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Application of Pull-off Test for Evaluating Bond Strength Properties of Modified Bitumen Emulsions

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ABSTRACT: Reduced adhesion properties between aggregate particles and bitumen binders, and reduced cohesion within the bitumen binders in asphalt mixes result in stripping and segregation distresses in road pavements. These will ultimately result in pothole formation and other severe distress in pavements. In this research, with the aim of determination of adhesion and cohesion properties between aggregate particles and bitumen binders, the pull-off testing method, which is commonly used in characterizing road marking materials, was used to determine tensile strength values that are created between aggregate particles and bitumen emulsions. Two conventional cationic bitumen emulsions of rapid and medium breaking types were used as control binders. These were then modified using a latex liquid additive at various percentages. Two aggregate types were used, namely granite and a dolomite type. Their mineralogy was determined using the XRF testing method. In addition, the role of other parameters, such as curing time and curing temperature, were determined too. Pull-off testing results showed that modification of bitumen emulsions with %3 latex provided increased adhesion properties and increased durability between bitumen emulsion and the two aggregate types that were selected in this research. It has also resulted that interaction between aggregate particles and the bitumen emulsions was great where latex modified bitumen emulsions were used. By comparing the role of the two aggregate types, it resulted that the dolomite aggregates provided superior adhesion properties. It was concluded that the role of curing time and temperature were dominant in providing adequate adhesion properties between bitumen emulsions and aggregate particles. The increase was more dominant in samples containing latex-modified bitumen emulsions.

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1- Introduction

One of the most important parameters in selecting bitumen emulsions for asphalt cold mixes is making sure that adequate adhesion is formed between aggregate particles and the bitumen binder. Reduced adhesion could result in several failure mechanisms, such as adsorption of bitumen emulsion into aggregates surface pores, change in pH values of bitumen emulsion once it is in contact with aggregates, and reduced water of the bitumen emulsion as it is adsorbed by aggregate particles [1]. Parameters such as bitumen emulsion type, aggregate mineral source, weather conditions and traffic loads are also among the factors that affect the adhesion resistance of bitumen emulsion [2]. Various standard testing methods have been proposed to test asphalt mixes, but little provides data with regard to the performance characteristics of mixes [3]. Pneumatic Adhesion Tensile Testing Instrument (PATTI) has been used to evaluate adhesion resistance and tensile strength characteristics of aggregate-bitumen combinations and adhesion properties of bitumen. The testing process in that Bitumen Bond Strength (BBS) is determined is described in AASHTO 91-11 Standard Method [4].

2- Methodology

Two aggregate types (granite and dolomite) from two different sources were used for preparing asphalt cold mixes. Granite is an acidic aggregate and in contrast, dolomite contains high percentages of calcium oxide. In cold mixes, the adhesiveness of aggregate particles to bitumen is highly dependent on the aggregate type and the selected bitumen emulsion properties. In this regard, there is a clear difference between the behavior of acidic and alkaline aggregates in mixes. Composition analysis of the aggregates was obtained by applying X-Ray Fluorescence (XRF) testing. Two bitumen emulsions, namely slow and rapid breaking cationic bitumen emulsions, were used to prepare two control cold mixes. These were then modified using Styrene Butadiene Rubber (SBR) latex and a Veloce Rubber. According to ASTM D6372, the minimum percentage of polymer in emulsion mixtures is 3%. This provides enhanced properties to the mix while will not affect much the construction processing phases. Based on this

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Fig. 1. Pull of Posi Test AT-A apparatus

concept, the above two additives were applied at the rate of %3 by weight of the retained binder from the emulsion. This amount provided appropriate homogeneity and consistency to the two modified bitumen emulsions. The SBR latex was consisted of %65 solid granules and had an acidity level of pH=5. With this composition and the above procedure, the modified bitumen emulsion was consistent and had similar consistencies to the control bitumen emulsions.

