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Laboratory Investigation of Materials Type Effects on the Microsurfacing Mixture

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Abstract

Pavement preservation is a quintessential system of treating pavements at the optimum time to maximize their useful life. One of the preventive maintenance treatment options is using microsurfacing system as the acceptable and economical solution. This study presents a laboratory investigation of aggregate type and adhesive materials and their relationship to microsurfacing pavement properties such as cohesion, wet track abrasion loss, excess asphalt and compaction. The method of this study relies on ISSA A143, using the Cohesion 30 min and 60 min, Wet track abrasion loss, Loaded-wheel excess asphalt and finally Loaded-wheel compaction. The verification of this method was achieved through measuring the various factors of specimens constructed in laboratory using two different aggregate sources as river and mountain aggregates and two binders as CSS-1h and CQS-1h. The results showed that mixes contain riverine aggregates showed more cohesion properties. Base on wet track test results mixes, mixes containing riverine type aggregate were more resistant to abrasion. In addition CQS-1h emulsion showed better adhesiveness against abrasion in both types of aggregates in asphalt mixes. With increased amount of emulsions in mixes, load wheel values increased as well. Loaded wheel compaction test results confirmed that river based aggregates are more susceptible to rutting failure. The results of wheel tracking test illustrated that CSS-1h emulsion applied in mixes had better resistance to rutting.

Key words: Microsurfacing; Aggregate; Cohesion; Wet Track; Loaded-Wheel Test; Polymer Modified Emulsion.

1. Introduction

Pavement preservation is a planned system of treating pavements at the optimum time to maximize their useful life. Pavement preservation enhances pavement longevity at the lowest cost. Both rigid and flexible pavement must withstand wheel loads, environmental effects, and temperature variations. Factors deteriorating asphalt pavements include environmental and wheel load-related factors. Load-related stresses develop fatigue cracking and rutting, whereas environmental factors induce thermal cracking, block cracking, and weathering and raveling [1]. Pavements must be treated in time in order to avoid increasing of deterioration rates due to these cracks [2].

Pavement condition changes with time and requires different types of treatments. The Pavement Condition Index (PCI) is a numerical index between 0 and 100 and is used to indicate the condition of a roadway. The PCI provides a numerical rating for the condition of road segments within the road network, where 0 is the worst possible condition and 100 is the best. If pavement is seriously cracked, major rehabilitation is required [2].

One of the preventive maintenance treatment options is using microsurfacing system as the acceptable and economical solution. Microsurfacing is a quick-traffic system that allows traffic to return shortly after placement. Normally, these systems are required to accept straight, rolling traffic on a 12.7 mm (0.5 in) thick surface within one hour after placement in specific application conditions. Stopping and starting traffic may require additional curing time. Microsurfacing should be capable of performing in variable thickness cross-sections such as ruts, scratch courses and milled surfaces. After curing and initial traffic consolidation, it should resist further compaction. The micro surfacing shall be applied as a homogeneous mat, adhere firmly to the prepared surface, and have a skid-resistant texture throughout its service life [4]. In the same category of pavement treatments as seal coating and thin hot mix asphalt (HMA) overlays, microsurfacing treatments cover the entire width of the roadway to which they are applied [5]. Generally microsurfacing is classified as a preventative maintenance treatment as opposed to a corrective

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maintenance treatment because of the significant ability of microsurfacing to seal and restore pavement surfaces but the disadvantage of microsurfacing is in improving structural failures to improve structural defects [6]. Due to this classification by agencies involved in road repair and maintenance, microsurfacing is most often used as a surface treatment to correct rutting, improve surface friction, and extend pavement life by sealing any cracks in the pavement surface [7]. Microsurfacing is shown to be most effective under certain conditions as treatment effectiveness is influenced by climate, traffic loading and highway class, with greater long-term effectiveness generally associated with lower freeze and traffic conditions, and lower pavement class [8]. While this appears to indicate microsurfacing would not be suitable for use on high-traffic roadways, there is a comparable decrease in efficiency of other treatments under heavy traffic loads. Microsurfacing perform well for 3-4 years on heavily travelled roads [9], microsurfacing treatments can be expected to last at least seven years when placed on medium to high volume roads [10]. Additionally, microsurfacing is very successful on both low and high volume roadways and is recommended for night applications on heavy-traffic streets [11].

