International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Effect of Polystyrene Polymer Modifier and Glass Powder Filler on the Mechanical Characteristics of Hot Mix Asphalt

Sinan Khaleel Ibrahim

Assistant Lecturer, Highway and Transportation Department / Faculty of Engineering / Mustansiriyah University / Iraq

Abstract: ***The main objective, of this research, was studied the mechanical performance of hot mix asphalt that used powder of glass as mineral filler and improved with polystyrene polymer as a modifier and found the best percentages of combine polystyrene and glass powder that give optimal mechanical properties of asphalt mixture. This purpose was achieved by testing asphalt mixture samples with Marshall Tests system and found the Marshall stability, bulk specific gravity and air voids. The work plan of this study, included prepare a specimens of hot mix asphalt according to Marshall procedure of asphalt mix design and ASTM standard method (D 1559).The specimens prepared by one gradation of aggregate (with maximum size 12.5 mm according to SCRB specification) mixed with one type of asphalt (40 - 50 penetration grade), five different percentages of asphalt cement content (4.5, 4.75, 5.0, 5.25, 5.5)% (by total weight of mix), three different percentages of waste glass powder (5, 7, 9)% (by total weight of aggregate) and five different percentages of polystyrene polymer (0, 1, 2, 3, 4, 5)% (by total weight of asphalt cement) each specimen was compacted by Marshall compactor to 75 blow in each face. The laboratory tests that performed, in this study, on the prepared were 1. Marshal Method, 2. Standard test of Bulk specific gravity. 3. Standard Test Method for calculating the Percent of Air Voids. From the results of testing samples in laboratory the following conclusions could be made: The using of polystyrene as a modifier lead to increasing the stability and bulk specific gravity of asphalt mixture and lead to decrease the air voids within the mixture. Increasing of glass powder filler from 5% to 7% lead to increase the stability and specific gravity slightly, while the increasing of glass powder filler from 7% to 9% lead to decrease the stability and specific gravity. Increasing of glass powder leads to decreasing the air voids within the asphalt mixture. Preferable percentage of asphalt content, polystyrene content and glass powder filler, that gave best performance of asphalt mixture, were (5%, 4%, 7%) respectively.***

Keywords: Hot Mix Asphalt, polystyrene modifier, Glass filler, asphalt content, surface coarse

1. Introduction

Polymer modified asphalt has preferable mechanical properties and high durability than unimproved asphalt mixture. European countries start to use polymers in the asphalt mixtures at 1960. In 1993, great than 8% of the asphalt mixtures that used in France flexible pavements was improved with polymer (Martinho et. al., 1995).Asphalt improved with polymers was used also in several roads in brazil at last decade of past century and at present time, it is widely used. The polymers are mixed with the asphalt mixture to improving the abrasion resistance, aging, permanent deformation and fatigue cracks at high temperatures. When added the polymers to asphalt should not made it viscous at temperature of mixing, or brittle at lower temperatures. The asphalt modified with polymer need to well stability during transport and storage so that promise preferable mechanical properties than unmodified asphalt (Bull and Vonk, 1994).Polymers are perhaps had greater promising among other types of additives. Although of the huge number of polymers exist, only some types are proper as asphalt modifier. To accomplish the aim of getting preferable asphalt properties, a chosen polymer should generate a minor network within asphalt material by molecular reaction or by chemical interacting with asphalt. The formation of a functional system of modified asphalt was depend on the micro spreading of polymer in asphalt material (Isacsson, 1998).The Polymers could be classified to (four) types; fibers, plastics, elastomeric, and coatings (additives). Plastics can be divided to thermo-plastics and thermo-sets. The elastomeric classified to; naturally and artificial rubber. Many types of the primary thermo-plastics had been used as modifiers for asphalt, such as; polystyrene (PS), polypropylene (PP), polyethylene (PE) and polyvinyl chloride (PVC). When mixing the asphalt material with these polymers, it associate with asphalt at surrounding temperatures and enhance asphalt stiffness at common service temperatures (Isacsson, 1995). The properties of asphalt modified with polymersis base on polymer type and concentration. The polymer concentrations values are generally can be range from (4 to 6) % by total weight of asphalt binder (Giovanni, 2004). The High polymers concentrations were not economically and may be reason for many troubles in pavement. Desired properties of asphalt modified with polymers consist of high softening point, large viscosity, larger elastic recovery and better cohesive strength (Ionela, 2007) and (Reynaldo et. al., 2005).The Essential matter in polymer modification are; optimization of polymer blend composition, time and temperature, produces modified asphalt binder with good rheological properties (Diego et. al., 2009) and (Kumar, 2011).One of these polymers is steel fiber which used to improve the performance of asphalt mixture. (AL-Ridha et al, 2014, 2016) studied the effect of micro-steel fiber on hot mix asphalt and found that micro-steel fiber increase the marshall stability at different testing temperature and compaction.

