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Research Paper

The most appropriate mixing method of polypropylene fiber with aggregates and bitumen based on binder mix design

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Abstract

Asphalt is used in road pavements as the binder of aggregates in a great extent all around the world. Asphalt Modifiers have used in pavement engineering in order to enhance the physical and mechanical properties of asphalt mixtures. One of the most important of them is Polypropylene Fiber that causes increasing stability in the mixture. In this article usage of this fiber in civil engineering and especially in asphalt mixtures is investigated; Mixing methods of fiber with aggregates and bitumen are dry, wet and complex are investigated and the most appropriate method because of homogenous mixing and better result is introduced.

Keywords: *Polypropylene Fiber, Mixing, Bitumen, Aggregates, Binder.*

1. Introduction

Asphalt is used in road pavements as the binder of aggregates in a great extent all around the world. Asphalt pavements must undergo heavy loads and unfavorable environmental conditions for an acceptable period of time. High-temperature rutting and low temperature cracking are the most considerable limitations of unmodified and pure asphalts. Therefore, modification and reinforcement of asphalt binder is necessary.
Development of modifiers has led to advanced characterization, prediction and control of properties of materials at submicron level. Polypropylene is widely used as commodity polymer known for its good process ability, low cost, integral hinge property, low density, high softening point and good mechanical properties.
In this paper, usage of polypropylene fiber in flexible pavement is studied and also best mixing method of it with bitumen and aggregates is discussed.

2. Literature review

Hejazi, S.M. et al (2008) evaluated kinds of loom materials on asphalt behavior. They concluded that between tested materials, glass fibers, because of high young modulus and polypropylene, because of low melting point, can increase compress stability of flexible asphalt [3]. Firouzei, F. et al (2012) in their studies concluded that by adding propylene fibers and cement to asphalt mixtures, flow decreases and unit weight increased [2]. Maurer, Dean, A. et al (2006) in a research showed that using fibers such as polypropylene can effect on reduction of flexible asphalt's cracks [7]. Abtahi, S.M. et al (2011) in a research used fibers of 6mm and 12mm of fibers in asphalt and finally concluded that adding polypropylene fibers in asphalt mixture based on dry procedure, increase Marshall Stability and VMA and decrease flow [4].
Abdul-Rahim et al (2005) in a laboratory study concluded that application of polypropylene causes increasing of asphalt stability [17]. Jenq, Y. S. et al (1998) in their research evaluated the failure concept on asphalt concrete modified with fibers. Results showed that stiffness increases while elasticity modulus doesn't change [8].Brown, S F. et al (1998) and Tapkin, S. (2007) studied some asphalt modifiers like polyester, polypropylene and etc. they did indirect tensile test, resilience modulus test on the samples. The results showed the increasing in indirect tensile resistance and resilience

modulus[6,9].Tapkin, S. (2008) in a research concluded that adding polypropylene fibers to asphalt mixtures in dry procedure, causes increasing of marshall stability and aging and decreasing flow [10].Kumar, P. et al (2009) in a research studied modified asphalt with PP and concluded that in dry procedure, by adding 0.5% of PP, marshall stability increases by 32% ; meanwhile optimum bitumen content increases a little, too[5].

3. Materials and methods

3.1. Polypropylene fiber

Polypropylene is a widely used commodity polymer known for its good process ability, low cost, integral hinge property, low density, high softening point and good mechanical properties. Filling, reinforcing and increasing stability and etc specifications of this fiber has attracted many attentions to it. Polypropylene fibers are made by polymerization of polypropylene as linear polymer and called abbreviating PP. PP are produced after ziglernate catalyst. PP is consisted of (CH2=CHCH3) that forms as lateral production in producing Ethylene by oil molecule breaking in petrochemical industry. Produced PP could be 6 times longer than original length to gain desirable mechanical properties [3].
Polypropylene fiber which is used in this research is supplied from Sepahan-Negin-Rose loom industry, Esfahan, IRAN. Physical and mechanical characteristics of PP are based on table (1).

Table 1: Physical Properties of Polypropylene Fiber

Properties Type	Specification Data Polypropylene, 100%
Cross Section	Round
Specific Gravity	0.91 gr/cm3
Diameter	19 Microns
Melting Point	160-165 ºC
Softening Point	140-165 ºC
Tensile Strength	400 MPa
Fiber Length	19 mm
Modulus of Elasticity	4.1 GPa
Acid and Salt Resistance	High

3.2. Aggregates and bitumen

In this study mixing design, aggregates are used from Jahad-e-nasr asphalt plant, Kermanshah, Iran. Mixing ratio of aggregates for Binder layer is based on table 2 and their aggregation is based on figure 1.

