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II CONGRESO DE VIALIDAD Y TRANSITO

Ciudad de Encarnacion – Paraguay

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Polymer Modified Asphalt

OPTIMISED PAVEMENT DESIGN FOR BETTER ROADS

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Use of Modified Bituminous Binders & Value Engineering

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Key Projects – Recent

Hamburg Container handling yards pavements (Germany)
New Doha International Airport (Qatar)
Dubai International Airport (UAE)
Muscat International Airport (Oman)
Abu Dhabi International Airport (UAE)
Suweihan Airbase (UAE)
Al Udaid USAF Airbase (Qatar)
Sohar International Airport (Oman)
Jeddah International Airport (Saudi Arabia)
Emirates Highway - 210 kms (12 lane) (UAE)
Sheikh Zayed Highway - 90 kms (12 lane) (UAE)
Bid Bid Sur Highway -120 kms (dual lane) (Oman)
Thumrait – Salalah Highway - 75 kms (dual lane) (Oman)
Qatar Express Way upgrade Program – 890 kms (varying lane provision) (Qatar)

Muscat Ring Highway – 70 kms (8 lane) (Oman)

Jeddah – Mecca Highway – 92 kms (6 lane) (Saudi Arabia)

Mafraq – Gweifat Truck Express way - 110 kms (8 lane) UAE/Saudi Arabia (First concessionary road project in ME)

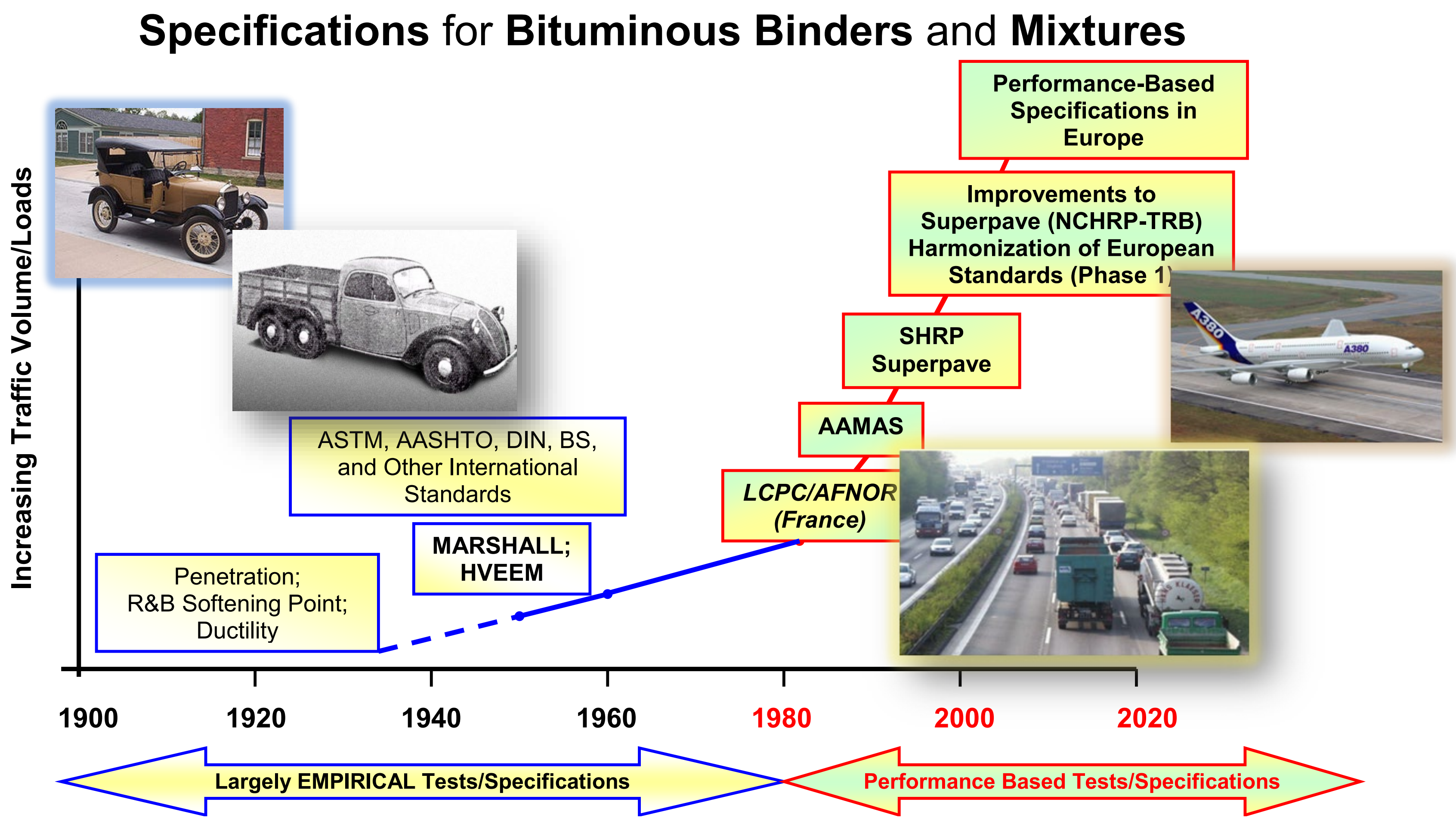
Dubai Dry dock Road system (UAE)

