Influence of Polymers on the Properties of Asphalt Concrete Paving Materials

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Abstract

Additives are usually suggested in asphalt concrete paving mixtures wherever extra performance and durability are desired. Polymer modification, using solutions lolls using either plastomers or elastomers, seems to be among the best solution to improve asphalt mixture properties.

The objective of this research program is to identify through laboratory testing the most promising polymer type and content for the reduction of permanent deformation at high temperature (higher stiffness) and the provision of more resistance to thermal cracking at low temperature (higher tensile strength), using locally available materials.

A selected gradation of aggregate and mineral filler within the specification requirement of asphalt concrete wearing course, together with a (50-60) penetration graded Baiji asphalt cement, and three types of polymers including polyvinyl chloride, polyethylene (plastomers) and rubber (elastomer), at different contents have been used for this purpose.

The desired polymer content by weight of optimum asphalt has been determined to be equal to 1.5% for polyvinyl chloride, 5.0% for polyethylene and 2.0 % for rubber.

The use of polyethylene plastomer showed the highest increase in mixture stiffness modulus with an improved resistance to permanent deformation or distortion at high temperature.

The rubber, through the creation of an elastonieric lattice in the asphalt binder, provided the highest tensile strength with a_{ll} improved resistance to thermal cracking at relatively low temperature.

الخلاصة

المضافات يتم اقتراحها في خلطة الرصف الإسفلتية عند وجود متطلبات الأداء العالي والديمومة. التعديل بالبوليمرات باستخدام محلول إما البلاستزات او الايستومرات التي تعتبر من أفضل المحاليل لتطوير خواص خلطة الإسفلت.

هدف برنامج البحث هو التحديد من خلال الفحص ألمختبري نوعية ومحتوى البوليمر في تقليل التشوه ألدائمي في درجات الحرارة العالية وإعطاء مقاومة أعلى للتشققات الحرارية في درجات الحرارة الواطئة وباستخدام مواد محلية.

تم استخدام ركام و فلر بتدرج ضمن حدود مواصفة الطبقة السطحية مع إسفلت (50–60) من مصفى بيجي وثلاثة أنواع من البوليمرات وبنسب مختلفة تتراوح (1.5 % ، 5% ، 2%) من وزن الإسفلت.

إن استخدام بوليمر من نوع بولي اثيلين أعطى أعلى أداء بالنسبة للتشوه ألدائمي في درجات الحرارة العالية في حين إن استخدام المطاط أعطى أداء جيد من ناحية مقاومة التشققات الحرارية في الدرجات الحرارية الواطئة.

Introduction

The several types of additives, progressively emerged for use in asphalt concrete pavements, may include polymers (plastics and rubbers), extenders (sulpher), fibers (polypropylene), mineral fillers (hydrated lime), antioxidants (calcium salts), hydrocarbons (recycling oils), and combinations(Terrel and Walter ,1986) .

The term polymer can be applied to many chemically crosslinked Structures each of which has its own chemical and physical properties(Becker, Mendez and Rodriguez, 2001). To warrant consideration of a suitable polymer, it has to be sufficiently compatible with asphalt cement (Oliver and Tredrea ,1997) . Polymers are expected to change the rheological properties of asphalt material, extending the useful temperature range during In- service life of pavement(Maccarrone, Holleran, and Knanaseelan ,1995).

The purpose of this work is to evaluate the influence of some polymers on performance-related properties of asphalt paving mixtures for wearing courses using the locally

Materials

The materials used in this work included the following:

- A (50-60) penetration graded asphalt cement from Baiji refinery meeting the requirements of the SCRB General Specification (Section R9)(SCRB , 2003) with a specific gravity of (1.040).
- Crushed coarse and fine aggregate from Samurra (Asphalt Plant of Albuhl Company), with Portland cement as a mineral filler.

The combined gradation has been selected within the specification requirements of SCRB General Specification (Section R9) for 12.5 mm nominal maximum size (type III A) as shown in Figure No. (1).

The effective specific gravity of combined aggregate and mineral filler has been determined to be equal to (2.638).

