Watch the slope value in the display. When the slope value starts to decrease, stop turning the depth-control screw. Remember, depth changes occur slowly over a distance equal to five tow arm lengths, and the slope value may continue to decrease. To stop the slope change, turn the depth-control screw in the opposite direction until no resistance is felt. At that point, the screed is at equilibrium and is floating without changing elevation (thickness).

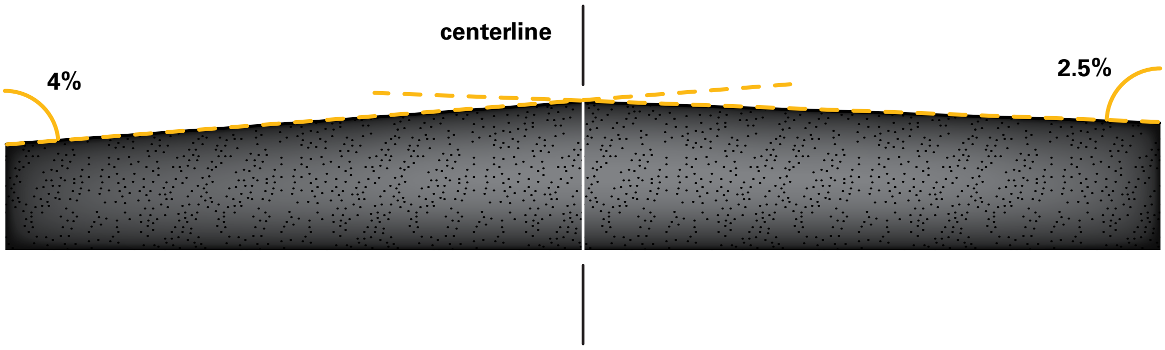
Under the same conditions, turn the depth-control screw in the direction to decrease layer thickness and, therefore, increase slope from left to right.

MANUALLY INCREASING SLOPE

User Tip: *Screed operators have to be alert for several conditions when making slope changes manually or automatically. When increasing layer thickness to correct the slope, the feeder system may tend to run faster due to the increased demand for material. The paver operator may have to make frequent adjustments to the ratio control dials to maintain the correct auger speed. Conversely, decreasing layer thickness to change slope, the feeder system may slow down too much. Or, more importantly, the screed may begin to drag aggregates, if the layer thickness is too thin to support the floating screed.*

Slope in conjunction with screed crown can be used to pave different slopes on either side of the structure's center line.

STRUCTURE WITH DUAL SLOPES



Some structures have slope left and slope right extending from a centerline. Sometimes the slope to the left and the slope to the right are not the same. The tendency would be to pave the left side of the structure in one pass creating the desired slope. Then, pave the right side of the structure at its specified slope. It is possible, however to pave this structure in one wide pass by simultaneously crowning the screed and sloping the screed. Setting up for this application requires some basic mathematics.

First, add the two slope percentages:

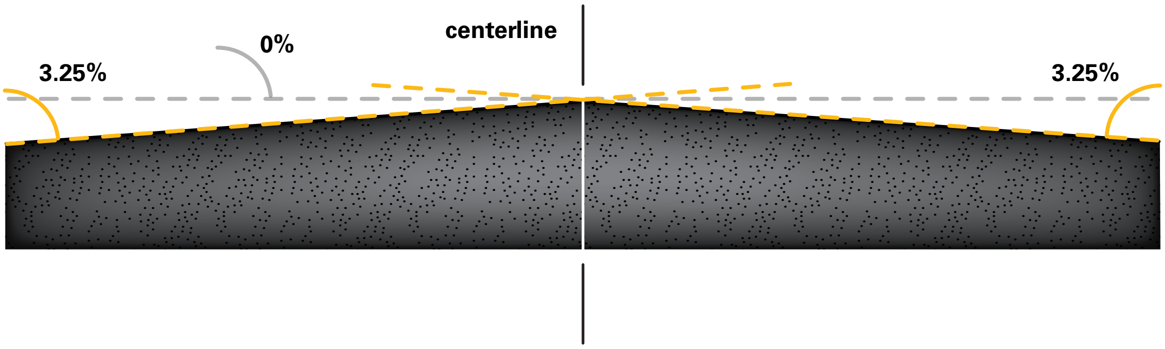
4% + 2.5% = 6.5%

Next, divide the sum of the slopes by 2:

$$\frac{6.5\%}{2} = 3.25\%$$

The result: The amount of crown in the main screed should be set to 3.25%.

CROWNED STRUCTURE



By crowning the main screed to 3.25 percent and centering the main screed directly over the centerline of the structure, the slopes will be identical on either side of the centerline. To create the desired 4 percent slope right and 2.5 percent slope left, the main screed will require slope. Determining the correct slope calls for some additional calculations.

Subtract the smaller slope from the larger slope:

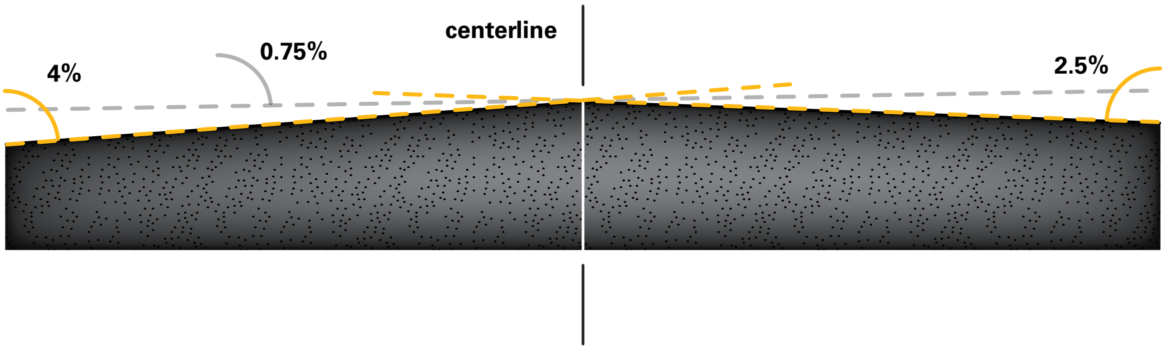
$$4\% - 2.5\% = 1.5\%$$

Divide the difference of the slopes by 2:

$$\frac{1.5\%}{2} = 0.75\%$$

The result: 0.75% is the amount of slope.

CROWNED & SLOPED STRUCTURE



The 0.75 percent slope from right to left decreases the right side crowned slope to 2.5 percent, and increases the left side crowned slope to 4.0 percent.

In summary, use slope control when the conditions require corrections to the existing transverse profile or when specified in the project plans. Slope control has two goals. One is to create the proper flow of water toward shoulders and/or drain inlets. The second is to have the proper contours for traffic safety. Be aware that slope control can interfere with yields and ride quality.

[IMPROVING RIDE QUALITY]

Everybody benefits from smooth roads and streets. In addition to the pleasure of operating vehicles on a smooth surface, other reasons are prompting public works departments to focus on specifications that require high levels of smoothness. First, research has proven that smooth roads last longer than rough roads—all other factors being equal. So, life cycle costs decrease; tax dollars have a bigger return on investment; and there is less disruption to traffic flow when repairs or maintenance steps are not as frequent. Second, smooth roads contribute to better fuel economy due to decreased rolling resistance. Less fuel consumed means fewer emissions.

Creating smooth bituminous layers involves managing the four factors that contribute to quality paving. Executing the fundamentals correctly and avoiding big mistakes are important for smoothness. However, the other two factors, paving efficiently and proper use of grade and slope control are even more important.

Most projects that have smoothness specifications lend themselves to efficient paving. Prior to paving, the superintendent or crew supervisor should calculate the paving speed that will minimize paver stops. There are formulas for calculating speed based on hourly tonnage, weight of material, paving depth and paving width. Software such as the Paving Production Calculator simplify the process of calculating paving speeds. (See Unit 2 for details on pre-project planning.)

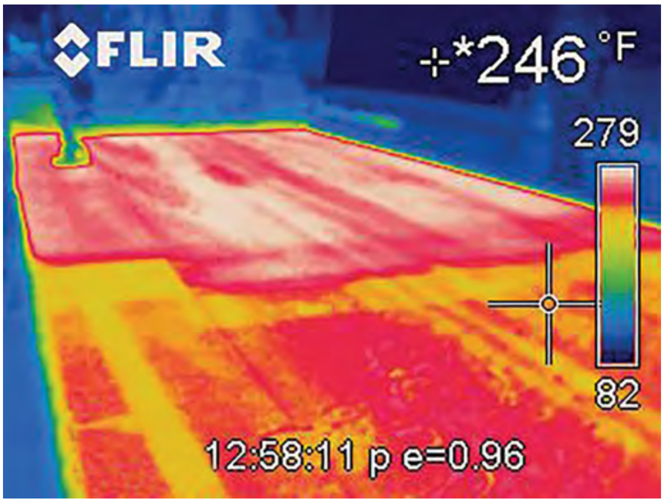
PAVER SPEED CALCULATOR

- Trucking
- **Paver Speed**
- Compaction
- Windrow
- Yield
- Slope
- Thickness
- Job Summary
- Legal
- Exit

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[2.56] *in*	[65] *mm*
Paving Width:	[16.00] *feet*	[4.877] *meter*
Material Density Uncompacted:	[140] *lbs/ft³*	[2243] *kg/m³*
Paver Speed @ Given Production Rate		
Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Calculated Paving Speed - 100% Efficiency:	[15.3] *ft/min*	[4.67] *m/min*
Calculated Paving Speed - 95% Efficiency:	[16.1] *ft/min*	[4.90] *m/min*
Calculated Paving Speed - 90% Efficiency:	[16.8] *ft/min*	[5.14] *m/min*
Calculated Paving Speed - 85% Efficiency:	[17.6] *ft/min*	[5.37] *m/min*
Calculated Paving Speed - 80% Efficiency:	[18.4] *ft/min*	[5.60] *m/min*
Calculated Paving Speed - 75% Efficiency:	[19.1] *ft/min*	[5.84] *m/min*
Effective Paving Speed:	[15.3] *ft/min*	[4.67] *m/min*

Paving speeds vary according to the efficiency factor.

On any project that has long passes, the minimum efficiency factor should be 75 percent. In other words, the paver should be placing material at least 45 minutes out of every hour. Ride quality improves as the efficiency rate goes up. Short interruptions to the paving process, typically during truck exchanges, are often unavoidable and do not necessarily mean that substantial roughness will result. But, the best ride quality occurs when paving is continuous—all other factors being equal. In the previous example, the best ride quality results if the paving speed can be maintained at 4.7 m / minute (15' / minute) for 100 percent efficiency. Ride quality will begin to deteriorate as the efficiency rate goes down. The crew can still place the hourly production rate by adjusting the working speed upward a little, but stops tend to create some roughness.



Temperature differential created by stopping the paver.

Paver stops can create roughness in two ways. One is by creating a temperature differential between the portion of the bituminous layer confined by the screed and the portion of the layer that is directly behind the screed in the area where the initial phase compactor cannot reach. Depending on the ambient temperature and the thickness of the layer, the material may lose heat rather quickly. When the temperature differential exceeds 15° C (59° F), there is likely to be a compaction differential. In other words, the hotter material confined by the screed will compact at a different rate than the colder material exposed to the ambient conditions behind the screed.

User Tip: *To determine how long it will take for a given layer thickness to lose 15° C (30° F) under specific ambient conditions), use PaveCool software. PaveCool is available as a download from the Minnesota Department of Transportation.*

Screed imprint in the bituminous layer created by stopping the paver.

The other way that paver stops may contribute to roughness is by creating a screed settlement mark in the surface of the bituminous layer. The depth of settlement marks is affected by several factors.

Mix Parameters

- Temperature (hotter mixes deform easier)
- Grain size (finer mixes deform easier)
- Gradation curve (well graded mixes deform easier)
- Stiffness (stiff mixes deform less)

Paving Parameters

- Layer thickness (thicker the mat, the deeper the dent)
- Paving width (the more extension, the deeper the dent)
- Ambient temperature (hotter the day, deeper the dent)
- Head of material (lower the head of material, deeper the dent)
- Length of stop (longer the stop, deeper the dent)

Paver Parameters

- Paving speed (higher the speed, greater the settlement)
- Tamper amplitude (higher the amplitude, lower the settlement)
- Tamper speed (higher the speed, lower the settlement)
- Screed set-up (higher the angle of attack, greater the settlement)

The initial phase roller may erase the settlement mark, but roughness is still a concern. For example, the grade and slope control system may react to the screed settlement when the paver resumes operation. Watch the tow-point. If the tow-point makes a significant move (more than 12 mm / 0.5") when the paver resumes operation, there will be enough of a layer deviation to be felt by a vehicle.

Cat pavers are equipped with a screed counterbalance system that reduces the amount of screed settlement during stops. Some Cat pavers also feature a screed lower lock system. Consult the Operation and Maintenance Manual for instructions about the operation of the screed counterbalance and screed lower lock systems.

Material transfer devices, this one equipped with a windrow elevating head, enable the paver to operate continuously at the same speed.

The use of material transfer devices makes high efficiency rates possible. With proper planning, it is possible to pave for hours without stopping or changing the paving speed.

Material transfer devices include machines such as windrow elevators that attach to the front of the paver and are pushed by the paver. Self-propelled material transfer vehicles that operate independently of the paver are also available. Some material transfer vehicles have as much as 23 tonnes (25 tons) of surge capacity. Inserts are often installed in the paver's hopper to increase the amount of material that is available while a new truck is being positioned to supply the transfer device.

It is common to have as much as 36 tonnes (40 tons) of total material available for production between trucks. Do not consume all of the material that is stored in the transfer vehicle or hopper insert when continuing to pave. Using all the material, especially if it is a large-aggregate base material, can cause segregation in the bituminous layer.

Assume that 27 tonnes (30 tons) is available for paving between trucks and a layer that is 65 mm (2.50") thick and 3.66 m (12') wide will be placed. The planned production rate is 200 tonnes per hour (220 tons per hour). The calculated paving speed at 100 percent efficiency under those conditions is 6.25 m / minute (20.5' / minute).

YIELD CALCULATOR

Trucking			
Paver Speed	**General Inputs**	*Imperial Units*	*Metric Units*
	Paving Thickness:	[2.56] *in*	[65.0] *mm*
Compaction	Paving Width:	[12.00] *feet*	[3.658] *meter*
Windrow	Material Density Uncompacted:	[140] *lbs/ft³*	[2243] *kg/m³*
Yield	Truck Capacity or Total Tonnage:	[30.0] *ton*	[27.2] *tonnes*
Slope	**Length of Mat at 100% Yield:**	[167.41] *feet*	[51] *meter*
Thickness	Actual Length of Mat produced:	[0.00] *feet*	[0.00] *meter*
Job Summary	**% Yield for given truck load or tonnage:**		[0]
Legal			
	Thickness:	[2.56] *in*	[65.0] *mm*
	Length of Mat produced:	[0.00] *feet*	[0.00] *meters*
Exit	**Width:**	[12] *feet*	[3.658] *meters*

The yield calculator provides length of paving for a given weight of material.

Use the Yield Calculator function of the Paving Production Calculator. If 27 tonnes (30 tons) are available in the transfer vehicle and insert, a length of 51 m (167') can be paved. At a paving speed of 6.25 m / minute (20.5' / minute), there will be just over eight minutes of paving production. If it is taking more than eight minutes to complete a truck exchange, something is wrong with the procedure. A truck exchange should take no longer than three minutes unless severe traffic congestion is encountered.

Caterpillar recommends the use of material transfer devices on projects that have a ride quality specification or anytime there is a need to significantly improve smoothness. Non-stop paving at a continuous speed will produce a 10-15 percent smoother ride compared to stop-and-go paving—all other factors being equal.

In addition to continuous paving at a constant speed, installation of averaging skis is another proven way to create better ride quality.

Mechanical averaging skis are suitable for applications where there are long passes and few obstacles such as drain inlets and utility boxes. Mechanical skis like the Cat 9-meter (30') Outboard Leveler should be installed when there is a suitable grade reference outside the paving width. Mechanical skis like the Cat Fore 'N Aft Leveler should be installed when the only suitable grade reference is inside the paving width. Caterpillar recommends using mechanical averaging skis on both sides of the paver when there is moderate to severe roughness in the surface to be paved.

Dual, mechanical averaging skis can produce up to a 60-70 percent improvement in one-pass smoothness.

Granular bases often have a high degree of roughness. Some milled surfaces have moderate roughness as well. Using the International Roughness Index as a reference, moderate roughness can be classified as total deviations between 1.9 m / kilometer and 2.8 m / kilometer (120" / mile and 180" / mile). Extreme roughness as measured by the International Roughness Index would be deviations in excess of 2.8 m / kilometer (180" / mile).

Caterpillar research indicates that a paver equipped with mechanical averaging skis on both sides and paving at a continuous speed can reduce roughness by 60 – 70 percent in one pass when moderate to severe roughness exists. For example if the grade deviations total 2.3 m / kilometer (150" / mile) prior to paving, the predicted deviations will be lowered to around 80 cm / kilometer (53" / mile) in one pass when dual mechanical averaging skis are installed on the paver.

During installation of another bituminous layer using a paver equipped with two mechanical averaging skis, another 20-40 percent smoothness improvement can be realized. Using the previous example, expected deviations can be lowered to around 56 cm / kilometer (37" / mile). The percentage of smoothness improvement will be even less if a third layer of bituminous material is added.

Non-contact skis are more versatile and more convenient than mechanical skis. Non-contact skis can be installed to reference grade inside the paving width or outside the paving width. Non-contact skis use electronic averaging to reduce roughness. The roughness reduction factor of non-contact skis is not quite as high as the roughness reduction factor of mechanical averaging skis. Non-contact averaging skis are most suitable on projects where there is light to moderate roughness in the surface to be paved. Excellent smoothness results have been obtained with non-contact skis on projects where the milled surface has the correct transverse profile and a reasonably smooth longitudinal profile.

Non-contact skis do not have to be removed in order to move the paver around the worksite. Therefore, Caterpillar recommends installing non-contact skis on projects with time constraints, like night shifts. Non-contact skis are not affected by obstacles like drain inlets and are preferred for their convenience by many crews.

Non-contact skis offer convenience and adequate averaging for surfaces with light to moderate roughness.

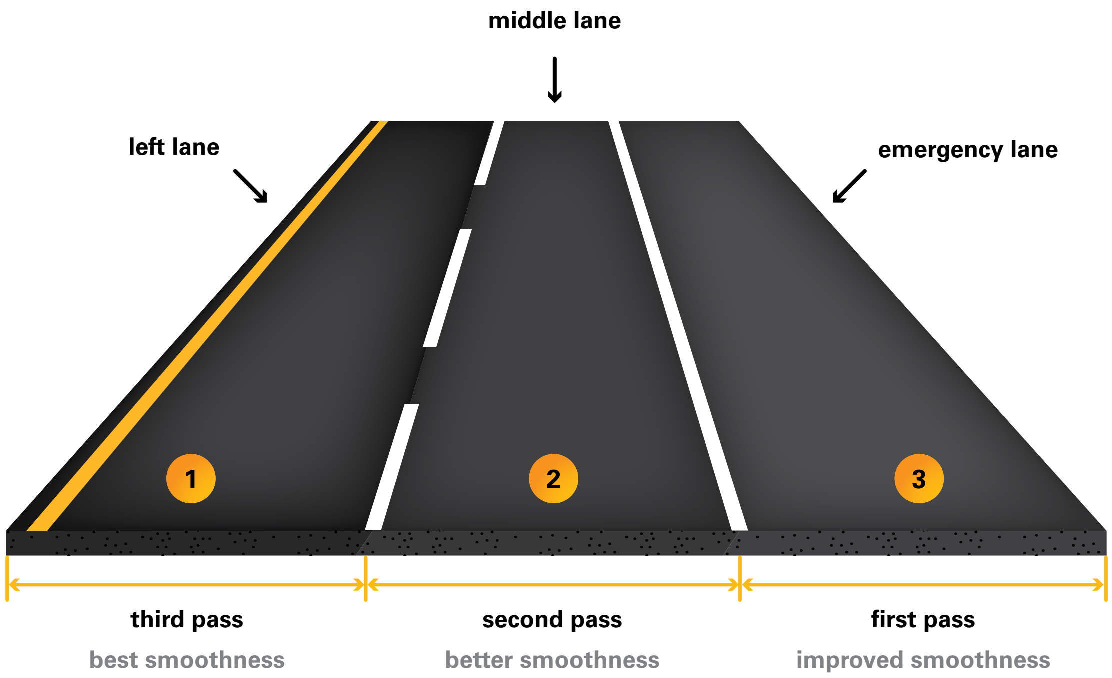
Another technique that can help improve smoothness in driving lanes is to pave the emergency lane (shoulder) first. When the emergency lane is paved first, it becomes an improved grade reference for the averaging ski when the paver works on the adjacent driving lane. Plans don't always specify paving the emergency lane first, but it is a good idea to ask for permission.

Paving emergency lanes first improves the smoothness of adjacent driving lanes.

The emergency lane that has been paved first should be a better grade reference than a milled surface, or granular base or even an existing bituminous surface. Plus, the emergency lane provides a place for the compactors to stop and reverse without leaving marks in the new layer of the driving lane. Remember, the emergency lane is not measured for smoothness. Only driving lanes are measured.

Smoothness will continue to improve as the paver completes adjacent driving lanes because the smoothness of the grade reference is constantly being improved.

Averaging ski using emergency lane as a grade reference.



Smoothness of the emergency lane should be improved when compared to a milled surface, for example. Then, the smoothness of the driving lane adjacent to the emergency lane will be better than the score of the emergency lane. Finally, the far left driving lane will have the best smoothness.

In summary, to maximize the smoothness of a bituminous layer, plan for continuous paving at a constant speed. Pave with averaging skis installed on both sides of the paver whenever possible. Choose the type of averaging ski that is appropriate for the application. Avoid the use of slope control unless it is a requirement of the specification or if the transverse profile needs correction. Whenever possible, pave the emergency lane first to provide an improved grade reference for the driving lanes.

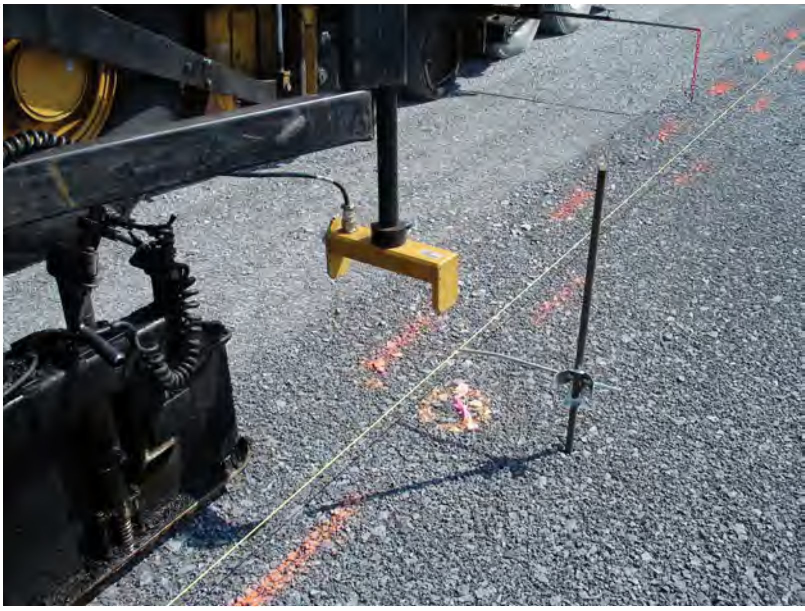
[PAVING TO ELEVATIONS]

As it relates to asphalt paving, the term elevation means the height above sea level of any geographic location. Various types of survey equipment, sometimes in conjunction with Global Positioning Satellites, measure elevations on construction projects. Surveyors record elevations, and engineers use them to help create the plans for a project. Some construction equipment that uses three-dimensional systems mentioned in Unit 6 incorporate the engineering plans in their guidance systems. More commonly, at least at the time of this guidebook's publication, the elevations of a bituminous structure, such as a highway or airport runway, are controlled by referencing a stringline or grid marks on a surface.

