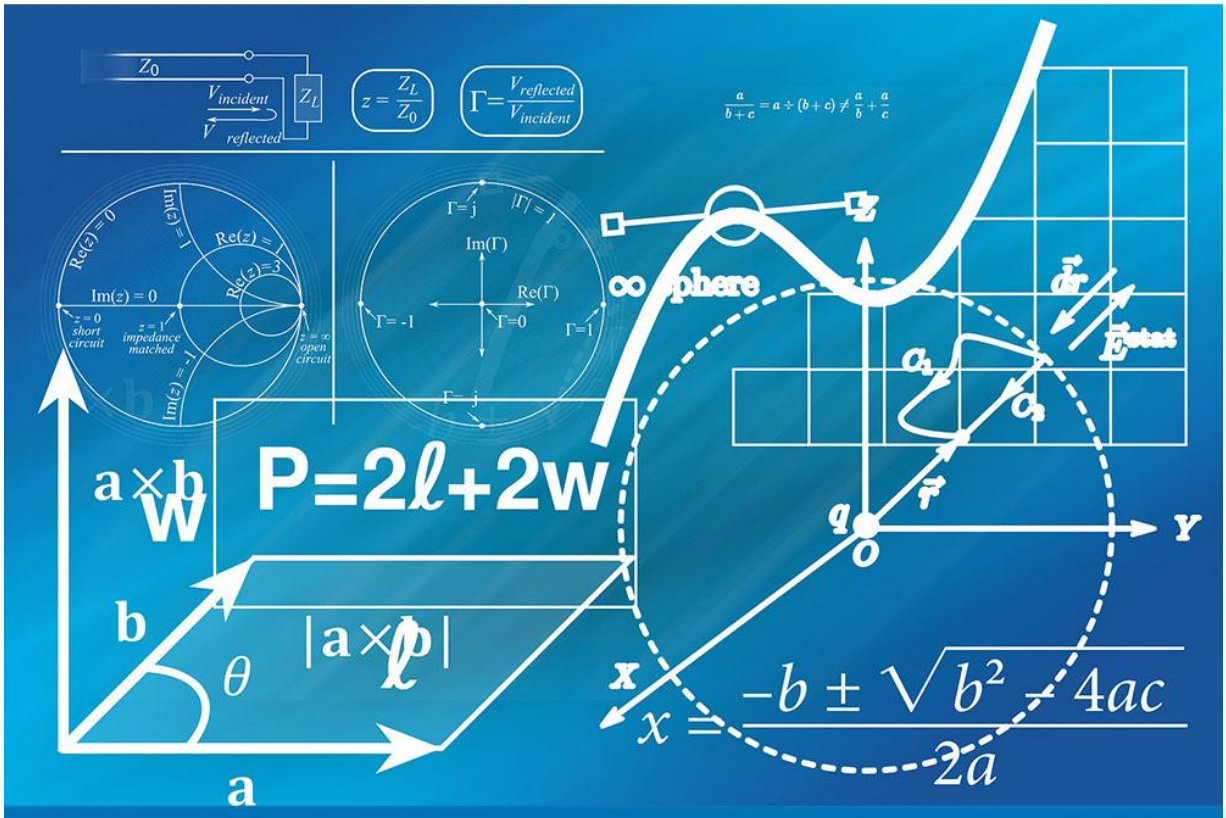
INTERNATIONAL STANDARD SERIAL NUMBER
ISSN-2349-0772

IJOSTHE



Volume 6, Issue 2, April 2019

"Formulation of Modified Bituminous Macadam with Different Grades of Plastic Waste: A Review"

Vaibhav Srivastava[1], Akhil Nema[2], Pravin Kumar Kushwaha[3]
P.G. Scholar[1], Asst. Prof.[2], Asst. Prof[3]
Department of Civil Engineering, OIST, Bhopal

Abstract: Road construction is associated with high investments. An exact design configuration can save a lot of speculation to get reliable road performance without taking advantage of it. Two elements are important in the structure of the adaptable road, the road structure and the contour. The accessibility of plastic waste is huge today. The use of recycled waste, Plastics, such as packaging for transporters, containers, etc., are growing. About half of 60% of the plastic aggregate is used for pressing. Once used, plastics are discarded and left as waste. Plastic contaminants are solid and not biodegradable. In this study we are review the past researches and techniques developed by the researchers in utilization of waste product especially plastic waste in bitumen.