2. Objective of Study

The main objective, of this research, was studied the mechanical performance of hot mix asphalt that used powder of glass as mineral filler and improved with polystyrene polymer as a modifier and found the best percentages of combine polystyrene and glass powder that give optimal

mechanical properties of asphalt mixture. This purpose was achieved by testing asphalt mixture samples with Marshall Tests system and found the Marshall stability, bulk specific gravity and air voids.

3. Properties of Material

The aggregate and asphalt cement that used in this study are available locally and used in the projects of roads erection. The filler (powder of glass) can be produced locally by crashing glasses to appropriate particles size. The polystyrene polymer (PS) can be found in local market but did not used for roads paving in Iraq until now.

3.1 Asphalt Cement

The asphalt cement has brought from Al-Duraa refinery and tested in laboratory. the penetration grade of asphalt was (40-50), and the other physical properties of were represented in table (1).

Table 1: Physical Characteristics of Al-Duraa Asphalt Cement

Properties	ASTM (Designation Number)	Asphalt Cement Grade (40-50)	
		Test Result	Specification Limits (SCRB, 2003)
Penetration (25°C, 100 gm, 5sec), (1/10 mm)	D-5	48	40 - 50
Softening Point (Ring and Ball), °C	D-36	57	---------
Ductility, Cm	D-113	114	> 100
Flash Point (Cleveland Open-Cup)	D-92	330	> 232
Specific Gravity, 25 °C	D-70	1.04	----------
Loss On Heat (5 Hrs, 163 (°C), 1/8" (thick)), %	D-1754	0.18	----------

3.2 Coarse and Fine Aggregate

The aggregates that used to prepare the samples in this study were crashed and obtained from AlNibaey quarries. The aggregates was sieved, washed, dried and then recombined to meet the standard requirements of gradation for surface coarse (type III B), according to the state corporation of roads and bridges (SCRB, 2003). one grade was selected at the middle range of surface course specification with maximum size (12.5)mm, as shown in figure (1), while table (2) listed the physical properties of coarse and fine aggregate.

Table 2: Physical Properties of Fine and Coarse Aggregate from AlNibaey quarries

Property	ASTM (Designation Number)	Test Result of aggregate	
		Coarse	Fine
Apparent Specific Gravity	C-127	2.673	2.681
Bulk Specific Gravity	C-127	2.608	2.652
Absorption of Water, %	C-127	1.22	2.1
Los Angles Abrasion , %	C-131	23.8 (max.) 30) %	----

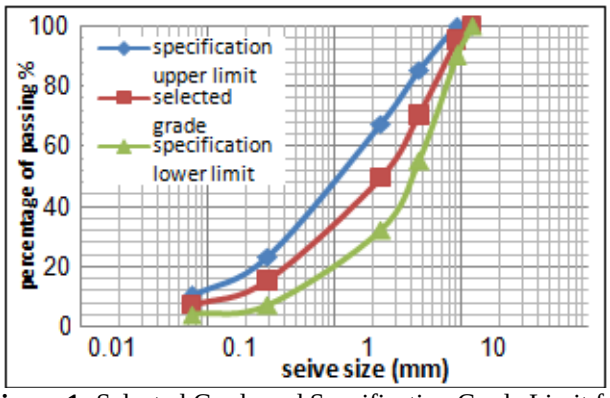

Figure 1: Selected Grade and Specification Grade Limit for Surface Coarse (Type BIII) According to SCRB

3.3Filler

The type of filler, that used in this study, was powder of glass, which can be produced by crushing the waste glass until the particle size can passing through sieve No. 200 (0.075 mm).Three percentages of glass powder (5, 7, 9)% were used in this work, and these values were selected according to the Iraqi specification (SCRB, 2003) which specified the range value of filler content for the surface coarse type BIII by (4-10)% by total weight of aggregate. Table (3) represented the gradation and the specific gravity for glass powder filler.

