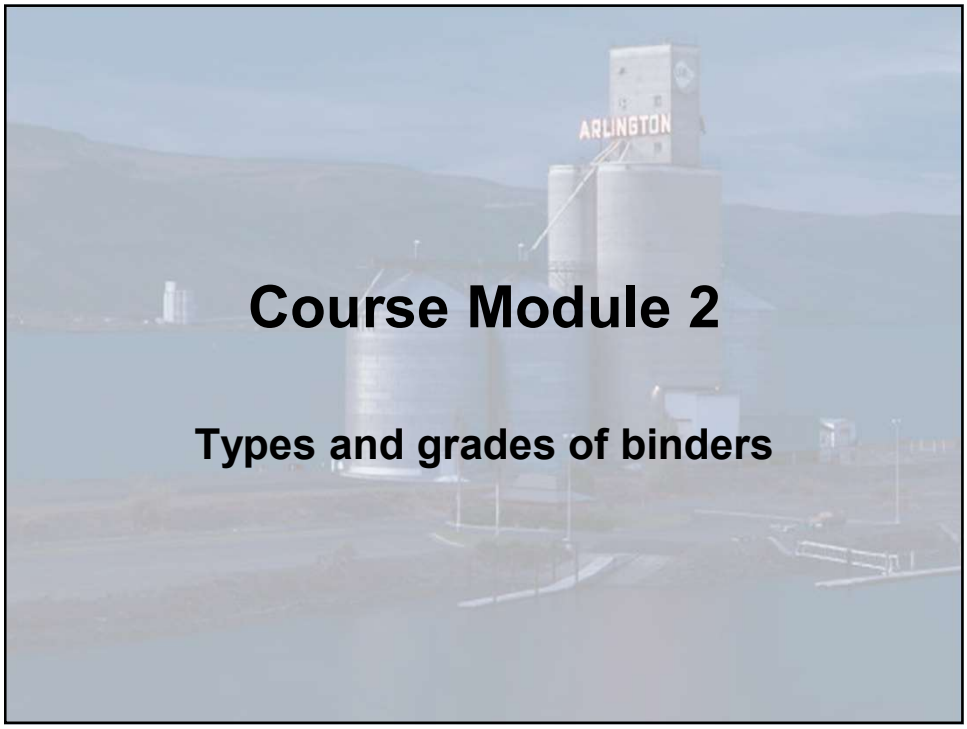


Course Module 2

Types and grades of binders

Bituminous binder types

- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions
- Stone precoating fluids
- **P**erformance **G**rade classification

Penetration grade bitumen

Manufactured either by:

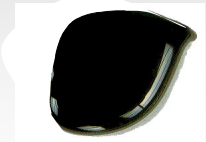
- straight-run distillation or
- by blending two base components - one hard (e.g. 40/50 pen) and the other soft e.g. 150/200 pen).

Penetration grade bitumen is used either as a primary binder or base bitumen for the manufacture of

- cutback bitumen
- modified binders
- bitumen emulsions.

Bituminous binder types

- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions
- Stone precoating fluids



Bitumen

+

Solvents

Cutback bitumen

- A blend of penetration grade bitumen and petroleum solvents
- Type of solvent determines the rate at which the bitumen will “set up” or cure when exposed to air
  - 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 - can be applied at lower temperatures than penetration grades because of their lower viscosities
- A disadvantage - they consume non-renewable energy resources

Bituminous binder types

- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions
- Stone precoating fluids

Modified bitumen

The ***rheological properties*** of conventional binders may be modified by the introduction of:

- Elastomers
- Plastomers
- Crumb rubber
- Hydrocarbons

Modified bitumen/cont…

Modification is costly and is justified in terms of improved performance under severe conditions such as:

- steep gradients,
- slow moving traffic,
- very high road surface temperature,
- high traffic loading or heavily trafficked intersections
- use on highly flexible and cracked pavements.

