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INVESTIGATION OF THE EFFECTS OF MODİFİED BITUMEN ON ASPHALT CONCRETE PERFORMANCE BY INDUSTRIAL WASTE

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ÖZET

Sıcaklık ve yükleme doğasındaki mevsimsel değişim, viskoelastik doğası nedeniyle asfalt davranışı üzerinde önemli bir etkiye sahiptir. Asfalt bağlayıcısının bu davranışı nedeniyle, rutting ve yorgunluk çatlaklarının çok yaygın olduğu çeşitli esnek kaplama hatası / sıkıntısı meydana gelir. Bu çalışmada, baz bitümün katkıları olarak Düşük Yoğunluklu ve Yüksek Yoğunluklu Polietilen ve Kırıntı kauçuğu kullanılmıştır (PG 64-10).
Dinamik Kesme Reometresinden (DSR) elde edilen kompleks modül (G *) ve faz açısı (δ), bağlayıcının sürtünme ve yorulma çatlaması ile ilgili davranışını değerlendirmek için kullanılan temel çevre ölçerleridir. Düşük Yoğunluklu Polietilen (LDPE), Yüksek Yoğunluklu Polietilen (HDPE) ve Kırıntı Kauçuk (CR) modifiye edilmiş bağlayıcının bağlayıcının reolojik özelliklerinde önemli bir gelişme gösterdiği sonucuna varılmıştır. Ayrıca, bu belediye atıklarının geri dönüştürülmesi, bu atıkların çöp sahalarında birikmesinden kaynaklanan Orta Doğu ülkelerindeki çevresel sorunların çözülmesine katkıda bulunacaktır.
Çevre kirliliği Mısır gibi gelişmekte olan ülkelerde büyük bir sorundur. Atık polimerlerin yeniden kullanılması, çevre beyazı kirliliği ve yol kaplama ve bakım maliyetlerinin azaltılması için cazip bir çözüm olarak kabul edilmektedir. Bu araştırma, polipropilen ve polyester elyaf olarak bazı endüstriyel atıkları kullanarak kaldırım için çevre dostu sıcak karışım asfalt (HMA) hazırlamayı amaçlamaktadır. Karışımdaki katı malzemeler arasında normal ve oldukça gözenekli agregalar bulunur. Özel bağlayıcılar hazırlamak için asfaltın ağırlıkça% 5 ve% 10'u atık polimerleri kullanıldı. Örnekler fiziksel özellikleri, kimyasal özellikleri, yaşlanma, taramalı elektron mikroskopisi (SEM) ve termo-gravimetrik analiz (TGA) açısından test edilmiştir. Sonuçlar, atık polimerin% 5'ini kullanarak hazırlanan HMA'nın sıradan olana kıyasla yüksek performansa sahip olduğunu ve atık polimerin yol yapımında kullanılabileceğini göstermiştir.

Anahtar Kelimeler: çevre kirliliği, asfalt betonu, endüstriyel atıklar

ABSTRACT

The seasonal change in temperature and loading nature has a significant effect on asphalt behavior because of its viscoelastic nature. Several types of flexible pavement failure/distress occur due to this behavior of asphalt binder, among which rutting and fatigue cracks are very common. In this study, Low Density and High Density Polyethylene and Crumb rubber were used as additions to base bitumen (PG 64-10).
Complex modulus (G*) and phase angle (δ) obtained from Dynamic Shear Rheometer (DSR) are the basic perimeters used to evaluate the behavior of the binder in respect to rutting and fatigue cracking. It was concluded that Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE), and Crumb Rubber (CR) modified binder showed significant improvement in rheological properties of the binder. Furthermore, recycling these municipal wastes will contribute to solving environmental problems in the of Middle East countries caused by the piling up of these wastes in dumpsites.
Environmental pollution is a major problem in developing countries like Egypt. Reuse of waste polymers is considered an attractive solution for environmental white pollution and reducing of the costs of road pavement and maintenance. This research aims to prepare environmentally friendly hot mix asphalt (HMA) for paving using some industrial wastes as polypropylene and polyester fibers. The solid materials in the mix include normal and highly porous aggregates. 5% and 10% of waste polymers by weight of the asphalt were used to prepare special binders. The samples were tested for their physical properties, chemical properties, aging, scanning electron microscopy (SEM) and thermo-gravimetric analysis (TGA). The results revealed that the prepared HMA using 5% of waste polymer had high performance as compared to the ordinary one and the waste polymer could be used in road construction.
Keywords: environmental pollution, asphalt concrete, ındustrıal waste

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1. INTRODUCTION

Bitumen, a residue from crude oil distillation, is a complex mixture of four main families of compounds, referred to as SARA fractions (saturates, aromatics, resins and asphaltenes) .

