



BAKELITE
SYNTHETICS

TUFFTREK

Products for Roads and Roofing

RENEWABLE OIL TECHNOLOGY

TUFFTREK 4002 is a highly effective modification oil for meeting the performance needs of paving, recycling, and roofing applications. Using renewable oil technology, it is sourced from feedstocks that are 100% bio-based and is highly compatible with asphalt.

TUFFTREK 4002 is designed to:

- Produce softer asphalt grades with wider PG temperature spreads than what an asphalt source could yield on its own.
- Rejuvenate aged asphalt by reversing the effects of oxidation.
- Improve durability, stress-relaxation, and age-related cracking properties of asphalt.
- Adjust stored asphalt that may age out of spec.
- Improve an asphalt's compatibility with SBS polymer.
- Have a high flash point.
- Not be hazardous to health or the environment.

Advantage: TUFFTREK 4002

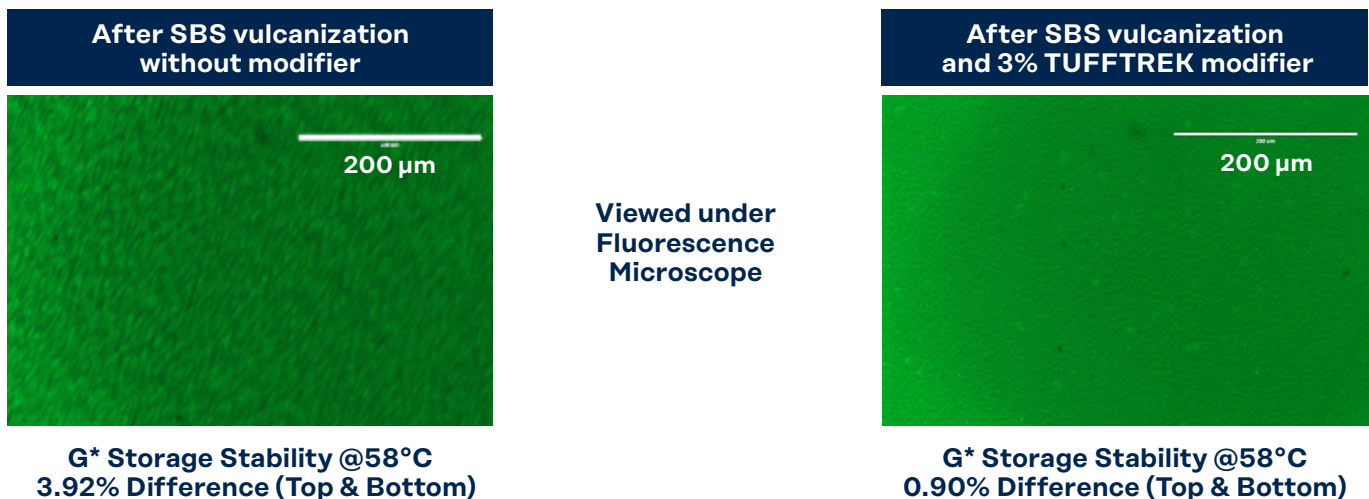
	TUFFTREK 4002	Aromatic Oil	Base Oil
PG Grade Reduction	Low dosage required to reduce PG	Nearly 3x additional modifier required to achieve same low PG reduction	Nearly 15% additional modifier required to achieve same low PG reduction
40 hr PAV ΔT_c	Greatest impact on ΔT_c . Improvement maintained at high dosage level.	Moderate impact on ΔT_c	Low impact on ΔT_c at low dosage. Detrimental to ΔT_c at high dosage
HSE	Biobased, renewable. Not hazardous to health or the environment.	Non-renewable	Non-renewable

Comparing TUFFTREK 4002 Technology to petrochemical modifiers Modification of Base Asphalt PG 64-22 Results

Modifier	Base Asphalt*	TUFFTREK 4002		Aromatic Oil		Base Oil	
		3	6	3	6	3	6
Dosage Rate, %	0	3	6	3	6	3	6
Mass Change, %	-0.347	-0.369	-0.444	-0.393	-0.468	-0.419	-0.560
Δ in high PG per 1% added modifier		-1.9	-1.9	-1.1	-1.0	-1.6	-1.5
Δ in intermediate PG Stiffness per 1% added modifier		-2.0	-1.8	-0.8	-0.7	-1.3	-1.3
Δ in low PG Stiffness per 1% added modifier		-1.6	-1.7	-0.5	-0.6	-1.3	-1.5
Δ in low PG m-value per 1% added modifier		-1.8	-1.9	-0.6	-0.7	-1.4	-1.2
20 hr PAV ΔT_c (S-m)	1.3	2.2	3.1	1.6	2.3	1.4	-0.3
40 hr PAV ΔT_c (S-m)	-1.6	0.0	0.0	-0.7	-0.5	-1.3	-2.7

*High quality asphalt sourced from MN. TUFFTREK 4002 benefits may be magnified with lower quality base asphalt.