Modified bitumen/cont…

The use of modified bitumens is increasing as a result of increasing:

- Tyre pressures
- Axle loads
- Traffic volumes

Improved performance achieved in two ways:

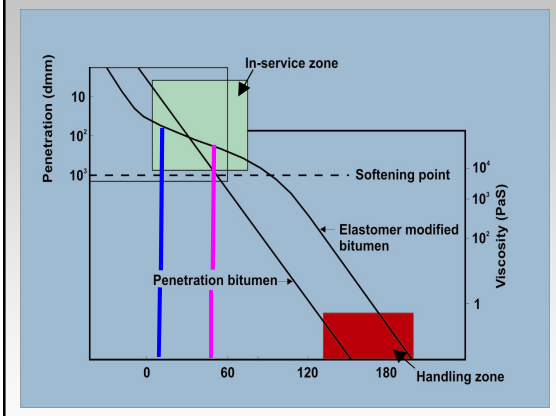
- Increase in the elastic component and reduction of viscous component of G*
- Stiffening of the bitumen to reduce viscous response of the layer

Other properties improved

Wide range of properties improved

- Durability
- Aggregate retention
- Resistance to permanent deformation
- Resistance to fatigue cracking
- Cohesion (internal strength)
- Elasticity
- Viscosity less susceptible to temperature changes

Effect of elastomer on rheological profile of bitumen



- At higher road temperatures – modified binder has higher viscosity than straight bitumen
- Together with its elastic nature will exhibit significantly higher resistance to permanent deformation and fatigue cracking
- At low service temperatures – modified binder more flexible and less prone to cracking

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 3 types of elastomers in general use:

- Styrene-butadiene-rubber (SBR) latex
- Styrene-butadiene-styrene (SBS)
- Rubber crumb

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

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 in spray seals and microsurfacing
- SBR modified binders exhibit elastic properties – ideal for resealing lightly cracked roads

Styrene-butadiene-styrene (SBS)

- Available as powder or pellets
- Used for modifying hot bitumen
- Depending on concentration of SBS it increases:
  - Cohesive strength
  - Elasticity
  - Low temperature flexibility
  - Resistance to permanent deformation
- SBS modified bitumen used in both spray seals and asphalt to enhance all-round performance characteristics

Rubber crumb

- Obtained from grinding selected vehicle tyres
- Blended with hot bitumen (20 - 25 % at 170 – 210° C) containing some extender oil
- During reaction time (1 hour) aromatic oils in the bitumen are absorbed by rubber particles causing it to swell
- Bitumen-rubber must be used within 6 hours of completion of blending
- Bitumen-rubber is used extensively in spray seals, asphalt to:
  - dampen crack reflection
  - avoid flushing (bleeding) surfaces
  - improve durability

Polymers

Two basic classes:

- ***Elastomers*** – improve the strength and elastic properties (including bitumen-rubber
- ***Plastomers*** – increase the viscosity 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 copolymer that has the most pronounced effect on the modified bitumen's end properties are:
  - Molecular mass
  - Vinyl-acetate content
- EVA modified bitumen is used in asphalt 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:

