

TRINIDAD LAKE ASPHALT IN ROAD PAVEMENTS

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ABSTRACT

Trinidad Lake Asphalt is a natural asphalt and has been used extensively over the past 100 years in flexible road paving.

Research has established that the unique bituminous micelles and fine mineral matter of TLA combine to deliver stabilising and improved durability characteristics to pavements, when used in various asphalt mixes. It is shown in this paper that both user-producer and performance based specifications can be met with selected percentages of TLA modification through traditional blending procedures, and its modulus and performance characterisation facilitate the use of most design codes for new surfacings and overlays.

The economic efficiency of TLA surfacings, based on HDM III analysis, is such that society derives between \$1.5 to \$2.5 TT in life cycle benefits per Kilometre when TLA cements are used instead of straight bitumen in road paving works. These savings accrue mainly from reduced maintenance intervention and reduced road user costs, which usually derive from strong and durable pavements. Case studies in support of this observation of strength and durability are presented for roads, tunnels and bridges. In these cases the service demand of the facility and type of remedial intervention are described and the resulting performance is noted. Generally, the pavements have proved to be strong and durable.

1. INTRODUCTION

Roads, Tunnels and Bridges are an important part of the Transportation system for all communities and must be maintained when they become older. Nothing lasts forever. If you do not provide the means for people and industry to have safe and economical access to their destinations, then they both suffer increased user costs and reduced net incomes respectively.

One such material that has proven that it is strong, does the job and is economical to use is **Trinidad Lake Asphalt**. It has proven over and over again that it is a strong pavement material, and can be adapted to local construction procedures. It has been around a long time, and has a successful “track record” of Infrastructure repair and rehabilitation for many Airports, Tunnels and Bridges as well as other Transportation facilities around the world.

This paper discusses the nature and characteristics of TLA and TLA modified asphalts, their production and incorporation into design codes. Additionally the performance based efficiency of TLA surfacings is established, and case studies are presented on the rehabilitation of several infrastructure facilities with TLA mixes.

2. TLA THE MATERIAL

2.1 Production

Trinidad Lake Asphalt is a naturally occurring semi-solid asphalt found in an emulsified form in an asphalt lake to the south of the island of Trinidad. The lake is commonly referred to as the “**PITCH LAKE**” and is classified as one of the wonders of the world.

The genesis of the lake has not yet been fully understood and the many formatory causes or processes propagated (1) include polymerisation, selective absorption by silica and

clay minerals, electrostatic accumulation of pitch bodies and geothermal oxidation of a parent crude.

Refined TLA is produced by ripping the lake surface with light tractor machinery and transporting the crude material to refining stills. Here it is heated by steam coils to a constant temperature of 160°C to remove excessive water and volatiles and then screened to remove traces of extraneous and deleterious material. Essentially the refining process is one of dehydration with relatively low temperature and impurity removal; it is not a distillation process. The product obtained is called Refined Trinidad Lake Asphalt or Epure.

2.2 Composition and Physical Properties

The composition and physical properties of the crude and refined TLA are given in Table 1. In both the crude and refined states TLA has an appreciable proportion of mineral matter, with a predominant bitumen component. Over the past 100 years the composition of 53-55% bitumen, 36-37% mineral matter, and 9-10% water of hydration, adsorbed bitumen and volatiles have proven to be consistent (2). The mineral matter is extremely fine with 90% finer than 75 microns and some 44% finer than 10 microns and has been identified by X-Ray diffraction to be mainly quartz and clay minerals (Kaolinite and Illite) (2). This fine mineral matter in the bitumen provides a very tolerable sandpapering effect to vehicle tyres. Overall it is this intimate colloidal mixture of the mineral matter dispersed in the bitumen phase that imparts the hard character (penetration 1-4, R&B softening pt. 93-98 deg. (C) and stable structure up to 500°C which give rise to the unique characteristics and performance of the Epure (3).

2.3 Chemical Properties

The fractional composition of Epure is 36% malthenes and 18% asphaltenes; in terms of the soluble bitumen it is 67-70% malthenes and 30-33% asphaltenes. Ideally TLA is found to be more of a gel than a sol structure with an index of colloidal instability of 0.68 (2).