Table 3: Gradation and Properties of Glass Powder Filler

Sieve Size (mm)	% Passing (sieving Result)	% passing (SCRB Specification limits)
0.6 (No. 30)	100	100
0.3 (No. 50)	99	100 - 95
0.075 (No. 200)	96	100 - 70
	Test Result	SCRB specification
Apparent Specific gravity	2.71	-----

3.4 Additive

The additive, which used in this work, was the polystyrene polymer (PS) which was a type of Crystal granule polystyrene. This polymer manufactured by (HiMedia Laboratories Pvt. Ltd. - India) and can be found in local market of Iraq. Table (4) represent the physical properties of the polystyrene polymer as provided from supplier. The polystyrene polymer crushed in laboratory by mechanical crasher to very small particles to obtain a homogenous mixture when mixed with hot asphalt. The polystyrene was add to asphalt mixture as a percentage of total weight of asphalt binder and these percentages were (1, 2, 3, 4, 5) %.figure (2) show the polystyrene polymer that used in this paper.

Table 4: Polystyrene Polymer Properties

Properties	Testing Result	ASTM Designation
Appearance	Transparent	------
Density, g/cm^3	1.05	ASTM D1505
Tensile Strength, (Yield), MPa	41.2	ASTM D638M
Elongation at Break, %	2.0	ASTM D638M
Flexural Yield Strength, MPa	7.35	ASTM D790
Flexural Modulus, GPa	2.84	ASTM D790
Softening Point, °C	86.0	ASTM D1525B

Figure 2: Crystal Granule Polystyrene Polymer

The work plan of this study, included prepare a specimens of hot mix asphalt according to Marshall procedure of asphalt mix design and ASTM standard method (D 1559).The specimens prepared by one gradation of aggregate (with maximum size 12.5 mm according to SCRB specification) mixed with one type of asphalt (40 - 50 penetration grade), five different percentages of asphalt cement content (4.5, 4.75, 5.0, 5.25, 5.5)% (by total weight of mix), three different percentages of waste glass powder (5, 7, 9)% (by total weight of aggregate) and five different percentages of polystyrene polymer (0, 1, 2, 3, 4, 5)% (by total weight of asphalt cement) each specimen was compacted by Marshall compactor to 75 blow in each face. Figure (3) illustrated the flow chart of the work plan for this study.

4. Work Plan

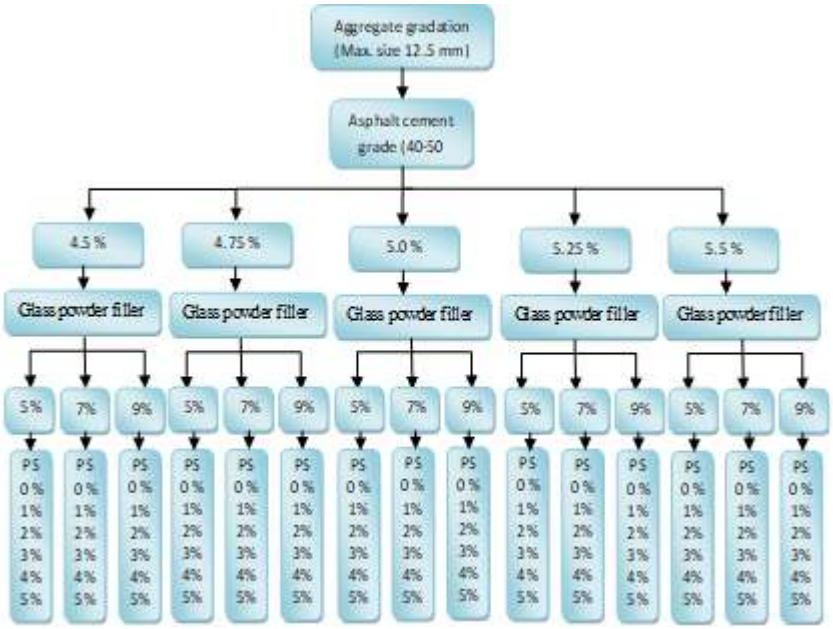

Figure 3: Flow chart of experimental work

5. Testing Method

The laboratory tests that performed, in this study, on the prepared samples and used to evaluate a performance of hot mixture of asphalt were:

1) Marshal Method, (ASTM D 1559), Resistance to Plastic Flow.
2) Standard test of Bulk specific gravity (ASTM D 2726).
3) Standard Test Method for calculating the Percent of Air Voids (ASTM D 2041).