Improvements in rutting and friction characteristics are the most frequently mentioned benefits gained from microsurfacing [7, 9, 12, 13 and 14]. There is a 40% reduction in the amount of original rutting, and substantial increases in the friction characteristics of the pavement [13]. In the aforementioned Texas Department of Transportation (TxDOT) study, microsurfacing was shown to perform most efficiently at reducing bleeding and increasing PCI [15]. Microsurfacing produced a higher PCI and maintained it longer than chip sealing. Conventional thin asphaltic concrete overlays are expensive and often do not perform well in harsh environments [16]. Also, chip seals, in addition to their performance limitations, are often associated with windshield breakage and increased noise, while microsurfacing does not suffer from either of these limitations to the same degree [17]. Microsurfacing allows for rapid opening of roadways to traffic, often within 1 hour or less of its application under a range of conditions [18]. Reports of a great reduction in ride roughness support microsurfacing immediate benefits [19], while additional benefits are seen over time as microsurfacing effectively addresses rutting, increases ride quality, and has a significant service life [14].

Compatibility between aggregates and asphalt emulsion does play an important role in micro-surfacing mixture design procedure and evaluation [2].

Among all mix design guidelines for microsurfacing, International Slurry Surfacing Association (ISSA) and American Society for Testing and Materials (ASTM) guidelines are the most accepted and practiced around the world. ISSA developed A143 guideline for microsurfacing, and ASTM suggested D6372 for microsurfacing [2].

According to ISSA A143 It is normally not required to specify all tests for every project. A compilation of the results from the listed tests should be indicative of system performance. Failure to meet requirements for an individual test does not necessarily disqualify the system. If, for example, the system to be used on the project has a record of good performance, an individual test result may be waived [4].

1.1. Objectives of the Study

The scope of this evaluation included measuring and analyzing various characteristics of two types of aggregates used in microsurfacing mixes in Iran and two types of binders and evaluation of their effects on the properties of microsurfacing system using the tests according to recommended performance guideline for microsurfacing (ISSA A143) provided by International Slurry Surfacing Association. The intent of this guideline is to aid in the design, testing, quality control, measurement and payment procedures for the application of micro surfacing. The characteristics are texture of aggregates, Los Angeles weight loss and sodium sulfate soundness on aggregates, the tests on the binder and the tests on the prepared microsurfacing specimens.

2. Materials and Methods

Materials used in this study consist of two types of aggregates and two asphalt emulsions concluded a cationic quick setting (CQS-1h) and a cationic slow setting (CSS-1h).

2.1. Aggregates

The aggregate shall be a crushed stone such as granite, slag, limestone, chat, or other high-quality aggregate, or combination thereof. Two types of aggregates obtained from the Arshia and Molayem sand factories in Tehran, Iran, that respectively are from the river and mountain quarry were used in this investigation. The aggregates specifications are shown in table 1. Aggregate sizes range is from 0-5 mm. These sources contained mainly the crushed stone coarse aggregates, fine aggregates, and same types of mineral fillers. Typical use of filler levels are normally 0.0 - 3.0 percent and considered as part of the aggregate gradation. When using Arshia and Molayem aggregates, same filler type contained in aggregates was used. The acceptable values of specifications according to the ISSA A143 are shown in each table and it can be seen all of the two types of aggregates passed this specifications except sand equivalent. But it can be waived considering the nearness to the minimum value of the sand equivalent.

Table 2 presents the gradation of aggregates. Based on ISSA A143 specifications for microsurfacing, both types of aggregates used in this study are considered as type II aggregate gradation. This aggregate gradation is used to fill surface voids, address surface distresses, seal, and provide a durable wearing surface.

Table 1. Molayem and Arshia aggregates specifications

Tests	Standard Methods	Result for Molayem Aggregate	Result for Arshia Aggregate	ISSA A143 specification limit
Los Angeles abrasion Loss (%)	ASTM C 131	23%	19%	<30
Sodium sulfate soundness (%)	ASTM C 88	0.4% Coarse Aggregates 1.1% Fine Aggregates	0.8% Coarse Aggregates 2.3% Fine Aggregates	<15
Fractured Particles	ASTM D 5821	100% one face 100% two face	100% one face 100% two face	100
Sand Equivalent	ASTM D 2419	62	62	>65

Table 2. Gradations of the aggregates according to ISSA A143

Sieve Size		Passing by Weight (%)			Stockpile Tolerance, %
in	mm	Arshia	Molayem	Specification limit (ISSA Type II)	
3/8	9.500	100	100	100	-
No. 4	4.750	96	96	90-100	5%
No. 8	2.500	80	80	65-90	5%
No. 16	1.250	58	58	45-70	5%
No. 30	0.630	40	40	30-50	5%
No. 50	0.315	25	25	18-30	4%
No. 100	0.160	15	15	10-21	3%
No. 200	0.075	10	10	5-15	2%

In this study the mean gradation of maximum and minimum of the microsurfacing limits suggested by ISSA A143 was selected that its curve has been shown in Figure 1.

