Bituminous binder types

- Conventional bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions

Conventional bitumen

- Manufactured either by:
  - straight-run distillation or
  - by blending two base components - one hard; the other soft
- Conventional bitumen used as a base bitumen for the manufacture of
  - cutback bitumen
  - modified binders
  - bitumen emulsions.

Bituminous binder types

- Conventional bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions

Cutback bitumen

- Blend of conventional bitumen and petroleum solvents
- Solvents reduce viscosity - ease of handling
- Solvent type - determines rate of “set up” or cure
  - A rapid-curing (RC) solvent will evaporate quicker than a medium-curing (MC) solvent.
  - The viscosity of the cutback bitumen is determined by the proportion of solvent added.
- When solvent has evaporated, the binder reverts to the original penetration grade.
- An advantage of cutback bitumens - applied at lower temperatures conventional bitumen
- A disadvantage - consume non-renewable energy resources
- In SA only medium curing cutbacks are specified

Bituminous binder types

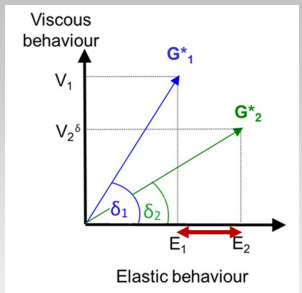
- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions

Modified bitumen

- Modification of ***rheological properties*** of conventional by the introduction of:
  - Elastomers
  - Plastomers
  - Crumb rubber
  - Hydrocarbons
- May prove cost-effective through improved performance and extended life

Improved performance

- Achieved in three ways:
  - Increase in elastic component of G* (improved durability)
  - Stiffening of the bitumen
    - increase the flexural stiffness and load distribution of layers
    - Reduced susceptibility of viscosity to temperature changes.



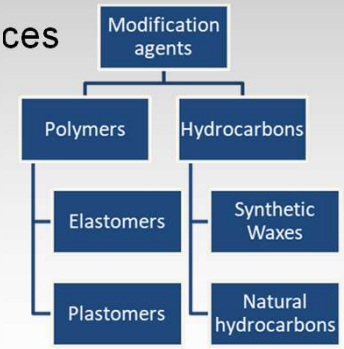
Typical situations

- High stress situations
  - heavy traffic
  - low speeds (steep slopes, intersections and curves)
- Prevailing temperatures
  - high ambient temperatures for long periods
  - large daily/seasonal temperature fluctuations
- Slow down crack propagation
- Resistant to fuel spillages
- Remote areas for improved durability
- Upper layers of highly flexible (and cracked) pavements;
- Layers requiring a high binder film thickness

Modification agents

Modification is achieved by addition of:

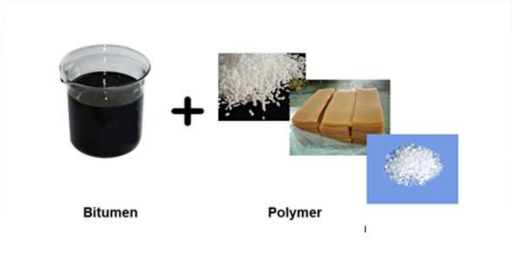
- Polymers
- Hydrocarbon substances



Polymers

Two basic classes:

- ***Elastomers*** – improve the strength and elastic properties (including bitumen-rubber)
- ***Plastomers*** – increase the viscosity of the bitumen



Elastomers

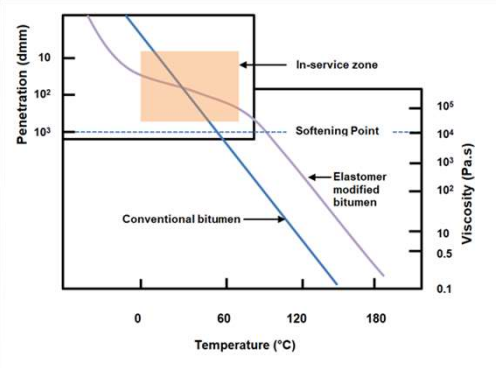
In SA 4 types of elastomers in general use:

- Styrene-butadiene-rubber (SBR) latex
- Styrene-butadiene-styrene (SBS)
- Reactive Elastomeric Terpolymer (RET)
- Rubber crumb

(Although not classified as a polymer, the behaviour of bitumen modified with crumb rubber is similar to one modified with an elastomer)

