SOLSTICE TITAN®

For Roads That Go A Long Way



Solstice

POLYMERS FOR BUILDING BETTER ROADS

Solstice Titan® is a family of polyolefin-based products that can be blended with asphalt binders to build durable and sustainable pavements at lower overall costs. They increase the stiffness of the binder at high temperatures, and also enhance its lubricity. This lubrication effect not only boosts density with less compaction effort, but also increases the number of "contact points" between aggregates, the main load bearing components of the pavement asphalt layer.

Solstice Titan also improves the adhesion of the asphalt binder to aggregates which improves pavement durability, and delivers several essential benefits such as:

- Strong rutting resistance
- Water (moisture) damage resistance
- Increase in dynamic modulus
- Easier compaction and faster paving
- Excellent fuel resistance

STRONG RUTTING RESISTANCE

Adding Solstice Titan polymers to asphalt significantly reduces rutting in pavements. As shown in Table 1 and Chart 1, there is a notable improvement in resistance to rutting as measured by the AASHTO TP79 (2009) Flow Number (FN) Test.

Resistance to rutting is also measured using the Hamburg Wheel Tracking Test (AASHTO T 324). As shown in Chart 2, Solstice Titan added at less than 1.5% weight of the binder can significantly reduce "Creep Rate" and increase the cycles to the Stripping Inflection Point (SIP) and to reach the allowable rutting limit.

Table 1: Flow Number Test (AASHTO TP 79)

MIX	FN
Control	136
SBS	739
Solstice Titan (HON)	896
Solstice Titan + SBS (Hybrid)	1744

Chart 1: Results of the FN test (AASHTO TP79)

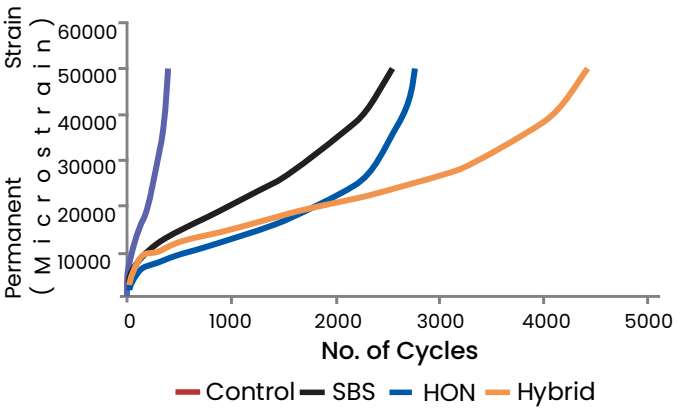
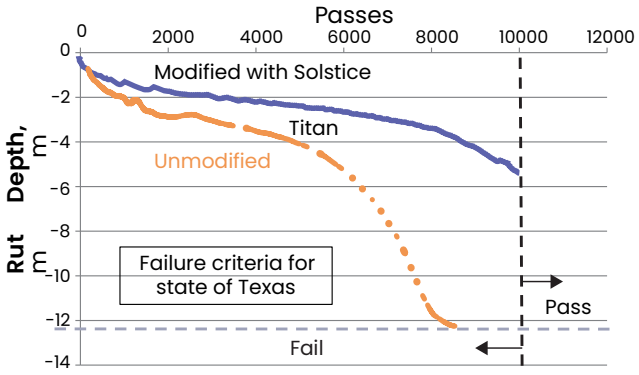


Chart 2: Results of the Hamburg Wheel test (AASHTO T324)



These improvements are due to the ability of Solstice Titan to elevate the binder properties and to optimize packing of the aggregates by increasing the number of "contact points" between aggregates as shown in Figure 1. The increased resistance in rutting has been verified for numerous types of mixtures composed of various aggregates sources and binders as shown in Table 2. **Relative Improvement as high as 700% could be achieved with less than 1.5% Solstice Titan.**

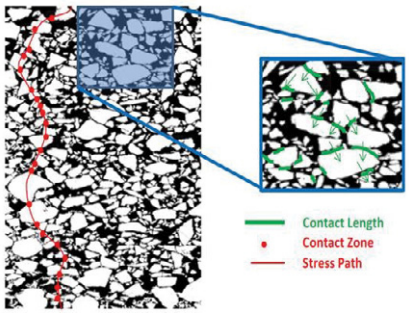


Figure 1: Image analysis showing the better packing of aggregates with Solstice Titan

