"Development of Sustainable Asphalt Pavement Mixture Using Polymers and Waste Engine Oil"

Abdelzaher E. A. Mostafa, Mohamed. S. Ouf and Mohamed M. Elkerdany

Abstract- Recycled asphalt is a particularly valuable material to the HMA industry, and its value will continue to increase as the cost of virgin aggregate and bitumen rise. In Egypt, there are many tons per year of recycled asphalt materials are not used. The objective of this project is to evaluate the potential for using RAP content mixes as a base layer on medium and high level traffic highways. An experimental investigation was carried out according to a programmer devised to compare various properties of mixes containing various proportions of RAP (0%, 15%, 20% and 25%) with traditional asphalt; the experiments were conducted by Marshall Tests. At this stage of the experimental study, a fatigue study conducted to compare the fatigue properties of recycled mixes with that of conventional mixes by Indirect Tensile Strength (IDT) and Wheel Tracking Test (WTT). The effect of additives, WEO, PP and SBR, was also studied. The additives were evaluated in five contents of WEO (0%, 3%, 5%, 7%, and 9%) of bitumen ratio. The addition of polymer materials has also been used (PP, SBR) were tested in percentages (0%, 2%, 4%, 6%) of bitumen with the same previous ratios of RAP. The Marshall Test results of mixes with 0%, 15%, 20% and 25% RAP are given Stability gradually increases with the increase in the amount of RAP in the recycled mixes. As regards Flow, there was little decrease between the flow values of the four different mixes. A laboratory investigation conducted has shown that recycled mixes perform consistently well in comparison with the corresponding conventional mixes which were used for control purposes and tend to be stiffer. Based on extensive laboratory evaluation of different Marshall Mixtures containing RAP concludes that the blending of virgin and RAP material overall improve the mixture properties. The indirect tensile strength results of mixes indicate that at the specified range of RAP, IDT gradually increases with the increase in the amount of RAP in the recycled mixes. Also the Wheel Tracking Test (WTT) specimens were prepared in the laboratory. It has been observed that there was decrease between the flow values of the four different mixes; it shows also that rut depth decrease with the increase in percentage of RAP.
The results from a laboratory study in which the influence of waste engine oil (WEO) on the performance of hot-mix asphalt (HMA) containing recycled asphalt pavement (RAP) was evaluated. The results from the research indicated that the incorporation of WEO into HMA with RAP offset the increase of stiffness caused by RAP. Marshall Stability and Flow value with different WEO contents, the stability decreases with increasing WEO content. There is an increase in flow due to reduced viscosity of bitumen due to addition of WEO and addition of WEO caused to decrease Rigidity contrary to what caused the RAP to increase. The addition of polymer materials (PP, SBR) observed that the Marshall Stability values increased and Flow values decreased in a noticeable manner. The Rigidity of these specimens was also increased.
Keywords: Recycled Asphalt pavements (RAP) - Waste Engine Oil (WEO) - Polypropylene (PP) - Styrene Butadiene Rubber (SBR)

1. Introduction and background

The evolution of road industry and the tremendous surge in number of vehicles on roads has been a rationale that has promoted exploiting all viable available resources to build better roads of prolonged service life. Incorporating unconventional construction material in the road construction commenced in the 70's where conventional raw materials such as bitumen began to scarce **(M. Tuncan, A. Cetin, 2003)**. The process of producing aggregates materials has been causing extreme disruption to the environment **(H. Akbulut & C. Gürer, 2007)** and to the economic owing to the severely depletion the natural resources **(A. Athanasopoulou & G. Kollaros, 2015)**. Furthermore, the alarming rate of increased waste production is what underpins the efforts to investigate the potential incorporation of various by-products in road construction **(S. Paranavithana & A. Mohajerani, 2006)**. The most dominant recycling materials that are in practice at present include plastic wastes, scrap tires, recycled concrete aggregates, recycled asphalt pavement, steel slag, waste engine oil ...etc. Much research has been conducted in these directions **(J. M. Reid, 2000)**. And still there are ongoing researches and field studies continue the investigation for better utilization of these recycled materials. Certain recycled material and waste by-products possess considerable salient properties over others and great benefits would be acquired when characterized properly and incorporated with some other construction materials **(S. W. Lee & K. L. Fishman, 1993)**.

The quality and price of asphalt use in the road industry has been another pile of advocating the quest for anther replacement. Shortfalls and scarcity of natural quality aggregates, heavy imposed traffic loads, and extreme environmental conditions have taken tolls on road paving industry **(C. Holbert, J. Drelich, 1997)**. Researches on existing recycling material were to valorize the utilization of recycled materials in road constructions and improve the long-term performance of asphalt pavement (**M. Pettinari & A. Simone, 2015)** any successful applications of recycled materials in road construction works oriented towards the efforts of achieving a sustainable pavement construction **(S. Saride, A. J. Puppala, 2010)**.

