Asphalt Mixture Release Agent from Vegetable Oil for Environmentally Friendly, High-Performance Asphalt Pavement

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ABSTRACT: We investigated vegetable oil-based agents as a means of preventing asphalt mixture from adhering to equipment surfaces during preparation and application of asphalt paving. Until now, diesel oil has been used for that purpose. However, there is a problem with safety and environmental impact. It is known that vegetable oil is harmless to the human body and that its environmental releases have little impact due to the substance's biodegradability. In this study, we developed a product, which is a release agent based on vegetable oil and surfactant, and we verified that the diluted solution (product-to-water ration of 1 to 10) can release the asphalt mixture as efficiently as diesel oil. Moreover, it was also confirmed that this product was a better release agent in terms of asphalt quality, worker's safety and environmental safety.

KEY WORDS: Aggregate scatterings, potholes, environmental compatibility, asphalt quality, release effect.

1 INTRODUCTION

The asphalt mixture for road pavement is made by mixing an aggregate (stone, gravel and sand) with a bonding agent (asphalt). Asphalt, however, is solid in normal temperature, so it needs to be mixed under high temperature (>150˚C). It is then transported by a truck while it is still hot, and is utilized for paving work. Under this circumstance, asphalt adheres to the truck's bed, and renders the work less efficient. Therefore, diesel oil is generally used in order to prevent adhesion of asphalt mixture. However, diesel oil dissolves the asphalt serving as a bonding agent, which leads to weaker combination of asphalt mixture materials and results in more potholes and aggregate scatterings.

In this regard, the Tokyo Metropolitan Government replaced the use of diesel oil with other release agents that do not affect asphalt quality as its primary means to solve those problems since fiscal 2005 (Minegishi, 2008). Moreover, diesel oil not only harms the health of workers, but also causes soil and water pollution when released into the environment. Although the petroleum odor of newly paved asphalt roads is exempted from the requirements of the Soil Contamination Countermeasures Act of 2003, the use of release agents that may cause significant environmental impact, such as diesel oil, remains undesirable.

These days there is a demand for products that are safe and friendly to the environment. The purpose of this study is to design an effective asphalt mixture release agent which is based on vegetable oil and surfactant and to investigate its effect and performance with consideration to workers' and environmental safety.

2 PRODUCT DESIGN

2.1 Development of vegetable oil-based release agent (V-AR)

In developing the V-AR, our first concern in the product design process was environmental compatibility (worker's safety and environmental safety). Specifically, the following requirements were set out:

(1) It should use materials that do not affect asphalt quality.
(2) For both environmental and economic reasons, the product should be an emulsion-type formulation that requires less vegetable oil for its production
(3) It should not use harmful surfactants.

Typically, preparation of a stable vegetable oil emulsion requires the adjustment of specific gravity and viscosity, followed by a robust mixing process using a homomixer or similar device. Additionally, distribution of a substance in the emulsion state requires the use of preservatives. Furthermore, the bulky packaging required to ship such materials incurs a significant environmental impact during distribution. For these reasons, we concluded that the design of a product in the emulsion state was inappropriate and opted instead to design a formulation that would be diluted 10 times with water at the time of use. We finalized the product specifications with the goal of creating an emulsion that could be prepared easily without the use of separate equipment and that would offer emulsion stability for half a day (Takayanagi and Imamura, 2003).

2.2 Selection of vegetable oil

Vegetable oil is produced by extracting oils contained in plant matter. Therefore, it is theoretically possible that any plant variety containing oil could serve as the raw material in the production of vegetable oil. Soybean, rapeseed, sunflower seeds, peanut, linseed, sesame seeds, the palm, the olive, etc. are widely used as the raw material in vegetable oil production. Each vegetable oil differs in fatty acids composition by the origin, which determines a given vegetable oil's chemical properties.

Eventually, we selected soybean oil and rapeseed oil as main vegetable oil sources, because their stability in normal temperature is relatively high, and supply and price conditions are manageable.

3 ENVIRONMENTAL SAFETY TEST

Because V-AR is an asphalt mixture release agent made by mixing vegetable oil with a very safe surfactant, it exhibits a high level of environmental safety, a fact that is borne out by its certification as an Eco Mark Product in the Biodegradable Lubricating Oil product category under the standards of the Japan Environment Association (certification number: 01110013). Below is a summary of biodegradability test and ecological effect test results.