- Naturally occurring hydrocarbons
- Aliphatic synthetic wax

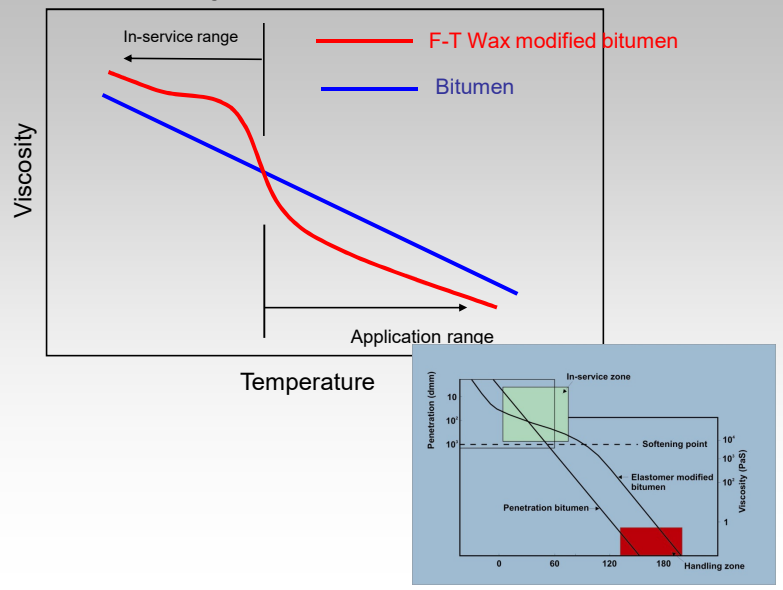
Naturally occurring hydrocarbons

- Deposits in North and South America
- Gilsonite and Durasphalt respectively
- High asphaltene content >70%
- Used to stiffen bitumen (by raising the softening point and lowering the penetration)
- Asphalt mixes containing these modifiers display high stiffness (i.e. good load spreading capability) and resistance to permanent deformation)
- Hydrocarbon modification is not recommended where flexibility is required (e.g. on pavements with high deflections under load)

Aliphatic synthetic wax

- Long-chain hydrocarbons (high molecular mass) ***wax***
- Produced in the Fischer-Tropsch 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…



Classification of modified binders

In accordance with TG1: ***The use of modified bituminous binders in road construction***, they are classified according to:

- Type of application
- Type of modifier
- Type of binder system
- Level of modification

Classification system allows for a ***polymer-blind specification***

Type of application

- S – seal
- A – asphalt
- C – crack sealant

Type of modifier

- E – elastomer;
- P – plastomer
- R – rubber crumb
- H – hydrocarbon

Type of binder system

If the product is an emulsion (cold applied) the letter C will follow immediately after the letter indicating the type of application.

Level of modification

A numerical value

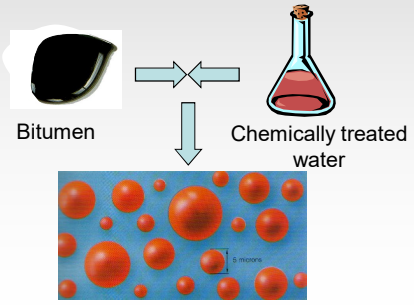
- increases in relation to softening point values,
- not necessarily indicative of improved overall performance characteristics.