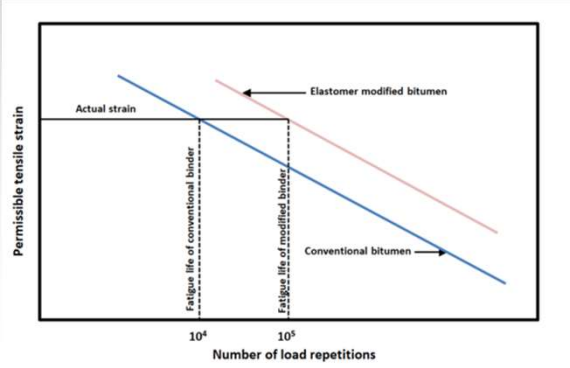
Effect of elastomers

- At elevated temperatures (50 - 60°C) significantly higher viscosity than conventional bitumen
  - Increased stiffness
  - higher resistance to permanent deformation
- At lower temperatures remains more flexible
  - less prone to brittleness
  - Increased flexibility & resistance to fatigue



Effect of elastomers / cont. ..

- Fatigue life of bitumen can be increased by order of magnitude.
- Improved performance where high tensile strains are likely to occur in asphalt layers.



Styrene-butadiene-rubber (SBR) latex

- Available as an anionic or cationic latex
- Facilitates blending with ***bitumen emulsions***
- Can be used to modify hot bitumen (after removing the water phase)
- Used extensively as cold applied modified bitumen emulsion (chip seals & microsurfacing)
- SBR modified binders exhibit elastic properties – ideal for resealing lightly cracked roads

Styrene-butadiene-styrene (SBS)

- Available as powder crumb or pellets
- Used for modifying hot bitumen
- High shear mixers for high polymer content
- Depending on concentration increases:
  - Resistance to viscous flow
  - Cohesive strength
  - Elasticity
  - Low temperature flexibility
- Used to enhance performance characteristics
  - chip seals
  - asphalt

RET (Reactive Elastomeric Terpolymer)

- Chemical bonds with some bitumen components
- Form a network around the asphaltenes
- Asphalt mixes made with RET modified bitumen:
  - improved rutting resistance
  - improved resistance to the adverse effects of fuel spillages.

RET / cont. …

- Three polymers (ENBAGMA).
  - Ethylene
    - being a hydrocarbon it is compatible with bitumen;
    - provides stiffness and viscosity to prevent rutting.
  - n-Butyl Acrylate
    - provides elastomeric properties to prevent cracking and rutting;
    - improves adhesion to aggregates.
  - Glycidyl Methacrylate
    - reacts with bitumen to provide a homogeneous, storage-stable modified binder.

Rubber crumb

- Ground tyre rubber or alternative rubber compounds (with specific, grading, morphology and composition)
- Blended with hot bitumen (20 - 25 %) at 170 – 210° C
- Contains extender oil, additives (and modifiers)
- During reaction time (1 hour) aromatic oils in the bitumen are absorbed by rubber particles causing it to swell
- Bitumen-rubber applied within 6 hours of blending
- Not a homogeneous binder – special equipment for pumping and spraying
- Bitumen-rubber is used extensively in spray seals, asphalt
- The carbon black in rubber - anti-oxidant, improves durability

Polymers

Two basic classes:

- ***Elastomers*** – improve the strength and elastic properties (including bitumen-rubber
- ***Plastomers*** – increase the viscosity (resistance to permanent deformation) of the bitumen

Plastomers

- One type of plastomer in general use is Ethylene-vinyl-acetate (EVA)

Ethylene-vinyl-acetate (EVA)

- Available in pellet form – easily dispersed in hot bitumen
- EVA modified bitumen - thermally stable at normal handling temperatures
- Properties of EVA which influence modified bitumen's end properties are:
  - Molecular mass
  - Vinyl-acetate content
- EVA modified bitumen is used in asphalt primarily to improve resistance to permanent deformation (e.g. rutting and shoving)

Modification agents

Modification is achieved by addition of:

- Polymers
- Hydrocarbon substances

Hydrocarbon substances

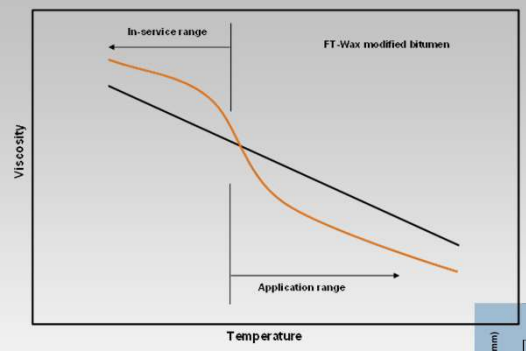
This category of modifier is ascribed to both:

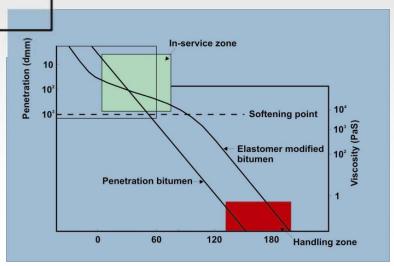
- Aliphatic synthetic wax
- Naturally occurring hydrocarbons

Aliphatic synthetic wax

- Long-chain hydrocarbons (high molecular mass) ***wax***
- Produced in Fischer-Tropsch (fuel) synthesis process
- Known as F-T wax
- F-T wax modification displays unique properties:
  - Lower viscosity than unmodified bitumen above 100° C
  - At lower (in-service temperatures) viscosity is higher than conventional bitumen
  - Allows asphalt to be mixed and placed at lower temperatures than those incorporating conventional binders

Aliphatic synthetic wax/cont.…





Hydrocarbon substances

This category of modifier is ascribed to both:

- Aliphatic synthetic wax
- Naturally occurring hydrocarbons

Natural hydrocarbons

- Natural deposits in:
  - North America – *Gilsonite*
  - South America – *Durasphalt*
- High asphaltene contents (>70%)
- Used to enhance the performance of asphalt:
  - increased stiffness (improved load spreading)
  - Reduced temp. susceptibility of viscosity
  - Improved resistance to permanent deformation

Summary of modifiers

Modifier type		Varieties
Polymers	Elastomers	Styrene-butadiene-styrene (SBS)
		Styrene-butadiene-rubber (SBR) latex
		Reactive Elastomeric Terpolymer (RET)
		Rubber Crumb
	Plastomers	Ethylene-vinyl-acetate (EVA)
Hydrocarbon substances	Aliphatic synthetic wax	Fischer-Tropsch (FT) wax
	Natural occurring hydrocarbons	Gilsonite
		Durasphalt

Bitumen additives

- Not intended to modify or improve the rheological properties
- Improve performance characteristics to extend the service life of ***asphalt***, in particular.

Common types of additives

Additive type	General purpose	Examples
Extender	▪ Substitutes portion of bitumen to decrease the amount of bitumen and/or polymer required ▪ Improves the storage stability of SBS modified binders.	Sulphur
Fibre	▪ Improving the tensile strength and cohesion in asphalt; ▪ Allows higher binder content with reduced risk of drain-down in open-graded asphalt and SMA; ▪ Allows increased binder film thickness for improved durability	Rock wool Polypropylene Polyester Fibreglass Mineral Cellulose
Anti-oxidant	▪ Increases the durability of HMA by retarding oxidation	Carbon black
Anti-stripping agents	▪ Reduce stripping of binder from aggregate.	Amines Lime
Fuel resistance	▪ Improves the resistance of the HMA to fuel spillages.	FT Wax EVA RET

Classification of modified binders

- **TG1**: ***The use of modified bituminous binders in road construction*** presented:
  - Empirical (arbitrary) classification based on e.g.
    - Modifier type (**E**lastomer, **P**lastomer, **R**ubber, **H**ydrocarbon …)
    - Application
    - Concentration of modifier
- **SATS 3208: *Performance Grade (PG) specifications for bitumen in South Africa***
  - Differentiates between products based on ***performance characteristics***, rather than their components
  - ***Use is advocated on this course***

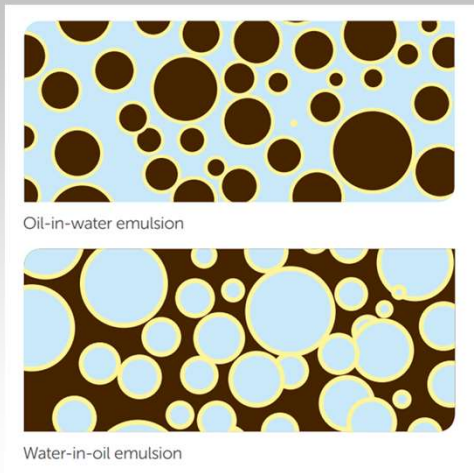
Bituminous binder types

- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions

Bitumen emulsion

- Two-phase systems - dispersion of **bitumen** globules in **water** containing an emulsifier
- Emulsification - means of ***reducing*** the ***viscosity*** of a binder to behave as fluid during application
- Two systems
  - Oil-in-water – water is continuous phase
  - Water-in-oil – bitumen continuous phase