Keywords: Plastic, Waste, Bitumen, Review, Utilization, Techniques, Pavement, Stability.

I. INTRODUCTION

The use of polyethylene in road development is not new. Some sums are very hydrophile (water lovers). Just like the bitumen is made of polyethylene (hate water) in nature. Therefore, the expansion of the hydrophobic polymers by wet or dry mixing techniques with the black mixture causes an immediate variation of the water resistance of the mixture. The polyethylene is mixed with hot bitumen and the mixture is applied like a normal asphalt road. Plastic streets mainly use plastic bags, expandable containers, polyethylene packaging and PET jars recovered from waste as essential components of the treatment material. The alteration of polymers can be considered one of the solutions to live in weakness, which reduces the cracks due to the rumble and heat of the plaster. The production of a customized bituminous mixture using recycled polymers (for example, polyethylene) which improve the properties of the HMA mixtures would result in a harder flooring and would also be an advantageous process for the transfer of many recycled plastics. The accessibility of plastic waste is huge today. The use of plastic, such as the transport of bags, containers, etc., is constantly increasing. About half of 60% of the plastic aggregate is used for pressing. Once used, plastics are discarded and left as waste. Plastic contaminants are robust and non-biodegradable. The shameful transmission of plastic can lead to diseases of the breast, conceptual problems in humans and in living things, genital deviations from the norm and much more. These plastic protectors are mixed with water, disintegrate and take on the types of small beds that cause the death of fish and other marine species they use as food material. In some cases, they are stuffed or burned. Plastic polluters get confused with civil waste or are thrown to the ground. All the methods listed above are not environmentally friendly because they contaminate soil, air and water. Under these conditions, the optional use of these plastic protectors is required. Therefore, any technique that can use this plastic waste for development purposes is constantly invited.

a review of the literature on HMA and waste recycling technology. It will examine the different technologies currently used in the industry to obtain stable and binding properties for an ideal blend of bitumen. The literature review also examines current industry practices for manufacturing and testing polyethylene for the construction industry and current issues related to field performance, as well as design methods for blends used in the industry.

II. LITERATURE REVIEW

Reinke and Glidden et al. (2002) attempted to neutralize HMA mixtures using DSR (Frem Friction) slip and recovery tests and found that the result shows improved durability when the polymer propagates.

Mohammad T et al. (2007) Checks that the development of road development over the last two decades, combined with a lack of maintenance in terms of inadequacy for future use, has led to a sharp and infinite degradation of roads in Jordan. To facilitate this technique, a series of measures can be successful, for example: ensuring maintenance interruptions, improving road alignment, using better material properties and using all the broadest development methods. The use of polymers in the darkness as a modifier began in the eighties of the last century

and was attempted in several countries of the world. In this study, polyethylene is used as a type of polymer to study perspectives to improve the best properties of the dark mixture. The objectives also consolidate the selection of the best type of polyethylene used and its grade. Two types of polyethylene were added to coat the aggregate [high density polyethylene (HDPE) and low density polyethylene (LDPE)]. The polymers were familiar with the mixture in two states (soil and not). The preparation of the Marshall mixture was used to select the perfect bitumen blocking agent first and then further test the modified properties of the mixture. In and out, 105 cases were prepared (21 tests were used to select the content of the cover and the other cases were used to study the effects of the darker mixture modification). The darker substance was 5.4%. Efforts have been made to obtain seven types of polyethylene of all types and their weight in terms of perfect coverage content (6, 8, 10, 12, 14, 16 and 18%). The tests confirm the confirmation of the thickness of mass, quality and flow. The Marshall Mix scheme requires confirmation of the air and air pore rates of mineral aggregates. The results showed that the granulated HDPE polyethylene modifier provides better planning properties. The recommended modifier level is 12% by weight of the bitumen content. It was found that reliability is established, that the thickness is reduced and that the air and the cavities of the minerals have increased imperceptibly.

