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TRINIDAD LAKE ASPHALT IN PAVEMENT PERFORMANCE*

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ABSTRACT

Trinidad Lake Asphalt (TLA) 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 stablising 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 TT$1.5 to TT$2.5 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 Trinidad and Tobago airports and the New York Metropolitan airports, 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 proven to be strong and durable.

1.0 INTRODUCTION

Roads, airports, tunnels and bridges are an important part of the transportation system for all countries and must be maintained when they become older. Nothing lasts forever. If the means for people and industry to access an area are not provided, then the economy of that area suffers because *"they will not come if you do not build it"*.

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 character 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.

2.0 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

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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 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 maltenes 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].

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 a modifier in paving grade asphalt cements.

3.0 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, 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.

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 [5] may be used for establishing suitable TLA percentages.

$$\%\text{TLA} = 1/b \ln [\text{Pen}_m/\text{Pen}_o] \qquad r^2 = 0.91 \qquad (1)$$

where $b = 0.01\,(1.86 + 0.005\,\text{Pen}_o)$

Pen_m = Desired modified penetration

Pen_o = Penetration of original bitumen or feedstock

REFINED LAKE ASPHALT (Epure)	
Composition:	
Bitumen (Soluble in Carbon Disulphide)	53-55%
Mineral Matter (Reduced to Ash)	36-37%
Mineral Matter (Reduced during Reduction to Ash)	1.5%
Bitumen (Adsorbed by Mineral Matter)	0.5%
Water of Hydration of Mineral Matter	4.3%
Organic Material (Insoluble in Carbon Disulphide)	3.2%
Properties:	
Specific Gravity	1.40-1.42g/cm^3
Penetration (77°F) mmx10^{-1}	1-4
Softening Point (RB)	93-98°C
Volatilisation Loss (5 hrs @ 163°C)	1.1

EPURE COMPONENTS (Epure)	
Bitumen in Epure:	
Specific Gravity	1.05-1.08g/cm^3
Penetration (77°C) mmx10^{-1}*	60-80
Softening Point (RB)	65-78°C
Loss of Mass (5hrs @ 163°C)	1.9%
Viscosity (Engler)	168 sec
Flash Point (Open Cup)	238°C
Chemical Composition:	
Carbon	82.3%
Hydrogen	10.7%
Sulphur	6.2%
Nitrogen	0.8%
Mineral Matter in Epure:	
No. 10-No. 100	2.8%
No. 100-No. 200	8.0%
No. 200-60 µ	8.0%
No. 60 µ-10 µ	39.1%
Finer than 10 µ	44.1%

* Varies with method of extraction

Table 1: Physical Consistency of Trinidad Lake Asphalt [1]

The performanced-based requirements as specified by SHRP are also covered by this TLA dosage. However, careful selection of the bitumen feedstock and the percentage of TLA is critical to a successful blend product. Typical performance-based properties are given in **Table 3** for a 25% TLA dosage [6]. As shown, TLA modification can provide a good safeguard against fatigue and rutting and can be safely stored without excessive aging. 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 stirrer, but other tanks capable of the blending function may be used.

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

Table 2: Requirements for Trinidad Lake Modified Asphalt for Use in Pavement Construction
ASTM D5710-95 Trinidad Modified Asphalt Specification

SHRP Grade Determination		75/25 Blend	Specification Limit
		As Received Asphalt	
Flash Point, COC,°		270	≥230°C
DSR G*/sin δ, kPa		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*/sin δ, kPa	[76°]	>2.2	≥ 2.2kPa
		PAV Residue	
DSR G*sin δ, 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

Table 3: Typical SHRP Properties of Trinidad Lake Asphalt

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.

4.0 TLA IN PAVEMENT DESIGN

4.1 New Pavements

The elastic modulus of the asphalt-aggregate surfacing layer is a fundamental design input parameter in most pavement design codes in use today [7]. It plays a primary role in the relationships between subgrade strength, equivalent standard axle loadings and layer

