Assessment of Mechanical Properties of HMA modified by EVA

تقييم الخواص الميكانيكيه للمزيج الاسفلتي الساخن المعدل بالاثينيل فينيل اسيتات

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Abstract

Asphalt become plastic material with the high temperature effect, so it describes as thermoplastic material, the polymers was used to enhance asphalt properties in mean of increasing the temperature range over which it resists both rutting and thermal cracking; the polymers like EVA has been widely used to increase both the workability of the asphalt during compaction and its resistance to deformations in service. Hot Melt Glue is type of thermoplastic adhesive containing the EVA copolymer with Terpene-Phenol Resin (TPR) tackifier. The used asphalt was from the crude oil refinery of Al-Nasiriya (southern of Iraq) its classified grade (60-70), is used with deferent percentages of the Hot Melt Glue. Two stages of work plan were adopted: the first was to study the effect of the Glue on asphalt then at the second stage Glue effect on the asphalt mixture. Tests like penetration, softening point and ductility of asphalt, and resistance to flow (stability & flow) by Marshall Method (for mix) were adopted in this research. The results show that the Hot Melt Glue reduces the penetration and specific gravity of the asphalt, on the other hand the softening point increased with increasing of the Glue. There is a little increasing of the susceptibility to high temperature with increasing of the glue (to 2%) then begin to degrease with increase the glue. There is significant decreasing in ductility with the increasing of the glue and after the percent 2.5 the ductility reduced less than requirements of specification (100 cm). The flash point not influenced with increasing of glue till 6%. The Marshall Stability increases while the flow decreases with the increasing the Glue. There is a little reduction in density and air voids with increasing of the glue.

Key words: Hot Melt Adhesive Glue, Ethylene-Vinyl Acetate (EVA) copolymers, Asphalt Mixture, Marshall Stability, temperature susceptibility.

الملخص

يصبح الاسفلت ماده لدنه مع تاثير درجات الحراره العاليه لهذا يوصف بانه ماده لدنه بالحراره، وقد استخدمت البوليمرات في تحسين خصائصه بمعنى زيادة نطاق الحراره التي في مداها يقاوم التخدد والتشققات الحراريه على حد سواء، استعملت البوليمرات مثل EVA بشكل واسع لزيادة كلا من القابيله التشغيليه للاسفلت اثناء الدمك وزيادة مقاومته للتشوهات اثناء الخدمه. الغراء المذاب بالتسخين هو نوع من انواع اللاصق اللدن المتاثر بالحراره و يحتوي على بوليمر EVA مع التربين فينول اللاصق. الاسفلت المستعمل كان من مصفى النفط الخام في الناصريه ضمن تدرج (60-70)، استعمل مع نسب مختلفه من الغراء المذاب بالتسخين. تضمنت خطة العمل مرحلتين: الاولى لدراسة تاثير الغراء على الاسفلت ثم في المرحله الثانيه تاثير الغراء على الخلطة الاسفلتيه. فحوصات مثل الغرز، نقطة الليونه والاستطاله للاسفلت، و مقاومة الجريان بواسطة طريقه مارشال للخلطه الاسفلتيه تم اعتمادها في هذا البحث. اظهرت النتائج بان الغراء المذاب بالتسخين قد قلل من درجة الغرز والوزن النوعي من ناحيه اخرى فقد رفع من درجه حرارة الليونه للاسفلت. هناك زياده قليله في الحساسيه لدرجات الحراره العاليه مع زيادة الغراء حتى 2% بعدها تبدا الحساسيه بالنزول مع زيادة الغراء. هناك نقصان ملحوظ في الاستطاله مع زيادة الغراء وبعد نسبة 2.5 فان الاستطاله تصبح اقل من متطلبات المواصفه (100 سم). ان نقطة الوميض لم تتاثر بزيادة الغراء حتى 6%. يزداد ثبات مارشال بينما يقل الجريان بزيادة الغراء. هناك نقصان طفيف في الكثافه و الفجوات الهوائيه مع زيادة الغراء.

الكلمات المفتاحيه: الغراء اللاصق المذاب بالتسخين، بوليمر الاثينيل فينيل اسيتات، الخلطه الاسفلتيه، ثبات مارشال، الحساسيه للحراره.