Asphaltenes are generally regarded as the constituent which gives asphalt its “body” and play an important role in the structural response of the asphalt. The asphaltenes in TLA are hard brittle sub-micron particles which do not melt but only intumesce on heating, yielding 26% of fixed carbon (4). The structure of the asphaltenes is somewhat complicated by the additional presence of submicron mineral matter resulting in the micelle of TLA being somewhat larger than those in other gel structure bitumens.

The composition of the asphaltenes is approximately CARBON-82.8%, HYDROGEN-7.8%, and SULPHUR-10.2%. The malthenes are soft and exceedingly sticky, like “maltha” and around 39% prove to be unsaturated hydrocarbons. On ignition these malthenes yield 6.3% of Fixed Carbon (4).

TABLE 1
PHYSICAL CONSISTENCY OF TLA (1)

REFINED LAKE ASPHALT (Epure)	EPURE COMPONENTS		
<u>Composition:</u>		<u>Bitumen in Epure:</u>	
Bitumen (Soluble in Trichloroethylene)	53-55%	Specific Gravity	1.05-1.08
		Penetration (25 °C)	g/cm ³ 3-12
Mineral Matter (Reduced during Reduction to Ash)	36-37%	Softening Point (RB)	65-78 °C
Mineral Matter (Reduced to Ash)	1.5%	Loss of Mass(5 hrs @ 163 °C)	1.9%
		Viscosity (Engler)	168 sec
Bitumen (Adsorbed by Mineral Matter)	0.5%	Flash Point (Open Cup)	238 °C
Water of Hydration of Mineral Matter	4.3%	<u>Chemical Composition:</u>	
		Carbon	82.3%
		Hydrogen	10.7%
		Sulphur	6.2%
		Nitrogen	0.8%
Organic Mat'l (Insoluble in Trichloroethylene)	3.2%		
<u>Properties:</u>		<u>Mineral Matter in Epure:</u>	
Specific Gravity	1.40-1.42g/cm ³	No. 10-No. 100	2.8%
Penetration (25 °C)	1-4	No. 100-No. 200	8.0%
Softening Point (RB)	93-98 °C	No. 200-60μ	8.0%
Volatilization Loss (5 hrs @ 163 °C)	1.1	No. 60μ-10μ	39.1%
		Finer 10μ	44.1%

When considered altogether TLA is a unique natural asphalt, the soluble bitumen being more of a gel than a sol (gel-sol) with a potential to provide improved structural performance and reduced thermal sensitivity through the unique size and nature of the asphaltenes. The fine mineral matter reinforces the bitumen in TLA and imparts hardness and improved pavement surface characteristics (better tyre/road surface interaction), if incorporated as modifier in paving grade asphalt cements.

3. BITUMEN MODIFICATION WITH TLA

3.1 Specifications

Because of its high surface tension, TLA blends most readily with most refinery bitumens, both soft and hard grades, to produce homogeneous quality modified asphalt cements for pavement construction covered by user-producer and performance-based specifications. In essence, user-producer specifications cover the storage, safety and

handling, consistency, hardness and elastic rebound of an asphalt cement, while the performance-based specification covers storage, safety, handling, rutting, fatigue and low temperature cracking resistance properties of the asphalt cement.

TABLE 2
REQUIREMENTS FOR TRINIDAD LAKE MODIFIED ASPHALT FOR USE
IN PAVEMENT CONSTRUCTION
ASTM D5710-95 Trinidad Modified Asphalt Specification (5)

	Min	Max	Min	Max	Min	Max	Min	Max
Penetration at 77F (25C), 100g, 5 sec	40	55	60	75	80	100	120	150
Kinematic Viscosity at 275F (135C), cst	385	-	275	-	215	-	175	-
Ductility at 77F (25C), 5cm/min, cm. (A,B)	100	-	100	-	100	-	100	-
Flash point, deg. F	450	-	450	-	450	-	450	-
Solubility in trichlorethylene, % (c)	77	90	77	90	77	90	77	90
Retained penetration after thin-film oven test, %	55	-	52	-	47	-	42	-
Ductility at 77F (25C), 5cm/min, cm, after thin-film oven test	50	-	50	-	75	-	100	-
Inorganic matter (ash), %	7.5 19.0		7.5 19.0		7.5 19.0		7.5 19.0	