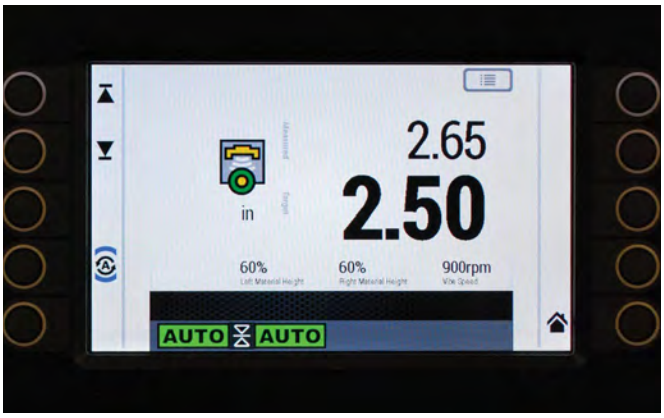
Controlling base layer elevation with an erected stringline on new highway construction.

User Tip: *The Cat Grade Control System has a feature called "cross coupling." When cross coupling is left at the default setting of 100 percent, slope control acts simultaneously with grade control corrections. There is no delay in tow-point movement on the slope control side. Slopes will be more accurate and the crew will have an easier time with joint matching as they pave any adjacent lane.*

A stringline can be used as the reference for elevation. The stringline can be a temporary device used for one phase of construction. Or, a stringline can be used for many phases of earthwork and paving all the way to the final bituminous surface layer. The stringline is a reference for one side of the paver. A sonic grade sensor or a mechanical grade sensor with a wand follower can be used to reference a stringline. The other side of the paver can use grade control or slope control. The use of slope control, either manual or automatic, is more commonly used on the side opposite the stringline. The grade side assures that the elevations are correct while the slope assures that the transverse profile will direct water in the right direction. Additionally, the elevations will transfer correctly across the width of the layer as long as the slope is correct.



Cat Grade Sensor in stringline orientation.



A stringline guidance symbol will appear on the screen when Sonic Sensor over Stringline has been selected. This view shows that the sensor is centered over the stringline.

There are a few things to remember when using the Cat Grade Sensor. First, orient the sensor so it is perpendicular to the stringline with the cable connection on the left side of the sensor when facing forward. Position the sonic sensor 40 to 45 cm (16 - 18") above the string and centered as much as possible over the stringline. The three center transducers will read the stringline and the average of those three measurements provide the signal sent to the control module. The outer two transducers enable horizontal guidance for the display.

When the operator selects the Sonic Sensor over Stringline icon in the Machine System area, the position of the sensor over the stringline is shown in the Guidance area. Five guidance symbols provide excellent visual reference.

A green circle around the yellow string means the sensor is centered over the stringline. (As shown in the adjacent illustration.)

A red arrow on either side of the yellow string means the sensor is slightly off center, left or right, but still functional and accurate.

If the center of the sonic sensor moves too far away off the center of the stringline, then the red arrow remains and the entire guidance symbol will be highlighted. As long as the stringline is more than 5 cm (2") above the grade or body of the ski, the sensor will lock to grade. Grade control is no longer functional and will not operate until the operator re-centers the sensor over the stringline.

Sometimes a stringline is not erected. Rather, elevations are marked on the grade to be paved. The elevations are laid out in a grid with marks spaced every 7.6 m (25'). The screed operator looks ahead to determine what elevation difference, if any, exists at the next mark.

A survey crew may mark elevations directly on the grade in a grid pattern.

The screed operator wants the elevation change, if any, to occur in less than 7.6 m (25'). Assume, for example, that the elevation change is 6 mm (0.25") upward from one survey mark to the next. The operator will push the UP arrow on the display five times. Grade control changes occur in increments of 1.3 mm (0.05") for every time the UP or DOWN arrow is pushed.

With the grade sensor located just ahead of the auger chamber, tow-point movement will be about three times farther than the distance of the correction that was called for. In this case, the tow-point will move up about 18 mm (0.75"). The screed will begin to move up immediately and will complete its movement to a new elevation in about 3.5 m (12'). A sensor located just ahead of the auger chamber is a good choice for following elevation changes that are 7.6 meters (25') apart.

Grade sensor position just ahead of the auger chamber helps create fast screed reaction.

The speed of the screed reaction can be affected by adjusting the Elevation Valve Speed. Enter the Installation Menu on the Home Display. Select Control Settings, then Valve Speeds, and finally Elevations. The default value is 50 percent. If faster screed reaction is needed, use the slider on the touchscreen to increase the value of the valve speed. Adjust upward, for example, to 75 percent and verify that elevation changes are occurring within the grid distance.

Increasing the value of the Elevation Valve Speed also speeds up screed reaction.

User Tip: *Caterpillar recommends using automatic grade control when paving to meet exact elevations. Grade control is extremely accurate and can be made to act quickly. If manual elevation control is used, the change in elevation will occur over a distance of about five tow arm lengths or 12 meters (40').*

Producing a straight edge to match is the first step in longitudinal joint construction.

[CONSTRUCTION OF LONGITUDINAL JOINTS]

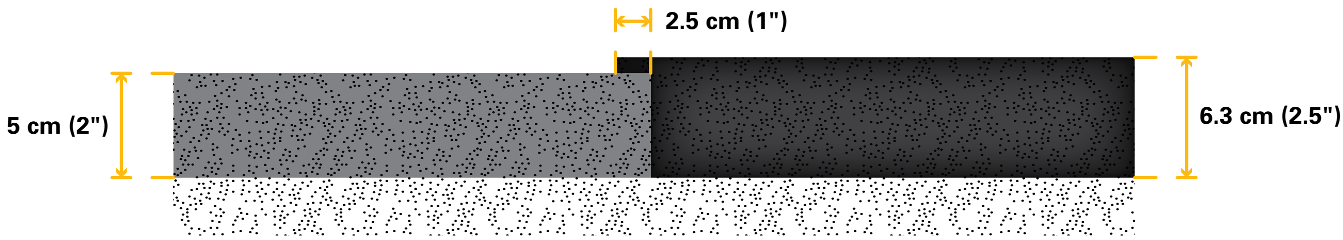
Poor longitudinal joint construction is recognized as one of the major problems in bituminous pavement construction. Considerable research has been done over the years with no universal solution other than eliminating the joint. The solution to the problem, as dictated by some public works departments, is to pave wider passes with no joints between lanes or to pave in echelon. Realistically, these solutions are not always possible and cost effective. Echelon paving and full-width paving techniques, covered later in this unit, may require closing entire roads for paving and possibly stretching capacities for pavers, rollers, and asphalt plants. This section assumes longitudinal joint construction consisting of a hot / cold or hot / warm joint.

In order to be successful at longitudinal joint matching, the crew has to have an unconfined edge that is straight and reasonably smooth. Prior to the start of paving, create a steering guide for the paver operator. Lay out the paving pass and position the paver and screed extensions so any changes to the paving width are accomplished using the side of the paver that will not have a joint match. Caterpillar recommends running the end gate skis down so they float on the grade being paved and create a straight vertical face on the edge that will be matched.

To promote the bond between the cold side of the joint and the hot side, the face of the joint should be thoroughly covered with tack or joint adhesive. Be careful not to overlap the joint with the spray bar too much onto the cold side. The end gate ski will ride on this surface and may be affected by the sticky tack. Plus, the area close to the joint may be used as reference for a mechanical, contact-type averaging ski. A contact ski can be affected by the build-up of tack on its runners or shoes.

Tack or adhesive must be applied to the face of the joint, as well as the base prior to paving.

CORRECT SQUARE JOINT — END GATE DOWN



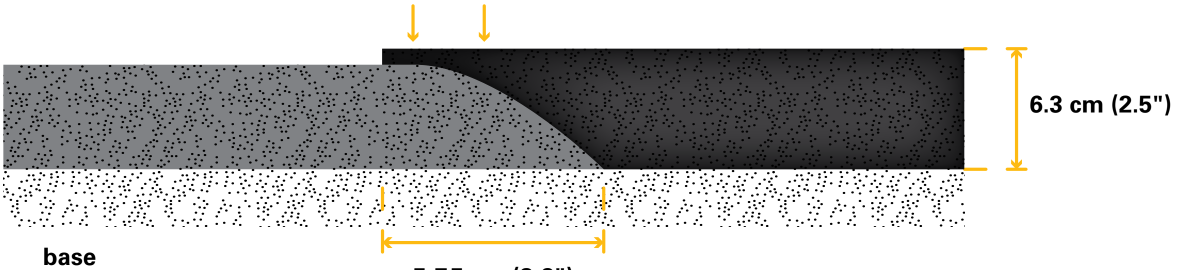
With the end gate ski floating on the cold side, overlap the cold side up to 25 mm (1").

Once paving has started, maintain a slight overlap onto the cold side of the joint. When matching a straight line, the extender should not have to constantly move in and out. Up to 2.5 cm (1") overlap is acceptable. If there is excessive overlap, a laborer will have to rake the extra material away from the joint over onto the hot side of the joint. Maintain the height of the hot mat according to the compaction rate of the material. For example, to match a compacted layer that is 5 cm (2") thick, the thickness of the hot matching layer may be 6.3 cm (2.5"). If there is an incorrect height match, a laborer will have to rake the joint.

While light bumping of the joint is acceptable, longitudinal joint raking should be avoided as much as possible. Raking tends to push material away from the face of the joint and, depending on the size of the aggregate in the bituminous mixture, can cause a segregation stripe adjacent to the joint. Raking has a negative effect on joint durability as it increases permeability allowing moisture penetration. The goal should be to always construct longitudinal joints that do not need to be raked.

Too much overlap or incorrect height match can cause excessive raking of the joint.

INCORRECT SQUARE JOINT — END GATE UP



Running end gates up creates joint problems.

When creating an edge for joint match, always run the end gates down on the grade. When paving with the end gates up, which some operators like to do to gauge layer thickness, the edge of the layer will be rounded, especially after compaction. The overlap is too much when the joint match pass extends on to the cold side. And, more importantly, there will be an area over the joint where the screed is dragging aggregates due to loss of layer thickness. The compaction process will fracture aggregates in this area. The two flaws that should be avoided at the longitudinal joint—poor density and high permeability—will be more likely to occur.

Specialty longitudinal joints may be required. Some public works departments specify notched wedge joints for two reasons. First, in some high traffic areas, it is prohibited to have an unconfined edge open to traffic if the edge is 5 cm (2") or higher. Second, if the notched wedge is correctly constructed, the longitudinal joint density tends to be as high as conventional vertical edge joints.

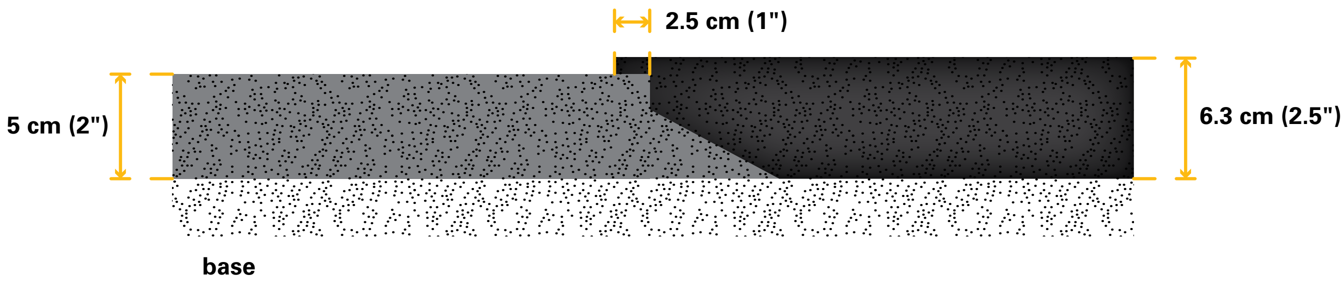
The notched wedge attachment fits inside the screed extension. The height of the notch and the angle of the wedge are adjustable.

Some crews tow a small steel drum (shown to right) or rubber tire behind the screed to compact the wedge. Other crews use a tamper plate compactor to compact the wedge.

Notched wedge joints are required on some projects.

A notched wedge joint should overlap the same way that a vertical face joint would overlap. Keep the overlap at 25 mm (1") maximum and calculate pre-compaction height of the hot layer.

CORRECT NOTCH WEDGE



Overlap a notched wedge joint the same as a vertical face joint.

User Tip: *One very important consideration about notched wedge joints is the height of the notch. The height of the notch should be 1.5 times greater than the size of the largest aggregate in the bituminous mixture. This height clearance will allow mix to flow through the notch area without dragging. If drag marks are visible at the intersection of the hot and cold layers, increase the depth of the notch.*

Caterpillar recommends using automatic grade control for matching the height of the cold layer. Matching the height of the cold layer can be accomplished manually, but automatic grade control is easier and more accurate.

At one time, most crews installed a single sensor on the joint match side. The sensor would usually be held by mounting hardware attached to the screed end gate. The sensor would always be relatively close to the auger chamber, a sensor position that creates a fast-acting screed.

Cat Grade Control enables the crew to install mounting hardware on the screed end gate or on the tow arm. For the most versatility, Caterpillar recommends installing grade sensor mounting hardware on the tow arm. There is one installation position toward the rear of the tow arm. There is another installation position in the middle of the tow arm. A third position is just behind the tow-point cylinder at the front of the tow arm. The mounting arm pivots so the sensor can be positioned to match the application requirement for screed reaction.

A single sensor is often used for height match on a longitudinal joint in parking lots and streets.

As long as the compacted layer is reasonably smooth, the screed does not have to be extremely reactive. Crews will often position a grade sensor about halfway between the auger chamber and the tow-point connection. (See photo on page 216.) The screed will be responsive, but will not make large, immediate height changes with a single grade sensor at the mid-point of the tow arm.

If a very fast screed reaction is desired, leave the sensor mounting hardware in the same position and simply pivot the sensor back toward the auger chamber.

A single grade sensor set-up is suitable for joint matching in street and parking lot applications where there is no specification for ride quality.

User Tip: *Remember, it does not matter where the mounting arm is attached. What affects screed reaction is the position of the grade sensor relative to the tow-point connection or the auger shaft. Many crews have been trained to install the mounting hardware on the screed end gate. Installing the mounting hardware on the end gate limits the versatility of the grade control system. Use the tapped holes in the tow arm to attach the mounting hardware.*

Increased utilization of ride quality specifications has prompted many crews to perform joint matching with averaging skis. At one time, crews thought that an averaging ski could not provide adequate height match because the screed moves very slowly when the grade sensor uses an averaging ski for grade reference or when an electronic averaging ski is installed.

If the compacted layer does have a moderate to severe level of roughness, then the height match provided by an averaging ski will not be accurate. There will be some high spots and some low spots at the longitudinal joint. In that case, it would be better to use a single grade sensor for improved height match. However, if the compacted layer was placed under the control of one or two averaging skis, its ride quality will normally be acceptable and an averaging ski will provide an acceptable height match with the adjacent layer.

Joint matching with averaging skis is common when there is a ride quality specification and the adjacent layer is reasonably smooth.

Pre-heating the cold, compacted layer is specified on some applications.

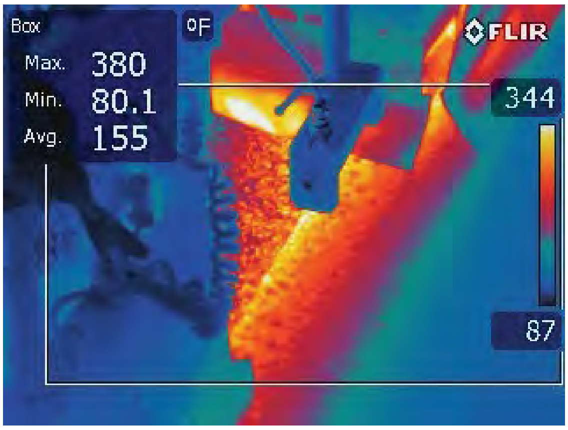
A longitudinal joint that is properly constructed, treated with a good adhesive, and properly compacted should resist moisture penetration and stay bound together. Another technique that can help longitudinal joints last longer is pre-heating prior to compaction.

Research conducted by public works agencies, associations and universities has proven that pre-heating the cold, compacted layer just prior to joint matching and compaction increases joint density and decreases permeability. For some applications, joint heating is a method specification mandated by the project owner.

There are various types of joint heaters. Some attach to the paver and are towed by the paver. Others are towed by some other vehicle. Often, the decision to tow with the paver or another vehicle is determined by the width of paving.

Joint heaters generate high temperatures, but not so high as to damage the properties of the asphalt cement used as binder. A propane heater with infrared technology can heat the cold joint to a typical average of about 120° C (250° F) while being towed at normal paving speeds. The cold layer becomes flexible at the joint to a depth of around 25 mm (1") for improved bonding with the adjacent hot layer.

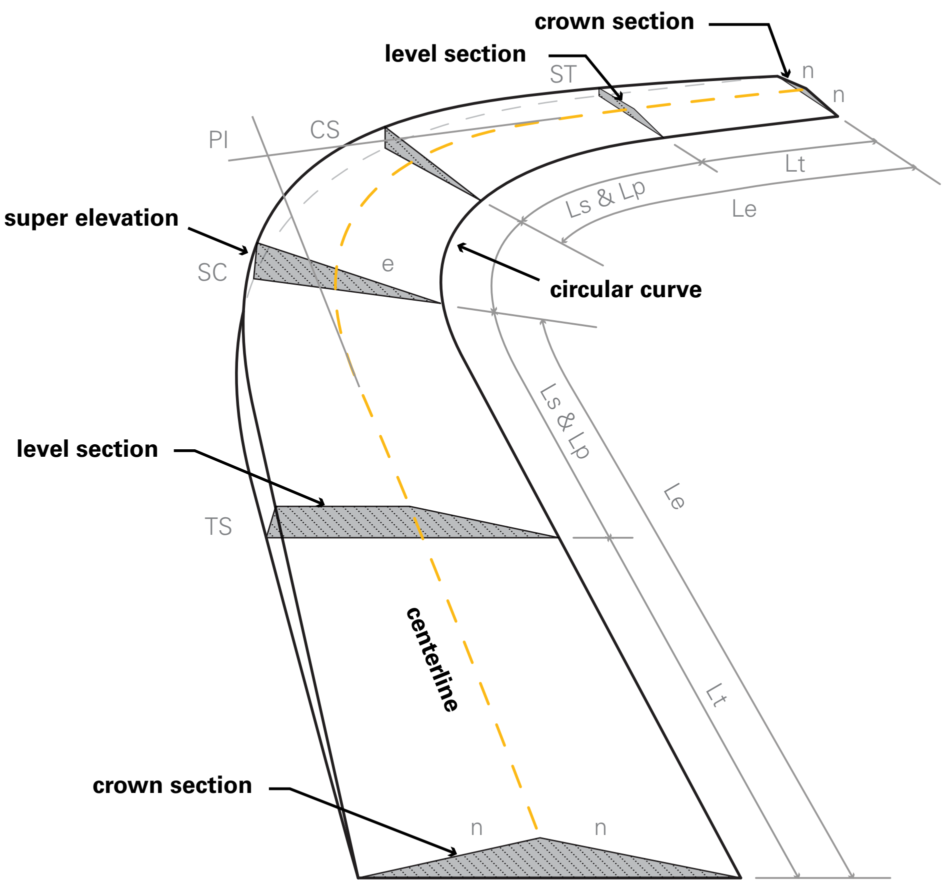
In summary, the construction of longitudinal joints is one of the most important responsibilities for the paving crew. The main elements of good joint construction are: straight line easy to match; correct overlap up to 25 mm (1"); correct height allowing for compaction rate; and no raking.



Heat from the joint heater penetrates the cold layer at the longitudinal joint.

[PAVING SUPERELEVATIONS]

The curved sections of highways and streets are commonly constructed with transverse profiles called superelevations. In the superelevation, one edge of the roadway is elevated higher than normal compared to the other edge. This superlevation is classified in terms of crossfall, or slope, rather than in centimeters or inches. The higher than normal slope creates a "banked" section in the curve that helps counteract the centripetal acceleration produced as a vehicle rounds the curve. The normal maximum slope for superelevations in high-speed highways is 6 percent. Higher slopes may be used for lower traffic, lower speed roads and streets.



Typical Superelevation Diagram

Being familiar with the sections that make up a typical super elevation is important. At the entrance to the curve, the structure has a crown at the center. That is called the crown section. In this example, there is a 2 percent slope on either side of the crown in the center of the roadway.

At some distance in front of the crown section is the level section. At the point of the level section, the upper half of the structure (left lane) is flat, 0 percent slope. The lower half of the structure (right lane) still provides a 2 percent slope. The distance between the crown section and the level section is referred to as the tangent runoff. The transition between the crown section and the level section (tangent runoff) should occur as a gradual change in the transverse profile.

At some distance in front of the level section is the superelevation. This is the point of the structure's maximum slope. There is no crown in the structure. In this case, the slope is 6 percent from left to right. The distance between the level section and the superelevation is referred to as the superelevation runoff. Again, the transition between the level section and the superelevation should be gradual.

The distance between the normal pavement section and the maximum slope of the superelevation is the distance that is used to develop the maximum slope in the curve. That distance varies depending on the type of roadway and speed limits.

The profile of the superelevation will be constant at the maximum slope for some distance in the middle of the curve.

As the curve begins to straighten, the transverse profile begins to change back to the level section where half of the structure is flat and half has 2 percent slope.

Finally, at some distance where the roadway is straight, the normal crown section with 2 percent slopes begins again.

From the standpoint of the paving crew, how they set up to pave the superelevation depends on the quality of the work done in front of them by the base preparation crew (new construction) or by the milling crew (cold plane and repave) or by the condition of the existing structure (overlay).

Prior to paving, check the slopes of the grade to be paved at various locations for the length of the curve. Use a 2.5 m (8') slope board or a calibrated electronic slope meter.

The slopes should be clearly marked on stakes adjacent to the roadway. Prior to paving make sure that all the stakes are in place and easy to see from a distance of at least 15 m (50'). Check the slope of the grade at each stake location and between the stakes as well.

Check slopes throughout the length of the superelevated curve.

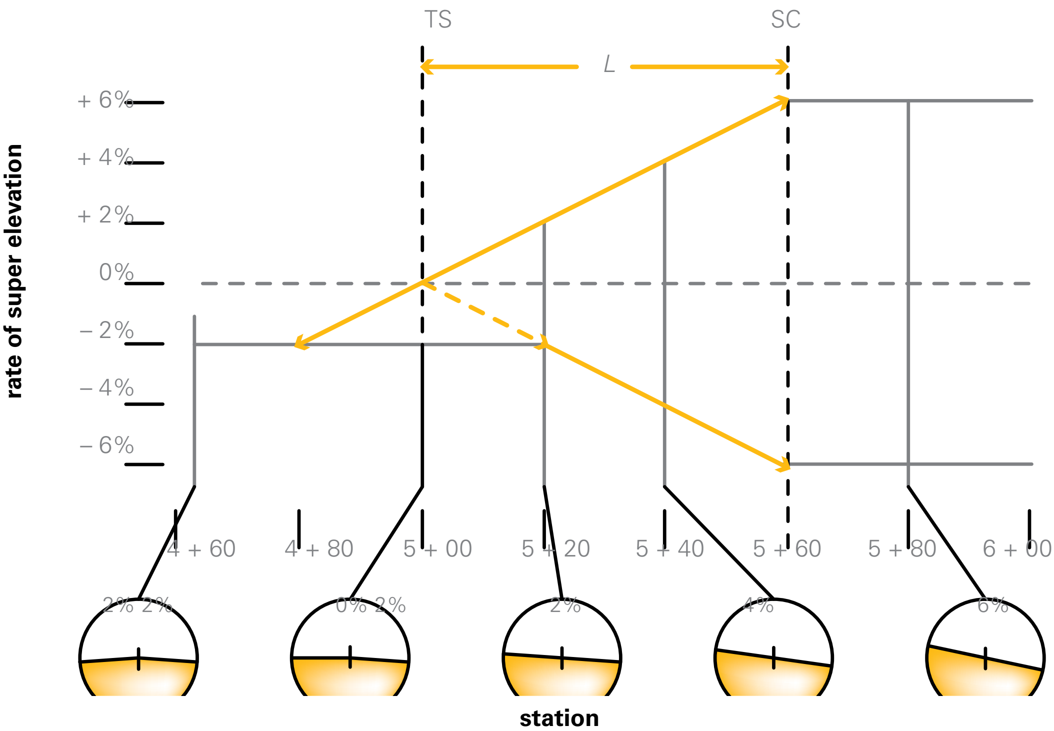
Grade stake showing slope at a point in the superelevation runoff.