More Complete SBS dispersion with TUFFTREK Technology

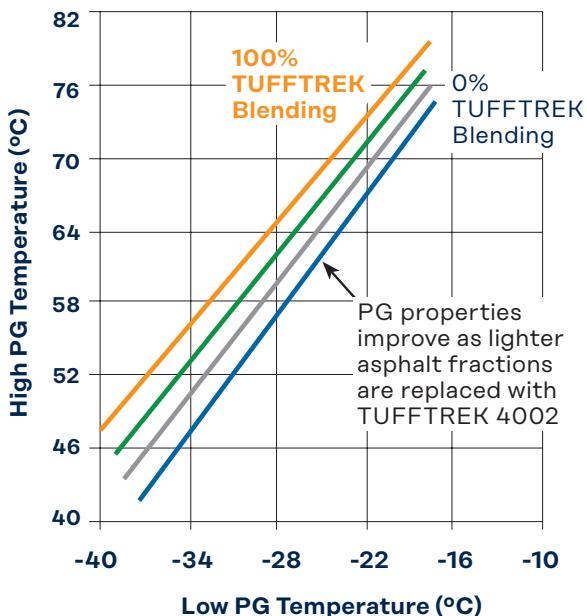


BLENDING APPLICATIONS

TUFFTREK 4002 has the benefit of upgrading the asphalt quality of a hard-base asphalt. When blended with asphalt, TUFFTREK 4002 softens the asphalt while widening the temperature spread beyond the capability of the original asphalt's distillate fractions.

In the example below, an asphalt blended with its own lighter distillate fractions would yield a PG 58-22, while TUFFTREK 4002 blended with the hard pen yields a PG 64-28.

As shown in the orange line, TUFFTREK 4002 can be blended with asphalt at different percentages to create multiple grades from a single source. Grades as soft as a PG XX-40 are achievable.



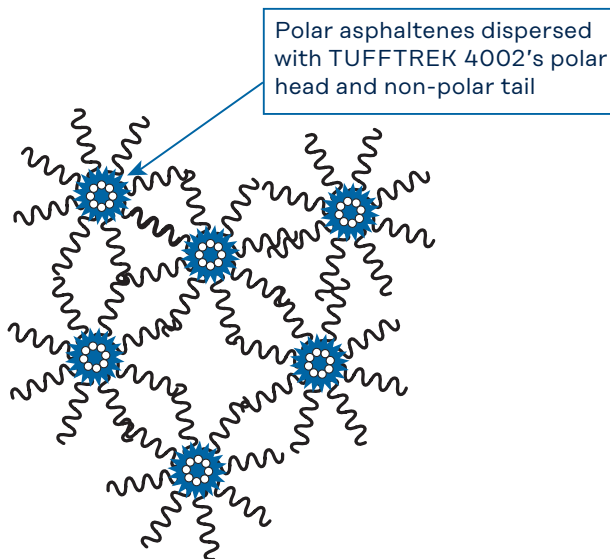
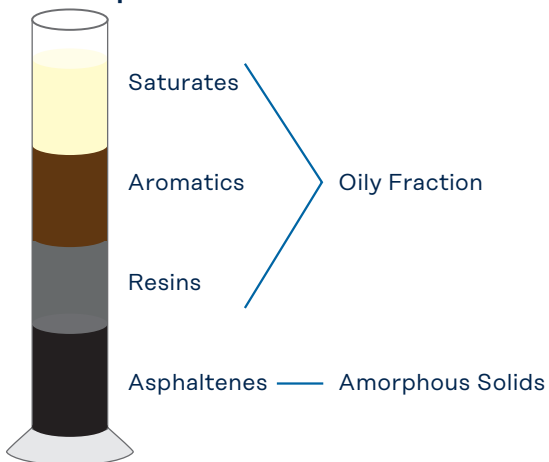
- Hard Pen blended with gas oil from same distillation makes PG 58-22
- Hard Pen blended with a 27% TUFFTREK 4002 and 73% gas oil blend
- Hard Pen blended with a 73% TUFFTREK 4002 and 27% gas oil blend
- Hard Pen blended with 100% TUFFTREK 4002 makes PG 64-28

THE SCIENCE BEHIND IT

TUFFTREK 4002 has both polar and non-polar components. Non-polar fatty acid chains orient with the non-polar oily fraction in asphalt, and the polar components orient with the polar asphaltenes. In theory, TUFFTREK 4002 works similarly to an emulsifier by stabilizing asphaltenes as it reduces viscosity, which in turn reduces durability cracking and environmental stress cracking.