2. Recycled asphalt pavement

The characteristics of RAP vary from one source to another according to the type and properties of aggregates material, binder content and binder stiffness of the scraped asphalt. The concentration of RAP in the new asphalt mixture is considered pivotal factor influencing performance of HMA. The

Abdelzaher E. A. Mostafa is currently Professor, civil engineering in Helwan University, Cairo, Egypt, and E-mail: zaher292@yahoo.com
Mohamed. S. Ouf is currently Associate Professor, civil engineering in Helwan University, Cairo, Egypt, and E-mail: drmohamedouf@hotmail.com
Mohamed Elkerdany is currently pursuing Ph.D. degree program in civil engineering in Helwan University, Cairo, Egypt, and E-mail: mkerdany064@gmail.com

ISSN 2229-5518

widespread use of RAP in the pavements industry is proof that it is cheaper to produce. In the current study the Marshall method was used for the performance evaluation of asphalt mixtures containing various RAP ratios. The wearing course mixtures with 15%, 20% and 25% RAP content were made and compare the results with the control design (No RAP content).

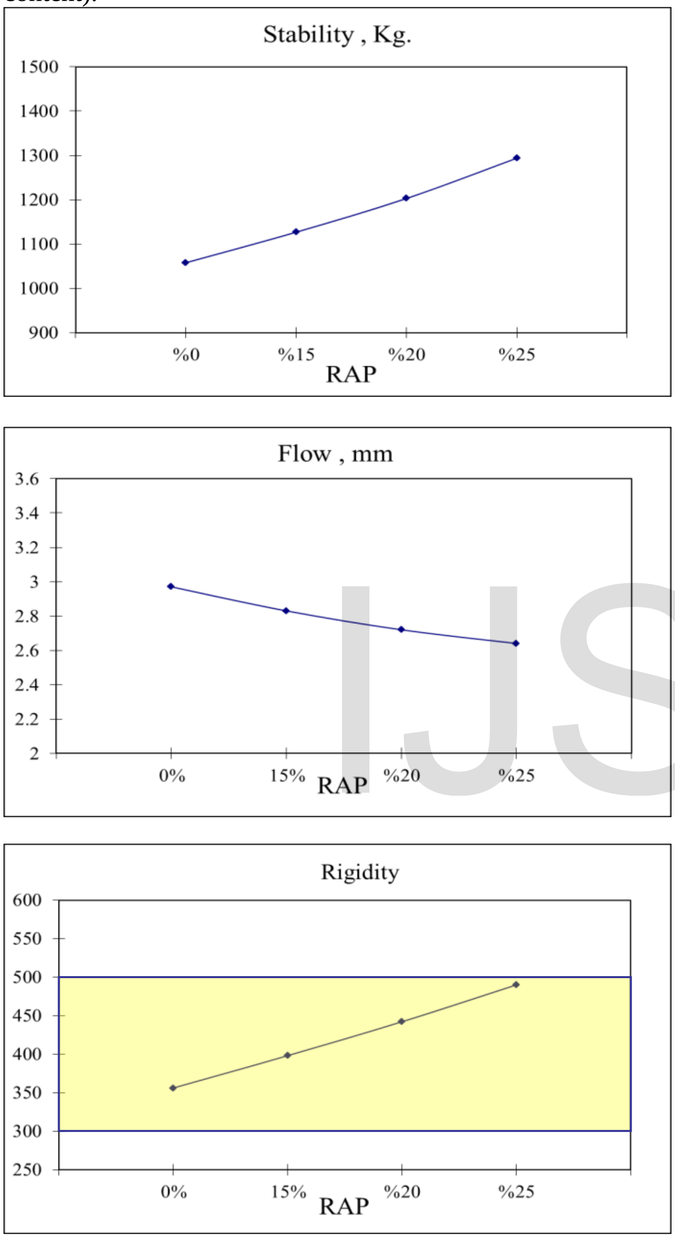

Figure (1) Marshall Stability, Flow and Rigidity

The purpose of this research was to design good wearing surface with high RAP content without compromising the performance. The quality of the virgin aggregates and also the quality of RAP material greatly affect the mixture volumetric properties. Figure (1) shows graphs of the Marshall Stability, Flow and Rigidity. The results shown in Figure indicate that at the specified range of binder contents, Marshall Stability gradually increases with the increase in the amount of RAP in the recycled mixes. In addition, the values of Marshall Stability of the mixes were acceptable according to the design criteria of the Engineering specifications. As regards Marshall Flow, there was little decrease between the flow values of the four different mixes. All the flow values were within the acceptable limits over most of the binder content range. The results shown in Figure (1) indicate that the mix stiffness represented by Marshall Quotient (MQ) tended to increase with the increase in the percentage of RAP and all inside the limits of rigidity according to specifications (LRAS).

3. Fatigue Properties of Recycled Mixes

Fatigue is a phenomenon by which the structure of a material is gradually weakened by repeated application of stresses lower than its ultimate stress. Fatigue distress has recently been recognized as an important factor in pavement performance. Although fatigue is complicated in bituminous mixes by viscoelasticity, heterogeneity, anisotropy and temperature susceptibility, much valuable knowledge has been gained through laboratory fatigue testing. However, little has been done on fatigue characteristics of recycled mixes. Fatigue life of asphalt pavements depends on the stiffness of the mix, content of bitumen, viscosity of bitumen, grading of aggregates, construction practice, traffic, and climate **(M. Saltan & F. S. Fındık, 2008)**.

At this stage of the experimental study, the results were promising, so that a fatigue study could be conducted to achieve several objectives:

(a) To compare the fatigue properties of recycled mixes with that of conventional mixes.

(b) To evaluate the long-term laboratory performance of recycled mixes.

(c) To examine the relative effectiveness of different categories of recycling agents on the fatigue properties of recycled mixes.

