Asphalt Emulsions

"A Green Technology Comes of Age"

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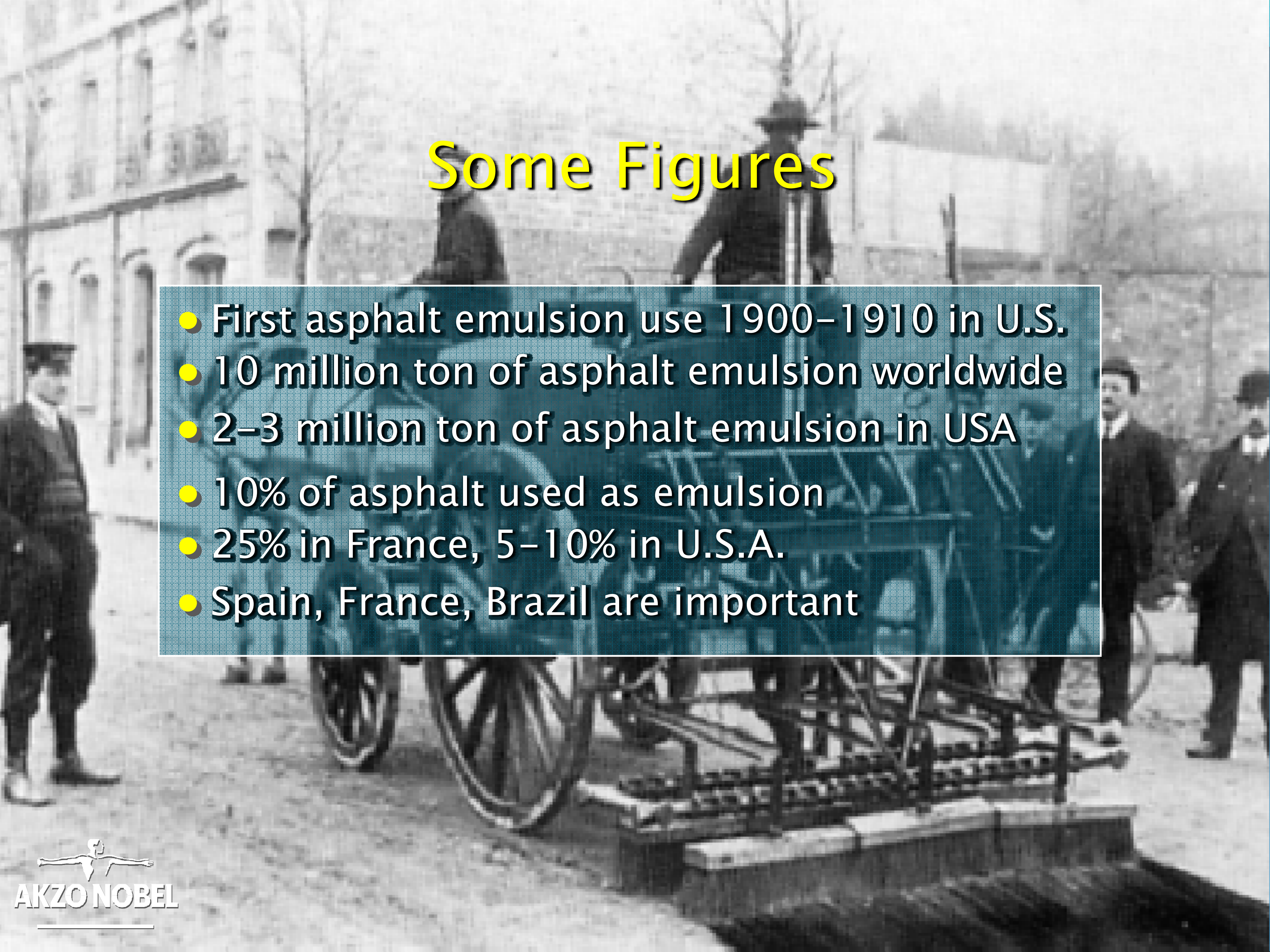
Presentation

1. What are asphalt emulsions
2. What are the types of asphalt emulsions
3. Manufacturer of emulsions
4. Setting and breaking of emulsions



Some Figures

- First asphalt emulsion use 1900-1910 in U.S.
- 10 million ton of asphalt emulsion worldwide
- 2-3 million ton of asphalt emulsion in USA
- 10% of asphalt used as emulsion
- 25% in France, 5-10% in U.S.A.
- Spain, France, Brazil are important

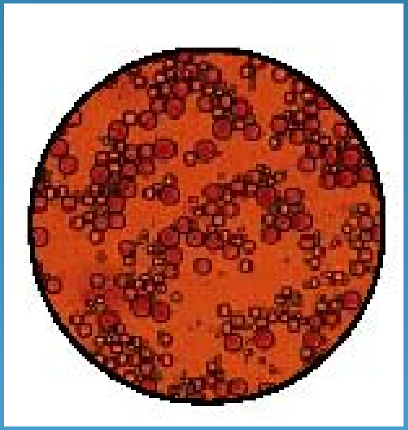
AKZO NOBEL

Emulsions Surrounds us

Emulsion Basics

- Emulsions are MIXTURES of two immiscible liquids, such as oil and water, STABILIZED by an EMULSIFIER

- Emulsifier PROTECTS the droplet



How?

Why Use Emulsions?

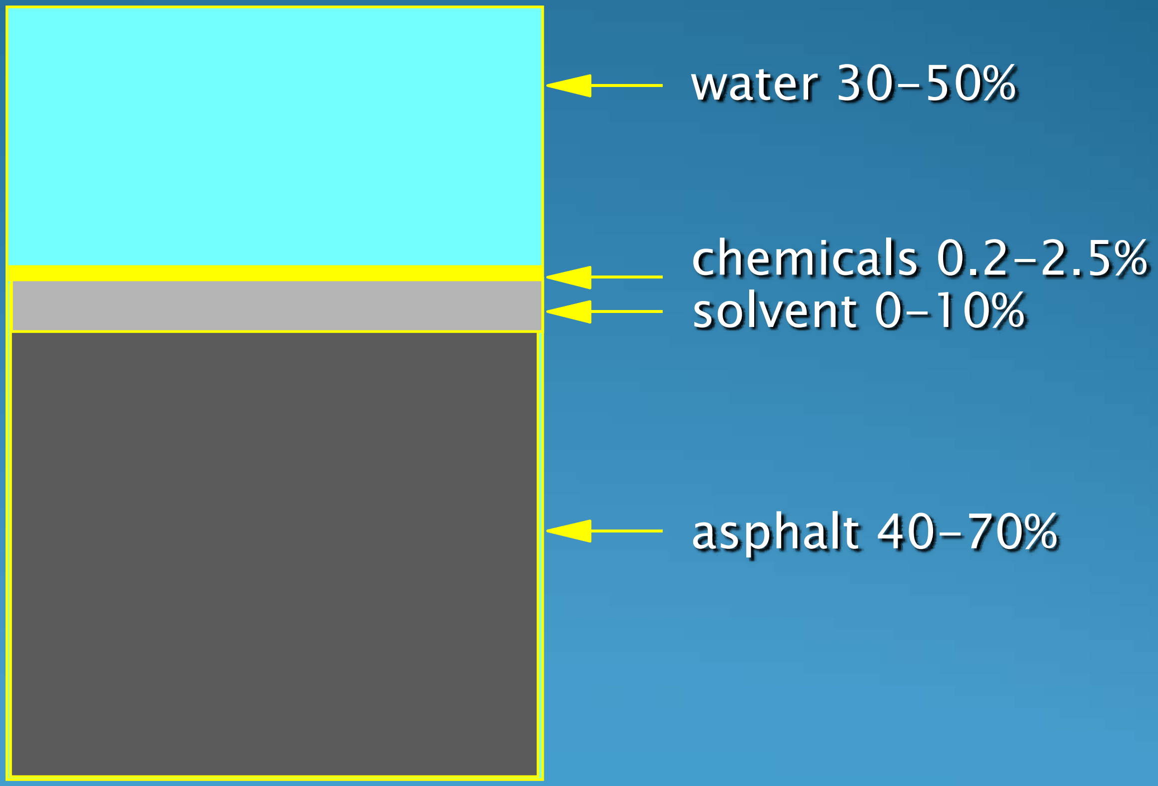
- Cold processes save energy
- easier handling and Storage (Low viscosity)
- safe and environmentally friendly
- low-cost on-site and in-place techniques
- water dilutable
- easily mixed with latex

Necessary Components

- Continuous phase - Water
- Non-continuous phase - Asphalt (dispersed phase)
- Surfactant - Emulsifying Agent
- Mechanical Energy – Shear (colloid mill)

The emulsion is a chemically stabilized system; <u>all</u> components contribute to the stability of the system

Asphalt Emulsion composition



Emulsion Applications

- Surface
  - Fog seal
  - Chip seal
  - Cold mix
  - Slurry Seal
  - Microsurfacing
  - Cape seal
  - Scrub seal
- Structure
  - Cold in place recycling (CIR)
  - Full depth reclamation (FDR)