- Three types of polymers including:
  - Polyvinyl chloride plastomer $(CH_2, CH\ C1)_n$ with a density of 0.984 gml/cm^3.
  - Polyethylene plastomer $(CH_2\ CH_2)_n$, with a density of 0.920 gm/cm^3. Both plastomers have been supplied from Alhaditha Co. for Paints Industry.
  - Powdered rubber elastomer $[-CH_2 -CH = C\ (CH_3) - CH_2 -]_n$ from
  - Diwaniyah Tire Factory.

Test Methods

The testing program, performed in Baghdad Center for Building Research, included the following:

- Preparation of asphalt concrete mixtures in accordance with the procedure suggested by ASTM D1559. The dispersion of polymer in asphalt cement were prepared by slowly adding the weighed quantity of polymer powder to the heated asphalt maintained at a temperature of 160°C T while the mixture was being stirred.
- Asphalt contents of 4.5, 5.0, and 5.5 % by weight of total mix have been added. Polymer content of 1.67, 3.33, 5.00, 6.67, and 8.33 percentage by weight of asphalt cement have been employed in preparing the modified mixture.
- Theoretical maximum specific gravity of mixtures (ASTM D2041).
- Bulk specific gravity of compacted mixtures (ASTM D2726).
- Air voids in compacted mixtures (ASTM D3203).
- Marshall resistance to plastic flow at 60°C (ASTM D1559) with 75 blows/end.
- Indirect tension test at 25 °C (ASTM D4123).

Test Results and Discussion:

For the selected combined gradation of aggregates and mineral filler, influence of asphalt content on Marshall test properties of original mixture is shown in Figure (2) including bulk density, stability, flow, and air voids.

An optimum asphalt content of 5 % by weight of total mixture has been selected. The corresponding, original mixture properties are as follows:

Bulk density	=2.352 gm/cm^3
Marshall Stability	= 9.75 kN
Marshall Flow	= 3.55 mm
Max. Theo. Specific gravity	=2.450
Air voids	=4%
Marshall Stiffness	=2.75 kN/mm

The influence of polymer content on the properties of modified asphalt concrete mixtures prepared at optimum asphalt content of 5 % are shown in Figures (3), (4) and (5) for polyvinyl chloride, polyethylene and rubber polymers respectively. Mixture properties included bulk density, stability, flow, and stiffness.

The results show that plastomers (polyvinyl chloride and polyethylene) are useful modifiers for increasing stiffness of asphalt concrete and confer additional pavement stability at elevated temperatures to minimize rutting and distortion. The increased flow rates reflected the greater plasticity.

Elastomers (rubbers) tend to provide greater ability to stretch even though mixture stability is decreased. The selection of the desirable polymer content is presented in Figure (6) with concentrations of 1.5% for PVC, 5.0 % for PE and 2.0% for rubber. Figures (7) and (8) show the variation of Marshall stiffness and indirect tensile strength respectively at selected polymers contents for original and modified mixtures.

The results confirmed the role of plastomers in improving the resistance deformation (increased stiffness) and the role of elastomers in modifying the resistance to thermal cracking (increased tensile strength).

Conclusions and Recommendations

Within the limitations of materials and test program used in this work, the following are concluded:

1. It has been determined that polymers (plastomers and elastomers) are useful modifiers for the improvement of adhesivity, and tensile strength of asphalt paving mixtures.
2. Polyethylene and polyvinyl chloride plastomers have shown an additional resistance to plastic flow (15 % increase) providing greater stiffness for the asphalt concrete layer.
3. The use of rubber elastomer provided a remarkable increase in tensile resistance of paving mixtures with lower stiffness modulus.
4. The desired concentration of polymer has been determined to be equal to 1.5 % polyvinyl chloride, 5 % for polyethylene and 2% for the powdered rubber, by weight of asphalt cement binder.
5. For pavements subjected to heavy loading conditions in hot environments, it is commended to use polyethylene plastomer as an additive in order to modify mixture stiffness and improve its resistance to plastic flow, thus, minimizing possible rutting and distortion.
6. Rubber elastomer is recommended to be used as an additive in paving mixture where it is desired to reduce reflective cracking, or thermal cracking at low ambient temperature, thus reducing early distress end extending service life of pavement.
7. Field trails using paving mixtures with and without polymer additives are required demonstrate the effectiveness of field modification.