Awwad and Shbeebyear et al. (2007) showed that the modified mixture had a higher strength and that the VMA content contrasted with the unparalleled mixtures and had a significant impact on the frictional strength of these mixtures in this direction. By modifying the black mixture on HDPE polyethylene, the properties of their properties are much better than those of LDPE polyethylene.

Fernandez et al. (2008) examined the geometric evaluation of black closures modified with a polymer with a styrene-butadiene-styrene thermoplastic elastomer (SBS) and analyzed modified folio properties developing shale oil and fragrant oil to improve perfectly. The rheological properties of PMB-SBS were examined in a dynamic remoter (DSR) and morphology was determined by fluorescence microscopy. The results showed that candy and shale oils influenced the microstructure, the quality of the accumulation and the adaptive viscosity of the PMB. In this way, shale oil could be used as compatibilizer without loss of ownership or even replace the sweet oil.

Sabina et al. (2009) studied the performance of mixtures of modified plastic / polymer asphalt and discovered that bituminous mixtures the delayed effects of the robustness and sustainability of balanced polythene are 1.21 and 1.18 times higher than standard mixtures 8 and 15% (by weight) use polyethylene bitumens to test the introduction of 60/70 bitumen. However, a balanced mixture of 15% polyethylene showed little reduced properties of Marshall stability compared to the 8% modifier mixture.

Yousefiyear et al. (2009) reported that polyethylene particles do not tend to break into asphalt and that these particles should combine to form larger particles because between the surfaces and between the molecular forces of attraction and main tempering in the regulation process, the presence of particles formed using segments of liquid bitumen. According to the author, at each point, the particles had enough vitality to move together and hit the bitumen residual thin film that isolated particles, beat the combination of polyethylene occurred particles and caused the polymer scale division.

Bindu and Beenayear et al. (2010) examined how to use plastic waste as a balanced substance in stone-based asphalt when the mixtures were subjected to performance tests, including stability, elasticity and print quality testing. and Tri-Pivot test. It turns out that adaptive coatings with superior and strong resistance can be purchased with 10% of destroyed plastic.

Albasheeret. et al. (2011) HMA or Black-Top Solid Gesso are the bound layers of the adaptable asphalt structure. It is a blend of black and total mineral top cover. The black closure has the shape of a black blend or a custom black cement. It is a paste that holds all the particles together to form a thick, water-resistant mixture.

Gawande et al. (2012) provided a diagram of the use of plastic waste on the asphalt road using the wet and dry technique. They said that the use of modified bitumen with the expansion of recycled plastic waste from about 5 to 10% by weight of bitumen improves the durability and performance of the floor, which shows the use of asphalt in the suburbs and the use of plastic waste in the bitumen strip Roads and buried materials also help to absorb a large amount of plastic waste. In this way, these procedures are extremely important socially and provide a better basis.

Khan and Gundaliyayear et al. (2012) have suggested that the polyethylene yarn bitumen installation process improves protection against cracking, caving and furrows by lengthening the softening point, the hardness and reduction of friction due to water, thus increasing the overall performance of the roads for a longer period. The period has improved. As indicated by them, the polyethylene waste used in the mixture forms molds that cover the entire mixture, which reduces porosity, equalizes moisture absorption and improves sealing properties.

Rohith N., J. Ranjitha et al. (2013) Here, the author sought to compare the properties of the WMA Marshall product with chemical dependencies "ZycoTherm" and HMA for dense bituminous Macadam (DBM), level 2. The mixing temperatures used for HMA were 155 ° C, 130 ° C and 115 ° C and the mixing temperatures for WMA were 130 ° C and 115 ° C with an additive dosage of 0.1% by weight of the binder. The optimal content of the binder must be determined individually for mixing for different mixing temperatures and additive dosing. The laboratory study concluded that the addition of the additive improved the stability and Marshall properties of the WMA mixture. The present study includes the preparation and testing of laboratory samples for the Marshall test of the HMA mixture at 155 ° C, 130 ° C and 115 ° C and a WMA mixture at 130 ° C and 115 ° C with a dosage rate additional 0, 1% binder according to the required specifications.