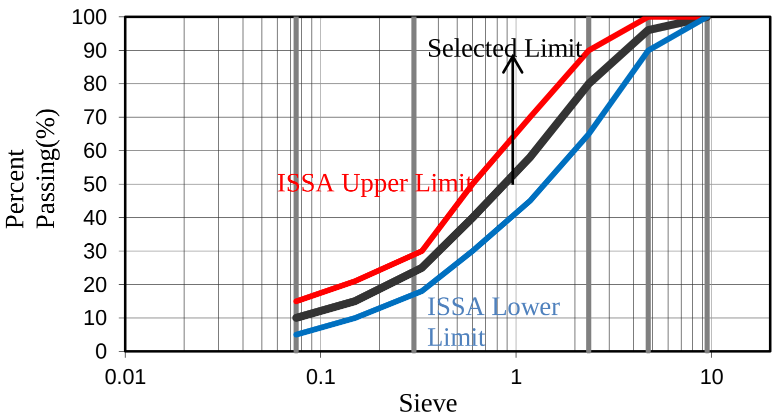

Figure 1. Gradation curve for 0-5 mm aggregates

2.2. Bitumen

The binders used in this research were based on two asphalt emulsions obtained from Tehran refinery and it concluded a cationic quick setting (CQS-1h) and a cationic slow setting (CSS-1h).

Conventional bitumen tests according to ASTM standard were performed on two types of emulsions in order to determine their physical properties. The results are reported in Table 3.

Table 3. CSS-1h and CQS-1h asphalt emulsion specifications

Tests	Standard Method	Emulsion CQS-1h Results	Emulsion CSS-1h Results	ISSA Specifications	
				Max	Min
Viscosity, Saybolt Furol seconds @ 25°C	ASTM D 244	85	84	100	20
Sieve, retained on No. 20, %	ASTM D 244	0.02	0.02	0.10	-
Coating Test, %	ASTM D 244	94	91	-	80
Residue by Distillation	ASTM D 244	64	65	-	62
Particle Charge	ASTM D 244	Positive	Positive	Positive	
Settlement and Storage Stability, %, 24h	ASTM D 244	0.2	0.2	1	-
Tests on Residue					
Softening Point by R 7 B, °C	ASTM D 36	63	61.4	-	57
Penetration @ 25°C, 100 g, 5 sec	ASTM D 5	78	76	40	90

2.3. Methods

Four commonly used tests were applied to investigate properties of mixes under definite conditions. In this research, the repeatability of test results obtained from the four mixture design tests proposed by the ISSA were tested. The testing methods are:

- **ISSA TB139**:

Method to classify emulsified asphalt/aggregate mixture systems using a modified cohesion tester and the measurement of set and cure characteristics; Modified Cohesion Tester is used to measure cohesion of the mixture at suitable time intervals such as 30, 60, 90, 150, 210, and 270 minutes after casting. To do this, a torque wrench is used to measure the torque required to rotate neoprene cylinder in contact with the specimen. Set time is defined as the elapsed time after casting when a slurry system may not be remixed into homogenous slurry. A plot of torque versus time is developed based on modified cohesion test results to classify the system in terms of set time and traffic time.

- **ISSA TB100**:

Method for wet track abrasion of slurry surfaces, one-hour soak and six-day soak; Wet track abrasion test is a field simulation test to measure the wearing qualities of microsurfacing mixture under wet abrasion conditions. Wet track abrasion test establishes the minimum asphalt emulsion content necessary to prevent excessive raveling of cured micro-surfacing mixture. This test was conducted after curing the samples. Wet track abrasion test were performed on 1-hour and 6 days soaked sample to determine susceptibility to short term moisture exposure. The result of the test is the loss in weight of the specimen expressed in grams per square meter (or square foot) and is reported as the wear value, also denoted as WTAT loss.