If the slopes are all within 0.2 percent of the slopes that are marked on the grade stakes, grade control can be used to pave the superelevation. If the slopes that are close (within 0.3 percent to 1 percent) to the slopes marked on the grade stakes, automatic slope control can be used to make precise slope changes that match the design. If the slopes reveal that corrections in excess of 1 percent need to be made, then manual slope control should be used.

Remember the formula used to calculate elevation changes when using slope control. For every 1 percent of slope correction, the elevation (layer thickness) will change 1 cm per meter (0.125" per foot) of paving width. When using automatic slope control to make large slope corrections, it is likely that the tow-point cylinder will run out of stroke. The slopes will not be accurate and the operator will be forced to “gain back” tow-point cylinder while trying to pave the superelevation. (Refer to the section, Paving with Slope Control, in unit 6 on pages 167-168.)

Electronic slope meter showing 3.6 percent slope from right to left adjacent to where the grade stake on page 221 shows 4 percent required.

Cross sections show the profile of the roadway at various stations on a project. Thinking of the cross sections as two separate paving passes makes it relatively easy to understand how to set up and control the screed and create the profile for one side of the structure.



Superelevation diagram, showing roadway cross sections.

Assume that paving of the structure starts on the right side of the centerline. At the crown section, the screed has no crown and there is a 2 percent slope from left to right. At the level section and at station 5 + 20, there is still 2 percent slope from left to right. Slope begins to increase gradually until it reaches 6 percent at station 5 + 80. Slope eventually reverses this sequence until the end of the curve and a new crown section starts.

Now, assume that paving is occurring on the left side of the structure. This layer will be a joint match to the right lane. At the crown section, the screed will have a 2 percent slope from right to left. Begin to decrease slope until 0 percent is reached at the level station, 5 + 00. Then following marks on the grade stakes begin to create a left to right slope and gradually climb to 6 percent slope by the time station 5 + 00 is reached. Then, reverse the sequence to start a new crown section at the end of the curve.

Now assume that full width paving will occur through the superelevation. Before starting, make some calculations and use them as a reference when paving the superelevation.

STATION 4 + 60, CROWN SECTION

The crown section is the normal profile when paving full width. The center of the main screed is aligned with the centerline of the structure. The main screed has a 2 percent crown.

STATION 5 + 00, LEVEL SECTION

Step 1: Sum of the slopes divided by 2 = crown

$$\frac{0\% + 2\%}{2} = 1\% \text{ crown}$$

Step 2:

Subtract the smaller slope from the larger slope:

$$2\% - 0\% = 2\%$$

Divide the difference of the slopes by 2:

$$\frac{2\%}{2} = 1\%$$

The result: 1%, is the amount of slope.

Starting at the crown section 4 + 60, begin to gradually flatten the main screed crown to create 1 percent crown at level station 5 + 00. Starting at the crown section 4 + 60, begin to create left-to-right slope ending at 1 percent slope at the level section.

STATION 5 + 20, TRANSITION STATION

The screed is flat at station 5 + 20. In other words, there is one slope running through the centerline. Starting at the level section 5 + 00, begin to gradually flatten the main screed crown to create 0 percent crown at transition station 5 + 20. Starting at the level section 5 + 00, begin to increase left-to-right slope ending at 2 percent slope at station 5 + 20.

STATION 5 + 80, SUPERELEVATION

At transition station 5 + 20, continue to increase left-to-right slope. At station 5 + 40, the slope should be 4 percent. Finally at station 5 + 80, the slope should be 6 percent. Continue to pave at 6 percent until entering the transition out of the curve. At that point, reverse the steps to eventually return to the normal profile of 2 percent main screed crown.

When paving a superelevation using automatic slope control, slowly make the required slope changes. Slope changes are made in 0.1-percent increments using the UP or DOWN arrows on the display or using the grade adjustment knob on some other systems. For example, if it's required to change slope from 2 percent to 3 percent over a distance of 15 m (50'), start to make the changes when the screed is adjacent to the grade stake marked 2 percent.

Try to space out the slope changes so the last change will occur just before the grade stake marked 3 percent is reached. Increase the slope to 2.1 percent. When paving at a speed of 5 m / min (17' / min), it will take about three minutes to reach a grade stake that is 15 m (50') away. Wait about 15 seconds and increase the slope to 2.2 percent. Continue this pattern until 10 slope adjustments of 0.1 percent have been made. This will create a gradual change in slope and the slope should be correct—3 percent when the grade stake marked 3 percent is reached. Remember, slope changes occur quickly. It only takes approximately one meter (a yard) for the change to fully occur. Monitor the tow-point connection. Don't let the tow-point cylinder run out of stroke.

Use the display or control box to slowly make slope changes.

Paving superelevation with averaging ski on left, slope right.

At least one side of the paver will be under grade control while paving through a superelevation. On a highway project, the grade side may be using an averaging ski. Depending on the length of the superelevation and how quickly the slopes change, use of the averaging ski may need to be discontinued. An averaging ski is normally at least 9 m (30') long. The front of the ski may be referencing a significantly different elevation than the rear of the ski in the transition areas of the superelevation and, consequently, the screed reaction may be erratic. If the tow-point starts to make large and frequent moves when entering a transition area in a superelevation, turn the grade control system to Manual mode. Control the thickness of the layer manually until paving of the normal crown section resumes.

In summary, always verify the accuracy of the actual slopes in the superelevation before paving. Be sure that the slopes are clearly marked on grade stakes and easily visible from the screed at a distance of up to 15 m (50'). Depending on the accuracy of the slopes, decide whether to pave with dual grade control, one side grade control and one side automatic slope control, or one side grade control and one side manual slope control.

[ECHELON PAVING]

When two or more pavers are placing bituminous material at the same time in the same direction on a roadway, that is commonly called echelon, or staggered, paving. Echelon paving creates a hot longitudinal joint for the compaction process and is a proven method to improve joint density. To perform echelon paving, it may be necessary to arrange for two asphalt plants to supply the material needed.

Note: If more than one plant is supplying material for the project, designate which paver is supplied by which plant.

Depending on the type of roadway, it may be necessary to close the roadway and direct traffic to alternate routes or set up traffic control to divert traffic to opposite lanes. Echelon paving also requires some additional planning.

- Calculate working speeds that balance the production rates of the pavers.
- Adjust working speeds to the capability of the least productive paver.
- Select pavers with similar screeds that develop uniformly high pre-compaction.
- When using non-similar screeds, adjust to the results produced by the lowest performing screed.
- Whenever possible, create similar paving widths for all pavers.
- When paving non-similar widths, paver with largest width should lead.
- Select compactors with drum widths that will create uniform rolling patterns behind each paver regardless of paving widths.

Assume that the base layer is being paved on a roadway that is 11.6 m (38') wide. The paving depth is 75 mm (3"). Two asphalt plants will be supplying the project with 400 tonnes (440 tons) per hour. The plan calls for three pavers to be used for the project.

The left side paver will pave 4.7 m (15.5') wide. That paving width includes an inside paved shoulder with 2 percent slope from right to left and the left driving lane with 2 percent slope from left to right.

The center paver will pave the right driving lane at a width of 3.7 m (12') and a 2 percent slope from left to right.

The right paver will pave the right emergency lane at a width of 3.2 m (10.5') at a slope of 4 percent from left to right.

The left paver will be slightly ahead of the other two pavers. Limit the longitudinal gap between pavers to no more than one paver length in order to maintain nearly equal temperatures between the layers, so density produced by the compactors across the width of paving is equal.

FIRST LAYER

To calculate the paving speeds of the three pavers, first add the three paving widths.

Paver 1: **4.7 m (15.5')**
Paver 2: **3.7 m (12')**
Paver 3: **3.2 m (10.5')**

Total width: **11.6 m (38')**

Now divide the total width by the width of each pass. The result will be the percentage of hourly production for each paver.

Paver 1: $\frac{4.7\text{ m }(15.5')}{11.6\text{ m }(38')} = 40\%$

Paver 2: $\frac{3.7\text{ m }(12')}{11.6\text{ m }(38')} = 32\%$

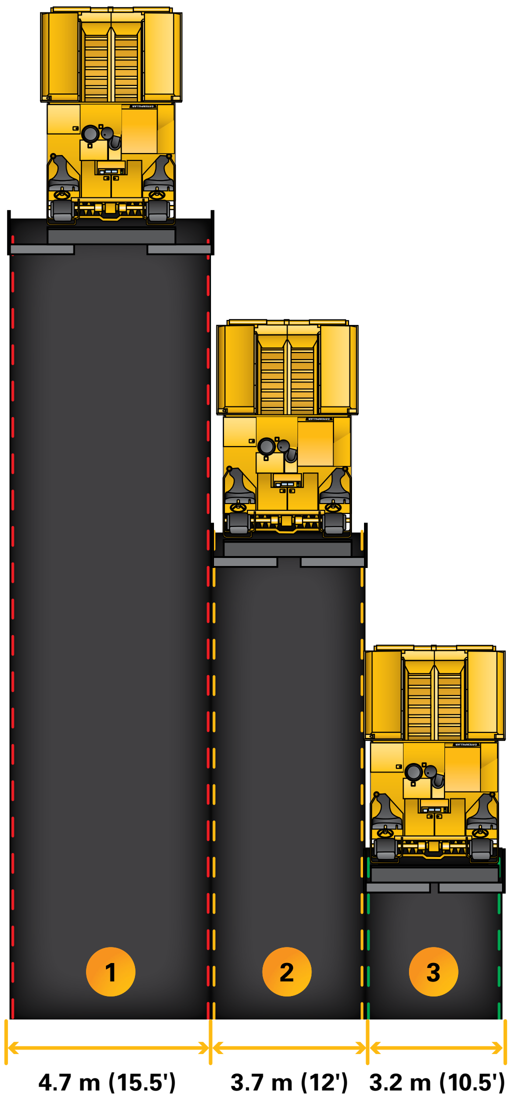
Paver 3: $\frac{3.2\text{ m }(10.5')}{11.6\text{ m }(38')} = 28\%$

Finally, divide the hourly production rate by the percentage of each paver. This will provide the hourly production rate in tons for each paver.

Paver 1: $\frac{400\text{ T}}{40\%}$ = 160 tonnes (176 tons)/hour

Paver 2: $\frac{400\text{ T}}{32\%}$ = 128 tonnes (140 tons)/hour

Paver 3: $\frac{400\text{ T}}{28\%}$ = 112 tonnes (124 tons)/hour



paving speed: **3.7 m (12')/min.**
paving depth: **75 mm (3")**

The Paving Production Calculator can be used to confirm that each paver will be operating at the same speed based on the hourly tonnage allotted. Assume that material transfer vehicles will be used and the efficiency rate will be 95%.

PAVER ONE

Trucking | **Paver Speed** | Compaction | Windrow | Yield | Slope | Thickness | Job Summary | Legal | Exit

General Inputs	Imperial Units		Metric Units	
Paving Thickness:	[2.95]	in	[75.0]	mm
Paving Width:	[15.42]	feet	[4.7]	meter
Material Density Uncompacted:	[140]	lbs/ft³	[2243]	kg/m³
Paver Speed @ Given Production Rate				
Production Rate of Hot Plant:	[176]	tons/hr	[160]	tonnes/hr
Calculated Paving Speed - 100% Efficiency:	[11.1]	ft/min	[3.39]	m/min
Calculated Paving Speed - 95% Efficiency:	[11.7]	ft/min	[3.56]	m/min
Calculated Paving Speed - 90% Efficiency:	[12.2]	ft/min	[3.73]	m/min
Calculated Paving Speed - 85% Efficiency:	[12.8]	ft/min	[3.90]	m/min
Calculated Paving Speed - 80% Efficiency:	[13.3]	ft/min	[4.07]	m/min
Calculated Paving Speed - 75% Efficiency:	[13.9]	ft/min	[4.24]	m/min
Effective Paving Speed:	[11.1]	ft/min	[3.39]	m/min

The actual paving speed for Paver One is 3.6 m (12′) per minute using 95 percent efficiency rate.

PAVER TWO

Trucking | **Paver Speed** | Compaction | Windrow | Yield | Slope | Thickness | Job Summary | Legal | Exit

General Inputs	Imperial Units		Metric Units	
Paving Thickness:	[2.95]	in	[75.0]	mm
Paving Width:	[12.14]	feet	[3.7]	meter
Material Density Uncompacted:	[140]	lbs/ft³	[2243]	kg/m³
Paver Speed @ Given Production Rate				
Production Rate of Hot Plant:	[141]	tons/hr	[128]	tonnes/hr
Calculated Paving Speed - 100% Efficiency:	[11.2]	ft/min	[3.42]	m/min
Calculated Paving Speed - 95% Efficiency:	[11.8]	ft/min	[3.59]	m/min
Calculated Paving Speed - 90% Efficiency:	[12.3]	ft/min	[3.76]	m/min
Calculated Paving Speed - 85% Efficiency:	[12.9]	ft/min	[3.93]	m/min
Calculated Paving Speed - 80% Efficiency:	[13.4]	ft/min	[4.10]	m/min
Calculated Paving Speed - 75% Efficiency:	[14.0]	ft/min	[4.28]	m/min
Effective Paving Speed:	[11.2]	ft/min	[3.42]	m/min

Paver Two operates at 3.7 meters (12') per minute also. Note that the hourly tonnage is less than Paver One and the paving width is also less than the Paver One.

PAVER THREE

- Trucking
- **Paver Speed**
- Compaction
- Windrow
- Yield
- Slope
- Thickness
- Job Summary
- Legal
- Exit

General Inputs	Imperial Units		Metric Units	
Paving Thickness:	[2.95]	in	[75.0]	mm
Paving Width:	[10.50]	feet	[3.2]	meter
Material Density Uncompacted:	[140]	lbs/ft³	[2243]	kg/m³
Paver Speed @ Given Production Rate				
Production Rate of Hot Plant:	[123]	tons/hr	[128]	tonnes/hr
Calculated Paving Speed - 100% Efficiency:	[11.3]	ft/min	[3.45]	m/min
Calculated Paving Speed - 95% Efficiency:	[11.9]	ft/min	[3.62]	m/min
Calculated Paving Speed - 90% Efficiency:	[12.4]	ft/min	[3.80]	m/min
Calculated Paving Speed - 85% Efficiency:	[13.0]	ft/min	[3.97]	m/min
Calculated Paving Speed - 80% Efficiency:	[13.6]	ft/min	[4.14]	m/min
Calculated Paving Speed - 75% Efficiency:	[14.1]	ft/min	[4.31]	m/min
Effective Paving Speed:	[11.3]	ft/min	[3.45]	m/min

The paving speed calculation for Paver Three confirms that all three pavers are in balance, each with its own production rate based on the width of its pass.

The truck guides on the project are responsible for directing the haul units to the appropriate pavers and transfer vehicles. In some cases, one transfer vehicle may be supplying two pavers. Using one transfer vehicle to supply two pavers takes some coordination, but if the pavers have large hopper inserts and paving speeds under 6 m (20') per minute, it can be done without stopping the pavers.

The next layer will require new calculations.

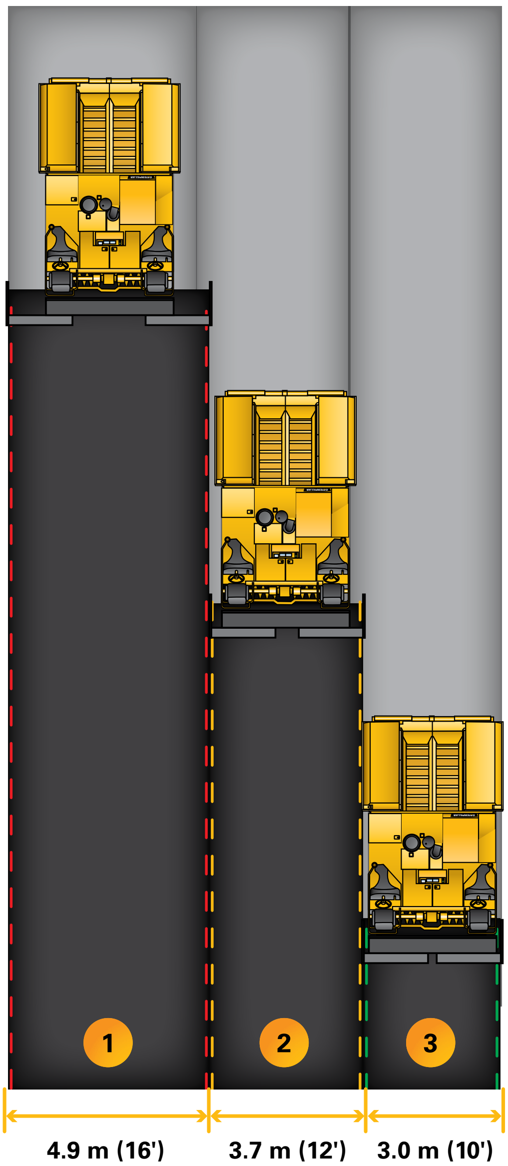
New calculations are needed for two reasons. First, the depth of paving for this layer has been reduced to 50 mm (2"). Second, the widths of two of the passes have also changed. The far left pass is now slightly wider; it's 4.9 meters (16') wide. Changing the pass width is done to avoid aligning the longitudinal joints directly above each other. The longitudinal joints should always be staggered, or offset to help prevent moisture penetration through the joints.

The center pass is still 3.7 meters (12') wide, but is now offset 15 cm (6") to the right compared to the layer below.

The right pass is now reduced to 3 m (10'). These are the final widths of the driving lanes and shoulders.

Offset longitudinal joints in an alternating fashion for each layer. The offset is normally between 15 cm to 30 cm (6" to 12"). Normally, the smaller offset should be selected if there is a slope change at the longitudinal joint. The smaller offset creates a smaller thickness change due to the slope changes.

Do the same calculations to determine the paving speed for the new layer thickness and pass widths. Assume the same hourly production rate from the plants supplying the material.



paving speed: **5 m (16.5')/min**
paving depth: **50 mm (2")**

SECOND LAYER

Paver 1: **4.9 m (16')**
Paver 2: **3.7 m (12')**
Paver 3: **3.0 m (10')**

Total width: **11.6 m (38')**

Now divide the total width by the width of each pass. The result will be the percentage of hourly production for each paver.

Paver 1: $\frac{4.9\text{ m }(16')}{11.6\text{ m }(38')} = 40\%$

Paver 2: $\frac{3.7\text{ m }(12')}{11.6\text{ m }(38')} = 32\%$

Paver 3: $\frac{3.0\text{ m }(10')}{11.6\text{ m }(38')} = 26\%$

Finally, divide the hourly production rate by the percentage of each paver. This will provide the hourly production rate in tons for each paver.

Paver 1: $\frac{400\text{ T}}{42\%}$ = 168 tonnes (185 tons)/hour

Paver 2: $\frac{400\text{ T}}{32\%}$ = 128 tonnes (140 tons)/hour

Paver 3: $\frac{400\text{ T}}{26\%}$ = 104 tonnes (115 tons)/hour

The Paving Production Calculator can now be used to calculate the paving speed that will balance the three pavers on the project. Again, assume that material transfer vehicles will be utilized and the efficiency rate will be 95 percent.

PAVER ONE

- Trucking
- **Paver Speed**
- Compaction
- Windrow
- Yield
- Slope
- Thickness
- Job Summary
- Legal
- Exit

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[2.00] *in*	[50.8] *mm*
Paving Width:	[16.00] *feet*	[4.877] *meter*
Material Density Uncompacted:	[140] *lbs/ft³*	[2243] *kg/m³*
Paver Speed @ Given Production Rate		
Production Rate of Hot Plant:	[185] *tons/hr*	[168] *tonnes/hr*
Calculated Paving Speed - 100% Efficiency:	[16.5] *ft/min*	[5.03] *m/min*
Calculated Paving Speed - 95% Efficiency:	[17.3] *ft/min*	[5.28] *m/min*
Calculated Paving Speed - 90% Efficiency:	[18.2] *ft/min*	[5.53] *m/min*
Calculated Paving Speed - 85% Efficiency:	[19.0] *ft/min*	[5.78] *m/min*
Calculated Paving Speed - 80% Efficiency:	[19.8] *ft/min*	[6.04] *m/min*
Calculated Paving Speed - 75% Efficiency:	[20.6] *ft/min*	[6.29] *m/min*
Effective Paving Speed:	[16.5] *ft/min*	[5.03] *m/min*

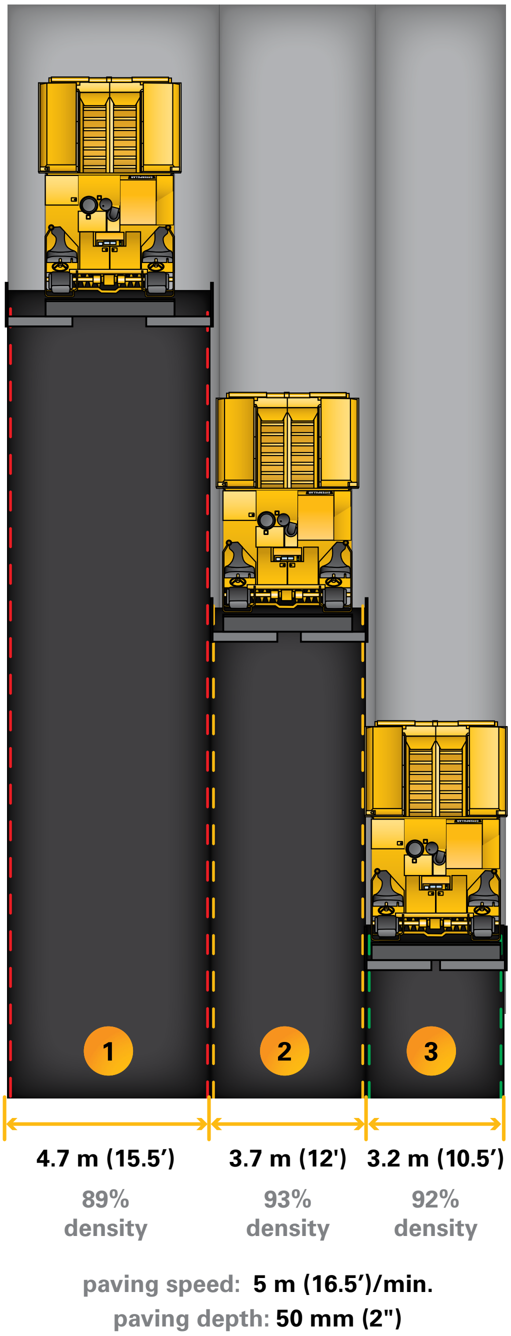
Each paver will be paving just over 5 m (16.5') per minute. There is another consideration involved with echelon paving. In some cases, the paving speeds may be affected by the density of the layer behind each paver.

