INVESTIGATION OF ADHESION PROPERTIES IN CHIP SEALS WITH PULL OUT TEST

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ABSTRACT

One of the important parameters affected on chip seal performance is adhesion. It was known that a lot of parameters affected on the adhesion. However, Vialit adhesion test is used the determination of the adhesion parameters. In this study scope, it was studied about new kind of adhesion test alternate to Vialit adhesion test. Also, the method was known pull-out test method in literature. Pull-out test device was developed in Suleyman Demirel University, Civil Engineering Department transportation Laboratory. In this study, it was performed pull out test on the embedded aggregate samples in the bitumen samples on the steel plate after 24 hours. In the test, aggregates maximum rupture forces, tension stresses and extension of bitumen film were determined. In this study scope, 13 different aggregate samples and four different bitumen samples were used and test results were compared with each other and aggregate and bitumen variations how affected on adhesion properties were investigated.

Keywords: Chip seals, adhesion, pull-out test

1. Introduction

Chip sealed pavements is the one the most used asphalt pavement type in the Turkey. Adhesion is the bond between aggregate and bitumen that is the most affected on the performance of the chip sealed pavements. Many research were performed about the adhesion between aggregate and bitumen (Mathews, 1958; Scott, 1978; Yoon, 1987; Terrel and Shute, 1989; Tarrer and Wagh, 1991; Kandhal et.al. 1998; Senadheera et.al., 2006; Bahia, 2008; Milne et.al., 2008; Karaşahin et.al., 2009; Gürer, 2010), but still many unknowns are exist about bitumen-aggregates adhesion. Scott (1978) and Yoon (1987) demonstrated that asphalt–aggregate adhesion is strongly influenced by the pH of the contact water. Terrel and Shute (1989) describe four theories that are often used to explain the adhesion between asphalt and aggregate: (*a*) chemical reaction, (*b*) surface energy, (*c*) molecular orientation, and (*d*) mechanical adhesion. Tarrer and Wagh (1991) list a number of factors that influence the asphalt–aggregate bond: surface texture, penetration of pores and cracks with asphalt, aggregate angularity, aging of the aggregate surface through environmental effects, adsorbed coatings on the surface of the aggregate, and the nature of dry aggregates versus wet aggregates.

Adhesion between aggregate and bitumen can be loss because of the variety of factors such as dust on the aggregate particle, water, using unsuitable binder etc. Then, loss of aggregate occured on the chip sealed pavement surface, in next time permeable surfaces, settlements in the base and potholes on the pavement surface can be seen. Some reasons of the loss of adhesion between aggregate and bitumen are; spreading of aggregate after the bitumen temperature was decreased, using dusty or humid aggregate, delaying the rolling time of the aggregate spread or inadequate aggregate embedment depth, opening to the traffic of newly constructed chip sealed pavements, using insufficient or inadequate bitumen to construction of chip seal or absorbent base surface etc. (Karaşahin and Gürer, 2007). Using dirty aggregate in the construction of chip seal is one of the causes of important adhesion problem. Dusty aggregates may generally be referred to as aggregates coated with materials smaller than 75 µm. This may cause a problem in developing an acceptable bond between fine and coarse aggregate because the asphalt binder tends to coat the dust and not the aggregate, leading to greater probability for bond interruption and hence displacement. (Senadheera, 2006) (The aggregate surface chemistry is important factors affecting the adhesion between the aggregate and the asphalt binder) (Hicks, 2003).

Because a lot of parameters affect the adhesion between aggregate and bitumen, measuring the adhesion is very difficult. Vialit adhesion test that was developed early 1960 is the common method for the measuring adhesion between aggregate and bitumen however various new methods have been developing (Senadheera et al. 2006; Gürer, 2010). A new test to quantify bitumen-aggregate adhesion has been developed and accepted as an ASTM standard. The “Sweep Test” ASTM D7000 provides a practical methodology for measuring bitumen aggregate adhesion and bitumen binder cohesion (ASTM D7000, 2004). The test involves preparing a sample of bitumen with aggregate embedded into the surface. The bitumen/aggregate plate is then placed in a mixing bowl with a brush head touching the bitumen sample. The sample is rotated at 0.83 gyrations/s for 60 seconds, subjecting shear stresses to the aggregate-bitumen bond. Adhesion and cohesion for a given mix are quantified through calculation of the mass loss of the specimen after testing (Bahia et al, 2008). The Road and Traffic Authority (RTA) of New South Wales, Australia (RTA 2001) have been using a test protocol to evaluate the aggregate-binder compatibility in their seal coats. This test method (RTA T-

238) allows the user to assess the extent of adhesion between aggregate and a bituminous binder under wet and dry test conditions and known as a Australian Aggregate Pull-Out test (Senadheera et al., 2006). In this study different aggregates adhesions properties were investigated with pull out test and the findings were discussed.