6. Testing Results

To study the effect of polystyrene polymer on performance of asphalt mixture with glass powder filler, the results of laboratory testing were divided to three groups. First group study that affect with Marshall Stability. Second group study that affect with Bulk specific gravity. Third group study that affect with percentage of air voids.

6.1 Effect of Asphalt Content and polystyrene percentage on Marshall Stability at different percentages of glass powder filler

Figures (4, 5 and 6) represented the relationships among asphalt content, polystyrene content and Marshall Stability at glass powder percentage (5, 7 and 9) % respectively.

These figures show that; at percentage of (5) % glass fiber, the higher stability value result from mixture has PS (4) % and asphalt content (4.75)% ; and this value of stability increased by (70 %) when compared with stability of sample without polystyrene.

The best percentage of polystyrene polymer, which gave higher Marshall Stability, was (4) % for asphalt mixture has (5 and 7) % glass powder filler content, and (4 and 5) % for asphalt mixture has (9) % glass powder filler content. That mean the increasing in glass powder filler content required increasing in polystyrene content to reach a higher Marshall stability. these figures also show that, the optimum asphalt content was increased if the percent of glass powder filler increase (for the same percentage of polystyrene polymer),

while The optimum asphalt content was decreased if the percentage of polystyrene polymer increase (at same percentage of glass powder filler).

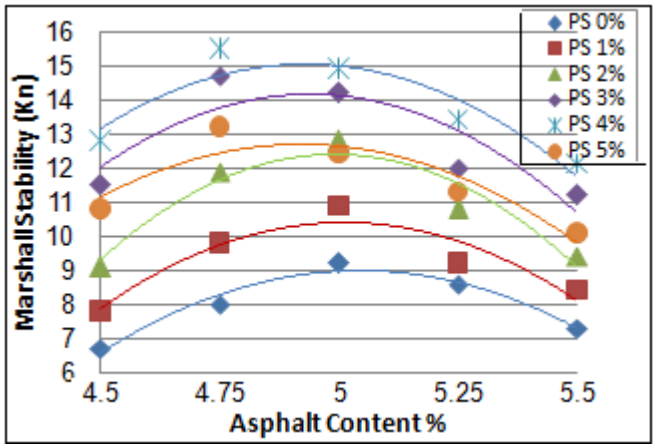

Figure 4: Relationship of asphalt content, polystyrene content and Marshall stability at glass powder content (5%).

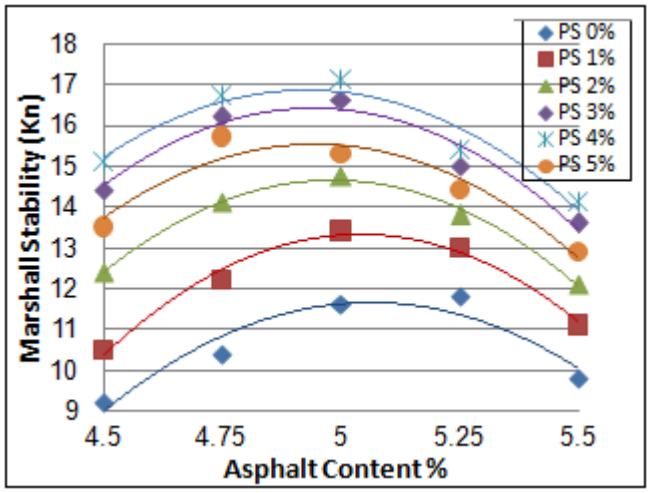

Figure 5: Relationship of asphalt content, polystyrene content and Marshall stability at glass powder content (7%).