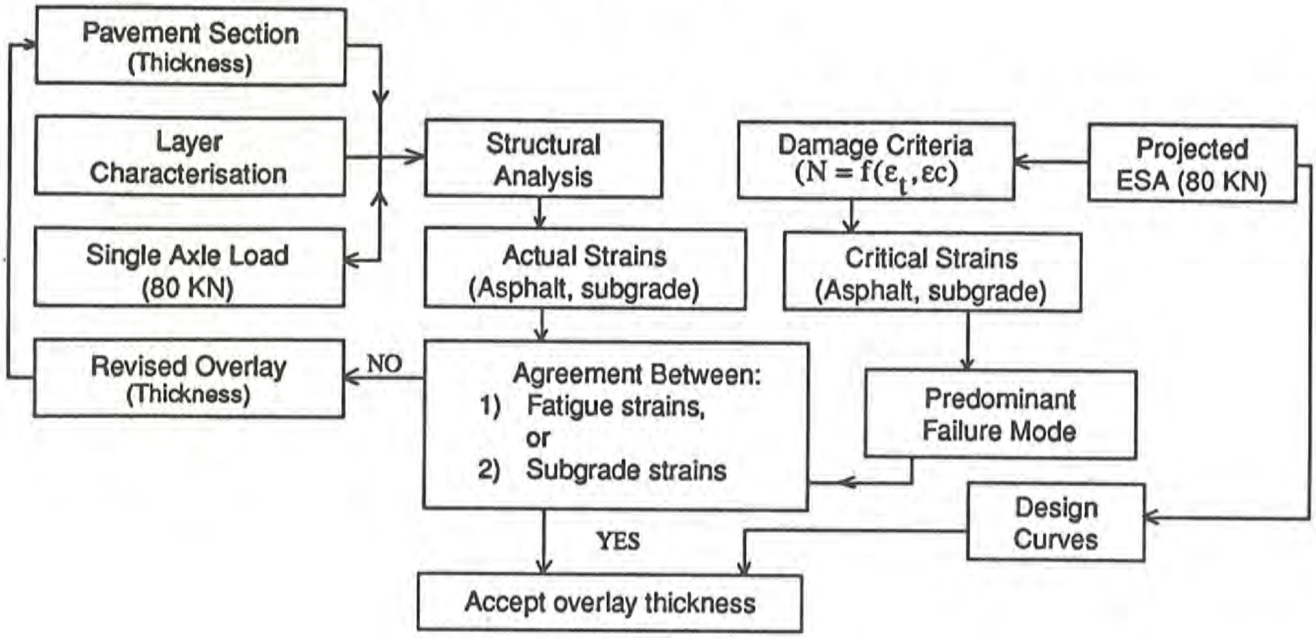

Figure 1: **TLA Overlay Design System [9]**

thickness. Through the use of this parameter, TLA can be incorporated in the design of any flexible pavement. Previous work done by Witczak [3] 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 (Modified TLA/Straight 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.

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

4.2 Overlays

The incorporation of TLA in pavement overlay design can be done through the use of the representative elastic modulus and design codes, or mechanistic designs which are based on the determination of elastic stresses and strains [8]. A particular mechanistic design procedure for TLA, developed by Charles and Grimaldi [9], is given in **Figure 1**. Typical output from the system is summarised in **Figure 2** for the overlay of cracked pavements and represents the axle loading to initiation of distress. Here, the superiority of the TLA modification is seen to produce thinner layers to carry the same amount of axle loadings as unmodified asphalt pavements, resulting in relative economy for pavement design and construction.

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

Table 4: Typical Guidelines for Modulus Ratio Values of Modified Trinidad Lake Asphalt Mixes

5.0 PERFORMANCE

5.1 Life-Cycle Costs and Efficiency

Estimated 15-year life-cycle costs per kilometre determined through HDM 111 analysis [10] 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** (11).