Emulsion Stability

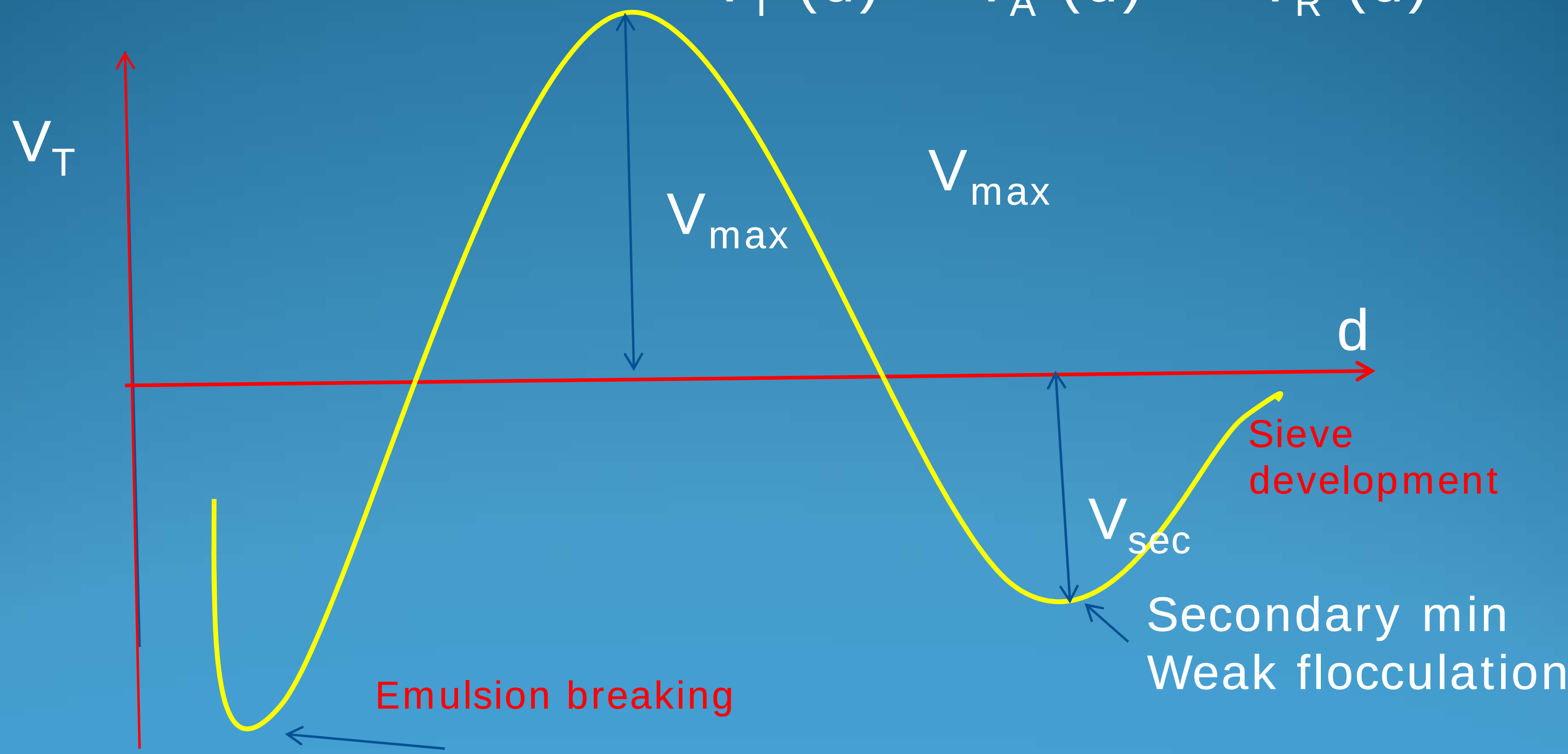
= Balance of attractive and repulsive interactions

Attractive >> Van der Waals Forces

Repulsive >>> Electrostatic forces

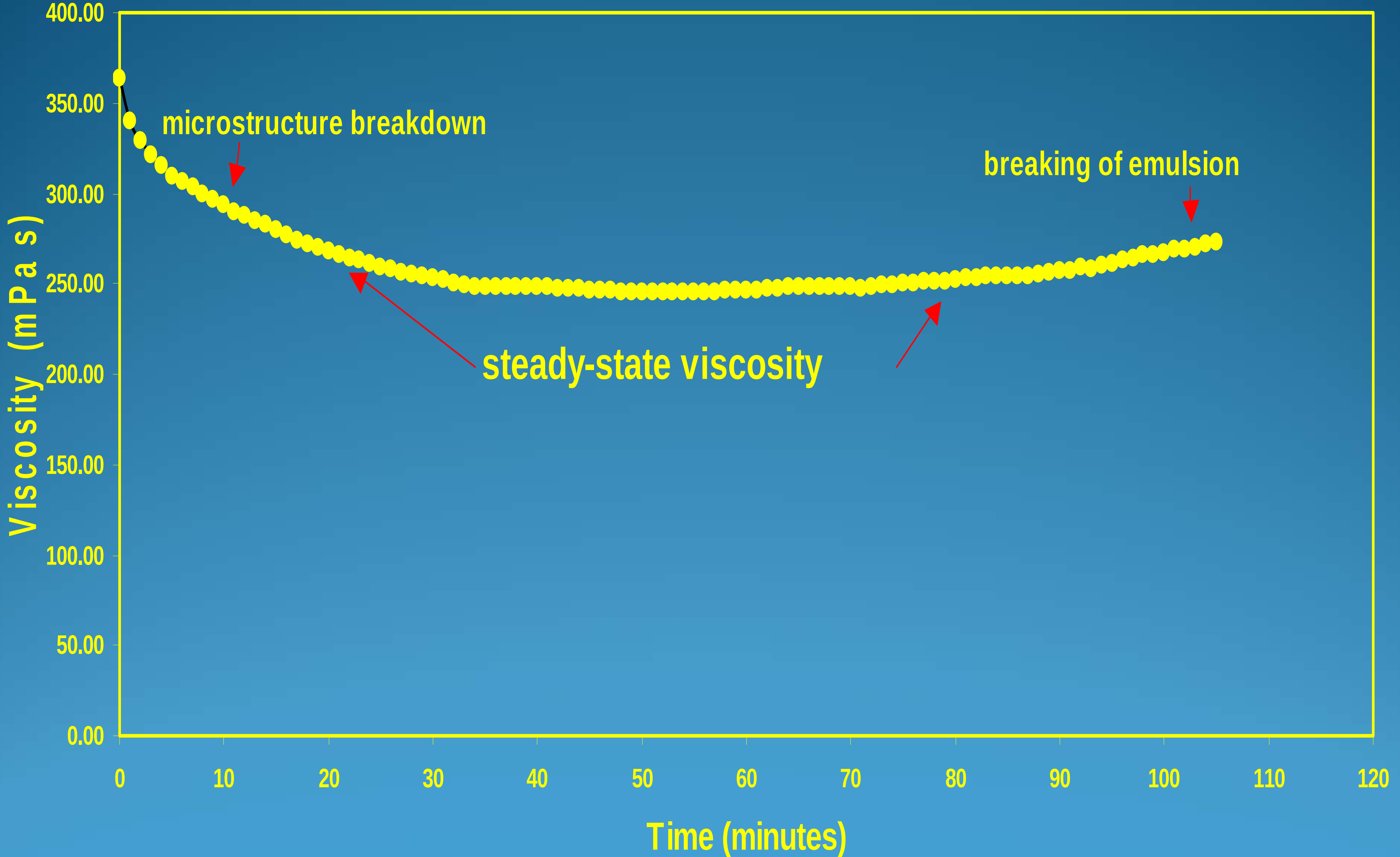
DLVO = Derjaguin-Landau-Verwey-Overbeek THEORY developed in 1930

$$V_T\ (d) = V_A\ (d) + V_R\ (d)$$



Primary minimum: irreversible flocculation

Effect of constant shear at 50 RPM and 50°C on emulsion viscosity



Surfactants and Emulsifiers

- Surfactant = Surface Active Agent
- Emulsifier = Type of Surface active agent
- Wetting Agent = type of surface active agent

Emulsifiers lowers energy at the interface

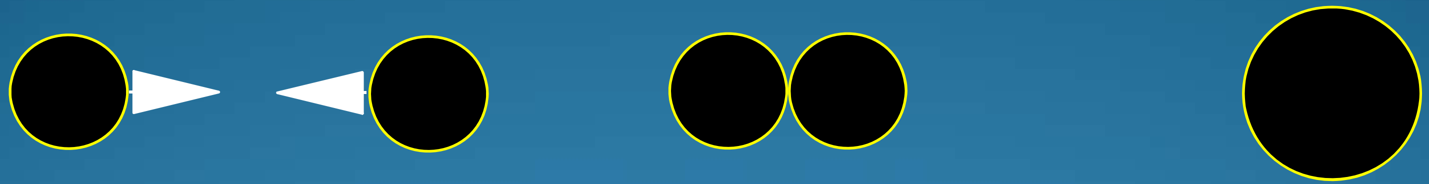
- Water-air or water-oil interface is high tension (energy)
- Surface Active Agent adsorbs at interface
- Lowers the tension (energy) at the interface
- Lowers the work needed to make new interface