References

ASTM (1986). "Annual Book of ASTM Standards", vol. 04-03.

Becker, Mendez and Rodriguez, (2001). "Polymer Modified Asphalt", Vision Technological, vol. 9, No.1.

Maccarrone, Holleran, and Knanaseelan (1995). "Properties of Modified Binder and Relationship to Mix and Pavement Performance", Journal of the AAPT, vol. 64.

Oliver and Tredrea (1997). "The Change in Properties of Polymer Modified Binders Simulated Field Exposure", Journal of the AAPT, vol. 66.

SCRB , (2003) "General Specification for Roads and Bridges", section R9, Revised Edition.

Terrel and Walter (1986). "Modified Asphalt Pavement Materials - The European Experience", Proceedings AAPT, vol. 55.

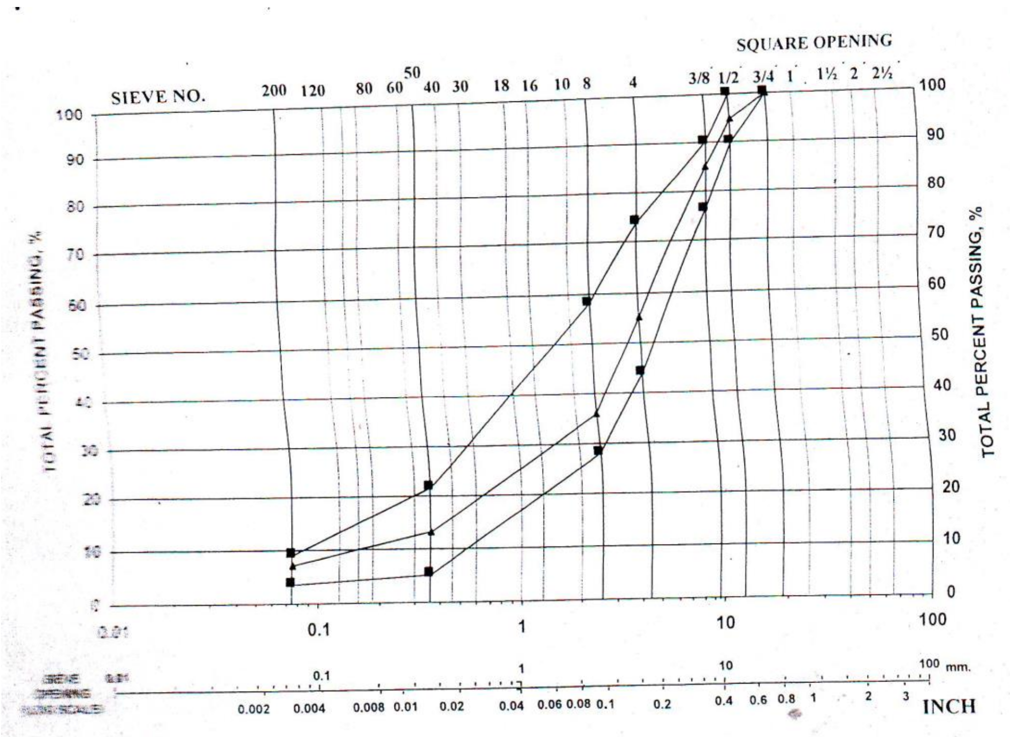

Figure (1): Selected Gradations within Specification Limits

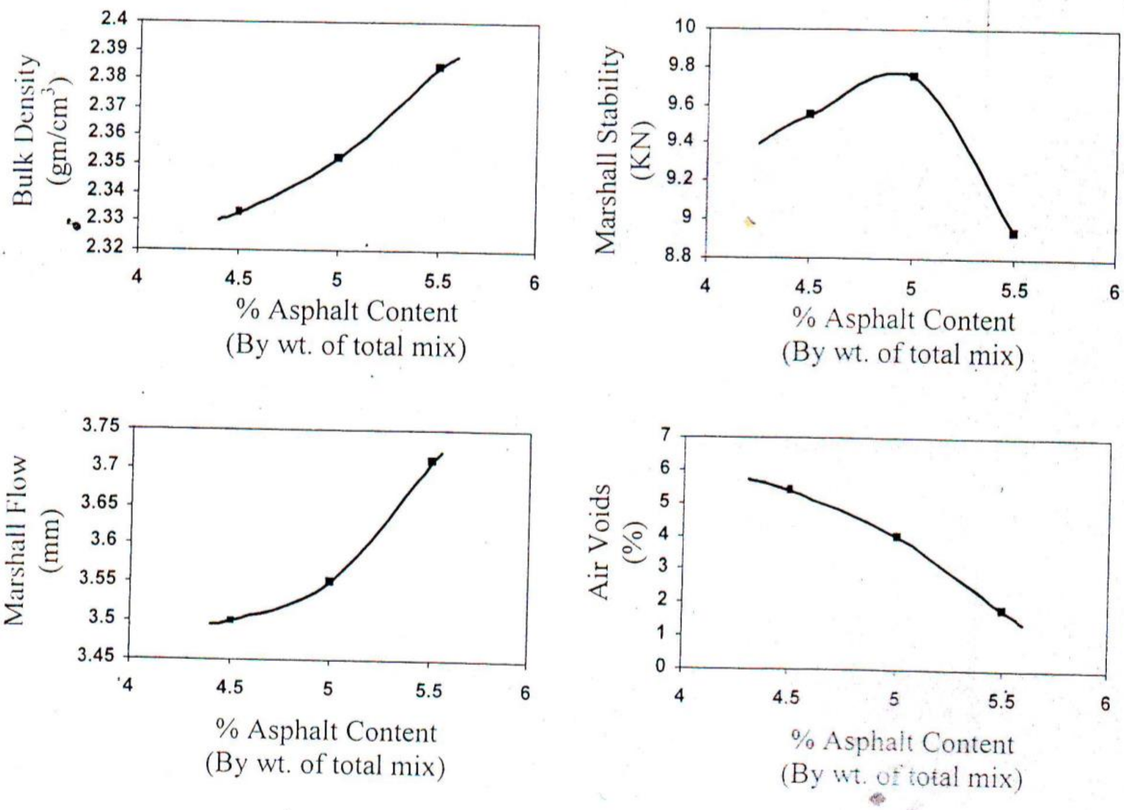

Figure (2): Influence of Asphalt Content on the Properties of Original Asphalt Concrete Mixture

