Assessment of Modified - Asphalt Cement Properties

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ABSTRACT

The Asphalt cement is produced as a by-product from the oil industry; the asphalt must practice further processing to control the percentage of its different ingredients so that it will be suitable for paving process. The objective of this work is to prepare different types of modified Asphalt cement using locally available additives, and subjecting the prepared modified Asphalt cement to testing procedures usually adopted for Asphalt cement, and compare the test results with the specification requirements for the modified Asphalt cement to fulfill the paving process requirements. An attempt was made to prepare the modified Asphalt cement for pavement construction in the laboratory by digesting each of the two penetration grade Asphalt cement (40-50 and 60-70) with sulfur, fly ash, silica fumes. Three different percentages of each of the above mentioned additives have been tried using continuous stirring and heating at 150 ºC for 30 minutes .

The prepared modified Asphalt specimens were subjected to physical properties determination; the penetration, softening point, ductility before and after laboratory aging. It was concluded that all percentage of additives has reduced the penetration value of asphalt cement, an exception to that could be noticed when using asphalt cement (40-50) and when adding sulfur. Softening point was increased with the addition of all percentage of additives except that with 7% sulfur by wt. of asphalt cement (40-50) it decreased by 8%.

After aging in general, the penetration decreased by about 37% for control specimens and the softening point increased by about 8% for control specimens.

For asphalt cement 40-50 after aging, Sulfur has the least impact on ductility since it reduces it by 20%. Silica fumes have moderate effect on ductility when it reduces it by 35%, while fly ash shows the highest impact of 36%.

For asphalt cement 60-70 after aging, sulfur was able to almost retain its ductility, while fly ash shows moderate reduction in ductility within a range of 20-36% and silica fumes shows high impact on ductility in the range of 30-50%.

Keywords: Ductility, Fly ash, Silica Fumes, Modified asphalt cement, sulfur, softening point, penetration.

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الخلاصة

يتم إنتاج الاسفلت السمنتي كمنتج ثانوي من قبل صناعة النفط، ويجب ان يخضع للعديد من العمليات من اجل السيطرة على النسب المئويه من مكوناته المختلفة بحيث تكون مناسبة لعملية الرصف.والهدف من هذا العمل هو إعداد أنواع مختلفة من الاسفلت السمنتي وتعديلها باستخدام المضافات المتوفرة محليا، وإخضاع الاسفلت السمنتي المعدل لعديد من إجراءات الاختبار.وبذلت محاولات لتحضير الاسفلت السمنتي المعدل في المختبر حيث تم استخدام نوعين من الاسفلت السمنتي ذو اختراق درجة (40-50 و 60-70) مع المضافات (الكبريت ,الرماد المتطاير و غبار السيليكا).وتم استخدام ثلاثة نسب مختلفة من كل من المواد المضافة المذكورة أعلاه وخضعت عينات الأسفلت المعدل للخلط مع التسخين بدرجة 150 مئوية ولمدة نصف ساعة. اجريت العديد من. الفحوصات لتحديد الخصائص الفيزيائية؛. اختراق، نقطة الليونة،القدره على السحب قبل وبعد التقادم المختبري .
تم الاستنتاج بان المضافات قامت بتقليل قيم الاختراق بصورة عامة باستثناء الاسفلت السمنتي نوع 40-50 بعد اضافة الكبريت بينما ازدادت درجة حرارة الليونة عند استخدام المضافات مع استثناء حالة اضافة الكبريت بنسبة 7% حيث قلت بمقدار 8% للاسفلت ذي نوع 40-50.
بعد التقادم تقلصت قيمة الاختراق بصورة عامة بمقدار 37% وازدادت قيم درجة الليونة بمقدار 8% عنها في النماذج المرجعية.
للاسفلت السمنتي 40-50 بعد التقادم يظهر الكبريت اقل تاثير على السحبية حيث تقل بمقدار 20% بينما يبين تاثير ابخرة السليكا بصورة متوسطة على السحبية حيث تقل بنسبة 35% اما الرماد المتطاير فيعطي اكبر تاثير وبقيمة 36%.
للاسفلت السمنتي 60-70 بعد التقادم يظهر الكبريت امكانية المحافظة على قيم السحبية بصورة عامة بينما يظهر الرماد المتطاير تاثير متوسط على السحبية حيث تناقصت بمقدار 20-36% اما ابخرة السليكا فتظهر اكبر تاثير على السحبية بمقدار 30-50%