The behavior of bitumen depended on the relative concentration and the chemical features of asphaltenes and maltenes; thus, variation in its composition strongly affects its mechanical properties . It presents a large set of interesting potential properties: impermeability, ductility, adhesivity and resistance to the effect of weathering and chemicals, etc. . In the last 20 years, a wide spectrum of modifying polymeric materials has been tested with bitumens for their use in road construction. For a polymer to be effective it must blend with bitumen and improve its resistance at high temperatures without making the bitumen too viscous at mixing temperatures or too brittle at low temperatures. It should be capable of being processed by conventional equipment, available, not expensive and physically and chemically stable during storage, application and service. In actual modified bitumens, thermoplastic rubbers, as well as some thermoplastic polymers, were mainly used. The use of secondary (recycled) aggregates, instead of primary (virgin) materials helped in easing landfill pressures, reducing the need for extraction, protecting environment and minimizing the consumption of original resources. Polyester polymer, thermoplastic Polyethylene terephthalate (PET) and mineral fibers are the additives mostly used to produce a strong and durable reinforcement bitumen .

Due to rapid urbanization and population increase, the production of waste is rising significantly in Middle East countries. Currently, there is no robust recycling program in place; as a result, municipal waste is simply sent to dumpsites, which is affecting human health and the environment. The most promising way to recycle a certain portion of this waste, consisting of HDPE, LDPE, and crumb rubber, is to use it in the construction of roads and other infrastructure. On the other hand, the majority of flexible pavements fail prematurely due to severe temperatures and heavy loading within the Kingdom, as well as due to the use of conventional grade bitumen (PG 64-10) without modifications. Hence this research was carried out to search for possible ways to modify conventional binder from PG 64-10 to higher grades, as well as to recycle this particular type of municipal waste in order to contribute to a cleaner environment. Many studies have been carried out for the re-use of these wastes in different ways. The economic and social development of the nation depends on transportation infrastructure.

The growth in any country's economy has a strong relationship with the development of its transportation sector. In the of Middle East countries, the road network has received significant funding for the building of better highways.

The Ministry of Transportation suggested the use of polymers as an asphalt additive to meet the harsh local environmental conditions. Different modifiers (e.g. low and high density polyethylene, sulfur, and crumb rubber) can be used to improve the performance of pavement against rutting and cracking.

The susceptibility to rutting of asphalt pavements can be significantly reduced by adding reclaimed asphalt pavement (RAP) to the mix . The addition of RAP would help stiffen the mixture .

The addition of sulfur to bitumen showed significantly higher fatigue life. The presence of a gel-like structure results in good bonding with aggregates. The marshal stability and resistance to rutting can also be improved using a sulfur-asphalt mix . Epoxide Natural Rubber (ENR) and Polyethylene Terephthalate (PET) can be used as a bitumen modifier to improve the binder resistance against rutting and fatigue. Similarly, using Rice Husk and Wood Sawdust Ash as asphalt modifiers result in decreasing phase angle and increasing complex modulus, which shows more elastic behavior compared with controlled bitumen [6, 7, 8, 9]. Municipal Solid Waste (MSW), which includes cardboard, paper, plastic, wood, metal and glass, amounts to about 3800 m3/day in the Eastern Province of Middle East countries.

Due to a lack of systematic recycling methods, all this MSW is deposited in open dumpsites . However, practical experience over the last four decades has shown that the modification of the asphalt binder with polymer additives, offers several benefits. These include improved adhesion and cohesion properties, enhanced fatigue resistance, improved thermal stress cracking, decrease in temperature susceptibility and reduction of rutting .

As a result, bitumen modified with polymers is a common means of providing optimally performing pavement. This work aims to determine the effect of polythene modified bitumen on the properties of hot mix asphalt.

Asphalt is known as brittle and hard in cold environments and soft in hot environments. As a pavement material, it is characterized with a number of failures represented by the low temperature cracking, fatigue cracking, and the rutting (or permanent deformation) at high temperature, causing its quality and performance in pavement of roads to decrease. Though, it has been historically the most popular paving material for roadways. Any improvement in service life of road pavements will be off course of a great economical advantage and any modifications of asphalt are attempts to extend the service life and improve the performance of asphalt pavements [2].