Functions of the Emulsifier

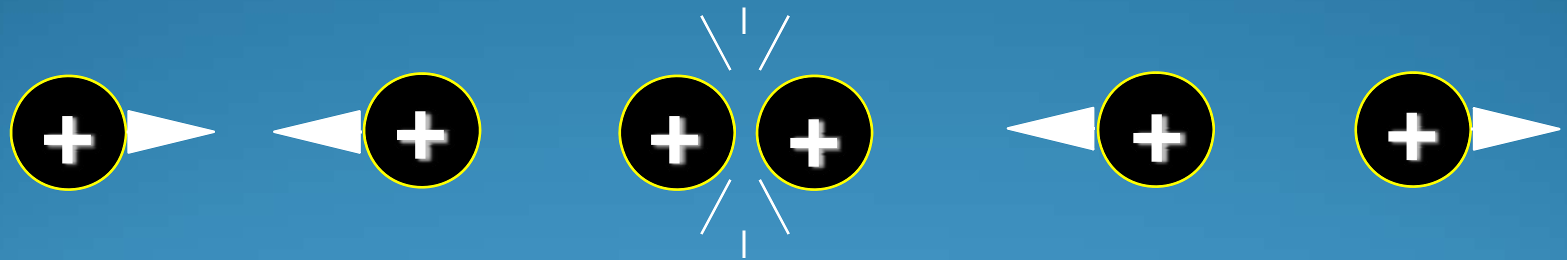
- *Determines type of emulsion formed. i.e. O/W or W/O*
- *Reduces energy needed to emulsify asphalt*
- *Determines charge on emulsion droplets*
- *Stabilizes emulsion droplets as they are formed in the colloid mill*
- *Stabilizes the droplets during storage of the emulsion*
- *Provides the right setting behavior*
- *Influences the physical properties of the emulsion*
- *Influences properties of cured road material.*

Stabilization of Asphalt Droplets

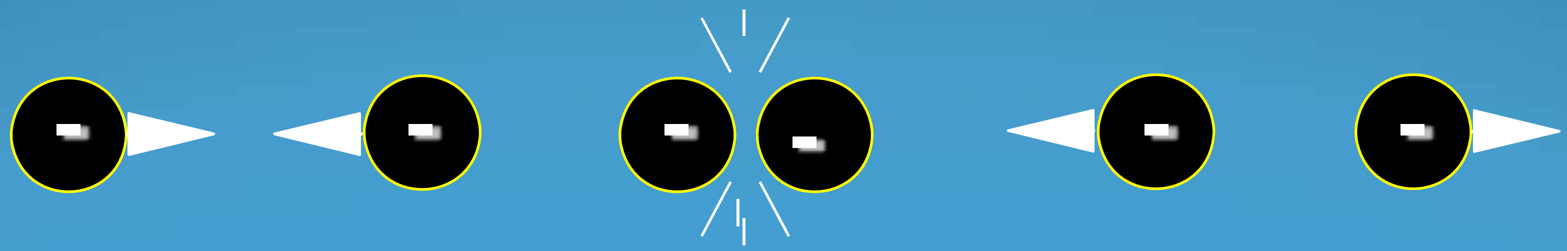
No emulsifier-droplets can come into contact and coalesce



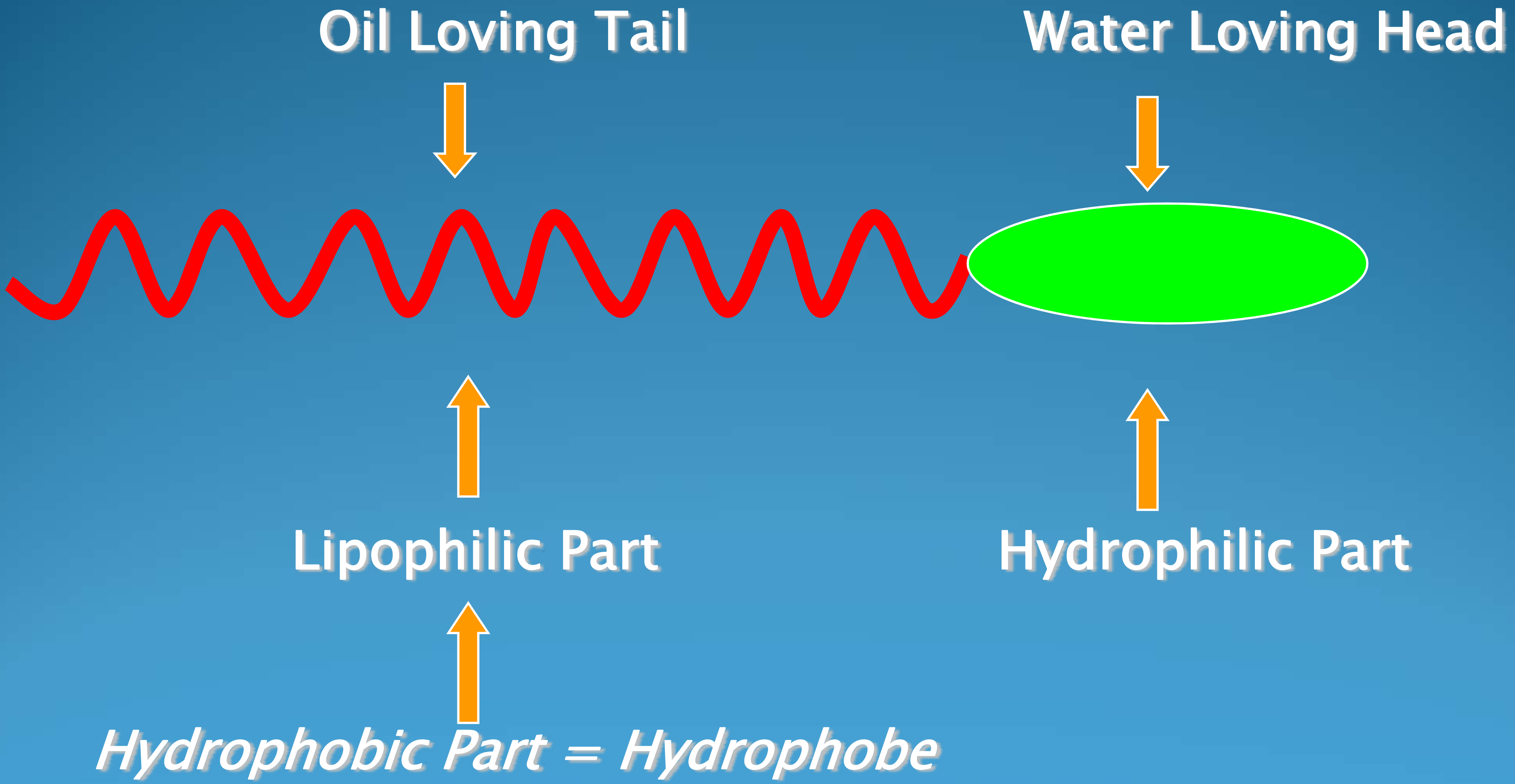
Cationic emulsifier-electrostatic repulsion prevents close approach of drops



Anionic emulsifier-electrostatic repulsion prevents close approach of drops



Surfactants



If an asphalt droplet were the size of the earth, then the emulsifier head would occupy an area of 4 square miles and the hydrocarbon tail would penetrate 5 miles deep

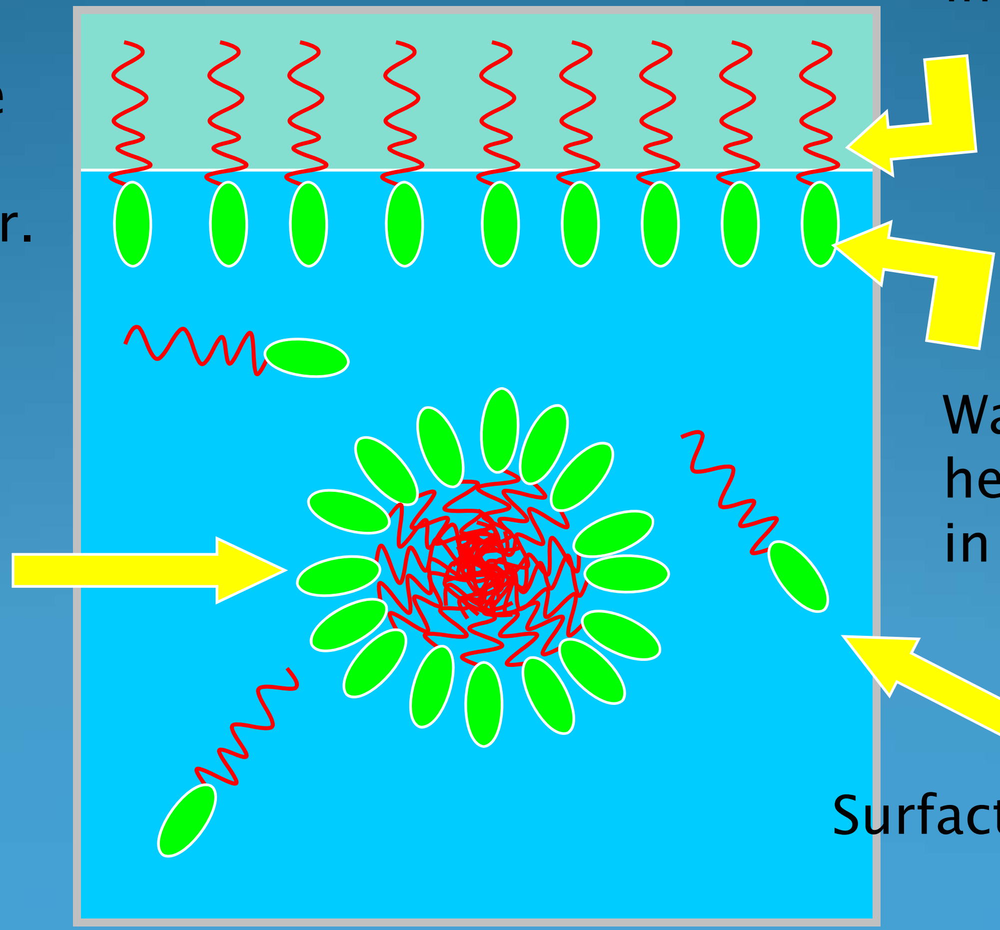
asphalt droplet diameter 3/1000 mm

emulsifier length 3/1 000 000 mm

Surfactants at Water-Oil interface

There is an equilibrium between surfactants at the interface and those in the water.