كلمات رئيسية: السحبية، رماد متطاير،ابخرة السليكا، اسفلت سمنتي محسن، كبريت، درجة اليونة، نفاذية

1. INTRODUCTION

Highways play an important role in the economic and social development of societies; therefore, many studies are directed towards modifying pavement properties. In Iraq as well as other countries, pavement surface cracks and rutting are considered as major problems in roads. Asphaltic material with aggregate is usually used as a pavement mixture which is designed considering flexibility, durability and stability. Asphalt binder physical properties are critical to road performance. If an asphalt binder is too soft, rutting may occur soon after completion of the road due to traffic loads. On the other hand, if the binder is too hard or brittle, thermal cracking will occur during periods of cold weather. In addition, oxidative aging causes the binder to harden, thereby compounding its thermal cracking susceptibility over the life of the pavement, **Domke , 1999.**

The quality and grade of the asphalt binder varied due to the crude oil sources and the refining processes which often caused considerable distress to the pavement. Over the past few years, road networks have been subjected to more severe traffic conditions characterized by an increase in the number of vehicles, the load limits and by tire inflation pressures, **Sarsam , 2008**. Despite the use of asphalt mixes poor in binder quality and the enforcement of stricter specifications for materials – especially asphalt, the limits of mechanical stability of road surfacing have often been exceeded and this has resulted in damage such as cracking

and deformation. To control these phenomena, road surfacing must have better resistance to fatigue, increased resistance to permanent deformation, greater flexibility at low temperatures, higher resistance to raveling and stripping, and adequate resistance to ageing.
The use of modified asphalt makes it possible to improve these properties especially for some types of surfacing under particularly severe conditions of services, **Sarsam , 2012**.
Improvements made by adding modifiers to asphalt include increasing the viscosity of the binder, reducing the thermal susceptibility of the binder, and increasing the cohesion of the bitumen, **Sarsam , 2011**.
Increasing the resistance to permanent deformation and improving the resistance to fatigue at low temperatures could mark a good start, on the other hand, improving binder-aggregate adhesion (higher viscosity of the binder), Slowing down the ageing process (thicker film of binder around the aggregate) are considered to be vital for long term service of the pavement, **Vonck and Van , 1989.**
Collins and Bouldin , 1992. stated that the handling properties of the modified asphalt depend on the following factors: Asphalt type, modifier type and content and methods of modification. The effect of silica fumes and Phospho - gypsum as additives have been studied by **Sarsam , 2012,** and its positive impact on asphalt rheological and physical properties were pointed out.

2. MATERIAL

2.1 Asphalt Cement

For the purpose of this work, two type of asphalt cement penetration grade were considered, (40-50) and (60-70). Both types are obtained from the Duraa refinery, south-west of Baghdad. The asphalt cement properties based on the conventional penetration grading system.

2.2 Fly Ash

Fly ash, a by-product of coal combustion, is widely used as a cementation and pozzolanic ingredient in Portland cement concrete and asphalt concrete. Fly ash is available in local markets with low cost. This fly ash has low specific gravity (2.0) as compared with ordinary Portland cement (3.15), and specific surface area ranged to (500-750) m^2/kg. Chemical components of fly ash are tested in the laboratories of General Directorate of Geological survey and Mining and given in **Table.** while **Fig.1** present a sample of the fly ash used.

2.3 Sulfur

It was obtained from Al-Meshrak state company (30 km north of Mosul). The physiochemical properties of these materials are shown in **Table 2. Table 3.** present physical properties of sulfur. While **Fig2** present sample of the sulfur used.