Khalifa Port Road System and container handling area pavements (UAE)

Hambantota International Airport (Sri Lanka)

Colombo – Hambantota Airport Highway 62 kms (6 lane) (Sri Lanka)

ASPHALT TECHNOLOGY HISTORY



Rutting

- Problem identified since mid 1980s' in the US and 1970s' in Europe
- Heavy loads and high tyre pressures in trucks; stiffer tyre side walls
- Need bituminous binders with higher stiffness and adequate elasticity at high service temperatures, higher traffic densities and loads

Rutting

Rutting

Rutting

Fatigue Cracking

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- Increased truck traffic
- Repeated loads cause fatigue cracking
- Need bituminous binders with lower stiffness and higher elasticity at intermediate service temperatures (after ageing)

Fatigue Cracking

Fatigue Cracking

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Low Temperature Thermal Cracking

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- Occurs at low service temperatures
- Unmodified bitumen cannot cope with the range of extreme minimum and maximum pavement temperatures
- Need bituminous binders with lower stiffness at low temperatures and higher stiffness at high temperatures

Low Temperature Thermal Cracking

Advantages of Modified Binders

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- Stiffens the binder and the asphalt mix at high temperatures (minimize rutting)
- Softens the binder at low service temperatures (minimize low temperature cracking)
- Improve fatigue resistance especially where high strains are imposed on the bituminous mix

Advantages of Modified Binders

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- Improves aggregate-bitumen bonding (reduce stripping potential)
- Improve bituminous pavement durability (increase pavement service life and reduce life-cycle costs)
- Provide thicker binder films on aggregate in special mixes (stone matrix asphalt and open graded asphalt friction courses)

Development and Use of Modified Binders in Europe

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- Europeans ahead of the US in the 1970s'

- Modification became attractive because cost of bitumen had increased

- Highway authorities expect innovations in bituminous pavement technology from contractors who warrant the projects – concessions toll model

- Higher quality material preferred to reduce life-cycle costs

Development and Use of Modified Binders in Europe

- Beside improving the performance of hot mix asphalt, modified binders highly successful in:
  - Durable surface dressing
  - Thin HMA wearing course
  - Open graded friction course (porous asphalt)
  - Durable slurry seals (micro surfacing)
  - Asphalt wearing course on bridge decks

North America Experience

- Rutting problem experienced in 1980s
- No unified guide specifications for modified binders from Europe
- Proliferation of different types of modified binders created confusion
- AASHTO Task Force 31 developed different specifications for different PMBs (elastomers and plastomers) in 1992

North America Experience

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- Separate specification was available for CRMB (called Asphalt-Rubber in the US)
- Specifications based on empirical tests such as penetration, softening point and ductility similar to Europe