ANNUAL ESAL (1000'S)	AVERAGE IRI		AGENCY COSTS		VEHICLE COSTS		SOCIETY COSTS		NPV /km	ECONOMIC EFFICIENCY	CHANGE IN AGENCY COSTS
	BIT m/Km	TLA m/km	BIT $	TLA $	BIT ($M)	TLA ($M)	BIT ($M)	TLA ($M)	$/Km		%
Single Overlay CBR = 8											
61.6	4.6	4.8	594000	644000	12.646	12.566	13.18	13.147	33000	0.051	8.417
92.8	4.7	4.6	638000	606000	27.453	27.911	27.911	27.956	-45000	-0.074	-5.01
138.3	4.9	4.7	633000	606000	40.281	40.858	40.181	40.727	131000	0.216	-4.265
169.7	4.9	4.5	642000	747000	53.642	54.229	52.229	53.017	1212000	1.622	16.355
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	7.988
138.3	4.2	3.5	676000	730000	39.231	38.417	39.847	39.073	774000	1.06	7.988
169.7	4.8	3.7	683000	730000	52.527	50.731	53.148	51.39	774000	2.408	6.881
Single Overlay CBR = 2											
61.6	4.6	4.8	563000	644000	12.55	12.597	13.057	13.179	-122000	-0.1894	14.387
92.8	4.6	4.7	677000	606000	27.34	27.511	27.949	28.056	-107000	-0.176	-10.487
138.3	5	4.6	773000	693000	40.559	40.04	41.225	40.664	561000	0.809	-10.349
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	-1.217
92.8	3.8	3.5	739000	730000	26.519	26.314	27.186	26.972	214000	0.293	-1.217
138.3	4.4	3.6	739000	730000	39.452	38.482	40.119	39.139	980000	1.342	-1.217
169.7	4.5	3.8	792000	730000	52.714	50.891	53.427	51.548	1879000	2.573	-7.828

Table 5: **Life Cycle Economic Costs**
Thin Asphalt Pavements [11]

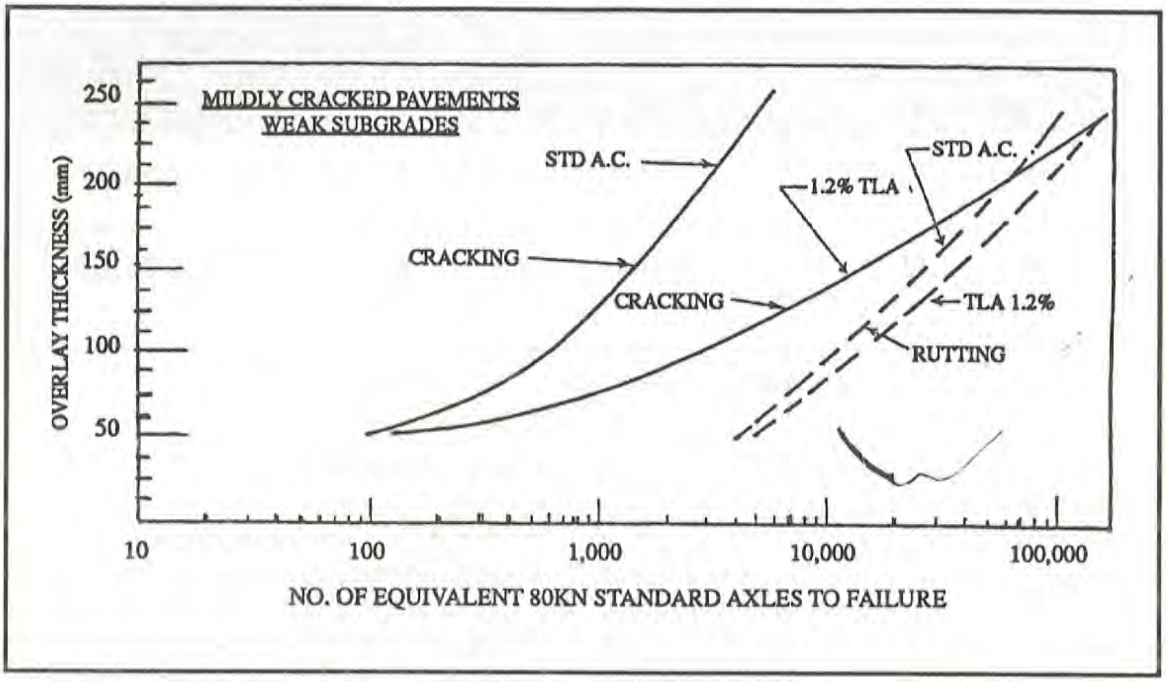

Figure 2: Typical TLA Overlay Design Curves [9]

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 (Table 5). 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-year 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 (61,000 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 5, range from TT$64,000 to TT$1.76M 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 TT$78,000 to TT$1.88M per kilometre. For the single overlay policy on strong subgrades, continuous benefication is obtained for ESA loadings in excess of 93,000 to the tune of TT$131,000 to TT$1.2M. At 93,000 ESA loadings, there are no benefits but losses of some TT$45,000 per kilometre. Lower ESA loadings, however, produce benefits up to TT$33,000 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 TT$561,000 to TT$1.5M 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

Pavement Component	Marshall Stability (min) lb (Kg)	Flow Value 0.01" (mm)	[illegible] Value [illegible]
Membrane Mix	1.000 (454)	15 to 40 (3.5 to 10)	0.5 to 1.0
Wearing Course	1.800 (816)	8 to 16 (2 to 4)	2.0 to 6.0

Table 6: Membrane and Wearing Course Design Criteria

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 straight-run surfaced pavements.

