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PREDICTED THE PULL OFF TENSILE STRENGTH OF ASPHALT BINDER USING MODIFIED BBS TEST

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KEYWORDS: Affinity between aggregate and asphalt binder, Pull Off Tensile Strength and Bitumen Bond Strength Test.

ABSTRACT
Affinity is a term used to describe the amount of the adhesion bond between asphalt binder and aggregate. Adhesion force may be used as indicator to the amount of energy or work required to breakdown the adhesive bond between asphalt binder and aggregate.

Four types of aggregate brought from various regions of Iraq to study of affinity between asphalt binder and these aggregate; taking into consideration mineral composition in order to measured required force to separate asphalt binder from aggregate. Standard and modified device are manufacture locally to obtained more accurate and realistic experimental result. the Pull Off Tensile Strength of aggregate type S5 brought from Diyala was greater than other types of aggregate for dry and wet test condition and different stub (standard and modified). Also had less Pull off Tensile Strength Losses than other types due to increased present of calcite and high pore size with high stiffness of aggregate.

INTRODUCTION
The pavements mixture have distinctive On material properties Furthermore serve different purposes In light of climate, movement load, soil aspects Furthermore other elements. The environmental factors associated to moisture have the most major impact on the performance, quality and serviceability of asphalt mixture.The expression of moisture damage is a very complex mode of distress and prompts a conditioning process as a result of presence of moisture in pavement structure. The interaction of moisture with aggregates and asphalt binder caused loses in structural strength and stiffness of the asphalt mixtures. Moisture- damage may be make happen by two prime mechanisms. The first one is associated with the chemical interaction of moisture with aggregates and asphalt binder lead to the loss of affinity bonding between aggregates and asphalt binder and loss of cohesive bonding within the asphalt. The second one is the buildup of pore pressure due to the saturation of voids with moisture and the dynamic load of traffic. The moisture damage have numerous forms to reveal on the surface of the flexible pavement such as stripping, raveling and fatigue crack, with absence of any maintenance would lead to structural failure. The moisture damage in flexible pavement has two modes of failure, adhesion and cohesion failure. Cohesion failure happened within asphalt particles or aggregate due to freezing the entrapped water in the pavement **(Kim & Coree 2005; Asphalt Institute 2007)**. Adhesion failure happened between aggregate and asphalt binder. On the other hand, the most common mode of moisture damage is cohesion within asphalt and adhesion between asphalt and aggregate **(Kanitpong & Bahia 2003; Solaimanian et al. 2007)**. Affinity between aggregate particles and asphalt binder can be defined as the amount of bond between asphalt and aggregate, moisture damage is recognized that decrease the affinity between aggregate and asphalt binder and also the primary cause of pavement distress. Moisture damage can be characterized by adhesion failure between asphalt and aggregate **(Kennedy et al. 1982, Fromm 1974; Majidzadeh & Brovold 1968; Tunnicliff & Root 1982).** Adhesive bond strength is the most significant major properties for surface coatings. The knowledge and technology of adhesive bond strength has designed a large amount of testing techniques and procedures used for measuring the adhesive bond strength of coatings of composite materials such as metals, glasses and plastic. Among the most usually used testing techniques and procedures are pull off test and peel test**. Alhaddad and Khalid al. (2015)**, Establish the criteria and procedures for the proposed adhesion test method in terms of test setup and apparatus, specimen preparation, testing and data analysis; and study different parameters (binder thickness, aggregate types, rate of applied load, test temperature and conditioning procedure) on the maximum tensile bond strength and tensile energy required to produce failure**. Abedali et. al. (2016**) ; develop and establish

simple practical and reliable monotonically- loaded laboratory adhesion test method for direct measurement of the adhesive bond strength of asphaltic material and aggregate.

OBJECTIVE OF THIS STUDY

The objectives of this work can be summarized as:

- Develop draft protocol method for measuring directly adhesive bond strength.
- Determining the affinity between asphalt and aggregate.
- Predicted tensile strength force required to take off the asphalt binder.

