Research Article
Volume 13:3, 2023

Journal of Civil & Environmental Engineering

ISSN: 2165-784X Open Access

Investigating the Effect of Viatop Plus AD 10 Fiber on Moisture Sensitivity and Potential Asphalt Drain down from Stone Mastic Asphalt Mixtures

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Abstract

Because of the gapping in their gradation and the high bitumen content, the SMA have a high potential of asphalt drain down. Using cellulosic fibers is one of the solutions for this problem. To conduct the study, 38 Marshall non-fibrous samples containing 0.3, 0.4, 0.5, 0.6 and 0.7 weight percentage mixtures of Viatop plus were designed and prepared by Marshall design method. Based on the results, use of 0.5% of fibers with an optimum asphalt content of 6.85% is the optimum amount of fiber used to prevent asphalt drain down. In addition to decreasing the drain down rate below the range determined in the relevant regulations, The Marshall quotient index experienced a maximum amount of 296.66 kg/mm and shows a growth of 22% comparing to non-fibrous samples. However, with increasing amount of fiber, in spite of decreasing asphalt drain down potential, the Marshall quotient index decreases. The percentage of stripping of the samples was estimated by boiling water test. In addition, the moisture sensitivity test was carried out by using the Latman method on samples. Boiling water test results and a significant increase in the TSR index in samples modified with fiber, show the positive effect of this fiber against moisture damage on SMA.

Keywords: Viatop plus AD 10 fiber • Schlenberger • Marshall quotient • Cellulosic fibers • SMA

Introduction

Pavement life is influenced by several factors. There are various defects in different parts of the highway that is due to the difference in soil type, traffic volume, traffic type and the amount of rainfall in the various areas through which the road passes and the absence of timely inspection and evaluation and not repairing them, leads to a quick breakdown of the highway and destruction of huge financial assets and dissatisfaction of road users; therefore, using new asphalts to increase the pavement life and reduce the cost of pavement is very important. In early 1970, the European road industry felt a need for a pavement, resistant to rutting, abrasion and various damages caused by heavy traffic loads. In order to meet these requirements, road pavement custodians have invented SMA asphalt mixes. These types of mixtures have important advantages such as high durability, resistance to permanent deformation and rutting, resistance to glide and reducing water splash [1].

SAM is a hollow grain mixture that contains a large amount of coarse grain materials to maximize the contact of aggregate to aggregate and to create an efficient grid for the load distribution in which the coarse grain materials are bonded together by a mortar rich in filler or polymer with a relatively thick layer of bitumen. This type of mixture contains large amounts of coarse aggregate and small amounts of fine grains and so-called their aggregations have a gap. High VMA for coarse aggregates and relatively high consumption of bitumen in SMA mixtures is a factor in causing drain down of bitumen from these mixtures. The drain down of bitumen from the mixture, when carrying the SMA, should be known as a disadvantage for these kinds of mixtures. One of the methods for stabilizing bitumen in these mixtures is the use of cellulosic fibers. The coarse grained structure strengthens the mixture by introducing more aggregate to aggregate contact and its high bitumen content increases the durability of the mixture [2].

Segregation of aggregates from the asphalt surface is called stripping of aggregates, in which the bond between aggregate and bitumen is broken by water. Not only this failure is an independent failure, but also it can be the introduction of other early breakdowns including cracking, rutting, stripping, hollows and alligator cracks. Stripping is usually caused by directly the effect of moisture or it is intensified by moisture, so it is also called moisture damage, which can weaken or eliminate the overall adhesion between aggregate surface and bitumen.

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Received: 23 November, 2019, Manuscript No. JCDE-23-4905; **Editor assigned:** 28 November, 2019, Pre QC No. P-4905; **Reviewed:** 12 December, 2019, QC No. Q-4905; **Revised:** 14 June, 2023, Manuscript No. R-4905; **Published:** 12 July, 2023, DOI: 10.37421/2165-784X.2023.13.497

The purpose of this study has been attempted in order to provide an usable additive as an alternative in SMA mixtures and to obtain an easily accessible and more economical mixture. The main purpose of this study was investigating the effect of Viatop plus AD 10 on the moisture damage and the potential of bitumen drain down from SMA and increasing this pavement life times [3].