2.4 Silica Fumes

Silica fumes are produced by a vapor phase hydrolysis process using chlorosilanes such as: silicon tetrachloride in a flame of hydrogen and oxygen. silica fumes is supplied as a white, fluffy powder, **ACI 234R, 1996.** Chemical compositions were tested in the laboratories of

General Directorate of Geological survey and Mining and given in **Table 4.,** The physical properties are given in **Table 5.** ,while **Fig3.** present the silica Fumes sample used.

3. PREPARATION OF MODIFIED ASPHALT CEMENT

3.1 Fly ash-Asphalt cement mix

Asphalt cement has been heated to 160° C for asphalt cement (40-50), 150°C for asphalt cement (60-70), and the fly ash was added gradually with continuous stirring on the hot plate for 30 minutes as blending time. Three percentage of the fly ash (5%, 10%, and 15%) by weight of asphalt cement (40-50) and (60-70) have been implemented. Samples were subjected to physical properties determination before and after aging process using thin film oven test.

3.2 Sulfur-Asphalt cement mix

Asphalt cement has been heated to 160° C for asphalt cement (40-50), 150°C for asphalt cement (60-70), and sulfur was introduced in a powder form to it and mixed using manual mixing and constant stirring on the hot plate for 30 minutes as blending time. Three percentage of the sulfur (3%, 5%, and 7%) by weight of asphalt cement (40-50) and (60-70) have been implemented based on work by **Sarsam , 2006**. Samples were subjected to physical properties determination before and after aging process using thin film oven test.

3.3 Silica Fumes -Asphalt cement mix Asphalt cement has been heated to160° C for asphalt cement (40-50), 150°C for asphalt cement (60-70), and then silica fume was added with mixing using manual stirring on the hot plate for 45 minutes as a constant blending time. Three percentage of the silica Fumes (1%, 2%, and 3%) by weight of asphalt cement (40-50) and (60-70) have been introduced based on previous work by **Sarsam (2012)**. Samples were subjected to physical properties determination before and after aging process using thin film oven test.

4. TESTING PROGRAM

4.1 Penetration Test

The penetration test, **ASTM D-5 (2002)** is an empirical measure of asphalt consistency. In this test, a container of asphalt cement is placed at the standard test temperature (25°C) in a temperature-controlled water bath. A prescribed needle, weighted to 100 grams, is placed on the surface of the asphalt cement for 5 seconds. The depth of penetration, expressed in units of 0.1mm, is considered the “penetration” of the asphalt cement.

4.2 Softening point test

The softening point test, **ASTM D36 (2002)** is also used to measure asphalt consistency. The test is performed by confining asphalt samples in brass rings and loading the samples with steel balls. The samples are placed in a beaker of water at a specified height above a metal plate. They are then heated at a specified rate. As the asphalt heats, the weight of the steel ball pulls the sample down toward the plate. When the sample and ball touch the plate, the water temperature is measured and designated as the ring and ball softening point of the asphalt.

4.3 Ductility Test

The ductility of a asphalt cement can be defined as the “distance to which it will elongate before breaking when two ends of a briquette specimen of the material, are pulled apart at a specified speed (5cm/min ±5.0%) and at a specified temperature (25±0.50C) **ASTM D113-99 (2002).** This test method provides measure of tensile properties of bituminous materials and may be used to measure ductility for specific requirements. Ductility is an indicator of flexible behavior of asphalt under various temperatures.

4.4Thin film oven test

Physical properties of asphalt cement changes with respect to time and temperature. Consequently, the performance of pavement will also witness some changes. To take into account the effects of mixing and compaction temperatures as well as the storage time on the behavior of asphalt cement and asphalt mixture. All the asphalt samples have been exposed to accelerated aging by heating the samples in an oven for 5 hours at 163°C .The **ASTM D -1754 (2002)** has the satisfied information about this test. Ductility, Penetration and softening point after thin film oven test have been determined for asphalt cement for all percentage of modifiers that will be used.

