Journal of Engineering and Applied Sciences 13 (21): 8929-8934, 2018
ISSN: 1816-949X

The Feasibility of Using Plastic Wastes to Improve the Properties of Natural Asphalt

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Abstract: The industrial importance and application of asphalt in different fields such as pavement and roofing, etc. was a certain reason for this study. Many improvement processes have been applied in this research on Hit natural asphalt HNA from Hit city in Iraq to use it for industrial purposes. The HNA was modified by using solid plastic wastes (disposed plastic cans). Recycled wastes are used to achieve two aims: 1 in HNA improvement and 2 ridding the environment from the accumulation of plastic waste that being classified as contaminated materials. Modification process involved the addition of Polyvinyl Chloride (PVC) powder as a recycled waste to improve the properties of HNA . An old PVC pipes were crushed and transformed to powder and finally added to HNA in different ratios of PVC: HNA, (10, 20 and 30). The physical characterization of the new mixture was analyzed using penetration and softening point tests while the chemical properties have been characterized using (UV) and (IR) waves tests to study the changes in the rheological properties. The results revealed the economic importance of using recycled (PVC) powder to improve the properties of HNA and to reduce the adverse effect of these wastes on environment.

Key words: Plastic, waste, improve natural asphalt, PVC, HNA, UV

INTRODUCTION

Solid wastes are a main pollution source of the environmental pollution includes the disposed residue from the industry (Demirbas, 2011), that disposed from the residential areas (Minghua *et al*., 2009), food waste (Galanakis, 2012) consumed canning boxes (Iribarren *et al*., 2010), nylon bags (Hovell *et al*., 1986) glass, metal and plastic bottles (Cheng *et al*., 2010).

Recently, the recycling and transformation of solid wastes has a wide interesting in the scientific researches particularly when the wastes are degraded to its raw materials. The natural processes of waste degradation or transformation are considered tardy comparing to its accumulation and to confront this matter by human there will be two ways (Demirbas, 2011), firstly is to find a novel process and to assist the nature to degrade the wastes to its raw materials, secondly is to find a new use of these wastes in various important fields of human life which provides the necessary raw material for industry such as waste paper and plastic waste raw materials.

Scientific researches revealed that plastic waste which has a long-term life such as Polyvinyl Chloride (PVC) (Murthy, 2004). PVC should not treated as other industrial solid wastes because it can produce the most dangerous and poisons gases such as dioxins during combustion and also it can pollute the groundwater and causes pollution for the lakes and rivers (Dey, 1989). It was found that such pollution could be controlled by recycling and reuse processes through using them as a fuel for conventional electrical power plants (Rojer, 2009).

Plastic recycling is the process of reproducing and using the domestic, industrial or agricultural wastes to reduce the influence of these wastes and its accumulation on the environment. Recycling of plastic means, the reuse of wastes that contain about 10% of plastic which can be used as raw materials (Jin *et al*., 2008). The properties of plastic products depend on quality and quantity of additives during manufacturing process as well as on chemical composition of polymers or asphalt.

Amelioration process applied on natural aims to increase the stiffness of the asphalt to withstands the ambient environment and make it adequate for industrial purposes and that can be achieved by different methods as follows:

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Binder additives: This method includes adding polymers such as thermoplast or rubber. The binder can increase the bonding forces between asphalt and other materials of asphaltic mixture that lead to increase the cohesion forces between them. Styrene-Butadiene Rubber (SBR) and PVC are considered the most important types of polymers (Demirbas, 2011). Binding polymers give an improvement to the asphalt surface and its thermal properties (Zhou and Scullion, 2003).

Modification of hydrocarbonic chains: In this type of modifications a replacement reaction is occurs for the hydrocarbonic chains which includes replacing the hydrogen atoms by another groups which have more polarity to enforce and strength the chains to become stronger that give the asphalt substratum more rigidity and resistance for the ambient conditions. The chlorination is one of these methods which includes replacing the chlorine atoms by hydrogen atoms in the hydrocarbonic chains of asphalt (Dorf, 2000). The modification may be conducted by adding sulphur element so it is possible to benefit from the bilateral linkage sulphur ion to connect each two subsequent hydrocarbonic chains to each other.

Filler additives: This type of modifications include adding materials in forms of fillers powders such as organic salts, wastes or another materials which reduce the voids between the particles and supporting the asphaltic body and increasing the stiffness. It increases the cohesion between asphalt particles by forming a chemo-physical linkages as when using metal powders, metallic oxides or chlorides and alkali powders (Murthy, 2004). Researches that affirmed that the granular size should be small and the material should be dry enough to get thecomplete homogeneity between the hydrocarbonic chains.