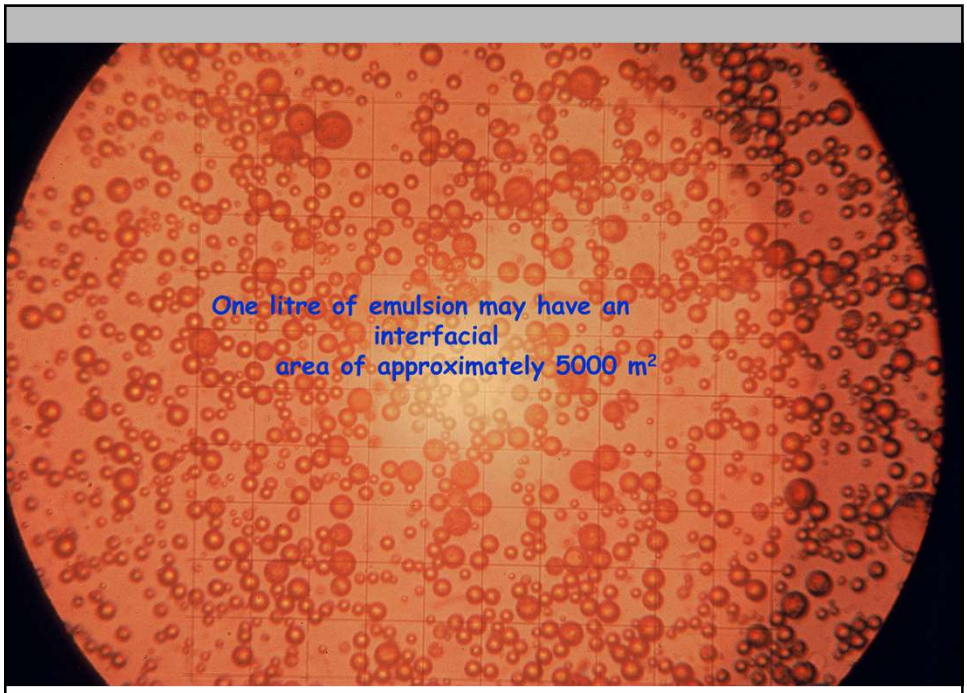
Bituminous binder types

- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions
- Stone precoating fluids

Bitumen emulsion

- Two-phase systems consisting of a dispersion of bitumen globules (0.1 – 50 μm) in water containing an emulsifier
- Emulsification of bitumen is a means of reducing the viscosity of a binder to behave as a fluid during application





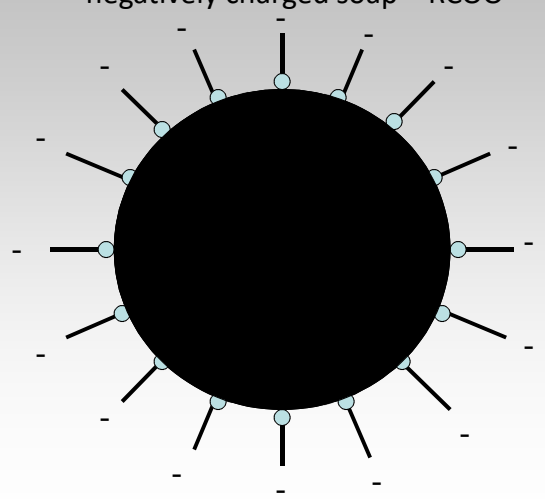
Emulsion classification

- Commonly bitumen emulsions are available in classes:
  - cationic;
  - anionic; and
- The terms ***cationic*** and ***anionic*** derive from the electrical charges on the bitumen globules
  - In a cationic emulsion the bitumen particles are positively charged (i.e. would adhere to the cathode)
  - In an anionic emulsion they are negatively charged (i.e. they would adhere to the anode)

