Chemical Recycling of Polyethylene Terephthalate (PET) as Additive for Asphalt

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***Abstract*--Utilization of waste material in asphalt pavement would be beneficial in order to find an alternative solution to increase service life of asphalt pavement and reduce environmental pollution as well. One of these waste materials is plastic water bottles (Polyethylene Terephthalate) (PET) which are being produced in large amount. In this research Polyethylene Terephthalate (PET) was used to investigate the possibility of using waste plastic bottles made of Polyethylene Terephthalate (PET) as additives in bituminous mixture to overcome the pavement problems. Six different proportions (w/w %) of (PET) in (2, 4, 6, 8, 10, and12) has been added to bitumen to prepare the specimens. The tests include examination of Fourier Transform Infrared Spectroscopy analysis (FTIR) before and after PET chemical recycling, then ductility and penetration for bituminous. The results showed that the modification has increased by increasing the content of (PET %). This addition gives maximum flexibility and rigidity of the asphalt according to ductility increasing and penetration decreasing, by comparison with non-modified mixtures and give better resistance against permanent deformations and better engineering properties.**

Keywords: Polyethylene Terephthalate (PET), Recycled, Asphalt, Waste Bottle

I. INTRODUCTION

Plastic is a simple useful material. It's used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. Has founded for a long time on the earth and it is growing rapidly, the amount of waste plastic bottles being generated had become a serious problem to our environment. Studies have linked the improper disposal of plastic to problems as distant as breast cancer and reproductive problems in humans and animals, genital abnormalities and much more [1, 2].

The growth in different types of industries together with population growth has resulted in enormous increase in production of various types of waste materials world over. So many attempts are still being made to find methods for effective utilization of some of these waste materials. one of this attempts show that it has been possible use of the processed plastics to improve the performance of bituminous mixes used in the surfacing course of road pavements, with the help of various types of additives to bitumen such as polymer, rubber latex, crumb rubber-treated with some chemicals etc., also recycled plastic, mainly polyethylene is used in the manufacture of polymer–modified asphalt cement or bitumen [3, 4].

The use of in innovative technology not only strengthened the road construction but also increased the road life so will help to improve the environment. Plastic roads would be a boon for Iraqi's hot climate in summer, where temperatures frequently cross 50°C [5].

The asphaltic paving mixture is normally subjected to various detrimental types' of distresses during its service life. These distresses are caused by load (heavy traffic), poor binders (asphalts) properties, weathering (temperature, humidity, rain...) and bad mix designs. The result of these distresses includes rutting (permanent deformation), shoving, stripping, and fatigue cracking which finally may lead to completed failure of pavement. Such distresses will reduce the performance of asphalt pavements under the effect of heavy traffic loading, high temperatures and water damages, so specific requirement are needed to control the quality of highway pavement materials in order to increase its durability [6].

There are different ways to improve asphalt mixture properties, first is constructing road pavement with higher thickness, second is using different types of additives as modifier (e.g. different types of fibers and polymers) in asphalt mixture constructing high-thickness pavement will cause considerably higher construction cost. Thus, using additives might be a better solution to overcome the pavement deterioration problem [7].

II. AIM OF THE PRESENT WORK:

1. Recycling of waste plastic (water bottles) again in a different application.
2. Improved properties of the paving material.
3. Study the effect of adding different percentages of PET on the properties of asphalt mix.

III. MATERIALS AND METHODS:

A. Materials:

- **Polyethylene Terephthalate (PET):**

Polyethylene terephthalate (PET) is linear, aromatic polyester that has an aliphatic-aromatic polymer composition and thermoplastic, shows a rather hydrophobic nature due to its rigid structure, PET has the wide range of mechanical properties, relative high melting point and glass transition temperature, insensitivity to common solvents and moisture, chemical inertness. PET Characterizes tough, shatter resistant, gas permeation resistant. PET Can is recycled so that the PET can be used over and over again. This research includes adding Ethylene glycol (EG), which was used as a solvent for glycolysis; zinc acetate was of analytical reagent grade to PET.

- **Bituminous material:**

The asphalt used in this research is petroleum asphalt brought from Al-Obaidy asphalt plant refinery. The properties of asphalt binder that fall were within the values of Iraqi specification for Roads and Bridges (2003) of surface course.