When the concentration of surfactants in the water reach the "CMC" then micelles start to form

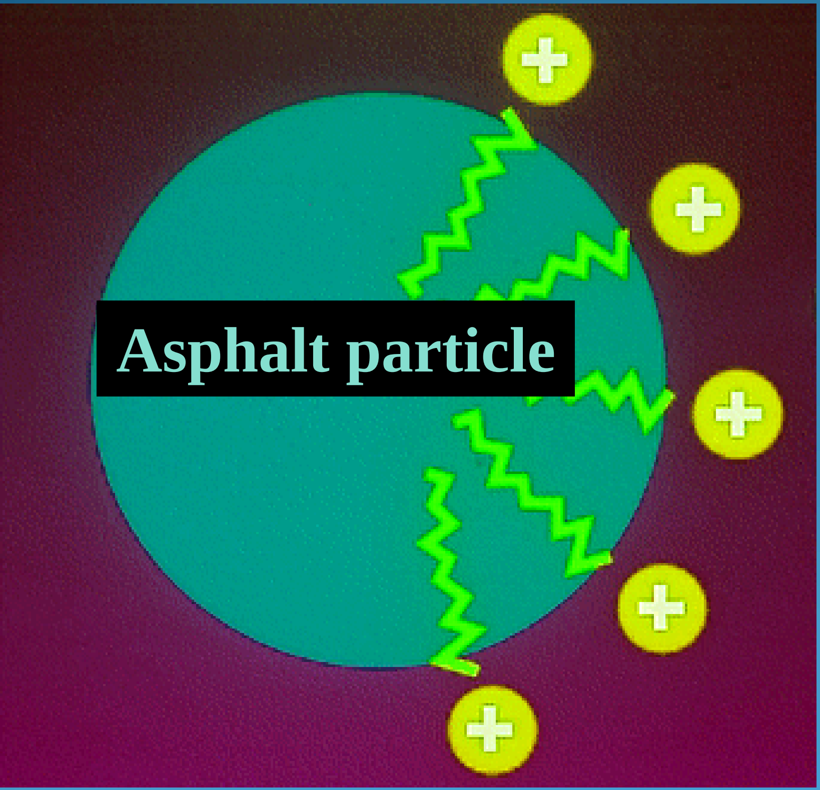


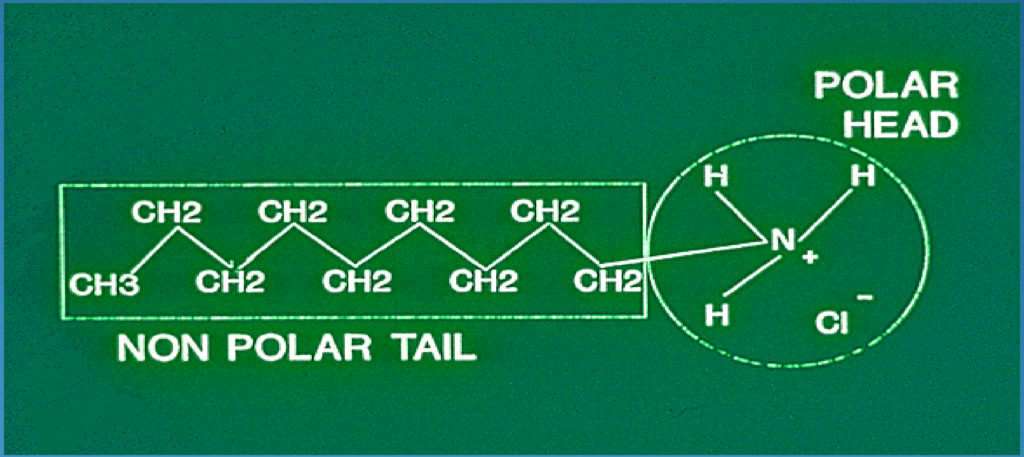
Water hating tails point out in the oil or air

Water loving heads immersed in the water

Surfactant molecule

Emulsifiers stabilize particles -cationic example:



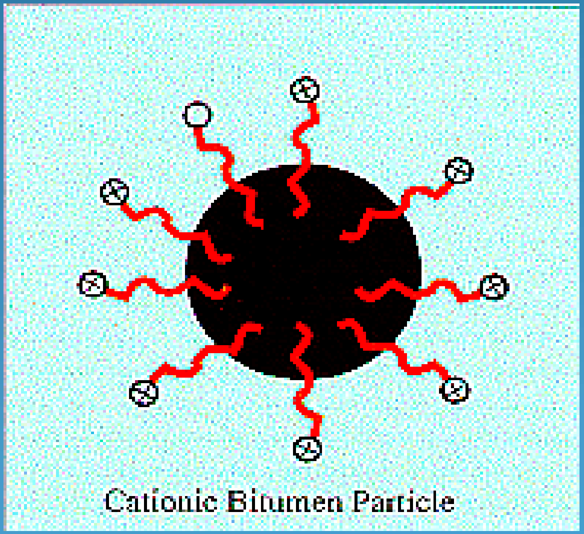


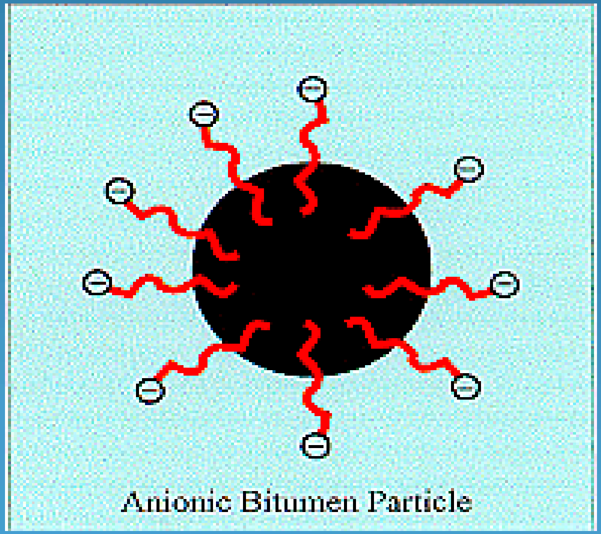
Positively charged emulsifier

Popular Emulsion types

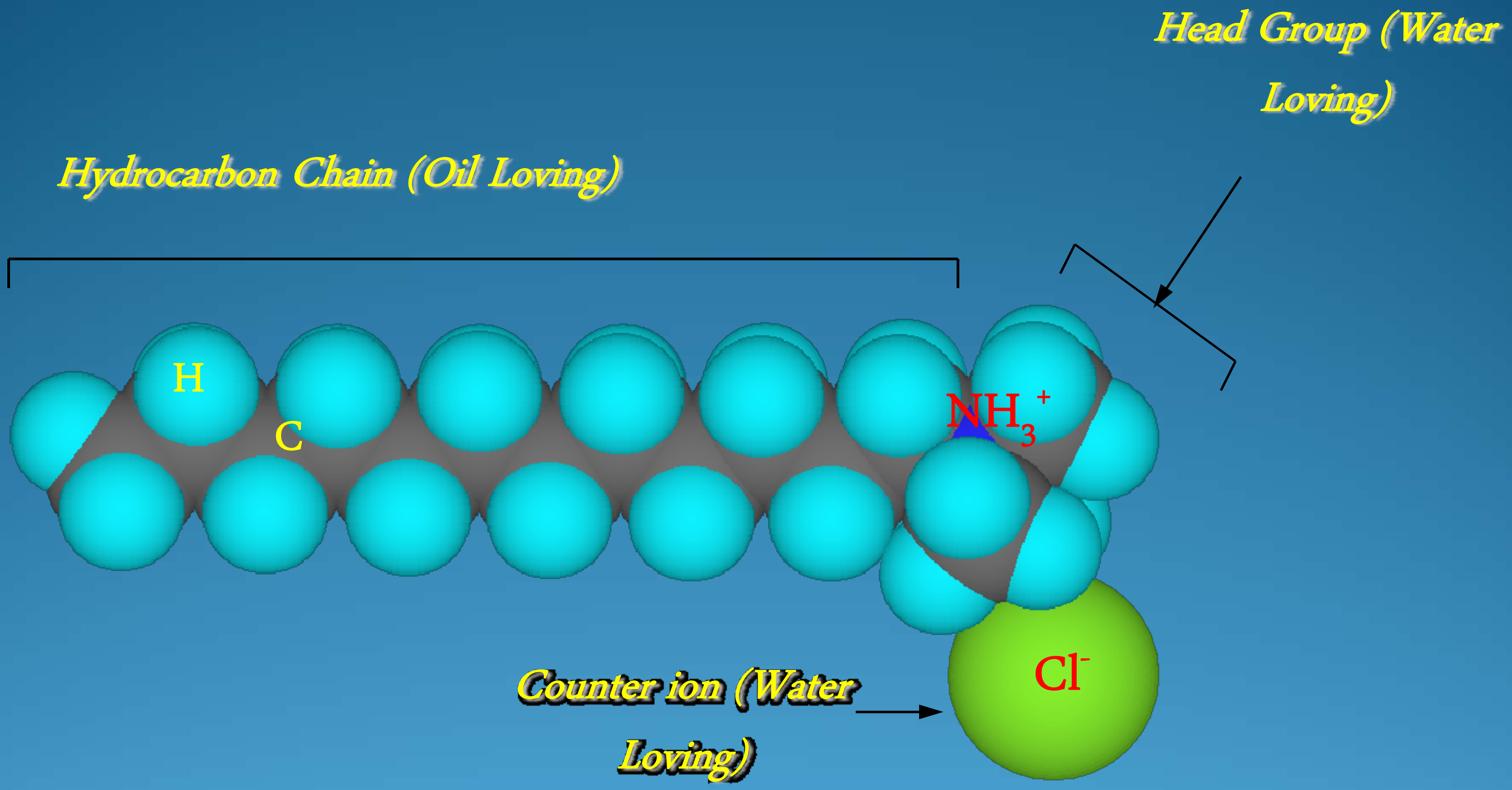
Cationic

Anionic

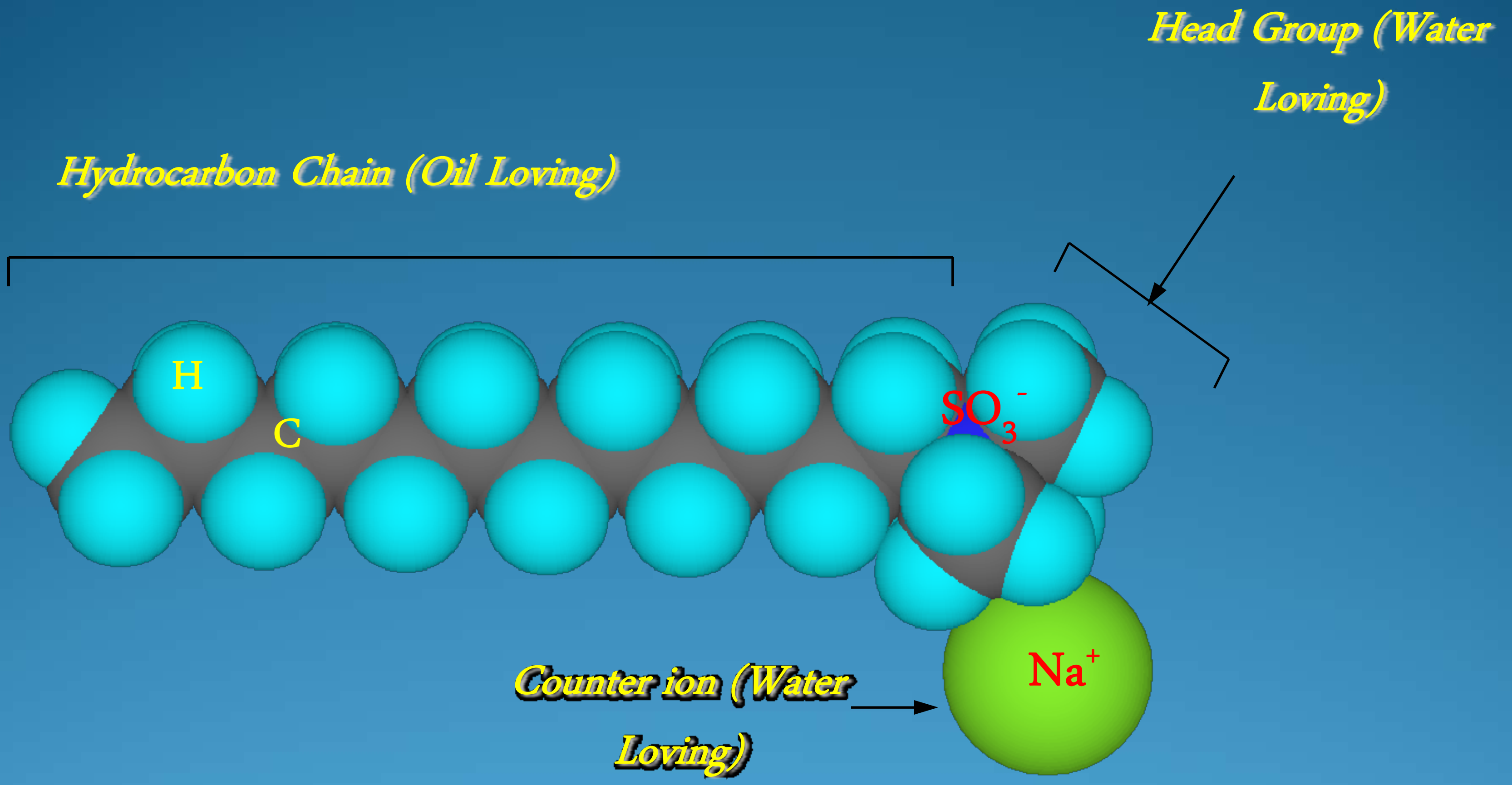




Cationic Emulsifier



Anionic Emulsifier



Typical Emulsifier Structures

Hydrocarbon tail with 12-20 carbons | hydrophilic head group | counter ion

R(tallow) ------------------------------------	$N^+(CH\ )_3$	Cl^-
R(tallow) ------------------------------------	$NH_2^+CH_2CH_2CH_2NH_3^+$	$2Cl^-$
R(nonylphenyl) -------------------------	O----$CH_2CH_2OCH_2CH_2O$---H	none
R(tall oil)-------------------------------------	COO^-	Na^+
R(lignin)---------------------------------------	SO_3^-	Na^+

R = long chain hydrocarbon

Cationic Soaps are prepared from amines and acid

$RNH_2 + HCl = RNH_3^+ + Cl^-$

insoluble neutral form + acid = soluble cationic 'soap'

$RNH_2 + H3PO4 = 2RNH_3^+ + HPO3^{2-}$

