White Paper

Putting Screed Performance in Context

While the asphalt paving process has changed little over the last 80+ years, the economics of the business have shifted dramatically. The continued emphasis on pavement quality, introduction of new mixes - including warm mix asphalt - the pressure to maximize the profitability of each job while minimizing total cost of equipment ownership has never been more acute. The extent and cost of paving mistakes — issues such as centerline segregation, screed marks, uneven transverse joints, mat bleeding, shadowing, etc. — are magnified.

As a result, more attention is being paid to the design of the conveyor, screed and control systems. Advanced capabilities such as automatic laser-guided and sonic leveling, on-board controls for mat depth, width and angle of attack are available on many of the newer screed models. But does making improvements in screed performance and capabilities necessarily result in a better end paving product? The short answer is "yes" and "no". The longer answer is a bit more complex.

On the most basic level, the purpose of the screed is to smooth over the various imperfections created during the paving process. The base layer, for example, uses larger aggregate material that creates a roughly, but not totally, level surface. With each new layer of pavement, the smoothness of the mat can be improved up to 70 percent.[i]

When problems arise in the quality of the mat, very often the issue can be traced back to something other than the screed. These include evening out the peaks and valleys of the base layer, redistributing variances in the material head and ensuring dimensional accuracy of the mat regardless of the terrain, paver operation or mix characteristics.

While there are a multitude of individual variables that can affect the quality of the final paved surface, most can be lumped into one of three categories:

- Mix integrity
- Head of material
- Screed quality and capabilities

Understanding how the screed performance is affected by other paving functions can help troubleshoot paving problems, improve job profitability and even lower the total cost of ownership of the paver by reducing unnecessary wear. This white paper has been developed to provide the commercial paving contractor an overview of the role that the screed plays in the overall paving performance. It also illustrates how advanced technology, such as that featured in LeeBoy's Legend Screed, is helping contractors improve job performance and profitability.

> *"It has become a cost-driven business that expects a high return on investment, which means the paving industry has become more productivity- and quality-driven than it has ever been."*
>
> *– Bryce Davis, LeeBoy*

Mix integrity: minimize sheer, maintain heat and reduce separation

There are a wide variety of HMA recipes available from open-graded to fine mixes to mixes tailored for specific regional climates. Mix designs are optimized for a number of characteristics, including durability, skid resistance, workability, permeability and cost. The Federal Highway Administration, divides surface mixes into four categories—fine dense-graded asphalt (FDGA), coarse dense-graded asphalt (CDGA), open-graded friction course (OGFC), stone mastic asphalt (SMA). Within each category are dozens of mix variations featuring a variety of additives and alternative materials.

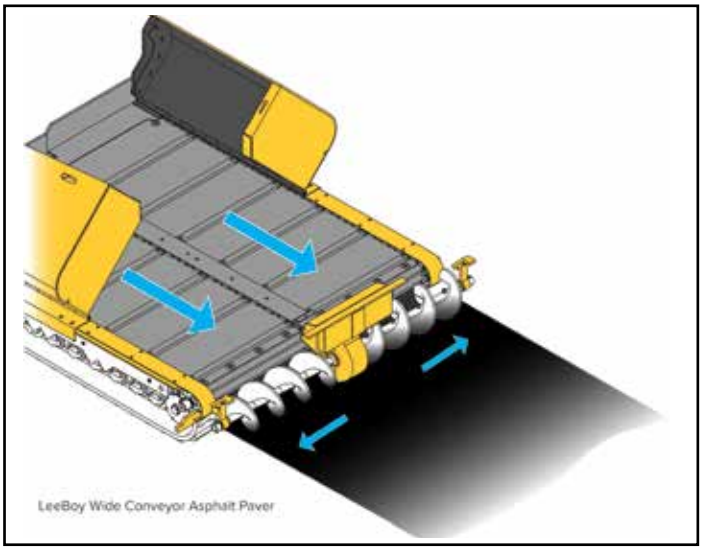
Each individual mix presents unique differences and challenges in terms of how it must be handled, conveyed, placed and compacted. For example, the workability of HMA with polymer-modified binders decreases substantially at a given temperature since the modifiers tend to increase the viscosity of binders.[ii]

The increasing concentration of recycled asphalt (RAP) present in today's mixes is also a limiting factor. "Today's mixes can contain anywhere from 20 to 40 percent RAP. It doesn't heat consistently, doesn't hold the heat as well and tends to clump," said Mark Bolick, who spent over 22 years as paver operator for Sigmon Paving and is the current General

Manager of Product Support at LeeBoy. More than 95 million metric tons of asphalt paving material is recycled each year, making it America's most recycled material.[iii]

Despite their many differences, all HMA designs are structurally fragile until they are compacted and allowed to cool. The more the mix is disturbed prior to levelling and compaction, the greater the risk that the final paving quality will be compromised, either through aggregate segregation or by starting to set prior to paving and compaction.