THIRD LAYER

In the example shown here, there are three pavers equipped with vibratory and tamping screeds. A quality control specification on this project requires that this layer have 92 percent density behind the screed. Working at 5 m (16.5') per minute, the two pavers completing the center and right passes are meeting this specification. Working at 5 m (16.5') per minute, the paver working on the left side of the roadway is only developing 89 percent density on the bituminous layer.

The crew has adjusted the tamping frequency upward to its maximum capacity, but the screed is still not developing the required density. In this situation, there are two possible solutions. First, if another paver is available, replace the paver that is not producing the specified results. Perhaps, the tamper foot is badly worn and the screed needs repair or rebuilding. Second, slow the speed of the paver until the density reaches the required level.

The speed of the least productive paver has to be the speed of all the pavers. When paving in echelon, the pavers must stay close together.



User Tip: *When doing echelon paving, one or more pavers will be matching a longitudinal joint. Two factors need to be controlled. One is the height of the end gate ski. Be careful not to apply too much downward pressure on the ski. The ski may leave a mark in the hot, uncompacted bituminous material. Second, be sure the compactor operators have clear instructions regarding when to compact the longitudinal joint. If a trailing paver is using the area close to the joint edge as reference for the grade sensor, the compactors cannot roll the edge before the trailing paver completes the height match.*

[TRUCK EXCHANGE PROCEDURES]

Truck exchange procedures can affect the quality of the bituminous layer being placed by the crew. The drivers of the haul units should be considered part of the paving team. Drivers need training and clear instructions regarding their roles on the project.

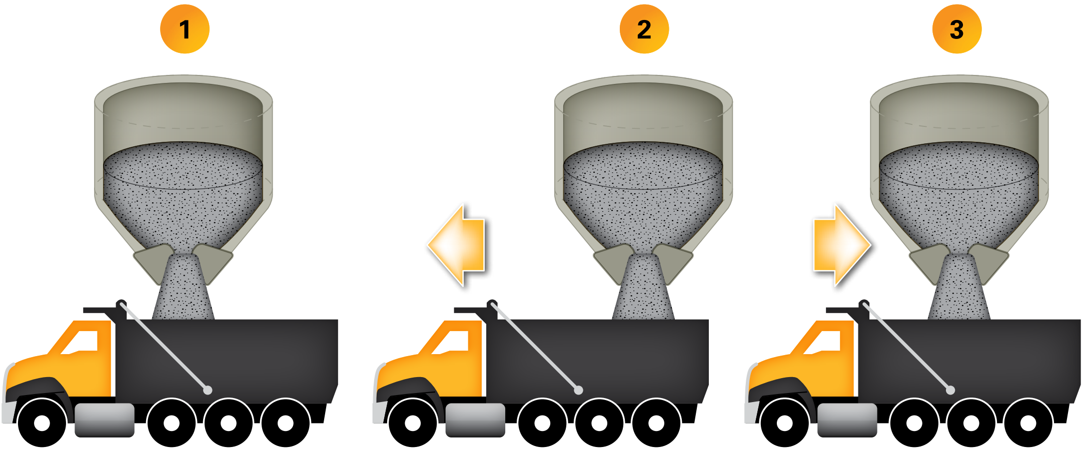
Truck drivers must be alert for instructions while discharging material.

Truck Driver Responsibilities

- Coat the truck bed with approved release agent.
- Follow loading procedures.
- Cover the load.
- Drive the approved route.
- Stage where directed.
- Stop short of the paver or transfer device.
- Maintain light brake pressure.
- Watch for and follow material discharge instructions.
- Clean out where directed.

Preventing the buildup of material in the truck bed is one of the drivers' responsibilities. Most asphalt plants have a platform located near the loading area where truck drivers can apply release agent. As the film of release agent deteriorates, material begins to stick to the bed. Eventually, these agglomerations break off and contaminate the load.

Truck beds require periodic application of approved release agent.



The driver follows instructions at the plant for loading.

Truck drivers are responsible for obeying all loading instructions at the asphalt plant. There may be lights or signs that instruct the drivers to reposition trucks for different discharges from the storage silos. Once the truck beds are full, drivers receive the load tickets from the scale operator.

In most areas, the load must be covered—not just to preserve heat, but also to prevent any aggregates from spilling onto the roadway.

Each driver should receive directions for driving an approved route to the worksite. The project manager or superintendent determines the route based on traffic and load weights. It is the drivers' responsibility to stay on that route and not stop, unless there is an emergency. Trucks should arrive at the project at intervals that are consistent with loading at the plant and traffic conditions.

Depending on the type of project, haul units may have to park temporarily at a staging area. At this point, each truck driver must be alert for directions from the crew. The drivers and the crewmembers should have an agreed upon series of signals that direct the drivers' actions.

Watching the paver operator or the truck guide, the driver backs the haul unit to the front of the paver. At the signal from the operator or truck guide, the driver stops the truck just short of the push rollers. Never back into the push rollers. If the truck hits the paver, the screed will be pushed back and down and will leave a dent in the fresh layer.

The truck always stops short of the push rollers.

As the paver moves forward to contact the rear tires of the truck, the driver should apply light brake pressure to prevent the truck from rolling away from the paver. An optional hydraulic truck hitch provides a positive connection between the truck and the paver.

A truck hitch provides a positive connection between the haul unit and the paver.

As a general rule, trucks should line up in the center of the hopper to make it it easier for the paver operator to steer a straight line. However, there are times when trucks should line up off-center. For example, when paving through a superelevation (see adjacent image), the crew must compensate for a larger than normal slope to one side of the paver. The trucks should always move over close to the edge of the hopper that is aligned with the high side of the sloped surface. Gravity will move material from the trucks toward the low side of the hopper. The low side conveyor stays full while the high side conveyor runs empty. The paver operator must stop the paver to avoid running out of material in the auger chamber. When the trucks pull away, there will be a spill in front of the paver on the low side. In that situation, aligning the trucks to the high side will eliminate or minimize the spill.

Improper truck alignment leads to hopper spills.

The truck driver raises the bed to break the load and start supplying the paver hopper. The material should flow into the hopper as a surge, not as a slow trickle of material. A slow transfer of material tends to cause segregation, especially if the material has aggregates that are 19 mm (0.75") or larger.

When the bed is empty, the paver operator or truck guide signals the truck driver to pull away from the front of the paver.

Break the load and watch for signals to raise the bed.

Often, material remains on the discharge lip of the truck bed, and sometimes a little material is left in the truck bed. Clean up this material at an approved location on the project. Truck cleaning should not occur in front of the paver. The material that gets dumped on the grade when cleaning in front of the paver has to be removed. Never pave over spills on the grade or piles left from cleaning up trucks. That cleaning process takes time and interrupts production. It is always advisable to send trucks to an approved location for clean-out.

Truck clean-out should not occur in front of the paver.

When operating the paver during a truck exchange, the first option is to continue paving at normal speed while the empty truck is pulling away. The operator, perhaps with help from the truck guide, has to monitor the level of material in the hopper. As the level in the hopper decreases, the paver operator can begin to slowly raise the hopper wings to combine material from the sides of the hopper with material in the center of the hopper. The crew needs to make sure that material does not spill from the front of the hopper over the flashing while folding the hopper wings.

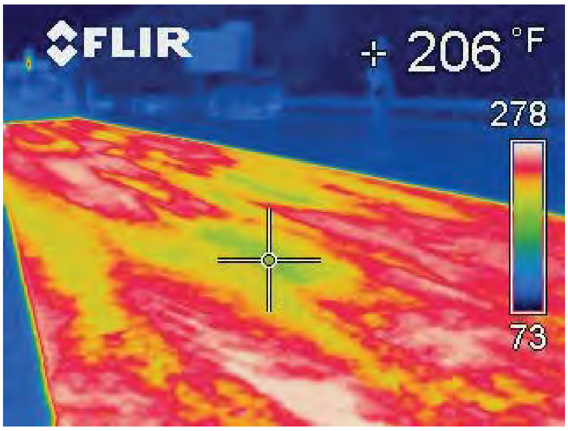
The paver continues to pave at normal speed as the empty truck pulls away.

User Note: *When direct dumping from trucks into the paver, a front folding apron can help minimize spills and eliminate costly cleanup efforts.*

When the level of material has gone down in the hopper, but the conveyors are still full, stop the paver and wait for the next truck to get in position. If paving continues between trucks, there is a risk of running low on material in the hopper and in the auger chamber in front of the screed. Remember, maintaining the correct head of material in the auger chamber is a fundamental of paving. Violating that fundamental is a big mistake. The screed will begin to move downward as the head of material decreases. When the auger chamber is refilled, the screed will begin to climb. This procedure creates bumps in the mat due to inconsistent material flow.

Stop paving with the left and right conveyors still full of material.

The roughness caused by running low on material will be accentuated if the hopper wings are folded when there is little material in the hopper. Cold mix that has accumulated at the sides of the hopper will be transferred onto the conveyors without being combined with hot material. The cold material will not compact the same as hot material. Not only will the potential result be an area of low density and high air voids, the surface will also be rougher due to the compaction variation caused by the temperature differential.



Folding the hopper wings when the hopper is low on material can create cold spots in the bituminous layer.

User Tip: *Never cycle the hopper wings late in the truck exchange process when the hopper is almost empty.*

There may be times when the hopper wings should not be cycled during truck exchanges, either because of a written specification prohibiting the cycling of hopper wings or due to quality issues. For example, when placing bituminous material with large aggregates (19 mm / 0.75" or larger), there is a tendency for these large aggregates to segregate and roll to the outer edges of the hopper. When the hopper wings are folded, this segregated material tends to pass through the feeder system as a mass and show in the bituminous layer as a patch of large aggregates. The patch segregation shows up as a pattern during truck exchanges and is often referred to as end-of-load segregation. (Unit 8 will discuss segregation causes and cures.)

It is highly recommended to not cycle the hopper wings on certain projects.

In situations where the hopper wings are not to be folded, be alert for an accumulation of material at the sides and near the front of the hopper. A large amount of material can prevent the truck's tailgate from opening. The lack of fresh material can cause the conveyors to run empty, decreasing the head of material in the auger chamber. This extra material at the front of the hopper can also cause a spill directly in line with the paver's undercarriage or in line with the grade sensor if the grade sensor is located close to the side of the paver. Periodically remove this excess material from the front of the hopper to avoid spills and to facilitate the discharge of material from trucks.

Accumulations of material at the sides of the hopper can interfere with the truck's tailgate.

In many situations, the paver operator must stop the paver to wait for a new load of material. Depending on the type of mix, the weight of the screed and the length of the paver stop, the screed settlement mark may be so deep that the initial phase compactor is unable to roll out the mark. A deep settlement mark would be a sign that the operator should engage the screed counterbalance system and/or the screed lower lock.

Caterpillar does not recommend reducing the normal paving speed during truck exchanges as a means of avoiding paver stops. Remember, when the operator lowers the paving speed, the screed tends to rise. The grade control system, if used in the automatic mode, will sense the screed movement and cause the screed to move back down. A series of bumps or ripples may result from changing the paving speed to avoid running out of mix during a truck exchange.

Stopping the paver during truck exchanges can cause a screed settlement mark.

The paving speed should be calculated based on hourly production from the plant, paving width and paving depth. Calculate a speed that compensates for the paver stops during truck exchanges.

PAVER SPEED CALCULATOR

- **Trucking**
- **Paver Speed**
- **Compaction**
- **Windrow**
- **Yield**
- **Slope**
- **Thickness**
- **Job Summary**
- **Legal**
- **Exit**

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[**2.95**] *in*	[**75.0**] *mm*
Paving Width:	[**15.00**] *feet*	[**4.572**] *meter*
Material Density Uncompacted:	[**140**] *lbs/ft³*	[**2243**] *kg/m³*
Paver Speed @ Given Production Rate		
Production Rate of Hot Plant:	[**220**] *tons/hr*	[**200**] *tonnes/hr*
Calculated Paving Speed - 100% Efficiency:	[**14.2**] *ft/min*	[**4.33**] *m/min*
Calculated Paving Speed - 95% Efficiency:	[**14.9**] *ft/min*	[**4.55**] *m/min*
Calculated Paving Speed - 90% Efficiency:	[**15.6**] *ft/min*	[**4.76**] *m/min*
Calculated Paving Speed - 85% Efficiency:	[**16.3**] *ft/min*	[**4.98**] *m/min*
Calculated Paving Speed - 80% Efficiency:	[**17.0**] *ft/min*	[**5.20**] *m/min*
Calculated Paving Speed - 75% Efficiency:	[**17.8**] *ft/min*	[**5.41**] *m/min*
Effective Paving Speed:	[**14.2**] *ft/min*	[**4.33**] *m/min*

The calculated paving speed is based on the efficiency factor that considers how material is transferred from the truck to the paver.

When the material is transferred directly from the haul unit to the paver, the efficiency rate must account for the length of the paver stops during the truck exchanges. On any project that has mostly long, uninterrupted paving passes, target at least 75 percent efficiency.

Assume that the production rate is 200 tonnes (220 tons) per hour. The paving width is 4.6 meters (15'). The paving thickness is 75 mm (3"). In that example, the actual paving speed will be about 5.5 m / minute (18' / minute) with a 75% efficiency factor. As the paving efficiency increases, the actual paving speed decreases until 100 percent efficiency is reached, or non-stop paving. In this example, continuous paving at 4.3 m / minute (14' / minute) would consume 200 tonnes (220 tons) in one hour.

Continuous paving without a material transfer device is usually not possible due to the limited storage capacity of the paver hopper. Still, some calculations can be made to determine if continuous paving at normal paving speed is possible without a transfer device. Assume, for the sake of the calculation that there are 7 tonnes (7.7 tons) available in the hopper and conveyors that could be consumed before running the conveyors empty.

YIELD CALCULATOR

Trucking
Paver Speed
Compaction
Windrow
Yield
Slope
Thickness
Job Summary
Legal
Exit

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[3.00] *in*	[76.2] *mm*
Paving Width:	[15.00] *feet*	[4.572] *meter*
Material Density Uncompacted:	[140] *lbs/ft³*	[2243] *kg/m³*
Truck Capacity or Total Tonnage:	[7.7] *ton*	[7.0] *tonnes*
Length of Mat at 100% Yield:	[29.33] *feet*	[9] *meter*
Actual Length of Mat produced:	[29.53] *feet*	[9] *meter*
% Yield for given truck load or tonnage:		[101]

Thickness:	[3.00] *in*	[76.2] *mm*
Length of Mat produced:	[29.53] *feet*	[9] *meters*
Width:	[15.00] *feet*	[4.572] *meters*

The yield calculation shows the paving distance for a given amount of tonnes.

The yield calculator portion of the Paving Production Calculator shows that 7 tonnes (7.7 tons) assumed to be available in the hopper would allow the paver to place 9 m (29') of material at the width and depth of this example. The calculated paving speed at 100 percent efficiency is 4.3 m / minute (14' / minute). Therefore, approximately two minutes are available before the hopper and conveyors run out of material. If the empty truck can leave and another truck be positioned in less than two minutes, theoretically the paver could continue paving at normal speed without stopping.

In most instances, the paver cannot pave continuously between trucks without running low on material. In order to pave without stopping or slowing between trucks, the paving speed will have to be reduced. This means reducing hourly production.

[MATERIAL TRANSFER VEHICLES]

Using a self-propelled material transfer vehicle to supply the paver makes it possible to pave at normal paving speed without stopping. Various types of material transfer vehicles have different storage capacities. Some material transfer vehicles include remixing technology. In other cases, remixing occurs in the hopper insert included with the transfer vehicle.

Some public works departments have written method specifications that describe the type of material transfer vehicle that must be used on designated projects. When considering the use of any material transfer device, consult local specifications and regulations.

Material transfer devices come in different shapes and sizes, but have one common feature. They totally separate the haul unit from the paver. Therefore, the paver operator is no longer dependent on the volume of material in the hopper to determine how long to pave between trucks. Each material transfer vehicle has a specified storage capacity, and a hopper insert is frequently placed in the paver. Smaller transfer vehicles have around 11 tonnes (12 tons) storage capacity. Hopper inserts vary in capacity from around 12 tonnes (13 tons) to 16 tonnes (18 tons). Based on a fully loaded small transfer vehicle and a full hopper insert, up to 27 tonnes (30 tons) could be available for continuous paving between trucks.

A material transfer vehicle does not contact the paver as it transfers material from the haul unit.

YIELD CALCULATOR

Trucking
Paver Speed
Compaction
Windrow
Yield
Slope
Thickness
Job Summary
Legal
Exit

General Inputs	Imperial Units	Metric Units
Paving Thickness:	[3.00] in	[76.2] mm
Paving Width:	[15.00] feet	[4.572] meter
Material Density Uncompacted:	[140] lbs/ft³	[2243] kg/m³
Truck Capacity or Total Tonnage:	[30.0] ton	[27.2] tonnes
Length of Mat at 100% Yield:	[114.29] feet	[35] meter
Actual Length of Mat produced:	[115] feet	[35.05] meter
% Yield for given truck load or tonnage:		[101]

Thickness:	[3.00] in	[76.2] mm
Length of Mat produced:	[115] feet	[35.05] meters
Width:	[15.00] feet	[4.572] meters

Yield calculation showing distance of paving with added storage capacity.

The added storage capacity in the material transfer vehicle and the hopper insert increase the distance that can be paved before the paver runs empty. Assume the calculated paving speed is 4.3 m / minute (14' / minute) at 100 percent efficiency.

Since the paving distance for 27 tonnes (30 tons) is 35 m (114'), the time available for paving between trucks is about eight minutes. Compare that time to the roughly two minutes available when discharging directly from the truck into the paver.

Larger material transfer vehicles have more storage capacity.

Larger material transfer vehicles carry and store more material. A material transfer vehicle with 23-tonne (25-ton) storage capacity in combination with the large hopper insert has approximately 40 tonnes (44 tons) of material available between trucks.

YIELD CALCULATOR

Trucking | Paver Speed | Compaction | Windrow | **Yield** | Slope | Thickness | Job Summary | Legal | Exit

General Inputs	*Imperial Units*		*Metric Units*	
Paving Thickness:	[3.00]	*in*	[76.2]	*mm*
Paving Width:	[15.00]	*feet*	[4.572]	*meter*
Material Density Uncompacted:	[140]	*lbs/ft³*	[2243]	*kg/m³*
Truck Capacity or Total Tonnage:	[44.0]	*ton*	[39.9]	*tonnes*
Length of Mat at 100% Yield:	[167.62]	*feet*	[51]	*meter*
Actual Length of Mat produced:	[167.00]	*feet*	[50.90]	*meter*
% Yield for given truck load or tonnage:			[100]	

Thickness:	[3.00]	*in*	[76.2]	*mm*
Length of Mat produced:	[167.00]	*feet*	[50.90]	*meters*
Width:	[15.00]	*feet*	[4.572]	*meters*

Yield calculation showing distance of paving with even more storage capacity.

The added storage capacity provided by the larger material transfer vehicle and the hopper insert increases the distance that can be paved before the paver runs empty. Again, assume the calculated paving speed is 4.3 m / minute (14' / minute) at 100 percent efficiency. Since the paving distance for 40 tonnes (44 tons) is 51 m (167'), the time available for paving between trucks is almost 12 minutes. Compare that time to the roughly two minutes available when discharging directly from the truck into the paver or eight minutes available when paving with a smaller material transfer vehicle.

This much paving time between trucks opens up more possibilities. For example, supplying two pavers working in echelon (staggered paving) with one material transfer vehicle is possible. This application requires some coordination but experienced crews utilize this approach on a regular basis.

The other possibility is reducing the number of trucks required.

TRUCKING CALCULATOR

- **Trucking**
- **Paver Speed**
- **Compaction**
- **Windrow**
- **Yield**
- **Slope**
- **Thickness**
- **Job Summary**
- **Legal**

Exit

General Inputs	*Imperial Units*	*Metric Units*
Production Rate of Hot Plant:	[220] *tons/hr*	[200] *tonnes/hr*
Multiple Silo Plants: Initial Storage	[0] *tons*	[0] *tonnes*
Paving Hours:	[0.0] *hrs*	[0.0] *hrs*
Truck Capacity (size):	[24.3] *net tons*	[22.0] *net tonnes*

Truck Cycle Times *(minutes)*	
Load Time and Ticket:	[6]
Tarp:	[4]
Haul to Job:	[40]
Time on Site:	[12]
Dump / Clean:	[10]
Return Haul:	[40]
Truck Cycle Factor *(total time in hours)*	[1.9]
Number of Trucks Needed:	[17.2]

Trucks needed to haul 200 tonnes (220 tons) per hour with 1.9-hour cycle time.

Consider these project conditions for ordering trucks. The hourly production is 200 tonnes (220 tons) per hour. The average load for a haul unit is 22 tonnes (24 tons). Six minutes have been assigned to load from the storage silo and four minutes to cover the load. It is a 40-minute haul to the project and 40-minute return trip. On the project, assume an average of 12 minutes waiting time to unload. Assume 10 minutes to discharge into the paver hopper and clean the truck bed before leaving the worksite. The total cycle time is 1.9 hours. To deliver the hourly production rate under these conditions, 18 trucks must be ordered.

TRUCKING CALCULATOR

Menu
Trucking
Paver Speed
Compaction
Windrow
Yield
Slope
Thickness
Job Summary
Legal
Exit

General Inputs	*Imperial Units*		*Metric Units*	
Production Rate of Hot Plant:	[220]	*tons/hr*	[200]	*tonnes/hr*
Multiple Silo Plants: Initial Storage	[0]	*tons*	[0]	*tonnes*
Paving Hours:	[0.0]	*hrs*	[0.0]	*hrs*
Truck Capacity (size):	[24.3]	*net tons*	[22.0]	*net tonnes*

Truck Cycle Times *(minutes)*	
Load Time and Ticket:	[6]
Tarp:	[4]
Haul to Job:	[40]
Time on Site:	[6]
Dump / Clean:	[5]
Return Haul:	[40]
Truck Cycle Factor *(total time in hours)*	[1.7]
Number of Trucks Needed:	[15.4]

Trucks needed to haul 200 tonnes (220 tons) per hour with 1.7-hour cycle time.

If a material transfer vehicle is added to the project, the cycle time will change. The hourly production is still 200 tonnes (220 tons) per hour. The average load for a haul unit stays at 22 tonnes (24 tons). Six minutes can still be assigned to load from the storage silo and four minutes to cover the load. It is a 40-minute haul to the project and 40-minute return trip. On the project, because the trucks can discharge faster into the material transfer vehicle, the waiting time and discharge time are significantly reduced. Assume an average of six minutes waiting time to unload. Assume five minutes to discharge into the material transfer vehicle and clean the truck bed before leaving the worksite. The total cycle time shrinks to 1.7 hours. Only 16 trucks are needed to deliver the hourly production under these conditions.

Studies by public works departments and universities show that material blending occurs during the material transfer process. Blending is beneficial in helping to remix material that has segregated in the haul unit. All of the normal best practices must be observed to avoid mat defects, but material transfer vehicles with remixing capability produce bituminous layers that have improved visual appearance. Remixing also helps produce a layer with uniform temperature from edge to edge. It is common to measure layer surface temperature within a 10° C (15° F) range. Most notable, the temperature variations associated with truck exchanges virtually disappear when transfer devices are used on a project.

Material blending by the material transfer vehicle improves control of segregation, uniformity and layer temperature.

The crew must be aware of a few things when using material transfer devices and hopper inserts.

The same care should be taken to discharge from the haul unit into the hopper of the material transfer vehicle that would be taken when discharging into the hopper of the paver. If any spills occur, quickly clean them up. Be especially vigilant about spills that are directly in line with the paver undercarriage or the path of the grade sensors. Remember, paving over spills is never a good practice.

Crews need to avoid spills that can occur in front of material transfer vehicles.