The Marshall stability value of the HMA samples prepared at 155 ° C has good stability values. Compared to HMA samples, the stability and Marshall properties of WMA samples prepared at 130 ° C and 115 ° C were improved by adding Zycotherm to an additive dosage of 0.1% by weight of the binder. . It was found that the optimal binder content for the HMA mixture at 155 ° C was 5.4% and the WMA mixture at 130 ° C with 0.1% of ZycoTherm was 5.37%. This concludes that the optimal binder content for the mixture of HMA and WMA varies with the temperature and the dosing rate of the additive. Therefore, for HMA and WMA mixtures, the OBC must be determined individually for different temperatures and additional doses.

Mutiu Akinpelu1 et al. (2013) In this regard, the author noted that a steady increase in the number of vehicles not satisfied due to lack of funds led to an accelerated and continuous deterioration of the road network in Nigeria. Therefore, the author has studied the effect of polyethylene in pure bags in asphalt properties. Polyethylene was added to the ground state as a binder modifier. It was incorporated into the mix by dissolving it in the bitumen used to prepare the asphalt. The Marshall Mix design method was used to first determine the optimal bituminous binder content and then test the properties of the modified mixture. A total of 17 samples were prepared (10 samples were used to determine the binder content and the remaining samples were used to investigate the effect of changing asphalt mixtures). The optimal asphalt content was 7.0%. Six parts by weight of polyethylene having the optimum binder content for the test were selected (2.5, 5.0, 7.5, 10, 12.5 and 15%). The tested properties include apparent density, stability and fluidity of the concrete mixture. The optimal proportion of the obtained modifier is 12.5% by weight of the optimal bitumen content. It has been found to increase stability, reduce density and slightly reduce the bitumen sample flow. The authors of the experiment concluded that the apparent density of the modified polyethylene sample increases with the increase in the percentage of polyethylene and reaches its maximum with a polyethylene content of 10%, and therefore decreases. The flow rate of the modified bituminous concrete decreases with the increase of the polyethylene content and the values are lower than those of the control for all the percentages of polythene. The Marshall stability of the modified asphalt is generally higher than that of the control, reaching its maximum value around 12.5% of polyethylene.

This shows an approximately 100% increase in stability compared to control. Improving the stability of the modified polyethylene asphalt by increasing the adhesive and cohesive properties of the binder improves fatigue resistance, reduces thermal stress cracks and reduces temperature sensitivity and cracking.

Liliana M.B. Costa et al. (2013) With the expansion of road traffic, sidewalks are increasingly in demand, and in this sense the basic and useful execution of sidewalks should be promoted. One technique that can significantly improve the nature of adaptable tablets is to extend polymers to bitumen or black screed mixtures. Although the substitution of bitumen with pure polymers can improve the properties of mixtures with a black background, the use of recycled plastics can give comparable results in particularly natural and favorable circumstances. This work should evaluate possible preferences for bitumen substitution with various plastic projections, including polyethylene (high density HDPE and low thickness LDPE), ethylene-vinylacetic acid derivative (EVA), acrylonitrile-butadiene-styrene (ABS) and elastic Morel, taking into account the ultimate goal of improving the properties of the following fasteners for use in high quality black blends. The design of coatings modified with

recycled polymers was compared to that of ordinary bitumen and that of a workshop where the connecting element (Styrelf) was replaced. The implications of the research center tests (presentation of the material, dynamic thickness, versatility and stability of capacity) are used in the selection of the best plastic waste and production conditions to be used in the development of the bitumen to improve its performance and stresses that this test promotes the reuse of plastic waste in a more natural and more monetary way.