Anionic Emulsions

Fatty Acids/Rosins + Caustic Soda = negatively charged soap = RCOO⁻

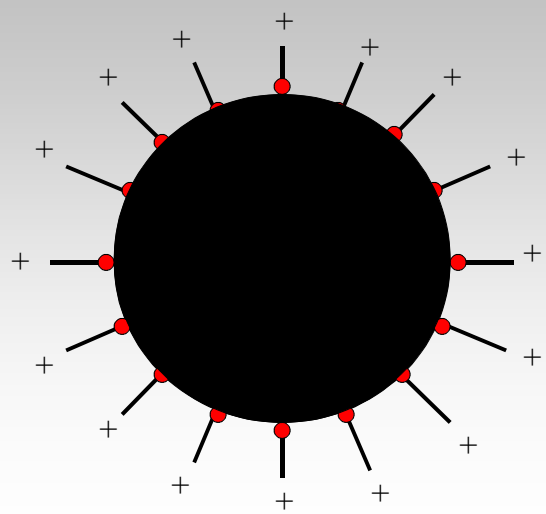
pH > 11



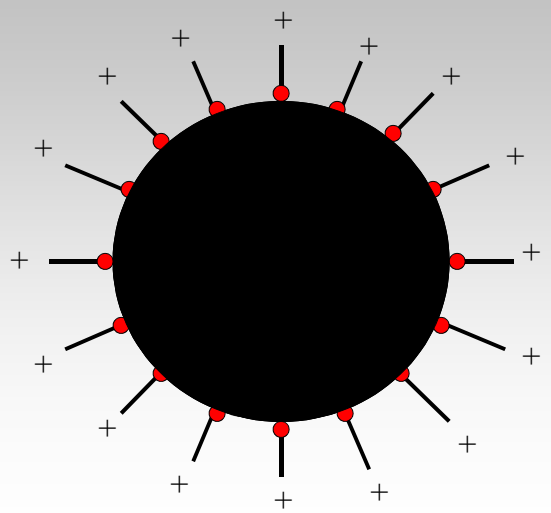
Cationic Emulsions

Amines + Hydrochloric Acid = positively charged soap = $RNH3^{+}$ =

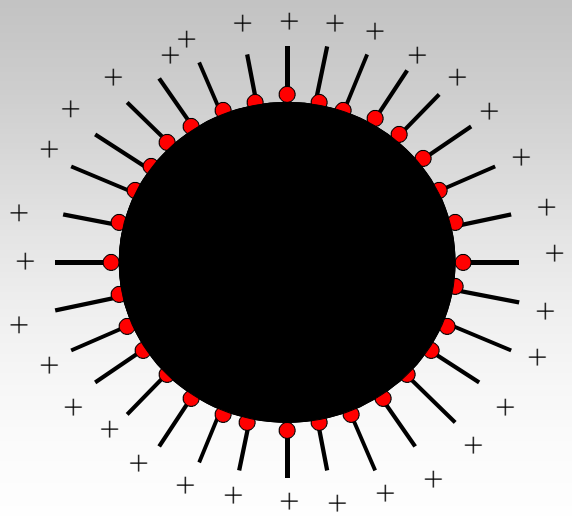
pH < 4



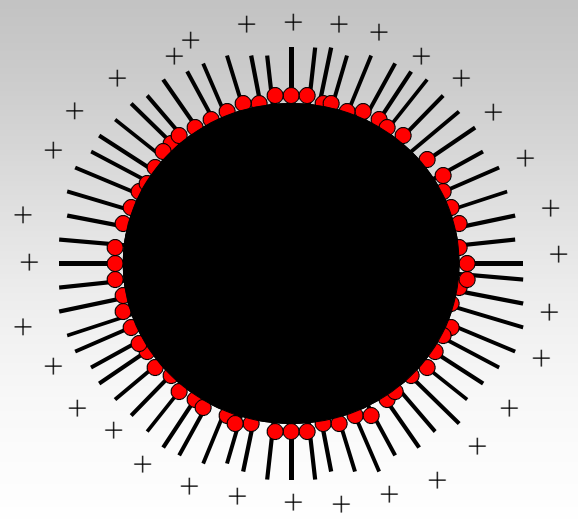
Cationic Spray Grade



Cationic Premix Emulsions



Cationic Stable Grade



Breaking processes

The term “break” refers to the separation of water and bitumen. After evaporation of the water phase it reverts essentially to the base bitumen used in its manufacture

Cationic emulsions break through:

- physical-chemical reaction
- evaporation of the water phase
- mechanical action such as rolling

Anionic emulsions break :

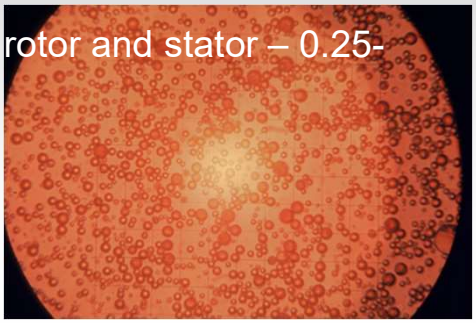
- predominantly when the bitumen particles agglomerate with the evaporation of the water
- through mechanical action such as rolling