Run the first few loads directly through the transfer vehicle when the transfer vehicle is cold.

At the start of a paving shift, do not fill the material transfer vehicle to its storage capacity, especially when the ambient temperature is under 15° C (60° F). Hot bituminous material sticks to cold metal. There is a possibility that material will begin to clog discharge areas and decrease the amount of material that is being transferred. To prevent material sticking to cold metal, run the first two or three truckloads straight through the transfer vehicle to heat metal surfaces.

When the bituminous material includes large aggregates, there can be some segregation in the storage compartment of the material transfer vehicle and/or in the hopper insert. Caterpillar recommends that the material level in the transfer device storage compartment or in the hopper insert be maintained at least one-third full, especially if the material has aggregates 19 mm (0.75") or larger. If the remaining material in storage is used, it may primarily consist of large aggregates.

Never use all the material in the hopper insert or transfer vehicle while paving.

Just as segregation can occur in the layer when the hopper wings are cycled over a hopper that is out of material, patches of segregated aggregate will also appear in the layer when a hopper insert or transfer vehicle runs low on material. For example, if the material transfer vehicle needs to be emptied to lighten the vehicle load when crossing a bridge, do not use the last of the material for paving. Instead, discharge that material into a haul unit and salvage that last-of-load material later.

Patch segregation caused by running low in the hopper insert.

[WINDROW ELEVATORS]

Windrow elevators were the first material transfer devices. They are still widely used in some areas and are favored because they provide the most economical means of creating continuous paving at a consistent speed.

High-production windrow elevator transferring material into a paver with hopper insert.

Windrow elevators attach directly to the front of the paver.Bituminous material is discharged from haul units as a windrow onto the grade in front of the paver. Some windrow elevators have combining augers that push material toward the center of the transfer conveyor. Slats on the transfer conveyor pick up material from the windrow and deposit the material on the conveyor. Material drops off the end of the conveyor into the hopper. To increase the storage capacity of the paver hopper, many crews install rubber belt flashing across the front of the hopper or they install a hopper insert.

An adjustable moldboard is located behind the combining augers and the discharge conveyor. Set the height of the moldboard 6 mm to 12 mm (0.25" to 0.50") above the grade to avoid leaving bituminous material on the grade.

The same guidelines apply for maintaining the hopper or hopper insert at least one-third full while paving. This is especially important if paving with a mix that has aggregates 19 mm (0.75") or larger.

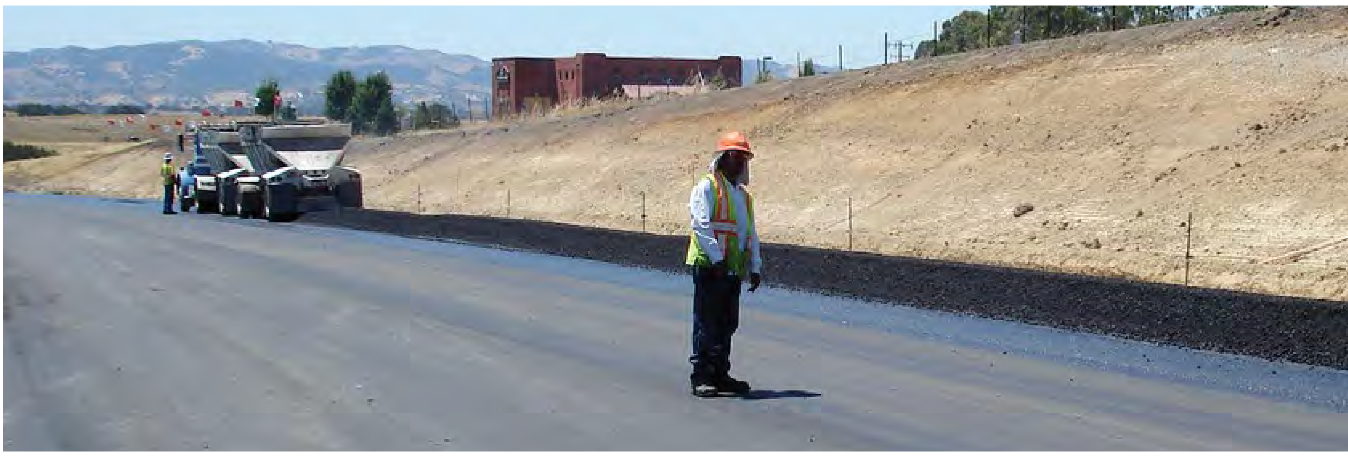
The most common type of haul unit used for windrow paving is referred to as a "belly dump" or a "bottom dump." This type of truck can be a single or tandem unit. The discharge is from the bottom of the truck body.

Where belly dumps are not readily available, dump trucks with modified discharge openings and live-bottom trucks have been successfully used.

The skill of the operator who is controlling the material discharge to form the windrow is critical to the paving process. This operator, referred to as the "dump man," must balance the size of the windrow with the demand for material passing through the paver. Sometimes a gap in the windrow is needed to avoid overfilling the hopper or insert. At other times, an overlap in the windrow from one truck to another is needed to supply additional material. High-production windrow elevators with wide pick-up openings make it easier to transfer large or off-center windrows.

Various types of haul units can be used to create windrows.

To avoid heat loss in the bituminous material, crews manage the length of the windrow according to ambient conditions. For example, when the ambient temperature is less than 25° C (80° F), the crew may limit the length of the windrow to what one truck can haul. On hot days, when there is little risk of heat loss, windrow length may be what two trucks can haul. Remember, every time hot bituminous material is transferred, some heat is lost. To verify heat loss, use a probe to check interior temperature of the windrow as soon as it leaves the haul unit. Then, check the interior temperature of the windrow again just before the windrow elevator picks it up. If the heat loss is more than 5° C (10° F), shorten the length of the windrow to reduce the time that it sits on grade exposed to the elements.



When ambient temperature conditions permit, there may be a long windrow in front of the paver.

[ROLLER-COMPACTED CONCRETE]

Roller-compacted concrete is a cement hydraulically-bound material used for pavements and other applications. The material is placed with asphalt paving equipment, but gains strength through compaction by rollers in addition to chemical curing that is associated with Portland cement concrete. Due to the rapid gain in strength, roller-compacted concrete may be opened to traffic much sooner than what is possible using conventional concrete pavement.

Roller-compacted concrete is a zero-slump material that is easily transported. It is most common to use end dump trucks, although mixer trucks may also deliver material to the worksite. Since it is compacted by a roller, the surface is relatively smooth and dense. It is suitable for heavy-duty, industrial applications and for road pavements where loads are heavy but speeds are low. For high-speed roadways, the surface of the roller-compacted layer is overlaid with one or more bituminous layers.

Some major applications of roller-compacted concrete include:

- Commercial parking areas
- Industrial storage and parking
- Waste transfer areas
- Container storage areas
- Truck and freight terminals
- Applications where speed of construction is essential
- Low-volume urban and rural roads or shoulders
- Aircraft parking areas (with thick bituminous overlay)

Roller-compacted concrete can be transferred to the paver by an end dump truck or by a cement mixer truck.

Thick layers of roller-compacted concrete are normally laid down with combination screeds.

Pavers perform initial compaction through vibratory screeds or through screeds that combine vibration and tamping energy. Vibratory screeds usually develop 80 percent to 85 percent density, while combination screeds develop 90 percent or more of the design density. Either way, compaction by rollers is required to reach the typical minimum density standard of up to 98 percent.

Pavers equipped with vibratory screeds normally place layers of roller-compacted concrete to a maximum depth of 15 cm (6"). If the design depth is more than 15 cm (6"), multiple layers must be paved.

Pavers equipped with vibratory and tamping screeds can develop adequate density while paving layers up to 30 cm (12") thick.

User Tip: *When placing multiple layers of roller-compacted concrete, lay the second layer on the first layer within one hour to create an adequate bond between the layers.*

User Tip: *When paving at a depth of 15 cm (6") or more of roller-compacted concrete, be sure to activate the screed counterbalance system. Taking some weight off the screed will help the screed float when paving thick layers. Also, be sure to add additional angle of attack to the main screed. Turn the thickness screws on both sides of the screed into the plus range to add angle of attack to the main screed. Adjust the counterbalance pressure and the angle of attack until the texture of the layer is correct at the desired thickness.*

Use the screed counterbalance system to help the screed float properly when laying down thick layers of roller-compacted concrete.

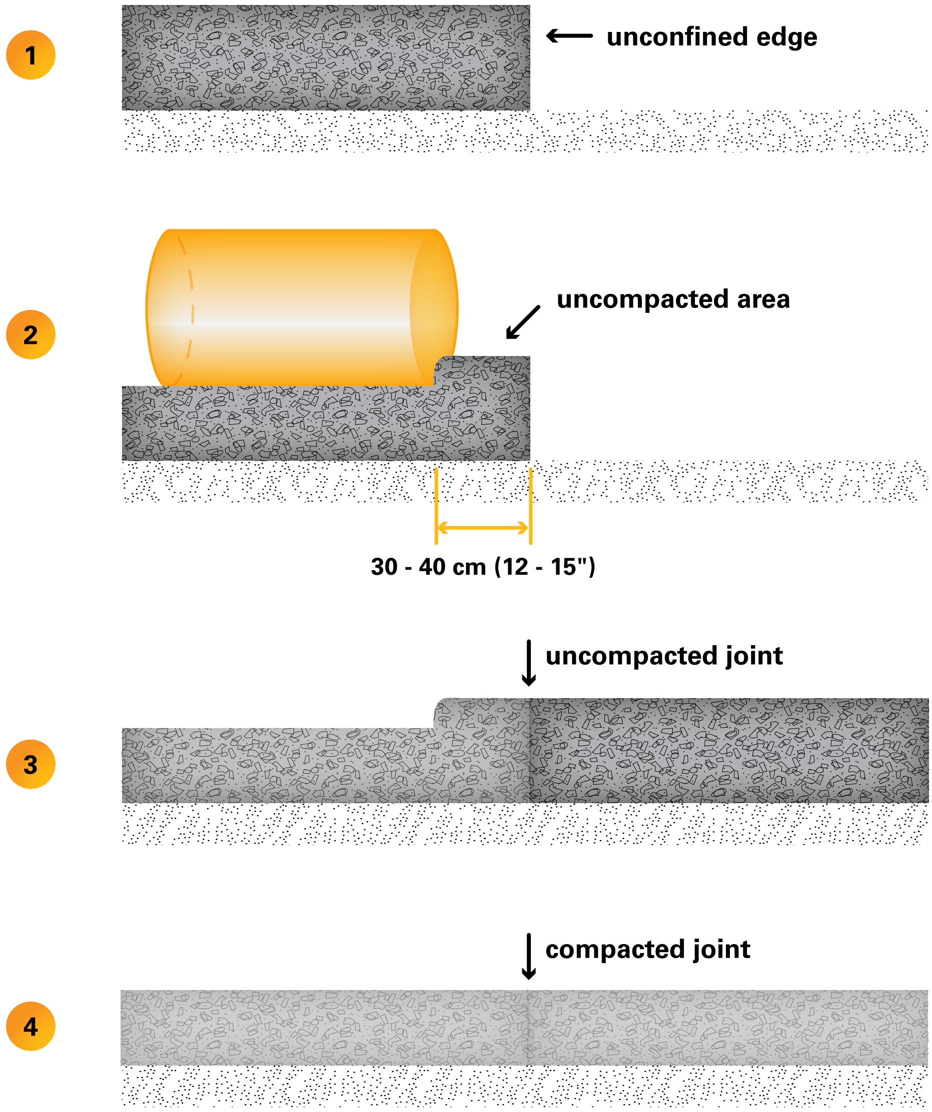
Roller-compacted concrete tends to move laterally when subjected to compaction forces. To avoid lateral displacement, try to avoid constructing unconfined edges. If that option is impractical, simply:

- Extend the pavement 30 to 45 cm (12 to 15") beyond the design width and cut back to fully compacted material after compaction.
- Use a temporary edge restraint.

In general, roller-compacted concrete should be compacted within one hour of mixing. However, at longitudinal joints, it is acceptable to delay compaction up to an additional hour when adjacent layers form a longitudinal joint.

Compacting longitudinal joints requires a special pattern.

CONCRETE ROLLER-COMPACTION SEQUENCE



When possible, compaction of unconfined edges is delayed until the adjacent lane is paved.

The compaction process can begin as soon as the first layer of roller-compacted concrete is started. The compactor(s), however, must stay away from the unconfined edge that will be part of the longitudinal joint.

To avoid deforming the edge, stay away from the edge 30 cm to 40 cm (12" to 15").

During the joint matching pass, the paving crew uses the uncompacted edge of the previous layer as the height reference.

As the matching layer is being paved, start the compaction by straddling the longitudinal joint with half the drum on each side. Depending on the type of material, the depth of the layer, the density developed by the screed and the specified final density, it may be necessary to start with a relatively light compactor and progress to heavier vibratory or pneumatic compactors.

Straddle the longitudinal joint when making the first pass forward.

[PAVING AGGREGATE BASE]

Using a paver to place aggregate base or plant-manufactured, stabilized aggregate base is preferred on some projects because of the paver's ability to provide precise depth and width control. Pavers equipped with combination vibratory and tamping screeds also develop relatively high initial density compared to conventional grading procedures. The depth of the aggregate layer can be up to 30 cm (12") with minimal or no modifications to the screed lift cylinders and the auger lift cylinders. Depending on the density specification and the availability of high-production compaction equipment, laying down multiple, thinner layers may produce better results.

The width of the aggregate layer can be set to the limits of any screed. Often the paving width is determined by the desired production and the paving speed that best matches the target for initial layer density.

2.5 m (8') combination screed laying down aggregate base 3.5 m (11.5') wide and 30 cm (12") deep.

For example, assume a project where the production rate is 500 tonnes (550 tons) per hour. At a layer depth of 25 cm (10"), the 2.5 m (8') combination screed that is planned to be used normally develops around 85 percent density at a working speed of 4 m (13') per minute. The Paving Production Calculator can be utilized to determine the paving width that matches the hourly production.

PAVER SPEED CALCULATOR

- Trucking
- **Paver Speed**
- Compaction
- Windrow
- Yield
- Slope
- Thickness
- Job Summary
- Legal
- Exit

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[9.84] *in*	[250.0] *mm*
Paving Width:	[16.40] *feet*	[5] *meter*
Material Density Uncompacted:	[120] *lbs/ft³*	[1922] *kg/m³*

Paver Speed @ Given Production Rate		
Production Rate of Hot Plant:	[551] *tons/hr*	[500] *tonnes/hr*
Calculated Paving Speed - 100% Efficiency:	[11.4] *ft/min*	[3.48] *m/min*
Calculated Paving Speed - 95% Efficiency:	[12.0] *ft/min*	[3.65] *m/min*
Calculated Paving Speed - 90% Efficiency:	[12.5] *ft/min*	[3.83] *m/min*
Calculated Paving Speed - 85% Efficiency:	[13.1] *ft/min*	[4.00] *m/min*
Calculated Paving Speed - 80% Efficiency:	[13.7] *ft/min*	[4.18] *m/min*
Calculated Paving Speed - 75% Efficiency:	[14.2] *ft/min*	[4.35] *m/min*
Effective Paving Speed:	[11.4] *ft/min*	[3.48] *m/min*

Select the Paver Speed screen. Enter the paving thickness, 250 mm (10"). Enter the material density, 1922 kg/cm³ (120 lb/ft³) in this example. Enter the production rate, 500 tonnes (560 tons) per hour. Then, experiment with the paving width. For this project, assume an efficiency rate of 85 percent based on trucks transferring directly to the paver hopper. A paving width of 5 m (16.4') will be exactly right to produce a working speed of 4 meters (13') per minute.

Or, make calculations to determine the maximum productivity that is possible using a paver to lay down the base aggregate. It may be beneficial to compare the use of a paver against the use of a motor grader. To determine the maximum productivity, the paver's maximum paving width and maximum paving depth must be known. Also, the working speed that will develop the desired initial density must be known.

Again, select the Paver Speed screen. The paver to be utilized has a maximum paving depth of 30 cm (12") and a maximum paving width of 7 m (23'). Enter those values. A working speed of 4 m (13') per minute normally produces acceptable initial density. Assume an 85 percent efficiency rate. Experiment with hourly production until 4 m (13') per minute appears as the calculated paving speed at 85 percent efficiency. In this example, the maximum hourly production rate is 850 tonnes (952 tons). To think in terms of volume rather than weight, that's 440 cubic meters (578 cubic yards) per hour.

PAVER SPEED CALCULATOR

- **Trucking**
- **Paver Speed**
- **Compaction**
- **Windrow**
- **Yield**
- **Slope**
- **Thickness**
- **Job Summary**
- **Legal**
- **Exit**

General Inputs	*Imperial Units*	*Metric Units*
Paving Thickness:	[**11.81**] *in*	[**300.0**] *mm*
Paving Width:	[**22.97**] *feet*	[**7**] *meter*
Material Density Uncompacted:	[**120**] *lbs/ft³*	[**1922**] *kg/m³*
Paver Speed @ Given Production Rate		
Production Rate of Hot Plant:	[**937**] *tons/hr*	[**850**] *tonnes/hr*
Calculated Paving Speed - 100% Efficiency:	[**11.5**] *ft/min*	[**3.51**] *m/min*
Calculated Paving Speed - 95% Efficiency:	[**12.1**] *ft/min*	[**3.69**] *m/min*
Calculated Paving Speed - 90% Efficiency:	[**12.7**] *ft/min*	[**3.86**] *m/min*
Calculated Paving Speed - 85% Efficiency:	[**13.2**] *ft/min*	[**4.04**] *m/min*
Calculated Paving Speed - 80% Efficiency:	[**13.8**] *ft/min*	[**4.21**] *m/min*
Calculated Paving Speed - 75% Efficiency:	[**14.4**] *ft/min*	[**4.39**] *m/min*
Effective Paving Speed:	[**11.5**] *ft/min*	[**3.51**] *m/min*

Set up the paver with grade and slope control the same way as when placing bituminous material. A single grade sensor located adjacent to the auger chamber will produce the best yield. An averaging ski will produce the best longitudinal profile. Slope control may be used to correct the transverse profile.

Conventional grade and slope control provides precise depth and transverse profile.

Following are five items to remember when paving thick layers of aggregate base.

1. Adjust tow-point to the depth of the layer. When laying down thick aggregate bases, the tow-point will be near the top of its range.

2. Adjust the thickness screws on both sides to give the main screed the correct angle of attack. Turn each screw, so the indicator is in the "plus" range whenever the paving thickness is 15 cm (6") or more.

3. If the paver has two positions for the connection of the auger lift-cylinder rod, select the lower position. The lower position gives the auger additional clearance when the rod is fully retracted.

4. Tow-point modifications may be required to permit laying down thick base layers. Consult the equipment supplier for assistance.

5. Increase the frequency of inspection on wear items. Laying down aggregate base causes more wear on components like conveyors, augers and screed plates. Unlike bituminous mixtures that have lubricating properties from the asphalt cement, water is the only binder for aggregate bases. Therefore, aggregate mixtures are much more abrasive. Expect to see higher wear than normal. To help minimize wear on screed plates, always activate the screed counterbalance system when laying down aggregate mixtures. Also, maintain the correct angle of attack to avoid excessive wear on the trailing edge of the screed plates.

[SUMMARY]

Each paving application has its own requirements. Those requirements must be discussed and understood by the crewmembers prior to paving. What is most important on the application: yield, elevation, smoothness, slope or appearance? In general, the paver can be setup to meet any of these requirements.

If special attachments or tools such as averaging skis are required, be sure to make timely arrangements for their delivery to the project. Some projects have written method specifications that dictate use of certain types of equipment, attachments or techniques. Be sure to follow all mandatory guidelines.

Set up grade and slope controls to satisfy project requirements. Crewmembers should be able make decisions regarding the position of grade sensors to control screed reaction. Stress the importance of mounting grade sensor hardware in a manner that permits the crew to position the sensors where they need to be. Crewmembers should be able to decide whether to use automatic slope control or to make slope corrections manually.

Consider all the project variables when selecting averaging skis. Mechanical averaging skis provide maximum reduction in roughness. Non-contact averaging skis provide the most versatility and convenience.

For special applications, such as roller compacted concrete or deep-lift aggregate base installation, be sure to make the necessary machine modifications.

Finally, lay out each project to maximize efficiency and communicate production goals, as well as quality control concerns to each crewmember.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Unit 8
TROUBLESHOOTING GUIDE

Troubleshooting can transform a disaster into a routine day at the worksite. Recognizing mat defects, determining their causes, and preventing or correcting them require a team effort involving supervisory personnel, paver and screed operators and quality control. When problems occur, knowing what to look for and how to adjust will help maintain quality, productivity and overall worksite efficiency.

Recognizing common defects in bituminous layers, how to determine the cause of those defects, and how to prevent or correct them is critical to every paving contractor.

Often times, mat defects are the result of crews not executing the fundamentals of paving correctly. Small missteps often result in much larger flaws. When crews perform the fundamentals correctly, many potential issues can be avoided.

This unit covers visible defects as well as other defects such as roughness and the conditions that contribute to the problem.

Paving efficiency dramatically affects the quality of the bituminous material. Continuous paving at a consistent speed makes it easy for the crew to keep all the factors that affect the screed in balance.

Proper use of automatic grade and slope control contributes to quality—not just smoothness or yield, but the appearance of the material as well. If the crew understands the most important project requirements, they should be able to set up grade and slope to meet those requirements. However, they must realize that “automatic” does not mean grade and slope are set up the same way on every project.

Developing knowledge of the causes and cures of paving issues is a continual process. Every project presents an opportunity to use past experiences and gain new knowledge. Equipment changes over time and specifications change, too. What was learned a few years ago, may not be helpful today.

[SURFACE TEXTURE]

The surface texture of the bituminous layer should be uniform from edge to edge across the full width of the layer. The type of material being placed does have an effect on surface texture. Dense-graded mixtures will appear tight and somewhat shiny. Open-graded mixtures will have a more open texture and will look darker. However, no matter what type of mixture is being paved, the texture should be the same to provide the best quality. If texture stripes are visible, use the following checklist of the most common potential causes to identify and correct the problem:

- Cold screed plate
- High spots in the grade
- Compacted spill in front of the paver
- Wavy screed plate
- Screed plates with different lengths
- Strike-off attachments
- Damaged screed
- Incorrect angle of attack
- Augers set too low

A screed that is not properly heated or that has cold sections will create drag marks and texture stripes.

When any portion of the screed plate is significantly colder than the bituminous material passing under it, the hot material will stick to the cold metal. The surface of the bituminous layer will look open or torn in that area. Normally, this will be readily apparent as the paver pulls away from the starting reference.

Stop paving and let the cold screed plates rest on the hot mat for a short period of time before resuming. The hot asphalt will quickly heat them. Cold screed plates also create drag that causes the screed to drop as it pulls away from the starting reference. A depression is often formed and repair may be necessary. Hand repair can take place while waiting for the screed plates to heat.

Another solution for repairing the depression is to return to the starting reference. Heat the screed adequately. Conduct start-up procedures and lower the screed to the starting reference. Start paving again and monitor the mat for drag marks and texture stripes.

User Tip: *Caterpillar recommends leaving the generator activated when paving with an electrically heated screed, especially when paving on urban projects with frequent restarts. The electric screed heating system will automatically energize screed heating elements, if the temperature sensors detect that the screed plates lost too much heat and are below the target temperature.*

On some projects, high spots in the grade may exist. When the screed passes over these high spots, the texture of the asphalt layer will appear open because aggregates are being dragged. This is especially a problem when paving with automatic slope control. As a rule, the thickness of the layer must be at least 1.5 times greater than the largest aggregate size for the mixture to pass under the screed in a uniform manner.

High spots in the grade can be the result of:

- Improper cold planing procedures
- Rutting and shoving
- Improper grade preparation
- Base deformation by haul units

Prior to paving, repair high spots in the grade. Always check grade conditions prior to paving.