1-Introduction and Literature Review:

Due to the properties of asphalt in high viscosity and adhesive with little elasticity made it good material to use, it is have plasticity with the high temperature effect so that it describe as thermoplastic material and we should study the asphalt kind with the environment when it will use to make the adequate and compatibility mixture to environment conditions. To enhance bitumen properties in mean of increasing the temperature range over which a binder resists both rutting and thermal cracking the polymers are the most common modifiers being used [1].

Ethylene-Vinyl Acetate (EVA) copolymer has been widely used in the road construction industry for more than 40 years, where improves both the workability of the asphalt during compaction and its deformation resistance in service, but depending on the bitumen source and the polymer characteristics [2]. Hot melt glue type of thermoplastic adhesive containing the EVA copolymer with Terpene-Phenol Resin (TPR) tackifiers, their mixture is found in low-cost and most common form as the glue sticks [3], [4]. The performance of bitumen is particularly improved when 1% of recycled EVA or virgin EVA is added [5]. By using EVA with asphalt the softening point has increased, on the other hand the specific gravity, penetration and ductility values have decreased [6], [7], and [8]. The rate of change of penetration and softening point gradually decreases as the polymer percent is increased [7]. Researchers [9], [10] have found that the temperature susceptibility of the modified binder with EVA is also improved. Marshall Stiffness increases with increasing the copolymer, EVA can improve both the mixture elasticity and stiffness [11], [12].

As compared with Polypropylene and polyethylene terephthalate thermoplastic modified asphalt, EVA modified asphalt have better improvement of the physical and mechanical properties than the others, it can be related to the increase of the adhesive bonding between asphalt cement and aggregate particles, and displayed the lowest rate of heat dissipation [13], the using EVA is due to their thermoplastic behavior at higher temperatures and its ability to form networks after cooled [7].

Mjthab, et al**.** [7] studied on two kind of Asphalt deferent in penetration grade and the effect of ethylene vinyl acetate (EVA) on them, the two base asphalt are from two crude oil sources in (Iraq): Baiji paraffinic asphalt that derived from Kirkuk crude oil & Qaiyarah aromatic asphalt from Qaiyarah aromatic crude oil with the EVA copolymer vinyl acetate content of 19%. They found a good stability results for blends containing 2% EVA for both asphalts.

2-Methodology:

Two stages of work plan were adopted: the first was to study the effect of the hot melt glue on asphalt when add it as a percent by weight of the asphalt then glue effect on the asphalt mixture at the second stage. Then Compare results with Iraqi specifications limits according to the State Corporation of Roads and Bridges/ R9 [14]. The tests which adopted in this work (according to AASHTO, 1997[15]) consisted of:

1. Penetration test according to AASHTO T49-96.
2. Softening point test according to AASHTO T 53-96.
3. Ductility test according to AASHTO T 51-94.
4. Specific gravity test according to AASHTO T 228-94.
5. Flash point test according to AASHTO T 48-96.
6. Resistance to flow by Marshall Method according to AASHTO T 245-94.

3-Materials and Experimental Work:

3-1 Materials

Asphalt: The used asphalt was from the crude oil refinery of Al-Nasiriya (southern of Iraq) its classified grade (60-70) and the physical properties were exhibited in the research tests.

Aggregate: The coarse aggregate was crushed aggregate from al- Neba'ay quarries clean and empty from soluble salts with specific gravity 2.68 and absorption 2.8% and fine aggregate crushed sand from al-Najaf city quarries clean empty from soluble salts with specific gravity 2.63 and absorption 6%. Grade separated to partials sieves then washed good and heated to dry.

Filler: Its material that have fineness value very high be powdered and passed from sieve No. 200 and satisfy the Iraqi general specification limits for gradation. The al- Jisser Portland cement was used from Karbala city industries, its fineness 93%.

Hot Melt Glue: Its available commonly in local markets as sticks used for clothes and furniture, it is thermoplastic polymer composes from EVA copolymer and TPR tackifier are characterized by softening on heating and hardening on cooling within 3 seconds, table (1) shows the physical properties of the Glue. EVA copolymers tends to improve the stiffness and high temperature properties of asphaltic mixtures, its easily dispersed and have good compatibility with bitumen and recommended that the blended product should be thoroughly, mixed before use [16].