Widespread researches were studied about natural asphalt and studied the temperature exerted on the mixture of chlorinated ethylene added as improving material to natural asphalt using grains having various sizes. They deduced that the additive leads to increase the enetrating index and the penetration viscosity number when using elastic polymers as binding martial. Crumbs of used tires were studied to improve the properties of paving asphalt and this study produced a new material with high resistance to environmental effect (McGennis, 1995). By adding to asphalt, it is provided an endurance to resist abrading and erosion resulted from the tires movement and resistance to the stretching or shrinkage during summer or winter. It has been deduced that adding the polymer gives smoothness to the asphalt surface, improvements in thermal properties and increasing cohesion between asphaltic mixture components. It was found that rubber can enhance the physical properties of asphalt when Low Density Polyethylene (LDPE) is used for asphalt modification by decreasing the penetration about 70% (Shatnawi and Holleran, 2003). The properties of asphalt were highly effected by the motley rate of polymer and asphalt which resulted from the interlacement between asphalt and polymer (Youngblood *et al*., 2009). Some polymers were successfully used and produced correlative relation between the components of asphalt in low temperature degrees.

Recently, polymers where used to modify the asphalt to make the paving material (Villanueva and Zanzotto, 2008). Combining asphalt with thermoplastic such as polyethylene and polypropylene can produce modified asphalt having high stability even in severe environmental conditions (Shen and Amirkhanian, 2005; Ghaly, 2008). Rubber powder of consumed or used tires was added to the Hit Natural Asphalt (HNA) as a filler material. The modified HNA fulfilled the Iraqi and International specifications as a roofing material (Mahmood and Saadoon, 2009). The dynamic behavior of binder at high temperatures has been investigated by using a combined system of Rubber polymer and contributed polymer (homogenous polymer-contributed polymer) which produced modified rheological properties of asphalt. On the same context, the addition of polypropylene tactic to the mix of asphalt and combined rubber (Styrene-Butadiene) produced improvements in the rheological properties of asphalt at different temperatures (Ghaly, 2008).

Objectives: The main objective of this research is to investigate the methods of improving the properties of HNA by adding local and cheap materials such as (PVC). The study aimed also to enhance the properties of HNA which cannot be used in its currently form to produce modified HNA that can be used for different purposes. This research investigates the hazardous effect of plastic materials on the environment which increases daily. The recycling process is considered an Environment-Friend project with economic benefits.

MATERIALS AND METHODS

Hit natural Asphalt HNA: HNA is naturally formed and characterized as light stature, easy of liquidity has high emissions of inadmissible smell such as hydrogen sulfide H_2S and contains a certain percentages of volatile matters. It was dried naturally by under the effect. The residue is dried in the oven at 110°C to eliminate the humidity totally before conducting any measurements.

Plastic powder: Used Polyvinyl Chloride (PVC) pipes are crushed and grinded and then sieved to get a powder has a particles size <1 mm as shown in Fig. 1.

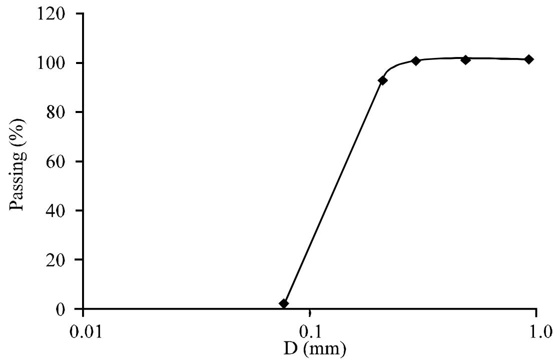

Fig. 1: Grain size distribution of PVC

Tests

Penetration test: This test is used to determine the stiffness of HNA. It was conducted according to ASTM (D5-83) (ASTM, 1973).

Softening point test: The test is used to determine the temperature at which the asphalt soften. It was measured according to ASTM (D36-70) (ASTM, 1986).

Infra-Red IR spectroscopy and Ultra Violet UV spectroscopy measurement: IR and UV spectroscopy tests are conducted according to procedures explained in references (Parikh, 1974; Hamid, 1992), respectively.

RESULTS AND DISCUSSION

PVC powder was added to HNA in different percentages (10, 20 and 30) of PVC/HNA. A significant decrease in penetration due to increase in PVC percentage can be seen in Fig. 2. The penetration values decreased from 210 (0.1 mm) at PVC% = 0 to be 88 (0.1 mm) at PVC% = 30. At the meantime, adding the PVC has a significant effect on the result of softening point as shown in Fig. 3. The addition of PVC to HNA increased the softening point values from 34 °C at PVC% = 0 to be 45°C at PVC% = 30.

Results indicate the fact that PVC powder has a positive effect on the rheological properties of HNA by increasing the viscosity of mixture and that can be explained by the results of penetration and Softening point tests. It could be related to the chemical rapprochement between the two PVC and HNA, especially, since, they are considered Hydro-Carbonic materials which provide more cohesion and adhesion between them.