Paving over a high spot in the grade will create texture differences in the surface of the asphalt layer.

Texture stripes caused by high spots may appear and disappear. When there is adequate layer thickness and all other factors are equal, the surface texture is normal. However, when the layer gets too thin, as when paving over a high spot, the texture becomes open and torn.

Temporary texture stripes caused by paving over high spot in milled surface.

Some high spots in the grade occur during the paving process when material is spilled and not immediately cleaned up. Spills become major problems when compacted by the haul unit tires or by the paver undercarriage. The compacted spill is no longer loose material, but is a hard, high spot.

Spills in front of the paver can cause high spots in the grade.

Drag mark caused by paving over compacted spill.

Depending on the thickness of the compacted spill, the screed may loose its floating characteristic when paving over the spill. The screed may ride up over the high spot, causing roughness. Drag marks and open texture will be apparent. Open texture surfaces lose heat faster than tight textures. Therefore, the area of open texture will be significantly cooler than the surrounding material. Fractured aggregates in the area over the compacted spill may be visible, because the layer is too thin to absorb vibratory energy. All these factors contribute to roughness, poor density and unacceptable layer thickness.

Texture stripes in the surface of the bituminous layer can be caused by a wavy screed plate. When screed plates are installed, the trailing edge should be checked for flatness. If high points exist, those areas of the screed plate will exert more pressure and the surface will appear tight and shiny. If there are low spots along the trailing edge of the screed, the screed will exert less pressure and open texture stripes will appear in the surface of those areas. If left wavy, eventually the screed plate will wear itself flat. However, the uneven wear pattern will shorten the service life of the screed plate.

A wavy screed plate exerts uneven pressure and creates texture stripes.

User Tip: *Cat dealers can provide clear instructions for replacing screed plates. Ask for "Screed Checks and Adjustments."*

On some screeds, the length of the main screed plate and the length of the extension screed plates are different. For example, the main screed plate may be 45 cm (18") long (front to back) and the extension screed plates may be 30 cm (12") long (front to back). Because the screed plates have different lengths, they exert different pressures on the surface of the layer. The texture differences are normally relatively minor. Adjust the screed extensions' angle of attack to create a more uniform texture.

Screed plates of different lengths can cause minor texture differences.

The screed angle of attack has a major influence on the texture of the bituminous layer surface. If the angle of attack is too high, the surface will have a tight and shiny appearance. If the angle of attack is too low or if the nose of the screed is angled down, the surface will appear open and torn.

Multiple texture stripes caused by multiple factors.

The image above shows examples of an incorrect angle of attack, a damaged screed plate, and open texture behind a strike-off plate.

1. On this project, there is a requirement for a 60 cm (24") wide, 30 degree taper at the edge of the paved surface. The crew forms the taper using an angled strike-off attachment. There is no screed plate to create texture. There is only a strike-off edge. Therefore, the texture will be very open. This is to be expected, and the crew should not take any action.

2. There is a 45 cm (18") wide extension bolted to the end of the left screed extension. The bolt-on extension is running flat. In other words, there is not enough angle of attack. The texture of the surface is much more open, than the texture of the surface toward the center of the layer. The crew should adjust the trailing edge adjusters on the bolt-on extension until the angle of attack is correct and the texture matches the remainder of the layer.

3. The strike-off in front of the bolt-on extension was damaged when it struck a drain inlet. The bent strike-off is causing the darker texture stripe. The crew must repair or replace the bolt-on extension to get rid of that texture stripe.

4. There is also open texture behind the left portion of the left screed extension. This texture stripe may be caused by a wavy screed plate. More likely, it is caused by the screed running with a flat or nose-down angle of attack. Notice the excessive head of material in front of the left extension. Too much weight in front of the extension causes the extension to climb. The grade averaging ski on the left side of the paver will detect this screed movement. The grade control system will constantly be sending signals to the tow-point to move down to compensate for the lifting force created by the head of material. Consequently, the angle of attack is always nosed down. The solution to the problem is lowering the head of material by adding additional auger segments and more mainframe extensions.

This is an example of what can happen when fundamentals are not closely followed. Never pave with a continuously excessive head of material.

When the augers are too low, a distinct texture pattern appears. The surface of the bituminous layer will be tight in the center. There will two areas of open texture on either side of center. Those texture stripes, commonly called "auger shadows," will be the same width as the augers. The edges of the layer will have a tighter texture, similar to the stripe in the center.

To eliminate the auger shadows, increase the auger height until the texture of the surface becomes uniform. Auger shadows are more likely to occur when the mix has large aggregates, 19 mm (0.75") or larger. The rule of thumb is to maintain auger height about 50 mm (2") above the surface of the layer. When paving with large aggregate mixes, the height may need to be increased to 75 mm (3") above the surface of the layer.

Running with the augers too low can cause two areas of open texture directly behind the auger shafts.

[SEGREGATION]

The bituminous material being placed by the paver is supposed to be a uniform blend of aggregates, fine material, asphalt cement, additives, recycled material and so forth according to the mixture formula. For a variety of reasons, the larger aggregates in the mixture sometimes separate from the smaller aggregates and show up as stripes or patches in the bituminous layer. These areas of segregated larger aggregates are susceptible to moisture penetration and usually develop lower than acceptable density. Eventually, areas with segregation may become cracked and end up as potholes.

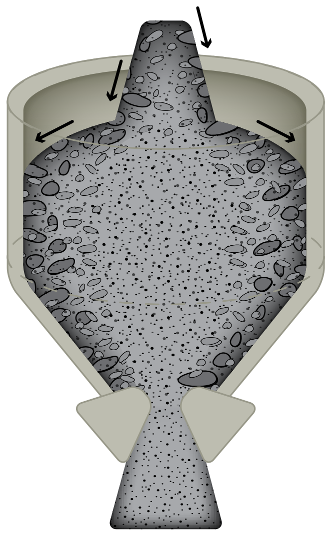
Although material segregation can occur in almost any type of bituminous mixture, mixtures that are the most prone to material segregation are those with aggregates 19 mm (0.75") or larger. Larger aggregates are heavier than their smaller counterparts. Anytime a mixture is transferred, dumped or moved, the larger aggregates can roll away from the smaller aggregates and accumulate as segregated pockets.

Segregation can occur at various places:

- In the storage silo
- In the haul unit
- In the transfer device
- In the paver hopper or hopper insert
- In the auger chamber

Segregation in storage silos can occur as a natural by-product of the silo loading process or can occur if the loading or discharging components are defective.

During silo filling, the contents can form some sort of cone or peak directly under the filling point. Some segregation takes place during the filling as more of the larger aggregates roll further down the slope of the cone toward the walls of the silo. When emptying through a single central outlet, the cone inverts and a hole develops down the center above the outlet. The initial flow of material will show a shift toward fine, and when the hole reaches the diameter of the silo, it will shift back, becoming coarser. When further material is put into the partially emptied silo it will segregate to form a coarse layer (immediately above the level of the partial load) as the cone builds up to the full diameter of the silo. This will show up as a coarse accumulation the next time material is taken from this level. Repeated cycling can build up layers of segregated material.



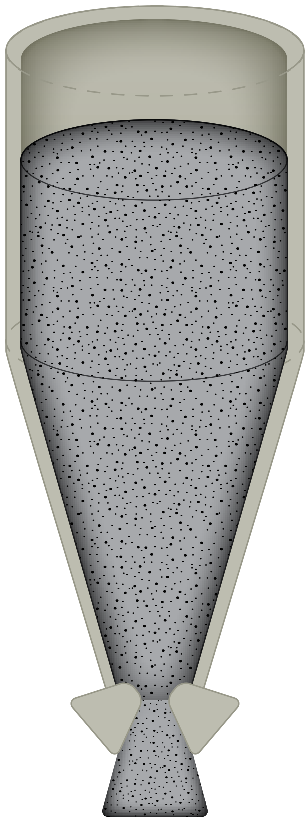
Larger aggregates can roll to the outside of a storage silo during loading.

Material that has been segregated in such a manner in the storage silo will show up as random patches of large segregated aggregates in the bituminous layer. The segregated mix can be detected as it is discharged from the haul unit into the paver or into the transfer device.

Anti-segregation devices (plates, deflectors), as well as rapid-opening clam gates to load batchers and mass-flow, steep-angle discharge systems, help minimize this problem.

Rapid-opening clam gates minimize segregation during the loading of the storage silo. Rather than loading the silo from a conveyor, the mix is transferred to a batch storage bin at the top of the silo. When the batch bin is full, twin clam gates open rapidly and the mix falls as a mass into the silo. The mix flattens on impact and does not flow to the sides of the silo.

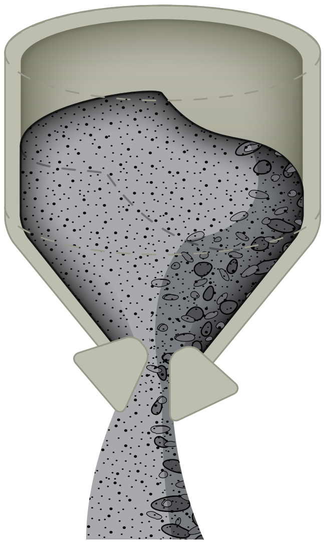
Mass-flow silos have discharge cones with steep angles. The cone angle is usually between 66 and 72 degrees. The mass-flow pattern allows material to move down the silo as a column with no flow channels. There are fewer areas with stagnant, non-moving mix, so the effects of segregation within the storage silo are eliminated or minimized.



Silos with steep discharge angles minimize segregation.

Sometimes, There may be large aggregates in one side of the layer and smaller aggregates in the other side of the layer. This mat defect is usually not created by the paver. Rather, this type of segregation comes from the storage silo. If a clam gate is not opening properly, mix can be directed to one side of the silo. The off-center drop makes larger aggregates roll to the opposite side of the silo. Smaller aggregates and fines end up on the loading side of the silo.

Material that has been segregated in the storage silo will show up either as random patches or as half-and-half segregation. Another type of segregation will show up in a repetitive pattern.



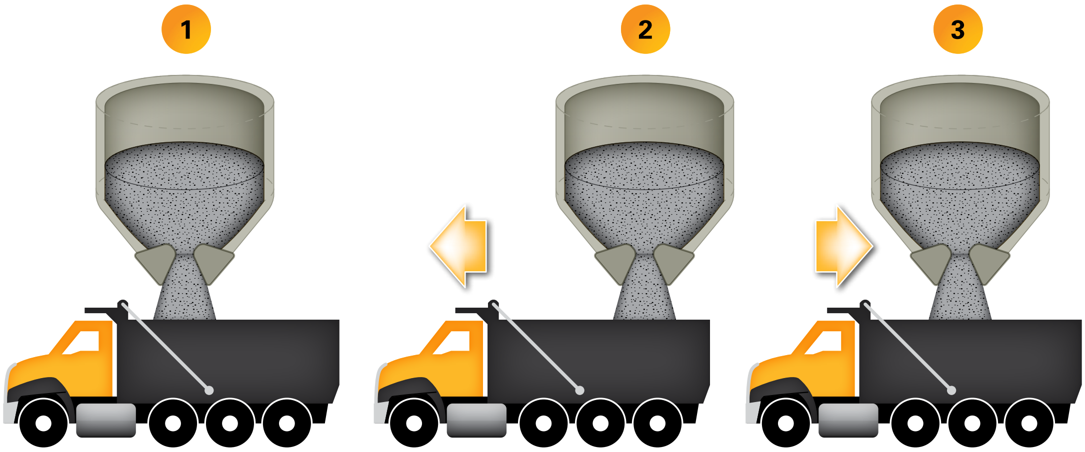
Off-center loading can create segregation on one side of the silo.

User Tip: *To confirm that the half-and-half segregation is coming from the storage silo, load several haul units from the opposite direction under the silo. If the segregation in the layer changes from side to side when the mix from these trucks is sent through the paver, it can be determined that the segregation is originating in the storage silo.*

End-of-load segregation is usually easy to identify because it appears in the bituminous layer at regular intervals. For example, if the average load in a haul unit will supply the paver for a distance of 30 meters (100'), patches of segregated material will appear every 30 meters (100'). The segregation patches may form a V-shape or may be circular. Their appearance indicates that material is probably segregated in the bodies of the haul units.

End-of-load segregation shows up at regular intervals as patches or V-shapes in the asphalt layer.

How the haul units are loaded at the asphalt plant has a significant impact on the occurence of segregation in the bituminous layer.



Multiple drops help reduce segregation in haul units.

One way to reduce end-of-load segregation is to make sure that trucks are loaded by a three-drop method at the plant. For the first drop, the truck should be positioned so mix fills the front of the truck bed. The front wall of the bed helps confine the mix, so a conical pile is not formed. For the second drop, pull the truck ahead, so the mix falls into the rear of the bed. Now, the tailgate is the vertical barrier that prevents the conical pile. Finally, move the truck back slightly so the third drop is in the center of the bed. The first and second drops help confine the third drop, and there will be much less roll-down of large aggregates.

The three-drop procedure is especially important for mix designs that have a large amount of aggregates 19 mm (0.75") and larger. Fine mixes are less prone to segregation, but the three-drop method is still recommended.

If segregation is not occurring during the truck loading process, continue to troubleshoot the cause of the pattern segregation.

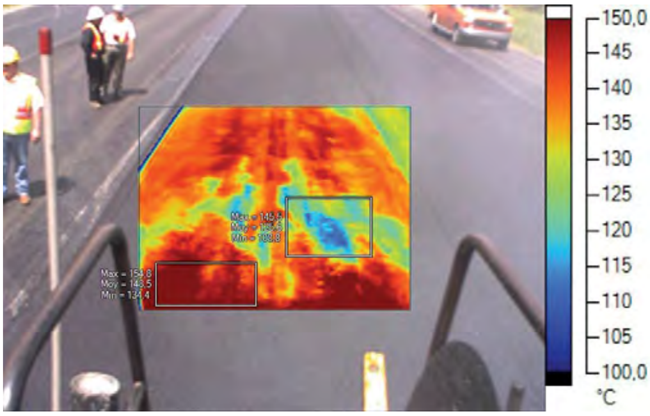
When transferring mix directly into the paver hopper from the haul unit, accumulations of larger aggregates at the sides of the hopper may occur. This phenomenon is an unavoidable consequence of discharging mix from the haul unit into the hopper, especially if there are large aggregates in the mix. Some of the larger aggregates will roll to the sides of the hopper. The key to reducing the amount of segregation in the layer is to stop cycling the hopper wings or, at a minimum, cycle the hopper wings when there is still material in the center of the hopper. Never cycle the hopper wings when the conveyors are low on mix or empty.

Look for segregation in the paver hopper.

Cycling of the hoppers should only occur while the conveyors are are full of material. Cycling the hopper wings over empty or partially empty conveyors will increase the amount of end-of-load segregation. The problems created by cycling the hopper wings are widely recognized. In fact, some public works agencies have written specifications that prohibit cycling hopper wings on certain types of projects.

Severe segregation in the hopper caused by cycling the hopper wings when the level was too low.

Even if there is no material segregation in the hopper and no visible segregation in the bituminous layer, there can be a large temperature differential caused by cycling the hopper wings. When there is a temperature differential that is 15° C (30° F) or greater, there is a high likelihood of experiencing a significant density variation and also a detectable bump. Some public works agencies have written specifications that require documentation of layer temperature as part of the quality control process. Infrared cameras and on-board heat sensing systems will be more common in the future and can be an important troubleshooting tool.



Large temperature differential caused by cycling hopper wings when the conveyors were almost empty.

The use of material transfer devices helps to eliminate or minimize end-of load segregation. However, material transfer devices do not guarantee that segregation can be avoided in the bituminous layer. Several factors need to be monitored.

Hopper inserts are often used in conjunction with material transfer devices. Depending on the type of mix, the level of mix in the hopper insert and the height from which mix is transferred, a cone forms in the center of the hopper insert and large aggregates roll to the sides of the insert—similar to what can happen when loading a storage silo. When segregation in the hopper insert is observed, be careful not to run the material level low in the insert between trucks.

Segregation can occur in the hopper insert.

Segregated large aggregates that have accumulated around the outer diameter of the hopper insert will pass through the paver as a mass when the level in the insert gets too low. Try to keep the insert at least half full to minimize segregation caused by large aggregates that are the last fraction of the load to transfer out of the insert. Random patch segregation can occur when material in the transfer vehicle empties.

Random patch segregation caused by running the mix level low in hopper insert.

User Tip: *Use the Paving Production Calculator to determine the amount of time that is available to pave during truck exchanges. Using half the volume of the transfer vehicle and half the volume of the hopper insert as the amount that can be consumed while exchanging trucks, determine how far that volume will pave (yield). For example, the amount of mix available may yield 30 meters (100') of paving. If the paving speed is 6 meters per minute (20 feet per minute), there are five minutes of paving time before running the hopper insert and / or transfer vehicle so low that segregated material may begin to pass through the paver.*

It is better to stop the paver and wait for mix rather than continue paving and risk introducing segregated material into the layer. It is also better to stop paving at the end of the shift or the end of a paving pass before consuming all the mix in the transfer vehicle. Keep an empty haul unit at the project. Load the last few tons out of the transfer vehicle into the empty truck. Remove any portion of the bituminous layer that has segregated material from the last portion of the mix adjacent to the hopper insert.

When windrow paving, there may be, segregated aggregates at the end of the windrow. The last material out of the body of belly-dump trucks can be a mass of large aggregates. The dump person should try to feather out the remaining material from the truck. Then, overlap the end of the windrow so the segregated mix is covered with good quality mix. Some blending will occur as the windrow elevator picks up the material.

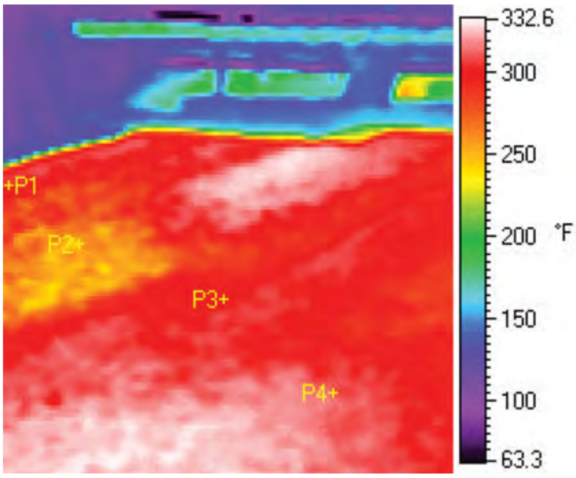
The end of a windrow often consists of segregated aggregates.

Improper adjustments to the feeder system may cause other segregation issues.

Auger speed has an impact on the appearance of the bituminous layer. The proper auger speed is between 20 and 40 revolutions per minute. When the auger speed is too high, the augers can actually cause the aggregates in the mix to separate. The larger aggregates will roll and stop in the stagnant areas under auger bearing hangers or at the end of the tractor frame. These will be continuous stripes if the augers are turning too fast all the time. If the auger speed varies between an acceptable range and a speed that is too fast, the stripes will come and go.

To slow down the augers, increase the conveyor speed or raise the flow gates. Remember, each conveyor and each auger has individual adjustments. It is possible for one side of the feeder system to function in the acceptable range and the other side to function improperly. There may be a segregation stripe inline with the the right auger bearing support and not on the left side of the mat. This condition indicates that the right side feeder system needs to be adjusted to create acceptable auger speed.

Continuous segregation stripes often relate to high auger speed.



Random patch segregation can be seen and also detected in thermal images.

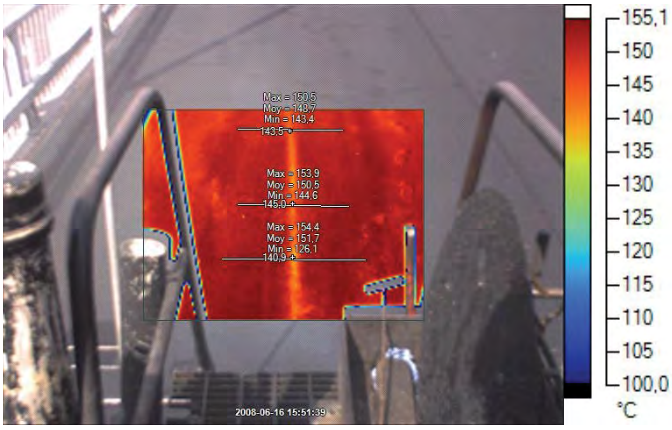
When segregated aggregates appear occasionally in the layer, that condition is referred to as random patch segregation. Random patch segregation is usually associated with the feeder system operating erratically. In other words, both augers or either auger may rotate at the recommended speed for a period of time and then slow down or stop. When an auger slows or stops, the largest aggregates tend to roll toward stagnant areas. A pocket of segregated aggregates is formed and those aggregates show up as a patch of segregation in the layer. The segregation stops when the augers are rotating at a normal, continuous speed. Hence, the appearance of the segregation is random.

If the augers operate at variable speeds, reposition the feeder sensor. Erratic operation of the feeder system results when the sound pulses emitted by the feeder sensor do not reflect back to the sensor.

Use a tape measure or folding ruler extended 45 cm (18"). Hold the ruler on the end of the sonic feeder sensor. Be sure that the target is about 45 cm (18") away from the sensor and that the sensor is perpendicular to the target, so the sound pulses will reflect back. Position the sensor until the material-height dial and/or conveyor speed dial have the ability to produce consistent feeder system operation on both sides of the paver.

Centerline stripes can be related to feeder system operation.

Segregation stripes in the center of the bituminous layer can result from a variety of causes. The stripe sometimes occurs when the area under the auger chain case restricts material flow. The larger aggregates tend to accumulate in this area and will show up as a stripe, sometimes barley detectable by sight.



A thermal image confirms the open-textured, segregation stripe in the center.

Any area of segregation in the bituminous layer will have a more open texture compared to other surface areas of the layer. The open-textured surface loses heat more rapidly than those areas where the surface is tighter. Using an infrared camera, it is possible to confirm the exact location of the segregation stripe and the severity of the temperature differential.

The head of material under and in front of the center chain case can be stagnant.

The auger drive chain case extends into the auger chamber. The chain case impedes the flow of material to the center of the main screed. To improve the flow of material under the chain case, there are various types of paddles or segments installed on the inner ends of the left and right augers. On some pavers, these segments are installed so both push material under the chain case to eliminate the possibility of voids in the center of the auger chamber. When both segments are pushing material under the chain case, the head of material in front of the chain case may be stagnant. In other words, the material is trapped there, and heat loss along with a possible accumulation of larger aggregates may occur. In this situation, change one of the center auger segments to create a flow of material that has one segment pushing material under the center chain case while the other segment is pulling material away from the chain case. The head of material in front of the chain case will become active, and the segregation stripe should disappear while the temperature uniformity improves.

Inspect these reversing augers or kicker paddles frequently. They experience more wear and damage than the other auger segments. Excessive wear can also cause variations in material flow and stripes.

Don’t let material build up on components in the center of the auger chamber. The deflector plates in several locations are designed to help the flow of material and prevent segregation. At the end of the shift, inspect these plates and clean them to prevent the accumulation of cold bituminous material.