Table (1): The Physical Properties of the Used Hot Melt Glue

Property	Penetration (0.1 mm)	Softening point (^{o}C)	Ductility (cm)	Specific gravity
Result	5	78	9	0.26

3-2 Experimental Work:

Work consisted of the following steps:

1- Testing pure asphalt and glue individually to find their properties.

2- Preparing and physical testing the modified asphalt (binder) samples: adding the glue as percent by total weight of asphalt (sample (1) 2% glue + 98% asphalt, sample (2) 4% glue + 96% asphalt, sample (3) 6% glue + 94% asphalt), heating them separately till melting then mixing them using spindle for few minutes.

3- Designing the mixture to find the optimum asphalt and basic properties: the Marshall method was adopted, the used aggregate and filler was blended and graded as a mid. Point of the surface course gradation requirement according to Iraqi specification for roads and bridges type IIIA, table (2) shows the grades and table (3) shows the mix properties results.

4- Mixing the glue with asphalt by total weight (content of 5%) to remaining the binder with 5% (asphalt + glue) percent by total mass of the mixture then preparing Marshall Samples to test the mechanical properties of mixture. Noticed that the high volume of glue compared to the asphalt for the same weight so, the specific gravity of glue less than the asphalt.

Table (2): The Grades of Aggregate for Asphalt Layers [14]

Sieve size	mm	Type I	Type II	Type IIIA	Type IIIB
		Base Course	Binder or Leveling Course	Surface or Wearing Course	
		% Passing by Weight of Total aggregate + Filler			
1 ½ in	37.5	100			
1	25.0	90-100	100		
¾	19.0	76-90	90-100	100	
½	12.5	56-80	76-90	90-100	100
⅜	9.5	48-74	56-80	76-90	90-100
No. 4	4.75	29-59	35-65	44-74	55-85
No. 8	2.36	19-45	23-49	28-58	32-67
No. 50	300 µm	5-17	5-19	5-21	7-23
No. 200	75 µm	2-8	3-9	4-10	4-10
Asphalt Cement (% weight of total mix)		3-5.5	4-6	4-6	4-6

Table (3): Mix Basic Properties

O.B.C %	Stability kn	Flow mm	V.T.M %	Density g/cm^3	V.M.A %	VFA %	P_{ba}	P_{be}
5	8.12	3.7	4.94	2.33	16.2	69.7	0.17	4.83

4- Results and Discussions:

1- Penetration Test

Figure (1) shows the relationship between penetration of asphalt and the percent of glue. The results show that there is reduction in penetration with increasing the glue due to low penetration (hardness) of glue, and this reduction rate is decreased with increasing of glue concentration.

2- Softening Point Test:

Softening point increased with the increasing of the glue percentage as shown in Figure (2), due to the high softening degree of glue compared with the used asphalt, this induced to the development of a continuous polymer network within the bitumen blend that tend to reduce the interpartical distance between the blend particle, which increases the softening point of the polymer-bitumen blend. Hence, thermoplastic polymer modified bitumen can perform better in hot climate areas as compared to unmodified bitumen [11].

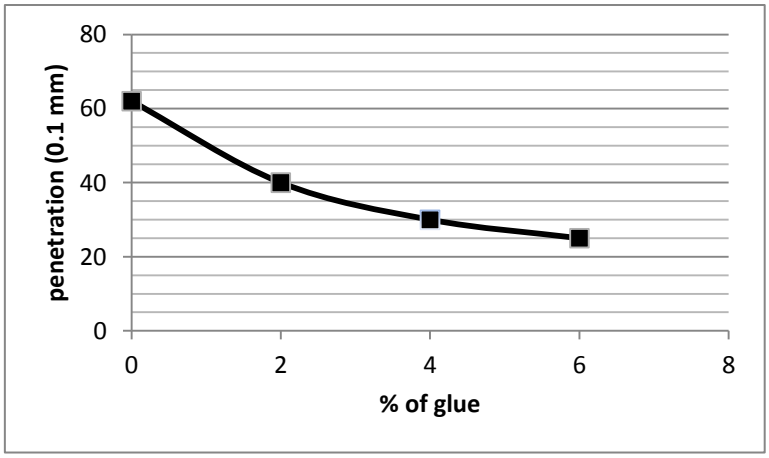

Figure (1): The Relationship between the Penetration of Asphalt and Percent of Glue