The results show that the modified HNA fall within asphalt grade 85/100 according to American Society for Testing and Materials (ASTM) and asphalt grade 70/100 according to European Standard EN. Accordingly,

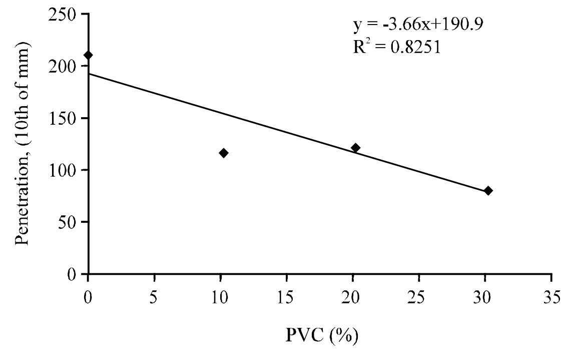

Fig. 2: Penetration values at different percentages of PVC

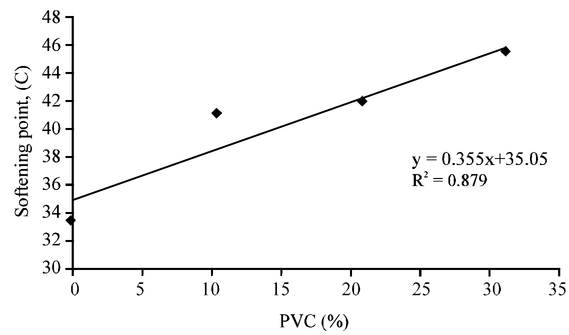

Fig. 3: Softening point values at different percentages of PVC

the modified HNA can be used for asphaltic pavement layers in cold climate regions. This is one of the benefits of using PVC to modify HNA, so, it is expected that new low cost modified asphalt can be produced from these two useless and cheap materials.

Another usage of PVC-modified HNA is as building material instead of disposing to the land field. Based on, a comparison between the rheological properties (i.e., penetration and softening point) of the mixture of (PVC and HNA) at 30% and the Iraqi pecification 1196-88 and international ASTM specification D312 is established as shown in Table 1.

Unfortunately, the permitted period for using the laboratory at Anbar University has been exhausted, so that, no further experiments could be done. Therefor equations shown in Fig. 2 and 3 are used to expect that when PVC is mixed with HNA at about 50% percentage, the resulted PVC-modified HNA can satisfy the Iraqi Specification 1196-88 and international ASTM Specification D312 as roofing materials as shows in Table 1.

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Table 1: A comparison between the Iraqi and ASTM specifications for the results of (UPVC : Asphalt)

Test	Iraqi specification 88-1196 Min.	Max.	ASTM specification D312 Max.	Min.	PVC-modified HNA properties 0	10 (%)	20 (%)	30(%)	The expected results at about 50-60 (%)
Softening point, (°C)	57	66	57	66	33.5	41	41.5	45	57
Penetration (0.1 mm)	18	60	18	60	210	123	123	88	26

FTIR spectrum was performed on the PVC-modified HNA samples to locate the adsorption of the bonds, meanwhile samples were diluted by Carbon Chloride (CCl_4) where the expected effects on the radiation adsorbing groups of this solvent are known because its activity and polarity.

Characterization of the following transfers in the UV-spectrum for all samples before and after the addition of PVC where similar. Figure 4 shows that the following transitions can be distinguished in the UV spectrum: A signal of type (n-π*) at the site 407.77 nm and a signal of type (π-π*) at 267.46 nm.

Figure 5 shows that the addition of 10% of PVC is responsible for the transitions signal of type (n-π*) at the site 407.22 nm and a signal of type (π-π*) at 268.00 nm. The difference is marginal indicating the fact that PVC has no effect on the results.

Figure 6 shows that the addition of 20% of PVC is responsible for the transitions signal type (n-π*) at the site 407.15 nm and a signal type (π-π*) at 267.54nm. The difference is also marginal indicating the same previous results.

Figure 7 illustrates that the addition of 30% of PVC is also has insignificant effect on the results as indicated by the resulted UV transitions signal of type (n-π*) at the site 407.00 nm and a signal of type (π-π*) at 267.41 nm.