3.1 Testing for Indirect Tensile Strength

The tensile characteristics of bituminous mixtures are evaluated by loading the Marshall specimen along a diametric plane with a compressive load at a constant rate acting parallel to and along the vertical diametrical plane of the specimen through two opposite loading strips (Figure 2). This picture represents a cylindrical specimen is loaded diametrically across the circular cross section. The loading causes a tensile deformation perpendicular to the loading direction, which yields a tensile failure. By registering the ultimate load and by knowing the dimensions of the specimen, the indirect tensile strength of the material can be computed.

Fig. (2) Schematic of Indirect tensile test setup

The peak load is recorded and it is divided by appropriate geometrical factors to obtain the split tensile strength using the following equation:

St = 2000 P / π t D

St = IDT strength, kPa

P = maximum load, N

t = specimen height immediately before test, mm

D = specimen diameter, mm

Asphalt Content %	RAP 0%	RAP 15%	RAP 20%	RAP 25%
Indirect tensile strength (MPa)	0.767	0.798	0.881	0.932

Table (1) The indirect tensile strength results of mixes with 0%, 15%, 20% and 25% RAP
(MPa Pressure Conversion Factors 10.1972 kg/cm2)

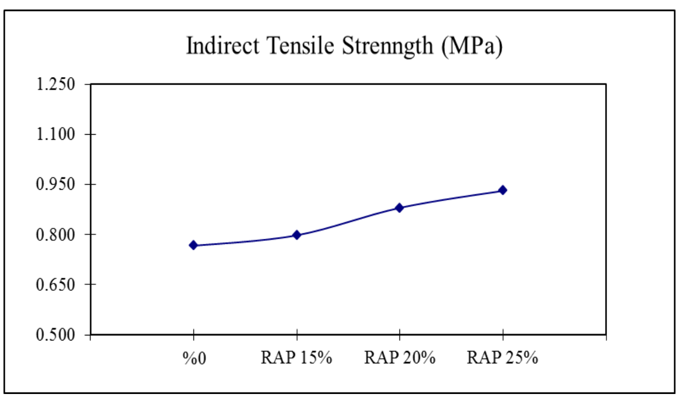

Fig. (3) Variation of IDT of HMA with RAP

The indirect tensile strength results of mixes with 0%, 15%, 20% and 25% RAP are given in Table 1; Figure 3 shows graphs of the Variation of IDT. The results shown in Figure indicate that at the specified range of RAP, IDT gradually increases with the increase in the amount of RAP in the recycled mixes. This behavior is because, the tensile strength is related primarily to a function of the binder properties, and its stiffness influences the tensile strength. Presence of RAP in the mixture makes it stiffer. The improvement in IDT would be due to absorption and adhesion of bitumen which improves the interface adhesion strength and recycled asphalt pavement. RAP can also be cause to fill the blanks, leading to increased stability, including increased IDT.

3.2 Mix Design Concepts and Rutting

Rutting refers to permanent deformation of the asphalt surface that accumulates in the wheel paths. It is primarily the result of repeated traffic loading cycles. Rutting may be accompanied by fatigue cracking and other distresses, making it a serious concern and potential indicator of pavement failure (Figure 4).

Figure (4) Rutting is apparent in the wheelpaths of this street

The stability of the asphalt mix is an important element in its ability to resist rutting and thus a key factor to evaluate. The wheel tracking test (WTT) is an important tool to define asphalt mixture rutting performance. The performance test has become a common way to evaluate asphalt mixture behavior and a tool to assist in the mixture design.

The wheel tracking test device of Materials laboratory, faculty of Engineering - Mattaria - Helwan University, was employed (Figure 5). WTT Test specimens were used for this test having dimensions 40 x 30 and a height 5 cm. (Figure 6)

Figure (5) The wheel tracking test device

Figure (6) The wheel tracking test specimen

In this study, a load of 700 Newton (N) was applied. Mixes were tested at temperature of 60 °C for a period of 10,000 cycles. Figure 7 shows the installation of the sample in the device and then close it and turn on the machine at 60 ° C. The wheel tracking device was placed in a chamber to allow maintaining the sample at the test temperatures required. Slab specimens of the control mix and the recycled mix with (0%, 15%, 20% and 25%) RAP was prepared.

Figure (7) Operation the wheel tracking test device

The table 2 illustrates the results of Wheel Track Test in terms of Rut Depth (mm) from different available RAP mixes. It has been observed from table 2 that there was decrease between the flow values of the four different mixes; it shows also that rut depth decrease with the increase in percentage of RAP. Rutting curves (figure 8) can be produced using the data exported from the WTT system to characterize the increase in the specimen's rut depth with the increase in the number of passes while running the test.