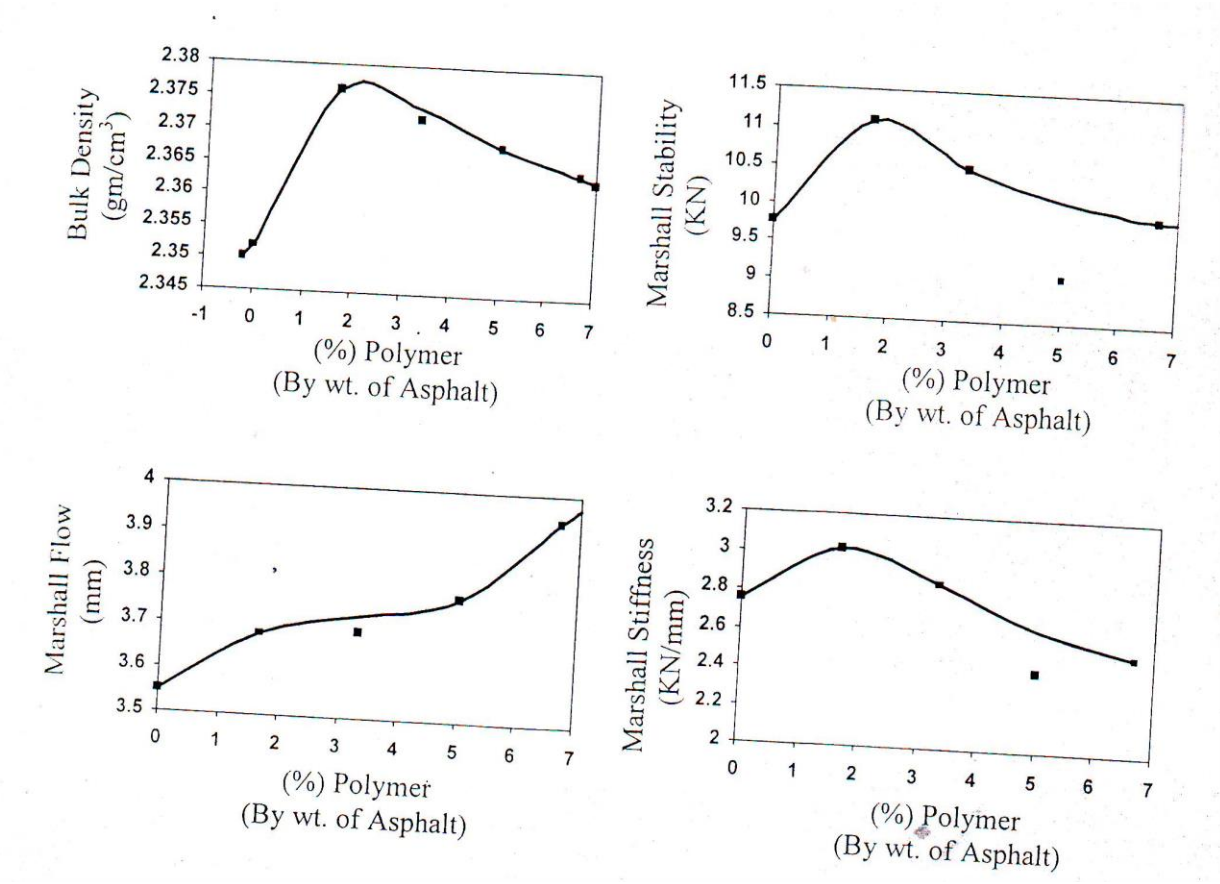

Figure (3): Influence of Polymer Content on the Properties of Asphalt Concrete Mixture Modified with Polyvinyl Chloride (Asphalt Content=5%)