The amount of emulsion bitumen required inside the silicon is calculated from Equation (1) below:

$$EA(g) = \frac{0.45}{AC(\%)} \quad (1)$$

In this Equation, AC is the percentage of bitumen in the emulsion bitumen and EA is the weight of the emulsion bitumen that is poured into each of the silicone molds. In the next step, the aggregate plates, silicon and emulsion bitumen should be stored in the oven to perform the curing process. The temperature conditions selected in this study were 20 and 40 degrees Celsius, which was selected in accordance with the usual environmental conditions. The curing time of the samples was 1, 3 and 24 hours, respectively, because according to ISSA TB 109, the fast-setting time for reopening traffic in 60 minutes and achieving a minimum torsion of 20 kg.cm is done. Figure 1 shows how to perform the tensile strength test with the Posi Test AT-A automatic device. The piston chassis is pulled back and placed on the steering surface. By applying a slight force to the handle, the device is locked and ready to start the test. The test temperature is 25 degrees Celsius.

Interpretation and analysis of the surface failure of bitumen samples were performed by observation with the naked eye and digital photography analysis. Failure between bitumen and aggregate can occur in different ways. One is the failure inside the bitumen and the other is occurred between the bitumen and the surface of the aggregate. To analyze the failure of the surface of emulsion bitumen samples, if the bitumen remains completely on the surface of the aggregate, failure has occurred inside the bitumen. If the bitumen is completely separated from the surface of the aggregate, a failure has occurred between the bitumen and the surface of the aggregate. A third case may occur in which the bitumen is incompletely separated from the Aggregate surface. Using Image J software, it is possible to detect the type of surface rupture.

3- Results and Discussion

In this study, to evaluate the adhesion resistance of emulsion bitumen and aggregates, 288 samples were stretched and removed. According to the AASHTO standard, tensile strength test and removal of emulsion bitumen from the aggregate surface in dry conditions were performed. The bond strength of granite was more rapid than that of dolomite. Despite the rapid setting of emulsion bitumen on granite at processing times of 1 and 3 hours, the highest strength was obtained in dolomitic ore. The results of tensile and tensile strength tests in emulsion and aggregate bitumen system showed that at two temperatures of 20 and 40°C, the adhesion resistance of quick-breaking emulsion bitumen and modified quick-breaking emulsion bitumen on dolomite aggregate compared to granite 9% and 10%, respectively Increased. Also, at 20 and 40°C, the adhesion resistance of bitumen emulsion and modified bitumen in modified dolomitic aggregate increased by 30% and 10%, respectively, compared to granite.

Due to the XRF test results of dolomite aggregate and its high calcium oxide content, this aggregate has a playful property and is hydrophobic and aspheric. This is one of the reasons for its superior adhesion resistance to dolomitic aggregates after the final setting of emulsion bitumen. This finding is in good agreement with the results of previous research in this field. It has also been observed in previous studies that the adhesion strength of bitumen to aggregate, as far as it is related to aggregate, in addition to being acidic or alkaline, also depends on the aggregate material and its surface texture [5].

Modification of emulsion bitumen by adding SBR rubber latex increased the adhesion resistance compared to unmodified emulsion bitumen. This increase in bitumen emulsion was more rapid than that of slurry emulsion. The results showed that with the addition of 3% SBR rubber, the adhesion resistance between dolomite and bitumen emulsion at 20 and 40°C increased by 13% and 16%, respectively, and in bitumen emulsion increased by 3% and 5%, respectively. Also, the adhesion resistance between granite aggregate and bitumen emulsion at 20 and 40 ° C increased by 13% and 14%, respectively, and in bitumen emulsion increased by 2% and 3%, respectively. The results obtained from the tensile and tensile strength tests with two types of bitumen and quick-breaking emulsion bitumen show that in the bitumen and aggregate system, the adhesion resistance in bitumen-breaking emulsion bitumen was higher than that of bituminous emulsion. This increase in adhesion resistance in pure emulsion bitumen and dolomite-modified emulsion bitumen systems showed a final 3% and 14.5% increase in final emulsion bitumen involvement. Also, the bond strength of pure emulsion bitumen and latex-modified emulsion bitumen

