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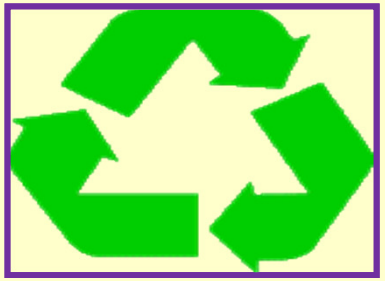

# The Use of Polyurethane Foam and Crumb Rubber For Bitumen Modifications

by

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- **Introduction**
- In recent years, one of the primary and global environmental problems is the landfill disposal of Polymer waste material (PWM).
- About 1.5 billion waste tires are generated each year on the world scale.
- Management of PWM in the world primarily has three ways to deal with; landfill, burning and recycling.

+

→ **Negative Environmental impact**

**Cont. Introduction**

- In the last few years, production of polyurethane foams (PUF) has been rapidly increased worldwide ? ----→ PUF has a very wide applications.

**17%** of shoes content = PUF → Light in wt + lasts longer + comfy + healthy

= Rising in shoes productions in last years.

- Receiving increased attention worldwide as a result of rapidly rising amounts and increasingly tight legislation on its treatment and disposal.
- In **2011**, China alone produced about **7.5** million tons of PU.

| Main Disadvantages of "PUF" Waste |
| --- |
| Stockpiling takes up a lot of area (storage is a problem) |
| Landfill disposal and pollution problems |
| Belong to white pollution and affecting living environment = toxic isocyanate is a component |

➡ The solution is RECYCLING

# Cont. Introduction



**Most Failure Modes of Pavement Asphalt**

- Many countries around the world face a problem with deterioration of their road structures represented in:

(I) Rutting failure = in roads constructed at regions of high temperature such as in north of Africa countries, where strain accumulates in the pavement and permanent deformation takes place in the form of ruts on the surface of asphalt pavement (right Photo).

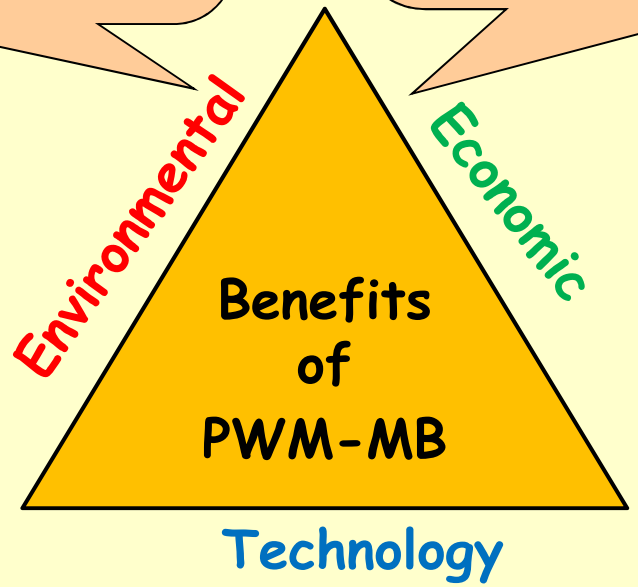
(II) Fatigue cracking (left photo).

- **Aim of the Study:** Modification of the bitumen binder by blending with PUF and crumb rubber (CR) wastes for use in road pavement application

## Why Polymer Waste Materials Modified Bitumen (PWM-MB)?

* Emissions reduction, Reduced waste quantities, Reduce traffic noise, Clean environment = Save human health

*Reducing structural road thickness, Reducing cost of pavements,
* Saving in energy & natural resources,
* Up to 50% thickness reduction by using PWM is possible




* Improvement of basic and rheological properties of modified asphalt binders (MA)

## ➢ Materials Used in This Study

I. Modifiers

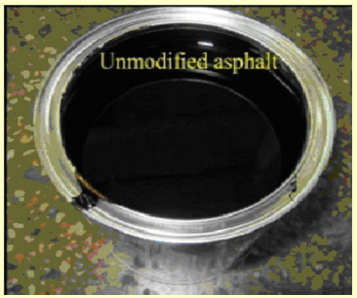
➢ PU can be simply obtained & collected from:

* Production processes
* Consumed shoes.