6.0 CASE STUDIES

6.1 Bridge Deck Pavement Rehabilitation

In the early 1980's, engineers from the Port Authority of New York & New Jersey were faced with a challenge for the rehabilitation of the lower six traffic lanes of the George Washington Bridge in New York City. After extensive evaluation of the bridge deck, the engineers decided that the existing concrete deck could be rehabilitated. The procedure selected included repairs to the concrete deck and the installation of a waterproof membrane, and a bituminous concrete wearing course. It was their opinion that this system would be sufficient to extend the functional life of the bridge deck which at that time was 20 years old.

The decision to use a blended Trinidad Lake Asphalt system resulted from the earlier successes the Port Authority had in 1975 with the TLA blended asphalt used on the Lincoln Tunnel elevated approach roadway.

A hot mix, water-proofing membrane was also developed along similar lines. Based upon information gathered about similar membrane mixes used in Europe, a TLA blend was developed incorporating 60% AC 20% and 40% TLA for the binder. Table 6 indicates the design criteria for the top and membrane courses.

All works on this contract had to be performed at night after the commuter traffic was over and had to be completed each morning before the rush hour began. This required each work area to have the existing wearing course completely removed, repairs made to the deck, cleaned, and then install the new 20 mm membrane layer and the 40 mm wearing course installed. After the contractor ironed out the initial "bugs" in the system, he was able to complete one lane (3.7 mm x 1,426 mm long) per weekend.

The new TLA blended paving system provided excellent use for more than 18 years. Former pavements had to be repaired on a regular basis due to reflection cracking resulting from the concrete filled steel grid structural deck. The Trinidad asphalt system extended the useful life of this bridge deck, and has served as the prototype paving system for many more bridge decks since then.

6.1.1 The Bayonne Bridge

The Bayonne Bridge crosses the Kill Van Kull between Staten Island, New York and Bayonne, New Jersey and was the longest steel arch span (510 m) in the world when it opened to traffic in 1931. The total bridge structure is 1,830 m long, and the A.D.T. is approximately 10,000 vehicles per day.

In 1977-78 the roadway was rehabilitated with a new wearing course consisting of a 25 mm thick Trinidad blended Asphalt. The 75A.C.20/25TLA was used for the binder. The pavement has now been in use for 18 years and still performing well. It is anticipated that the overlay will exceed its 20-year design life.

6.1.2 The Goethalls Bridge and Otterbridge Crossing

The Goethalls Bridge and Otterbridge Crossing are two other bridges that connect New Jersey with Staten Island, New York and were first opened to traffic in 1928. These two interstate bridges were also rehabilitated with a TLA-blended asphalt similar to the Bayonne and George Washington Bridges. Both bridges received the TLA hot mix membrane, and a high stability TLA pavement that was designed to be impermeable and prevent water and deicing salts from penetrating the concrete deck and causing damage to the reinforcing steel. Both bridges still contain the Trinidad Asphalt with the Goethall wearing course more than 18 years old, and the Otterbridge wearing course 9 years old.

6.1.3 New Jersey Turnpike - Route 18 Bridge

In 1993, a 44 mm TLA overlay was placed on this highway bridge that crosses over the New Jersey Turnpike in New Brunswick, New Jersey. This overlay was also a 75/25 TLA blend but was placed over a pre-formed membrane system. The placement temperatures of (160°C)was compatible with the membrane system and the roadway pavement is performing very well so far. Plans are currently being prepared for using the same TLA system on a number of highway bridges next Spring.

Experience with Trinidad Natural Asphalt binders has indicated that thin overlays can be constructed with this material while still providing good skid resistance and a hard surface that resists *"rutting"* caused by wear due to high channelised traffic on bridge decks. As a result of this good experience and successful track record, plans for two additional major interstate bridges are currently being prepared for the rehabilitation of their decks that include Trinidad blended asphalt. These bridges are:

1) Williamsburg Bridge - Crossing the East River, New York City
2) Walt Whitman Bridge - Crossing the Delaware River to Philadelphia.