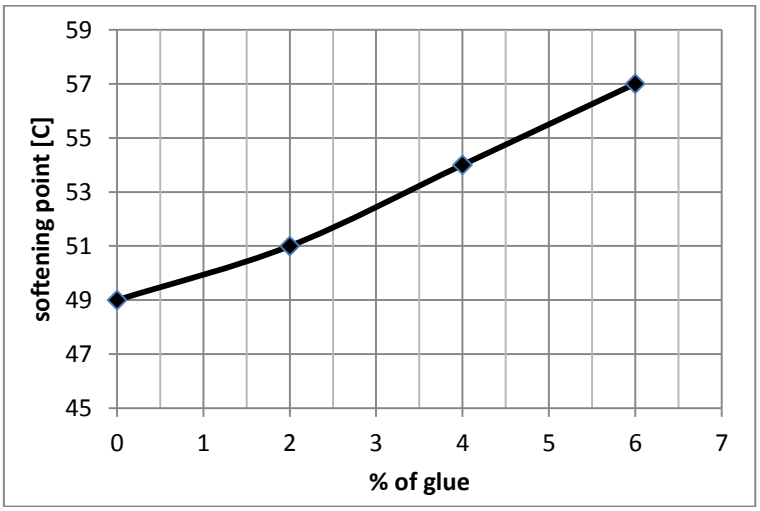

Figure (2): The Effect of Glue on the Asphalt Softening Point Temperature

By using the penetration index [16] to calculate temperature susceptibility of asphalt with deferent percentages of glue, Normal asphalt cements have a PI between -3 to +7 [16] or -2 and +2 and asphalt cements with a PI of more than +2 are of low temperature susceptibility, while those with a PI of less than -2 are of excessively high temperature susceptibility [17]. Table (4) show that the penetration index (PI), by depending on the penetration at 25 C and softening point, results show that a little increasing of the susceptibility to high temperature with increasing of the glue to 2% then begin to degrease with increase the glue due to effect of glue at low percent on hardness (penetration) more than effect it's on softening point and this effect rate on penetration decreased.

3- Ductility Test:

Figure (3) shows that the ductility test result (with 110 maximum value of test machine), there is significant decreasing in ductility with the increasing of the percentage of glue and after the percent 2.5% the ductility reduced less than requirements of specification (100 cm) due to hardness of binder with raising the cohesive and lowering the adhesive.

Table (4): The PI Affected by the Percent of Glue

% glue	Penetration at 25 ^{o} C	Softening point ^{o} C	PI
0	62	49	-0.95
2	40	51	-1.44
4	30	54	-1.33
6	25	57	-1.05

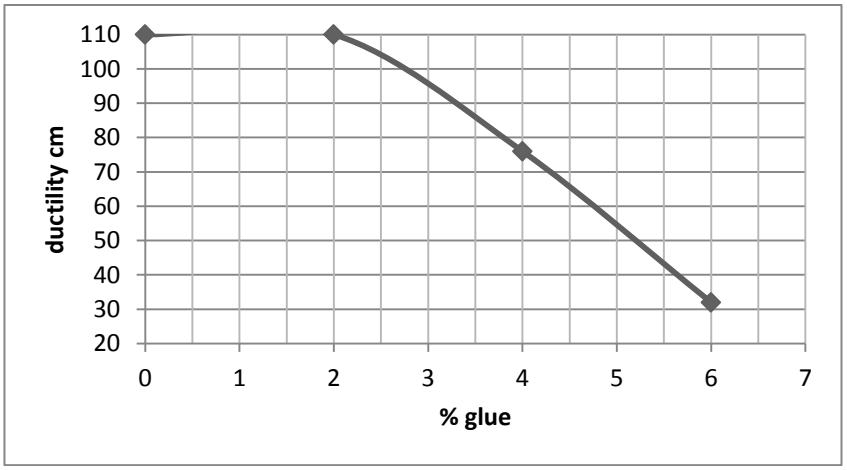

Figure (3): The Effect of the Glue on the ductility

4- specific gravity

Figure (4) shows that the specific gravity of modified asphalt with glue is decreased as the glue increases; it's due to the low value of specific gravity of the glue.