Table 2: Examples of Mix Designs That Improved Significantly in Rutting Resistance (Passes to Target Deformation) with Solstice Titan

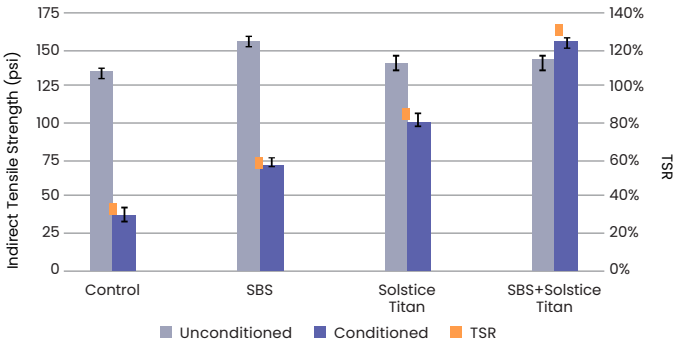
Mix Design	Solstice Titan Concentration (% in AC)	Passes to Target Deformation	% Increase in Passes relative to Control
1	Control - HMA plant produced	3450	190
	1.1% Solstice Titan - HMA plant produced	10000	
2	Control - plant produced	2450	716
	1.1% Solstice Titan- HMA plant produced	20000	

IMPROVED WATER (MOISTURE) DAMAGE RESISTANCE

Solstice Titan modifies the interface between asphalt and aggregate, providing superior adhesion properties, thereby reducing stripping due to moisture damage, as clearly evident in boiling test results shown in Figure 2. Results from the AASHTO T 283 test shown in Chart 3, clearly show that Solstice Titan enhances the moisture resistance of the hot mix sample by increasing the wet tensile strength, with or without the presence of a modifier, Styrene-Butadiene-Styrene (SBS). The wet tensile strength more than doubles (increased from 35 psi to 100 psi) when used with Solstice Titan only, and more than quadruples (increased from 35 to 150 psi) when combined with SBS. Chart 3 shows that the Tensile Strength Ratio (TSR) increases from 40% to more than 70% with Solstice Titan, and from 40% to almost 100% with the combination of Solstice Titan with SBS.

Although results can vary for different aggregates and/or base asphalt binders, Solstice Titan's mechanism of improving adhesion has been found to work with various types of difficult aggregates susceptible to moisture damage.

Chart 3: Tensile Strength Ratio Test (AASHTO T283)





3% SBS in asphalt binder



3% Solstice Titan in asphalt binder



2.25% SBS + 0.75% Solstice Titan in asphalt binder

Figure 2: A 10-minute boiling water test shows the Solstice Titan modified mix clearly retained more binder than the mix without Sostice Titan.

INCREASE IN DYNAMIC MODULUS

Pavement design methods incorporate the modulus of asphalt mixtures to determine the response of pavement asphalt layer to truck loading. Solstice Titan, due to its capability to improve binder properties and packing of aggregates, results in higher Dynamic Modulus (E*) at a relatively low dosage in asphalts. Table 3 shows a comparison of E* values (using AASHTO T 342 standard procedure) for the same mixture with and without Solstice Titan. As shown here, E* values of mixtures using only 2.5% Solstice Titan dosage ranges from ~10,000 MPa for a truck speed typical of interstate highway, to ~5,600 MPa for a truck speed at intersections. This is an increase of 65 – 75% in E* values compared with the same mixture produced with unmodified asphalt binder. These increases could reduce pavement deformation and increase durability significantly. Additionally, estimates using the most recent version of Pavement ME Design, the AASHTO software for pavement design, show potential of 100% to 300% more truck traffic (Equivalent Single Axle Load (ESALs)) to the same level of damage and same IRI (International Roughness Index) values.