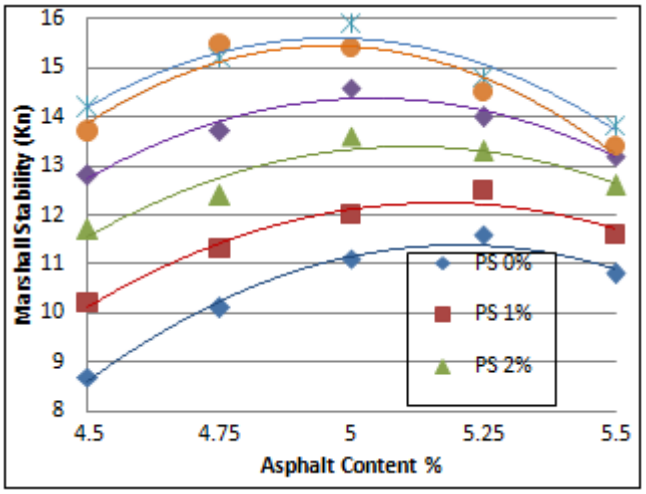

Figure 6: Relationship of asphalt content, polystyrene content and Marshall Stability at glass powder content (9%).

6.2 Effect of Asphalt Content and polystyrene percentage on Bulk specific gravity at different percentages of glass powder filler

Figures (7, 8 and 9) represented the relationships among asphalt content, polystyrene content and Bulk specific gravity at glass powder percentage (5, 7 and 9) % respectively. These figures illustrate that; when the percents of asphalt content and polystyrene constants, the increasing of glass powder filler lead to increase in bulk specific gravity.

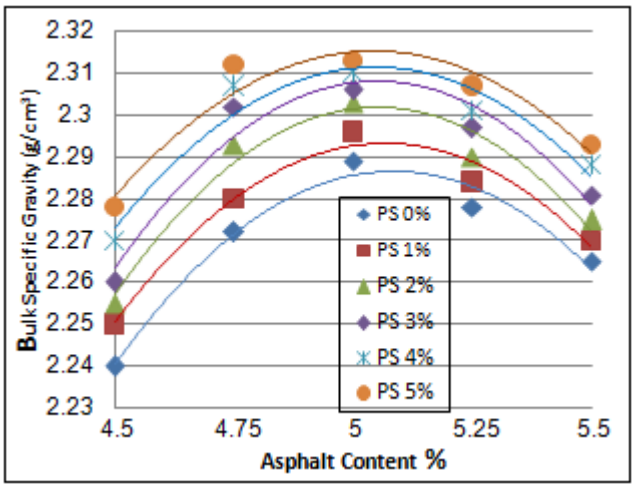

Figure 7: Relationship of asphalt content, polystyrene content and Bulk specific Gravity at glass powder content (5%).

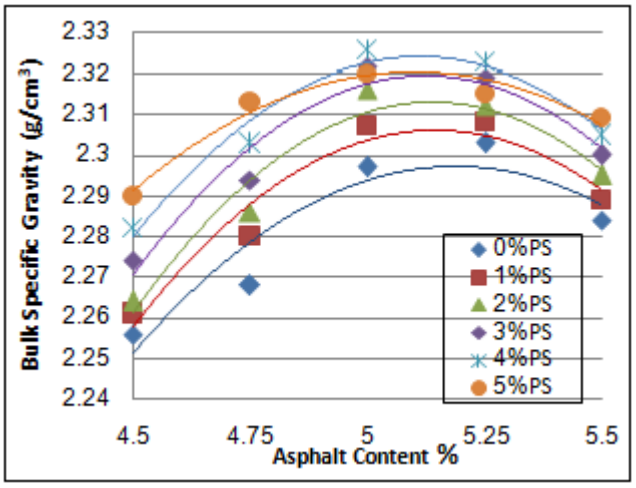

Figure 8: Relationship of asphalt content, polystyrene content and Bulk specific Gravity at glass powder content (7%).

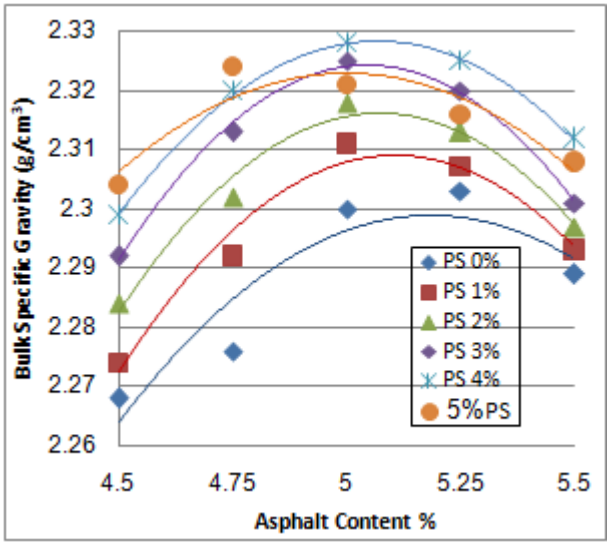

Figure 9: Relationship of asphalt content, polystyrene content and Bulk specific Gravity at glass powder content (9%).