North America Experience

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- Performance based bituminous binder specification developed in SHRP Project (1987-1992) to characterize binder from low to intermediate to high service temperatures
- Dynamic Shear Rheometer (DSR) used to measure visco-elastic properties of PG binders such as G* and phase angle delta

Superpave Asphalt Binder Specification Grades

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The grading system is based on climate

PG 64 - 22

Performance Grade

Average 7-day max pavement temperature

Min pavement temperature

North America Experience

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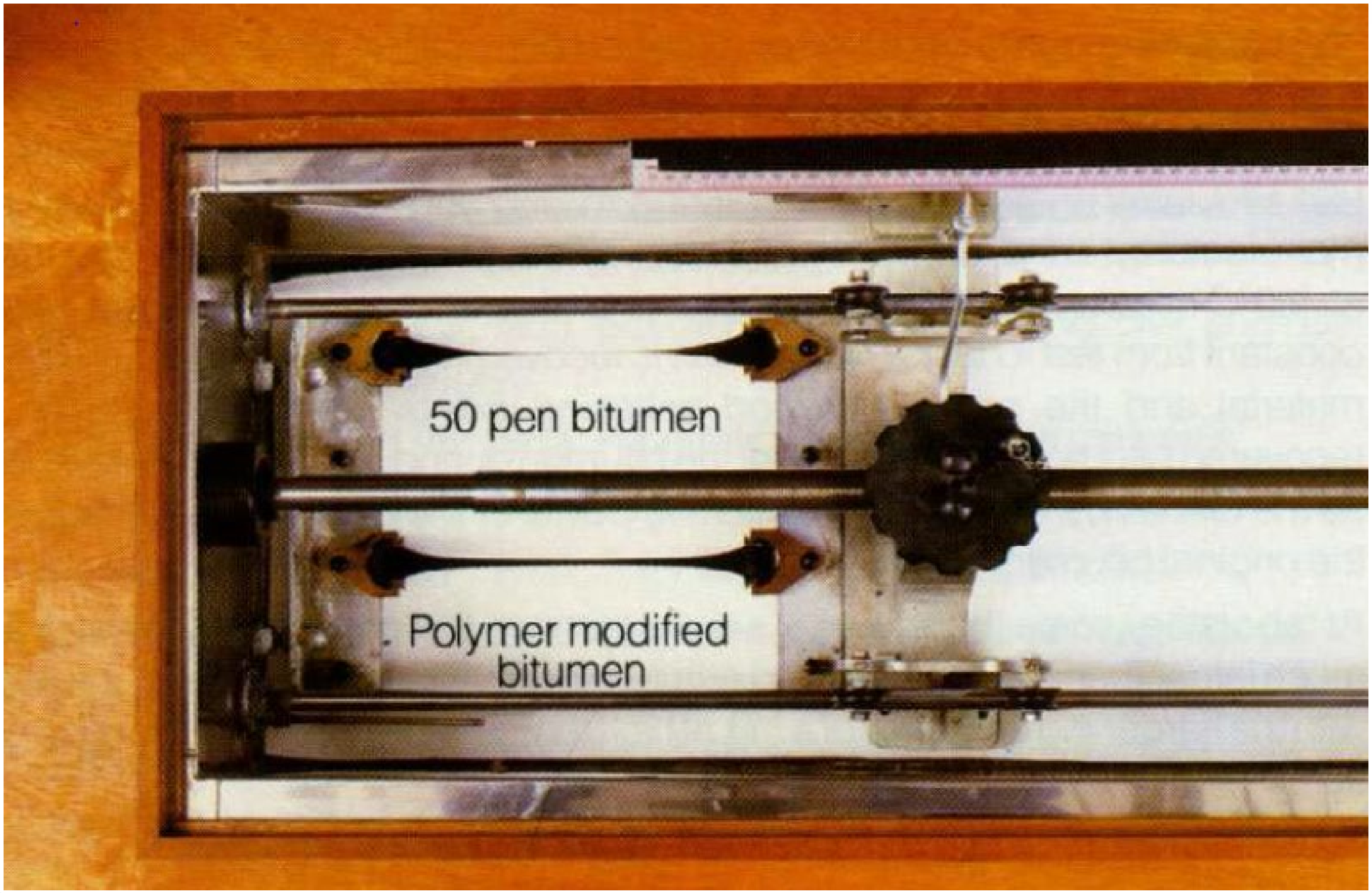
- PG Plus specifications adopted by some states to ensure adequate amount of elastomer in the PMB
- Phase angle of 75 degrees or less
- Elastic recovery using ductility machine