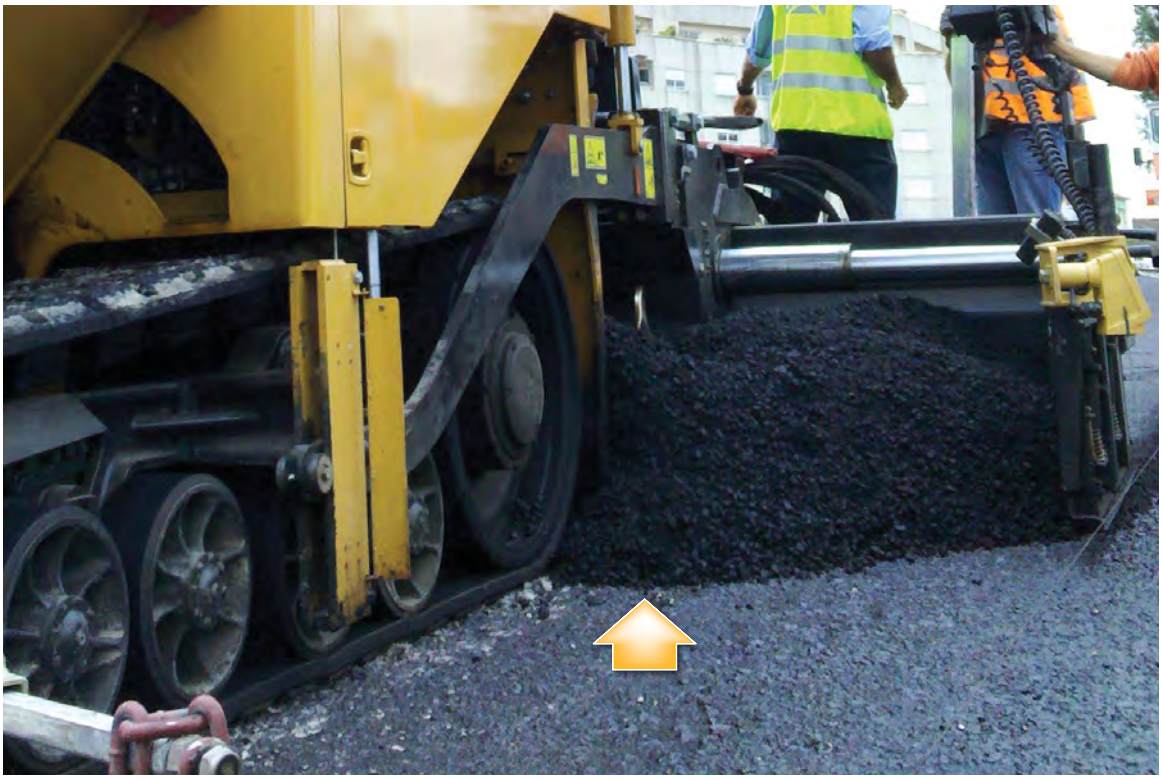
Because the area in the center of the auger chamber can have restricted flow of material, how the mix passes under the center of the screed can be affected. In particular when paving with stiff mixes that have large aggregates, a centerline stripe may appear due to low lead crown.

A centerline stripe can be caused by insufficient lead crown.

Most screeds are adjusted to be flat across the leading edge of the main screed plate as well as the trailing edge of the main screed plate. To help eliminate or reduce centerline stripes, Caterpillar recommends installing 3 mm (0.125") of lead crown into the main screed plate.

To install lead crown, first raise the main screed plate. With the screed raised and securely blocked, place a string across the leading and trailing edges of the screed plate. Use the power crown switch or manual crown adjuster to create a positive crown. Create a 3 mm (0.125") gap between the stringline and the leading edge of the screed plate in the exact center of the screed plate. Then use the trailing edge adjusters at the rear the screed plate to flatten the trailing edge. The leading edge will retain the 3 mm (0.125") lead crown. Confirm that the lead crown has the desired effect of reducing or eliminating the centerline stripe. If the center of the bituminous layer is tight and shiny compared to the rest of the layer, reduce or completely remove the lead crown.

Installing 3 mm (0.125") lead crown in the main screed plate helps reduce centerline striping.



Segregation can occur anywhere that the flow of material is incorrect.

If a segregation stripe becomes apparent in the surface of the bituminous layer, follow the stripe to its source. Observe the action of the head of material at that point. Verify the material is flowing in a uniform manner at the correct speed and volume. Any interruption to the normal flow characteristics can cause larger aggregates to separate and form stripes or patches.

For example, in the above illustration the material is flowing forward around the tractor mainframe instead of flowing out to the end gate. As the larger aggregates flow down the face of the pile, they separate and form a stripe. In this case, there is a simple explanation. At the start of this paving pass, the paving width was 5 meters (16.5'). Gradually the paving width tapered to 3.8 meters (12.5'). As the screed extensions were moved in to create the specified paving width, material was trapped between the end gate and the end of the main screed. The material in front of the screed extension became slightly compacted and formed a barrier to the loose material coming out of the auger chamber. Instead of flowing out to the end gate and under the screed extension, the material is rolling forward and segregating. There is a simple solution to this problem. Remove the compacted material in front of the extension until the area is filled with fresh, loose material that moves out to the end gate.

[TROUBLESHOOTING GUIDE]

Use the following troubleshooting guide to help determine the cause(s) of common defects in the bituminous layer. There may be more than one factor contributing to a defect. When troubleshooting any problem, be methodical and change one condition at a time.

SURFACE TEXTURE

Problem	Remedy
1. Open texture behind extension	- Increase extension angle of attack - Increase heat; check screed heat system for malfunction - Increase depth to prevent dragging
2. Shiny texture behind extension	- Decrease extension angle of attack
3. Texture stripes, continuous	- Flatten trailing edge of screed Increase heat; check screed heat - Inspect screed for damage or wear
4. Texture Stripes, intermittent	- Check for high spots in grade; correct grade defects; clean up spills - Increase depth
5. Open texture full width	- Raise tow-point to correct line of pull - Increase angle of attack at take-off - Reduce head of material to prevent overreaction by grade control system - Increase plant output temperature - Activate vibratory system - Increase vibratory frequency - Reduce paving speed - Increase screed heat temperature - Increase layer thickness
6. Shiny texture full width	- Lower tow-point to correct line of pull - Decrease angle of attack at take-off - Decrease vibratory frequency
7. Open texture either side of center	- Increase auger height - Decrease lead crown
8. Open texture in center	- Increase lead crown - Check condition of reversing augers - Clean deflector plates

SEGREGATION

Problem	Remedy
1. Segregation one side of layer	- Look for segregation in storage silo - Check opening of clam gates in silo - Inspect loads in haul unit bodies - Load haul units from opposite direction
2. Stripe at longitudinal joint	- Reduce overlap onto cold side - Adjust end gate height - Adjust notch height if using notched wedge joint
3. Continuous stripes	- Adjust auger speed to 20-40 rpm - Check for high spots in the grade - Check for worn or damaged augers - Check for trapped material - Add auger / mainframe extensions
4. Intermittent stripes	- Check for erratic auger speed - Adjust auger speed to 20-40 rpm - Clean up spills in front of paver - Check for high spots in the grade
5. Stripe in the center	- Clean deflector plates - Check reversing augers / paddles - Add lead crown
6. Repetitive patches	- Check haul unit loading at plant - Inspect for segregation in truck bodies - Keep hopper at least half full - Stop folding hopper wings - Fold hopper wings over full conveyors - Increase windrow overlap
7. Random patches	- Inspect material coming out of silos - Check for on / off auger operation - Adjust auger speed to 20-40 rpm - Stop paving before emptying hopper Insert - Stop paving before emptying transfer vehicle

ROUGHNESS

Problem	Remedy
1. Ripples	- Adjust feeder controls to get consisten head of material - Reduce head of material - Check for excessive auger wear - Check for worn screed plates - Adjust paving speed to be consistent - Reduce haul unit brake pressure - Check for variable material temperature; correct at asphalt plant - Check for excessive play at screed pivot point - Check for excessive play at thickness screws - Increase tamper bar frequency or reduce paving speed to achieve correct tamper overlap - Adjust tow-point height to get parallel line of pull - Adjust angle of attack to get correct 3 mm (0.125") nose-up attitude
2. Wavy surface (short)	- Avoid over-correction with manual depth screws - Calibrate grade control system - Adjust feeder controls to deliver consistent head of material - Adjust auger speed to 20-40 rpm - Reduce head of material - Position grade sensor closer to tow-point
3. Wavy surface (long)	- Check grade reference for long depressions or high spots - Reduce time stopped waiting for trucks; reduce paving speed - Activate screed counterbalance system - Increase pressure in screed counterbalance system - Activate screed hold system, if equipped - Stop paving with conveyors full - Stop folding hopper wings if segregation is occurring
4. Intermittent roughness	- Calibrate grade control system - Inspect grade sensor(s) - Monitor averaging ski operation while paving super elevations - Clean spills in front of paver - Clean spills in front of grade sensor(s) - Correct high spots in grade prior to paving - Monitor feeder system operation - Discontinue automatic slope control; control slope manually - Install averaging ski in place of single grade sensor

BLEMISHES

Problem	Remedy
1. Drag marks	- Clean spills in front of paver - Correct high spots prior to paving - Increase layer thickness - Check slope of grade prior to using automatic slope control - Monitor head of material; do not run low - Increase screed heat
2. Oversized material	- Check gradation screens at plant - Check scalping screens at recycle stockpile - Clean truck bodies - Lower flow gates, if equipped
3. Screed marks	- Trucks stop short of push rollers - Reduce time stopped waiting for trucks; reduce paving speed - Activate screed counterbalance system - Increase pressure in screed counterbalance system - Activate screed hold system, if equipped
4. Rich spots / bleeding	- Correct moisture in mixture - Reduce asphalt cement content - Reduce vibratory frequency - Switch to static compaction - Plant maintenance to eliminate dust balls
5. Separation marks	- Adjust screed extension height - Adjust screed extension slope - Adjust slope stop to flatten screed extension

[SUMMARY]

New technologies have simplified the asphalt paving process and made it easier for crews to optimize paver performance, productivity and efficiency. Yet the human element remains as the single, most important factor in utilizing pavers to their maximum advantage.

Many worksite circumstances can arise that result in problems laying down a high-quality mat and/or meeting daily production goals. There is no substitute for crewmember experience in preventing problems, and when they do occur, quickly solving problems.

Cat Paving Operations Training is one option that pays immediate dividends and much more over time. This *Guide to Asphalt Paving* is another key tool that should be available for ready reference. Unit 8 is a great guide to diagnosing and solving problems. Many of the topics may sound familiar, but even the most experienced supervisors, paver and screed operators, and quality personnel are likely to learn something new and gain a deeper understanding of many common defects, some visible, some not.

The surface texture of the bituminous layer should be uniform, edge-to-edge, across the full width of the layer. When problems appear in the mat, crewmembers need to know the possible causes, determine what actually happened, and immediately take corrective action. The photos and descriptions in Unit 8 will help with determining the cause.

Segregation can be a particularly annoying problem. Knowing where it is happening and what to do to eliminate or minimize its impact on the bituminous layer is critical. Guidelines for root cause analysis will help determine if the problem is originating at the plant, in the haul units, in a transfer device, in the paver hopper or hopper insert, or in the paver's auger chamber.

The concise Troubleshooting Guide at the end of this unit is a great resource for spotting problems and applying remedies involving surface texture, segregation, roughness and blemishes. Find a place to store this guide on the paver or in a worksite vehicle. When it comes to understanding what is happening on the worksites, knowledge is power. This guide presents decades of knowledge packed into an easy-to-use, illustrated format.

GLOSSARY OF TERMS

- A -

Aggregate	Aggregate refers to the type or types of stones used in the manufacture of bituminous paving material.
Crushed Stone	The mechanical reduction of gravel and rock by crushing machines. Crushed stone is graded by running through vibrating screens.
Gravel	Large granular material produced by the natural erosion or disintegration of rock. Gravel usually has rounded surfaces and is larger than 6 mm (0.25").
Sand	Fine granular material resulting from the natural disintegration of rock or the crushing of rock. Often classed as smaller than 6 mm (0.25").
Moisture Content	Moisture content is an important factor regarding the suitability of an aggregate for use in bituminous material. Excessive moisture means increased drying time and less production. Excessive moisture in the mix creates instability.
Air Voids	Air voids are pockets of air trapped within an asphalt layer that has been laid down by a paving screed.
Ambient Conditions	Ambient conditions include air temperature, wind speed and direction, and cloud cover. Ambient conditions affect heat loss in the asphalt from the time of manufacturing at the plant until transfer into the paver.
Approach	An approach is the connection to an existing structure, such as an intersection or ramp, that is perpendicular to one side of the primary paving pass.
Asphalt	Asphalt is the generic term used to describe bituminous paving material, also called hot mix asphalt or sometimes warm mix asphalt. Asphalt can also be classified as cold mix.
Asphalt Cement	Asphalt cement is the oil used in the manufacture of bituminous paving material. Asphalt cement is also called bitumin.
Cutback	Cutbacks are asphalt cements mixed with a hydrocarbon solvent, typically a petroleum distillate, in order to lower the viscosity of the asphalt cement.
Doped	Asphalt cement with additives that improve adhesion.
Elastometric	Polymer-modified asphalt cement with higher elastic properties and less thermal susceptibility.
Fluxed	Asphalt cement that is softened by the addition of low-volatile fluxing oil.
Modified	Usually refers to polymer-modified asphalt cement with increased stiffness.
Pigmented	Asphalt cement that has had a coloring agent added.
Asphalt Concrete	Asphalt concrete is another phrase used to describe bituminous paving material.
Thin Lift	Asphalt wear course 30-50 mm (1.2-1.9") thick.
Very Thin Lift	Asphalt wear course less than 30 mm (1.2") thick.
Asphalt Plant, Batch	A batch plant produces a fixed quantity of mix in one discontinuous operation. That batch is transferred to a storage silo.
Asphalt Plant, Continuous	Also known as a drum mix or continuous plant, it is continuously fed aggregates, additives and asphalt cement. Finished material is transferred to one or more storage silos.
Auger	Continuous, rotating screws used to move asphalt across the left and right faces of the screed.
Height	The distance between the bottom of the auger segments and the surface of the bituminous layer. Typically, auger height is adjusted to 5 to 8 cm (2 to 3").

Speed	Auger speed is the rotation speed of the augers during the paving operation. Normally set at 20 to 40 revolutions per minute.
Chamber	The space between the rear of the tractor frame and the face of the screed.
Auger Shadow	Auger shadows are open-textured stripes that appear in the surface of the layer in line with the augers. The shadows are caused by the augers being set too low.
Averaging Ski - Mechanical	A mechanical averaging ski is towed by the paver and contacts the grade reference. May be installed outside or inside the paving width.
Averaging Ski - Electronic	An electronic averaging ski is attached to the paver and does not contact the grade reference. An electronic ski uses multiple sonic grade sensors and averages the signals. May be installed outside or inside the paving width.

- B -

Baghouse	Wet or dry dust collection systems that are part of the air-quality-control system at an asphalt plant. Baghouse dust is commonly recycled as part of the asphalt mixture.
Base Layer	The base layer is usually the first layer of bituminous material in a roadway structure. The base layer usually consists of large aggregates and is laid 75 mm (3") thick or thicker.
Binder	Organic material (bitumen, coal tar) with properties of cohesion and adhesion that enable it to bond aggregates.
Binder Layer	The binder layer is bituminous material laid on top of the base layer. The binder layer consists of medium size aggregates and is usually 50 -100 mm (2 -4") thick.
Binder Content	Expressed as a percentage, binder content is the ratio between the weight of the binder and the weight of dry aggregates in the mix. Or, it is the ratio between the weight of the binder and total weight of the mix.
Bitumen	Bitumen is a black, sticky mixture of hydrocarbons found naturally or obtained as a residue from petroleum distillation. Bitumen is also called asphalt cement.
Modified	Modified bitumens contain additives such as polymers that improve the bitumen’s engineering properties.
Straight	Straight-run residue resulting from atmospheric distillation of petroleum crude oil.
Performace Grade	The performance grade system classifies bitumens based on engineering properties at various expected high and low pavement temperatures.
Bituminous Material	Bituminous material is the combination of aggregates, asphalt cement, and certain additives. Bituminous material is manufactured at asphalt plants.
Hot Mix	Bituminous material produced in an asphalt plant at temperatures between 150 – 180° C (300 – 350° F).
Warm Mix	Bituminous material produced in an asphalt plant at temperatures up to 40° C (100° F) lower than hot mix.
Cold Mix	Mixture of aggregates and binders that provides coating without heating and drying the aggregates. Bitumen emulsion is typically used as binder.
Bleeding	The undesirable effect of asphalt cement rising to the surface of a wear course.
Braking Force Coefficient	The coefficient of braking force is a measurement that characterizes skid resistance of the longitudinal roadway surface.
Bulk Density	Density of loose, or non-compacted bituminous material.

Butt Joint	A butt joint (also called a night joint) is a common term used to describe the transverse starting point for a paving pass that joins a previously laid pavement section with a new section.

- C -

Chamfer	A chamfer is the slope created by beveling the edge of the pavement, usually at a 45° angle. A chamfered edge resists deformation and the effects of weather.
Clam Gates	Clam-type discharge gates are designed to open simultaneously from the center and discharge a mass of hot bituminous material into a storage silo. Improper gate opening can lead to segregation in the storage silo.
Clean-out Area	An area specified for clean-out of haul units. May be on the project or at the asphalt plant.
Compaction	Compaction is the mechanical process of reducing air voids and developing load-bearing strength in a layer of bituminous material by moving aggregates into interlocking contact.
Compaction Rate	The difference in thickness between the layer passing under the screed (pre-compaction height) and the compacted thickness after the compaction process is complete.
Confined Edge	A confined edge is an edge of an asphalt layer that is confined by a previously laid layer. The intersection of the two layers is called a longitudinal joint.
Control House	The control station for the asphalt plant operator that contains all the controls for production, storage and discharge of bituminous material.
Conveyors	Located in the paver hopper, left and right slat conveyors move material from the hopper to the auger chamber in front of the screed.
Cooling Curve	A cooling curve is a graphical time chart of the heat loss in an asphalt layer based on layer thickness, type of material and ambient conditions.
Core Sample	A core sample is a small portion of the cooled, compacted asphalt layer that is removed by quality control personnel and taken to a laboratory for quality analysis.
Core Temperature	Core temperature refers to the temperature measured by a probe inserted into the center of an asphalt layer. Core temperature is always higher than surface temperature and is the true indicator of an asphalt layer's workability.
Corrugations	Corrugations, or washboarding, are a form of plastic deformation that results in ripples across the pavement surface. Usually caused by repeated vehicle braking at intersections.
Crack Seal	The use of an asphalt emulsion or similar product to fill cracks in the pavement and prevent moisture penetration. Depending on the type and age of the crack sealant, it may expand and cause bumps when covered with hot asphalt.
Cracking	Various types of defects, usually visible in the surface layer.
Fatigue	Series of interconnected cracks caused by fatigue failure of the surface under repeated traffic loading.
Longitudinal	A crack or discontinuity in a pavement that runs generally parallel to the pavement centerline. Longitudinal cracks may occur as a result of poorly constructed paving lane joints, thermal shrinkage, inadequate support, reflection from underlying layers, or as a precursor to fatigue cracking. Longitudinal cracking that occurs in the wheel path is generally indicative of alligator (fatigue) cracking.
Reflective	Reflective cracks occur in overlays and reflect the crack pattern in the underlying layer.
Slippage	Slippage cracks are crescent shaped cracks resulting from traffic-induced horizontal forces. Typically caused by a lack of bonding between the surface layer and the binder layer.

Transverse	Transverse cracks occur at approximately right angles to the centerline of the structure and often at regular intervals. The cause is movement due to temperature changes and hardening of the asphalt cement with aging.
Counterbalance System	The counterbalance system, when activated, puts a certain amount of upward hydraulic pressure in the screed lift cylinders. Screed counterbalance takes some weight off the screed and transfers that weight to the tractor. Used to minimize screed marks in the layer when the paver stops.
Cross Coupling	Cross coupling is a feature of some grade and slope control systems that ties together the movements of both tow-points to provide simultaneous grade and slope corrections.
Cross Section	A cross section is an engineering drawing that illustrates the transverse profile of a section of pavement at one location.
Crown - Structural	The crown of a structure is the intersection of two layers with opposing slopes.
Crown - Screed	The main screed plate may be set at the midpoint to create positive or negative opposing slopes.
Cutoff Shoe	A cutoff shoe is installed in the auger chamber to reduce the paving width to a measurement less than the width of the main screed.
Cycle Time	Cycle time is the time it takes for a haul unit to make a round trip between the asphalt plant and the project. Cycle time is the critical element in determining the number of haul units required to match plant production.

- D -

Delamination	The separation of two layers of bituminous material. Can be caused by insufficient tack between the layers or by the cold planing process.
Density	Density is the weight of a given volume of material, normally expressed as kilograms per cubic meter or pounds per cubic foot.
Density Testing Gauge	Density testing gauges are used to test density on the project while the bituminous material is still hot enough to make adjustments. The quality control technician calibrates and uses the gauge on the project.
Density - Theoretical Maximum	Theoretical maximum density is the weight of a given volume of bituminous material compacted in a repeatable, controlled manner in a laboratory environment.
Density Required	Required density is expressed as a percentage and represents the ratio between the weight of a sample of the compacted mix and the weight of a laboratory-compacted reference sample (Marshall, Duriez, for example).
Depth Crank	Depth cranks are located on each side of vibratory screeds. Layer thickness can be changed manually through the depth cranks.
Design Ratio	Design ratio is defined as the ratio between the thickness of asphalt layer and the largest aggregate in the layer. Most public works departments require at least 3:1 ratio of layer thickness to aggregate size. The design ratio has a direct effect on the compaction process. A higher ratio is better.
Drag Marks	Drag marks are open-textured stripes in the surface of the bituminous layer. They can be caused by a cold screed, a damaged screed, insufficient angle of attack, or layer not thick enough to float the screed.

- E -

Eccentric Weight	The eccentric weight is an off-center mass on a vibratory shaft mounted on the paving screed. Rapid rotation of the eccentric weight creates forces that cause the screed to vibrate and to transmit vibratory waves into the asphalt layer.

Echelon Paving — Echelon paving is the use of two or more pavers to lay down bituminous material while creating a hot longitudinal joint.

Edge Cutter — An edge cutter is an attachment, frequently installed on a compactor drum for trimming the unconfined edge of an asphalt layer to provide a vertical face and straight line for joint matching.

Effective Working Speed — The effective working speed is the actual working speed multiplied by the efficiency factor.

Efficiency Factor — An efficiency factor should be used when calculating the working speed of an paver to compensate for stop, waiting for trucks or for other reasons.

Elevation — In simple terms, elevation is the height of any pavement layer. Elevation is often expressed as the thickness of a given layer in relation to a surveyed grade.

End Gate — A paving screed has left and right end gates that confine the asphalt layer to the desired width. The bottom of an end gate has a metal strip called a ski. When the end gate is down, the ski floats on the grade and the edge of the asphalt layer is vertical for best joint matching.

Equilibrium — Equilibrium is the point at which all the factors affecting the screed are constant and the screed is floating in a relaxed condition at a constant level.

Extension Screed

- **Power** — An extender is the outer portion of the screed that can be moved in or out hydraulically to change the paving width. Screed extenders are in front of the main screed on some pavers and behind the main screed on others.
- **Bolt-on** — Bolt-on screed extensions are available in several different widths and are secured to the end of the power extenders for extra paving width.
- **Height** — The height of a screed extender is its vertical relationship to the main screed.
- **Slope** — A screed extender can have a positive or negative slope in relation to the main screed.

Extension

- **Auger** — Auger extensions are attached to the ends of the auger shafts to help move material out to end gates while maintaining an acceptable head of material.
- **Mainframe** — Mainframe extensions are bolted to the end of the tractor mainframe or may be hydraulically extendable. Mainframe extensions should always be added in front of auger extensions.

Extender Mark — An extender mark is a continuous, longitudinal line in the surface of the bituminous layer. Created by a height mismatch between the main screed and the extender.

- F -

Fat Spots — Dust clumps that appear in the bituminous layer. Their presence usually indicates that baghouse maintenance is needed.