6.3 Effect of Asphalt Content and polystyrene percentage on Air Voids at different percentages of glass powder filler

Figures (10, 11 and 12) represented the relationships among asphalt content, polystyrene content and air voids percentages at glass powder percentage (5, 7 and 9) % respectively. These figures illustrate that;

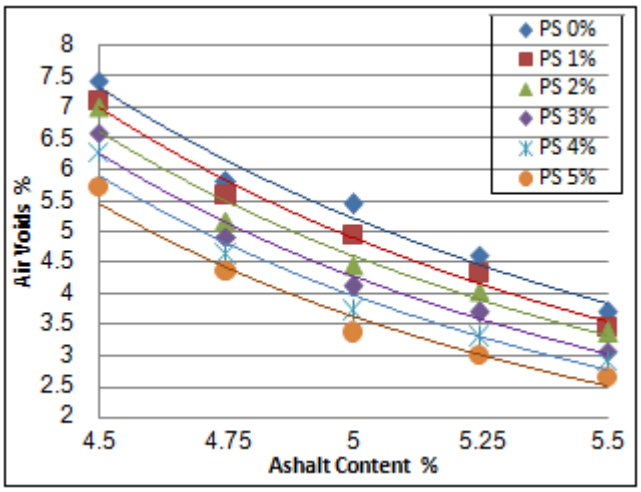

Figure 10: Relationship of asphalt content, polystyrene content and Air Voids percentage at glass powder content (5%).

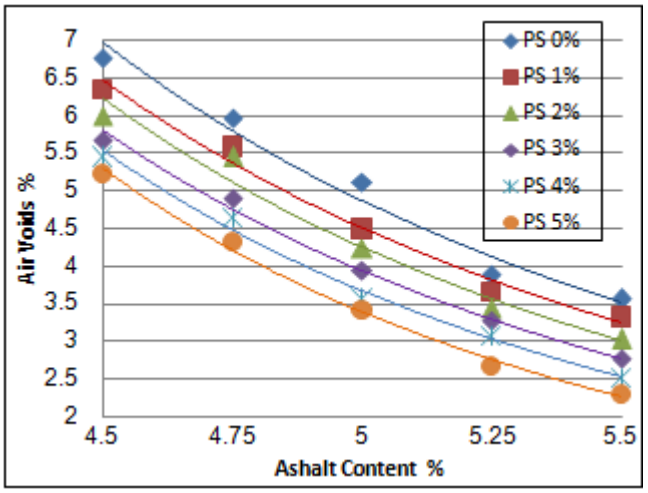

Figure 11: Relationship of asphalt content, polystyrene content and Air Voids percentage at glass powder content (7%).

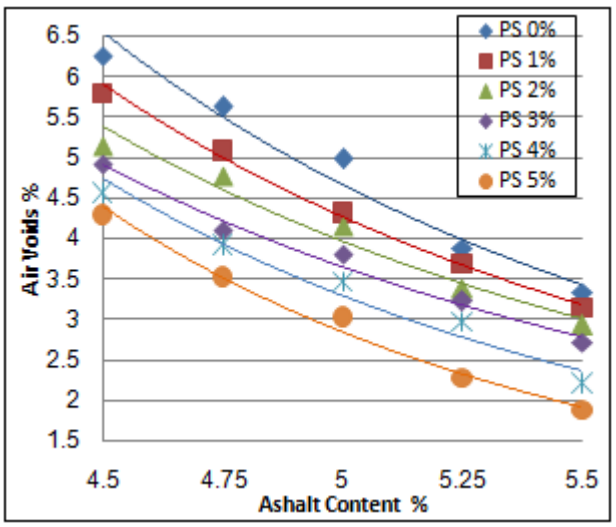

Figure 12: Relationship of asphalt content, polystyrene content and Air Voids percentage at glass powder content (9%)

7. Statistical Models

Effect of asphalt content, percentage of polystyrene and % glass fiber filler on stability, bulk specific gravity and air voids of hot mix asphalt mixture is examined by statistical analysis using SPSS statistical package. Three models were created to represent the behavior of stability, bulk specific gravity and air voids. The results of the statistical analysis are represented in table (5).

