Journal of Ferdowsi Civil Engineering, Vol.32, No.3, 2019.

Evaluating Moisture Damage of Crystalline Calcium Carbonate Modified Asphalt Mixtures

Gholam Hossein Hamedi[1] Mohsen Sohrabi[2]

1. Introduction

Researchers are currently using new approaches such as the use of the concepts of surface free energy (adhesion and bonding energies) that overcome the shortcomings of conventional experiments. These approaches can identify the mechanism of moisture damage and the influence of various factors such as bitumen and aggregate properties and additives on moisture failure. As a result, it is possible to predict the likelihood of these failures and to propose suitable solutions to reduce moisture damage at the time of mixing design. Therefore, the main goals of the present study can be categorized as:

- Measurement of surface free energy components of basic and modified calcium carbonate powder samples;
- Identifying the effect of aggregate modification on increasing adhesion energy and decreasing detachment energy;
- Investigation of the effect of aggregate surface modification on moisture sensitivity of asphalt mixtures by mechanical methods.

2. Laboratory program

In mechanical experiments, the mixing scheme will first be performed by the Marshall method. Subsequently, the moisture sensitivity test is performed on modified and controlled samples using the modified Lottman method to investigate the effect of using calcium carbonate coating on the aggregate surface.

In thermodynamic experiments, the surface free energy components of bitumen and aggregates are measured using the Wilhelm plate method and the USD device. Then, using the thermodynamic relationships, the free energy parameters of bitumen-aggregate adhesion and detachment energy in the presence of water are calculated to investigate the effect of using aggregate coating.

Modified Lottman test is the most common used laboratory method for evaluating the moisture failure of mixtures in which a horizontal cylindrical specimen is subjected to vertical loading. This loading causes tensile stress along its diameter, resulting in cracking and breakage of the specimen in wet and dry conditions. Indirect tensile strength ratio in wet to dry states gives the index of indirect tensile strength which is an index of moisture sensitivity in asphalt mixtures.

3. Results and Discussion

The results show that the surface modification of aggregates decreased and increased the acidic and base components of all three types of aggregates, respectively. Since bitumen is known as an acidic substance, playing with the aggregate creates better adhesion between the bitumen and the acidic aggregate. In addition, the results show that the modified aggregates have less polar components than the base samples. According to previous studies, the polarity of the aggregates indicates a high percentage of silicon dioxide in them.

According to the following table, the TSR ratio of the specimens also decreased with the increase of ice and thaw cycles. It can be seen that the use of micronized calcium carbonate anti-stripping additive has improved the resistance of the modified asphalt mixtures to the control samples. This ratio is higher for base and modified calcareous aggregates. In other words, calcareous aggregates have the highest resistance to moisture damage, while quartzite aggregates have the least resistance.

It is clear from the values in the Table 1that the surface modification of all aggregates in a wet state has a positive effect, resulting in an increase in the indirect tensile strength ratio. This increase in indirect tensile strength may be due to improved adhesion in the modified specimens. Due to the fact that calcium carbonate particles have alkaline (gamma) properties, its use has been able to increase the adhesion between bitumen and aggregates, especially acidic quartzite aggregates. In the five cycles of freezing and thawing TSR has increased by 26.10%. is. So that in five freeze-thaw cycles this ratio has a 26.10% increase in strength. It can be seen from Figure 5 that the adhesion energy between bitumen and quartzite aggregates is lower than that of granite and calcareous aggregates, which may be due to the acidic properties of quartzite aggregates.

The application of calcium carbonate coatings on calcareous aggregates increased bitumen-aggregate adhesion in the mixtures, but the modification of the granite and quartzite aggregates did not increase bitumen-aggregate adhesion energy of the mixtures. Rather, it reduced adhesion (to a small extent) in the dry state for granite aggregates. This may be due to a decrease in the surface area of the modified aggregates compared to the base aggregates. The detachment

[1] Corresponding Author: Assistant Professor, University of Guilan, Rasht, Iran
Email Address: hamedi@guilan.ac.ir
[2] MSC Graduated, Urmia University, Urmia, Iran

energy parameter is another important consideration that must be taken into account when assessing the moisture damage of asphalt mixtures. This parameter is equivalent to the adhesion energy between bitumen and aggregate in the presence of water. Its values can be calculated using the free energy components of bitumen, aggregate and water adhesion and debonding energy relation. Calculations show that the separation energy is negative in the presence of water. This means that all asphalt mixtures will become bare in the presence of moisture, but the intensity and velocity of this phenomenon will vary. The lower the negative energy value, the greater the amount of energy released by the reaction of bitumen and aggregate in the presence of water (stripping). Mixture with more negative debonding energy is more susceptible to moisture failure. That is, when water enters the bitumen and aggregate system, the mixture becomes unstable and will release energy to reach steady state. Therefore, the process of separating aggregates and bitumen in the presence of water is spontaneous. It should be noted that for the ease of analysis, the absolute magnitude of the separation energy is included in this study.

4. Conclusion

This study was conducted to evaluate the effect of using micronized calcium carbonate to cover and modify the surface of aggregates for reducing the moisture damage of asphalt mixtures. In this regard, two different mechanical and thermodynamic methods were used to evaluate the mixtures. In addition to assessing the moisture sensitivity of the base and modified mixtures, the mechanism of damage and the effect of the additive were evaluated.

The most important results of the above experiments are as below:

1. Modification of aggregate surface with micronized calcium carbonate powder increases TSR values and indirect tensile strength (ITS) of specimens made in wet state.
2. The use of calcium carbonate coating has reduced free surface energy of all the aggregates used. The reduction in total free surface energy increases the coating's ability to bind and bind to aggregates.
3. Calcium carbonate coatings by altering the acid component and aggregate play, increased adhesion between bitumen (which is an acidic substance) and aggregates. 4. Calcium carbonate has reduced the polar components of aggregates. This increases the friendliness of the oil and reduces the tendency for the aggregates to become more polarized like water. The surface coverage of aggregates increases the non-polar components for calcareous and granite aggregates, but for the quartzite aggregates the content of this component is reduced.
5. The use of calcium carbonate coating on calcareous aggregates has increased bitumen-aggregate adhesion in the mixtures. Regarding granite and quartzite aggregates, it did not affect the adhesion energy between bitumen-aggregates for mixtures but decreased the amount of adhesion for granite aggregates (to a small extent) in the dry state.
6. The use of hydrophobic coating of calcium carbonate reduces the amount of separation energy of the samples. This makes the bitumen-aggregate system more thermodynamically stable and decreases the severity of the stripping event.
7. The results of the two methods show a good correlation between the mechanical and thermodynamic method

Table 1. TSR values of control and modified asphalt mixtures

Asphalt mixtures	Control Limestone	Modified Limestone	Control Granite	Modified Granite	Control Quartzite	Modified Quartzite
1 cycle	84	87	73	63	74	72
3 Cycles	73	79	60	50	64	60
5 Cycles	59	68	48	34	49	46

.