5. DISCUSSIONS ON TEST RESULTS

5.1 Impact of additives on physical properties

Fly ash was added to the asphalt cement by the percentage of (5, 10 and 15%) by weight of asphalt cement (40-50) and (60-70). For asphalt cement (40-50), increasing the percentage to (15%) the penetration was decreased about 68.18%. **Figure 4** presents such behavior. The softening point was (50°C) at (5%fly ash). Increasing the percentage to (15%), the softening point was increased about 6%. **Figure 5** shows the impact. The ductility was (53) at (5% fly ash).Increasing the percentage to (15%), the ductility was decreased to (28). **Figure 6** illustrates such behavior.

For asphalt cement (60-70), increasing the percentage to (15%), the penetration was decreased about 18.18%. **Figure 7** shows such details. At (5% fly ash) the softening point was (45°C).Increasing the percentage to (15%), the softening point was increased about 6.25%. **Figure 8** discusses such behavior. The ductility was (60) at (5% fly ash) .Increasing the percentage to (15%) the ductility was decreased to (30). **Figure 9** demonstrates the impact on ductility.

Sulfur was added to the asphalt cement by the percentage of (3, 5, and 7%) by weight of asphalt cement (40-50) and (60-70). For asphalt cement (40-50), increasing the percentage to (7%), the penetration was decreased by (27.27%). The softening point was decreased to (44°C) at (3% sulfur).Increasing the percentage to (7%), the softening point was decreased by 8%. The ductility was (+100) at (3% sulfur) .Increasing the percentage to (7%), the ductility was decreased to (95).

At asphalt cement (60-70) it was noticed that at (3% sulfur) the penetration was increased to (80).Increasing the percentage over (7%) the penetration was increased by 48.48%. The softening point was decreased to (45°C) at (3% sulfur) .Increasing the percentage over (7%) the softening point was decreased about 16.66%. The ductility was (+100) at (3% sulfur).

Silica Fumes was added to the asphalt cement by the percentage of (1, 2 and 3%) by weight of asphalt cement (40-50) and (60-70). It was noticed that:
At asphalt cement (40-50) increasing the silica fumes percentage to (3%) the penetration was decreased by 4.5%. The softening point was increased to (55°C) at (1% silica fumes) and decreased to (52°C) at (3% silica fumes).The ductility was decreased to (19) at (1% silica fumes) and increased to (25) when using (3%) silica fumes.
At asphalt cement (60-70), increasing the silica fumes percentage to (3%), the penetration was decreased by 33.3%.
The softening point was increased to (52°C) when a (3%) silica fume was introduced. The ductility was decreased to (27) at (1% silica fumes) and decreased to (19) when (3%) silica fumes was adopted.
Table 6 demonstrates the impact of additives on asphalt cement (40-50) properties. While **Table 8** shows the impact of additives on asphalt cement (60-70) properties.

5.2 Impact of additives on aging behavior

The impacts of additives on physical properties of asphalt cement after aging are illustrated in **table 7**. The asphalt cement of grade 40-50 has retained 40% of its ductility after aging; the softening point was increased by 8%, and the penetration was decreased by 36%. When additives were introduced, their impact was variable; the ductility was reduced by a range of 10-60 % based on additive type and percentage. Sulfur has the least impact on ductility since it reduces it by 20%. Silica fumes have moderate effect on ductility when it reduces it by 35%, while fly ash shows the highest impact of 36%. The softening point increases after aging by a range of 6-8% when different percentages and type of additives were introduced. The penetration value shows variations by a range of 20-60% based on additive type and percentage.
On the other hand, the asphalt cement of grade 60-70 exhibit 22% reduction in penetration, 6% increment in softening point and 25% reduction in ductility due to aging. When additives were introduced, sulfur was able to retain its ductility, while fly ash shows moderate reduction in ductility within a range of 20-36% and silica fumes shows high impact on ductility in the range of 30-50%.
The impact of additives on softening point was in a range of 3-6% for various percentages and type of additives. Sulfur shows the lowest impact on penetration in a range of 5-15%, while fly ash and silica fumes shows higher impact within a range of 17-30%.
Such behavior of additives may be attributed to the increase in viscosity due to high specific surface area of silica fumes, and to possible chemical reaction took place in case of sulfur and fly ash.