THE EXPERIMENTAL RESULT

Material

The materials have been employed in experimental part of this study are asphalt cement brought from Al-Durah refinery in Baghdad City (capital of Iraq) with Penetration grade is (40-50) and several types of aggregate brought from different regions of Iraq. The properties of aggregates and asphalt cement are evaluated and the results obtained are matched with the state Cooperation of Roads and Bridge SCRB (R/9, 2003). The mineral composition and porosity of aggregates shown in Table (1)

Table 1 mineral composition, porosity and source of aggregates.

Aggregate type	Mineral composition	Porosity %	Aggregate region Source
S5	Calcite 91%,Kaolinite 3.8% Quartz 2.9%,Dolomite 1.4%	5.5	Diyala
S2	Calcite 98.3% ,Quartz 1.7%	9.11	Karbala
S3	Calcite 98% ,Carbon Graphite 2%	1.06	Erbill

Bitumen Bond Strength Test.

This test method used to quantify the tensile force that required removing a pullout stub adhered to substrate with asphalt binder. Sample is prepared at controlled environmental cabinet manufacture locally with different moisture conditions. Afterwards conditioning, a pneumatic load is applied to a pullout stub based on the requirement of **AASHTO Designation: TP-XX-11**. The pullout tensile strength and mode of failure are used to pronounce the bonding properties of asphalt binder and compatibility between asphalt binders and aggregates. The device as shown in plate (3) consist of: Piston and Reaction Plate, Gasket, other Apparatus and Stubs: The standard stub used manufacture from Aluminum with four diagonal gates to allow the excess asphalt to escape when the required binder thicknesses is achieved Modified stub there are not much different between the ordinary and the modified just in cuts on the edge of the stubs. Eight cuts on the edge instead of four that allowed the excess asphalt binder to flow out when the stub pressed on the aggregate plate surface (To ensure the escape of excess asphalt from more multiple gates and prevent the phenomenon of asphalt conglomeration and reduced cohesion effect in the central region of stub) . Perfect control of the asphalt binder film thickness is obtained so that a complete adhesion system between the asphalt binder and aggregate plates. This improvement of standard stub enhanced the PATTI became more reliable and the device useful to evaluate adhesion and cohesion bond between aggregate and asphalt binder. **(Santagata et al.,2009)** ; Modified stub shown in Plate (1).

a) ***Modified Stub*** ***b) standard stub***

Plate 1; types of stubs.

Plate 2 BBS Test Device

Analysis and Discussion of the Results

Bitumen Bond Strength test (BBS) (AASHTO designation TP-XX-11) is a quantitative test used to provide strength value of connection between surface of aggregate and asphalt binder earlier and afterward condition time. This test can provide the susceptibility of aggregate and asphalt binder to moisture by calculating the percentage of moisture damage.

When the test finish the actually outcomes are the pull off tensile strength and the shape of the failure of each types of aggregates .the failure type can be defined either adhesion or cohesion by using image processing with aided AutoCAD software.

The Pull Off Tensile Strength (POTS) at failure for wet and dry condition are calculated using eq.1 suggested by (Moraes et al. 2011) to produce moisture damage of loss of bond strength due to moisture present.

$$\mathbf{POSTL} = \left(\mathbf{1} - \frac{\mathbf{POTS_W}}{\mathbf{POTS_D}}\right) * \mathbf{100\%} \qquad \mathbf{1}$$

Where:

POSTL:Pull off tensile strength losses in ratio.

$POTS_W$: Pull off tensile strength in wet condition in psi.

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$POTS_D$: Pull off tensile strength in dry condition in psi.

The three types of aggregate S2, S3 and S5 were test in this local manufacturer BBS Test in standard and modified stub . The test results of pull of tensile strength are shown in Table (1-2) to (1-4) and Figure 1.
The experimental results of standard stub are tabulated as shown below;

Table (1-2) POTS (psi) Result of S2.

Trail	Condition Type	Type of Failure	POTS PSI
#1	Dry	100%C1	250.0
#2	Dry	3% C2, 97% C1	285.5
#3	Dry	3% C2 ,97% C1	285.5
		Mean psi	273.67
		Standard Deviation	3.17
		Coefficient variation	0.012
#4	Wet	60% C1 ,40% A	143
#5	Wet	3% C2 ,97% C1	178
#6	Wet	100% C1	164
#7	Wet	70% C1 ,30% A	143
		Mean psi	157
		Standard Deviation	17.145
		Coefficient variation	0.109
POTSL (mean dry/mean wet)			43%

Table (1-3) POTS (psi) Result of S3.