The ASTM requirements for user-producer specified TLA cements, ASTM D 5710-95, are generally met with a dosage of between 20% to 50% TLA to refinery bitumen and are given in Table 2. The actual percentage of TLA to be used will depend upon the consistency or penetration of the bitumen feedstock and the desired penetration. The following model (6) may be used for establishing suitable TLA percentages.

$$\begin{aligned} \%TLA &= 1/b \ln [Pen_m/Pen_o] & r^2 &= 0.91 & [1] \\ \text{where } b &= -0.01(1.86 + 0.005 Pen_o) \\ Pen_m &= \text{Desired modified penetration} \\ Pen_o &= \text{Penetration of original bitumen or feedstock} \end{aligned}$$

The performance-based requirements as specified by SHRP are also covered by this TLA dosage, however careful selection of the bitumen feed stock and the percentage of TLA is critical to a successful blend product.

TABLE 3
TYPICAL SHRP PROPERTIES OF TLA

SHRP Grade Determination		75/25 Blend	Specification Limit
As Received Asphalt			
Flash Point, COC, °C		270	≥ 230 °C
DSR G*/sind, kPa	76°	1.15	≥ 1 kPa
Brookfield Viscosity at 135 °C, Pa.s		51.6*	£ 3 Pa.s
RTFOT Residue			
Mass Loss, %		0.74	£ 1.0%
DSR G*/sind, kPa	76°	2.0**	≥ 2.2 kPa
PAV Residue			
DSR G*/sind, kPa	28°	2750	£ 5,000 kPa
BBR, Stiffness, Mpa	-18°	258	S £ 300 Mpa
BBR, m Value	- 18°	0.335	m ≥ 0.3

* **Waived on supplier certification**

Typical performance based properties are given in Table 3 for a 25% TLA dosage (7). As shown, TLA modification can provide a good safeguard against fatigue and rusting and can be safely stored without excessive ageing. The pumping requirement (viscosity) is often waived once the supplier certifies his ability to deliver to the mixing plant.

3.2 **Blend Production**

Typical large scale hot mix production usually requires a blending system for TLA modification, and the additional requirements of a storage tank for the bitumen feedstock and an asphalt blending tank for the TLA modification are easily integrated into the conventional hot mix asphalt plant system. Traditionally the blending of TLA modified asphalt cements has been carried out in a U-shaped heater storage tank fitted with stirrers, but other tanks capable of the blending function may be used.

A common procedure is to load the TLA at ambient temperatures into the blend heated to 150°C in the late afternoon and to melt this overnight. The refinery bitumen is pumped at 150°C into the blending tank during the early morning so as to have the complete modified asphalt ready for use at the normal “starting time”. TLA will of course be weighed in, this being facilitated by the fact that each TLA drum has its weight painted on it.

In another procedure, bitumen from the storage tank at 150°C is measured into the blending tank by volume. Crushed TLA is added via the conveyor until a predetermined mark on the tank is reached. The blending time varies with the TLA content; a 30% TLA modification takes about 20 minutes. When the blend has reached 150°C it is pumped to the asphalt cement storage tank where it is agitated by stirrers. An optional circulation pump may be incorporated into the storage system.

4. **TLA IN PAVEMENT DESIGN**

The elastic modulus of the asphalt-aggregate surfacing layer is a fundamental design input parameter in most pavement design codes in use today (8),(9). It plays a primary role

in the relationships between subgrade strength, equivalent standard axle loadings and layer thickness. Through the use of this parameter TLA can be incorporated in the design of any

flexible pavement. Previous work done by Witizak (8) has shown that the elastic modulus of TLA modified asphalt cement can be between 2.3 to 7.0 times that of an equivalent straight run bitumen. Values of the Modulus Ratio (Mod TLA/Mod St. Run) are given in Table 4 for varying percentages of TLA modification for a 70 pen bitumen. Applying the selected Ratio to the standard AC modulus will result in significantly higher modulus values for use in the design codes.

**TABLE 4
TYPICAL GUIDELINES FOR MODULUS RATIO VALUES**

TEMPERATURE (∞ C)	Percent Epure (Total Mix)		
	1.0	2.0	3.0
4	1.5	2.0	2.5
21	1.9	3.5	5.0
38	2.3	4.8	7.0

Because of the increased modulus, TLA mixes will therefore provide for the use of thinner layers and the extension of pavement life by least 5 years in most cases.