The fibers are used to, reinforce SMA mixtures, increase tensile strength, fatigue life and also stabilize bitumen in these mixtures. Mineral fibers and cellulose fibers are the most common type of fibers used in SMA mixtures and some of these fibers are relatively expensive depending on their source and method of production. The use of polypropylene has a good effect on improving the mechanical and physical properties of SMAs and consequently can be effective in increasing the strength of the mixture against rutting. According to studies, the use of rubber powder leads to a reduction in the drain down of bitumen from SMA. The use of cellulose fibers such as polypropylene, acrylic and viscose plays an important role in preventing the drain down of bitumen from SMA mixtures. Adding propylene to SMAs, in addition to reducing the thickness of the layer, increases the service life. The results of the studies show that, despite the higher initial costs in SMA mixtures containing fibers, due to the improvement of the functional characteristics of these mixtures, repair and maintenance costs are reduced and ultimately, life-cycle costs are reduced. In another study in 2014, measurements and comparisons of functional properties of asphalt mixtures, modified with glass and polyester fibers were evaluated. Adding 0.15% glass fiber to the asphalt mixture, showed an increase in the Marshall resistance, the indirect tensile strength and the resilient modulus by 10%, 25%, 38%, respectively. In addition, the cumulative creep strain decreases at a temperature of 60°C by 38% and the rutting potential at a temperature of 50°C and 2000 loading cycle by 14%. Furthermore, the tensile strength of the modified mixture with glass fiber, increases by 8% and 11% in dry and wet conditions, respectively [4].

Materials and Methods

In this laboratory study, the mineral aggregate of Ghareh Ghom Marand was used. Mechanical tests for determining the quality of aggregates according to the common standards is described in Table 1. The aggregates analysis curve was prepared by ASTM C136 method taking into account the upper and lower limits of gradation of the Iranian pavement regulations. The results are presented in Figure 1 [5].

Properties	Method	Requirement	Values
Coarse grain specific weight (gr/cm^3)	ASTM C-127-15	-	2.785
Fine grain specific weight (gr/cm^3)	ASTM C-128-15	-	2.77
Filler specific weight (gr/cm^3)	ASTM C-128-15	-	2.758
Los angles abrasion (%)	ASTM C-131	30 max	21
Water absorption percentage (%)	ASTM C-127-15	5 max	1.7
Flat and elongated (%)	ASTM D-4791	20 max	10.7
Crushed content (two faces) (%)	ASTM D5821	90 min	99

Table 1. Properties of used aggregates.

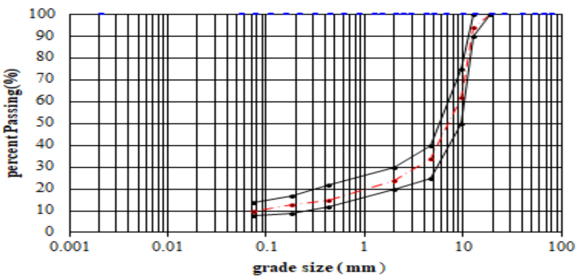

Figure 1. Selected gradation for SMA.

The bitumen used in this study is obtained from the products of the Pasargad oil company, manufactured at a factory located at Tabriz refinery, with a degree of penetration of 60-70. The tests carried out on the bitumen are described in Table 2 [6].

Parameter measured	Test method	Test value
Ductility (cm)	ASTM D-113	100
Softening point (°C)	ASTM D-36	65
Penetration degree (mm/10)	ASTM D-5	62

Ignition Temperature (°C)	ASTM D-92	260
Specific weight (gr/cm3)	ASTM D-70	1.01

Table 2. Physical properties of asphalt cement.