3.1 Biodegradability test

Test method: OECD (Organization for Economic Co-operation and Development) Guidelines for the Testing of Chemicals, 301c

Eco Mark certification standard: Biodegradability of at least 60% within 28 days

Result: 80%

3.2 Ecological effect test (acute toxicity test using killifish)

Measurement method: Acute toxicity test using killifish measured according to the OECD 203 method

Eco Mark certification standard: 96-hour LC50 (median lethal concentration) value of 100 mg/L or greater

Result: All fish survived, even at concentrations of 1,000 mg/L, or 10 times the certification standard level

3.3 Germination test of white radish sprouts

We investigated the effect of V-AR on plant germination using white radish sprouts by spreading tissue paper on a glass Petri dish with a diameter of 90 mm, adding a solution obtained by diluting 1 gram of V-AR with water in a 1:10 ratio, and placing 20 white radish sprout seeds in the dish. Then, the germination state was checked after the dish had been left in a darkened room for 7 days. For comparison purposes, the same experiment was performed with water, a diluted petroleum-based emulsion release agent (1:10), and a diluted surfactant-based release agent (1:10).

Seeds exposed to V-AR germinated and grew to the same extent as those exposed to water, while seeds exposed to the petroleum-based emulsion release agent and surfactant-based release agent germinated but did not grow.

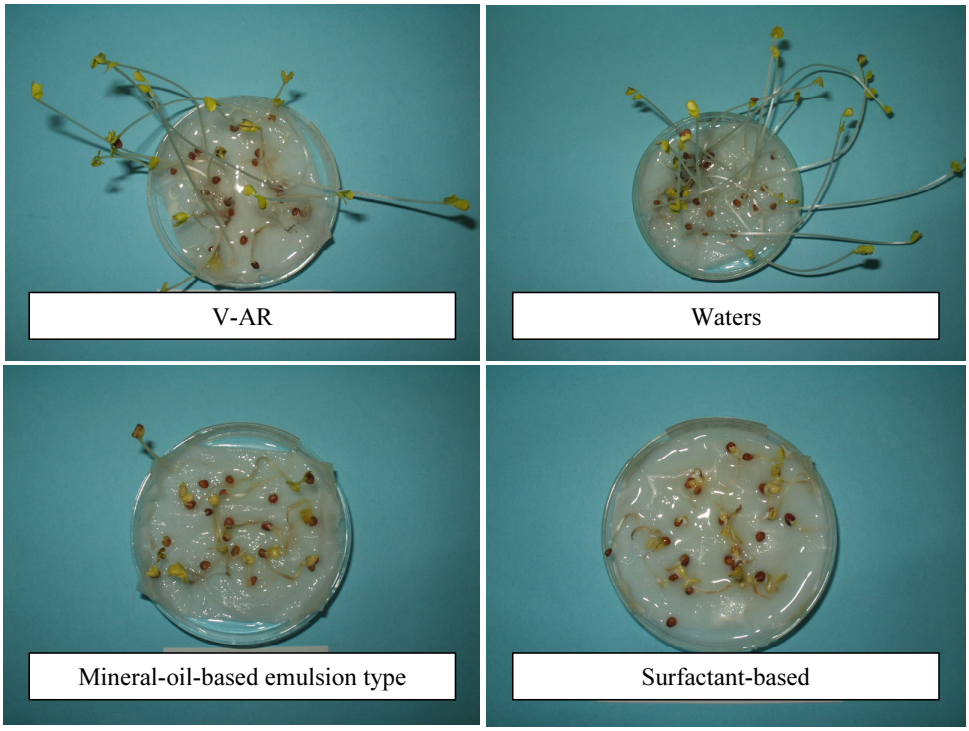

Figure 1: The result of germination test of white radish sprouts.

4 SAFETY OF V-AR

The flash point of V-AR is more than 279˚C, and its level of safety is high compared with the diesel oil whose flash point is 45-110˚C. Moreover, the danger of explosion or ignition at the time of use is minimum, since it is a product diluted 10 times with water.

5 ASPHALT SOLUBILITY TEST

We investigated the solubility of asphalt mixture. Five hundred grams of asphalt mixture was transferred into 500ml of diluted V-AR (1:10) and diesel oil, and they were left to settle at normal temperature for 1 hour. The mixtures were sifted by 1mm sieve, the amount of the sieve residue was measured, and dissolution rate was calculated by the following equation.

$$Dissolution\ rate\ (\%) = \frac{Input\ (g) - Sieve\ Residue\ (g)}{Input\ (g)} \times 100 \quad (1)$$

Tests employing hexane and water were also carried out as controls.

The dissolution rate of V-AR was the same as that of water; the dissolution rates were -3.8% and -3.9%, respectively. The reason why the value has become zero or less is that water and V-AR's diluted solution remained in sieve residues. Diesel oil exhibited the dissolution rate similar to hexane; 36.5% and 37.7%, respectively. Although not shown in the data, the asphalt mixture contained 0.5% of volatile component, 2.5% of hexane soluble component, 35% of sand sized 1mm or smaller, and 62% of gravel sized 1mm or larger. Therefore, this dissolution rate is configured by the component dissolved in hexane or diesel oil, and the sand sized 1mm or smaller.