Cycles	1000	2000	3000	4000	5000
0%	-1.438	-1.682	-1.74	-1.81	-1.891
15%	-1.122	-1.356	-1.404	-1.499	-1.562
20%	-0.651	-0.865	-0.92	-1.018	-1.111
25%	-0.291	-0.525	-0.629	-0.669	-0.762
Cycles	6000	7000	8000	9000	10000
0%	-2.01	-2.094	-2.137	-2.158	-2.179
15%	-1.691	-1.758	-1.821	-1.837	-1.863
20%	-1.242	-1.307	-1.35	-1.359	-1.392
25%	-0.853	-0.956	-0.988	-0.999	-1.018

Table (2) The results of Wheel Track Test

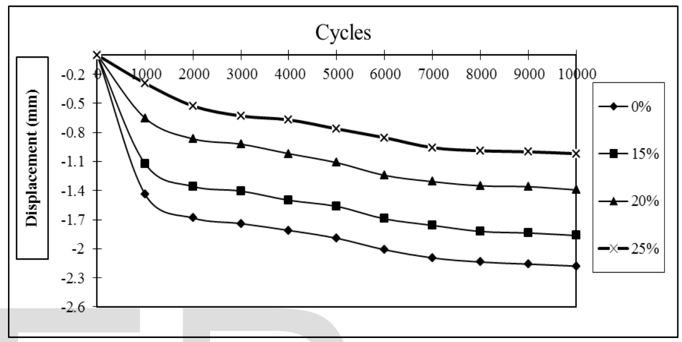

Figure (8) A comparisons of wheel track test results for lab-compacted specimens

4. The Effect of Additives Materials on RAP

The process of producing aggregates materials has been causing extreme disruption to the environment and to the economic owing to the severely depletion the natural resources. Furthermore, the alarming rate of increased waste production is what underpins the efforts to investigate the potential incorporation of various by-products in road construction **(S. Paranavithana & A. Mohajerani, 2006)**. Incorporating unconventional construction material in the road construction commenced in the 80's where conventional raw materials such as bitumen, crushed aggregates, and unbound aggregates mixtures began to scarce **(M. Tuncan, A. Tuncan, & A. Cetin, 2003)**.

Recycling materials have been reported to be utilized in different composition in different layers of road structure from the top surfacing layer to the underneath layers. The processing cost, the engineering properties, the evidence that demonstrate the viability of the material and its positive impact on the long-term performance of the road construction works are what characterizes and favors the use of that specific recycled waste material **(A. El-Assaly & R. Ellis, 2001)**. It is of the essence to properly understand the behavior of any recycled by-products, and investigate the influence on the proposed inclusion with a construction material in order to come with a suitable and viable utilization with regards to type of material and the employed dosage **(A. Athanasopoulou & G. Kollaros, 2015)**. Researches on existing recycling material were to valorize the utilization of recycled materials in road constructions and improve the long-term performance of asphalt pavement and any successful applications of recycled materials in road construction works oriented towards the efforts of achieving a sustainable pavement construction **(S. Saride, A. J. Puppala, 2010)**. The most dominant recycling materials that are in practice at present include plastic wastes; scrap tires, steel slag.....etc. Much research has been conducted in these directions.

And still there are ongoing researches and field studies continue the investigation for better utilization of these recycled materials **(J. M. Reid, 2000)**.

4.1 Polymers Additives

The term polymer is commonly used today in the plastics and composites industry, and it is often used to imply the meaning of "plastic" or "resin". Rubberized asphalt concrete (RAC), also known as asphalt rubber or just rubberized asphalt, is noise reducing pavement material that consists of regular asphalt concrete mixed with crumb rubber made from recycled tires. Since then it has garnered interest for its ability to reduce road noise **(Jerzy A. Ejsmont, 2016)**. In actuality, the term polymer means much more. Polymers range from familiar synthetic plastics such as polystyrene to natural biopolymers such as DNA and proteins that are fundamental to biological structure and function. Polymers, both natural and synthetic, are created via polymerization of many small molecules, known as monomers. Their consequently large molecular mass relative to small molecule compounds produces unique physical properties, including toughness, viscoelasticity, and a tendency to form glasses and semi crystalline structures rather than crystals **(Painter, Paul C. Coleman, Michael M. ,1997)**.

The aim of the research is to demonstrate new environmentally friendly asphalt mixes using polymer waste. By providing an avenue for its reuse, the research seeks to reduce environmental problems associated with polymer waste. The research will work with two types of polymeric waste: polypropylene (PP) and styrene butadiene rubber (SBR). It will create several asphalt mixes, modified with recycled polymeric waste at laboratory scale. Testing and evaluation of these new mixes will be carried out to characterize the performance changes associated with different mixers and polymer additions.

4.1.1 Polypropylene (PP)

Polypropylene ,also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles , laboratory equipment and polymer banknotes **(Todd Johnson, 2010)** (Figure 11). Polypropylene is the world's second-most widely produced synthetic plastic, after polyethylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. Polypropylene was first polymerized in 1951. By 1957, its popularity had exploded and widespread commercial production began across the world. Advantage of Polypropylene is that it can be easily copolymerized (essentially combined into a composite plastic) with other polymers like polyethylene. Copolymerization changes the material properties significantly, allowing for more robust engineering applications than are possible with pure polypropylene more of a commodity plastic on its own **(Creative Mechanisms Staff, 2016)**.

To assess the relative performance of mixes recycled with different agents, several tests have been employed. The Marshall test was used to design the recycled mixes and to assess the extent of the increase or decrease of the factors of stability and flow. In this research, asphalt specimens with polypropylene were manufactured at the optimum bitumen content with different ratios of RAP.