insoluble neutral form + acid = soluble cationic 'soap'

R = Hydrocarbon chain

Some charged emulsifiers do not need pH adjustment

$RN(CH)_3^{\ +}\ \ Cl^{\ -}$

soluble quaternary amine

$R\ SO_3^{-}\quad Na^{+}$

soluble olefin sulphonate

rapid-setting:

reactive emulsion sets quickly even with unreactive aggregates

medium-setting:

medium reactive emulsion which can be mixed with open graded aggregates with low fines content

slow-setting:

low reactive emulsion which can be mixed with reactive aggregates with high fines content

Naming of Emulsions(ASTM)

cationic

rapid-setting

CRS - 2

High viscosity
(65% asphalt)

cationic

slow-setting

CSS - 1h

hard asphalt

Low viscosity
(57% asphalt)

high-float

HFMS - 2s

with solvent

medium-setting
(anionic)

Anionic rapid setting

RS -2P

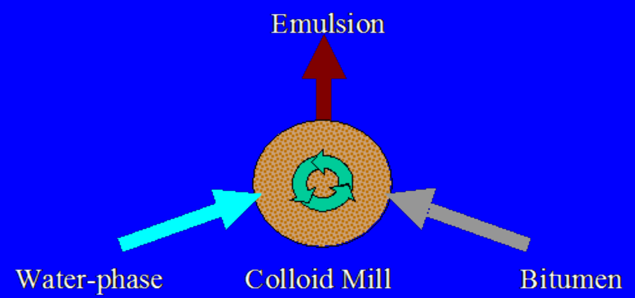
Polymer modified

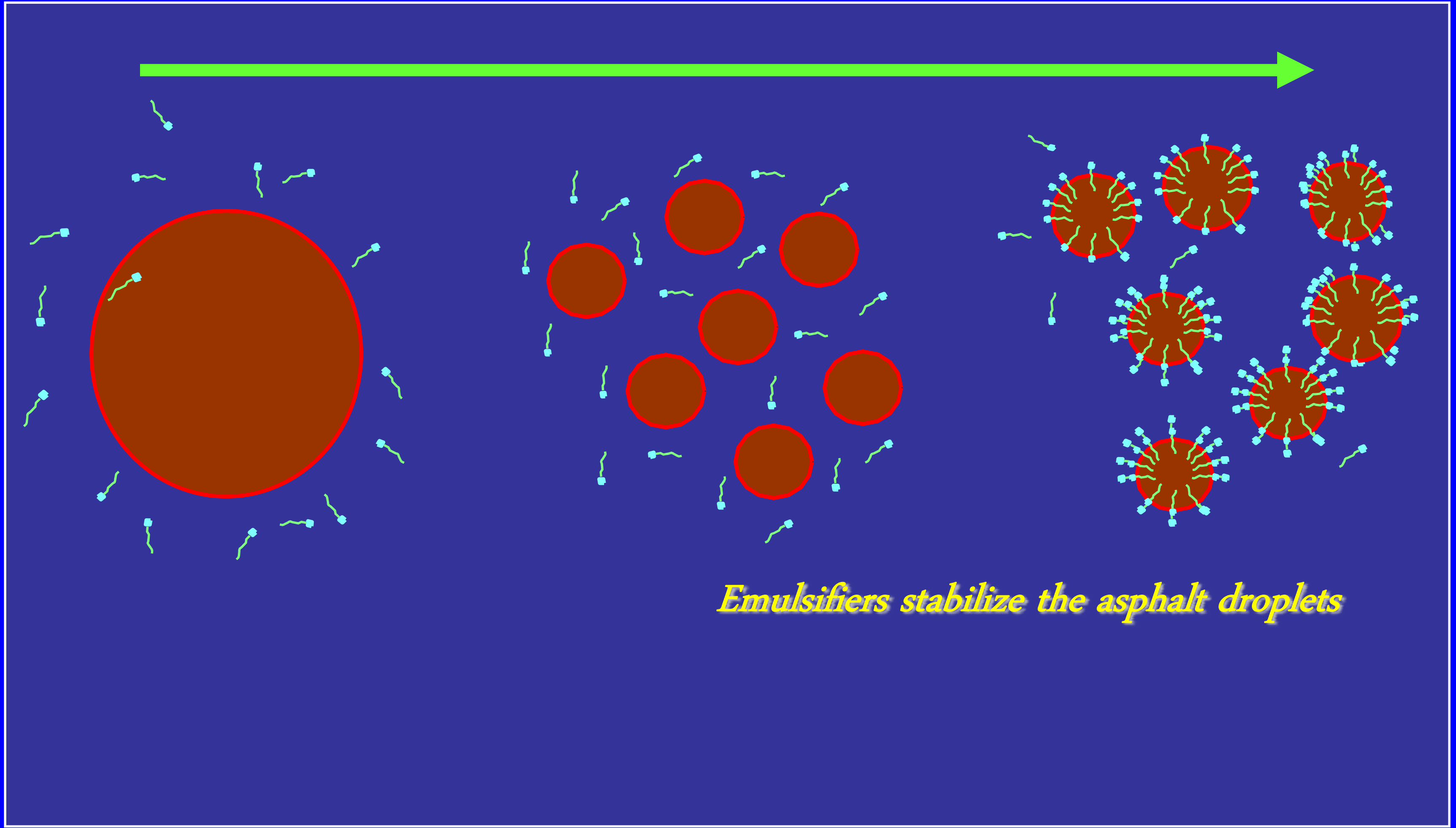
Emulsions are classified according to Setting Rate and Particle Charge