Table 6: Statistical Models

Case	Model	R^2
Stability	$S= -8.4\ Ac^2 +83.947\ Ac -0.262\ Ps^2 +2.222\ Ps -0.392\ F^2 +5.974\ F - 220.911$	0.889
Bulk Specific Gravity	$B.S.G= -0.112\ Ac^2 +1.14\ Ac -0.001\ Ps^2 +0.009\ Ps -0.001F^2 +0.013\ F - 0.667$	0.915
Air voids	$A=48.343e^{-0.344\ Ac} - 2.562e^{0.096\ PS} - 0.364e^{0.156F}$	0.819

where:
S: Stability (Kn).

B.S.G: Bulk specific gravity.
A: air voids %
Ac: Asphalt content %
Ps: polystyrene content %.
F: glass powder filler %.

8. Conclusion

From the results of testing samples in laboratory the following conclusions could be made:

1) The using of polystyrene as a modifier lead to increasing the stability and bulk specific gravity of asphalt mixture and lead to decrease the air voids within the mixture.
2) The increasing of glass powder filler from 5% to 7% lead to increase the stability and specific gravity slightly, while the increasing of glass powder filler from 7% to 9% lead to decrease the stability and specific gravity.
3) The increasing of glass powder leads to decreasing the air voids within the asphalt mixture.
4) The preferable percentage of asphalt content, polystyrene content and glass powder filler, that gave best performance of asphalt mixture, were (5%, 4%, 7%) respectively.

References

[1] Ahmed S. D. AL-Ridha, Atheer Naji Hameed, Sinan Khaleel Ibrahim (2014). Effect of steel Fiber on the Performance of Hot Mix Asphalt with Different Temperatures and Compaction**.** Australian Journal of Basic and Applied Sciences, 8 (6) April 2014, Pages 123-132.
[2] Ahmed S. D. AL-Ridha, Sinan K. Ibrahim, Layth Sahib Dheyab (2016). Steel Fiber Effect on the Behavior of Hot Mixture Asphalt with Variable Asphalt Content. International journal of advanced technology in engineering and science, vol. 4, special issue 1, Feb. 2016, pages: 204-2013.
[3] ASTM Annual Book of ASTM Standard., 1996. Section 4, Volume 04.03, Road and Paving Materials; Pavement Management Technology. American Society for Testing and Materials, Philadelphia, Pa.
[4] SCRB, 2003. General Specification for Roads and Bridges. Section R9, Hot –Mix Asphalt Concrete Pavement, Revised Edition.
[5] Martinho FG, Guarc DS¸ ONI, 1995. Santos CR and Pinto S. Information of Asphalt.
[6] Bull AL and Vonk WC. 1994. Shell Chemical Papers. TPE 6.3.1.
[7] Isacsson U, Lu X. 1998. Testing and Appraisal of Polymer Modified Road Bitumen's. In: Francken L editor, Bituminous Binders and Mixes, Rilem Report 17. London: E and FN Spon. p. 13–38.
[8] Isacsson U, Lu X. 1995. Testing and Appraisal of Polymer Modified Road Bitumen's. State of the Art. Mater Struct. 28:139–159.
[9] Giovanni Polacco, Jiri Stastna, Dario Biondi, Federico Antonelli, Zora Vlachovicova and Ludovit Zanzotto. 2004. Rheology of Asphalts Modified with lycidylmethacrylate Functionalized Polymers. J Colloid Interface Science. 280:366–373.
[10] Ionela Chiparus Glover. 2007. Wet and Dry Aging of Polymer–Asphalt Blends, Chemistry and Performance. Ph.D. Thesis, Department of Chemistry, Louisiana State University Agricultural and Mechanical College.
[11] Reynaldo R, Bjorn B and Christos Drakos. 2005. Guidelines for use of modified Binders. Final report, UF Project No. 4910-4504-964-12. Florida Department of Transportation, Florida; 22 September.
[12] Diego OL, José LA, Alejandra B, Cortizo MS (2009). A micro-structural and rheological characteristic of SBS-asphalt blends during their manufacturing. Construction and Building Materials 23 (8): 2769–2774.
[13] Kumar SA, Veeraragavan A. Dynamic mechanical characterization of asphalt concrete mixes with mo (2011) defied asphalt binders. Materials Science and Engineering A 528: 6445– 645