B. Work Method

In the first step, the mixture of 100 gm of PET, 116 ml of Ethylene Glycol (EG) (4:1, EG: PET, molar ratio) and with 0.5% zinc acetate based on a weight of PET as catalyst in 190 º C for 5 hours until the mixture becomes in the resin state, heat treatment included totally condensation (reflux) in close system with (no material losing), by using glass condenser water cooling, then separation of unreacted ethylene glycol solution from the previous mixture.

In the second step, the product was mixed with bituminous by (2, 4, 6, 8, 10, and 12) (w/w %) based on the product at 200ºC for 2 hours. Finally, then the product poured into a mold to cool at room temperature.

Close system of chemical recycle for (PET) and complete flow diagram have been shown in figures (1), and (2).

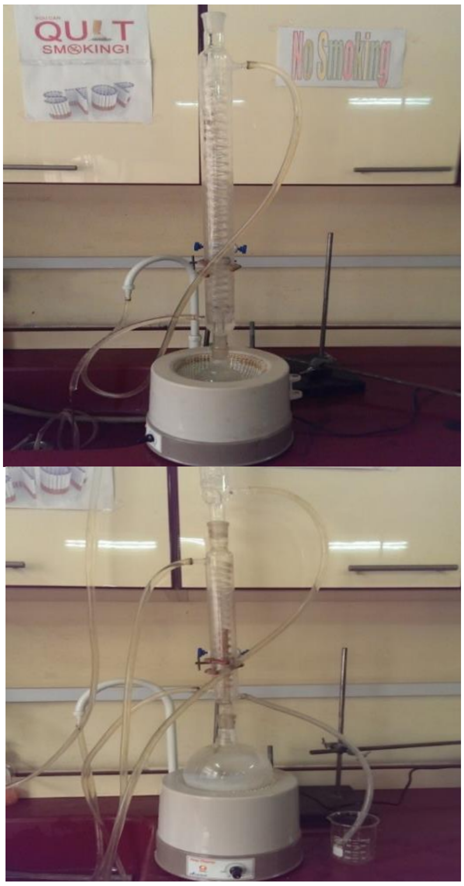


Figure 1. Close system of chemical recycle steps.

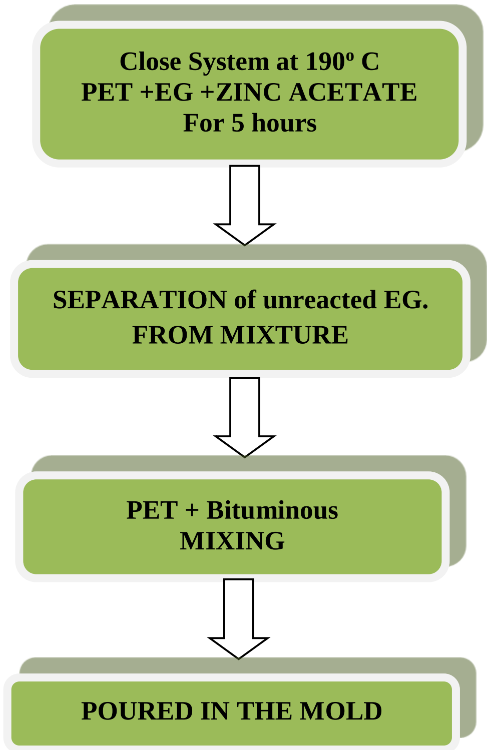


Figure 2. Flow diagram of experimental work.

C. Ductility test

Spec.: ASTM D113-1999, AASHTO T 51-2006

- **Objective:**

The ductility test is used to describe the ductile and tensile behavior of bituminous binders. The test, which is normally performed at ambient temperature as shown in figure (3).

Figure 3. Ductility testing machine**.**

D. Penetration test

Spec.: ASTM D5 -2006, AASHTO T 49- 2010

- **Objective**

The penetration test is used to measure consistency of bituminous materials expressed as the distance in tenths of millimeter that a standard needle vertically penetrates a sample of the materials under known conditions of loading, loading time and temperature. And to determine the penetration of a given sample of bitumen.

IV. RESULTS AND DISCUSSION:

The results have been focusing on mechanical and chemical bases:

A. Ductility & Penetration tests

The results showed that ductility increases gradually by the adding PET, from (82.67cm) for PET 0% (pure bituminous) to (150cm) when PET (12%),). While penetration decreases with the addition of %PET because of the better behavior of elasticity, as shown in Figure (4).