2. Materials and Methods

2.1. Materials

In this study 11 different aggregate samples were used. At the present time the samples have used to chip seal construction in different location of the Turkey. Some properties of aggregate samples can be seen in the Table 1, aggregates chemical properties are also given in Table 2.

Table 1. Aggregate Samples Properties

Aggregate Sample	Aggregate Type	Water Absorption (%)	Bulk Specific Gravity (gr/cm^3)	Vialit Test	Nicholson Stripping Test
I1	Limestone	0,701	2,702	2,7	81,9
I2	Limestone	0,314	2,683	3,7	60,0
A1	Limestone	0,650	2,731	3,5	60,6
A2	Limestone	0,600	2,693	4,0	46,9
A3	Limestone	1,048	2,580	3,0	65,0
K1	Limestone	0,200	2,696	4,7	82,5
K2	Limestone	0,650	2,652	3,7	70,0
K3	Limestone	0,178	2,688	4,3	75,0
AN	Limestone	0,237	2,682	3,0	72,5
E1	Basalt with andesite	1,276	2,290	10,0	33,1
E2	Basalt with andesite	1,890	2,653	3,0	66,2

Table 2. Chemical Properties of Aggregate Samples

Sample Name	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO
Unit	%	%	%	%	%	%	%	%	%	%
I1	1,450	0,070	0,050	0,550	55,060	0,030	0,020	0,010	0,010	0,010
I2	0,290	0,020	0,040	2,830	53,410	0,050	0,010	0,010	0,010	0,010
A1	0,220	0,030	0,070	0,450	55,950	0,030	0,010	0,010	0,010	0,010
A2	0,200	0,030	0,040	0,390	56,370	0,030	0,010	0,010	0,030	0,010
A3	0,170	0,020	0,060	0,890	55,800	0,030	0,010	0,010	0,010	0,010
K1	0,540	0,050	0,060	0,060	56,050	0,050	0,020	0,010	0,010	0,010
K2	0,650	0,020	0,040	0,210	55,930	0,050	0,010	0,010	0,020	0,010
K3	0,460	0,150	0,130	0,620	55,170	0,030	0,060	0,010	0,020	0,010

AN	54,470	16,540	6,990	4,190	8,280	3,710	1,550	1,030	0,450	0,100
E1	62,170	16,300	5,020	1,980	4,400	3,730	2,270	0,740	0,220	0,050
E2	40,610	7,090	2,360	1,310	25,580	1,530	0,740	0,250	0,070	0,070

100/150 penetration bitumen and penetration bitumen modified with Kraton D1192 E (modified bitumen 1) and BASF Butanol NS175 (modified bitumen 2) were used in this study as a binders and the results will be correlated own within. Kraton D1192 E is a clear linear block copolymer based on styrene and butadiene, with bound styrene of 30% mass. 100/150 penetration bitumen modified with Kraton D 1192 and butanol ratio of 5 % and 4 % respectively. BASF Butanol NS175 type butanol was used in the test. Typical properties of bitumen 100/150 sample, Kraton D 1192 and BASF Butanol NS175 were given in Tables 3, 4 and 5, respectively.

Table 3. 100/150 Penetration Bitumen Properties

Properties		**Specification Used**	**TCK Specification**
Source	Aliağa / Turkey	-	-
Penetration	120	ASTM D5	100/150
Softening Point (^{o}C)	43,6	ASTM D36	39-47
Loss on heating (%)	0,06	-	Max 0,8
Penetration after RTFOT	72	ASTM D2872	-
Permanent Penetration	60		Min 43
Softening Point after the RTFOT	49		Min 41
Rising of Softening Point	5,4		Max 10

Table 4. Kraton D1192 E Typical Properties

Property	Test Method	Units	Typical Value
Melt flow rate 200°C/5kg	ISO 1133	g/10 min	<1
Specific gravity	ISO 2781	mg/m³	0,94
Bulk density	ASTM D1895 method B	mg/m³	0,4
Hardness	ASTM 2240	Shore A (10 s)	70

Table 5. BASF Butanol NS175 Typical Properties

Properties	**Unit**	**Value**
Solids Content	%	70,0-72,0
pH	-	10,0-11,0
Viscosity (Brookfield RVT, Spindle #3, at 20 rpm)	mPa s	1000-1500
Bound styrene	%	24
Residual monomer	%	0.08 max
Surface tension	mN/m	34