➢ Cut into small pieces (0.5-1.0) cm

\+

II. Matrix




* 70/100 Pentration Grade
* Russian crude oil company
* Suplied by Lotos comp. (Poland)

* Scrap tires with 0.4 mm particle size
* Supplied by Orzel company in Poland

# Experimental Design Procedure Used in This Study

**Step I**

Materials Selection, Bitumen & Modifiers

Selection of content & modifier types levels

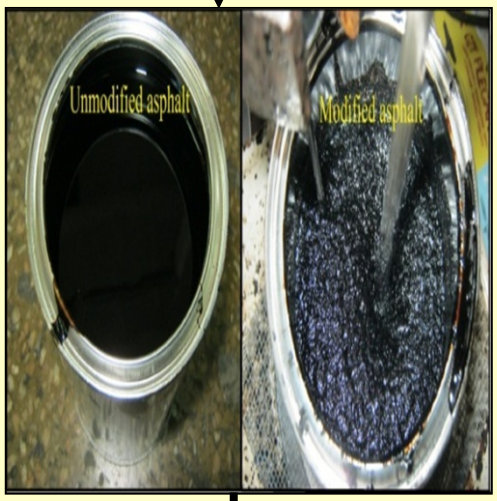
| Factor | Levels | | |
|---|---|---|---|
| | -1 | 0 | 1 |
| Modifier type | CR | PUF | CR : PUF |
| Modifier content | 5 | 10 | 15 |
| Weight fraction | 25:75 | 50:50 | 75:25 |