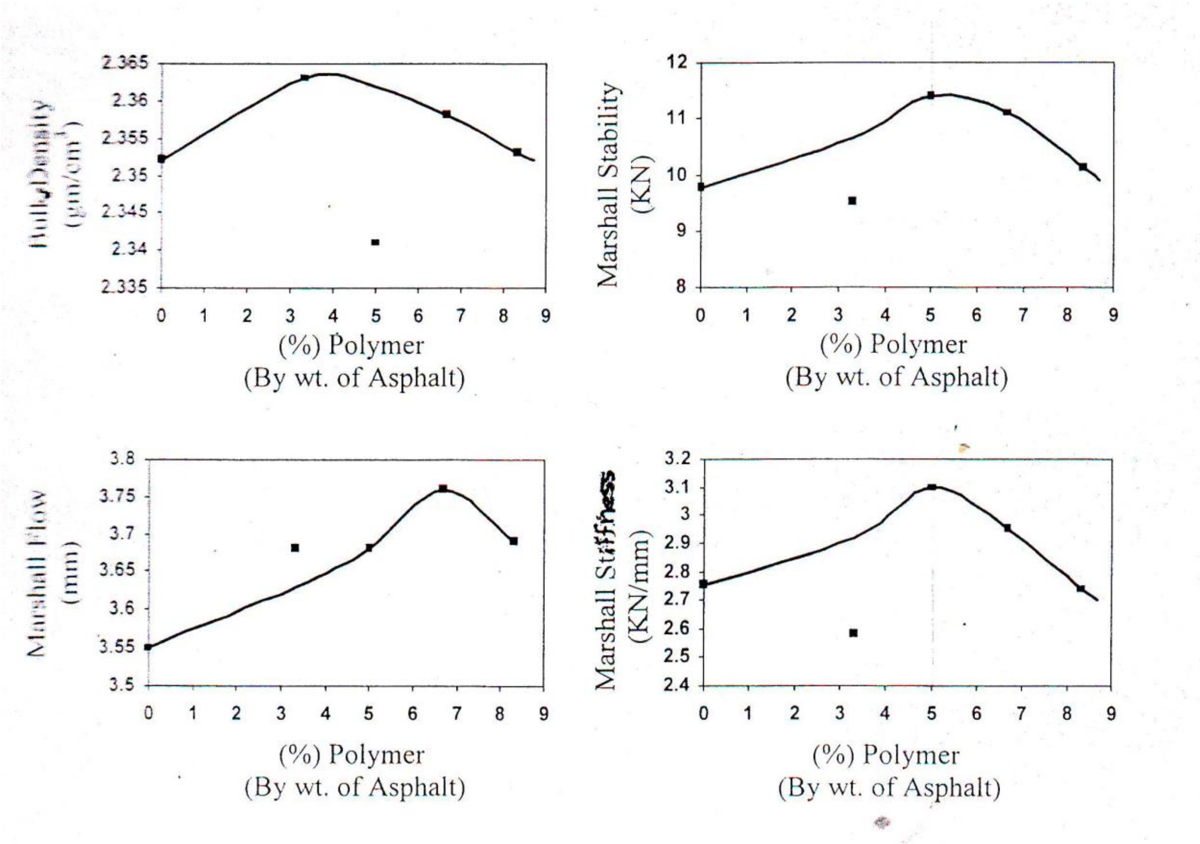

Figure (4): Influence of Polymer Content on the Properties of Asphalt Concrete Mixture Modified with Polyethylene (Asphalt Content=5%)