Trail	Condition Type	Type of Failure	POTS
#1	Dry	100%C1	285.5
#2	Dry	100%C1	285.5
#3	Dry	100%C1	285.5
		Mean psi	285.5
		Standard Deviation	0
		Coefficient variation	0
#4	Wet	100%C1	178
#5	Wet	100%C1	201
#6	Wet	100%C1	143
#7	Wet	100%C1	143
		Mean psi	166.25
		Standard Deviation	28.44
		Coefficient variation	0.17

POTSL (mean dry/mean wet)	42%

Table (1-4) POTS (psi) Result of S5.

Trail	Condition Type	Type of Failure	POTS
#1	Dry	10%A,90%C1	322
#2	Dry	100%C1	307
#3	Dry	100%C1	322
		Mean psi	317
		Standard Deviation	8.66
		Coefficient variation	0.027
#4	Wet	100%C1	271.5
#5	Wet	100%C1	271.5
#6	Wet	100%C1	271.5
#7	Wet	100%C1	271.5
		Mean psi	271.5
		Standard Deviation	0
		Coefficient variation	0
POTSL (mean dry/mean wet)			15%

It can be concluded from Tables (1-2) to (1-4):

- The Pull Off Tensile Strength of aggregate type S5 in dry and wet conditions after 24hr of curing time in distilled water are 317 psi and 271.5 psi respectively.
- By using image processing with AutoCAD software. The aggregate type S5 shows cohesion failure so that indicate a high affinity (adhesion bond) between aggregate surface and asphalt binder as well as excellent to resist stripping as compared with others type as illustrated in Figure (1) .
- The aggregate type S3 shows cohesion failure in dry and wet condition with acceptable affinity with asphalt binder.
- The aggregate type S2 shows cohesion failure in dries condition and both cohesion and adhesion failure in wet condition so that indicate the aggregate type S2 was more affected by water than aggregate types S3 and S5.
- The of Pull Off Tensile Strength Losses ratio for aggregate types S5,S3 and S2 are 15% ,42% and 43% respectively.It can be concluded the aggregate type S5 was less susceptible to water (stripping) as compared to other types .

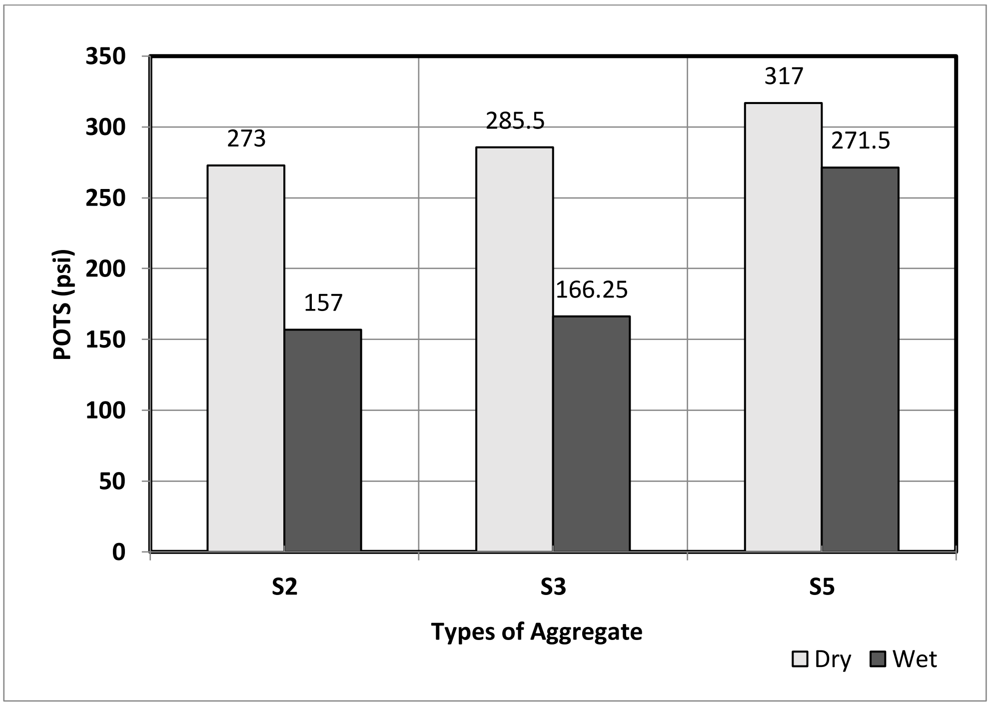

Figure (1) POTS for S2, S3 and S5 For Standard Stub Results.