6.2 Tunnels

6.2.1 Lincoln Tunnel

The successful experience with the Trinidad Asphalt bridge deck paving systems next led to its use for the wearing course material as a part of the rehabilitation of the roadway of the center tube of the Lincoln Tunnel in 1983.

The vertical distance between the roadway surface and the tunnel ceiling was critical and had to be maintained in order to provide proper truck clearance in the tunnel. The reinforced concrete slab repair permitted a maximum 25 mm bituminous wearing course. The earlier successful performance of a 25 mm Trinidad blended wearing course on the Bayonne Bridge led to the selection of the same material for the tunnel project.

Previous experience with thin asphalt pavements constructed from Trinidad blended asphalt indicated that such a pavement could perform well in a tunnel. The standard Lincoln Tunnel mix generally was designed for a Marshall Stability of 816 kg. Tests on previous TLA mixes consistently resulted in stabilities of 1,360 kg or more.

Taking all these factors into consideration, along with the good field performance of TLA mixes, it was decided to design a 32 mm thick wearing course for the tunnel roadway. In 1984, the complete centre tube was paved with a 75% A.C. 20 and 25% TLA mix as a part of the tunnel roadway rehabilitation.

The Trinidad blended asphalt surface is still performing well today, despite the heavy mix of bus/truck/car traffic using it each day going into Manhattan.

6.2.2 Holland Tunnel and Queens Mid-Town Tunnel

As a result of the experience gained in the use of TLA blended asphalt in the Lincoln Tunnel center tube, the other two tubes were later paved with a similar system. The Holland Tunnel is the other tunnel that goes under the Hudson River and connects New Jersey with New York and has been paved with a similar paving system. This has led to the selection of Trinidad blended asphalt for the repaving of the Queens Mid-Town Tunnel roadway in 1995. This tunnel goes under the East River in New York and connects Manhattan with the Borough of Queens.

6.2.3 The Cross Harbour Tunnel - Hong Kong

The Cross Harbour Tunnel joins the island of Hong Kong to Kowloon on the mainland of China. The mile long tunnel was opened in 1972 and since then has carried the majority of the island traffic. By 1980, traffic rose to over 2.5 million vehicles per month.

The wearing course consists of a 50 percent Trinidad Lake Asphalt-based binder and has performed well for the heavy density of traffic.

6.3 Airports

In order to resolve the pavement problems resulting from heavy wide-body jets and high temperatures, it became apparent that there was a need to improve the pavement properties of the binder materials. The experience gained from the work done with blending natural asphalt (Refined Trinidad Lake Asphalt) for rehabilitating of highway and bridge deck pavements demonstrated that a more durable pavement could also be developed for airport pavements. The experience with these materials also proved that no special equipment or expertise was required to mix, handle, or place the TLA-blended asphalt in the field. This was particularly important for airport work where paving work must fit in with the normal airport functions.

6.3.1 Piarco International Airport

Piarco International Airport (PIA) in Trinidad, West Indies was overlaid with 100 mm of TLA-modified mix in 1983. The PIA runway which is 45 m wide by 3,000 m long is located on a mixed sandy clay deposit with a high (1 m) and sometimes perched water table. The average subgrade conditions can be considered as fair to poor (CBR 4.0%) and the climate is rainy (150 cm per year). Prior to the overlay in 1983, runway dislevelment and extensive structural degradation were major obstructions to landing aircraft and annual maintenance costs averaged US$40,000 per year.

The overlay was placed in two layers; a 50 mm binder course and a 50 mm wearing course. The mix used was a dense, graded aggregate with 25 mm top size aggregate for the binder course and 12.5 mm top size aggregate for the wearing course. The binder was a TLA-modified 60/70 pen grade cement made up of 33% TLA and 67% of a 180/200 pen bitumen. The average asphalt content for the binder course was 5.5% and the wearing course had an average of 5.7% asphalt content. Marshall stabilities ranged from 10.7 KN (2,400 lbs) to 14.3 KN (3,200 lbs) and air voids content from 3.5% to 3.7%.