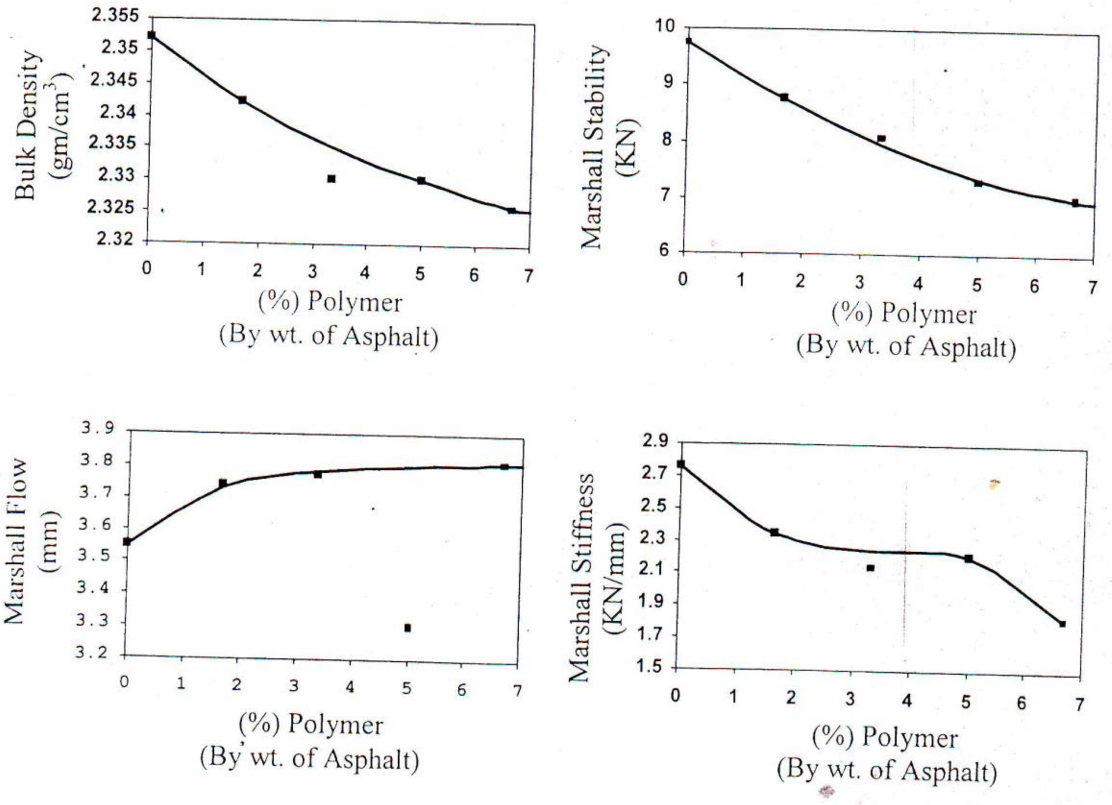

Figure (4): Influence of Polymer Content on the Properties of Asphalt Concrete Mixture Modified with Rubbewr
(Asphalt Content=5%)