2. HISTORY OF ASPHALT MIX INVENTION

The actions of modifying the asphalt paving material have begun long time ago and hopes were sought initially in earlier experiments of incorporating natural rubber with asphalt in 1840s, in order to capture the flexible nature of rubber in a longer lasting paving surface. Unfortunately, the aim was difficult to attain and the asphalt-rubber formulas did not bring a benefit, and the result was a modified asphalt pavement material that was more costly and shorter in service life than ordinary asphalt .

During 1900‟s, the technique of using asphalt in pavements was first used on rural roads to prevent the rapidremoval of dust from water bound macadam caused due to fast growth of automobiles. At initial stages, heavy oils were used as a dust palliative. The estimations of the exact quantity of the heavy oil in the mix were performed by an eyejudgment. The 1st formal method of mix design was called Habbard field method, which was actually developed on sand asphalt mixture. One limitation of this method, however, was the inability of dealing with mixtures with larger sized aggregate particles than dust. Latter, in 1927, a project engineer of California department of highways named Fransis Hveem has developed the Hveem stabilometer . He did not have any previous experience on judging the required mix from its colour, hence he decided to measure various mixture parameters to find the optimum quantity of asphalt. He had used the surface area calculation concept, (which was already in use in that time), to estimate the quantity of asphalt actually required. Then, just before the World War-II, Bruce Marshall has developed the Marshall testing machine which was adopted in the US Army Corps. of Engineers in 1930‟s and subsequently modified in 1940‟s and 50‟s .

The real evolution of mix started exactly in the 1960s, when a successful formulation was discovered by a bureau of public roads employee named Charles H. MacDonald while traveling across the country inspecting highway material sources and had a crack on his mobile trailer‟s roof. To fix the crack, he ran many attempts of using asphalt and did not succeed. He latter thought he could solve the crack if he incorporated rubber . And thus he experimentally tried the addition of ground tire rubber to hot liquid asphalt, and only after thoroughly mixing them and allowing it to react for a period of time, new material properties were obtained. This new product material captured beneficial engineering properties .

2.1. Processes Of Asphalt Mix With Industrial Waste

Production of asphalt mixtures with industrial waste in form of CR is usually established by mainly one of two common ways; the first one is called the wet process where rubber particles are mixed with asphalt at elevated temperature prior to mixing with the hot aggregates. The second type is called dry process, where rubber particles replace a small portion of the mineral aggregate in the asphalt mix before the addition of the asphalt .

The main differences between these processes include size of rubber; in the dry process rubber is much coarser than wet process rubber, amount of rubber; the dry process uses rubber 2 to 4 times as much as the wet process, function of rubber; in the dry process the rubber acts more like an aggregate but in the wet process it acts more like the binder, and finally the ease of incorporation into the mix; in the dry process no special equipment is required while in the wet process special mixing chambers, reaction and blending tanks, and oversized pumps are required. process, is called asphalt rubber. It has been defined by American Society for Testing and Materials (ASTM) as “A blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles” .

In wet process, asphalt is blended with a crumb rubber modifier (CRM) in a specialized blending unit at elevated temperatures (190 - 225°C) for a minimum of 45 min to promote the chemical bonding of the components. During the blending process, CR swells and softens with the asphalt.

3. CASE STUDIES

According to laboratory tests concerning the application of wet process of asphalt rubber mix , it was concluded that rubber particles retain a larger proportion of the asphalt compared with the aggregates, suggesting an interaction between asphalt and rubber. In another laboratory study by Pais et al., (2001) [16], they have reported that tire rubber inclusions can modify a conventional HMA in terms of a flexural fatigue life, since mixtures which include rubber treated using different processes (cryogenic or ambient) have shown greater fatigue life than conventional mixtures regardless of the void content. The last may vary from one mixture to another for the same category of asphalt. The examination of tensile strength characteristics of a dense asphalt macadam (DAM) mixes with CR by Punith et al.

have revealed improved characteristics in terms of Marshall stability and indirect tensile strength at various temperatures under soaked and unsoaked conditions. Both of these properties increased as the tire rubber percentage increased. For unsoaked conditions in particular, the indirect tensile strength was higher compared with that of the soaked samples, while it was decreased as temperature increased. Additionally, at high temperatures tensile strength was almost the same for both, the rubberized DAM mixture and the virgin asphalt; thus rubberised asphalt mixtures are expected to have a longer life than the conventional DAM. Another study was carried out by Rahman et al. (2004) on dense, graded rubberised asphalt mixtures produced using the wet process, and containing (3–5)% CR by total aggregate weight, showed that those mixtures are more susceptible to moisture damage compared with conventional mixtures while their stiffness reduced by (30–75)% depending on the CR content. However, when fine rubber particles (< 1.0 mm size) are added to asphalt mixtures, they have produced mixtures with improved characteristics in terms of stiffness, resistance to permanent deformation and rut, whereas particles of such gradation were more effective .