- **ISSA TB109**:

Method for measurement of excess asphalt in bituminous mixtures by use of a loaded-wheel tester and sand adhesion; Loaded-Wheel test measures the resistance of mixture against flushing under heavy traffic. This test establishes the maximum asphalt emulsion content necessary to prevent flushing of cured micro-surfacing mixtures. The mixture is compacted by means of a loaded, rubber tired, reciprocating wheel. The measured parameter is the sand adhesion, which is an indirect measure of the amount of excess asphalt in the mix. Sand adhesion value is a function of the number of cycles (usually 1,000 cycles conditioning and 100 for the test) and load (usually 57 kg (125 lbs.) plus the weight of the frame).

- **ISSA TB147**:

Methods for measurement of stability and resistance to compaction, vertical and lateral displacement of multilayered fine aggregate cold mixes. These methods cover three test procedures which measure the amount of compaction or displacement characteristics of multilayered, dense graded, fine aggregate cold mixes such as slurry seal or cold micro asphalt bituminous surfaces under simulated rolling traffic compaction by Loaded-Wheel Test, modified LWT or British Wheel Tracking machines. The prepared specimens after cooling for two hours to room temperature are measured centrally for width and net thickness using the gauge block. The net weight is obtained and recorded. The specimens are then mounted in the LWT machine and subjected to 1000, 57 kg (125 lbs.) cycles of LWT compaction at 22°C ± 2°C. The specimens are then removed from the LWT machine and immediately remeasured laterally and centrally in the wheel path and the results recorded.

2.4. Mix design

The test method includes four types of mixtures listed in table 4. There are all the different material combinations of binder and aggregate source investigated.

Table 4. Combination of different binder and aggregate sources

No.	Abbreviation	Material Combination
1	AS	Arshia aggregate and CSS-1h
2	AQ	Arshia aggregate and CQS-1h
3	MS	Molayem aggregate and CSS-1h
4	MQ	Molayem aggregate and CQS-1h

Three different percentages are used for each binder. The first property level termed formulation "A" has a low emulsion content of ten percent emulsion. Formulation "B" has a medium emulsion content of twelve percent, and Formulation "C" has a high emulsion content of fourteen percent. Ten percent water was used to mix each formulation, and no additive was used. The analysis was carried out for all four main ISSA design tests.

3. Results and discussions

3.1. Cohesion test results

30 min cohesion results (Figure 2) indicate that generally with adding the percentage of emulsions the amount of cohesion increases in both types of mixtures and it is harmonic in aggregate types which are related to river base, it can be conclude that the correlation is rather strong. The maximum amounts of cohesion is related to mixtures contain CQS-1h, which can be attributed to the strong interface, between the aggregate with mountain source. Subsequently, the maximum amount of increase is related to mixture, containing 12% of CQS-1h with mountainous aggregates.