Figure (11) Polypropylene (PP)

It was observed for PP-reinforced specimens that the Marshall Stability values increased and Flow values decreased in a noticeable manner. The Rigidity of these specimens was also increased. The improvement of the properties of asphalt shows the positive effect of polypropylene. The PP-reinforced asphalt mixture exhibits good resistance to rutting, prolonged fatigue life and less reflection cracking. Of the results of tests with different percentages of PP (2%, 4%, 6%) (Figure 12), it is evident that the presence of PP in the HMA with RAP mixtures effectively improves the stability values, which will result in an improvement of mixture toughness. This result indicates that the mixture using PP would result in higher performance than using the control mixture. Variation of Marshall Stability and Flow value with different PP contents are given in Figure 12.a indicates that the stability of PP stabilized mixtures increases and decrease with flow (Figure 12.b). Figure 12.c at Rigidity curves represents the effect of RAP and PP content on the limits of rigidity according to specifications value of the HMA mixtures. The Figure indicates that as the additive content increases, the Rigidity value increases initially, reaches a maximum at 6% PP. Figure shows that polypropylene with natural asphalt mixer reaches up to the limits of rigidity according to specifications (LRAS) at 6% of its addition. At the same limits, PP reaches up to 4.3% with 15% RAP and 2.1% with 20%RAP. All another percentages of 25% RAP occurred outside the limits.

These results mean that PP caused an increase in the usual stability and also decreased in the flow, which led to an increase in rigidity. The addition rate of 20% RAP did not exceed within LRAS with 2.1% of PP.

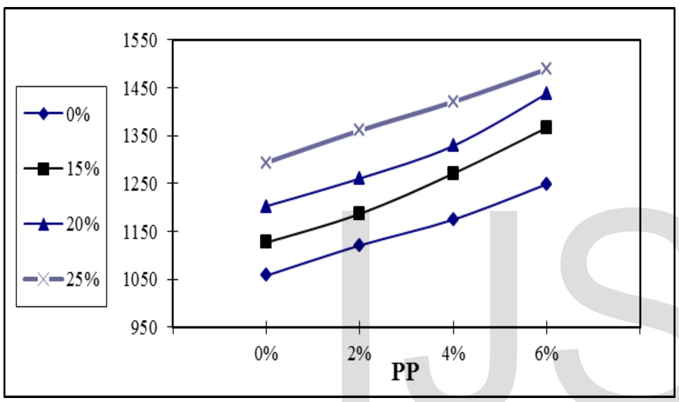

Figure 12.a Stability, Kg.

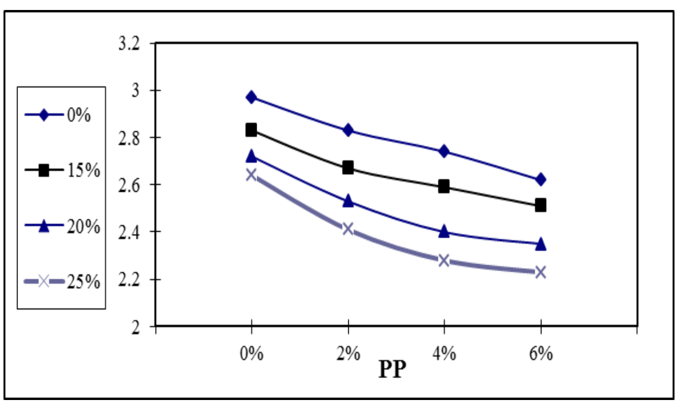

Figure 12.b Flow, mm

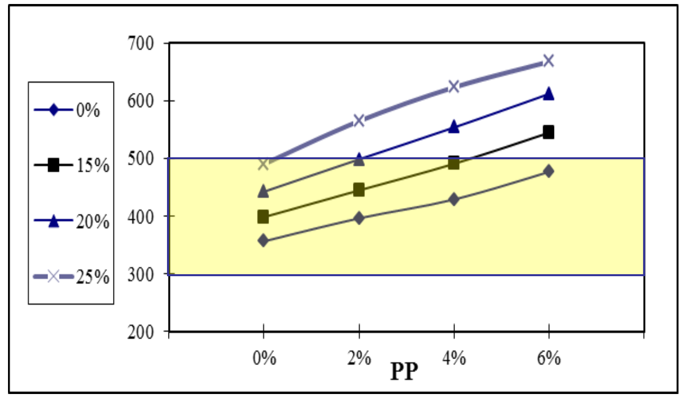

Figure 12.c Rigidity

Figure (12) Stability, Flow and Rigidity for PP

4.1.2 Styrene Butadiene Rubber (SBR)

Today's increasing loads, greater traffic volume and the need for better, longer-lasting roads demand better service from paving materials. Asphalts modified with SBR offer the best method of improving binders for highway, street and airport paving and maintenance projects. A dose of SBR modifier added to asphalt can improve asphalt's performance in stability, permanence, viscosity, and resistance to aging. Better application performances of asphalt pavement are affected directly by proper SBR modifying. SBR was created specifically for modifying asphalt binders; SBR easily blends with the asphalt to form a homogenous reinforced composite **(Ultrapave® SBR Latex Polymers)**. SBR contain emulsion polymerized random copolymers of styrene and butadiene in a water-based system. In latex form, the SBR particles are extremely small (averaging 0.5 microns). As a result, the physical dispersion of the polymer particles is rapid and thorough **(Butonal® SBR polymers)** (Figure 13). The base polymer is also available in various molecular weights for improved asphalt compatibility if needed. Airport authorities noted that the use of SBR allowed more binder in the mixture, thus increasing durability. It was also noted that successful porous friction courses were attained with SBR **(J. Zhang, J. Wang, Y. Wu, 2009)**.