6. CONCLUSIONS

Based on the testing program, the following conclusions may be drawn:
1. All percentage of additives has reduced the penetration value of asphalt cement, an exception to that could be noticed when using asphalt cement (40-50) and when adding sulfur.
2. Softening point was increased with the addition of all percentage of additives except that with 7% sulfur by wt. of asphalt cement (40-50) it decreased by 8%.

3. Ductility was decreased with the addition of all percentages of additives.
4. For asphalt cement 40-50 after aging, Sulfur has the least impact on ductility since it reduces it by 20%. Silica fumes have moderate effect on ductility when it reduces it by 35%, while fly ash shows the highest impact of 36%.
5. The softening point increases after aging by a range of 6-8% when different percentages and type of additives were introduced. The penetration value shows variations by a range of 20-60% based on additive type and percentage.
6. For asphalt cement 60-70 after aging, sulfur was able to almost retain its ductility, while fly ash shows moderate reduction in ductility within a range of 20-36% and silica fumes shows high impact on ductility in the range of 30-50%.
7. The impact of additives on softening point was in a range of 3-6% for various percentages and type of additives. Sulfur shows the lowest impact on penetration in a range of 5-15%, while fly ash and silica fumes shows higher impact within a range of 17-30%.

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Figure 1. Fly ash.

Figure 2. Sulfur.

Figure 3. Silica fumes.

Table 1. Chemical Components of Fly Ash as tested by the laboratories of General Directorate of Geological survey and Mining.

Oxide	Percent	ASTM Requirement C618 (%)
SiO2	61.95	---------
Fe2O3	2.67	---------
Al2O3	28.82	---------
SiO2+Fe2O3+Al2O3	93.44	70.0 min.
Na2O	0.26	1.5 max.
CaO	0.88	----------
MgO	0.34	5.0 max
SO3	< 0.07	5.0 max
L.O.I	0.86	6.0 max

Table 2. Physiochemical properties of sulfur waste Element (% by weight).

Material	% Content
Sulfur	88-90
Carbon	10-12
Ash	0.1
sp. gr.	2.03

Table 3. physical properties of sulfur.

Physical properties	
Phase	solid
Density	2.07 g·cm^{-3}
Liquid density	1.819 g·cm^{-3}
Melting point	115.21 °C, 239.38 °F

Table 4. Chemical Components of silica Fumes tested in the laboratories of General Directorate of Geological survey and Mining.

Oxide	Percent
SiO2	99.1
Fe2O3	35.0 p.p.m
Al2O3	< 0.035
TiO2	< 0.006
CaO	0.03
MgO	52.0 p.p.m
SO3	< 0.07
L.O.I	0.7

Table 5. Physical properties of silica Fumes as supplied by the Manufacturing Company (Weaker Company 47).

Physical Properties	Test result
surface area m²/g	50-600
Density kg/m³	160-190
Loss of weight% when drying at 1000˚c for 2hrs	< 2
Loss of weight% when drying at 105˚c for 2 hrs	< 1.5
PH	3.9-4.3
% retained on 40 µm sieve	< 0.04
Moisture %	0.82

Table 6. Physical properties of Modified Asphalt cement Grade (40-50) before aging.

Asphalt cement (40-50)	Penetration	Softening point	Ductility
Control	44	50	>100
5%fly ash	25	50	53
10%fly ash	15	50	30
15%fly ash	14	53	28
3% sulfur	68	44	>100
5%sulfur	63	45	97
7%sulfur	50	46	95
1% silica fumes	25	53	19.5
2% silica fumes	32	53.5	21
3% silica fumes	41	51	22

Table 7. Physical properties of Modified Asphalt cement Grade (40-50) after aging.