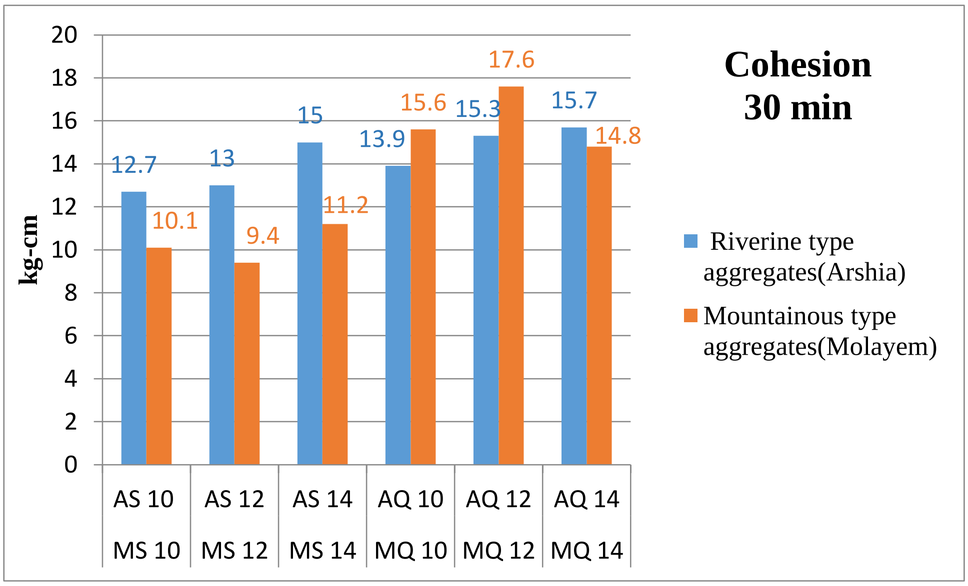

Figure 2. Results of Cohesion 30 min

Figure 3 shows that after 60 min the rate of increase in mixtures, containing mountainous type of aggregates with CSS-1h are more than those of contain either riverine type or CQS-1h emulsion, which can be related to creation a strong bond between CSS-1h emulsion and aggregates after some time. The maximum amount of cohesion is related to mixtures contain 12 and 14% of CSS-1h and CQS-1h with riverine aggregates, respectively.
It can be seen that the maximum rate of increase of cohesion is related to mixture containing 14% of CSS-1h with mountainous aggregate type with approximately 50% raise.

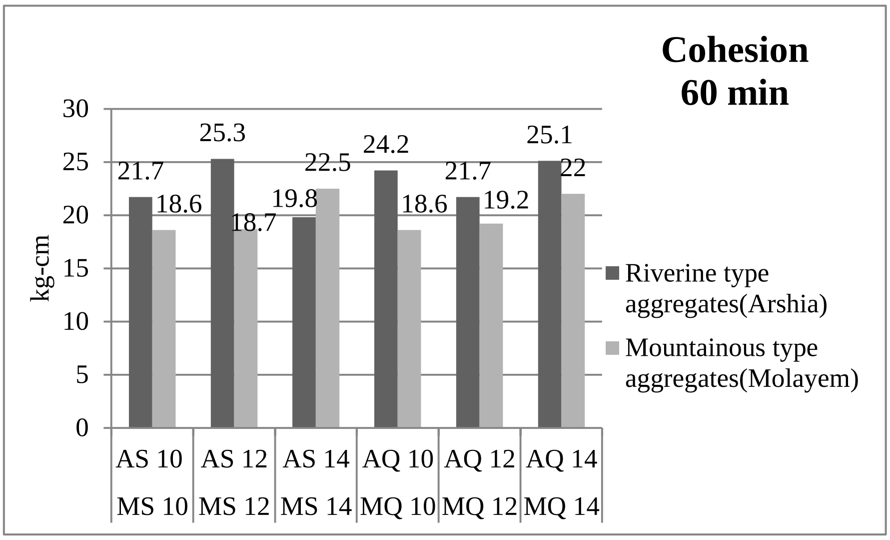

Figure 3. Results of Cohesion 60 min

According to Robati and the results of 30 min and 60 min cohesion of microsurfacing mixtures adding a little more or less asphalt emulsion than the optimum amount can be lead to cohesion loss. Also, it can be observed that type of aggregates has a few effects on the results.

3.2. Wet track test results

As it can be seen in Figure 4, the mixes containing mountainous type aggregates showed remarkable abrasion loss compared to those mixes prepared with riverine aggregates, in other words the strength of riverine aggregates against abrasion is greater than mountainous ones.

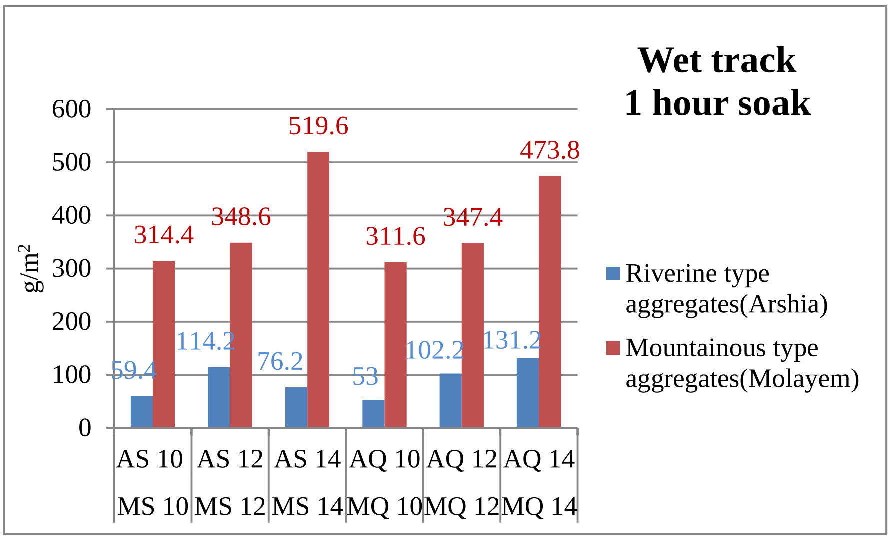

Figure 4. Results of Wet track 1 hour soak

The maximum value of abrasion is related to mixes contain mountainous aggregates with CSS-1h emulsion, it can be concluded there is incompatibility between these elements relationship. Also the maximum increase rate of abrasion value is considered for mixes contain 14% CSS-1h and mountainous type aggregate with approximately 50% greater than mixes contain 12% CSS-1h and mountainous type aggregate.