**End Step I.**

**Step II**

**Bitumen Polymer Blend Binary & Ternary**

**Modification conditions Has been Fixed**




**Modified samples**

**Step III**

**Sampling & testing**

**Basic properties (BP)**

**BP Improved**

**If Yes** **If Not**

**Include this modifiers content in Phase II**

**Exclude this modifiers content in Phase II**

**Selection of optimum modifiers content level** — **15%**

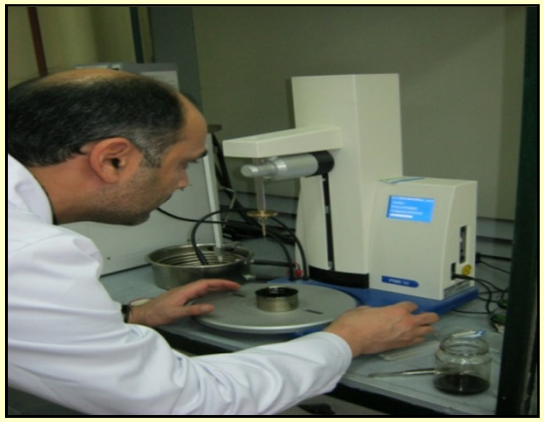
**Rheology test**

**Phase I**

**Phase II**

# Laboratory Measurements

Viscometer test

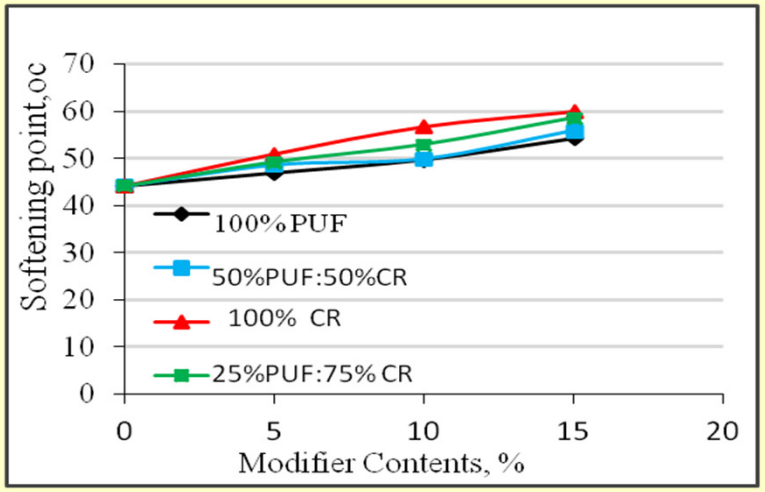


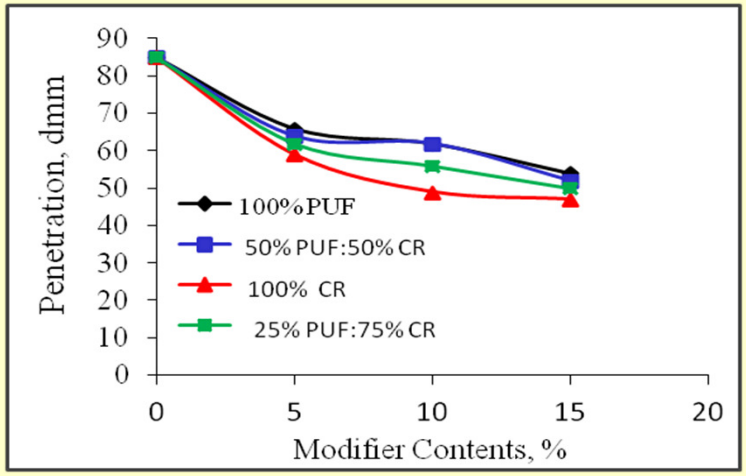
Penetration test

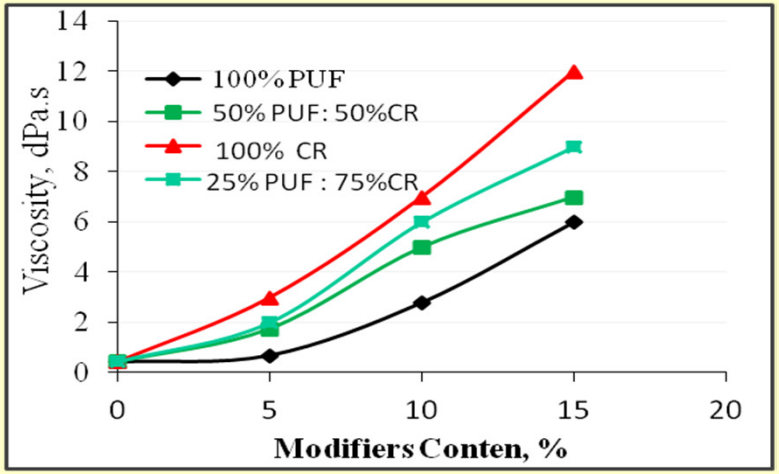
Ring & ball softening point

Rheometer device

## ➢ Results and Discussion: (Basic Physical Properties)

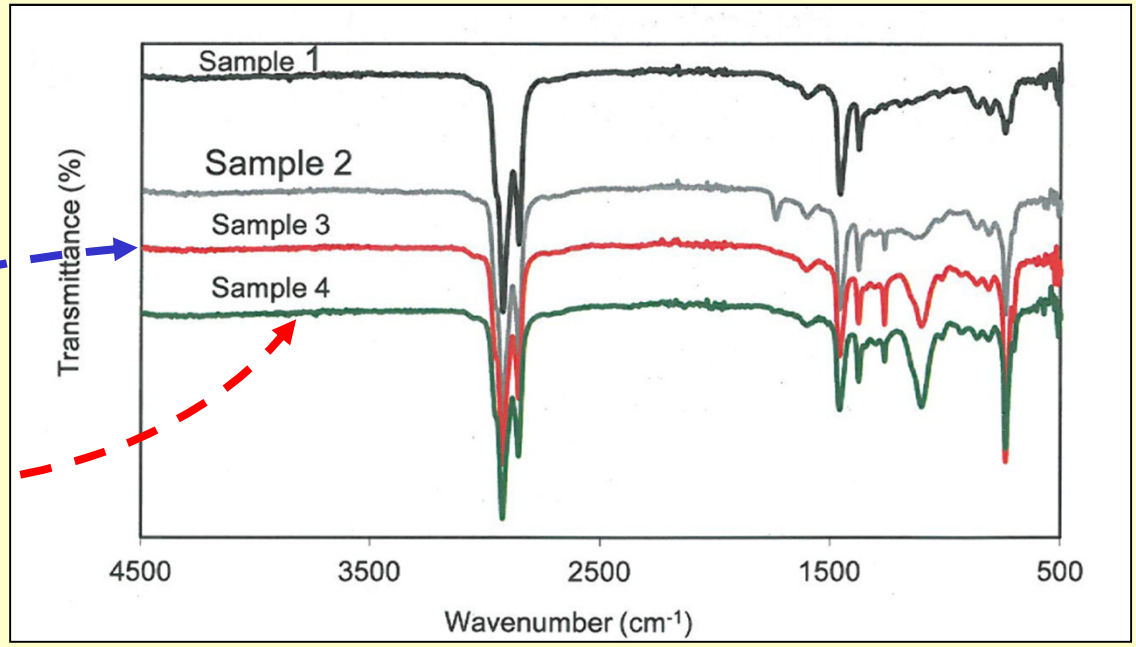