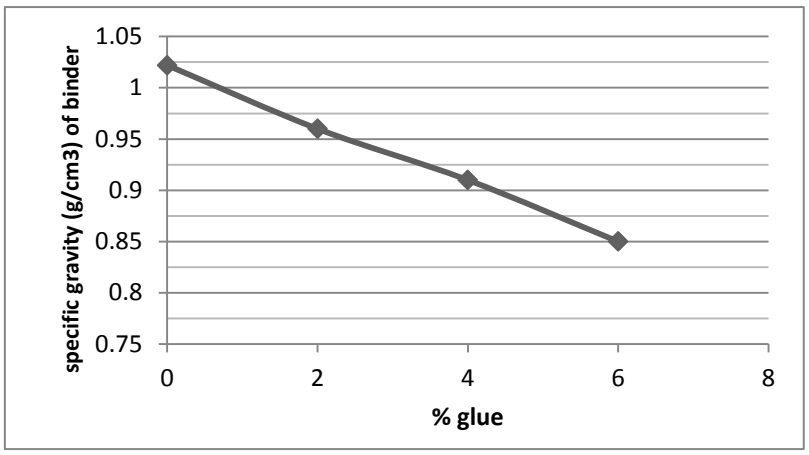

Figure (4): The Specific Gravity of Asphalt Modified with Glue

5- Flash Point Test:

The flash point of the asphalt alone was very high (274 C^o) and the glue percentages do not significant affected due to low percent of glue.

6- Resistance to Flow by Marshall Method:

Figure (5) shows increasing in Marshall Stability as increasing in glue (reduction in asphalt content substituted by glue) and there is decreasing in flow when increases the glue as shown in Figure (6) that is because of decreasing in asphalt content and hardening asphalt due to bonding improvement by the glue. This may be due to the increase in the viscosity of the modified bitumen mixtures, which lead to the formation of a thicker mixture film in asphalt [11]. The stability improved to 14.5, 33.6 and 39.7 % at 2, 4 and 6 % glue respectively. The flow reduced about 10.8, 18.9 and 27 % at 2, 4 and 6 % glue respectively.

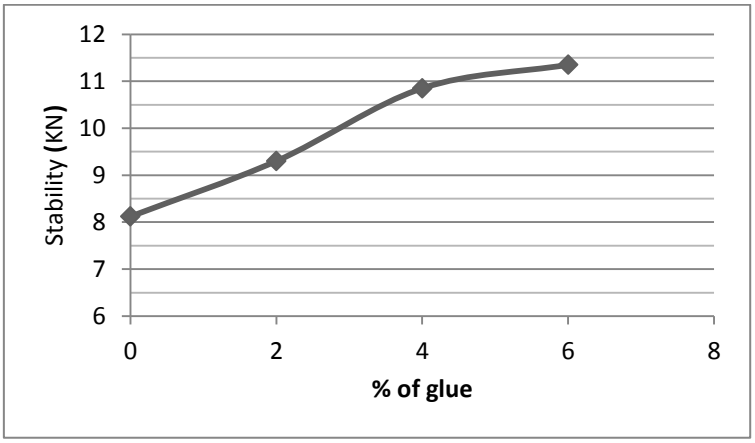

Figure (5): Relationship between the Stability and Percentage of Glue

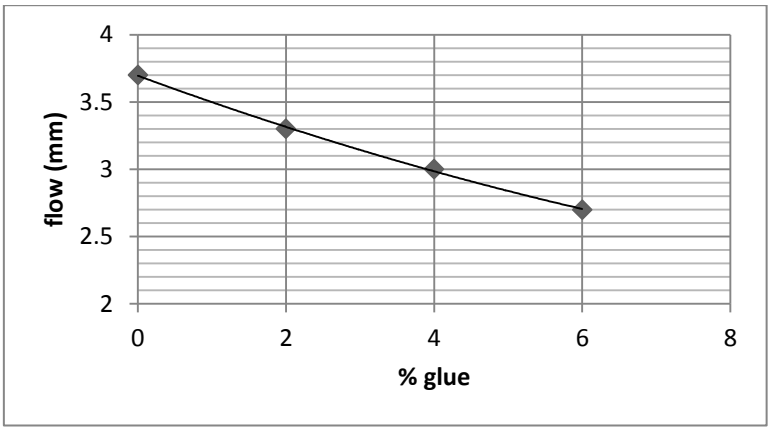

Figure (6): Relationship between the Flow and Percentage of Glue

Figure (7) shows that there is little decreasing in density when increase the glue (decreasing in asphalt content substituted by glue) due to the low specific gravity of the glue mean it have the higher volume than asphalt volume of the same weight, leads to increase the volume of binder.