Elucidates IR spectrum for HNA where adsorption occurred at peak of (3447 cm^{-1}) which refers to the existence of (OH) group. Another peak was occurred at (2934 cm^{-1}) which refers to non-symmetric group of saturated (CH_2), meanwhile a peak was occurred at (2862 cm^{-1}) which refers to the symmetric group of saturated (CH_2). The beam occurred at (1640 cm^{-1}) related to the aromatic bond as (C = O) group. Peaks of (920 cm^{-1}) refer to the compensators curvature in aromatic ring. Meanwhile in case of (10, 20 and 30%) percentages of PVC addition, beams of adsorption were identical to the basic asphalt with a simple distortion occurred because of the hydrogen bonds between PVC and HNA. The enclosed range between (600-800 cm^{-1}) represents (C-Cl) bond in mono chlorine compounds thus (680 cm-1) beam is related to (C-Cl) figure not shown.

The beam of (776 cm^{-1}) is related to the aliphatic (C-Cl) group which occurred at 20% of PVC. At the meantime, multi-chlorine beams was occurred in case of

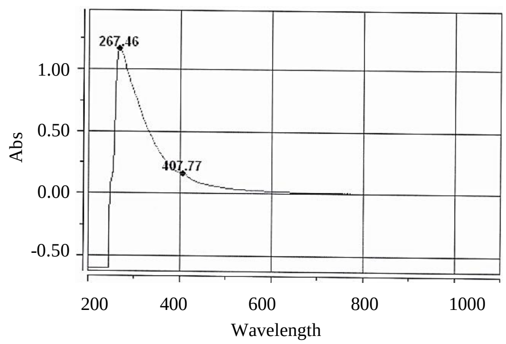

Fig. 4: UV spectrum for natural asphalt at PVC = 0

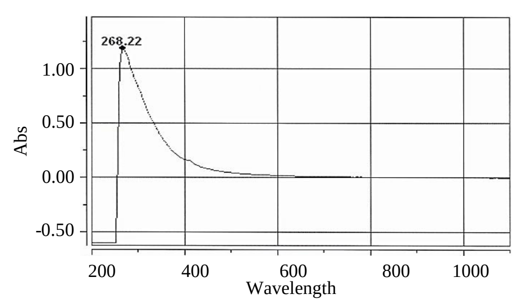

Fig. 5: UV spectrum for natural asphalt at PVC = 10

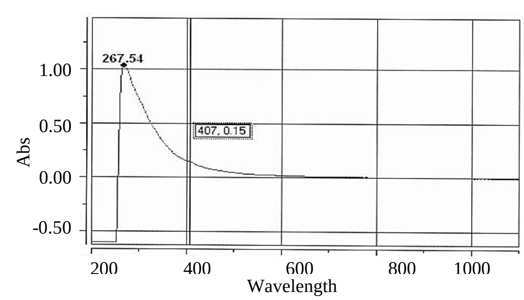

Fig. 6: UV spectrum for natural asphalt at PVC = 20

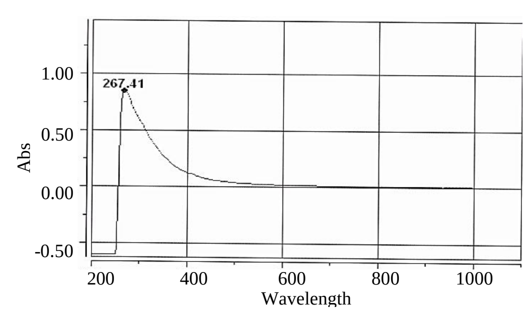

Fig. 7: UV spectrum for natural asphalt at PVC = 30

20% addition producing (1433 cm^{-1}) beam which is moderate intensity. When there are a lot of chlorine atoms which are connected with carbon atoms, higher frequencies are produced. Another types of beams occurred in (1031 cm^{-1}) which is related to the aromatic (C-Cl) group that a simple distortion happened because of the high induction between chlorine and the aromatic rings that called resonance State.

CONCLUSION

The main conclusions of this study are summarized in the followings: It is possible that hit natural asphalt can be used after mixing with waste material like PVC wastes at 30% in producing hot mix asphalt mixtures that can be used pavement layers instead of asphalt binder produced from petroleum product for cold regions. The PVC-modified HNA has a rheological properties similar to asphalt grades 58/100 and 70/100 according to international standards. This can help in reducing the cost of pavement layers.

It is expected that mixing PVC wastes with HNA at 50-60% can produce a new water-proof material that can be used for roofing purposes. The produced PVC-modified HNA has a properties as that required by the international standards as a roofing material. The produced new material is a low cost material since it has been produced from waste and unused materials.

The use of PVC to improve the properties of HNA has a significant effect on the environment by reducing the adverse effect of waste materials.

The chemical tests results (UV and IR) revealed that there are no chemical interactions between PVC and HNA. The enhancement in rheological properties of HNA are related to physical mixing features.

The study explained the procedures and percentages of materials that can be used to re-use waste and unused materials (e.g., PVC and HNA) to produce new beneficial and cost-effectiveness enhanced material for different purposes (e.g., paving and building).

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