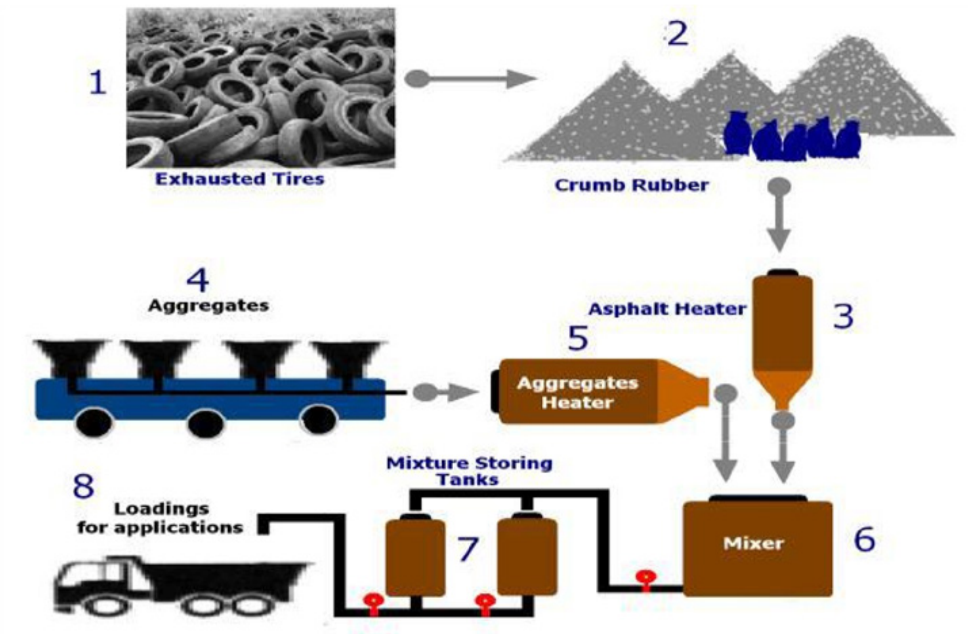

Fig. 1. (A-Up) Rubberized asphalt mixture by wet process, (B-Below)

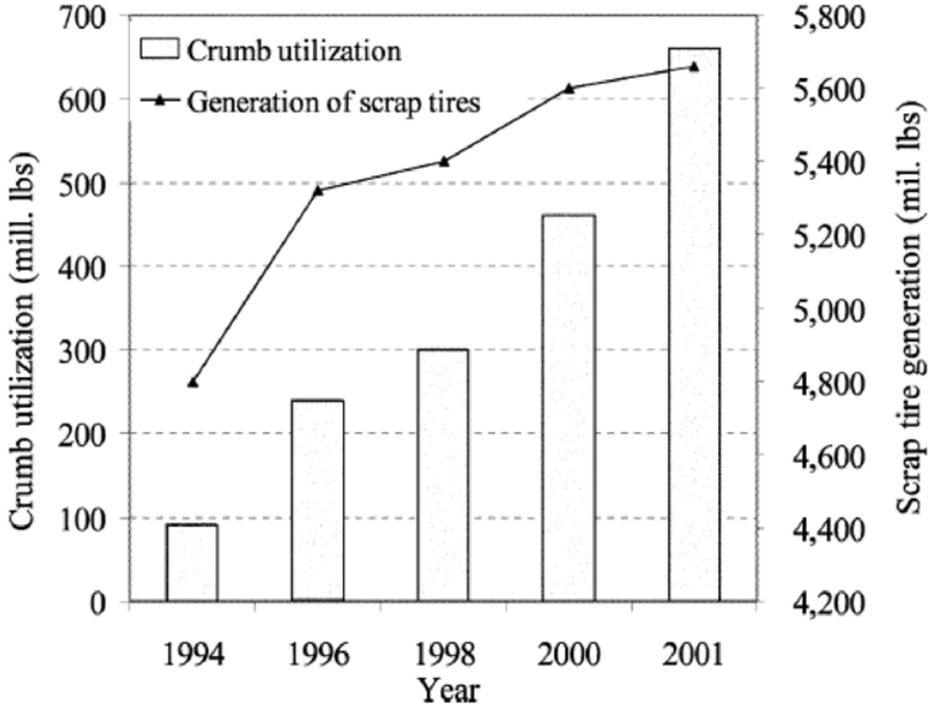

Fig. 2. Scrap tire utilization alternatives .