Asphalt cement (40-50)	Penetration	Softening point	Ductility
Control	28	54	60
5%fly ash	15	52	33
10%fly ash	11	53	19
15%fly ash	9	55	11
3% sulfur	22	48	81
5%sulfur	50	46	79
7%sulfur	51	46	77
1% silica fumes	33	56	8
2% silica fumes	25	58	19
3% silica fumes	15	57	16

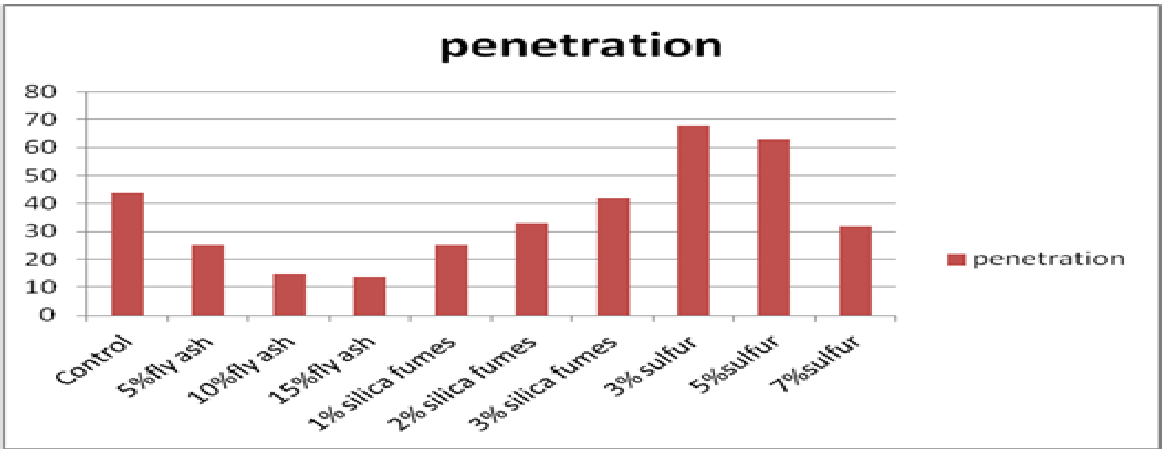

Figure 4. Effect of additive type and percentages on penetration value before aging for asphalt cement (40-50).

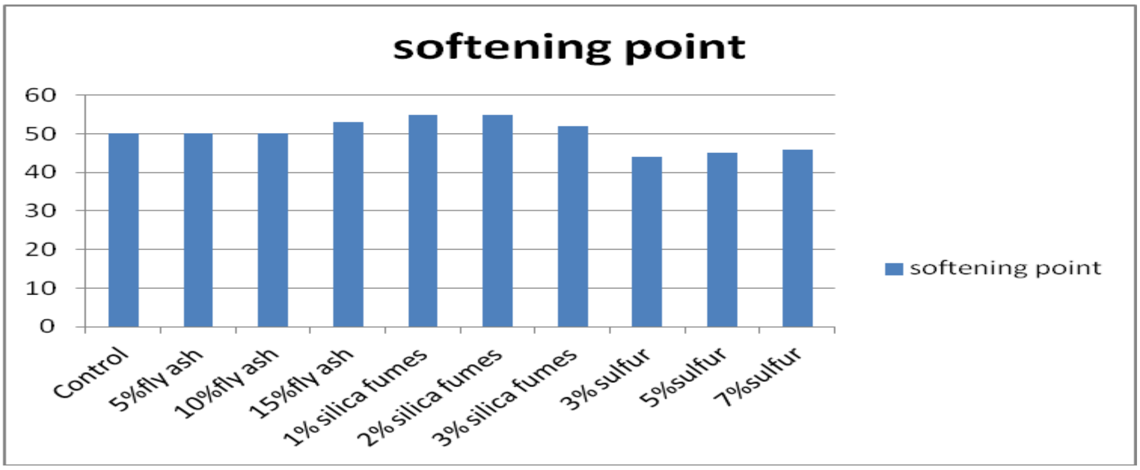

Figure 5. Effect of additive type and percentages on softening point value before aging for asphalt cement (40-50).