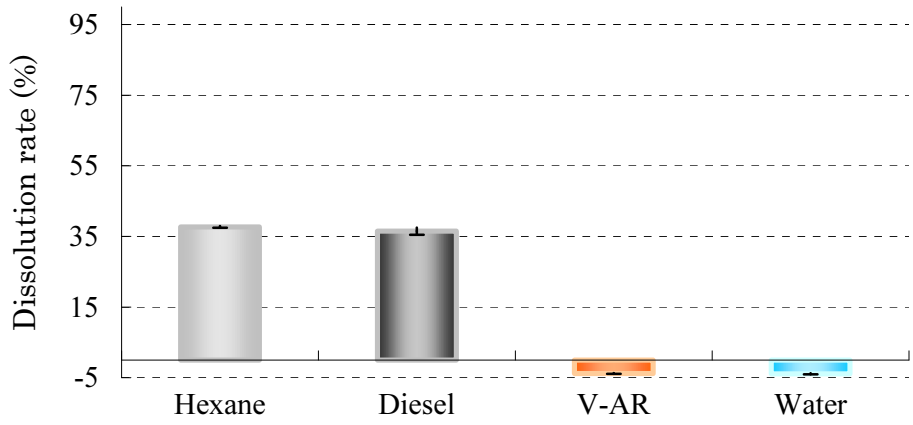

Figure 2: The result of asphalt solubility test

We verified that diluted V-AR did not affect the quality of the asphalt by soaking asphalt mixture in diluted V-AR and diesel oil at room temperature. While the diesel oil had dissolved the asphalt coating after 1 hour, V-AR exhibited no visible effect on the asphalt coating, even after 24 hours.

Figure 3: The effects of V-AR and diesel oil on asphalt

These results showed that diluted V-AR does not possess an ability to dissolve asphalt. Next, we investigated the release effect of asphalt mixture.

6 RELEASE EFFECT TEST

V-AR's release effect of asphalt mixture was investigated. Diluted V-AR (1:10) and diesel oil were spread on metal trays, on which the asphalt mixture heated at 150˚C for 30 minutes was placed. After 1 hour, the tray was flipped to remove the asphalt mixture. A tray with no spread was also used as a control.

Both V-AR and diesel oil did not show adhesion of asphalt mixture. The diesel oil, however, dissolved and left the asphalt component on the tray. On the other hand, the no-spread control showed leftover asphalt mixture.

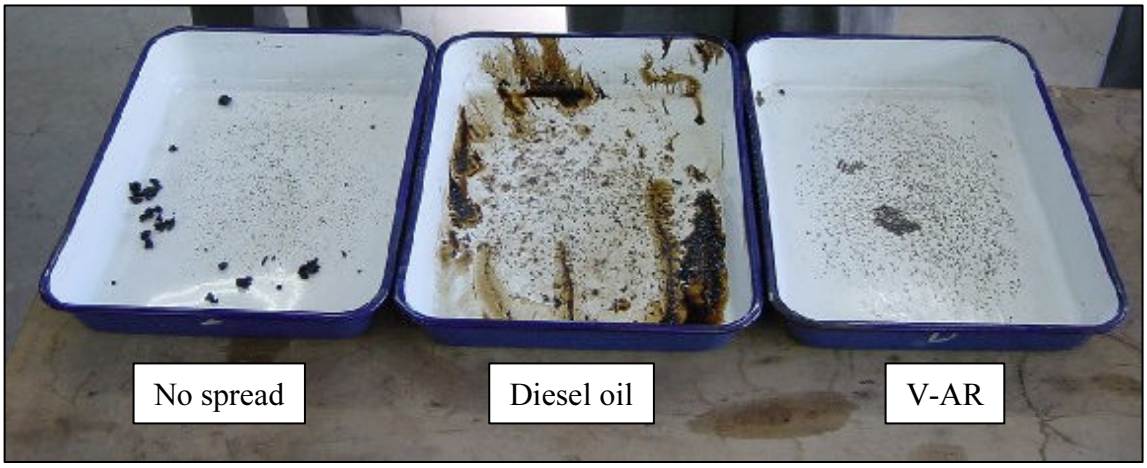

Fig 4: The result of release effect of asphalt mixture

7 TRACK RECORD AND EVALUATION OF V-AR

V-AR has a well-established track record of successful use, primarily in expressway paving. In Tokyo, the use of diesel oil during asphalt mixture transport and application has been focused on as the principal cause of potholes and aggregate scatterings in asphalt pavement. As the result of a model evaluation, investigators verified that the use of V-AR delayed the onset of pothole formation by a factor of 4 compared to diesel oil (Minegishi, 2003).

8 CONCLUSION

It was shown that V-AR is an environmental friendly product in the biodegradation test, the ecological effect test, and the germination test of white radish sprouts. Moreover, V-AR diluted 10 times with water did not dissolve asphalt, and also had a release effect. These results also demonstrated that V-AR is an effective release agent for asphalt mixture excellent in environmental compatibility. We believed that widespread adoption of vegetable oil-based asphalt mixture release agent would improve asphalt pavement quality while contributing to the preservation of the global environment.

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