The experimental results of modified stub:
In order to enhanced the test method and reduction of the phenomenon of blockage and aggregation of the asphalt binder due to the lack of the number of exit outlets (4 outlets for standard conditions). It was proposed to increase the number of gates for the discharge of the excess asphalt binder in the same way as the radial gate distribution adopted by the standard model.

More details about the results of modified stub are tabulated in the following tables

Table (1-5) POTS (psi) For S2 with Modified Stub

Trail	Condition Type	Type of Failure	POTS
#1	Dry	4% C2, 96% C1	242
#2	Dry	100%C1	242
#3	Dry	5% C2 ,95% C1	242
		Mean psi	242
		Standard Deviation	0
		Coefficient variation	0
#4	Wet	75% C1 ,25% A	120
#5	Wet	75% C1 ,25% A	120
#6	Wet	60% C1 ,40% A	120
		Mean psi	120
		Standard Deviation	0
		Coefficient variation	0
POTSL (mean dry/mean wet)			50%

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Table (1-6) POTS For S3 with Modified Stub.

Trail	Condition Type	Type of Failure	POTS
#1	Dry	100%C1	242
#2	Dry	100%C1	254
#3	Dry	100%C1	254
		Mean psi	250
		Standard Deviation	6.9
		Coefficient variation	0.027
#4	Wet	100%C1	133
#5	Wet	100%C1	151
#6	Wet	100%C1	145
		Mean psi	143
		Standard Deviation	9.16
		Coefficient variation	0.064
POTSL (mean dry/mean wet)			%43

Table (1-7) POTS For S5 with Modified Stub

Trail	Condition Type	Type of Failure	POTS
#1	Dry	100%C1	255
#2	Dry	100%C1	255
#3	Dry	100%C1	284
		Mean psi	265
		Standard Deviation	16.7
		Coefficient variation	0.063
#4	Wet	100%C1	224
#5	Wet	100%C1	218
#6	Wet	100%C1	230
		Mean psi	224
		Standard Deviation	6
		Coefficient variation	0.026
POTSL (mean dry/mean wet)			15%

It can be concluded from Tables (1-5) to (1-7) and Figure (2):

- The aggregate type S2 with modified stub shows cohesion failure in dry condition for three samples with mean Pull Off Tensile Strength 242 psi. On other hand after conditioning in water for 24hr the results show sample have cohesion failure with mean Pull Off Tensile Strength 120 psi.
- The aggregate type S3 with modified stub shows cohesion failure in dry condition for three samples with mean Pull Off Tensile Strength 250 psi. On other hand after conditioning in water for 24hr the results show sample have cohesion failure with mean Pull Off Tensile Strength 143 psi.

- The aggregate type S5 with modified stub shows cohesion failure in dry condition for three samples with mean Pull Off Tensile Strength 265 psi. On other hand after conditioning in water for 24hr the results show sample have cohesion failure with mean Pull Off Tensile Strength 224 psi.