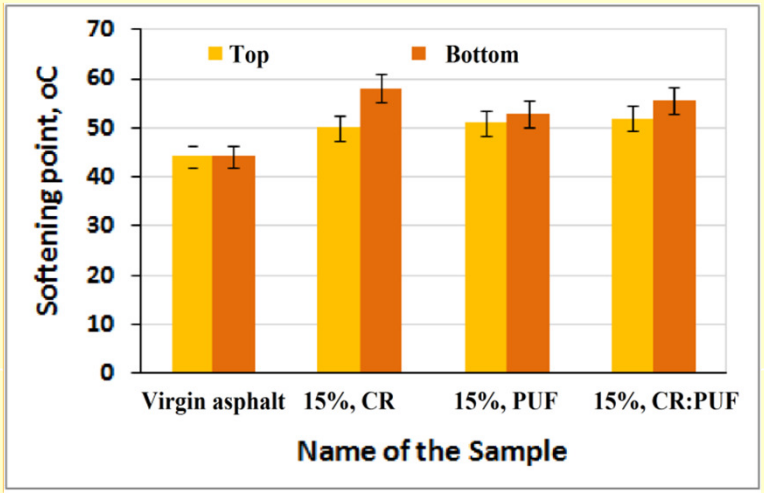



- **Cont. Results and Discussions (Basic Physical Properties).**

- **Storage Stability**

## ➢ Cont. Results and Discussion

Main rheological parameter

Total resistance of the binder to deformation when repeatedly sheared

Phase angle (δ)

Complex modulus (G*)

Storage modulus (G' ) Elastic component

Loss modulus (G") *Viscous component*

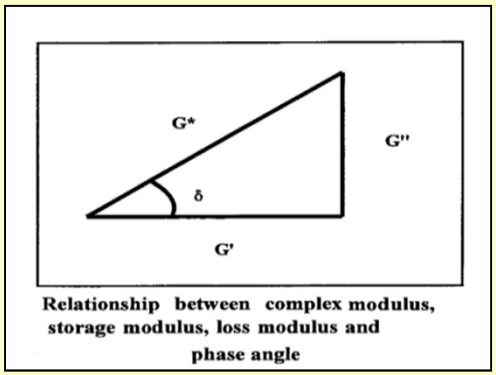
### Mathematical Relationship

$|G^*| = \sqrt{(G')^2 + (G'')^2}$ . . . . (1)

Temperature sensitivity = $(G^*)_{30\,^\circ C} / (G^*)_{60\,^\circ C}$ . . (2)

Tan (δ) = G"/ G' . . . . . (3)

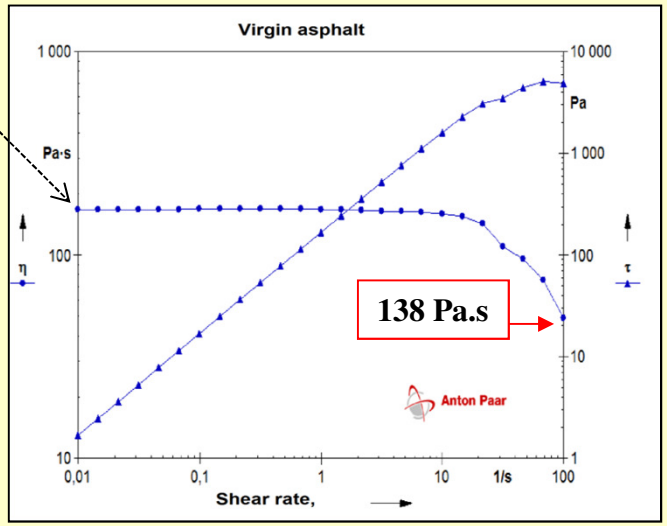
Rutting resistance parameter = (G*/sin δ). . . (4)



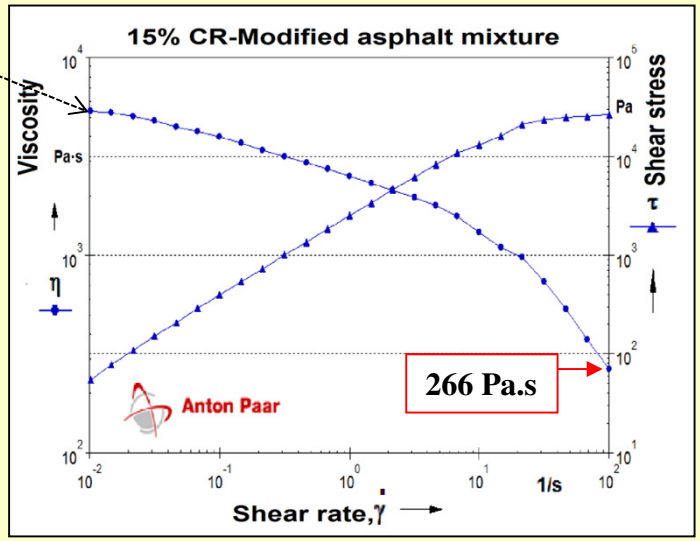
Relationship between complex modulus, storage modulus, loss modulus and phase angle