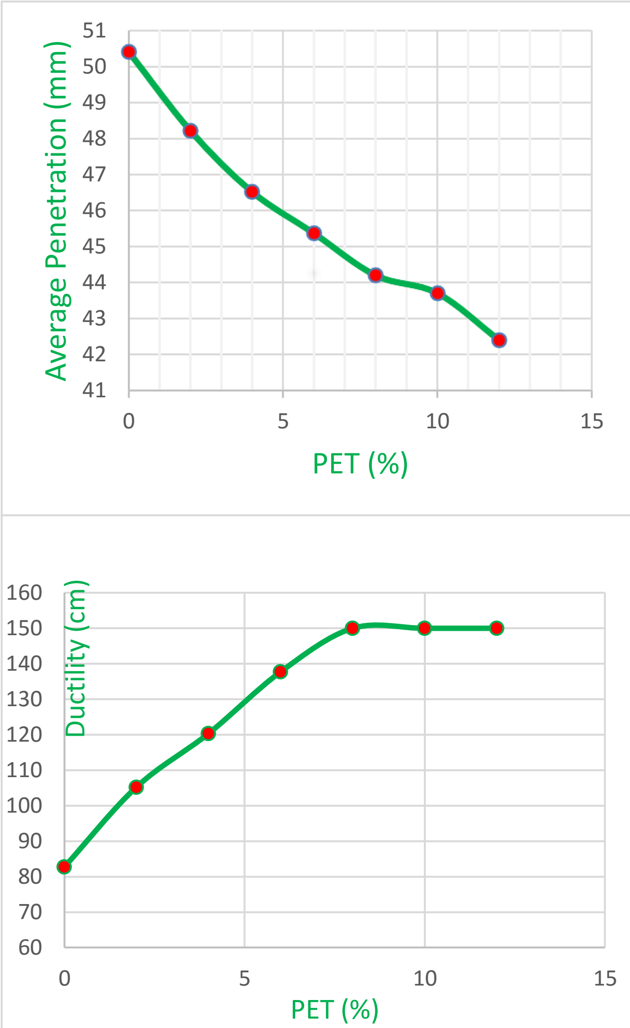


Figure 4. Ductility and Penetration Vs PET additive

B. FTIR Analysis:

In this work FTIR has been done, Figure 5 (a, and b) shows the changes in the composition have been occurred in PET of waste water bottles and after catalyst heat treatment.

The FTIR spectrum of the glycolysed product in Figure 5(a) shows absorptions at3445 cm^{-1} due to the OH (inter molecular hydrogen bonding), 2880-2950 cm^{-1} for C-H stretching, 1716 cm^{-1} for carbonyl group (CO), 1111 cm^{-1} for asymmetrical C-O-C stretching and 518-875 cm^{-1} indicative of aromatic ring. The FTIR spectrum of the pure PET bottle Figure 5(b), no OH appear with little C-H that exactly agreed with PET structure as shown below. The OH (inter molecular hydrogen bonding), and more C-H have appeared that means the volume of degradation in PET occurred.