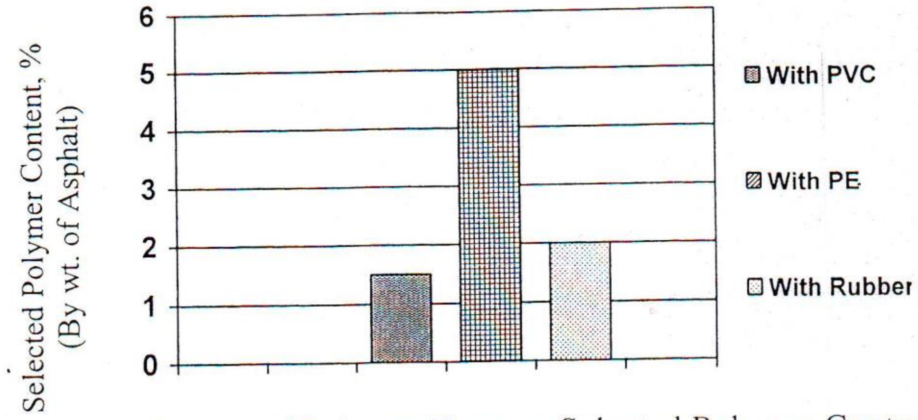

Figure (6): Influence of Polymer Type on Selected Polymer Content

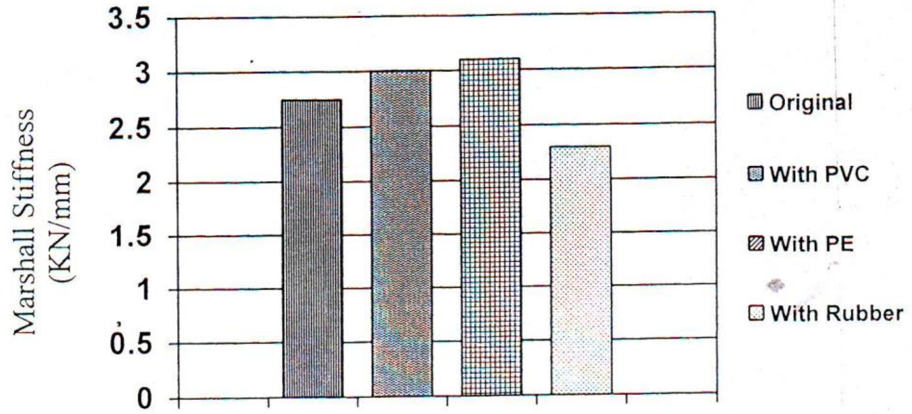

Figure (7): Influence of Polymer Type on Marshall Stiffness

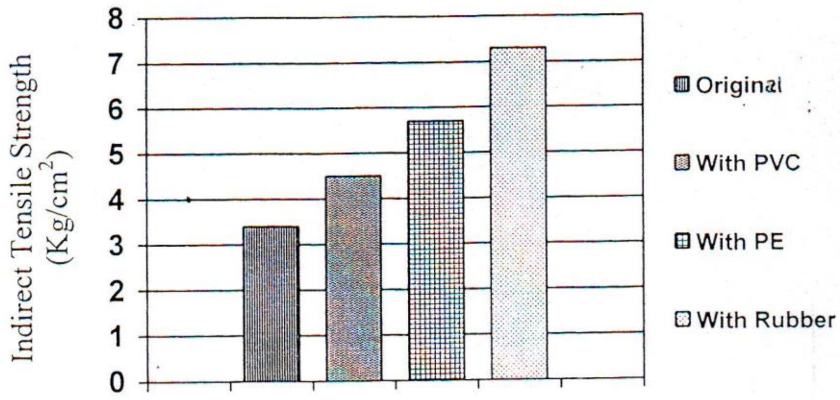

Figure (8): Influence of Polymer Type on Indirect Tensile Strength