Table 2: Aggregates Mixing Ratio

Aggregation	Mixing Percent
Coarse Gravel, 19-25 mm	15
Medium Gravel, 12-19 mm	15
Fine Gravel, 6-12 mm	19
Sand, 0-6 mm	40
Filler	11

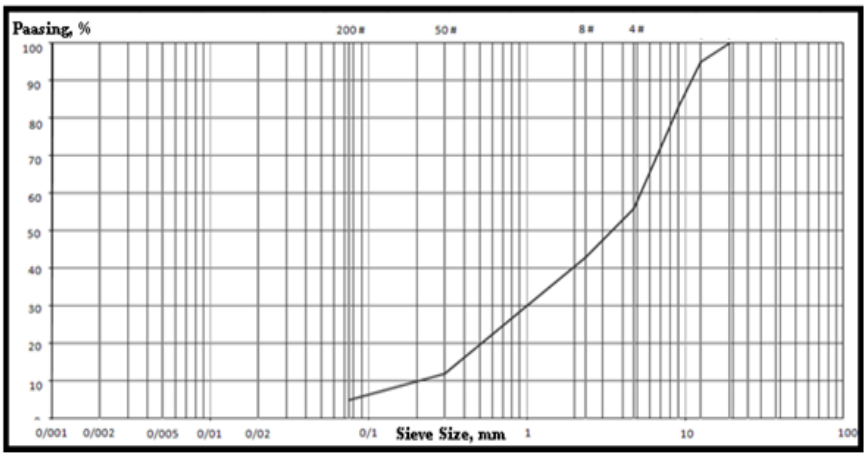

Fig. 1: Aggregates Mixing Grading Curve of Binder Layer

The 60/70 penetration grade bitumen was obtained from Isfahan Mineral Oil Refinery, Isfahan, Iran. Bitumen mixing temperature for used aggregation is about 148-154 ºC and compaction temperature is about 136-141 ºC. Table (3) shows the physical properties of the bitumen.

Table 3: Physical Properties of the Bitumen

Property	Test Method	Quantity
Specific gravity at 25 ºC (gr/cm3)	ASTM D-70	1.016
Penetration at 25 oC, 100g, 5 s	ASTM D-5	69
Softening Point, ring and ball (ºC)	ASTM D36	49.1
Flash Point, Cleveland open cup (ºC)	ASTM D-92	310
Ductility at 25 ºC at 5 cm/min (cm)	ASTM D-113	100+
Loss on Ignition, %	ASTM D-6	.05

4. Testing program

Generally, for adding PP in asphalt mixture, there are three methods as follow:

4.1. Dry method

In this method, first, aggregates and bitumen were heated according to ASTM-D1559 standard. Then Fibers added to aggregates and were mixed. After that, bitumen added gradually to mixture of aggregates and PP. In this method observed that fibers were shirked and there was no mixing between fibers and other materials; so it wasn't a suitable method for mixing of PP in asphalt mixture.

4.2. Wet method

In this method, first, aggregates and bitumen were heated according to ASTM-D1559 standard. Then fibers added to bitumen and were mixed. After that, aggregates added to mixture of bitumen and PP. In this method observed that because of absorbing bitumen by fibers, balling happened that resulted in unsuitable mixing of fibers with aggregates; so this method wasn't suitable for mixing, either.

4.3. Complex method

Since there were no homogenous mixtures in two first methods, so another method was evaluated that had better results. In this method as before methods, aggregates and bitumen were prepared according to ASTM-D1559 standard; then both were mixed for 5 to 10 seconds by mixer. After that, segregated fibers gradually were added to mixture. It was observed that fibers were completely mixed with the mixture homogenously and this would be the best method that in this research was used for constructing and performing experiments (Figure 2).

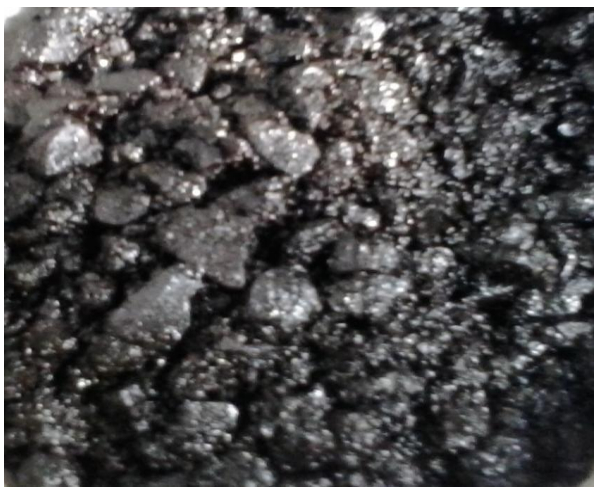

Fig. 2: The Mixture in Complex Method

In table (4), mixing methods of fibers with aggregates and bitumen are seen briefly.

Table 4: Mixing Methods Of PP With Aggregation And Bitumen

Method	Primary Mix	Secondary Mix
Dry	Aggregates + PP = A	A + Bitumen
Wet	Bitumen + PP = B	B+ aggregates
Complex	Aggregates+ Bitumen =C	C + PP

5. Conclusion

Engineers are constantly trying to improve the performance of asphalt mixtures by using various methods including asphalt binder modification and Polypropylene fibers' application in improving asphalt and concrete pavement always has been considered by them. This matter causes various experiments to be performed for assert this claim. Results of experiments imply efficient of using these fibers; for example, Polypropylene fiber causes pavement function increase significantly in long-term and also aging of bitumen to be less.

Polypropylene fiber has a function of reinforcing and by mixing it with aggregates and bitumen homogenously; increasing of mixture stability would be the result. Mixing this polymer in asphalt mixture is through dry, wet and complex methods that the one can provide homogenous mixture, is complex method. In complex method, first, bitumen and aggregates should be mixed together and then add Polypropylene fiber in primary mixture.

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