Mohammed Sadequeet. et al. (2014) studied the fact that polymeric bitumen is used to combat various road problems and increase the life expectancy of road surfaces. Unmodified bitumen can not function at its best with exceptionally low and extreme road temperatures. Bitumen polymers are regularly used to replace derivatives of ethylene, vinyl and acetic acid (VAS), styrene, butadiene and styrene (SBS). The purpose of this survey was to examine EVA performance and to modify bitumen. The bitumen has been adapted for use with discarded polyethylene (LDPE), polypropylene (PP) recovered in spill transport packaging and tires used for tires (CR). Polymeric waste reinforcement today, transfer is a big problem rather than an exorbitant virgin polymer. Since the test phase, it has been discovered that polymer waste further improves the properties of the bitumen as a virgin polymer.

Malik Shoeb Ahmad et al. (2014) considered that the use of polythene waste encouraged the introduction of bags in the adaptive development of road surfaces. Plastic waste derived from low weight polypropylene (LDPE / PW) was recovered from kitchen waste and plastic cans were used as additives in customizable corridors. Behind these materials, there is the motivation to use ecologically unsatisfactory waste and build a mix of higher quality materials to counter the increase in load and weight that causes cracks in the road surface. In the present study, plastic waste was cleaned and cut to such an extent that it passed through a 2 to 3 mm sieve with a shredder. In this study, a dense mixture of bituminous macadam (DBM) was prepared using standard bitumen as a control and bitumen mixed with low density polyethylene (LDPE / PW) at various grades, eg 2, 4, 6, 8, 10 and 12% by weight. The Marshall stability tests included the control and modified DBM mixes. It has been observed that the mixture of bitumens adapted to plastic waste bitumen has a limiting property, strength, thickness and insensitivity to water. Therefore, current innovation not only strengthens the development of the road, but also extends life on the road and also improves the planet.

Dr. Malik Shoeb Ahmad et al. (2014) Here, the author introduced the use of polyethylene garbage bags in the construction of flexible roads. Recycled plastic waste transported from low density polyethylene (LDPE / PW) was used as a flexible floor additive for kitchen waste and plastic bottles. In this study, plastic waste was cleaned and cut to size by passing it through a 2 to 3 mm sieve with a grinder. In this study, the dense bituminous mixture of macadam (DBM) was prepared using standard bitumen as a control and bitumen mixed with low density polyethylene (LDPE / PW) in different proportions, such as 10 and 12%. by weight. The Marshall stability tests were performed on controlled and modified DBM mixtures. It has been observed that the modified bitumen mixture containing plastic waste has better binding properties, stability, density and greater resistance to water. Therefore, current technology will not only strengthen road construction, it will also increase their life span and improve the environment. The test conducted by the authors showed that the addition of plastic waste to the mixtures has greatly improved the stability of the DBM mixtures. The modified plastic bitumen coating has also been significantly improved compared to normal bitumen. As a result, this study will result in fewer road repairs and the use of plastic waste will help to use non-biodegradable waste. The addition of LDPE (PW) reduces air voids, preventing moisture absorption and oxidation of the bitumen from trapped air. This led to an improvement in the stability value of Marshall. It has been observed that the stability values of the modified plastic mixtures have been significantly increased up to 14% -12% of WIP compared to the pure bitumen mixture. This demonstrates improving the strength of the mixture by adding plastic waste, which means that the inclusion of plastic waste increases the density of the mixture. The apparent density of the mixture also increases as the plastic waste content increases. The highest percentage of waste corresponds to a maximum density of 12% (2.51 g / cc), about 25% more than the density of the mixture obtained from pure bitumen.

Tariq Ali, Nouman Iqbal et al. (2014) The authors' study revealed that the increase in waste due to the excessive use of polyethylene in the products of daily life has become an important problem. Most of the waste is a nonbiodegradable species. Therefore, the author used plastic crushed as a polymer in bitumen up to 0%, 0.5%, 1%,

1.5% and 2%. The evaluated properties are the point of combustion, the flash point, the softening point and the penetration of the bitumen. Whatever the substitution rate, the bituminous polymer has shown satisfactory performance.