According to the Figure 5, the abrasion loss values of the mixes after 6 days are more than those of after 1 hour. It is obvious that water causes a weakness in bitumen and aggregate particles adhesiveness.

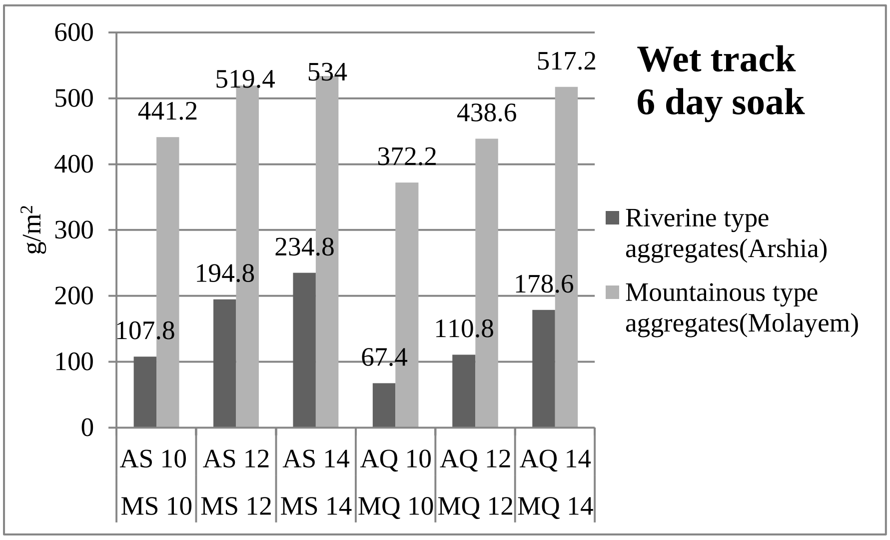

Figure 5. Results of Wet track 6 day soak

It can be seen that the stability of mixes contain riverine aggregates is greater than those of with mountainous mixes. Also the values of abrasions in mixes prepared with CSS-1h emulsion are more in comparison with those of prepared with CQS-1h emulsion. It may relate to the inherent interactions between particle charges and bitumen.

3.3. Loaded-wheel test results

Based on methodology section, the scope of the loaded-wheel test is to investigate the ability of mixes against flushing. Figure 6 illustrates that increasing the amount of emulsions the weight of specimens increase too, showing the adverse effect of emulsion increase to flushing and subsequently rutting. Also the results show mixes containing CQS-1h emulsion were more susceptible to such failures; it can be related to low stability of this type of emulsion and poor bond of it in presence of aggregates under definite load. According to Robati's study selection of optimum asphalt emulsion should be based on results obtained from test method for measurement of stability and resistance to compaction, vertical and lateral displacement of multilayered fine aggregate cold mixes (ISSA TB 147- Method A). Optimum emulsion content for rutting resistance can be determined at the minimum vertical and lateral displacements after 1000 cycle compactions of 56.7 kg load.