The fibers used in this study are Viatop plus that is a type of cellulose fiber, made in Germany. The picture of this fiber, along with its physical and chemical characteristics, is presented in Figure 2 and Table 3, respectively [7].

Figure 2. Viatop plus fiber.

Properties	Value
Cellulose content (%)	83%
Bitumen content (%)	10%
Amino acid amide (%)	7%
Flash point (°C)	500°C

Table 3. Properties of fibers.

Mixture design

Since the main factor in SMA mixtures design is the air void of the dense sample, the average amount of void presented in the regulation is used to determine the optimum bitumen content and the minimum amount of voids in the mineral aggregate, has a controlling role. 21 samples were prepared by Marshall design, which is used in the design of SMA as well as designing hot mix asphalts, was used to determine the optimum bitumen content according to the following steps:

- The weight percent of aggregates consumed in the mixes were determined according to the grading curve and the limits specified in the regulation which are described in Table 4.
- Marshall samples prepared with increasing bitumen content by steps of 0.5% from 4.5 to 7 by applying 50 hits to the upper and lower surfaces of them by Marshall Hammer, were compacted.
- Calculations and charts related to the specific weight parameters, voids in the mineral aggregate, the percentage of voids filled with bitumen and the percentage of voids filled with air, of the mixtures were calculated and plotted.

Materials type	Percentage
The weight percentage of coarse aggregates (Residue on the sieve number 4)	66
The weight percentage of fine aggregates (Passed from the sieve number 4, residue on the sieve number 200)	23
The weight percentage of filler	11

Table 4. Percentage of aggregate materials consumed in mixtures.

Marshall test

The Marshall quotient index indicates the rigidity of the asphalt mixture. As the ratio increases, the mixture becomes more rigid and its resistance to permanent deformations increases. In order to determine this index, 18 Marshall samples were prepared regarding to the optimum bitumen content by applying 50 hits to the upper and lower surfaces of the samples and compacting them. Then Marshall stability and flew of samples were determined by Marshall Jack in kilograms and millimeters, respectively. Determining the Marshall stability ratio to fluidity related to each sample, the Marshall quotient index of them was prepared in kilograms per millimeter [8].

Drain down test

In SMA, the coarse aggregates provide the strength of the mixture against permanent deformation and the high percentage of Bitumen leads to increased stability and durability of the mixture. Due to the high VMA gradation and the high contribution of coarse aggregates and high amounts of bitumen in this type of asphalt, the probability of Bitumen drain down and its severance from the rock materials is increased. In order to solve this problem and to achieve a homogeneous mixture, this asphalt requires preservatives called fiber. The dissolution mechanism of fiber coating at mixing temperature and breaking of their apparent structure due to the shear force applied by the aggregates, form a complex interconnected grid that is a disincentive to the detachment and drain down of bitumen. In order to determine the amount of bitumen drain down from the mixture, Schlenberg method has been used in this research [9].

According to this method, 1000 ml beaker was weighed in empty state with a precision scale of 0.01 g, then 1000 g of coarse-grained asphalt which is prepared at 135°C was purred inside the beaker and weighted and then the beaker's that contains the asphalt covered and placed in a dry heat oven for one hours in an 170°C. Ultimately, the beaker was evacuated and bitumen particles sticking to the wall of beaker were weighed. The amount of bitumen drain down is determined in percentage terms by calculating the difference in beaker weights along with the bitumen attached to the wall of it and the empty beaker. According to the regulations, the maximum amount of bitumen drain down from the samples is 0.3%. In line with the objectives of the study, after determining the optimum bitumen content at 0.3, 0.4, 0.5, 0.6 and 0.7 weight percent of mixtures, Viatop plus fiber AD 10 was added to the samples. Then, the both non-fibrous samples and samples containing fiber were tested by Schlanberger method of bitumen drain down [10].

$$\text{Drain down}(\%) = \frac{B-A}{W} \times 100 \quad (1)$$

Where A is the initial plate mass, B is weight of plate plus drained materials and W is the loose sample mass.