Invert emulsions

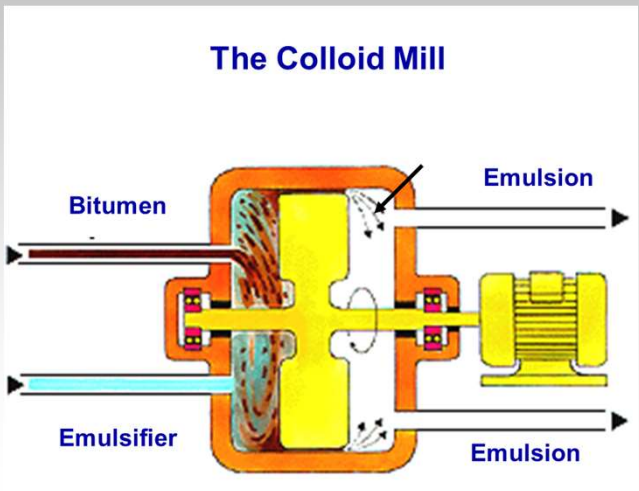
- Distinct from normal oil in water emulsions like cationic and anionic types
- Water is dispersed in the binder phase
- Manufactured with cutback bitumens and have water contents of less than 20 %.

Manufacture of emulsions

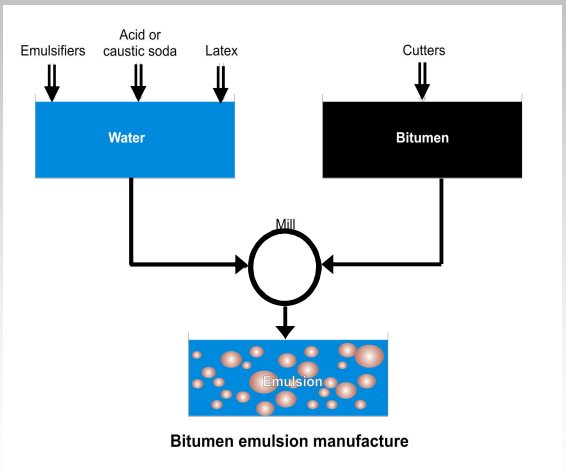
- Continuous process
- High speed colloidal mill
  - High speed rotor – 1000 – 6000 rpm in a stator
  - Clearance between rotor and stator – 0.25-0.5μm



Schematic of Colloid Mill



Manufacture flow diagram



Emulsion manufacture

- Water phase prepared
  - Emulsifier chemicals dissolved in heated water
  - Mixture saponified (with e.g. sodium hydroxide) for anionic emulsions or acidified (with inorganic acids) for cationic emulsions
- Bitumen temperature is controlled to:
  - Ensure correct viscosity for emulsification
  - Prevent boiling of water phase on exit from mill
- Base bitumen normally 80/100 pen
  - May be fluxed with solvents for specific types of emulsions

Emulsion manufacture/cont…

- Two phases (chemical treated water and bitumen pass through narrow clearance of mill
- Bitumen is sheared into microscopic particles
- On discharge of mill emulsion is allowed to cool in dedicated storage according to type and grade
- Stability is determined by amount of emulsifier

Note: accidental mixing of cationic and anionic emulsion will cause an almost immediate break (separate into water and bitumen)

Classification of emulsions

Emulsions are available in the following grades defining the stability when in contact with aggregates:

- Premix grade
- Quick setting grade
- Spray grade
- Stable mix grade

Premix grade

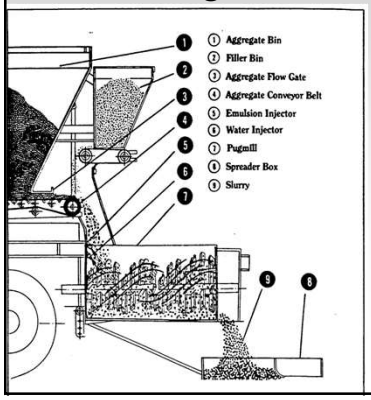
- Formulated to be more stable than spray grade emulsion
- Suitable for mixing with medium or coarse graded aggregate with the percentage aggregate passing the 0,075 mm sieve not exceeding 2 %.