Specific gravity	-	0,94
Antioxidant	-	None
Glass transition temperature °C -58 (DSC)	°C	-58
Weight/volume	kg/l	7,8/0,94

2.2. Pull-Out Test

SDU pull-out test device that was developed in the Suleyman Demirel University, Transportation Laboratory was used for test (Figure 1). Vialit test steel plates were used to produce the pull-out test sample. The hook bit was used to pull the limestone aggregate test sample and jamming tip was used to pull the basalt aggregate test sample. To pull the limestone aggregate sample, aggregate particles were drilled for the hole with 2 mm of diameter. After the drilling, all of the samples were washed and dried then small pythons were bonded within the hole on the each of the aggregate particle with epoxy and cured along 24 hours. Because the basalt aggregate samples couldn't drilled, the samples pulled with jamming bit. Steel plate temperature is 40 ^{o}C during to preparing the test sample plates. Between the aggregate particles on test plates have specific interval to avoid touching of the each other during the pulling. All of the plate samples were cured along 24 hours after the prepared. Then the plate samples were positioned on the test device and aggregate particles were pulled at 24 ^{o}C ambient temperature. Aggregate samples average pull out forces (kg), pull-out stresses and extension of bitumen film were saved and correlated with each other.

Figure 1. SDU Pull-Out Test Device (A), SDU Pull-Out Device Drilled Test Sample and hook tip (5), Different jamming tips (1-2-3-4)

3. Findings

According to the test results, comparative aggregate samples average pull-out forces, average aggregate pull-out stresses and average extension of bitumen films can be seen in Figures 2, 3 and 4, respectively.

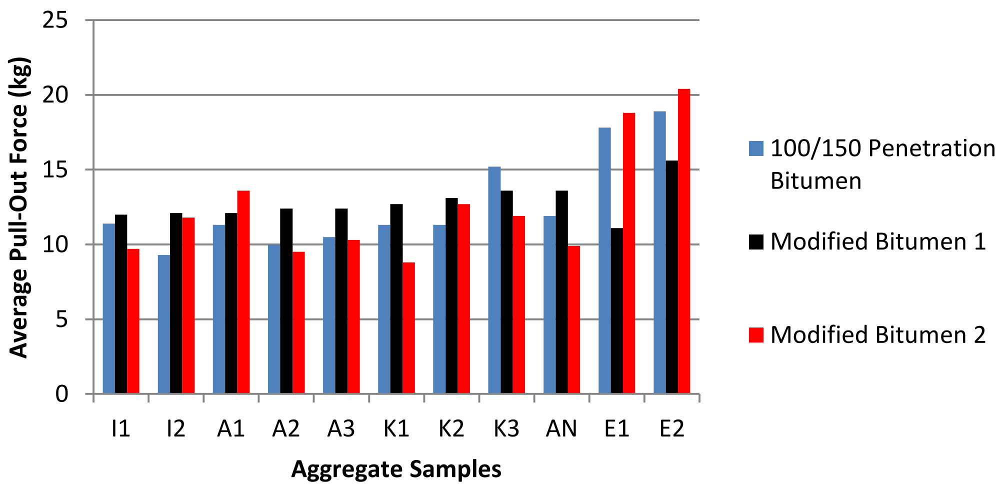

Figure 2. Average Aggregate Samples Pull-Out Forces

According to the average pull-out force measurement result, using modified bitumen 1 as binder test results is better in the limestone aggregates samples than 100/150 penetration bitumen, however in the basalt aggregates samples using modified bitumen 2 as a binder better than modified bitumen 1.