Moisture damage test

Lotman presented an indirect tensile strength test to predict the moisture sensitivity of the asphalt mixture under the conditions of serving real traffic. In this test, according to the AASHTO T283 standard, a group of samples is tested under dry conditions and another group is cured before the test. Dry samples will be kept at room temperature until the test is completed. In this group, the samples should be placed in a water bath at a temperature of 25°C for at least two hours and then the intended test be performed on them. The other group is saturated to a certain amount, (80%-55%) and then the specimens should be placed at minus 18°C for 16 hours. Immediately after this time, the samples are placed in a 60°C water bath for 24 hours and after, they are placed in 25°C water for about 2 hours and finally they are placed under the jaw of the machine for being tested (AASHTO T283). The indirect Tensile Strength (TSR) ratio is obtained from the ratio of saturated to dry [11].

$$ITS = \frac{2P_{max}}{\pi D t} \quad (2)$$

Where ITS is the tensile strength (kPa), P is maximum load (N), t is specimen thickness (mm) and D is the specimen diameter (mm).

$$TSR\% = \frac{ITS_{wet}}{ITS_{dry}} \times 100 \quad (3)$$

Boiling water test

In this test, various degree of stripping is determined visually, after boiling the uncondensed asphalt mixture for 10 minutes. About 500 g of water is poured into a container and heated to reach a boiling point. Then, 250 g of the uncondensed sample is heated inside boiling water up to 100°C (over 80°C) for 10 minutes and every three minutes the contents of the container are stirred up. Finally, the Bitumen on the surface of the water is removed to prevent resurfacing of the materials. After the contents of the container cooled to the room temperature, the water in the container is poured out and for further investigation; the mixture is placed on a white surface. The failure criterion will be determined by the visual observation of the stripped material [12].

Results and Discussion

The results and calculations of the SMA mix design

The optimum Bitumen content for our mixing plan in this study was determined and other characteristics of prepared samples with optimum Bitumen content were calculated. The results are presented in Table 5 [13].

Opt. bitumen (%)	Mixed special weight (gr/cm^3)	The theoretical special weight of the mixture (gr/cm^3)	V_a (%)	VMA (%)	V_F (%)
6/85	2/304	2/380	3/19	17/27	81/52

Table 5. The results of mixture design.

According to the results, 6.85% bitumen was determined as the optimum bitumen content of the mixtures and other parameters of the samples prepared with this content, have been met conditions listed in the regulations.

Marshall quotient index test results

As shown in the curve of Figure 3, the samples containing fiber have a better index than the non-fibrous samples [14].

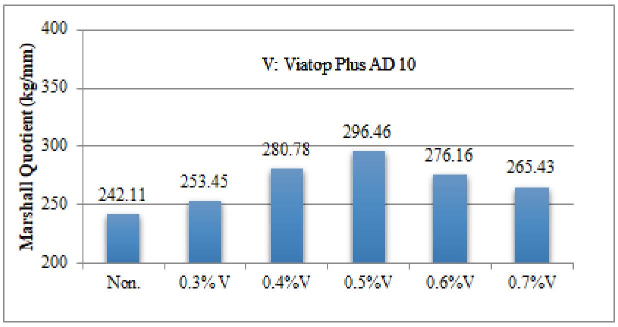

Figure 3. Marshall quotient result.

By increasing the fiber weight percentage to 0.5 of the mixture, the index increases and reaches its maximum value, 296 kg/mm. But with increasing the fiber content, these fibers replace the aggregates and lead to a decrease in Marshall resistance. As a result by increasing the percentage of fiber the Marshall quotient value increases. The results of these tests and the declining trend of the index after reaching a maximum value, in comparison with the results of tests conducted by Ziyari et al., show a good convergence [15].

Results of the tests on the potential of Bitumen drain down from the mixtures

The results of the bitumen drain down test from the mixtures by the Schlanberger method are presented in Figure 4.