Premix grade

- Formulated to be more stable than spray grade emulsion
- Suitable for mixing with medium or coarse graded aggregate with the percentage aggregate passing the 0,075 mm sieve not exceeding 2 %.

Quick setting grade

Specially formulated for use with microsurfacing seal types, where quick setting of the mixture is desired



Spray grade

An emulsion formulated for application by mechanical spray equipment in spray seal construction where no mixing with aggregate is required.

Stable mix grade

- An emulsion formulated for mixing with very fine aggregates - sand and crusher dust.
- Mainly used for slow-setting slurry seals and tack coats.

Modified emulsions

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

Emulsion-aggregate adhesion

- ***Acidic aggregates*** (e.g. granite and quartzite) which constitute a very large proportion of aggregates used in southern Africa, are ***negatively charged***, providing good adhesion to the ***positively charged bitumen*** in a ***cationic emulsion***. Cationic emulsions are thus more widely used.
- ***Basic aggregates*** (e.g. dolomite and limestone) are ***positively charged*** provide good adhesion to ***negatively charged bitumen*** in ***anionic emulsions*** and.
- If an anionic emulsion is used with granite or quartzite, effective adhesion is only obtained after the water has evaporated.

Bituminous binder types

- Penetration grade bitumen
- Cutback bitumen
- Modified bitumen
- Bitumen emulsions
- Stone precoating fluids

Stone precoating fluids

- A low viscosity bitumen-based binder containing
  - petroleum cutters
  - a chemical adhesion agent
- Used to coat surfacing aggregates to improve the adhesion of the aggregate to the bituminous binder.
- Low viscosity enables coating of damp or dusty surfacing aggregates
- Should dry in a reasonable period to deposit a non-tacky residue on the surface of the aggregates.

The use of bitumen emulsion or diesel has been found in most cases to be unsuitable for use as precoating fluids.

Bitumen additives

- These substances are sometimes used, particularly in asphalt applications
- Not intended to ***modify*** or improve the rheological properties of bitumen
- They improve certain performance characteristics to extend the service life of the asphalt.

Additives/cont…

Type	General purpose	Examples
Extender	Substitutes a 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 hot mix asphalt Allows higher binder content with reduced risk of drain-down in open-graded asphalt and SMA Improves durability through increased binder film thickness	Rock wool Polypropylene Polyester Fibreglass Mineral Cellulose
Antioxidant	Increases the durability of HMA by retarding oxidation	Carbon black
Anti-stripping agents	Reduces stripping of binder from aggregate	Amines Lime
Fuel resistance	Improves the resistance of the HMA to fuel spillages	FT Wax Selected grades of EVA

Types and grades of conventional bituminous binders

Type	Grade
Penetration grade bitumen	35/50 50/70 70/100 150/200
Cutback bitumen	MC10 MC 30 MC 3000

Types and grades of modified bituminous binders

Type	Grade
SBR	S-E2, A-E1,
SBS	S-E1, A-E2, C-E1
EVA	A-P1
Natural hydrocarbons	A-H1
F-T wax	A-H2
Bitumen-rubber	S-R1, A-R1, AR-2, C-R1

Types and grades of bitumen emulsions

Type	Grade
Conventional bitumen emulsions	Cationic spray grade 60, 65 & 70% binder content
	Cationic premix grade 60 & 65% binder content
	Cationic/anionic stable grade 60% binder content
	Invert cationic emulsion 80% binder content (inc flux)
Modified bitumen emulsions	SC-E1 SC-E2 AC-E1, AC-E2 CC-E1

Module 2 - Summary

- A wide range of bituminous binders are available to deal with range of 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