Asphalts with a "gel" structure have clustered asphaltenes and are prone to age-induced embrittlement. These asphalts may be aged, oxidized, or derived from waxy crudes. TUFFTREK 4002 helps disperse the asphaltenes within the oily/maltene fraction, thereby improving molecular mobility of the asphaltenes and turning the "gel" asphaltene structure into a "sol" asphaltene structure with a greater ability to relax stresses. As TUFFTREK 4002 reduces asphalt viscosity, the BBR* m-value** increases at a faster rate than the BBR Stiffness, which improves ΔT_c , phase stability, and durability parameters.

Fractured Asphalt



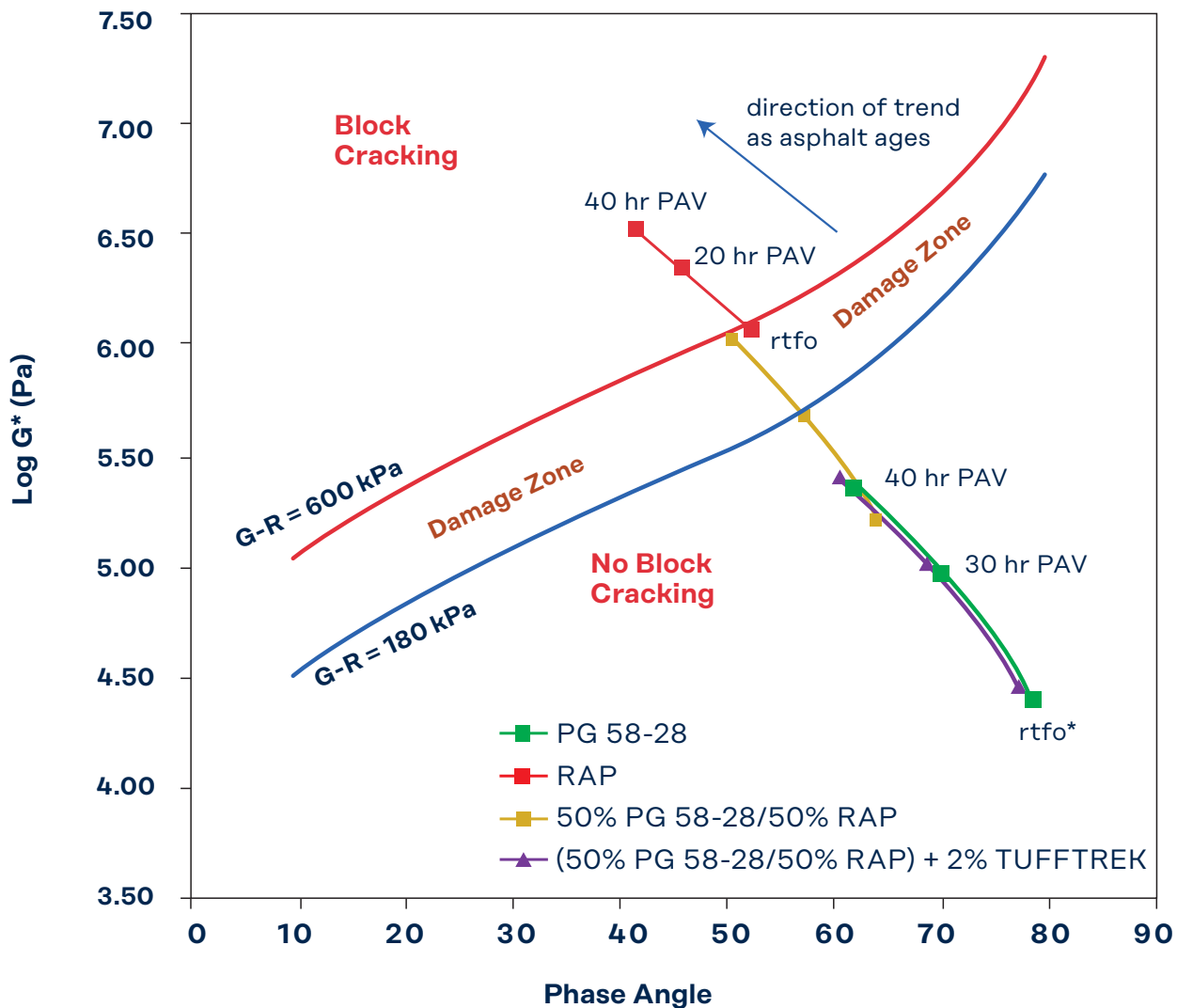
*Bending Beam Rheometer
 **Tangent of the creep curve at 60s load time