Emulsion phases



conventional emulsion

Inverted emulsion

Description of emulsion types

- In *conventional* emulsions(O/W):
  - bitumen dispersed throughout the water
    - 0.1 to 50 μm in diameter
    - held in suspension by electrical charges
    - net bitumen content: 60% - 70%.
- In *inverted* emulsions, (W/O):
  - manufactured with cutback bitumen
  - water contents of < 20%.
  - more rarely used than the O/W types – mainly as prime coats.

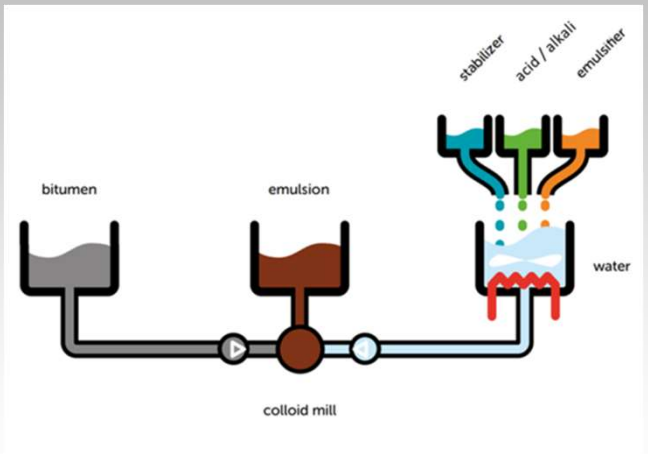
Benefits of using emulsions

- Considerably lower viscosity than bitumen
- Permitting used at lower temperature
  - reduced emissions
  - reduced energy consumption
  - less oxidation of the bitumen
  - reduction of hazards of heated bitumen.
- More environmentally friendly than cutback bitumen.

Manufacture of emulsions

- Continuous process
- High speed colloidal mill
  - High speed rotor – 1000 – 6000 rpm in a stator
  - Clearance between rotor an stator – 0.25 - 0.5μm
- Two phases (bitumen & chemically treated water) pass through mill
- In narrow space (rotor & stator) bitumen sheared into microscopic particles

Schematic of typical plant



Manufacture processes

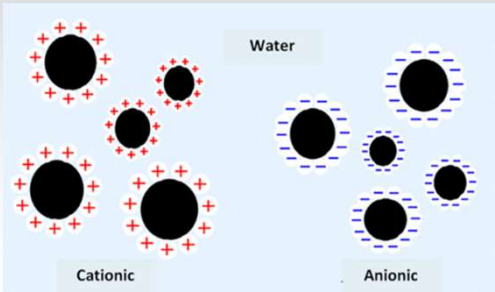
- Water phase prepared
  - Emulsifier chemicals dissolved in heated water
  - Mixture then:
    - saponified (with e.g. sodium hydroxide)
      or
    - acidified (with inorganic acids)
- Bitumen temperature is controlled
  - Ensure correct viscosity for emulsification
  - Prevent boiling of water phase on exit from mill
- Base bitumen normally soft grade
  - May be fluxed with small quantities of solvents (seasonally)

Emulsion classification

- Two parameters for classification
  - **Surface charge** of bitumen globules
  - Breaking (or setting **time**)

Surface charge

- ***Cationic*** **–** bitumen particles are positively charged (i.e. would adhere to the cathode)
- ***Anionic*** **–** bitumen particles negatively charged (i.e. they would adhere to the anode)

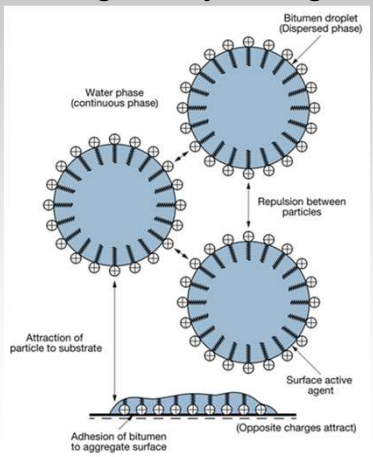


Choice of emulsion class

- Depends primarily on the mineral composition of aggregate
- Silica rich aggregate surface are electro-***negatively*** charged
  - a cationic emulsion (***+ charged bitumen particles***) should be used
  - will promote ***adhesion*** of bitumen to the aggregates