Aggregate segregation occurs when the larger aggregate becomes separated from the asphalt binder and fine aggregate material. Unless the larger aggregate can be recombined with the rest of the mix prior to hitting the screed, the result is rough spots on the finished pavement. The segregation can be caused by a number of factors including improper loading of the hopper and how the mix is conveyed from the front of the hopper to the flow gate.



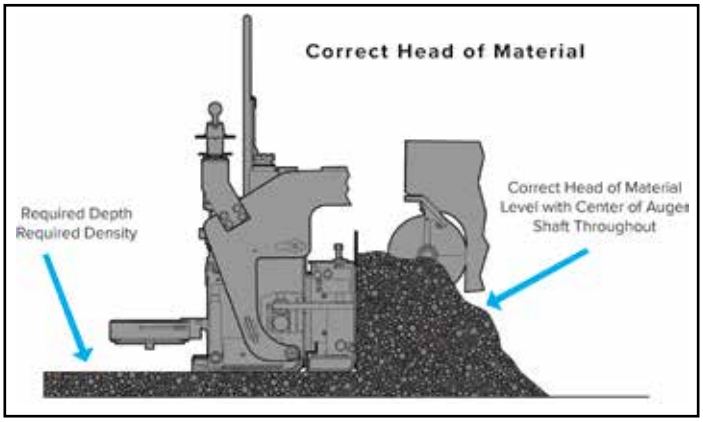
As the mix moves from the front of the hopper to the rear of the paver, machine vibration and the shearing forces of the conveyor slats begin to break down the composition of the mix. The faster the conveyors run, the greater the risk of separation. The same is true of the auger speed. The goal is to minimize the shearing forces on the mix while maintaining a consistent head of material in front of the screed.

Another significant consequence of disturbing the mix during conveyance is heat loss. Mix temperature is dependent on the grade of asphalt, with less viscous asphalt requiring a lower temperature and more viscous asphalt requiring a higher temperature. Each mix variation will have its own optimal temperature range as specified by the manufacturer. Each time the mix is disturbed, heat escapes. Turn the asphalt too much and it begins to set before it hits the base layer. This can result in the mix becoming overly stiff with defects like clumping and variances in mat density that can be difficult to overcome.

Thermally precise electric screeds can help contractors deal with overly stiff material, but only to a point. Screeds are typically heated to between 225 and 275 degrees Fahrenheit (107°C to 135°C). If the screed is not adequately heated or the mix is too cold, the tar in contact with the bottom of the screed begins to harden, resulting in buildup of paving material and excessive drag.

Material head: paver speed, flow rate and gate opening

According to some estimates, 95% or more of all material faults in asphalt paving are due to an improper head of material in front of the screed. The material head is the volume of HMA deposited from the flow gate in the paver onto the base layer and in front of the screed. If the amount of mix in front of the screed is allowed to fluctuate, the end results are bumps and waves in the finished mat.



The consistency of the material head, including its total volume and depth is determined in large part by the paver speed and material flow rate. Of these, maintaining a constant paving speed is especially critical.

The correct paving speed is based on a number of variables: number and size of trucks, volume and output of the mixing plant, rolling and compaction rates, crew capabilities, etc. Once the speed is set, it is important that it remains as steady as possible. Ripples, waves and irregular mat depth can occur when paving speed doesn't remain relatively constant. Changes in paving speed are commonly caused by trucks inconsistently arriving at the jobsite, or bumping the paver during the truck exchange.

A steady flow rate from the hopper to the front of the screed is also key to ensuring a consistent head of material. Proper flow rate is dictated by the amount of material in the hopper, conveyor speed and auger position. Regarding the volume of HMA in the hopper, a good general rule is to maintain a hopper that is one third full as this will ensure a safety margin should the next load truck be late in arriving.

The conveyors are responsible for transporting the material from the hopper to the augers. As discussed earlier, the conveyor speed can affect the integrity of the mix. The challenge then, is to move the material fast enough to maintain a productive paving speed but not so fast that you compromise the quality of the mix. The final variable involved in keeping a consistent head of material is setting and maintaining the optimum speed and position of the auger. To accomplish this, the Federal Highway Administration (FHWA) and Asphalt Institute recommends:

- Extending augers and tunnels to within 12 to 18 inches of the end gate to ensure a continual supply of fresh material is carried (not pushed) to either end of the paving width
- Coordinating paver and auger speed to allow for a uniform head of material across the entire width of the paver.

This enables the screed operator to minimize the amount of adjustments to the angle of attack and paving depth. Traditionally, monitoring the head of material has been the responsibility of the screed operator. However, newer pavers now feature sensors that automatically regulate the proper delivery and flow of material in front of the screed to ensure a consistent head. This produces a smoother finish and also minimizes the amount of raking, which will affect the integrity of the material as it cools.