Superpave Asphalt Binder

Superpave Asphalt Binder



Polymers

- "Polymer" simply refers to a very large molecule made by chemically reacting many (poly) smaller molecules (monomers)
- Long chains or clusters
- Sequence and chemical structure of the monomers determines the physical properties of a polymer
- Random or block copolymers are made from different types of monomers

General Categories of Modified Binders

- Elastomers
- Plastomers

Elastomers

- Can be stretched like a rubber band and recover the shape when the force is released
- Adds a little strength to bitumen, gets stronger when stretched (strained)
- Examples: SBS (styrene-butadiene-styrene) and ETP (ethylene tar polymer)

Elastomers

Plastomers

- Form a tough, rigid network within the bitumen
- Give high initial strength to bitumen to resist heavy loads
- May crack at high strains
- Examples: EVA (ethylene vinyl acetate) and polyethylene

Compatibility of Polymers with Bitumen

- Paving bitumen has complex chemical composition, colloidal structure, physical and chemical properties
- Polymers although distinct are also complex systems
- Bitumen-Polymer relationship is very complex

Polymer mixed with Hot Bitumen (Optimisation Stage I)

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- Mix is heterogeneous because polymer and bitumen are not compatible initially
- Both tend to separate from each other
- Initial mix does not behave like a typical bitumen

Polymer mixed with Hot Bitumen (Optimisation Stage II)

- Mix is totally homogeneous even at molecular level because polymer and bitumen are compatible

- Resulting binder is stable

- Improvement in service quality of binder is slight, only its viscosity increases

Polymer mixed with Hot Bitumen (Optimisation Stage III)

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- Mix is micro heterogeneous and consists of two distinct finely interlocked phases
- Compatible polymer absorbs some of the oily fractions of bitumen and swells to form a polymer phase distinct from residual bitumen
- Resulting binder has genuinely modified properties

Crumb Rubber Modified Bitumen (CRMB)

- When highway engineers in the US were trying to understand complex PMBs
- Came another far more complex and least understood modified binder: CRMB
- Rubber from discarded tyres is ground to crumb and then added to bitumen
- Called Asphalt-Rubber (AR) in the US

Crumb Rubber Modified Bitumen (CRMB)

Properties of CRMB

- Properties of CRMB depend on:
  - Bitumen crude source and method of refining
  - Source of crumb rubber (truck/car tyres; tread; sidewalls)
  - Grinding of rubber (ambient or cryogenically cooled)
  - Amount and size of crumb rubber

Use of CRMB in the US

- Use of CRMB not significant until 1991
- Mixed pavement performance results
- US Congress mandated its use in all 50 states in 1991 (strong rubber/environmental lobby)
- US FHWA Training Program in Qc/QA of CRMB in 1992
- Mandate ended in 1995

CRMB Quality Control Requirements

- Crumb rubber tends to separate and settle down in bitumen (needs mechanical agitation to keep in suspension)

- Crumb rubber prone to degradation (de-vulcanization / de-polymerization) when kept hot for extended period of time (must be used within 6-8 hours)

Value Engineering Design Concept

- Highly modified HiMA mixes (7.5% SBS) may be used in construction of pavements with lower layer thicknesses than those using standard modified mixes (3.0% SBS)

- Without a decrease in the resistance to fatigue and rutting and other performance characteristics

Value Engineering Example

Type of Layer	Type of Material	Standard SBS Thickness (cm)	HiMA Thickness (cm)
Asphalt pavement layer	Asphalt Concrete Standard SBS: PG 76S-22 HiMA: PG 76E-22	12.0	7.0
Cement stabilized based	Stabilized with Cement Portland	30.0	25.0
Non-stabilized layer	A-2-4	30.0	30.0
Soil	A-4	Semi-infinite	Semi-infinite