Overall, the overlay is performing remarkably well, having serviced in excess of 50,000 equivalent departures of a Boeing 747 at 3,482 KN (780,000 lbs) without any expenditure on pavement repairs over the thirteen year period since 1983.

6.3.2 Crown Point International Airport

The 45 m wide runway at the Crown Point International Airport (CPIA) was extended in 1990 to 3,000 m using a 33% TLA dosage to a 60/70 pen grade asphalt cement in a dense graded aggregate mix. The previous 2,000 m runway was overlaid with 100 mm of mix while the new 1,000 m had a 100 mm asphaltic base topped with a 100 mm surfacing.

The pavement has good, subgrade support and is performing remarkably well in its early life. So far, over the past four years, there has been no expenditure on structual maintenance after some 2,000 equivalent departures of a Boeing 747.

6.3.3 New York Metropolitan Airports

The first installation of the blended asphalt pavement at a New York City airport was an aircraft apron at La Guardia Airport in 1981.This installation was 100 mm thick and consisted of 75% A.C. 20 and 25% TLA for the bitumen. Marshall stability was 1,225 Kg.

Experience gained from this project led to the use of the same TLA blend being used wherever flexible airport pavements experienced similar problems. These pavement deformities generally occurring at the intersections of taxiways and runways as a result of heavily loaded jets turning to take off on the runway.

In 1981, the same TLA blend was used at Newark International Airport in New Jersey, to correct similar pavement problems on a number of taxiways.

Runway 13L-31R at John F. Kennedy International Airport (JFKIA) in New York City was rehabilitated with the TLA modified asphalt in 1984. This runway is 3,050 m long and was originally constructed of Portland Cement Concrete (PCC) and subsequently overlaid with about 175 mm of asphalt concrete. At the time of construction, the runway not only served both for take-offs and landings, but also as a taxiway for aircraft lined up for take-offs on the cross runway.

In the summer time, heavy rutting would be experienced on the runways as a result of stopping and going of aircraft lined up for take-off on Runway 4-22. The rutting was caused by the action of aircraft tyres, as well as other factors. Repairs had to be performed to correct the pavement deficiency and make the runway operational. This had to be done more than once a year in some situations.

The rehabilitation of the runway included the removal of the asphalt and the installation of 150 mm bottom course and 50 mm of top course with a 25% TLA modified A.C. 20 binder. The Marshall stability tested at 1,225 kg. Transverse grooves (6 mm x 6 mm @ 12.5 mm o.c.) were cut in the finished pavement surface for anti-hydroplaning purposes.

The Trinidad asphalt system corrected the pavement problems previously experienced and the transverse pavement grooves have remained straight, indicating the system also corrected the rutting and shoving problems. Overall, the structural maintenance costs for the runway pavement have decreased, compared to previous years. The runway surface is periodically tested for skid resistance and continues to maintain good surface characteristics. A Saab Friction Tester is used for the evaluation.

A new taxiway was constructed parallel to the runway a number of years later. The purpose of this taxiway was to assist in reducing aircraft delays at the airport and to increase the capacity of the runway, as well as provide more efficient access to the adjacent cargo area. The taxiway is 45 m wide and 2,010 m long. The surface course consisted of a TLA-blended asphalt similar to Runway 13-31 and last reports indicted that both the runway and taxiway pavements are performing well.

In the fall of 1994, the TLA-blended asphalt was used for the paving of the taxiway apron at the International Arrivals Building at JFK International Airport. This action was taken to correct pavement deformities in the apron pavement brought about by the heavy turning action of jet aircraft gear loads as they turned into gate positions for loading and unloading of passengers.

Trinidad Asphalt continues to be used at the three New York City airports whenever a pavement condition requires extraordinary materials.

6.3.4 Logan International Airport

In 1994, Trinidad Asphalt was used at Logan International Airport in Boston, Massachusetts. In this case, TLA was selected to correct a heavy rutting problem on a portion of a taxiway at the airport. The material has worked so well that the airport agency has made a contract for paving a complete taxiway at Logan with TLA in 1995.

7.0 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, TLA provides for reduced layer thickness, imparts improved structural performance and generates less maintenance intervention demand than pavements surfaced with straight-run bitumen mixes.

4. Road users, air and land transport, agencies and societies as a whole, enjoy life cycle savings when TLA is employed in overlay policies.

5. TLA overlays prove to be stronger and more durable than straight-run overlays on a life-cycle basis.

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