Table 3: Comparison of E* Values (using AASHTO T342 Standard Procedure)

Class of Highway	Approximate Speed (MPH)	Not Modified	2.5% Solstice Titan	4.0% Solstice Titan	7.5% SBS
		E* MPa			
Interstate	60 – 80	6,477	10,553	11,494	8,790
Arterial	30 – 40	5,353	9,092	10,165	7,710
Urban	15 – 20	4,595	8,001	9,152	6,910
Intersections	~ 5	3,164	5,648	6,883	5,171

EASIER COMPACTION AND FASTER PAVING

Solstice Titan enables remarkable reduction to mixing temperatures, road construction temperatures, and the number of roller passes, while allowing a longer paving season. For example, the number of rolling passes as shown below in Table 4, reduced from six (three breakdown passes, three finishing passes) to four, while lowering the temperature of production and placement by ~55 °F.

The reduction of temperature to produce hot mix results in lower energy costs and reduced emissions. It was estimated that a 13% fuel saving was achieved while reducing VOCs, SOx, NOx, and CO2, for the TXDOT trial shown above.

Chart 4 shows the compaction of hot mixes containing SBS, Solstice Titan only, and SBS + Solstice Titan. The %Gmm (% maximum density) is plotted as a function of gyrations in the Superpave Gyratory Compactor (SGC). The number of gyrations simulate field compaction with a roller in the field.

N92: The number of gyrations needed to reach 8% air voids

N96: The number of gyrations needed to reach 4% air voids

It shows that hot mixes with Solstice Titan reach N92 and N96 sooner than the SBS-only hot mix.

Not all mixtures are created equal and thus the amount of Solstice Titan and the type of product can vary from one mixture to another. As shown in chart 5, two SBS modified binders – PG 70-22 and PG 76-22 – were used to prepare hot mixes which were compacted in an SGC. The binders, when dosed with Solstice Titan, reduced the number of gyrations needed to reach 92% Gmm (N92) by an average of 35%.

Table 4: Lower Compaction Temperatures and Less Number of Roller Passes Achieved with Solstice Titan

	100% SBS	SBS + Solstice Titan
HMA Plant Temperature	335 °F	280 °F
Temperature Behind Paver	300-310 °F	245-260 °F
Roller Passes (Break down + Finishing)	3 + 3	2 + 2
Density	95.8%	96.7%

Chart 4: Compaction Benefit with Solstice Titan

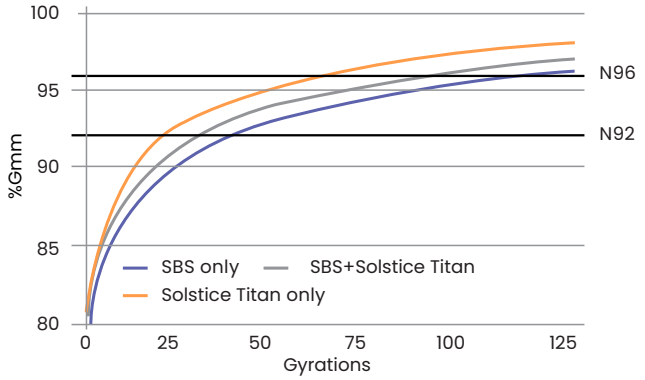
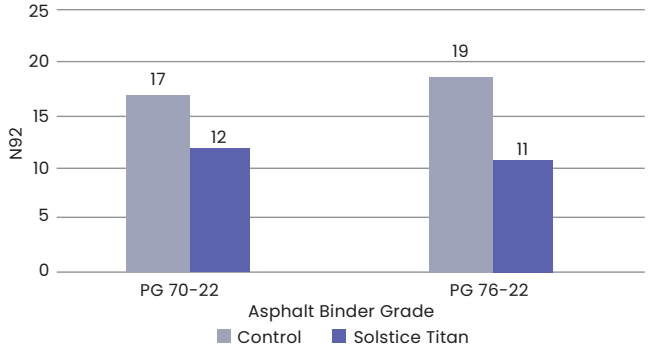


Chart 5: Number of Gyrations to achieve 92% Gmm (N92)



EXCELLENT FUEL RESISTANCE FOR AIRPORTS AND PORTS (FAA P-601 SPECIFICATIONS)

Federal Aviation Administration (FAA) specifications (P-601) requires a surface course that is fuel resistant. Replacement of a portion of SBS in the binder with Solstice Titan enables the hot mix to meet the 2.5% maximum weight loss criteria after immersion in kerosene. Results of a typical mixture with PG 82-22 binders before and after partial replacement of SBS modifier with Solstice Titan product, are shown in Figure 3. Details of results for the mass loss and Marshall Stability and Flow are shown in Table 5.