Screed performance

The integrity and temperature of the mix and a consistent and evenly distributed head of material can be considered the “raw materials”. It is the job of the screed and its operator to convert those materials into a final mat with a surface that is smooth, even and has a precisely accurate profile.

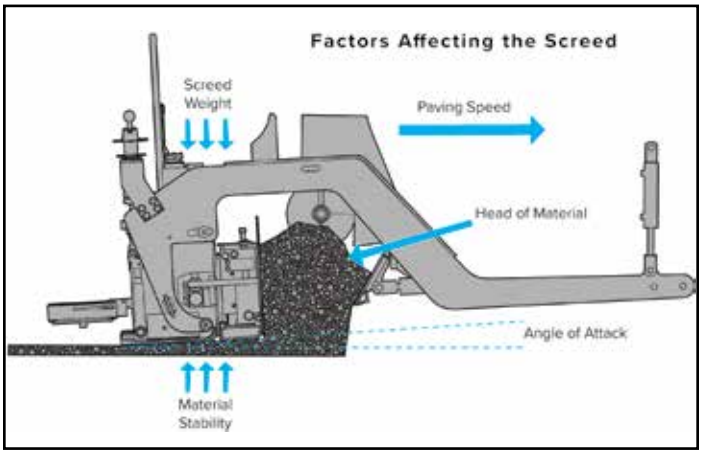
The purpose of the screed is to evenly spread the mix across the paving width, create the desired profile and provide initial compaction of the material. To understand exactly how and why the screed functions, it is necessary to understand the key variables that impact its performance. Three of these variables—paver speed, material condition and material head—have already been discussed. As mentioned earlier, these factors, while unrelated to the screed, have significant impact on its performance, as well as the profitability of the finished job.

That being said, there are three main variables for which the screed and its operator are directly responsible—angle of attack, initial compaction and profile control.

Forces and Factors Affecting Screed Performance

Screeds used for asphalt paving are free-floating, towed behind the paver. The leading edge of the screed strikes off the excess material then spreads and roughly levels the rest. The screed plate then uses its own weight, gravity and vibration to tamp and compact the surface. The goal is to achieve a finished mat that is completely level and has a consistent thickness.

In order to achieve this, there are six mechanical forces acting upon the screed that must be brought into equilibrium. They determine the position and angle of the screed.[vi]

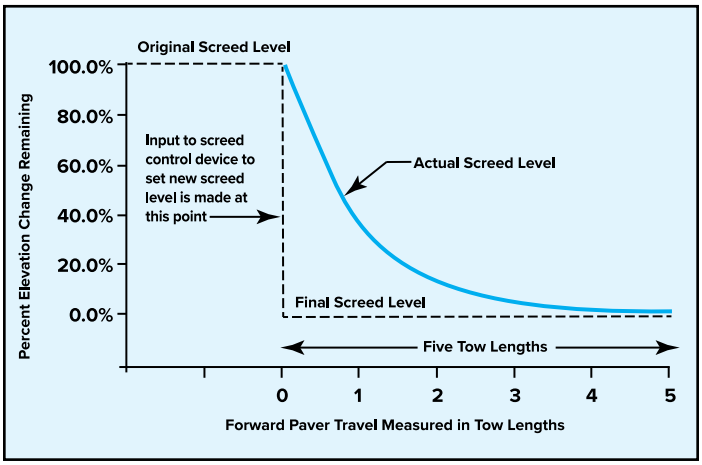


- **Towing force.** Pulling force exerted by the paver at the tow point
- **Forward resistance.** Force from the HMA head resisting the towing force.
- **Screed weight.** Downward force created by gravity and the weight of the screed
- **Upward resistance.** Tendency of the screed to rise as it passes over the material head
- **Tamping force.** Compacting force of the tamping bars or vibrators
- **Frictional force.** Resistance caused as the screed passes over the HMA

Since the screed is free floating it will slide across the HMA at an angle and height that will place these six forces in equilibrium. When any one of these forces is changed, the screed angle and elevation will change (which will change the mat thickness) to bring these forces back into equilibrium.

For example, changing the tow point elevation will affect screed angle and thus mat thickness. As a rule-of-thumb, a 25 mm (1 inch) movement in tow point elevation translates to about a 3 mm (0.125 inch) movement in the screed’s leading edge.[ii] Without automatic screed control, tow point elevation will change as tractor elevation changes.