# ➢ Cont. Rheological Properties: Viscous Flow at 60 °C

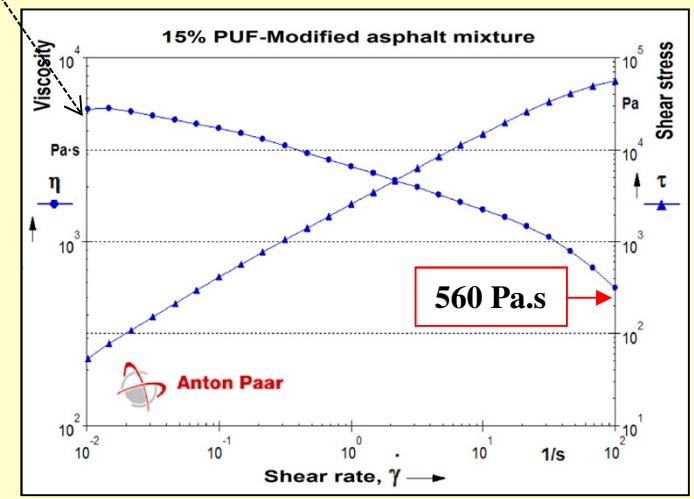
325 Pa.s



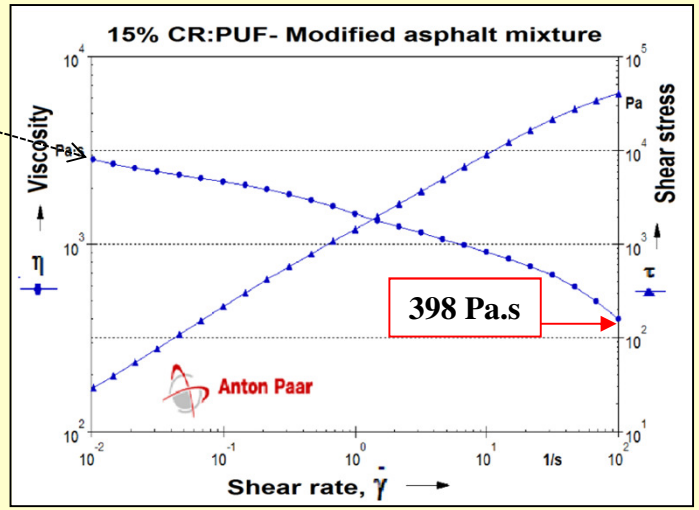

5340 Pa.s



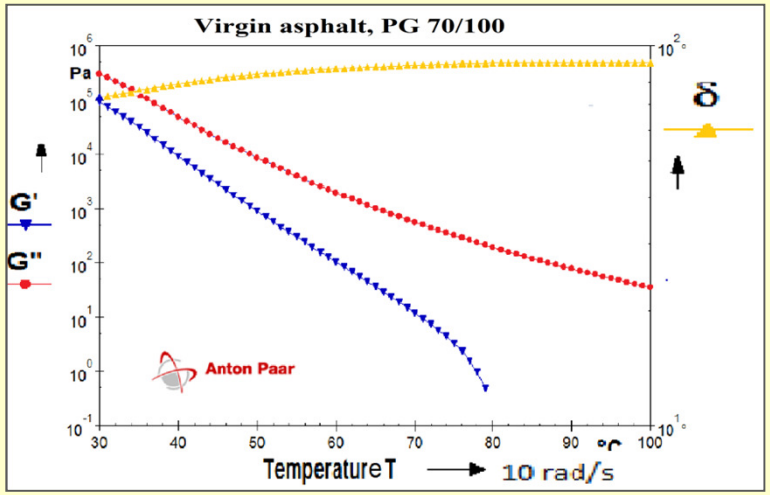

5230 Pa.s

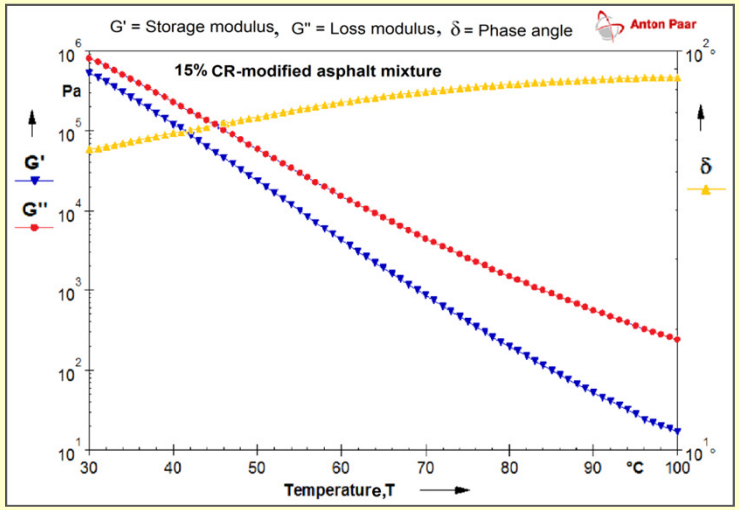


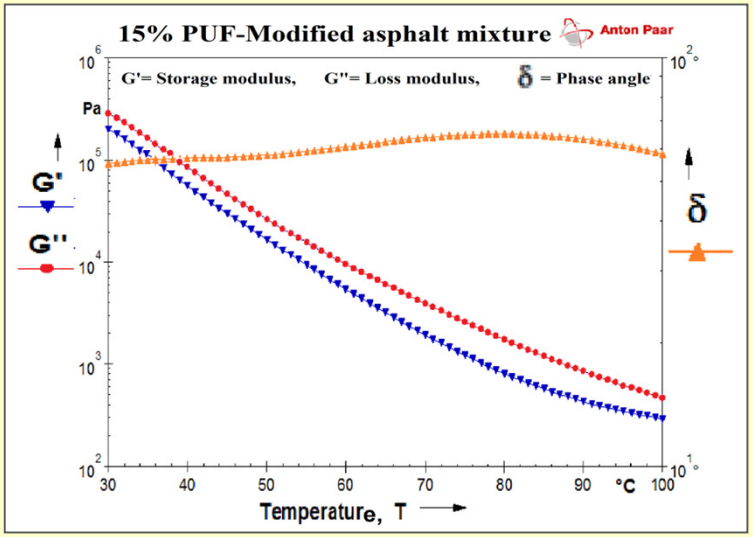

2820 Pa.s

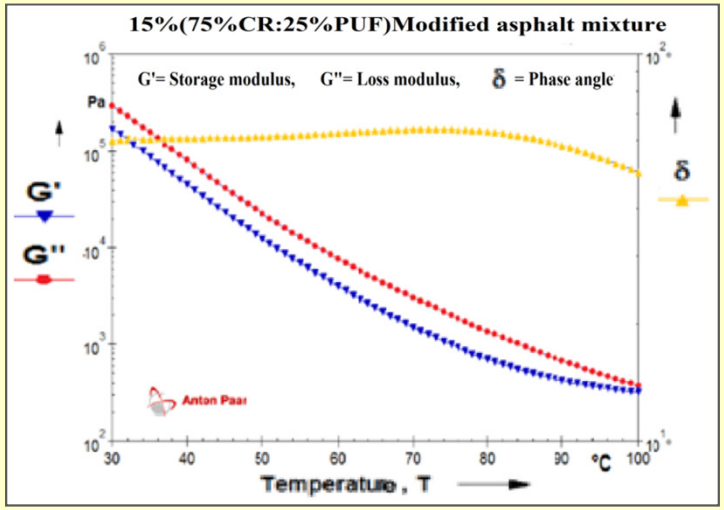


## ➢ Cont. Rheological properties: Temperature Sweep at 10 rad/s



## ➢ Cont. Rheological properties ( Temperature Sensitivity )

| Component | 30 °C Modulus (Pa) (10 rad $s^{-1}$) | | | 60 °C