RECYCLING APPLICATIONS

TUFFTREK 4002 is a highly effective recycling agent (rejuvenator) for recycled asphalt pavement (RAP) and recycled

asphalt shingles (RAS) applications. In the example below, only 2% TUFFTREK was needed to restore the Performance Grade, ΔT_c , phase angle, and Glover-Rowe parameter of a simulated 50% RAP blend back to a PG 58-28.

Sample	PG 58-28	60 hr PAV 64-22 RAP	50% PG 58-28 50% RAP	(50% PG 58-28/50% RAP) + 2% TUFFTREK
% TUFFTREK Added	0	0	0	2
High PG	59.9	94.6	77.4	62.9
Low PG	-28.4	-15.8	-23.0	-29.7
20 hr PAV ΔT_c (S-m)	1.6	-5.0	-2.1	1.1
40 hr PAV ΔT_c (S-m)	-1.1	-6.8	-3.8	-1.4



*Rolling thin film oven.

NEBRASKA DOT ASPHALT REJUVENATOR PROJECT

Project Overview

50% RAP Asphalt Pavement

TUFFTREK 4002 proved to be an effective rejuvenator in a 50% RAP (Recycled Asphalt Pavement) pavement placed in Nebraska. In September 2019, a 2200 ton test section was paved 15 miles north of Lexington, NE on Hwy 21. The mix design contained a 60% binder replacement rate. The control section used a PG 58V-34 binder, and the 2200 ton test section used a PG 58V-34 with 4% TUFFTREK 4002 (pre-blended at a terminal), a 1.6% addition by weight of total binder in the mix.

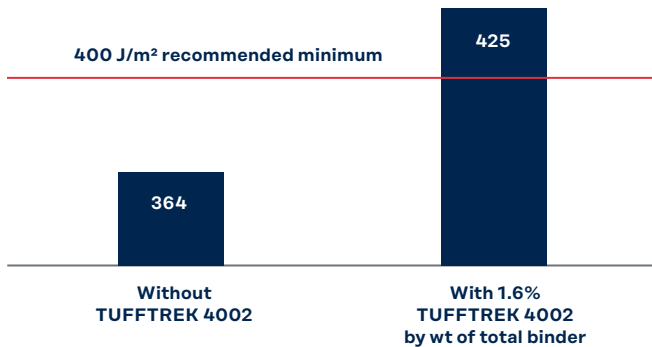
Evaluation and Results

A suite of performance tests were conducted on the production mixes. These tests included:

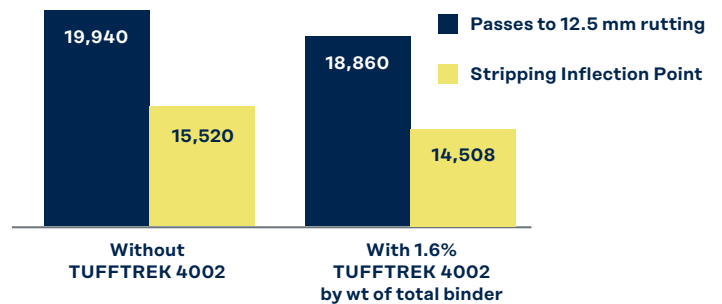
- Hamburg Loaded Wheel for rutting and stripping
- DCT Fracture Energy for low temperature cracking
- IDEAL-CT for intermediate temperature cracking.

The TUFFTREK test pavement demonstrated a higher resistance to cracking with minimal impact on rutting resistance and moisture damage. Additionally, ΔT_c results comparing the virgin binder with and without the TUFFTREK 4002 also predicted its ability to reduce the impacts of age-related binder hardening.

