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Review

Asphalt emulsions formulation: State-of-the-art and dependency of formulation on emulsions properties

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HIGHLIGHTS

- The properties of asphalt emulsions depend dramatically on formulation and process.
- Formulation of an asphalt emulsions depends on the final application.
- Handling and formulation of asphalt emulsions are very complex tasks.
- Industrial problems can be solved by staff with a strong background in formulation and rheology.

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ABSTRACT

Formulation of asphalt emulsions constitutes a complex task. Formulator must evaluate a series of parameters related to the emulsion properties and its application. Among these mainly parameters, one must consider the emulsion stability, viscosity (and rheological behavior), droplet size (and distribution) and other variables related to raw materials such as asphalt chemical composition, available surfactants, chemical reagents, etc. Other special considerations must also be taken into account, for example, the handling of the bitumen emulsion and the breaking process. Currently, the use of chemical additives such as asphalt or emulsion modifiers and adhesion promoters can play a significant role in the emulsion formulation. The current study aims to review the current state-of-the-art of asphalt emulsion manufacturing and also aims to provide a practical guide to improve its formulation when trying to fabricate a well-specified asphalt emulsion for its use on road infrastructure.

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1. Introduction

Asphalt emulsions can be used for any traditional hot-asphalt and cutback applications. Even they have been tested for some particular applications such as galvanic sludge and stabilization of destruction munitions wastes [1,2]. Asphalt emulsions are generally composed by 5–55 μm dispersed asphalt droplets in water [3]. Since water constitutes the continuous phase of the emulsion, the viscosity of the system exhibits a significant reduction compared to the original viscosity of asphalt. The droplets coalescence is avoided by the amphiphile molecule (surfactant), which is specially formulated to decrease the interfacial tension between asphalt and water in order to stabilize the system against coalescence and to allow the emulsification. The asphalt content can vary according to the application. However, for fabrication purposes is typically comprised between 50% and 80% (weight percentage).

Asphalt emulsion properties such as viscosity and stability depend on several variables: the continuous phase properties (salinity and pH), the water/oil ratio (WOR), the surfactant (molecular structure), the droplets size (and its distribution) and the established procedure to prepare the emulsion. Moreover, according to its further use, the main emulsion properties that must be considered are: the droplets size and droplets distribution, the emulsion stability and its rheological behavior. The emulsion viscosity is a particularly important parameter and must be set according to the pavement application. For example, a high viscosity is required when emulsion is spread over a high slope area, such as a mountainous terrain. Furthermore, a very slow viscosity is desirable for irrigation prime.

1.1. Asphalt emulsion stability

Emulsions are thermodynamically unstable systems. Nevertheless, emulsion stability is a discussable definition. This property may be determined by the rate of droplets coalescence. Then, it can be affirmed that an emulsion is more stable while slower is the droplets coalesce rate [4]. Wang et al. have proposed a laser diffraction technique to monitor asphalt emulsion stability [5] as an alternative tool to traditional storage stability test (ASTM D6933 and ASTM D-6934).

The existing mechanisms that occur during asphalt emulsion destabilization process are: droplets sedimentation, droplets flocculation and droplets coalescence. Nevertheless, the first two mechanisms are reversible and do not involve a definitive emulsion destabilization. This is what happens during emulsion storage when mechanical agitation is not provided to the system. Since density of asphalt droplets is higher than water (in most cases), they settle to the bottom of the storage vessel. As a consequence, droplets proximate to each other and even a physical contact among them can be expected to form a flocculated system. However, the original emulsion can be recovered by mechanical agitation as long as coalescence is not yet started. This final mechanism has a significant dependency on formulation.

1.2. Asphalt emulsions viscosity

In general, the viscosity of an asphalt emulsion depends on the WOR, the droplets size, the asphalt viscosity and the surfactant (chemical formulation) [6]. The WOR has an important effect on viscosity. It is reasonable to consider the droplets interactions, which are more significant as the WOR decreases (at higher asphalt concentration). When asphalt volume in emulsion is lower than 30%, the droplets interactions disappear and the rheological properties of the system are similar to those of the continuous phase (soap water). When increasing the asphalt content, droplets interaction become important, and the viscosity of the emulsion increases. This phenomenon can lead the system to exhibit a non-Newtonian behavior (shear thinning and even viscoelastic properties are usually important from an asphalt content of 60%).

Droplets size and droplets size distribution have also an important effect on emulsion viscosity. Nevertheless, it is a difficult task to control these parameters independently during the production of the emulsion. This is due to the fact that some properties such as interfacial tension, surfactant concentration and the surfactant type are all dependent parameters, e.g. interfacial tension changes when modifying the HLB of the surfactant and consequently, the droplets size, droplet size distribution and the asphalt emulsion viscosity change as well. However, it can be affirmed that emulsion viscosity increases as smaller is the average droplets size and emulsion viscosity decreases as narrower is the droplets size distribution [7].

When mixing two asphalt emulsions with the same WOR but different unimodal droplets size distributions, the resulting emulsion will exhibit a bimodal droplets distribution. If the resulting bimodal distribution presents a wide separation between the distribution modes, a significant viscosity reduction can be obtained (respect to the more viscous emulsion). This is possible considering that smaller droplets are distributed between spaces left by larger droplets, hence, droplet interactions decrease [8].

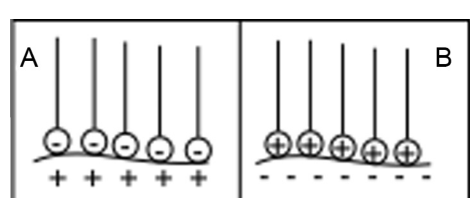

Fig. 1. A: Anionic surfactant adsorption by ionic change. B: Cationic surfactant adsorption by ionic change.

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