Modulus (Pa) (10 rad $s^{-1}$) | | | T-S $G^*_{30}$ / $G^*_{60}$ | % Reduction of T-S |
|---|---|---|---|---|---|---|---|---|
| | G′ | G″ | G* | G′ | G″ | G* | | |
| Virgin Asphalt | 70300 | 239000 | 249124 | 200 | 1800 | 1803 | 138 | --- |
| 15%, CR | 525000 | 798000 | 952262 | 4290 | 15300 | 15890 | 59 | 57% |
| 15%, PUF | 198000 | 283000 | 345092 | 5400 | 9550 | 10970 | 31 | 77% |
| 15%, CR:PUF 75%:25% | 167000 | 286000 | 331052 | 3990 | 7640 | 8619 | 38 | 72% |

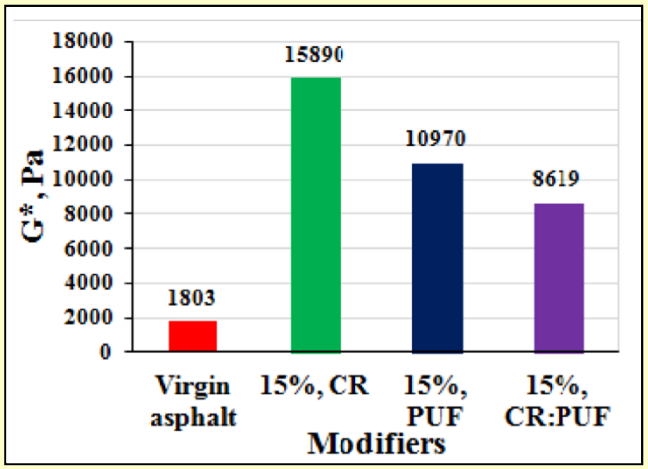
**From the above table it can be conclude,**