In this paper the effect of SBR that is one of the bitumen polymer modifiers on properties of bitumen is studied. In this regard, the rheological properties of base bitumen and the modified bitumen with 0, 2, 4, and 6 percent of SBR were analyzed with different percentages of RAP.

ISSN 2229-5518

Figure (13) Styrene Butadiene Rubber (SBR)

Figure 14.a illustrates the relationship between Marshall Stability and SBR content. It is obvious that there is SBR content which achieves maximum Marshall Stability, and this value is 6% with 25% RAP. The higher stability value was obtained with mixes modified with 6% SBR, this is because the addition of SBR to the asphalt binder increased its stiffness and reduced its viscous. Figure 14.b shows that there is a decrease in the values of Marshall Flow as the percentage of the SBR content is increased. This is may be due to the stiff nature of SBR comparing to the natural asphalt. Figure 14.c shows the Marshall Rigidity with optimum asphalt content for four percentages of SBR.

It is seen from this figure that the Marshall Rigidity increases when the SBR are increased. This is can be attributed to the increases in Marshall Stability and the decrease in Marshall Flow. Figure shows that SBR with natural asphalt mixer reaches up to LRAS at 4.1% of its addition. At the same limits, SBR reaches up to 2.5% with 15% RAP and 1.3% with 20% RAP. All another percentages occurred outside the limits. This is why polymer and traditional asphalt are used in many ways to increase durability.

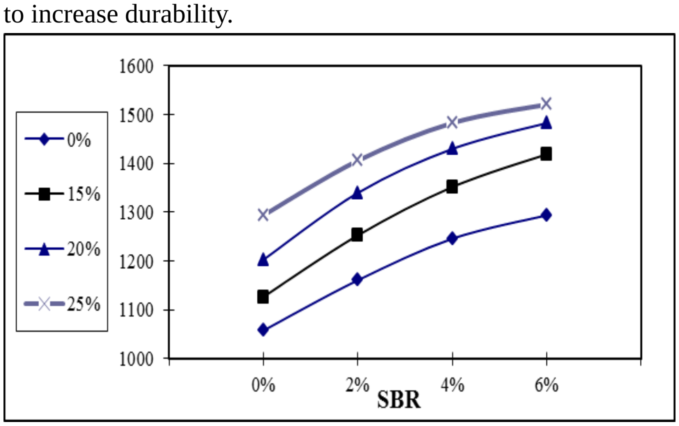

Figure 14.a Stability, Kg.

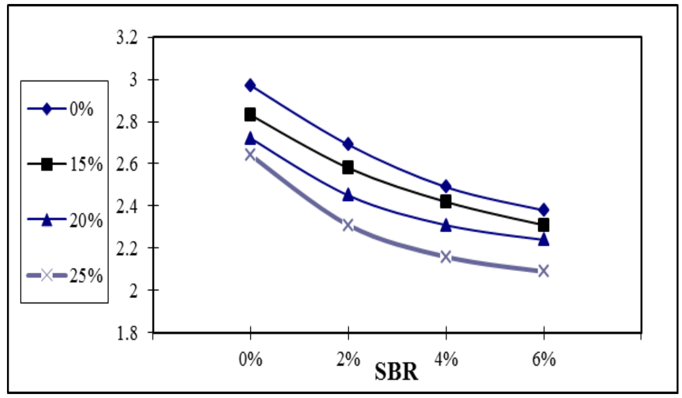

Figure 14.b Flow, mm

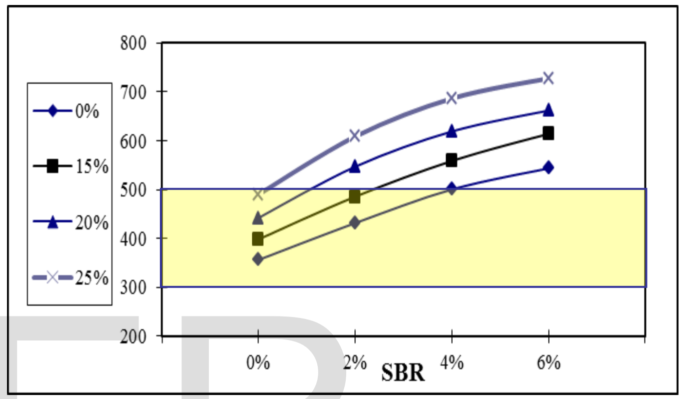

Figure 14.c Rigidity

Figure 14 Stability, Flow and Rigidity for SBR

4.2 RAP Blended with Waste Engine Oil

With a large volume of traffic, two key waste products are generated: engine oil and asphalt pavement material. Although the use of RAP is greatly documented, the use of RAP without modification is known to produce an overall stiffer blend. With the addition of waste engine oil (WEO), this increased stiffness can be offset in order to produce a pavement with consistent performance.

The primary objective of this research is to combine two waste streams (RAP and WEO) into one viable product. By characterizing the properties of RAP that has been blended with WEO, a proof of concept can be established as to the feasibility of WEO as a recycling agent **(Chen, J. S., P. Y. Chu, 2007)**. A comprehensive experimental program is designed to achieve this objective. WEO may supplement the missing soft components for aged binder, and act like a rejuvenating agent. From this perspective, the use of WEO may potentially improve the performance of asphalt mixtures containing RAP. This research presents the results from a laboratory study in which the influence of waste engine oil on the performance of hot-mix asphalt (HMA) containing recycled asphalt pavement (RAP) was evaluated.