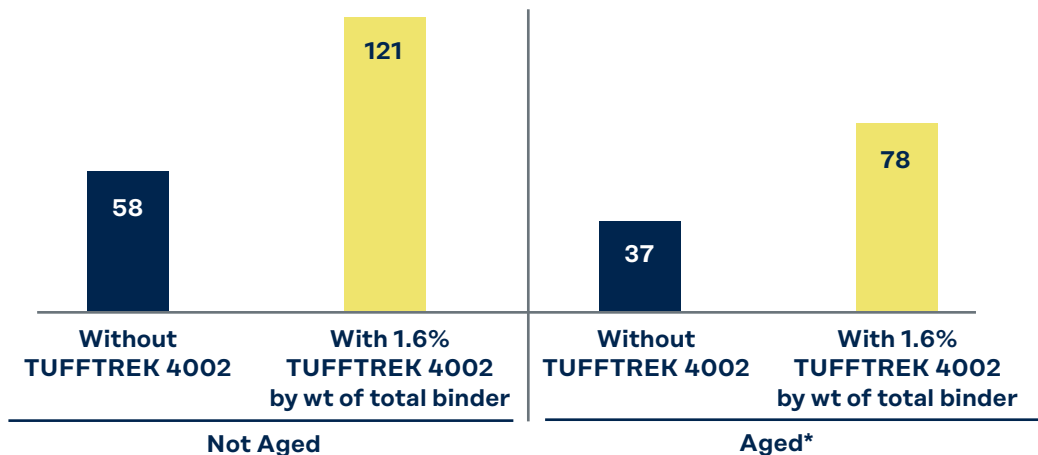
DCT Fracture Energy (-18°C)



Hamburg Wheel Tracking (45°C)



NEBRASKA DOT ASPHALT REJUVENATOR TRIAL IDEAL-CT (25°C)



*Aged test samples were prepared from field mix reheated in a 135°C oven for 2 hrs. and then conditioned in a loose mix state for 6 hrs.

Virgin Binder Test Results

	High PG	Low PG	40hr PAV ΔT_c
PG 58V-34	67.7	-36.9	-3.4
PG 58V-34 w/ 4% TUFFTREK 4002*	58.7	-40.4	0.0

*Binder was shipped from the same supplier but a different terminal.

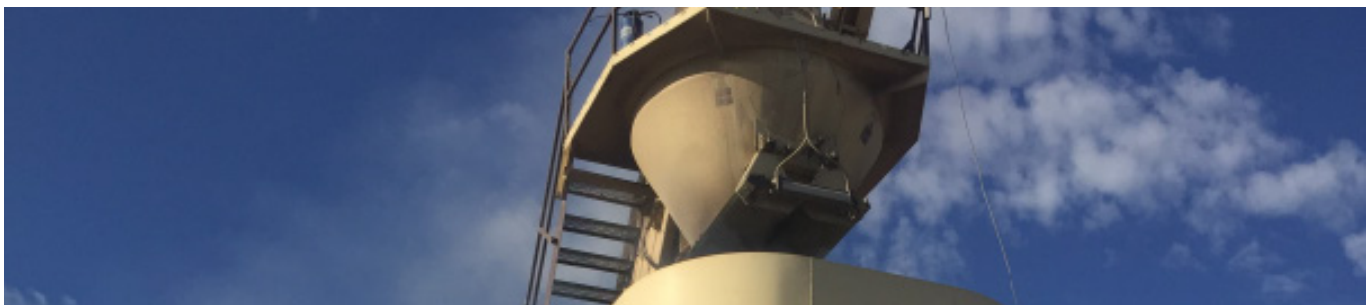
ROOFING APPLICATIONS

TUFFTREK 4002 Renewable Oil Technology improves the properties of oxidized asphalt for shingle coatings. The test data below from PRI Asphalt Technologies, Inc. demonstrate that adding TUFFTREK 4002 to asphalt prior

to oxidation results in a blown asphalt with higher penetration values without altering weathering performance. This increases a shingle manufacturer's ability to use different asphalt feedstocks for the air blowing process to achieve flexibility and durability requirements.