Value Engineering Design Approach

- Use Darwin-ME for pavement design
  - Allows use of laboratory to determine damage model coefficients (Fatigue and rutting)
  - Performance Calibrated
  - Quickly evaluate effect of thickness reduction on fatigue and rutting performance

- Determine fatigue and rutting coefficients in laboratory with std. lab tests
  - For both – HiMA and standard mixes

Value Engineering Design Assumptions

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- Darwin-ME may be used to predict performance of standard and HiMA mixes using laboratory determined coefficients
  - K factors (global) rather than ß factors (local)

- Predicted performance is conservative

- Performance may be further calibrated using field performance data
  - ß factors

What is HiMA?

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- HiMA technology uses modified binders with high content of SBS polymer (>7%) to produce hot mix asphalt.
- High polymer content gives a phase inversion, so the binder acts more like asphalt-modified rubber than rubber-modified asphalt with much higher toughness and resilience
- Increased toughness allows for the construction of pavements with lower thickness than traditionally modified binders without a decrease in the resistance to fatigue and deformation.

Value Engineering Design Approach

- Determine optimum layer thickness of the wearing course and base layers for high modulus mixes made using HiMA
  - Use Darwin-ME for pavement design method
    - Mechanistic-empirical design method
    - Requires mix modulus master curve
    - Requires fatigue model coefficients – kf factors for HiMA
    - Requires rutting model coefficients – kr factors for HiMA
- Compare HiMA layer thicknesses to those determined for standard SBS
  - Determine cost savings for a given life expectancy

Darwin-ME Data Needs…

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- Pavement Design Data for Darwin-ME
- Materials Data
  - Dynamic Modulus of mixes – mix design volumetrics etc.
  - Binder G* and phase angle
  - Fatigue coefficients – kf factors
    - endurance limit
  - Rutting coefficients – kr factors
- Unbound layers and subgrade soil data
- Traffic data
- Climate data
- Performance criteria

Mix and Binder Data

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- Dynamic Modulus – AMPT Testing on Mixes
  - Test Temperatures: 10, 40, 68, 100 and 130ºF
  - Test Frequencies: 0.1, 1.0, 5.0 and 10Hz
- Binder G* and phase angle, same temps at 10 rad/s
  - DSR testing on Binders
- Fatigue data at one temperature 20C and 4 strain levels
  - AMPT Pull-Pull test S-VECD approach (Dr. R. Kim)
- Rutting data
  - AMPT Flow number data at 3 temperatures
  - NCHRP 9-30A protocol – Mr. Harold von Quintus