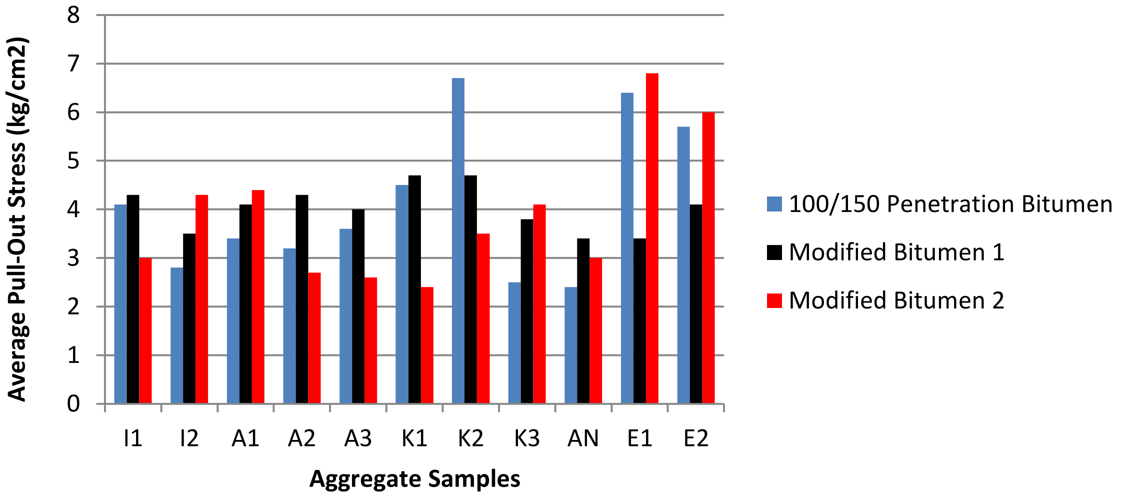

Figure 3. Average Aggregate Pull-Out Stresses

Similar to the average pull-out stresses results, pull-out stresses is higher in limestone aggregates samples when modified bitumen 1 was used as binder, however pull-out stresses is higher in basalt aggregates samples when modified bitumen 2 was used as binder. E_1 and E_2 samples have the highest value of pull out stress and forces. E_1 and E_2 also have low bulk specific gravity and higher water absorption value because of the volcanic origin they have higher surface porosity, for this reason E_1 and E_2 have highest adhesion resistance than others.

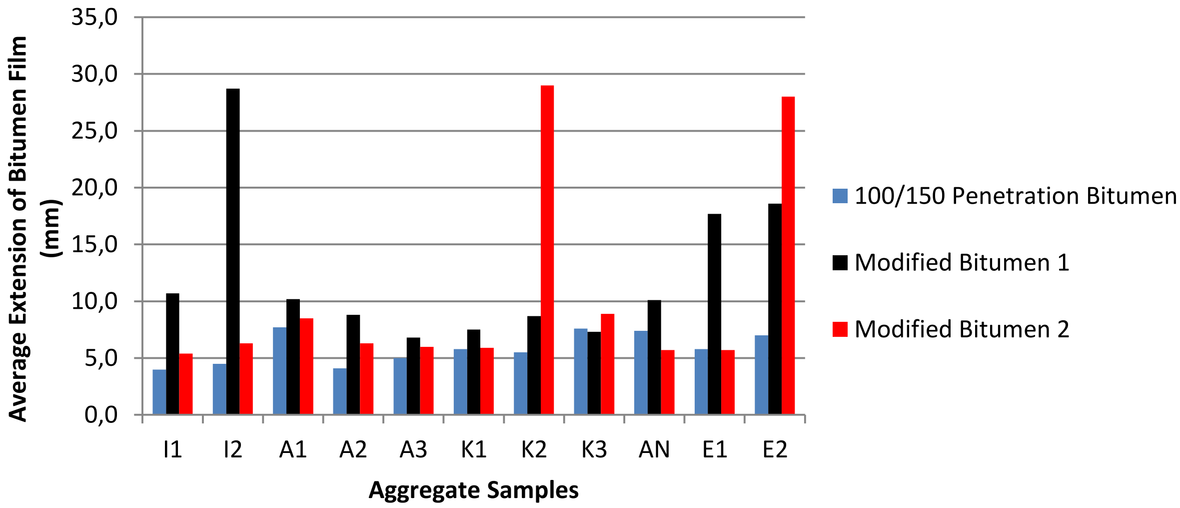

Figure 4. During the Pull-Out Test Average Extension of Bitumen Films

Generally average extension of bitumen films are between 4 and 10 mm, however, some samples that were used modified bitumen are higher than others.

4. Conclusions and Recommendations

According to the test results, it was reached that following conclusions and recommendations:

The results show that, a relation exists between aggregate type and adhesion properties. Likewise, Tarrer (1996) concluded that the bond between asphalt and aggregate depends on surface chemical activity. Also Jamieson et all. (1995) indicated that alkali earth metals (sodium and potassium) on the aggregate surfaces are detrimental to adhesion. Modified bitumen binders improve the adhesion properties but according to the results different modifier different affects on the adhesion properties of aggregates samples.

Because the basalt aggregate samples are the harder than limestone's, the aggregates couldn't be drilled so basalt aggregates pulled out with jamming tip in the SDU Pull-Out Test Device. In the next research, if all of the aggregate types pull out the same tips, the results will be improved.

Aggregate adhesion tests results is more quantitative with using the SDU Pull-Out Device and three different parameters (pull-out force, stress and extension of bitumen film) were measured. In next research study, the test device will be developed and new tests will be performed different ambient temperature, so the results will be improved.

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