For binder test, the extracted RAP binder was blended with virgin binder and WEO (Figure 9). The WEO was collected from a local auto repair shop.

For mixture test, the HMA containing RAP was evaluated at four RAP contents (0%, 15%, 20% and 25%) and five waste oil contents (0%, 3%, 5%, 7% and 9%). The results from the research reported in this paper indicated that the incorporation of WEO into HMA with RAP may offset the increase of stiffness caused by aged binder in RAP. The inclusion of waste engine oil decreased optimum asphalt content. The widespread use of RAP in the pavements industry is proof that it is cheaper to produce, but often the environment takes a backseat to the bottom line of cost savings.

Figure (9) Waste Engine Oil (WEO)

From the master curves (Figure 10), a combined effect of RAP and waste engine oil on rigidity was observed. There seemed to be a balance between the increase in rigidity from the RAP and decrease in rigidity from the waste engine oil.

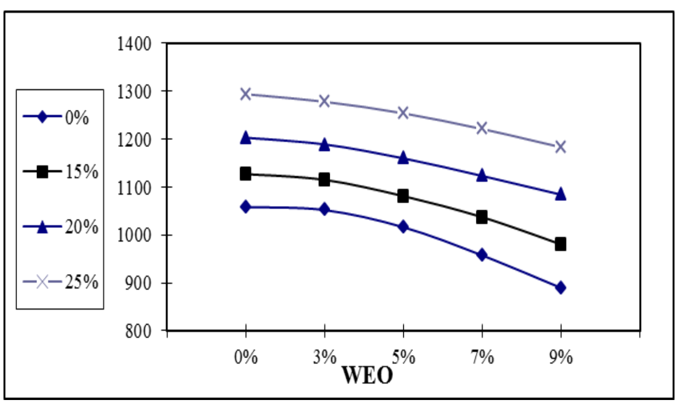

Figure 10.a Stability, Kg.

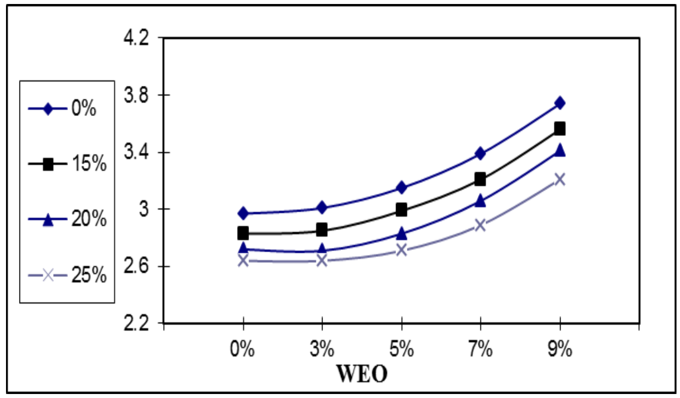

Figure 10.b Flow, mm

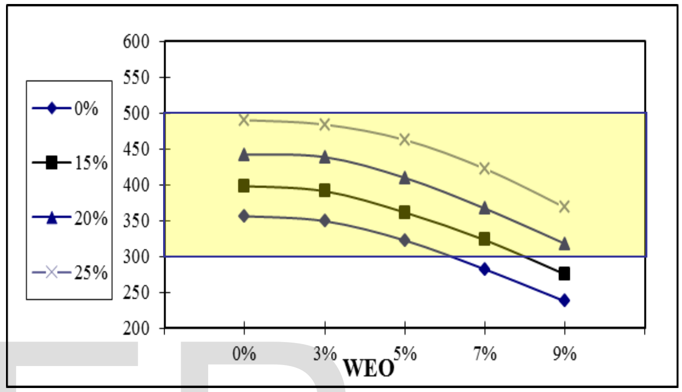

Figure 10.c Rigidity

Figure (10) Stability, Flow and Rigidity for WEO

Variation of Marshall Stability and Flow value with different WEO contents are given in Figure 10.a indicates that the stability of WEO stabilized mixtures very little increase initially up to 3% and then decreases with increasing WEO content.

In Figure 10.b, there is an increase in flow due to reduced viscosity of bitumen due to addition of WEO. Figure 10.c shows that the addition of WEO caused the entry of all Rigidity curves in the limits except some of the 20% & 25% of RAP; this means addition of WEO caused to decrease stiffness contrary to what caused the RAP to increase.

5. Conclusions

Based on the laboratory test results, the following conclusions were drawn:

1. The Marshall Test results of mixes with 0%, 15%, 20% and 25% RAP are given Stability gradually increases with the increase in the amount of RAP in the recycled mixes. As regards Flow, there was little decrease between the flow values of the four different mixes. All the Stability and Flow values were within the acceptable limits over most of the binder content range. A laboratory investigation conducted has shown that recycled mixes perform consistently well in comparison with the corresponding conventional mixes which were used for control purposes and tend to be stiffer.

Based on extensive laboratory evaluation of different Marshall Mixtures containing RAP concludes that the blending of virgin and RAP material overall improve the mixture properties.