It is important to note that adjusting the screed angle will not result in an immediate change in mat thickness. A common operator mistake is making frequent adjustments to the screed angle before seeing how it affects mat thickness. As the chart below illustrates, it takes about five tow-lengths before the new depth is set and can be visibly confirmed.[viii]



Proper Screed Selection

As we have seen, the screed is one of several components in the paving process. To ensure the best results and minimize the risk of having to repave the job, all components and every step in the process must carefully managed and coordinated. Therefore, the capabilities of the screed must match the performance and characteristics of the paver, conveyor and auger. These, in turn, must be calibrated to work with the specific HMA design, paving conditions and job demands. Similarly, because the forces acting on the screed are all inter-connected, the fewer adjustments the operator needs to make and the less disruptive those adjustments are, the more consistent and accurate the final mat will be. It is in these two area that the Legend screeds have been able to separate themselves.

The success of the Legend Screed is due in part to the unique design characteristics of the pavers for which they are designed. Specifically, LeeBoy pavers all have two key features that provide an optimal set up, enabling the Legend screed to produce a more consistent, smooth and dimensionally accurate pavement.

The conveyors on each paver run the full width of the machine. This means that for paving widths of eight feet or less – where extensions are not used – the augers are not needed. The material is conveyed along the full width of the paver from the hopper to the flow gate. This provides several important benefits. First it dramatically reduces the chance of aggregate separation. This is because the material is allowed to move as a single mass along the paver width as opposed to moving in a narrow pile in which the larger aggregate is allowed to roll down and collect on either side. The full-width conveyor slats also enable the system to move about twice as much material through the conveyor tunnel. As a result, the conveyor is able to run at about half the speed of a conventional paver. This minimizes the shearing forces on the mix, enabling it to retain more heat and structural integrity. Long term, this also helps to extend the serviceable life of the paver.

The screed itself features a number of standard and optional on-board adjustments that enable the operator to make changes on the fly without having to stop the paving operation. These include:

- Variable 3:1 angle of attack
- Crown profiling and extendable slope control
- Extension height adjustments
- Vibrating extensions
- Angled berm extensions

There are also a few design characteristics that aid the contractor in increasing the overall job quality and productivity. The Legend screed family uses larger chrome rods and fiber bushings to create greater stability on large commercial projects. This helps eliminates paving imperfections that can be caused by slight rocking – either side to side or front to back – as the equipment traverses the unpaved base layer.

The screed plate is rather unique as well; it is made of ⅜-inch Hardox® 450, a quenched and tempered steel alloy used in high-wear heavy-equipment applications such as dump bodies, crushers, feeders and cutter edges. The bolt-on design enables the screed plate to be easily replaced, extending the serviceable life of the screed. The screed heating elements are nested in a thermal grease to distribute heat evenly across the screed plate.

Understanding the Process of Paving

As mentioned at the outset, the basic process for paving with asphalt—distributing, spreading, leveling and compacting—has not changed since the 1930s when Barber-Greene introduced the first “finisher”, which consisted of a tractor, floating screed and vertical tamping bar. The equipment used in each phase of the multi-step process, however, has continued to evolve, growing increasingly more capable as well as complex.

As a result, contractors today have more control over the final paving product than ever before; more on-board sensors and automation tools for controlling material flow rate and volume, auger depth angle-of-attack and vibrations per second. Today’s advanced paving technologies and mix designs enable crews to lay down mile after mile of a perfect mat, in far less time and with less skilled operators than a few years ago.

With that enhanced capability, it is necessary—perhaps more than ever before—that crews understand the flow of material throughout the process. More importantly, they must understand where and how anomalies are introduced into the process, how to spot them in the finished product and what the potential impact may be. While the screed is responsible for producing the mat in its final form, there are so many other processes that must be handled flawlessly first: the structural integrity of the mix, heat retention, optimal flow rate, balanced loading of the hopper, even the arrival of the dump truck.

Today, screeds like the Legend series from LeeBoy, have the ability to overcome a wide range of issues while minimizing the cost. Some of these are corrected before the operator even realizes them. Many more, however, require a screed operator who is knowledgeable of the process, focused on the project and understands the capabilities as well as the limitations of his equipment.

[i] *Smoothness: a paving priority; Volvo Construction Equipment, white paper; May 2010*

[ii] *Workability of hot mix asphalt; National Center for Asphalt Technology research report; April 2003*

[iii] *"History of Asphalt"; National Asphalt Paving Association website*

[iv] *9 Essential Asphalt Paving Tips That Improve Quality; Heavy Equipment Guide; October 20, 2015*

[v] *FHWA and AI release longitudinal joints best practices; Asphalt Magazine; March 1, 2012*

[vi] *Hot Mix Asphalt Materials, Mixture Design, and Construction; National Asphalt Paving Association Education Foundation; 1996.*

[vii] *Application Tips: Small asphalt pavers; Equipment World; June 12, 2007*

VT LeeBoy, Inc. ▪ 500 Lincoln County Parkway Extension ▪ Lincolnton, NC 28092 ▪ 704.966.3300
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