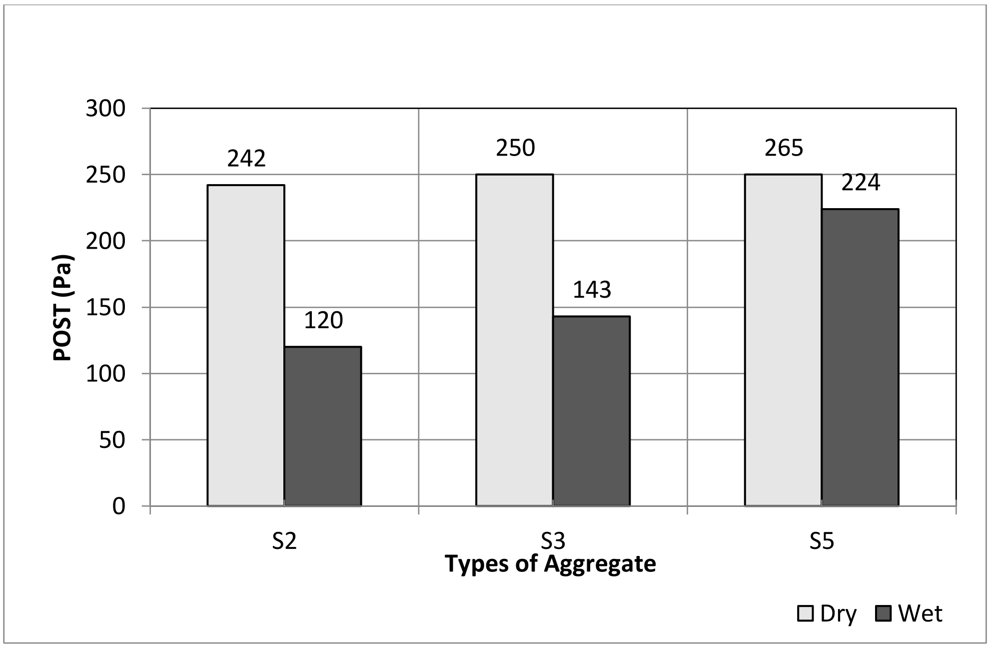

Figure (2) POTS For Both S2 , S3 and S5 with Modified stub.

Now to see the different in results of POST between the outcomes of ordinary pull off stub and modified stub in dry and wet condition as shown in figure(3) and (4).

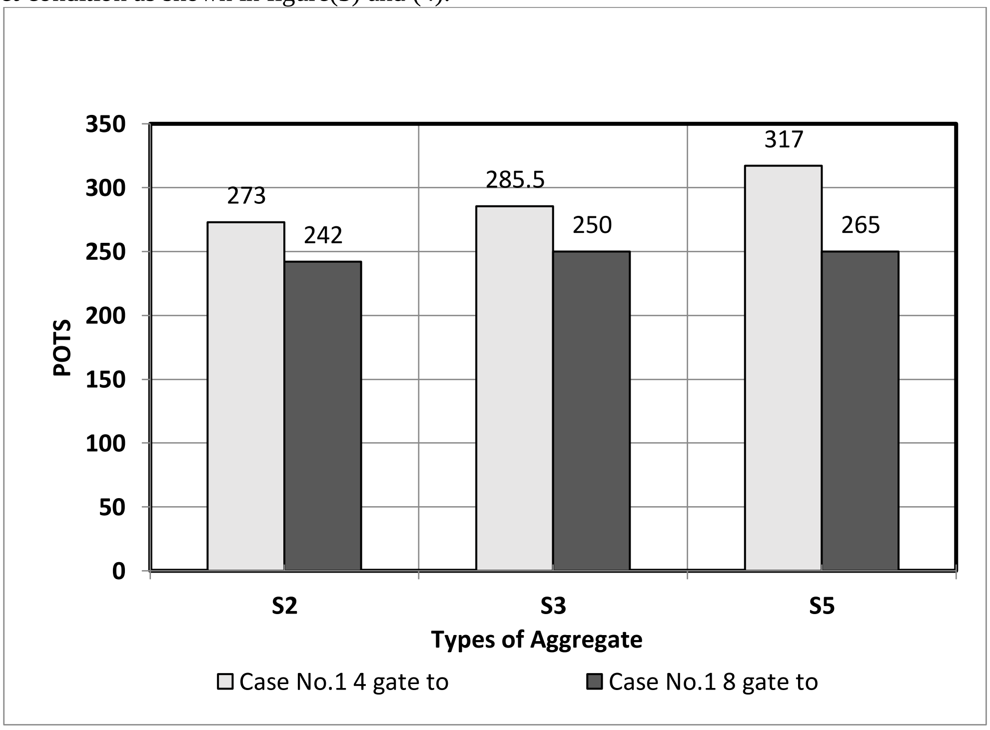

Figure (3) Pull Off Tensile Strength of Ordinary and Modified Stub in Dry Condition.