5. PERFORMANCE

5.1 Life-Cycle Costs and Efficiency

Estimated life-cycle costs per Kilometre determined through HDM, analysis for straight run and TLA modified mixes employing a standard maintenance intervention policy of 40 mm and 80 mm surfacings on strong and weak subgrades, are given in Table 5 (10).

For strong subgrades, CBR of 8%, the agency costs are generally higher by some 6% to 15% with the exception of the single overlay policy for mid annual ESA levels, of 92,800 to 138,300 (see figure 3). Here the reduced costs or relative savings in agency costs are due to the less frequent maintenance intervention because of superior TLA performance. That is, the agency has to do less intervention over the 15-yr life of the pavement.

For the weak subgrades, CBR of 2%, the situation is somewhat reversed with the agency deriving savings in most cases, of between 1% and 10%. The single overlay policy at low and high ESA levels (61,00 and 169,700) produces increases in agency costs of 14% and 7% respectively. Here we see more benefits of the TLA surfacings due to the reduced maintenance intervention demand.

The **user costs**, in this case the vehicle operating costs(VOCs), are generally lower for the TLA pavements as shown in Table 5. The total costs show a reduction in value, of between 0.5 and 3.5% per kilometre for the TLA pavements, and this reduction increases in value as the ESA loadings increase. This pattern is to be expected as the TLA surfacings provide a much smoother pavement (less roughness) which favours a reduction in the wear and tear of vehicles using the roadways. Most noticeable is the continuing increase in user savings with increasing ESA loadings.

The **benefits derived by society** through the use of TLA surfaced pavements, expressed in terms of the Net Present Value(NPV), given in Table 6, range from \$64,000 TT to \$1.76M TT per kilometre over the spectrum of ESA loadings examined for the double

overlay policy on strong subgrades. For the same policy, the benefits are even higher for weak subgrades, ranging from \$78,000 TT to \$1.88M TT per kilometre. For the single overlay policy on strong subgrades continuous beneficiation is obtained for ESA loadings in excess of 93,000 to the tune of \$131,000 TT to \$1.2M TT . At 93,000 ESA loadings there are no benefits but losses of some \$45,000 TT per kilometre. Lower ESA loadings, however produce benefits up to \$33,000 TT per kilometre. On the weak subgrades, there are no benefits derived up to an ESA loading of 93,000, but this is reversed for higher ESA loadings to \$561,000 TT to \$1.5M TT per kilometre.

The overall **economic life-cycle performance** of the TLA surfaced pavements can best be described in terms of the Economic Efficiency of expenditure with respect to the straight-run surfaced pavements. The economic efficiency is the ratio of the NPV to the agency costs. In this analysis the incremental economic efficiency was evaluated and it gives the relative savings derived in using TLA pavements for every dollar of agency expenditure as opposed to spending the dollar on straight-run surfaced pavements. Between 60,000 and 100,000 ESA loadings the efficiency is marginally close to zero, but it picks up thereafter reaching as high as 1.5 to 2.5 for 170,000 ESA. This means that for every dollar spent on a TLA pavement, the society as a whole would receive between 1.5 to 2.5 dollars in benefits(life-cycle savings) per kilometre, over the savings derived from spending the dollar on a straight-run surfaced pavements.

Generally, the higher the number of axle loadings the better the economic performance of TLA surfacings.

5.2 Case Studies

TLA is used in road, bridge and tunnel pavements in over 27 countries worldwide. Current Information on a few projects and their performance is given in Table 6 for pavements in New York, New Jersey, Hong Kong and Trinidad and Tobago. In New York and New Jersey, the dense graded asphalt-aggregate mix surfacing employed a 20% TLA modified AC-20 and the membrane a 40% TLA modified AC-20. In Hong Kong a 50% TLA modified binder was employed in the surfacing mix, while in Trinidad and Tobago a 36 % TLA modified AC-5 was used.

As shown in Table 6, the surfacings have service lives of between 12 and 21 years, the traffic covers a broad span varying between 1.6 and 96 million vehicles per year and there has been no maintenance intervention required to date. Generally, the pavement condition are in very good to excellent condition.