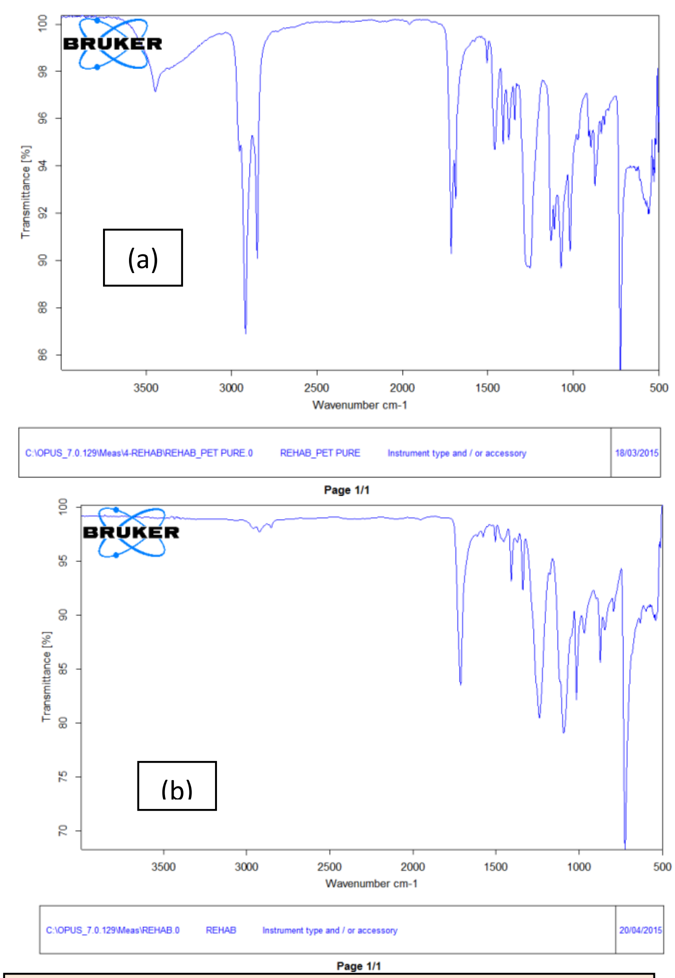
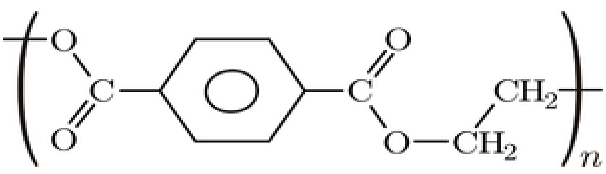


Figure 5. The FTIR spectrum of the glycolysed (a), & pure Bottle (b).



Polyethylene Terephthalate(PET)

V. CONCLUSIONS:

1. In this research the close system that used instead of the Nitrogen reflux [10] gave good results. EG vapors play role in the insulation of the system from air (preventing any oxidization process), as well as EG has been recycled and made this research more economic.
2. FTIR Analysis showed the changes in the composition that occurred in PET before and after catalyst heat treatment applied. It was seen change in the volume of degradation in PET due to more C-H appearance.
3. The appropriate amount of the additives was determined to be (2-12%) by weight for bituminous, 4% was the optimum modifier content of waste plastic water Bottles (PET).
4. The results of the study indicated that the modified mixtures, which indicates that the values of the ductility increase and the penetration values decrease.

References:

[1] Verma, S. S. "Roads from plastic waste." *The Indian concrete journal* (2008): 43-44.

[2] Schroeder, Robin L. "The use of recycled materials in highway construction."Public roads 58.2 (1994).

[3] Amjad K., Gangadhar, Murali M., and Vinay R., "Effective Utilization of Waste Plastic in Asphalting of Road"; Project Report, Bangalore, 1999.

[4] Flynn, Larry. "RECYLCED PLASTIC FINDS HOME IN ASPHALT BINDER."Roads & Bridges 31.3 (1993).

[5] Dr. Khalid M. Awaeed ,Dr.BesmaM.Fahad ,and Dalia AdilRasool(Dep. of Material engineering.University of Al Mustansiriya,"Utilization of Waste Plastic Water Bottle as a Modifier For Asphalt mixture Properties",Journal of Engineering and Development, Vol.20, No.2,march. 2015, ISSN 1813- 7822.

[6] Salim J.Sulaiman, Emad A.Ismail.,NaghamN.AL-Zadi "Improving Bitumen Properties by the Use of Scrap Tires Rubber" ,Journal of Engineering and Development, volume IVNo. 1, March (2000).

[7] Moghaddam, Taher Baghaee, Mohamed Rehan Karim, and Mahrez Abdelaziz. "A review on fatigue and rutting performance of asphalt mixes." Scientific Research and Essays 6.4 (2011): 670-682.

[8] Dr. Krishna P.Biligiri, Patil K. S., Suraj M. S., Sumit Jain, Postgraduate Research Interns,VTI, MANUAL,Center for *i*nfrastructure, Sustainable Transportation and Urban Planning,Indian Institute of Science, Bangalore, Karnataka 560012, INDIAC*i*STUP, IISc – *Advanced Pavement Engineering Laboratory*.

[9] Dr. Zaynab I. Qasim,Asphalt Laboratory, University of Technology,Building and Construction,EngineeringDep, Highways and Bridges Engineering Branch,2014.

[10] Mosadeghzad, Z., et al. "Preparation and properties of acacia sawdust/UPR composite based on recycled PET." Malaysian Polymer Journal 4.1 (2009): 30-41.