2. The indirect tensile strength results of mixes with 0%, 15%, 20% and 25% RAP indicate that at the specified range of RAP, IDT gradually increases with the increase in the amount of RAP in the recycled mixes. The improvement in IDT would be due to absorption and adhesion of bitumen which improves the interface adhesion strength and recycled asphalt pavement. RAP can also be cause to fill the blanks, leading to increased stability, including increased IDT; Recycled mixes are slightly more resistant to compaction.
3. The Wheel Tracking Test (WTT) specimens were prepared in the laboratory. In this study, a load of 700 Newton (N) was applied. Mixes were tested at temperature of 60 °C for a period of 10,000 cycles. It has been observed that there was decrease between the flow values of the four different mixes; it shows also that rut depth decrease with the increase in percentage of RAP.
4. The results from a laboratory study in which the influence of waste engine oil (WEO) on the performance of hot-mix asphalt (HMA) containing recycled asphalt pavement (RAP) was evaluated. The results from the research indicated that the incorporation of WEO into HMA with RAP offset the increase of stiffness caused by RAP. Marshall Stability and Flow value with different WEO contents, the stability decreases with increasing WEO content. There is an increase in flow due to reduced viscosity of bitumen due to addition of WEO and addition of WEO caused to decrease Rigidity contrary to what caused the RAP to increase.
5. The addition of polymer materials (PP, SBR) observed that the Marshall Stability values increased and Flow values decreased in a noticeable manner. The Rigidity of these specimens was also increased.
6. Recycling is used not only for asphalt but also for Waste Engine Oil.
7. As the basis of the environmentally analysis in these days, and any waste that is thrown into landfills will remain there, taking up space forever. It's much more environmentally responsible to choose a material that minimizes waste by repurposing old asphalt.

6. References

[1] A. Athanasopoulou & G. Kollaros, "Fly ash exploited in pavement layers in environmentally friendly ways," Toxicological & Environmental Chemistry, vol. 97, no. 1, pp. 43-50, 2015.

[2] A. El-Assaly & R. Ellis, "Evaluation of recycling waste materials and by-products in highway construction," The International Journal of Sustainable Development & World Ecology, vol. 8, no. 4, pp. 299-308, 2001.

[3] Butonal® SBR polymers for pavement preservation Microsurfacing. Pavement preservation - the systematic scheduling of nonstructural maintenance http :// www 2. basf . us /AcrylicsDispersions/asphalt/index.htm.

[4] C. Holbert, J. Drelich, W. Zmierczak, & J. D. Miller, "Viscosity of bitumen-crumb rubber blend (new paving material)," Petroleum science and technology, vol. 15, no. 5-6, pp. 523-543, 1997.

[5] Chen, J. S., P. Y. Chu, et al. (2007). "Characterization of binder and mix properties to detect reclaimed asphalt pavement content in bituminous mixtures." Canadian Journal of Civil Engineering 34(5):581-588.

[6] Creative Mechanisms Staff Blog Everything You Need To Know About Polypropylene (PP) Plastic, On May 4, 2016, https: //www. Creative mechanisms. Com /blog /all-about-polypropylene-pp-plastic.

[7] H. Akbulut & C. Gürer, "Use of aggregates produced from marble quarry waste in asphalt pavements," Building and Environment, vol. 42, no. 5, pp. 1921-1930, 2007.

[8] Jerzy A. Ejsmont (2016) "What is Rubberized Asphalt?Arizona Department of Transportation".

[9] J. M. Reid, "The use of alternative materials in road construction," in International Symposium on Unbound Aggregates in Roads–UNBAR, 2000, vol. 5.

[10] J. Zhang, J. Wang, Y. Wu, Y. Wang and Y. Wang, "Evaluation of the improved properties of SBR/weathered coal modified bitumen containing carbon black," Construction and Building Materials, vol. 23, no. 7, pp. 2678-2687, 2009.

[11]M. Pettinari & A. Simone, "Effect of crumb rubber gradation on a rubberized cold recycled mixture for road pavements," Materials & Design, vol. 85, pp. 598-606, 2015.

[12]M. Saltan & F. S. Fındık, "Stabilization of subbase layer materials with waste pumice in flexible pavement," Building and Environment, vol. 43, no. 4, pp. 415-421, 2008.

[13] M. Tuncan, A. Tuncan, & A. Cetin, "The use of waste materials in asphalt concrete mixtures," Waste management & research, vol. 21, no. 2, pp. 83-92, 2003.

[14] Painter, Paul C.; Coleman, Michael M. (1997). Fundamentals of polymer science: an introductory text. Lancaster, Pa.: Technomic Pub. Co. p.1. ISBN 1-56676-559-5.

[15] S. Paranavithana & A. Mohajerani, "Effects of recycled concrete aggregates on properties of asphalt concrete," Resources, Conservation and Recycling, vol. 48, no. 1, pp. 1-12, 2006.

[16] S. Saride, A. J. Puppala, & R. Williammee, "Civil Engineers Ground Improvement 163 February 2010 Issue GI1," sta, vol. 717, no. 715, 2010.

[17] S. W. Lee & K. L. Fishman, "Waste products as highway materials in flexible pavement system," Journal of transportation engineering, vol. 119, no. 3, pp. 433-449, 1993.

[18]Todd Johnson, 2010, "The term polymer" ,https :// www . thoughtco .com /what-is-a-polymer-820536.

[19] Ultrapave® SBR Latex Polymers for Asphalt Modification. http: //www. ultrapave.com/products/sbr-latex-polymers.