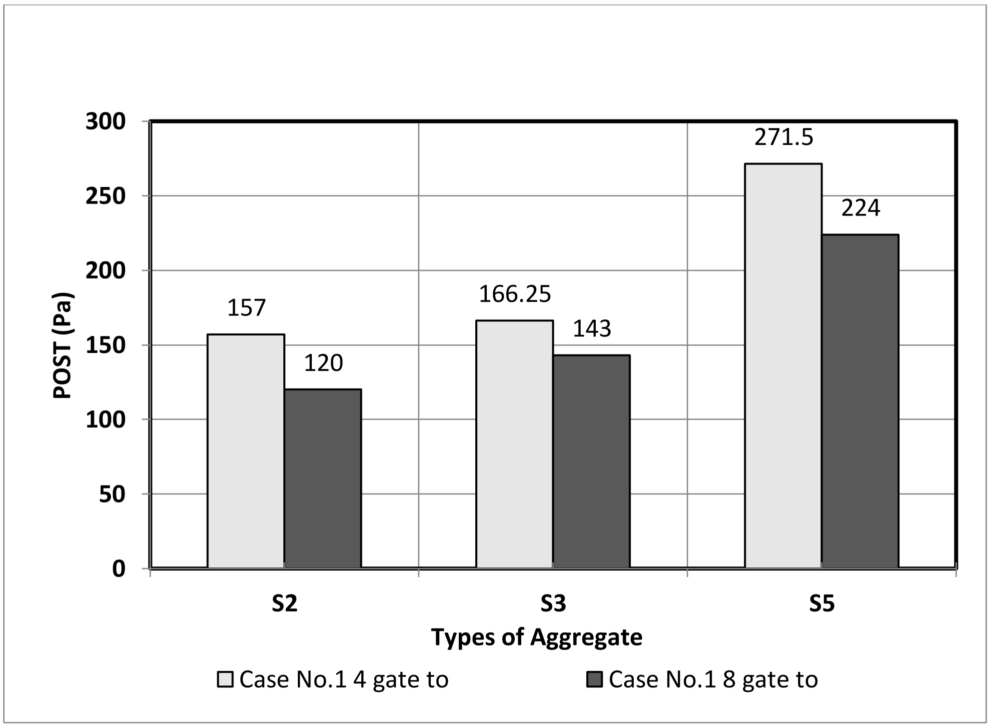

Figure (4) Pull Off Tensile Strength of Ordinary and Modified Stub in Wet Condition.

As shown in figure (3) and (4):
There are a moderate different of POTS between standard and modified stub such as POTS of S2 aggregate type in dry condition of standard stub is 273 psi more than the POTS of S2 aggregate type in dry condition of modified stub 242psi. The reason behind this different was the improving in stub design by making the excess asphalt binder flow out much better than the ordinary stub through it excellent controlling in asphalt binder film thickness so guaranteeing complete affinity between the aggregate plates and asphalt binder.

CONCLUSION

Within the limitation of test and materials used in this study, the following conclusions can be introduced:

- Physical properties of asphalt binder and aggregate plays significant role on affinity between asphalt binder and each one of the aggregate.
  The aggregate have high percentage of pore size indicates good resistance to stripping and reduced effect of moisture damage such as S5 according to experimental results from Bitumen Bond Strength.
- Time of immersion the aggregate and asphalt binder on water have a main role on moisture damage.
  If wet condition time of Bitumen Bond Strength test increase the loss of the pull off tensile strength increase.in this work we used 24hr curing time for all the aggregate types so as to compare between them.
- The modified stub allowed the excess asphalt binder to flow out when the stub pressed on the aggregate plate surface. Perfect control of the asphalt binder film thickness is obtained so that a complete affinity system between the asphalt binder and metal. This modification in PATTI became more reliable and the device useful to evaluate adhesion and cohesion bond between aggregate and asphalt binder system.
  The coefficient of variation of samples by modified stubs was very low (less variation from the average) as compared with results obtained from ordinary stubs.
- The Pull Off Tensile Strength Losses (POTSL) at failure for wet and dry condition can be calculated and used as parameter to indicated the advantage of modification of stub.

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