TABLE 6
PERFORMANCE OF TLA SURFACINGS

PROJECT	TREATMENT	YEAR	ANNUAL TRAFFIC (Million Veh/yr)	PAVEMENT CONDITION
George Washington Bridge	37.5 mm overlay 12,5 mm membrane	1981	96	Very good
Otterbridge Crossing	25mm overlay	1987	20	Excellent
Geothals Bridge	25mm overlay 12.5mm membrane	1982	20	Very good
Bayonne Bridge	25mm overlay	1978	5	Very good
Lincoln Tunnel	18.8mm overlay	1975	40	Very good
Holland Tunnel	31.3mm overlay	1983	26	Excellent
Cross Harbour Tunnel *	125 mm surfacing	1972	30	Very Good
Uriah Butler Highway**	125mm surfacing	1983	1.8	Very good

*..... Hong Kong to Kowloon

**.... Trinidad and Tobago

6. CONCLUSION

1. Trinidad Lake Asphalt (TLA) is a natural asphalt with unique physical and chemical properties.
2. TLA lends itself readily to blending with refinery bitumen to produce consistent, modified paving grade asphalt cements for both user-producer and performance-based specifications.
3. When employed in pavement surfacings it provides for reduced layer thickness, it imparts improved structural performance and generates less maintenance intervention demand than pavements surfaced with straight-run bitumen mixes.
4. Road users, transportation agencies and Society as a whole enjoy life cycle savings when TLA is employed in overlay policies.
5. TLA overlays prove out to be stronger and more durable than straight-run overlays on a life-cycle basis

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TABLE 5.
LIFE-CYCLE ECONOMIC COSTS
THIN ASPHALT PAVEMENTS (15 yr Life Cycle)

ANNUAL ESAL (1000'S)	AVERAGE IRI		AGENCY COSTS		VEHICLE COSTS		SOCIETY COSTS		NPV /km \$/Km	ECONOMIC EFFICIENCY	CHANC AGEN COS' %
	BIT m/Km	TLA m/kM	BIT \$	TLA \$	BIT (\$M)	TLA (\$M)	BIT (\$M)	TLA (\$M)			
Single Overlay CBR = 8											
61.6	4.6	4.8	594000	644000	12.646	12.566	13.18	13.147	33000	0.051	8.41
92.8	4.7	4.6	638000	606000	27.453	27.911	27.911	27.956	-45000	-0.074	-5.0
138.3	4.9	4.7	633000	606000	40.281	40.858	40.181	40.727	131000	0.216	-4.2
169.7	4.9	4.5	642000	747000	53.642	54.229	52.229	53.017	1212000	1.622	16.3:
Double Overlay											
61.6	3.4	3.2	730000	730000	11.992	11.936	12.658	12.594	64000	0.087	0
92.8	3.7	3.5	676000	730000	26.447	26.276	27.062	26.933	129000	0.176	7.98
138.3	4.2	3.5	676000	730000	39.231	38.417	39.847	39.073	774000	1.06	7.98
169.7	4.8	3.7	683000	730000	52.527	50.731	53.148	51.39	774000	2.408	6.88
Single Overlay CBR = 2											
61.6	4.6	4.8	563000	644000	12.55	12.597	13.057	13.179	-122000	-0.1894	14.3:
92.8	4.6	4.7	677000	606000	27.34	27.511	27.949	28.056	-107000	-0.176	-10.4
138.3	5	4.6	773000	693000	40.559	40.04	41.225	40.664	561000	0.809	-10.5
169.7	4.8	4.5	750000	804000	53.57	52.053	54.244	52.776	1468000	1.825	
Double Overlay											
61.6	3.4	3.2	739000	730000	12.013	11.943	12.679	12.601	78000	0.1068	-1.2
92.8	3.8	3.5	739000	730000	26.519	26.314	27.186	26.972	214000	0.293	-1.2
138.3	4.4	3.6	739000	730000	39.452	38.482	40.119	39.139	980000	1.342	-1.2
169.7	4.5	3.8	792000	730000	52.714	50.891	53.427	51.548	1879000	2.573	-7.8:

Note: \$US 1.00 = \$TT 6.00