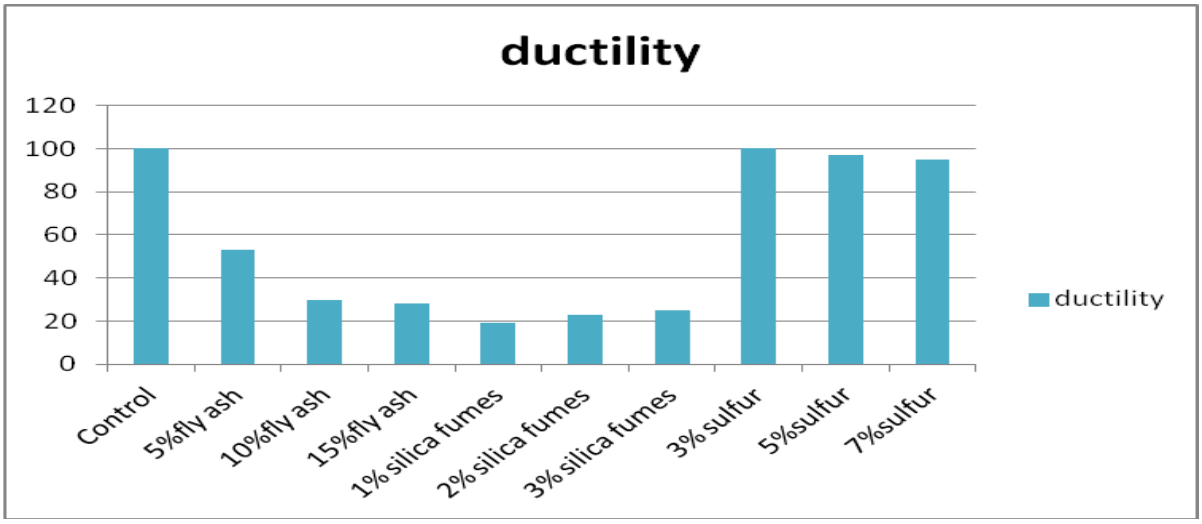

Figure 6. Effect of additive type and percentages on ductility value before aging for asphalt Cement (40-50).

Table 8. Physical properties of Modified Asphalt cement Grade (60-70) before aging

Asphalt cement (60-70)	Penetration	Softening point	Ductility
Control	66	48	>100
5%fly ash	52	45	60
10%fly ash	47	46	40
15%fly ash	54	51	30
3% sulfur	80	45	>100
5%sulfur	93	42	>100
7%sulfur	98	40	>100
1% silica fumes	63	48	27
2% silica fumes	57	54	25
3% silica fumes	44	52	19

Table 9. Physical properties of Modified Asphalt cement Grade (60-70) after aging.

Asphalt cement (60-70)	Penetration	Softening point	Ductility
Control	51	51	75
5%fly ash	41	46	48
10%fly ash	32	48	27
15%fly ash	42	53	19
3% sulfur	67	48	>100
5%sulfur	88	45	>100
7%sulfur	85	43	>100
1% silica fumes	52	50	19
2% silica fumes	41	55	16
3% silica fumes	32	54	9