	+ve	-ve	Application
rapid-setting	CRS	RS	chip-seal
medium-setting	CMS	MS	open-graded mix
slow-setting	CSS	SS	dense-graded mix

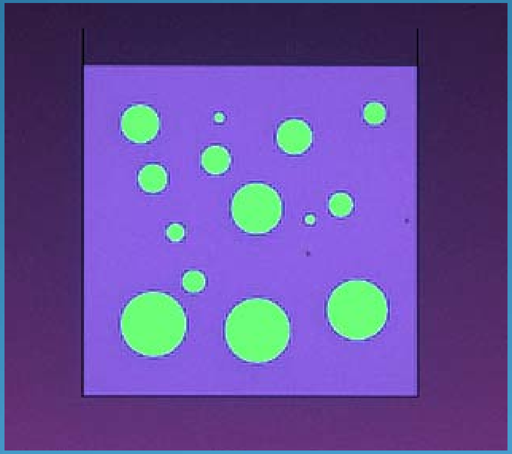
Manufacture of Asphalt Emulsions

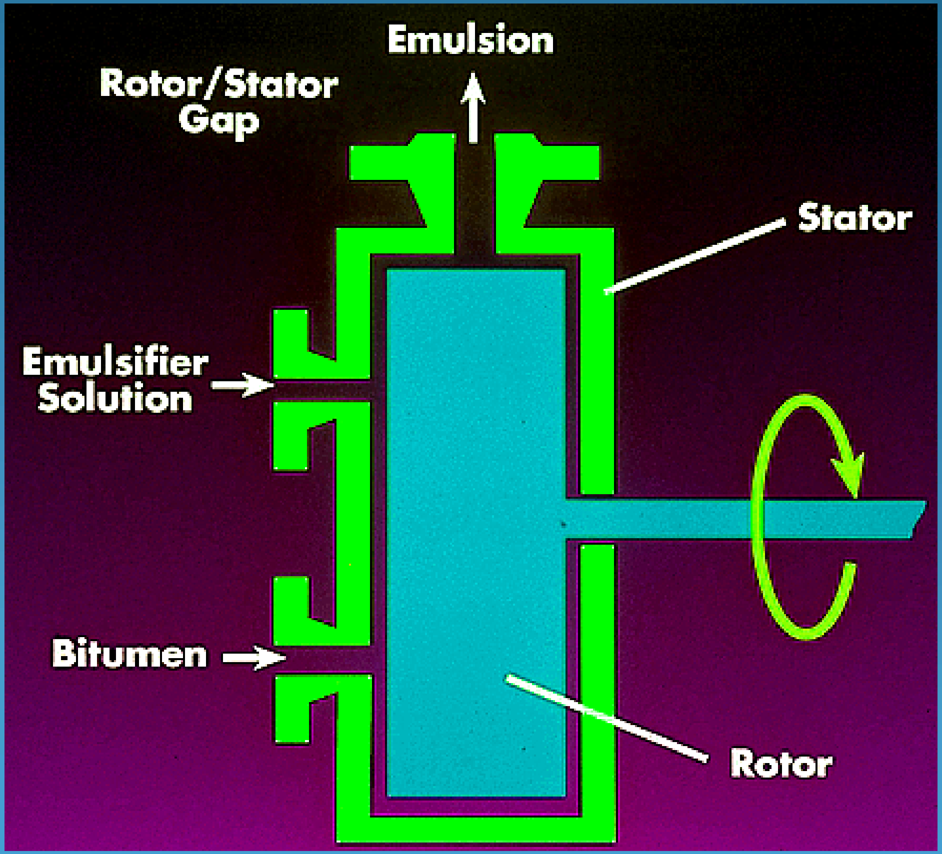
Emulsifiers in Emulsion Manufacture



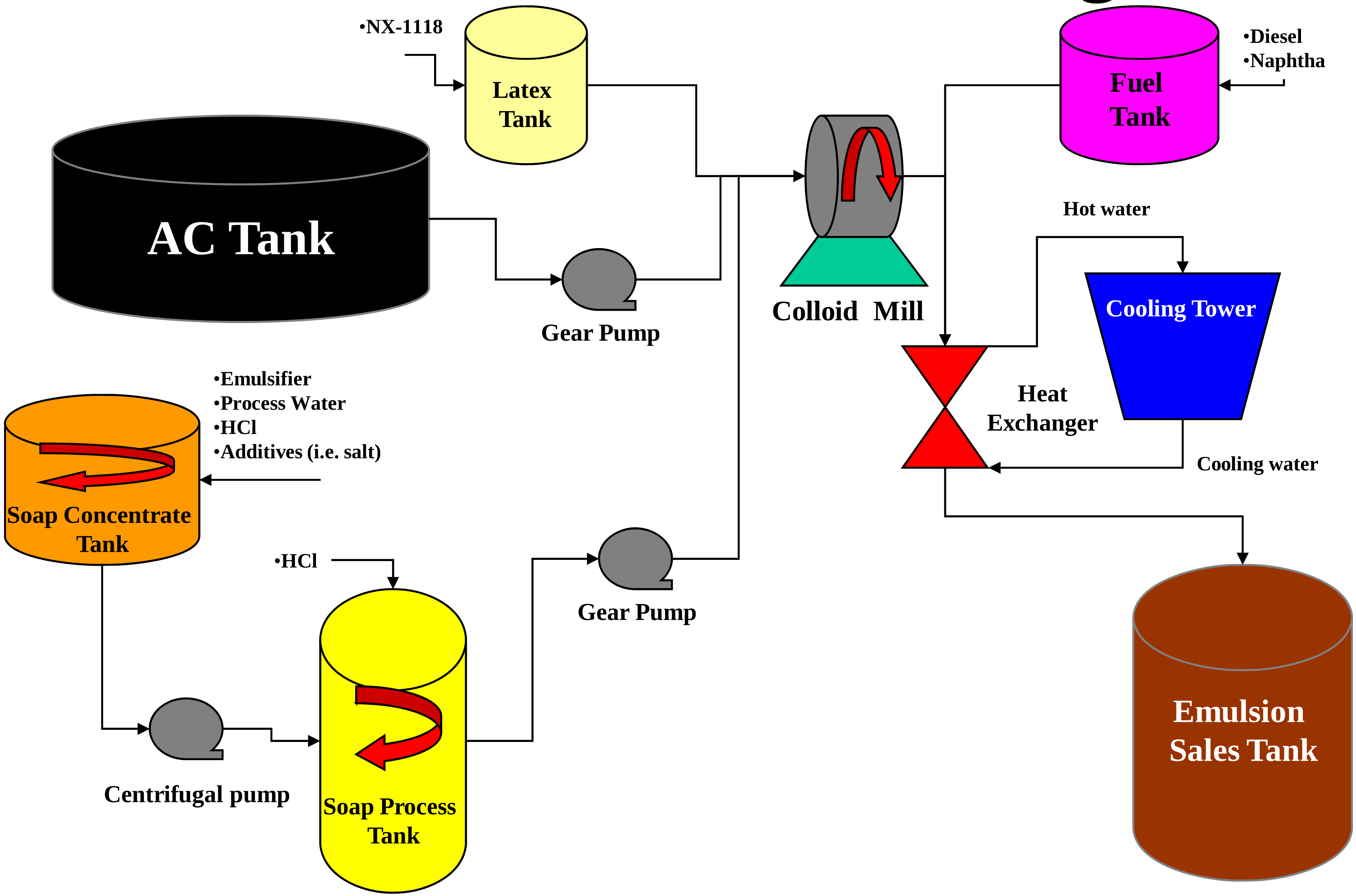


Disperse asphalt in water & chemical under high energy

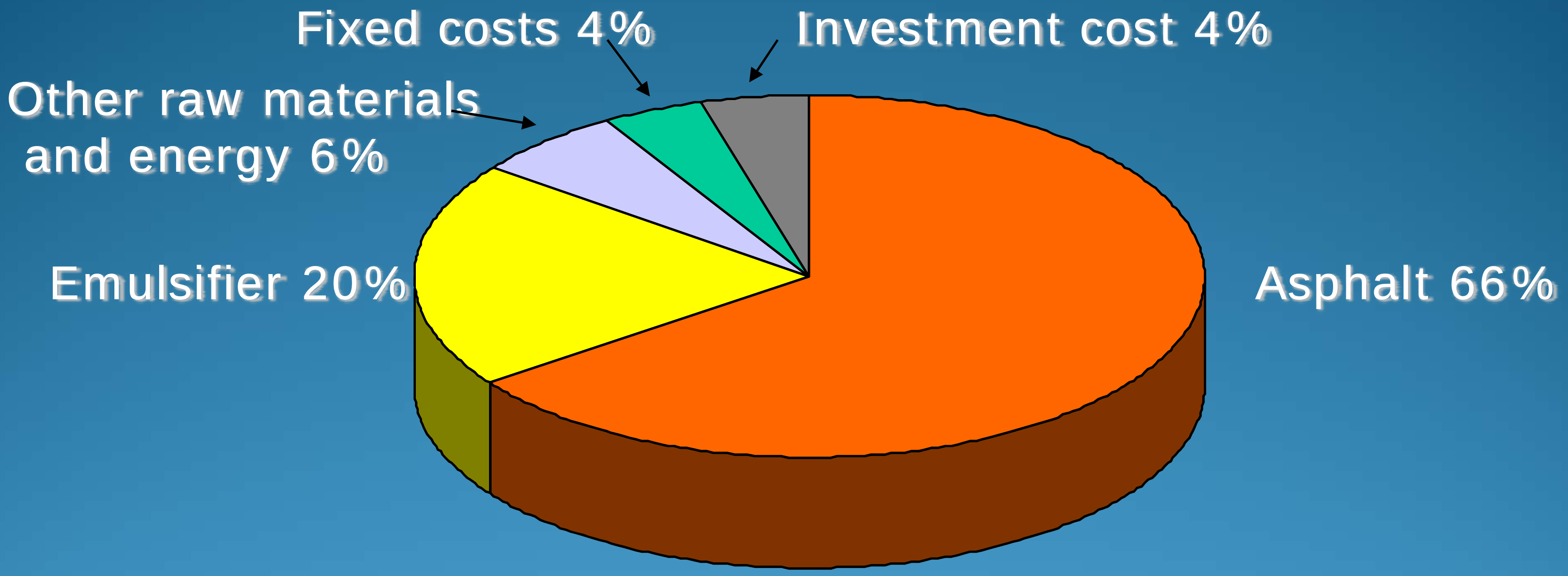




An Emulsion Process Diagram

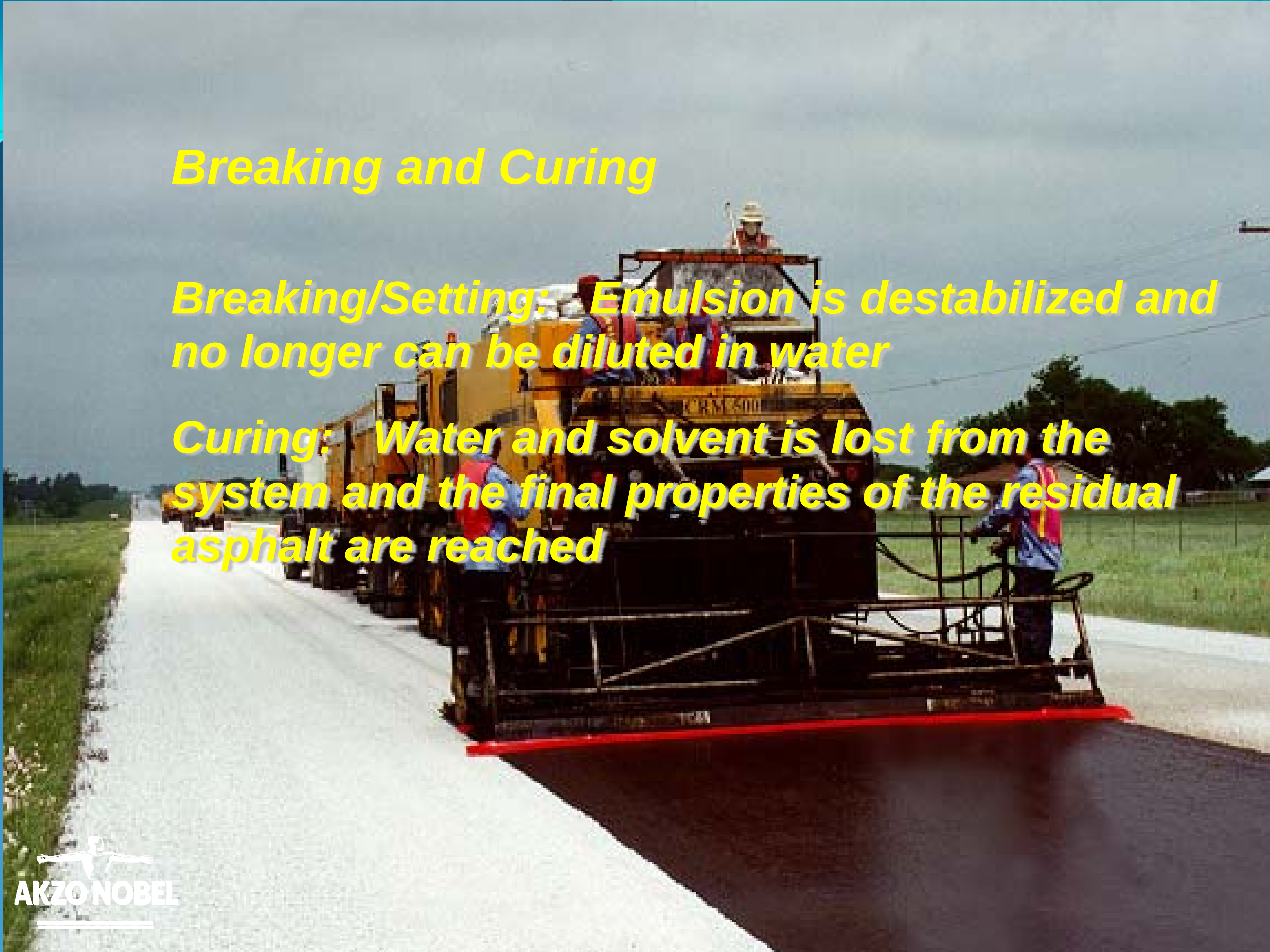


Cost Contributions per Ton of Emulsion



- Accurate flow control minimizes excess asphalt
- Inline water heating saves energy
- Innovative chemical dosage system reduces chemical waste

Setting and Curing of Asphalt Emulsions



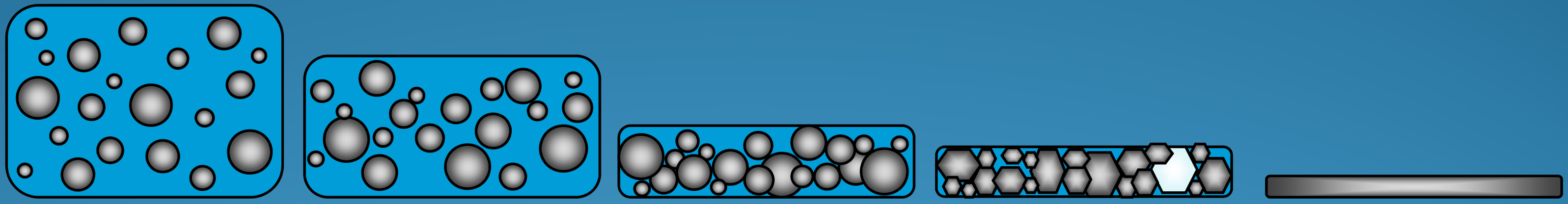
Breaking and Curing

Breaking/Setting: Emulsion is destabilized and no longer can be diluted in water

Curing: Water and solvent is lost from the system and the final properties of the residual asphalt are reached