Figure 3: Effect of Solstice Titan on Fuel Resistance of a Typical Airfield Asphalt Mixture



Figure 3a: PG64-22 + SBS only

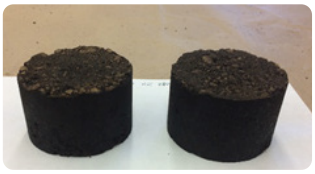


Figure 3b: PG64-22 + SBS + Solstice Titan

Table 5: Significant Reduction of Mass Loss from 13% to Less Than 2% by Using Solstice Titan.

Mix type	Optimum Asphalt Content	Stability (lbs)		Flow (0.01 inch)		Fuel Resistance Test (P-601)			
		Replicate	Average	Replicate	Average	Weight Before (g)	Weight After (g)	% Loss	Average
SBS	6.8%	3980	3910	17.0	18.0	1266.7	1110.3	12.3%	13.0%
		3840		19.0		1270.8	1097.7	13.6%	
SBS + Solstice Titan	6.8%	4950	4625	16.5	17.3	1266.3	1243.9	1.8%	1.4%
		4300		18.0		1263.3	1250.4	1.0%	
SBS + Solstice Titan	6.8%		Not Measured		Not Measured	1277.4	1257.5	1.6%	1.8%
						1257.1	1231.3	2.1%	



RECOMMENDED SOLSTICE TITAN DOSAGES & USAGE METHODS

Typical dosages for Solstice Titan are 1.1– 1.5% weight, based on Total Asphalt Content (virgin binder plus binder from RAP/RAS). However, this could vary based on the desired benefits for each customer. The exact dosage can be ascertained by laboratory trials and consulting with the Solstice team.

Unlike several other polymers used in modifying asphalt, Solstice Titan has a relatively low melting point of approximately 135 °C. It can thus be easily melted and incorporated into the asphalt binder with low shear stirring for 30 minutes or more, at ~ 150 °C (300 °F). It should be added gradually to prevent a build-up of the material.

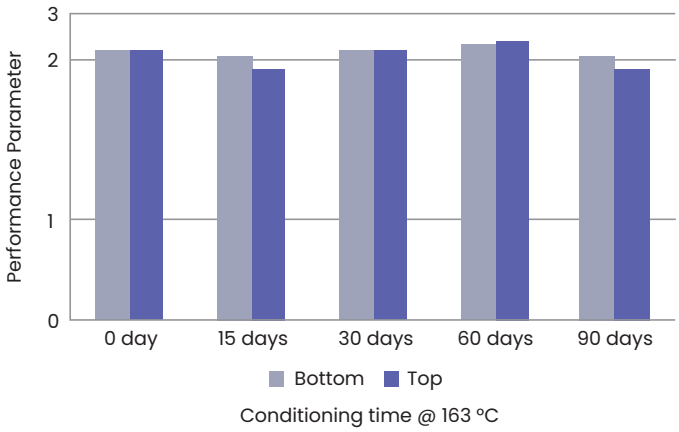
The incorporation of Solstice Titan polymer into an asphalt tank at the hot mix plant requires no special equipment. It can simply be added manually to the liquid asphalt tanks, with the support of mechanical agitation or recirculation (commonly found in most small & medium size hot mix plants). Alternatively, it can also be added using a skid-mounted continuous feed inline mixer system that is integrated with feed hopper, auger, mixer, and pumps (preferred by large volume hot mix plants). This system is equipped to precisely meter additives into the blending process. Further, it can be connected to the hot mix plant PLC for full remote access. Whatever may be your hot plant design, Solstice can help you determine the optimal polymer addition system for your plant.

STORAGE & SHELF LIFE

Solstice Titan polymer should be stored in a dry, cool, and wellventilated area. Keep away from heat, sources of ignition, and direct sunlight. The recommended shelf life for the product is three years.

When incorporated into asphalt binder, Solstice Titan is heat and storage stable. Storage stability testing (ASTM D 7173) of binder dosed with Solstice Titan has shown no performance degradation even after 90 days at 163 °C (325 °F), as shown in Chart 6.

Chart 6: Storage Stability Testing (ASTM D7173)



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