Conventional SBS Modified Asphalt PG 76-22

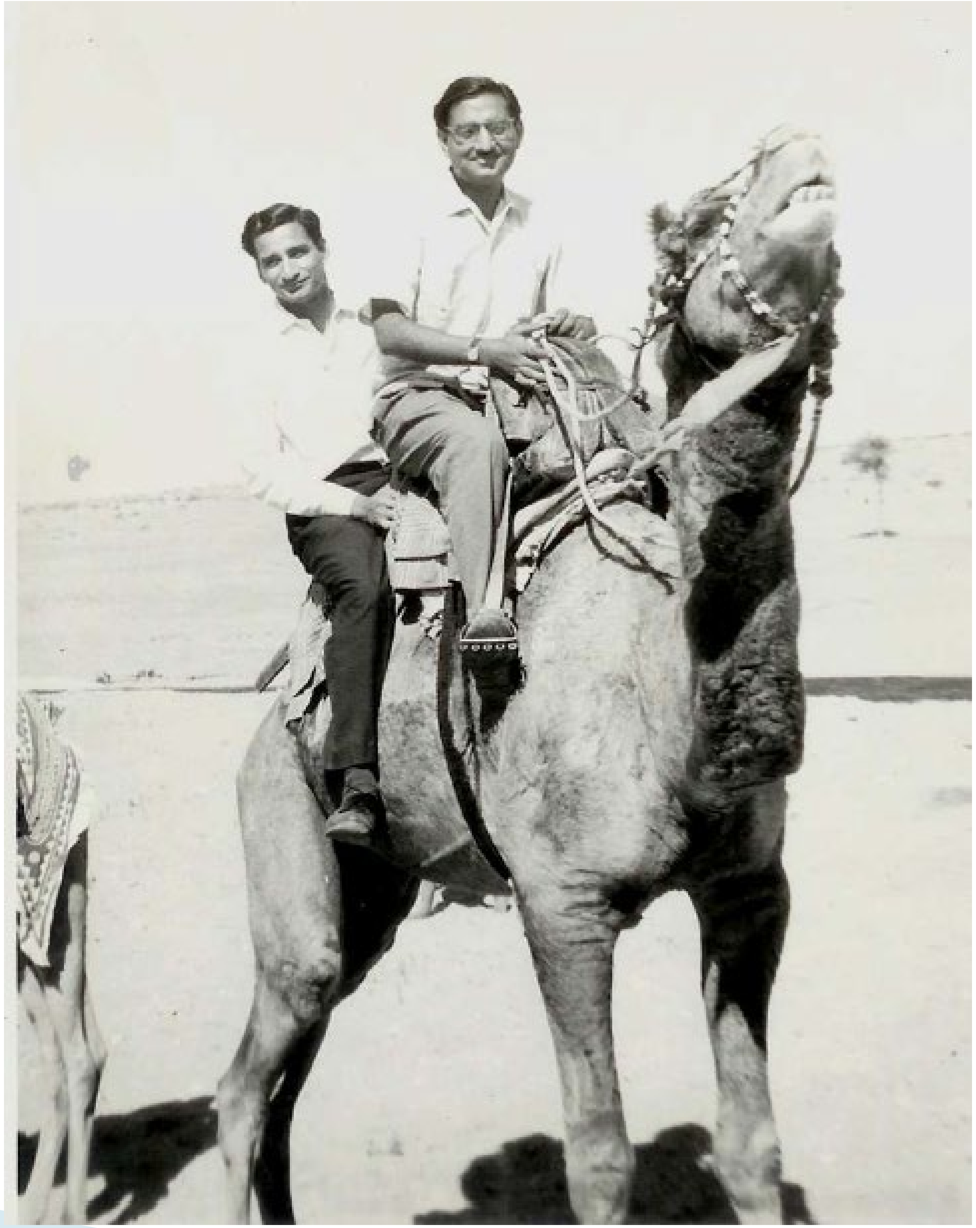
- Tests completed in small samples containing typical Asphalt binder, Penetration Grade 85/100 and PG: PG 58-28, Pen 60/70
- Asphalt binder modified with standard SBS polymer (3.5%)
- Properties and PG values:
  - Softening point: 60ºC
  - Elastic recovery: 5% at 25ºC after RTFO
  - Conventional or standard PG: PG 76-22
  - PG with MSCR PG: PG 76-22S (J_{nr}>4kPa^{-1})

Highly Modified Asphalt Binder (HiMA) PG76E-22

- Asphalt binder: Typical Refinery
  - Penetration grades: 85/100, PG 58-28 (PG 62.33-29.88) and PEN 60/70
- Polymer type: Reactive radial SBS
  - Polymer content: 7.5%
- HiMA – Highly Modified PMA
  - Softening point, SP: 85ºC
  - Elastic recovery: 95% at 25ºC after the RTFO
  - Conventional/Standard PG: PG 94-22
  - PG with MSCR: PG76-22E (J_{nr} = 0.1 kPar^{-1})
- The HiMA binder met the temperature and loading requirements of the project.

Summary Findings

- Highly Modified Binders maybe used to reduce Layer Thickness
- Darwin-ME calibration factors maybe determined successfully in the Laboratory
  - AMPT Pull-Pull test and S/VECD for Fatigue Coefficients
  - NCHRP 9-30A for Rutting Coefficients



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Muchas Gracias!
Espero verlos muy pronto para un enfoque mas tecnico!