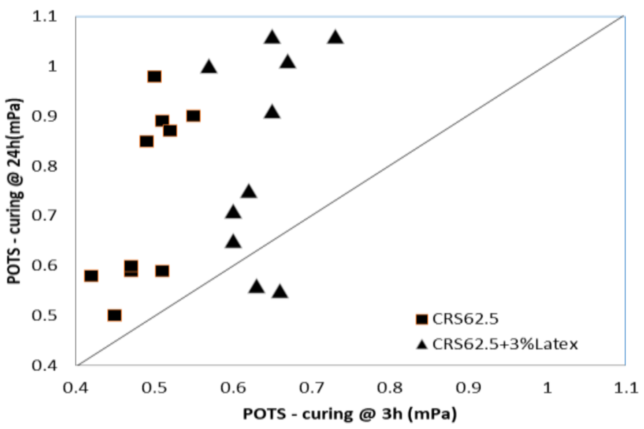

Fig.2. Effect of curing time on POTS values for CRS emulsion

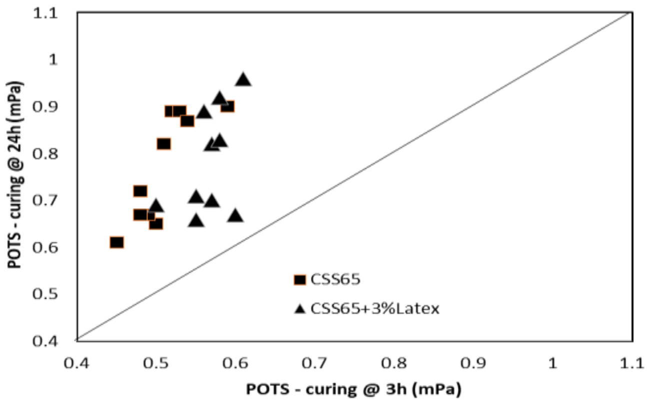

Fig. 3. Effect of curing time on POTS values for CSS emulsion

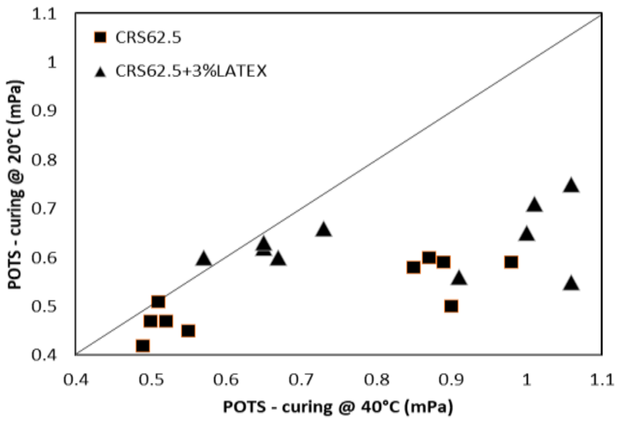

Fig. 4. Effect of temperature on POTS values for CRS emulsion

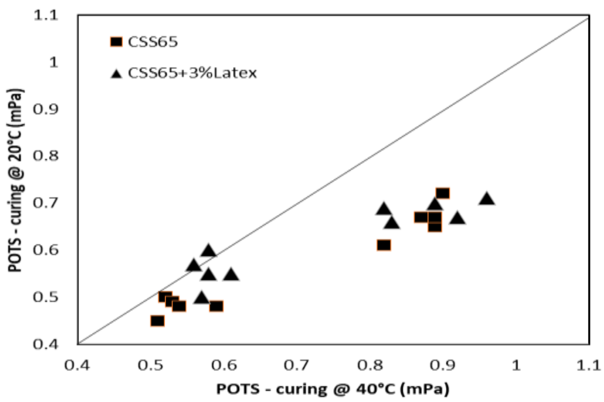

Fig. 5. Effect of temperature on POTS values for CSS emulsion

on granite in the final setting of emulsion bitumen increased by 3% and 15%, respectively. The obtained results show the superiority of adhesion resistance of bituminous emulsion over bituminous emulsion. The degree of this superiority was slight in pure emulsion bitumen but significant in modified emulsion bitumen. Figures2 and 3 show the diagrams of the effect of curing time of 3 and 24 hours on the adhesion resistance of bitumen, brittle and modified emulsion of these families. Figure 2 shows that 18 of the 20 available data are located above the equilibrium line. Therefore, increasing the curing time in quick-breaking emulsion bitumen and modified emulsion bitumen has increased the adhesion resistance. Figure 3 also shows that all 20 available data are above the equilibrium line. Therefore, increasing the curing time in bitumen emulsion and its modified emulsion bitumen has increased the adhesion resistance. According to the obtained results, it can be concluded that there is a direct relationship between increasing the adhesion resistance of emulsion bitumen and increasing the curing time.