PERFORMANCE OF OXIDIZED COATING UTILIZING TUFFTREK 4002

Asphalt Sample	TUFFTREK 4002	PG XX-34	PG XX-34 Oxidized w/ 0.2% FeCl ₃	PG XX-34 w/ 4% TUFFTREK 4002	PG XX-34 w/ 4% TUFFTREK 4002 Oxidized w/ 0.2% FeCl ₃
Softening Point, °F (°C)	-	97.0 (36.1)	206 (96.7)	76.5 (24.7)	206 (96.7)
Penetration @ 25°C, dmm	-	287	15	386	22
(Typical) COC Flash Point, °F (°C)	468 (242)	568 (298)	594 (312)	579 (304)	586 (308)
PMCC Flash Point, °F (°C)	415 (213)	455 (235)	467 (242)	453 (233)	457 (236)
Absolute Viscosity @ 60°C, cP	15.5	33,300	-	16,200	-
Rotational Viscosity @ 400°F, cP	-	18.75	383	16.75	444
Stain Index	-	-	2	-	2
Accelerated Xenon Arc Weathering, ASTM D4798	-	-	Pinholes/ cracks after 2,500 hours of exposure	-	Pinholes/ cracks after 3,500 hours of exposure
Mass Loss % (after 2500 hrs of exposure)	-	-	7.7%	-	10.3%



ROOFING APPLICATIONS

TUFFTREK 4002 can be blended with asphalt using low shear, pre- or post-oxidation, or pre- or post-polymer modification. The data in the chart below was generated by blending TUFFTREK 4002 with asphalt pre-oxidation.

98% of the TUFFTREK 4002 is in the resin fraction. By acting as a resin, TUFFTREK 4002 works as a peptizing agent for asphaltenes to help keep them in solution

and improve their mobility within the colloidal system. This is demonstrated by the higher Colloidal Stability Index (CI) to the PG XX-34 asphalt oxidized with TUFFTREK 4002 compared to the CI of asphalt oxidized without TUFFTREK 4002.

TUFFTREK 4002 also reduced the amount of asphaltene formation during the oxidation, which correlates to the higher penetration value reported on the previous table.

CHEMICAL CHARACTERISTICS OF TUFFTREK 4002

Asphalt Sample		TUFFTREK 4002	PG XX-34	PG XX-34 Oxidized w/ 0.2% FeCl ₃	PG XX-34 w/ 4% TUFFTREK 4002	PG XX-34 w/ 4% TUFFTREK 4002 Oxidized w/ 0.2% FeCl ₃
SARA	Saturates	<0.1	7.4	5.6	6.9	5.3
	Aromatics	0.8	49.3	21.1	47	18.1
	Resins (Polars I)	98.1	22.9	20.3	24.3	25.8
	Asphaltenes (Polars II)	1.1	20.4	53	21.8	50.8
Colloidal Stability Index		-	2.60	0.71	2.48	0.78



BLENDING PROCEDURE

Standard procedure for the dosing and blending of TUFFTREK 4002 with Asphalt products.

Equipment:

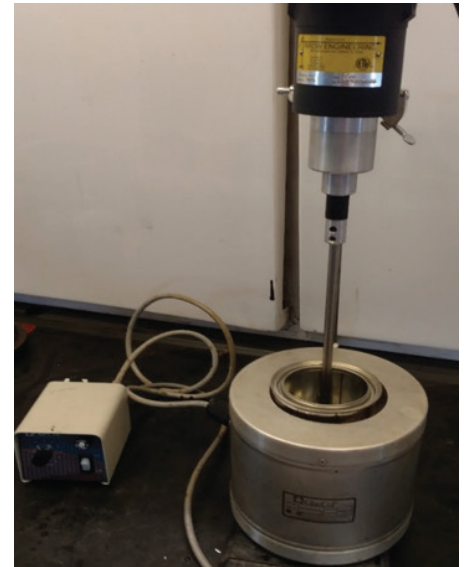
- Balance capable of measuring to 0.01g
- Low-shear mixer
- Quart-sized heating mantle
- Oven
- Timer

Procedure:

1. Pre-heat a quart-sized heating mantle to 300-325°F.
2. Heat supplied PG graded asphalt to 300-325°F in an oven.
3. Add 500 grams of asphalt to a quart can.
4. Dose the asphalt with TUFFTREK 4002 using the following equation:

$$\text{Mass of TUFFTREK 4002 (g)} = \left(\frac{\text{Mass of Asphalt (g)}}{(1 - \% \text{ Dosage Rate})} - \text{Mass of Asphalt (g)} \right)$$

5. Place the quart can of asphalt and TUFFTREK 4002 into the heating mantle.
6. Insert the mixer into the can with the propeller approximately 1" from the bottom of the can.
7. Mix sample at 200rpms for 10 minutes at 300-325°F.



Mixing Setup



Propeller at Bottom of Can



Learn more about the vision, products and history of bakelite on our website

bakelite.com

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