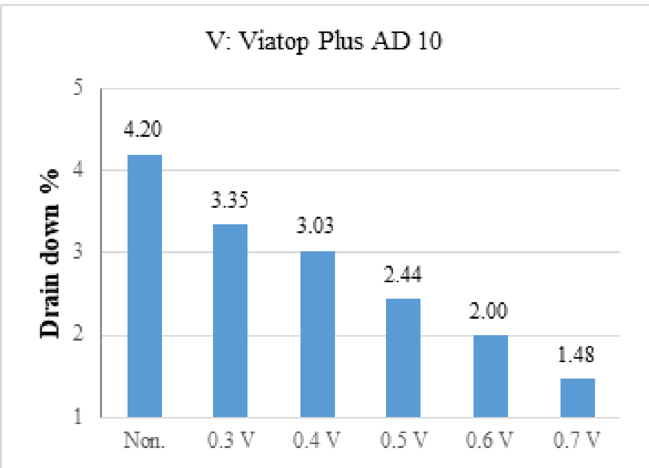

Figure 4. Drain down test results.

As it can be seen in this figure, by increasing the percentage of SMA fibers, the percentage of Bitumen drain down decreases and this indicates the significant effect of the polymer content on the bitumen drain down phenomenon. Increasing polymer content by the mechanism of dissolution of fiber coating at mixing temperature and breaking of their apparent structure due to shearing force from aggregates, forms an interconnected network which is a preventative factor for segregation and drain down of Bitumen. According to Figure 4, with increasing the fiber content by 0.5% and more of weight percentage of the mixture, the amount of Bitumen drain down decreases to below 0.3% which meets the limit specified in the regulation.

Moisture damage test results

This test was carried out according to the AASHTO T283-03 standard 25 by indirect tensile strength test equipment. For each mixture, 6 cylindrical samples were prepared; three samples used for testing under dry conditions (unsaturated) and three were used for testing under saturated conditions. The ratio of the saturated samples strength to the dry (unsaturated), results the TSR value. The results of these tests are shown in Figure 5.

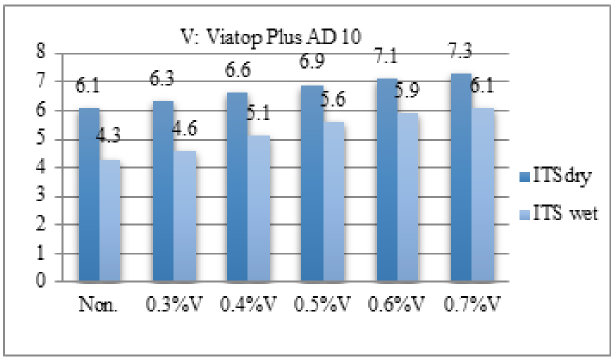

Figure 5. Comparative chart of dry and wet indirect tensile strength.

Regarding the results, the positive effect of the polymer can be clearly seen in the amount of ITS and TSR. The amount of ITS and TSR increases with increasing polymer content so that the indirect tensile strength in 0.3% fibers increased by 3% and in 0.7% of fibers increased by 18%. The TSR of mixtures have 0.5% and above fibers passed the super pave limit. SO can be said that the Viatop plus AD 10 increases the resistance of the SMA against moisture damage (Figure 6).

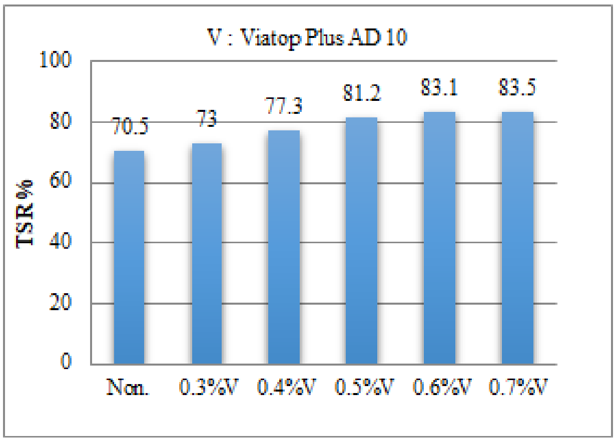

Figure 6. TSR values.