Figures 4 and 5 show the effect of curing temperatures of 20 and 40°C on the adhesion strength of bitumen, brittle and modified emulsion bitumen's. Figure 4 shows that 18 of the 20 data were below the equilibrium line. The results show that with increasing the curing temperature up to 40°C, the bond strength between bitumen emulsion with dolomite and granite has increased by 53% and 57%, respectively. Also, the bond strength between the bitumen of the quick-breaking emulsion modified with two dolomite and granite aggregates has increased by 54% and 57%, respectively. Therefore, increasing the curing temperature in bitumen emulsion and its modified emulsion bitumen has increased the adhesion resistance. Figure 5 shows that 18 of the 20 data are below the equilibrium line. With increasing the curing temperature up to 40 ° C, the adhesion resistance between bitumen emulsion bitumen with dolomite and granite aggregates has increased by 7% and 33%, respectively. Also, the adhesion resistance of bitumen-modified emulsion bitumen with dolomite and granite aggregates has increased by 9% and 29%, respectively. Therefore, increasing the curing temperature in slow emulsion bitumen and modified emulsion bitumen has increased the adhesion resistance. According to the obtained results, it can be concluded that increasing the adhesion resistance of emulsion bitumen's is directly related to increasing the processing temperature.

4- Conclusions

The performing tensile and tensile strength tests on samples of emulsion bitumen modified with rubber latex and selecting two types of dolomitic and granite aggregate materials were concluded:

• Increasing the curing time of emulsion bitumen increased the bond strength of bitumen. Considering the appropriate time for setting and processing of emulsion bitumen's was one of the important factors in obtaining quality asphalt pavement.

• Due to the acidity of granite obtained from the results of the XRF test, the bond strength between bitumen and granite aggregate in the first hours of the test was higher than the adhesion resistance of dolomite aggregate. Therefore, in routes that require immediate opening of the road after maintenance, it is important to pay attention to the type and origin of the stone and identify its components.

• As the emulsion bitumen curing temperature increased, the setting between the bitumen and the aggregate occurred faster and yielded positive results for all samples. Therefore, in cold regions, emulsion bitumen will break later and the reopening of the road will be delayed, so when using emulsion bitumen, the ambient temperature conditions should be considered.

• Modification of emulsion bitumen with 3% SBR rubber increased the adhesion resistance between emulsion bitumen and aggregate. The rate of increase in adhesion resistance of modified emulsion bitumen depended on the type of emulsion bitumen and the highest increase in adhesion resistance was obtained in modified early emulsion bitumen.

Comparison of adhesion performance of cationic and slippery cation emulsion bitumen's by Pull-off test showed that the adhesive strength of bitumen emulsion was higher. Slow-breaking cationic emulsion bitumen required more time to fully set between the curing times studied.

References

[1] A. James, Overview of asphalt emulsion, Transportation Research Circular E-C102: Asphalt Emulsion Technology, (2006) 1-15.

[2] F. Canestrari, F. Cardone, A. Graziani, F.A. Santagata, H.U. Bahia, Adhesive and cohesive properties of asphalt-aggregate systems subjected to moisture damage, Road Materials and Pavement Design, 11(sup1) (2010) 11-32.

[3] B. Shell, Shell Bitumen Handbook, England, UK, 2003.

[4] K. Kanitpong, H.U. Bahia, Role of adhesion and thin film tackiness of asphalt binders in moisture damage of HMA (with discussion), Journal of the Association of Asphalt Paving Technologists, 72 (2003).

[5] K. Louw, K. Spence, P. Kuun, The use of bitumen emulsions as a cost effective solution for constructing seals during winter, in: Proc., 8th Conference on Asphalt Pavements for Southern Africa (CAPSA), Sun City, South Africa, 2004.

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