Breakdown of the Emulsion

Evaporation of Water

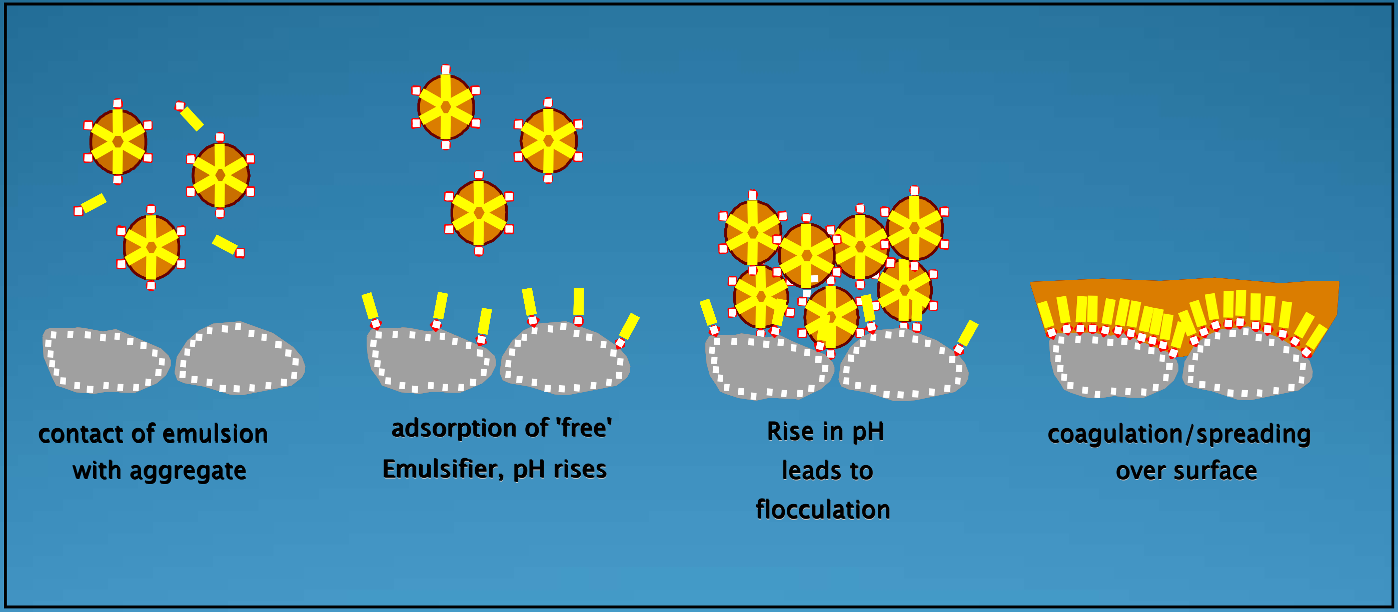


- *Evaporation of water forces droplets together and eventual coalescence*

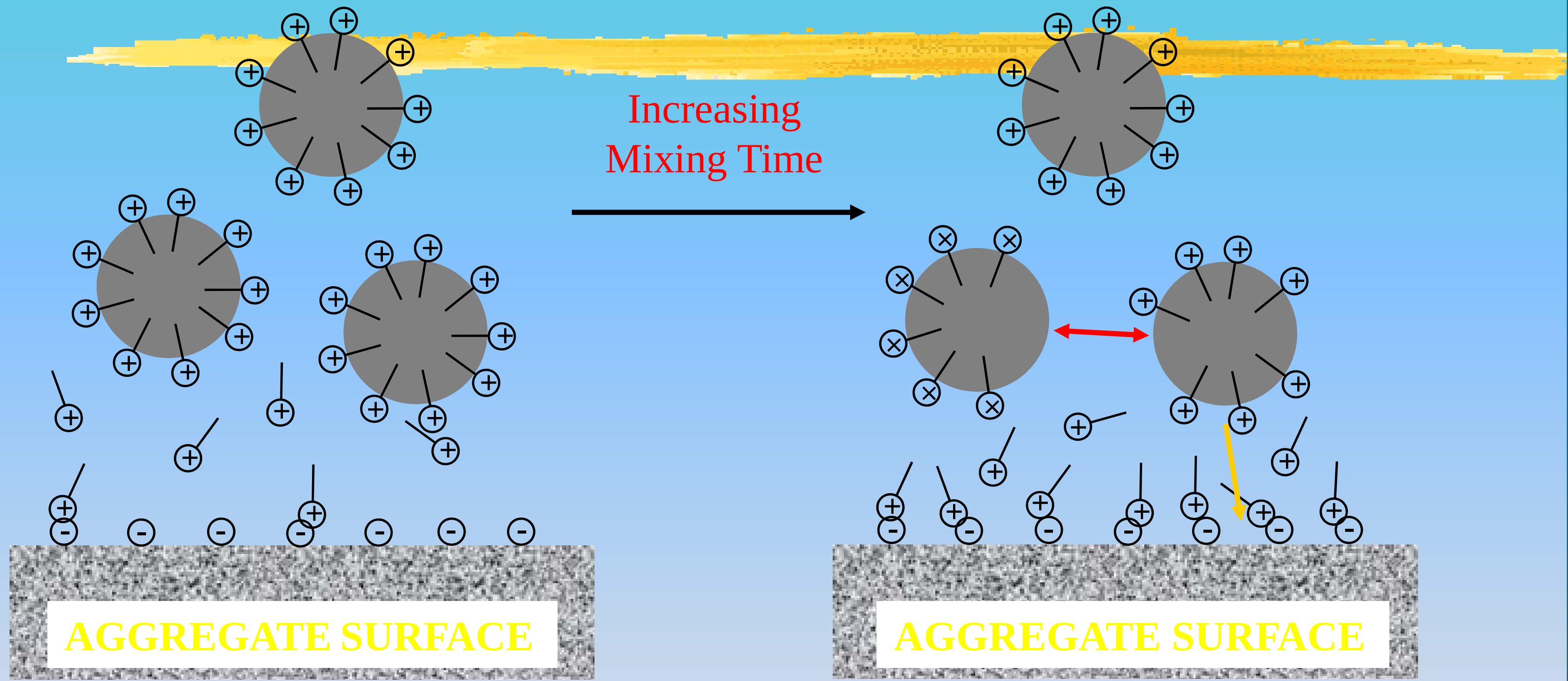
Factors Affecting Breaking and Curing

- *Aggregate reactivity*
  - *surface area, surface charge, surface chemistry*
  - *filler chemistry e.g. cement, lime*
- *Temperature, humidity, wind speed*
- *Emulsion reactivity*
  - *emulsifier chemistry, concentration*
  - *other additives*
  - *asphalt viscosity*
- *Mechanical treatment e.g. compaction*

Possible Stages in the Setting of a Cationic Asphalt Emulsion



Interaction of Cationic Emulsion with Aggregate

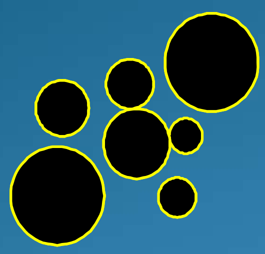


Equilibrium between interfacial and bulk emulsifier concentrations upset by introduction of charged aggregate.

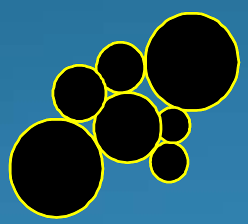
Adhesion of emulsifier to aggregate surface causes a decrease in bulk and interfacial concentrations. Droplets begin homo- and hetero-flocculation.

Breakdown of the Emulsion

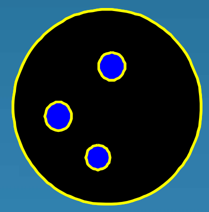
Flocculation and Coalescence



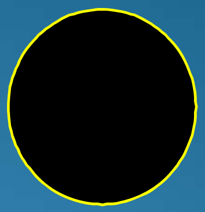
Emulsion Droplets
Charge on droplets prevents close approach



Flocculation
Close approach of droplets leads to adhesion between droplets. Water is squeezed out



Coalescence
Water drains between droplets and surfactant film breaks down, Droplets fuse, trapping some water

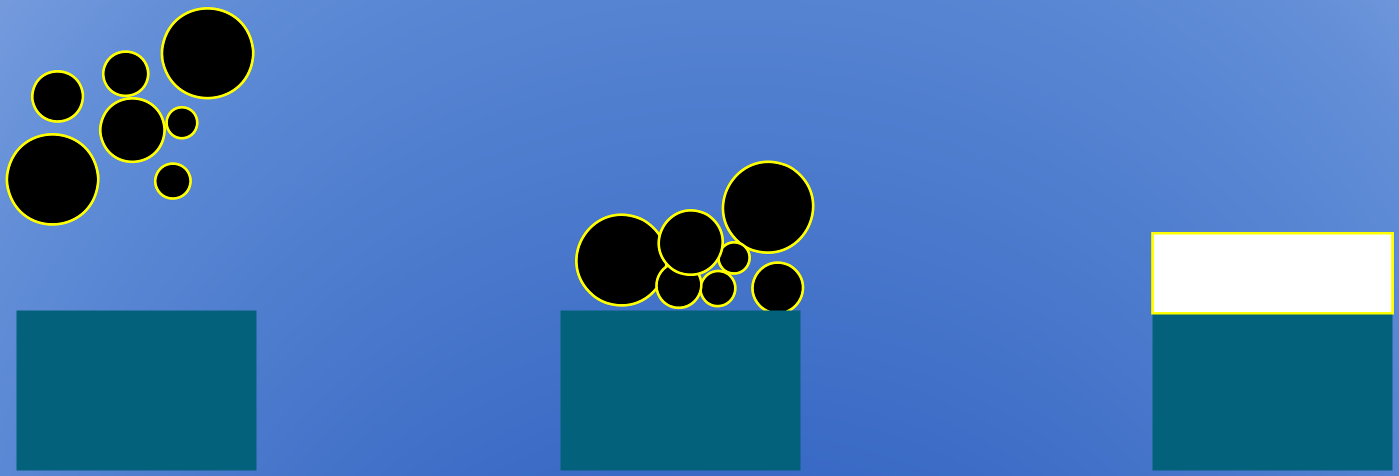


Coalescence
Trapped water diffuses out.

Setting

Curing

Breakdown of the Emulsion
Flocculation and Coalescence



- Flocculation and coalescence in contact with aggregate

What’s on the horizon for asphalt emulsion technology?

- Application of rheological type tests
- Faster curing spray seals
- Cold-pour crack sealant
- Use of emulsions for warm mix
- High residue emulsion
- Solvent free emulsions-penetrating prime coat

Studies and Resources

- Manual for Emulsion-Based Chip Seals for Pavement Preservation- NCHRP #14-7 (end:2-13-2009)
- Good Roads Cost Less: UTAH DOT Office of Research (2007)
- **Asphalt Emulsion Technology, TRB Circular, EC102, August,2006**
- **Asphalt Emulsion Technology, TRB Circular , EC-122**

Review of Asphalt Emulsion Residue Procedures, October, 2007

Basic Asphalt Emulsion Manual, AEMA & Asphalt Institute (see www.aema.org)

- Putting Fog and Rejuvenator Seals to the Test: Helen King, in BETTER ROADS , January,2008