Boiling water test results

ASTM D3625 has standardized a method that can be used to determine the adhesion decrease in the un-compact mixture, caused by boiling water. The results of this test are presented in Figure 7.

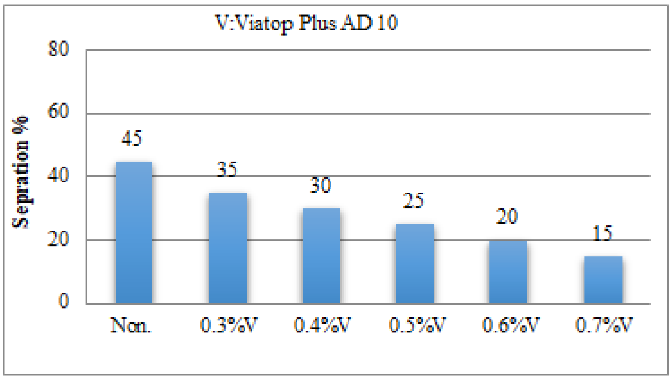

Figure 7. Boiling water test results.

These results, as the previous test did, indicate an improvement in moisture sensitivity with an increase in polymer content.

Conclusion

The purpose of this study was to investigate the effect of Viatop plus AD fibers on the reduction of bitumen drain down potential in SMA mixtures and to determine the optimal percentage of this type of fiber for being added. For this purpose, various samples were prepared by using the optimum Bitumen content and the required tests were performed on them. The addition of 0.5% of the Viatop plus AD fiber showed the best performance and is considered as the optimum amount of fiber to be added. The summary of the results is as follows:

- The Marshall index and the rigidity of the mixture increases with the addition of the Viatop plus fiber and the highest increase obtained by adding 0.5% weight percentage fibers, is about 22%.
- Considering that the increase in the Marshall index can improve the behavior of mixture against permanent deformations, including rutting, according to the results of this study, the addition of 0.5% weight percentage of the Viatop plus AD fiber to the SMA mixtures can improve the resistance of this type of the mixture against permanent deformation.
- As the fiber percentage increases from 0.5% weight percent of the mixture, the Marshall index, as a result of aggregates being replaced by fibers, decreases.
- With the increase in the amount of the Viatop plus AD to 0.5 weight percent of the mixture and more, the bitumen drain down rate decreases to below 0.3 percent that provides the limitation prescribed in the regulations.
- The results of the indirect tensile strength test carried out in saturated and unsaturated (dry) conditions indicate an improvement in the tensile strength ITS and the TSR's tensile strength ratio. This improvement was enhanced by increasing the percentage of polymer so that the TSR of samples containing 0.5 weight percentage of the mixture of fibers and Viatop plus AD, increase by 13% compared to non-fibrous samples.
- The results of the boiling test are qualitative and its error can be high, however; the positive effects of polymers in this test can be seen and compared. It is also observed that a decrease in the amount of bitumen drain down happens by increasing the polymer content.
- Considering the results of the Marshall index, determining the percentage of Bitumen drain down from the mixture, the ratio of indirect tensile resistance and boiling water tests, adding 0.5% of the Viatop plus fiber to the mixture has the best results and can be considered as an optimal percentage of this type of fiber in SMA mixtures.

According to the results of this research, we can conclude that the use of the Viatop plus 10 fiber, according to what has been shown in previous studies on the use of cellulosic fibers, improves the performance of the SMA mixes against the bitumen drain down from the mixture and the ease of carrying and mixing the mixture. And by increasing the strength of this type of mixture against permanent deformation and moisture sensitivity, reduces the maintenance costs.

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How to cite this article: Saedi, Sepehr, Seref Oruc and Golnar Sadeghian Asl. "Investigating the Effect of Viatop Plus AD 10 Fiber on Moisture Sensitivity and Potential Asphalt Drain down from Stone Mastic Asphalt Mixtures." *J Civil Environ Eng* 13 (2023): 497.