1- At low Temp. → *G′ = (2.4 - 7) times, G″=(1.2-3)* → ***Cracking resistance improvement***

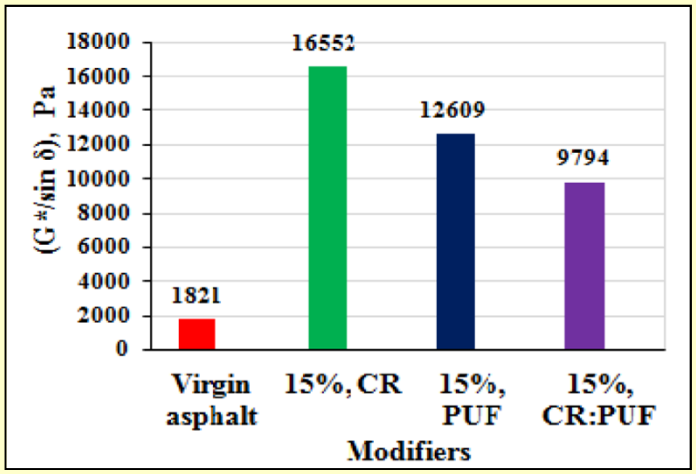
*2-* At high Temp. → *G′ = (20 - 27) times, G″ = (4-8) times* -→ ***Rutting resistance increasing***

## ➢ Rheological properties: Rheology parameter at 60 °C

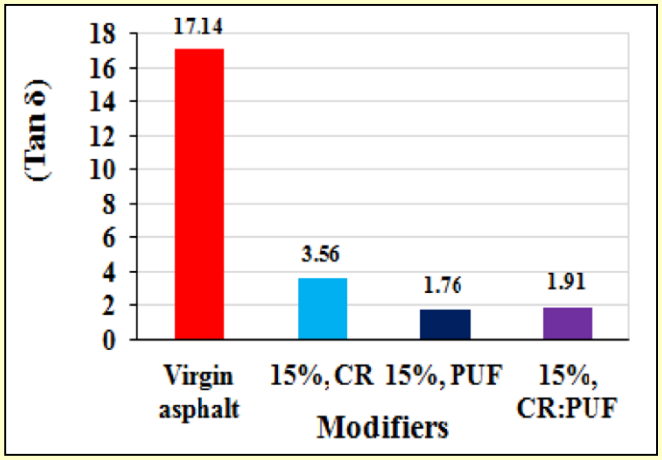
Increased by ( 5-9 ) times



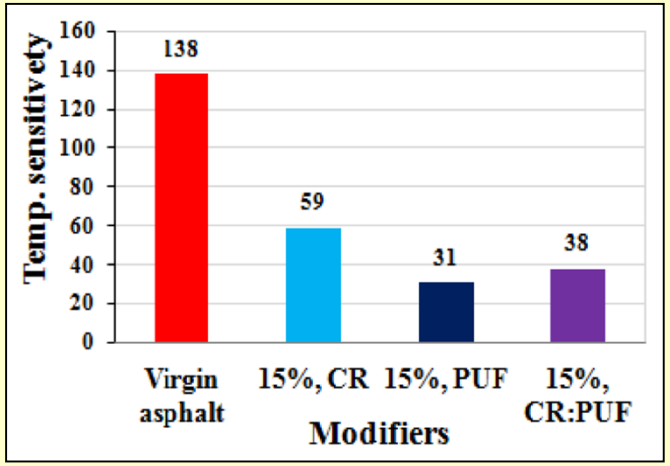

Increased by ( 5-9 ) times




Reduction by ( 5-10 ) times




Reduction by ( 2-5 ) times



## Main Advantages of PUF used as feedstock for bitumen-polymer blends

Completely melting into bitumen matrix

**(Homogenous products)**

Good compatibility with the bitumen

**(Storage stability improvement)**

Using a lot of PUF waste(cheap) with a small amount of virgin polymer (high expensive) is possible