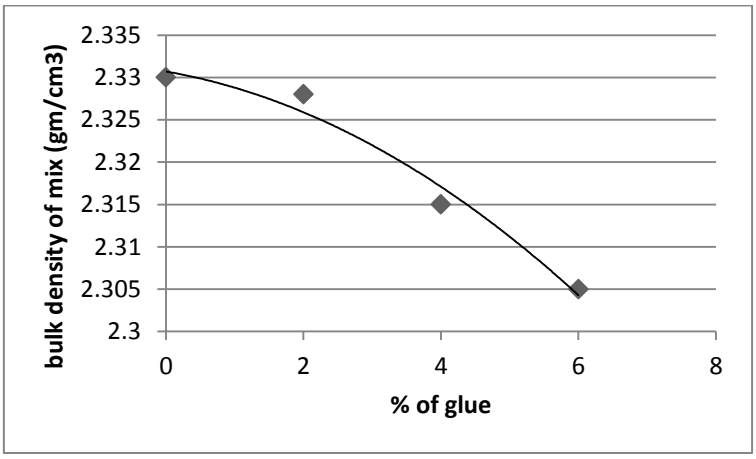

Figure (7): Relationship between the Density and Percentage of Glue

Air voids depend upon bulk density and max. theoretical density with effective specific gravity of aggregate of (2.662), and the results in Figure (8) show a little decreasing in the air voids with increasing of glue this may be because of increasing in the binder viscosity and improvement the bonding between binder and aggregate particles lead to reduce the inter-particles distance.

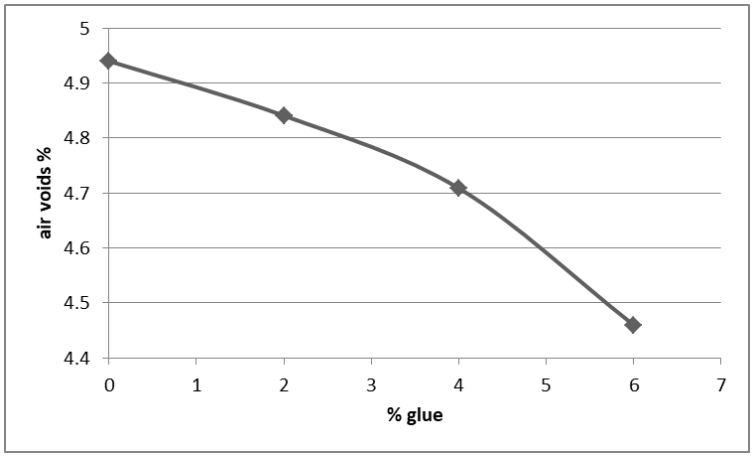

Figure (8): Relationship between the Air Voids and Percentage of Glue

Substitute a weight of asphalt by a same weight of the glue causes reduction in density and increasing in voids in mineral aggregate (due to the high volume of glue compared with the volume of the asphalt of the same weight), and due to decreasing in air voids that is lead to increases in voids filled with asphalt which it make the mix stiffer.

Table (5): Relationship between Voids and Percent of Glue

% glue	Bulk density	V.M.A %	Voids filled with asphalt %
0	2.33	16.2	69.7
2	2.328	16.3	70.4
4	2.315	16.8	72
6	2.305	17.2	74

4-Conclusions and Recommendations:

1- The Hot Melt Glue reduces the penetration and specific gravity of asphalt on the other hand the softening point increases with increasing of the Hot Melt Glue.
2- There is a little increasing of the susceptibility to high temperature with increasing of the glue to 2% then begin to degrease with increase the glue.
3- There is significant decreasing in ductility with the increasing of the glue and after the percent 2.5% the ductility reduced less than requirements of specification (100 cm). The flash point not influenced with increasing of glue till 6%.
4- The Marshall Stability increases while the flow decreases with the increasing the Glue.
5- There is a little reduction in density and air voids with increasing of the glue.
6- It recommended using the Hot Melt Glue at 2% of the asphalt that used in this study depending on the result of penetration and ductility of asphalt. For future studies, is recommended to find the optimum percent of glue to use with other grades or sources of asphalt cement.