Electro-chemical dispersion

- Repulsion between + charged bitumen (cationic emulsion) and attraction to a negatively charged (e.g. silica rich) aggregate



- Mixing anionic emulsion with cationic emulsion will cause the mixture to "break", (separate into water and bitumen, almost immediately
- Such situations should be avoided during both manufacture and handling of the products (e.g. transport and application)

Emulsion classification

- Two parameters for classification
  - Surface charge of bitumen globules
  - Breaking (or setting time)

Breaking / setting time

- "Setting" or “breaking” is the separation of water from the bitumen in an emulsion
- Stability of the emulsion (time lag before separation) determined by type and quantity of emulsifying agent

Mechanisms of setting

- Cationic emulsions break via:
  - physical-chemical reaction
  - evaporation of the water phase
  - mechanical action such as rolling.
- Anionic emulsions break via:
  - bitumen particles agglomerate with the evaporation of the water
  - mechanical action such as rolling

More on mode of setting

- Refer to Sabita Manual 2

Types of emulsion

- Based on the speed at which water evaporates and bitumen particles separate from water:
  - ***Rapid*** setting emulsion
  - ***Medium*** setting emulsion
  - ***Slow*** setting emulsion

Rapid setting type

- Emulsion sets and cures rapidly
- Used in chip spray applications
  - emulsion comes into contact with clean aggregate
  - no mixing with aggregate required
- Also referred to as ***Spray grade*** emulsions.
- Another type specially formulated for use with microsurfacing
- Termed ***Quick setting grade***.

Medium setting type

- Do not break spontaneously when in contact with aggregates
- Suitable for mixing with medium or coarse graded aggregate (-0,075 mm sieve < 2%)
- Also referred to as ***Premix grade***

Slow setting type

- Manufactured by using a special type of emulsifier
- Relatively stable & suitable for mixing with fine aggregates, e.g. sand and crusher dust
- Also referred to as ***Stable grade emulsion***.

Modified emulsions

- Available for specialised applications
- Three phase cationic emulsion systems
  - SBR latex is introduced as a third phase in the normal bitumen/water two phase system.

Source

- Conventional and cutback bitumen
  - 4 crude oil refineries
  - Not all grades always available at all refineries
  - Periodic imports
- Bitumen emulsions
  - numerous fixed plants around South Africa
  - All or most of the grades are available in bulk or in 200 litre drums

Source / cont. …

- Modified binders
- Manufacturers at plants around the country:
  - **Homogenous types**
    - SBS (styrene-butadiene-styrene)
    - SBR (styrene-butadiene-rubber)
    - RET (Reactive Elastomeric Terpolymer
    - EVA (ethylene-vinyl-acetate).
  - **Non homogenous type** – bitumen-rubber
  - **Hybrid types** – Blends of different polymers types
    - polymers and Rubber Crumbs
    - polymers and warm mix asphalt (WMA) additives
    - blends of Rubber Crumbs / WMA Additives and/or Polymers

Packaging

- Usually supplied in bulk road tankers to:
  - Storage (asphalt & manufacturing plants for modification emulsification;
  - Construction sites
  - Bulk-spray distributors, for direct application to the road surface.
- Bulk road tankers are generally fitted with LPG / oil heating systems
  - Heating only when tanker is stationary

Packaging / cont. …

- Bitumen (esp. emulsions) also supplied in non-returnable drums
  - Vol. 210 l; mass ≈ 200 kg
- Specific instances - transported and stored in special ISO type containers – *isotainers*
  - (25 tons) transported as a solid
  - special heating systems enable the bitumen to be liquefied for pumping
- Drums and isotainers are more commonly used for bitumen imports by sea.

Module 2 - Summary

- Wide range of bituminous binders available to deal with range of service conditions
- Binders with modified rheological properties could be cost-effective to deal with more severe operating conditions
- Bitumen emulsions offer the facility of a range of low temperature applications in the interests of improved sustainability
- PG specifications will enable optimal selection of binder for a particular application