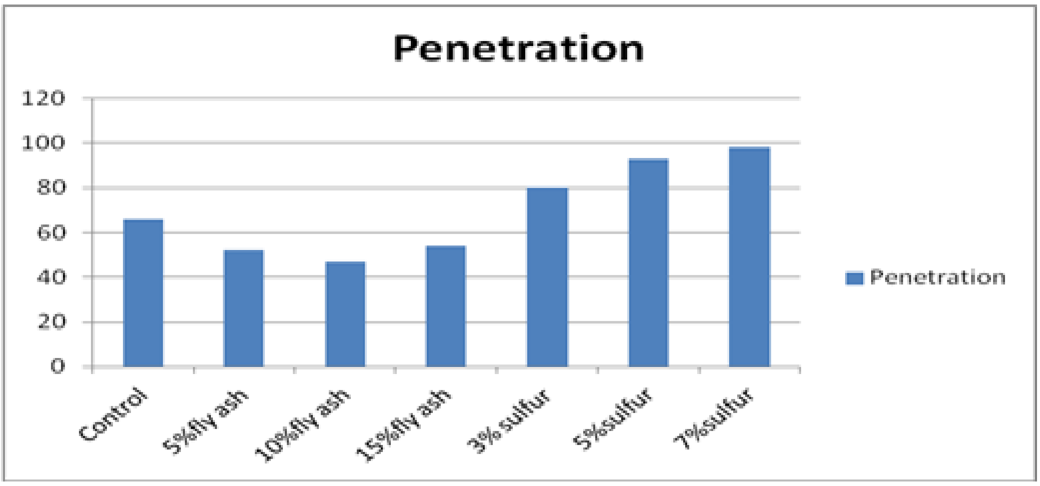

Figure 7. Effect of additive type and percentages on penetration value before aging for asphalt cement (60-70).

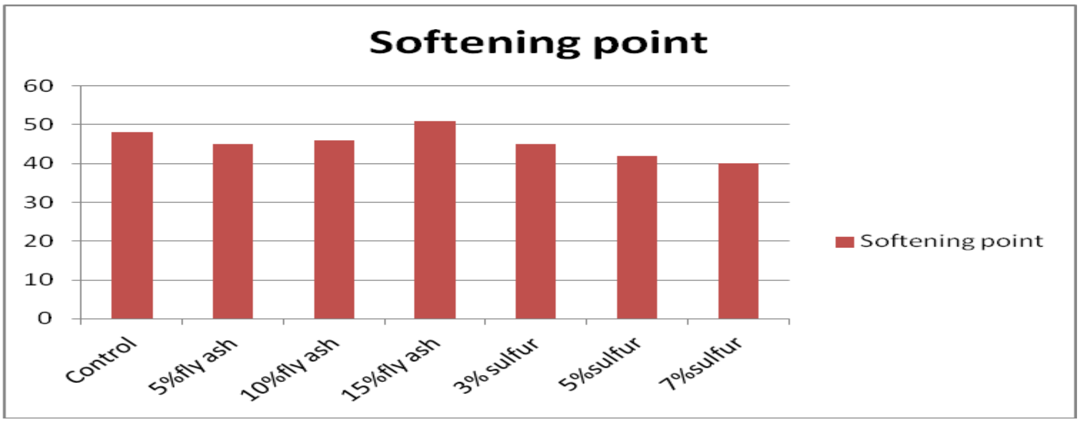

Figure 8. Effect of additive type and percentages on softening point value before aging for asphalt cement (60-70).

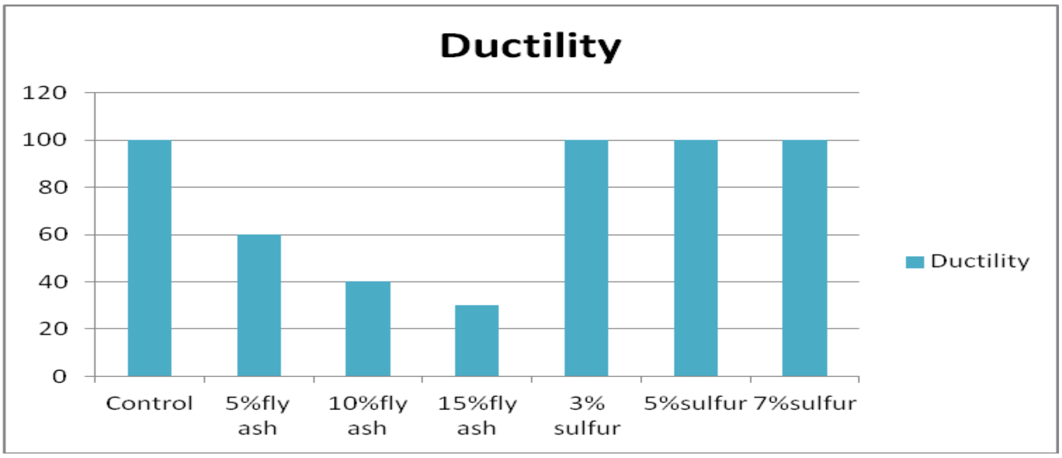

Figure 9. Effect of additive type and percentages on ductility before aging , asphalt cement (60-70).