5-References

[1] Maninder Singh, Praveen Kumar, M. R. Maurya, Manoj Gupta, (2012), "Aging Effect on Modified Bitumen", /IJESM Vol.2, No.3, International Journal of Engineering, Science and Metallurgy, ISSN 2249 – 7366.

[2] Haddadi, S., Ghorbel, E., and Laradi, N., (2008)," Effects of the Manufacturing Process on the Performances of the Bituminous Binders Modified with EVA", Construction and Building Materials, Vol.22, PP.1212-1219.

[3] Heinz Gerhard Gilch, Voithenberg Hubertus Von, Volker Schüll, (1990), "Hot-melt glue-sticks Application", Bostik Limited, Bostik France SA, Bostik GmbH, Application number EP19890311937, and Publication number EP0376461 A2.

[4] M. Nardin, M. Brogly, J. Schultz. (1993),"Effects of the composition of hot-melt adhesives on their bulk and interfacial properties", Journal de Physique IV, Volume 3, p. 1505.

[5] Gonzalez, O., Muno, M. and Santama, A. (2004). "Rheology and Stability of Bitumen-EVA Blends", European Polymer Journal, Elsevier Science Ltd, 40, 2365-2372.

[6] Panda, M. and Mazumdar, M. (1999), "Engineering Properties of EVA Modified Bitumen Binder for Paving mixes", Journal of Materials in Civil Engg., ASCE, 11(2), 131-137.

[7] Eman I. Mjthab Adil K. Hussien Niám M. Al-Layla, (2011), "Evaluation of the properties and storage stability of EVA polymer modified asphalt", Department of Chemistry / College of Science University of Mosul, J. Edu. & Sci., Vol. (24), No.3.

[8] Samy Dekhli, Khedidja Ait Mokhtar, Ferhat Hammoum and Djaffar Si Bachir (2015), "Rheological Behaviour of Ethylene-Vinyl-Acetate (EVA) Modified Road Bitumen", laboratory environment EAU geomcanique et ovrage, university of science technology, Houari boumediene, Algeria/journal of applied science, 15 (3) 444-455, ISSN 1812-5654.

[9] Mehndiratta H.C. and Chandra S. (2000), "Investigation on Bituminous Mixes with Blended Modifiers" Journal of Institution of Engineers, India, Vol. 81, pp 115-119.

[10] Romeo, E., Birgisson, B. and Montepara, A. (2010), "The effect of polymer modification on hot mix asphalt fracture at tensile loading conditions", International Journal of Pavement Engineering, Taylor & Francis, 11(5), 403-413.

[11] Khalid M. Eweed. (2011)," Polymeric Additives Effect on Mechanical Properties for Bitumen Based Composites", Engineering College, University of AL Mustansiriya /Baghdad , Eng. & Tech. Journal, Vol. 29, No.12. p.p: 2501-2519, ISSN: 16816900-24120758.

[12] Nikhil Saboo and Praveen Kumar, (2015), "optimum blending requirement for EVA modified binder", International Journal of Pavement Research and Technology Vol.8 No.3 ISSN 1997-1400 Int. J. Pavement Res. Technol. 8(3):172-178.

[13] Hassan y. Ahmed and Ayman m. Othman, (2007) "influence of thermoplastic polymer additives on properties of asphalt concrete mixtures", journal of engineering sciences, Assiut university, vol.35, no. 5, pp. 1255-1270.

[14] State Corporation of Roads and Bridges SCRB, (2003), "standard specifications for roads and bridges", design and studies department, Ministry of housing and construction, Republic of Iraq.

[15] American Association of State Highway and Transportation Officials AASHTO (1997), "Standard Specifications for Transportation Materials and Methods of Sampling and Testing", Washington DC, USA.

[16] Robert N. Hunter, Andy Self and Professor John Read, (2015), "The Shell Bitumen Handbook", Sixth edition, published for Shell Bitumen by ICE Publishing, One Great George Street, Westminster, London SW1P 3AA, ISBN 978-0-7277-5837-8.

[17] Mang Tia, (2011), "Bituminous Materials", Mang Tia courses, Civil and Coastal Engineering, University of Florida.