3.1. Reuse Of Sıw In Asphalt Pavements

One of the major environmental concerns worldwide is the landfill disposals of SIW. Disposals of expired automobile tires and plastics randomly are considered as one of those major causes damaging our ecosystem and posing health problems to all types of life alarmingly. Annually, large volume of tires become exhausted and thrown as wastes frequently seen on the sides of the roads and highways. Also, plastics have been habitually mixed with our municipal solid wastes and sometimes disposed over land areas. And both, in terms of their chemical characteristic represented by their chemical bonds, are very durables and non-biodegradables. As this action continuous to occur, this also calls for implementing very effective management worldwide. The aim is to facilitated technical plans based on control of the toxins resulting from decomposition mostly by means of recycling and reuse of such substances. As a result, many studies and researches have focused on reusing and recycling waste rubber tires and plastics in civil engineering such as in developments and improvements of asphalt surfacing material.

Table 1 : Examples Of Thermoplastıcs And Thermosettıng

Thermoplastics	**Thermosetting**
Polyethylene Teryphthalate (PET)	Bakalite
Polypropylene (PP)	Epoxy
Polyvinyl Acetate (PVA)	Melamine
Polyvinyl Chloride (PVC)	Polyester
Polystyrene (PS)	Polyuryurethane
Low density polyethelene (LDPE)	Urea – Formaldehyde
High density polyethylene (HDPE)	Alkyd

4. MATERIALS

Table 2 : Sources Of Waste Plastic Generations

Waste Plastics	Source
Polyethylene Teryphthalate (PET)	Drinking water bottles ... etc
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent ..biscuit, vapors packets, etc
Polyvinyl Chloride (PVC)	& Mineral water bottles, credit cards, toys, pipes gutters; electrical fittings, furniture, folders and pens, medical disposables ... etc
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps ,foamed polystyrene: food trays, egg boxes, disposable cups, protective packaging ... etc
Low density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining cosmetic & detergent bottles
High density Polyethylene (HDPE)	Carry bags, bottle caps, house hold, ... etc

5. DISCUSSION

5.1. Properties of Waste Materials – Bitumen Mixture.

Characteristics of Asphalt Concrete using Waste Materials as Modifier The results of these Marshall testing for waste materials as modifier on optimum bitumen content of 6% are illustrated . The figures show the relationship between modifier content and properties of mix such as stability, flow, Marshall quotient, density VMA and VIM. The effect of waste materials content as modifier on susceptibility of asphalt concrete using unmodified and modified bitumen to be attacked by water and loss of the cohesion between binder and aggregate were evaluated using the static immersion test.

Asphalt is used to construct flexible pavements by binding the aggregate together through coating the aggregates. In addition, the material promotes the strength as well as the life of the road pavement. However, due to its poor properties like resistance towards water, it is commonly improved by modifying its rheological properties by mixing with synthetic polymers such as rubber and plastics.

Since the use of waste plastic with asphalt is similar to using polymer modified asphalt, this experiment used waste plastic to evaluated performance of hot asphalt concrete based on fire, flash and softening points as well as penetration of Asphalt.

6. CONCLUSIONS

that waste plastic materials may be effectively used to modify asphalt for construction of flexible pavements. This may be achieved by mixing processed waste plastic of varying proportions by weight of asphalt to ensure substantial improvement in the Marshall stability, strength, and other related properties of the modified bituminous concrete in order to achieve longevity and better performance of pavement with minimal asphalt usage. The process is friendly to the environment. However, the study recommends further studies to ascertain the exact proportions of the mix that achieve the best modified bituminous concrete.

Based on the results of the experimental investigations conducted on normal and modified bitumen using waste materials in asphalt concrete mixes, the following summaries have been drawn:

1. Waste plastic more significantly influence on rheology of binder than fly ash.
2. Basically, the addition of waste materials in binder cause the Marshall stability increases.
3. The Marshall flow increases as waste materials content in binder increase and the optimum values of fly ash content is recommended at 4%.
4. The density of bitumen mixes prepared with using modified binder decrease as the waste materials content in bitumen increase.

5. Increasing waste materials content will increase void in mix value and the void in mix of bitumen mix prepared with waste plastic is higher than fly ash.
6. The VMA increases as the amount of waste materials in binder increases and the VMA value of mixes made with waste plastic in bitumen is higher than fly ash.
7. Waste materials used in binder can reduce the moisture susceptibility and recommended using fly ash content in binder at 4% and 1.5% for waste plastic.
8. In general the performance of bitumen mixes prepared using waste plastic and fly ash as modifier were better than origin bitumen mixes.

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