**( Economically)**

High content of PUF in the mixture with bitumen is possible

**(Minimizing of landfill disposal)**

High elasticity by increasing (G') of modified bitumen

**(High quality of bitumen)**

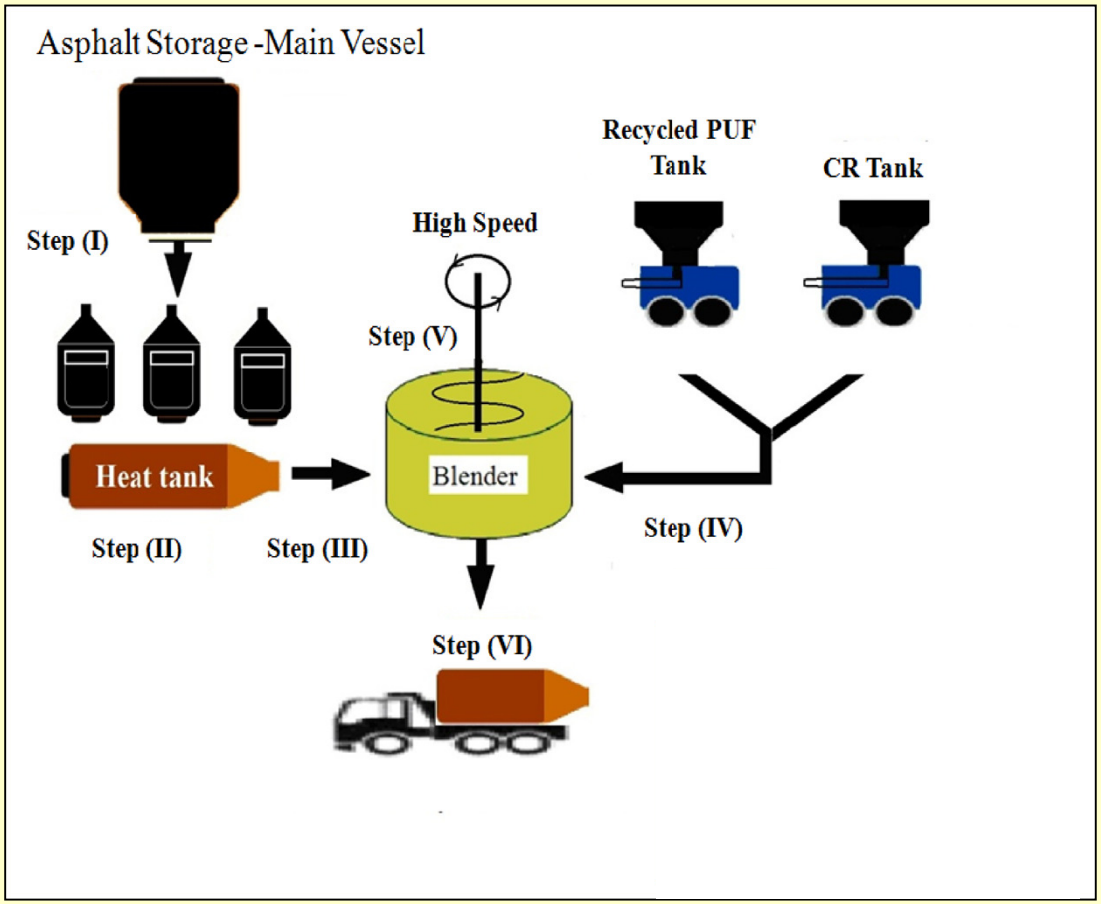
Rutting resistance parameter ($G^*/\sin\delta$) improvement

**(Improvement of permanent deformation)**

Supported by basic physical properties

Supported by rheological properties

# Modification Process at the Plant




Step(I): Bitumen pumped to small tanks

Step (II): Bitumen heating up to melt point

Step (III): Bitumen pumped to the modification process,

Step (VI): Addition of additives

Step (V): Blending system operation,

Step (VI): Product ready for road pavement

## ❑ Conclusion:

- CR and PUF wastes without treatment can be used for bitumen modification.

- All rheological parameters (G', G'', G* & G*/sinδ) of modified bitumen mixture were improved compared to the virgin bitumen mixture.

- An increase in G* and decrease in (δ) indicates high elastic behaviour of the bitumen binder -----→ (**decreases the permanent deformation**).

- Improve the service life of road pavement by increasing the (G*/sin δ), and SPT, and reduction of temperature sensitivity and penetration values.

- Temperature sensitivity was decreased by 57%, 77%, and 72% for (15%CR), (15%PUF), 15%(75%CR:25%PUF) respectively.

- Viscous flow results showed that, viscosity has been increased by (8-16) times at low shear rate, and by (2- 4) times at high shear rate dependence on the modifier's type. While PUF-Modified-Bitumen shows the highest viscosity at high shear rate.
- As a result, and from an environmental and economic point of view, the use of both CR and PUF instead of virgin polymer modifiers is possible and preferable recycling method for these wastes, resulting in cost savings, lower energy consumption and lower environmental pollution.

# Thank you

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Polymer Modified Bitumen

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Performance