Feed Bins

- **Cold** — Cold feed bins contain the aggregates used in a particular mix design. Each bin is loaded with one size aggregate. Conveyors move cold aggregates to the drum mixer or hot feed bins.
- **Hot** — Hot feed bins receive metered amounts of cold aggregates for heating prior to transfering them to the pugmill in a batch plant.

Feeder Sensors — Feeder sensors measure the level of the material at the end of the auger shafts or the level of material behind each conveyor in the auger chamber. There are sonic feeder sensors and mechanical feeder sensors.

Feeder System	The feeder system of a paver consists of left and right conveyors, left and right augers and feeder sensors.
Fines	The smallest particles in the mixture formula. Fines combine with asphalt cement to help create the binding effect between larger aggregate particles.
Aggregate Fines	Aggregates that pass through the 4.75 mm (0.2") sieve opening.
Baghouse Fines	Material added to the mix after dust collection in the baghouse.
Flow Gates	Flow gates are vertically adjustable strike-offs installed over the right and left conveyors at the back of the hopper. They provide one way to control the level of mix in the center of the auger chamber.
Foamed Asphalt	Mix that uses foamed (expanded) binder created by adding small amounts of water or steam to hot liquid asphalt.
Fore-'N-Aft Leveler	The Fore-'N-Aft Leveler is a mechanical averaging ski that is installed to extend over the screed and use a grade inside the paving width.
Frequency	
Vibratory	Vibratory frequency is the rotational speed, expressed as vibrations per minute, of the eccentric weight shaft installed on the paver screed.
Tamping	Tamping frequency is the number of vertical strokes made by the tamper bar in one minute.

- G -

Gradation	Referring to bituminous material, gradation is a systematic progression in the size of the aggregates used in the mix design formula. A gradation curve indicates sizes and amounts of each aggregate to be used.
Continuous	Term used to describe a gap-free gradation curve.
Dense-Graded	Dense-graded mixes are produced with a variety of aggregate sizes, asphalt cement and fines. The larger aggregates are surrounded by a mastic of fines and asphalt cement.
Gap-Graded	Gap-graded mixes use an aggregate gradation with particles ranging from large to fine with some intermediate sizes missing. Gap-graded mixes are permeable with lots of stone-on-stone contact.
Double Gap-Graded	Bituminous mix with a double gap in its gradation curve.
Grade	Often refers to the base over which the bituminous material is being laid.
Grade Control	Maintaining the correct elevation of the bituminous material's surface. Also refers to controlling the thickness of the bituminous layer.
Grade Control Automatic	Using an on-board control system with sensors and computers to regulate the elevation of the bituminous layer's surface.
Grade Sensor	A grade sensor, either sonic or mechanical, is a measuring device that sends data to the system controller regarding the elevation of the grade reference.
Grade Stake	A grade stake is a construction marker erected adjacent to the pavement for use as an elevation and/or slope indicator.
Guidance Value	A reference number selected by a screed operator and shown on the display of the grade and slope control system.

- H -

Haul Units	The trucks utilized to transport the asphalt from the production facility to the worksite.
Bottom Dumps	Dump from the bottom of a trailer in a windrow requiring a transfer device to feed the paver hopper.
End Dumps	Dump from the rear of the truck or a trailer into a material transfer device or directly into the paver hopper.

Head of Material — The level of material in the auger chamber in front of the screed. A major influence on how the screed floats.

High Modulus Asphalt — Stiff bituminous mix that resists deformation under load. Typically specified for roadways carrying high traffic volume.

Hopper — The hopper is a compartment at the front of the paver tractor. It provides limited storage capacity while the paver is receiving material from the haul unit. The sides of the hopper can be folded to move material from the sides of the hopper onto the conveyors.

- **Flashing** — Hopper flashing helps contain material at the front of the hopper.
- **Folding Apron** — A folding apron is an option that helps move material from the front of the hopper back to the conveyors.
- **Insert** — A hopper insert increases the storage capacity of the hopper so the paver can operate for longer intervals between trucks.

- I -

Impact — Impact is a dynamic compaction force. Impact occurs when the tamper bar in front of the screed moves into the asphalt layer.

Impact Marks — Impact marks are visible lines in the surface of the asphalt layer. Impact marks are caused by applying too much force to the asphalt layer or incorrect impact spacing.

Impact Spacing — Impact spacing is the relationship between the frequency of a tamper bar and the working speed of an paver. Impact spacing should be such that there is at least 6 mm (0.25") overlap between tamper bar impacts.

Infrared Camera — An infrared camera produces an image of the asphalt layer's surface temperature. The image usually encompasses the width of the mat for a distance of no more than 9 meters (30').

Infrared Scanner — An infrared scanner is a hand-held device that measures and displays the temperature of a point at the surface of an asphalt layer.

Initial Phase Compaction — The initial phase of compaction occurs immediately behind the paver where the asphalt layer is the hottest. The initial phase should achieve the majority of the target final density.

Intermediate Phase Compaction — The intermediate phase of compaction occurs immediately after the initial phase in a temperature zone where the asphalt layer is still hot enough to allow for gains in density. The intermediate phase should achieve the final density target.

Internal Friction — Internal friction is the resistance to movement by the aggregate in an asphalt layer. The shape of the aggregate determines the amount of internal friction.

International Roughness Index — The International Roughness Index is a measure of ride quality. A certified test vehicle drives over a paved surface at normal highway speed and records chassis movement that is induced by roughness.

- L -

Lead Crown — Lead crown exists when the front of the main screed plate has a slight crown, 3 mm (0.125") for example, while the trailing edge of the screed plate is flat.

Level Section — A level section is a portion of a pavement structure with 0 percent slope.

Leveling Layer — A leveling layer is a thin layer of bituminous material laid on a milled surface for the dual purposes of restoring profile and improving smoothness.

Lifting Force — Lifting force is the hydrodynamic force created by the material passing under and supporting the floating screed. Lifting force is affected by type of mix, layer thickness and material temperature.

Line of Pull — Also called the traction angle, line of pull is the relationship between the height of the tow-point and the screed pivot point.

Load Cell	Scales on either side of storage silos that measure the empty and loaded weight of haul units.
Longitudinal Joint	A longitudinal joint is the intersection of two asphalt layers along the edges that are parallel to the direction of paving.
Hot/Cold Joint	A hot/cold longitudinal joint is created by laying down a hot asphalt layer adjacent to a cold, previously compacted asphalt layer.
Hot/Warm Joint	A hot/warm longitudinal joint is created by laying down a hot asphalt layer adjacent to a layer laid down a short time before.
Hot/Hot Joint	A hot/hot longitudinal joint is created by two pavers laying down adjacent mats in echelon.
Loose Thickness	The thickness of the bituminous layer laid by the screed prior to compaction.
Loose Weight	The weight of the bituminous material prior to compaction expressed in kilograms per cubic meter (pounds per cubic foot). Useful when calculating paving speeds.
Lower Lock - Screed	On pavers with tamping screeds, the screed lower lock engages when the paver is in the Standby mode to prevent screed marks while the paver is stopped on uncompacted bituminous material.

- M -

Mastic Asphalt	Mixture of bitumen, aggregate and fillers that is fluid when hot. Mixed in a stationary or mobile plant, it is transported in a mixing truck. Used on sidewalks or wear courses or bridge decks as a waterproofing agent, mastic asphalt is spread by hand.
Material Transfer Vehicle	Self-propelled machine that receives material from the haul units and transfers the material to the paver hopper or hopper insert. Makes continuous paving easier and may provide remixing to reduce risk of segmentation.
Mechanical Sensor	A mechanical sensor, either grade-type or feeder-type, contacts the reference target.
Micro-milling	Removal of a specified amount of pavement material by a cold planer equipped with a high-density cutting drum.
Milled Surface	The grade left after a specified amount of pavement material has been removed by a cold planer.
Mineral Filler	Also referred to as fines, mineral fillers can be crusher dust, dry Portland cement, fly ash or lime. Fillers help fill in the spaces between larger aggregates.
Mix Formula	The formula or mix design approved for the production of bituminous material on a specific project. It describes aggregate gradation, asphalt cement type and asphalt cement content.
Mix Height Dial	Potentiometers located at each screed control box used to adjust the head of material at the outboard end of the augers. Pavers equipped with four feeder sensors also have mix height dials at the operator's station to control the head of material at the end of the conveyors.
Mix Sample	A small portion of bituminous material that will be tested for conformance to design parameters. Samples are taken from various locations such as the plant discharge, the paver hopper, the paver auger chamber and the layer itself.
Mobilization	Mobilization is activity associated with transporting equipment and supplies to a project location. Mobilization may be a separate item on a bid request.
Mounting Hardware	Mounting hardware consists of the arms that support grade sensors and averaging skis. Mounting hardware is attached to the paver tow arms or the end gates.

- N -

Nose Bar	The nose bar is a rounded wear strip installed in front of the screed plate.
Notched Wedge Joint	A notched wedge joint is created by installing a joint shaper at the end of the paving screed. Notched wedge joints are often specified to avoid creating a large vertical, unconfined edge that may be open to traffic.
Null, Screed	Null the screed by turning depth cranks to remove any twist in the screed while the screed is resting on the starting point.
Null, Sensor	Nulling, also called benchmarking, a grade sensor or slope sensor creates a reference distance for a grade sensor or a reference slope for a slope sensor.

- O -

Offset Joint	An offset joint is created by varying the width of layers that form a longitudinal joint as the pavement structure is built. Offsetting or staggering joints avoids creating a series of joints in one location when placing multiple layers.
Open-Graded Mix	Open-graded bituminous material is made up of only a few aggregate sizes with intermediate sizes absent. Modified asphalt cement is usually part of the design. There is a lot of stone-on-stone contact.
Outboard Leveler	An outboard leveler is a mechanical averaging ski that uses a grade reference outside the paving width.
Overlap	Overlap refers to the distance the end gate ski extends onto the adjacent asphalt layer
Overlay	Placement of bituminous material on existing pavement.
Oversize	Oversize is any material discharged into the paver hopper that is larger than the maximum aggregate size specified by the mixture formula.
Oxidation	Hardening of asphalt cement after exposure to oxygen over a long period of time.

- P -

Pass	A pass is one movement of the paver in one direction from the starting point to the point where the screed is picked up and paving stops.
Paving Train	The paving and compaction equipment assigned to a worksite from asphalt delivery through the compacted, finished surface.
Penetration Test	Test used to measure the hardness of bitumens. Based on hardness, bitumens are classed into various grades.
Permeable Asphalt	Also referred to as “draining asphalt,” these mixes have a high void content enabling water to flow through in the connecting voids.
Perpetual Pavement	Perpetual pavement is a term used to describe a full-depth asphalt structure designed to withstand an almost infinite number of axle loads without structural deterioration.
Pivot Point	The screed pivot point is the point on the screed from which the angle of attack is generated.
Planing Angle	The attitude at which the screed floats on the bituminous layer. Also referred to as the angle of attack.
Polymer Modified Asphalt	A polymer is a synthetic compound in the form of a string of similar-linked molecules. Polymers are added to asphalt cement to enhance layer strength at high temperatures and layer elasticity at low temperatures. Polymer-modified asphalt cement has high viscosity.
Pre-Compaction	Pre-compaction is the amount of density imparted to the asphalt layer by the screed. Pre-compaction rates are affected by screed weight, paving speed, and the energy delivered by a vibrating and/or tamping screed.

Profile — Profile is the cross section of a roadway structure, most often referring to the slope of the surface of the roadway for drainage.

- **Transverse** — Another way to refer to the slope of the structure.
- **Longitudinal** — Longitudinal section of a roadway that shows changes in elevation over a given distance.

Profile Index — Profile Index is a trace of the surface of a pavement structure. It is generated by pushing a profilograph over the surface to be measured or by driving an inertial profiler over the surface.

Proof Rolling — Confirmation of the stability of an aggregate or reclaimed base prior to paving. Commonly done with heavy pneumatic rollers.

Pugmill — A pugmill consists of a rotating shaft, or a series of shafts, with paddles used to blend aggregates and asphalt cement in a batch plant.

Push Roller — Push rollers are located at the front of the tractor. They contact a haul unit's tires when the paver is pushing the haul unit that is dumping its load into the hopper.

- Q -

Quality Anaysis — Quality analysis is testing, measuring and analyzing bituminous material and other specified aspects of a project in a laboratory or other controlled environment.

Quality Control — Quality control is testing, measuring and analyzing bituminous material and other specified aspects of a project at the worksite while work is in progress.

- R -

Ratio Control Dials — Potentiometers located at the operator's station are used to adjust the speed of the conveyors. Potentiometers provide one way to control the level of material in the center of the auger chamber.

Reaction, Screed — Screed reaction is the time it takes the screed to change elevation in response to a manual depth correction or to a correction sent by the automatic grade control system.

Reclaimed Asphalt Pavement — Reclaimed asphalt pavement, also called milled material, is the material removed from an existing asphalt layer. Reclaimed asphalt is often specified as part of a bituminous material formula.

Release Agent — A release agent is some type of liquid that helps prevent bituminous material from sticking to steel or rubber surfaces. Petroleum distillates, like diesel fuel, are prohibited in most locations because of their harmful effects on bituminous material. There are a variety of biodegradable release agents.

Reversing Augers — Reversing auger segments, or kicker paddles, are installed on the inner ends of the auger shafts. They move material under the center chain case to eliminate or minimize segregation in the center of the bituminous layer.

Rich Spot — A rich spot in the bituminous layer is an accumulation of asphalt cement and fines or dust.

Ripples — Ripples are closely spaced deviations or bumps in the surface of the bituminous layer. Also called corrugations or washboarding.

Rock — Naturally occurring minerals.

- **Igneous** — The result of cooling and hardening of molten materials beneath the surface of the earth. Igneous rock is a durable aggregate, but can cause accelerated wear on paver parts.
- **Metamorphic** — Formed by exposing sedimentary or igneous rocks to prolonged heat and pressure. Metamorphic rocks are very hard, but are brittle and can be damaged by heavy impact forces.
- **Sedimentary** — Formed from sediment collecting in water or wind-blown deposits such as limestone and sandstone. Can be fragile and easily damaged during paving and compaction.

Roller-Compacted Concrete	Roller-compacted concrete is a hydraulically bound cement material used for pavement layers and as base support layers. It gains strength through compaction and chemical curing.
Rolling Resistance	Rolling resistance is the force that works against the motion of an object on a surface. For example, a smooth pavement surface offers less rolling resistance than a rough pavement surface.

- S -

Screed	That portion of the paver that is towed by the tractor and establishes the layer width, layer depth and pre-compaction density.
Extendable	Screed that includes power extendable extensions used to vary the paving width.
Fixed Width	Screed that consists of a main screed of a given width. Hard extensions are bolted on to vary the paving width.
Screed Imprint	A screed imprint, also called screed settlement mark, is the indentation in the hot bituminous layer left by the screed during a paver stop.
Segregation	Segregation refers to the tendency of larger aggregates in a bituminous mixture to separate from the smaller particles and form pockets or stripes of large aggregates within the layer.
Stripes	Stripe segregation is a continuous line of large aggregates that appear in the surface of the bituminous layer.
Patch, Pattern	Pattern patches of segregated aggregates appear in a regular manner and are commonly associated with end-of-load segregation.
Patch, Random	Random patch segregation is the appearance of pockets of large aggregates at irregular intervals.
Self Leveling	The action of a floating screed that reduces high spots and fills in low spots while paving.
Separation Marks	Separation marks are continuous lines in the surface caused by height mismatch between the main screed and a screed extender.
Set-Back	A set-back is movement of the paver back to the start of the pass that was just completed in preparation for paving a matching pass.
Shear Force	The shear force is the screed's ability to pass a certain amount of material under the front of the screed while pushing the remainder of the material in the auger chamber.
Sizing Screen	Part of the aggregate feeder system at the plant, sizing screens help keep oversize material out of the dryer / mixer.
Slack	As related to an paver, slack refers to lack of tension in the tow arm connections and screed connections. Remove the slack by pulling the paver forward a few centimeters while the screed is resting on the starting point.
Slag	Slag is a nonmetallic byproduct of a blast furnace or a wet bottom boiler. Used as aggregate after testing and proper sizing. Can be porous and requires additional bitumen in the mix formula.
Slope	The transverse inclination of the surface of the bituminous layer. Usually expressed as a percentage, slope is the change in elevation (rise) over a given distance (run).
Slope Board	A slope board is a bubble-type level, usually 2.5 meters or 3 meters (8' or 10') long, used to measure the rise or fall (slope) of a pavement surface.
Slope Control	Maintaining the lateral inclination of the paving screed to create the desired surface slope of the bituminous material.
Slope Control - Automatic	Using a sensor and controller to maintain the lateral inclination of the paving screed.
Slope Meter	A slope meter is an electronic level, usually 1 to 2 meters (3' to 6') long, used to measure the slope of a pavement surface.

Slope Sensor	Installed on a transverse beam over the screed, the slope sensor measures the inclination of the screed and sends data to the system controller.
Slope Stop	The slope stop is the limiter for the slope of a screed extender.
Specification - End Result	An end result specification is a written quality control / quality analysis series of measurement targets for items such as ride quality, density and asphalt mix conformance.
Specification - Method	A method specification describes either the type of equipment and/or the technique(s) that must be used on a project.
Starter Boards	Starter boards are wood or metal strips placed under the paver screed before the screed is lowered to the starting point. Starter boards should be the same thickness as the compaction rate of the asphalt layer being laid down.
Stone Matrix Asphalt	Stone matrix asphalt is composed almost entirely of large aggregates, fines and modified asphalt cement. There is stone-on-stone contact, but the stones are coated with a thick mastic of fines and viscous asphalt cement.
Stockpile	Supply of one aggregate size at the asphalt manufacturing facility.
Strike-off Screed	Some screeds have a vertically adjustable strike-off located on the face of the screed. Strike-off position affects how material flows under the screed nose bar.
Strike-off Extension	Some screeds have a strike-off extension that is an integral part of the screed or one that is bolted onto the screed. Strike-offs are a leveling device and do not have a screed plate.
Stringline	A stringline is a mechanical grade reference based on survey data and erected on one side of the paver for precise elevation control.
Super-elevation	A super-elevation is a segment of the pavement with increased transverse profile (slope), usually designed to overcome the effect of centrifugal force on vehicles traveling through curved sections.
Runoff	A super-elevation runoff is the distance between a level section of pavement and a super-elevated section of pavement.
Surge Bin	A storage unit, or silo, used to store bituminous material prior to discharge into haul units at the asphalt manufacturing facility.
Surge Capacity	Surge capacity is the storage volume of a material transfer device or the paver hopper or hopper insert.

- T -

Tack	Tack is an emulsion consisting of paving grade oil, water and an emulsifying agent. Tack is applied to surfaces prior to paving to help improve the bond between layers.
Tamping Screed	A tamping screed uses one or more tamper bars to deliver extra compaction energy to the asphalt layer, thereby producing higher density in the asphalt layer prior to the compaction process. Tamping screeds typically use vibration to help tighten surface texture.
Amplitude	The distance that the tamper bar moves into the asphalt layer.
Dosing Angle	The angle on the face of the tamper bar.
Dosing Area	The length of the angled portion of the tamper bar.
Dosing Height	The distance from the top of the angled face to the tamper foot.
Tamping Foot	The bottom of the tamper bar that contacts the surface of the bituminous layer.
Tangent Runoff	Tangent runoff is the distance between a crown section of pavement and a level section of pavement. Commonly built at either end of a super-elevation.
Temperature Compensation	Sonic grade sensors have some sort of temperature compensation to maintain accuracy when operating in conditions where temperatures may change rapidly.

Test Strip	A test strip is used to confirm that the proposed rolling pattern and equipment are adequate to achieve target density and match the estimated paving production. The test strip may be part of the project or may be a separate element.
Texture - Surface	Surface texture is the appearance of the surface of the bituminous layer. Texture is affected primarily by the screed angle of attack.
Thickness Screws	Thickness screws on each side of tamping screeds are adjusted to set the correct angle of attack.
Three Dimensional Paving	A screed guidance system that receives input from sources that are independent of the paver.
Tie-in	A tie-in is the connection to an existing structure, like a bridge deck that is perpendicular to the direction of paving.
Tow Arms	The tow arms on an paver are the connection between the screed and the tractor, which provides the power to tow the screed.
Tow-Points	The tow-points are the location where the tow arms connect to the tractor.
Cylinder	The tow-point cylinder raises and lowers the tow-point connection to control tow-point height.
Height	The tow-point height affects the line of pull and the screed angle of attack, or planing angle.
Transducer	A transducer is that part of a sonic sensor that emits sound pulses and uses the returning echoes to measure the distance between the transducer and the reference target.
Transition	Transition is the change in transverse profile between crown sections, level sections and super-elevated sections.
Transverse Joint	A transverse joint, also called a butt joint, is the perpendicular intersection of two layers of asphalt. Often a transverse joint is the starting point for resumption of paving from a cold, compacted layer.
Transverse Profile	Transverse profile is the slope of a pavement section.
Traffic Control	Traffic control is the activity associated with changing the flow of traffic to accommodate all construction activity, usually within specified times and according to local safety regulations.
Truck Exchange	A truck exchange is the procedure to replace an empty haul unit with a loaded haul unit in front of the paver or material transfer device.
Truck Guide	The truck guide is the person who is responsible for helping direct the flow of haul units in front of the paver and for directing the discharge of material from the haul units into the paver hopper or a material transfer vehicle.
Truck Hitch	The truck hitch is an option on xspavers. Truck hitch arms extend ahead of the push rollers to contact the haul unit's wheels and provide a solid link between the paver and the haul unit.

- U -

Unconfined Edge	An unconfined edge is the edge of an asphalt layer that is open and not bound by an adjacent layer, curb or gutter.
Undercarriage	That portion of the propel system that provides traction between the paver and the surface of the grade.
Rubber Belt	Continuous reinforced rubber belt, either smooth or cleated. Preferred when traction and flotation are critical. Also provides high travel speed and tight turning radius.
Rubber Tire	Two pneumatic tires, sometimes with front wheel assist, propel the paver. Preferred for its smooth ride and high travel speed.
Steel Track	Continuous track-type undercarriage. High traction, but low travel speed.
Universal Total Station	A Universal Total Station is part of the guidance system used in three-dimension paving applications. Each station sends input to the on-board control system based on a computer-generated model.

- V -

Vibratory Screed A vibratory screed delivers vibratory force to the asphalt layer as the layer passes under the screed. Screed vibration increases the density of the asphalt layer by a small amount and also helps tighten the surface texture.

Viscosity Viscosity refers to the flow rate of a liquid at given a temperature. The viscosity of asphalt cement used in bituminous material is affected by temperature and by the additives mixed with the asphalt cement. For paving purposes, the viscosity of the asphalt cement affects the way the screed floats and how screed adjustments are made.

- W -

Waviness Waviness is characterized by widely spaced undulations in the surface of the bituminous layer.

Wear Layer The wear layer, often called the friction or surface layer, is the final layer in the roadway structure. Usually the thinnest layer, it is designed to be the stiffest layer.

Wedge Joint A wedge joint is a tapered edge that eliminates a vertical face on the unconfined edge that may be open to traffic. A wedge joint is formed by installing a shaper at the end of the paver screed.

Weight Ticket Printed document given to the truck driver at the asphalt plant. Contains load number, time, gross weight, net weight and cumulative daily project totals.

Windrow Elevator A windrow elevator is a transfer device that is attached to the front of a paver. An elevating slat conveyor picks up material that is left in a windrow by the bottom-dump haul units and transfers the material to the paver hopper.

Windrow Elevator Head A windrow elevator pickup mechanism with elevator used to load bituminous material deposited by bottom dumps in a linear column at grade into a material transfer vehicle.

Windrow Paving Windrow paving is the process where the bituminous material is laid in a windrow by the haul unit on the base to be paved and then transferred to the paver hopper by a windrow elevator.

- Y -

Yield Yield refers to the linear distance that a given amount of bituminous material will pave at a specified depth and width.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