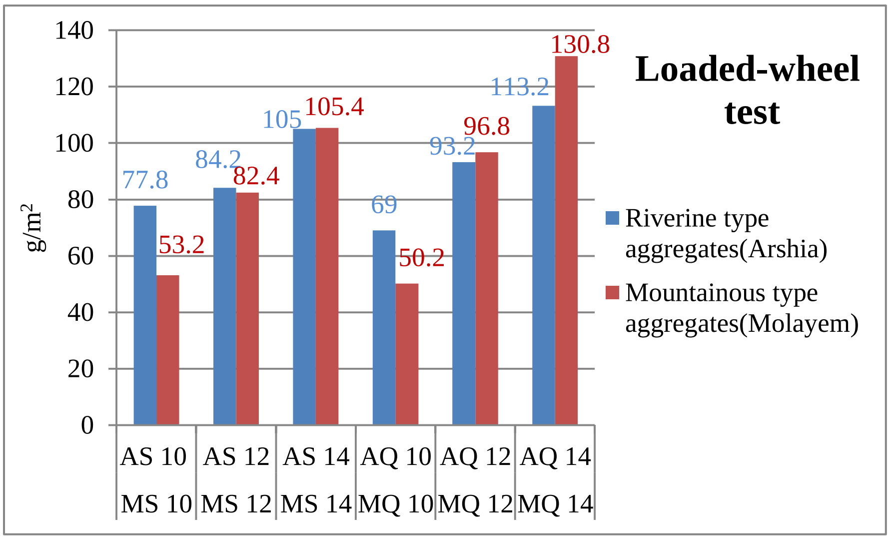

Figure 6. Results of Loaded-wheel test

3.4. Loaded-wheel (Compaction) test results

As it can be seen in Figure 7 the addition of emulsions will be resulted in increase of rutting values. The difference between values in mixes contain CQS-1h are more than those of with CSS-1h, it can be concluded that the bond between mountainous type aggregates and CQS-1 is better than other mixes. Also the values of Loaded-wheel test for mixes contain riverine type aggregates was more pronounced compared with those of with mountainous type aggregates, so it can be resulted the mountainous type aggregates show better resistance to rutting. Robati has shown that this test can be used as a method for selecting optimum asphalt emulsion residue in microsurfacing mixture according to maximum rutting resistance of the mixture.

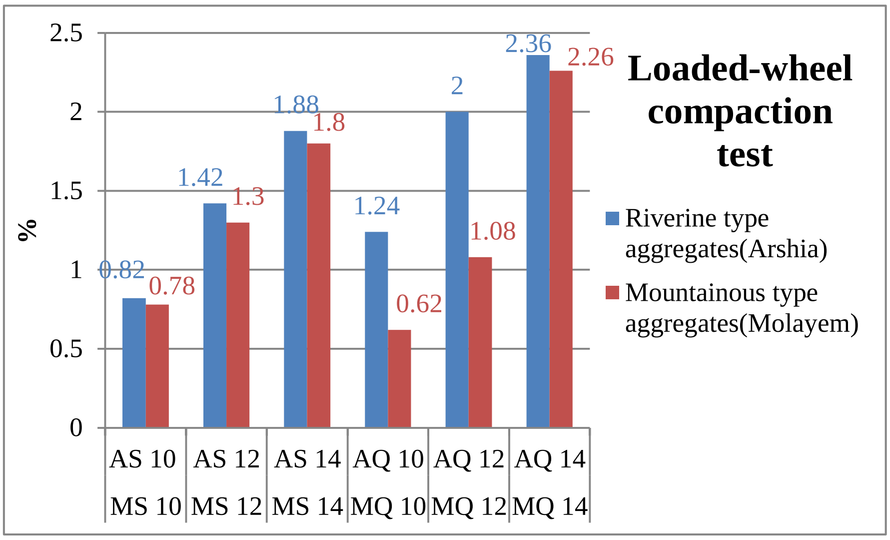

Figure 7. Loaded-wheel compaction test

4. Conclusions

Based on the results obtained from Cohesion test, Wet track test, Loaded-wheel and Loaded-wheel (compaction) tests that were performed on asphalt mixes, the following conclusions could be drawn:

1. Cohesion test results showed that mixes contain riverine aggregates showed more cohesion properties compared with those with mountainous type aggregates.
2. Base on wet track test results, mixes containing riverine type aggregate were more resistant to abrasion loads compared with those of with mountainous type aggregates.
3. According to wet track test results, CQS-1h emulsion showed better adhesiveness against abrasion in both types of aggregates in asphalt mixes.
4. Loaded wheel test (ISSA TB109) was effective in flushing phenomenon of asphalt mixes. With increased amount of emulsions in mixes, load wheel values increased as well.
5. Loaded wheel test (ISSA TB147) results confirmed that mixes contain river based aggregates are more susceptible to rutting failure than those of with mountainous types.
6. The results of loaded wheel test illustrated that CSS-1h emulsion applied to mixes had better resistance to rutting, so it can be recommended to use riverine aggregates with low dosages of CSS-1h emulsion.
7. The aggregates and asphalt emulsion compatibility does play an important role in microsurfacing mixture design procedure and operation time.

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