To determine the optimal polymer concentration in the HMA and a comparative analysis (added HMA polymer) and conventional HMA, the author conducted a penetration test to determine the hardness and softness of the mixture, measuring the depth of the polymer fraction. The results of the mixture and test indicated that the modified HMA polymer has better technical properties than simple bitumen mixtures and higher rigidity operating temperatures (summer), allowing to reduce the cracks. The bond of the asphalt and aggregates has improved, thus reducing detachment or sensitivity to moisture. To verify the physical reliability of the mixture, the softening point plays an important role. Indicates a certain temperature at which the sample in question should soften to a certain extent. The ringing and ringing method is used to evaluate this particular temperature. The results show that the mixture has increased the softening point. This phenomenon indicates that the resistance of the binder to heat is increased and that its tendency to soften when it is hot is reduced. Therefore, the addition of polyethylene makes the modified binder less susceptible to temperature changes. Several researchers have studied the effect of the softening point of a binder on the resistance to permanent deformation of bituminous mixtures. One example is hot-rolled asphalt, which has been found to reduce by half the rutting speed to 45 ° C, increasing the softening point by about 5 ° C (Fernando and Guirguisl, 1984). Therefore, the use of polyethylene in the bituminous mixture should reduce the thrust speed due to the increase in the softening point. The fire test revealed that the modified polyethylene asphalt mixtures are virtually heat-free or can not burn too easily at high temperatures (within certain limits). At a minimum temperature, when the vapors of some materials light up like lightning, some specifications are called the flash point of the sample to be tested. On the other hand, in some temperature steps, when the sample of the sample in question begins to burn and burn according to some specifications, the focal point in which the polymer modified bituminous mixtures tend to increase softening point, which will prove advantageous in cases extreme weather conditions, such as hot summer days, reduce bleeding and days of the rainy season, the bleeding is responsible for slippery. The mixture reduces the degree of perforation. This means that the addition of modified polyethylene mix harder and more coherent. In fact, it improves the overall performance of HMA improve resistance to HMA properties binders wrinkles, durability and resistance, weather resistance, and stability. The adhesion between aggregate ligand and asphalt is increased by applying polyethylene on the aggregates, thus reducing peeling.

Mohd. RosliMohd. Hasan, TekSek Yee et al. (2017) Here, the author conducted an experimental work to evaluate the properties of asphalt binders and mixtures made with a relatively new silane additive called ZycoTherm. In this study, 0.1% by weight of ZycoTherm was mixed with a bituminous binder to allow the production of a bituminous mixture at temperatures lower than normal and to improve the workability and compactness of the mixture. The performance of the asphalt with road floors in the tropical climate region was also examined. The properties of bituminous binder control (penetration levels 60/70 and 80/10) and bituminous binders containing 0.1% ZycoTherm have been described in terms of penetration, softening point, rotary viscosity, complex module and phase angle . To compare the performance of a bituminous conglomerate containing ZycoTherm asphalt the control mixture, cylindrical samples were then prepared at temperatures and negative air voids, depending on the type of binder and test requirements. The samples were tested for indirect tensile strength (STI), modulus of elasticity, dynamic sliding, Hamburger Radlauf and damage induced by humidity. According to the compaction data obtained with the Servopak centrifugal compactor, the samples prepared with ZycoTherm have a greater processing capacity and compactness compared to conventional mixtures. Based on the results of the mixing tests, the mixtures made with ZycoTherm showed comparable or better performance than the control of resistance to moisture damage, settings and breakage.

DivyaV, GyanenTakhelmayum et al. (2017) Here, the author presented the experimental study to evaluate the dosage of WMA additives (from 1 to 5% by weight of Sasobit, based on the binder, with an increase of 1% by weight and 0, from 0, 5% to 0.2% by weight of cyclotermia, based on the binder) was targeted with an increase of 0.05%). The properties of the Marshall blend design, including the apparent density of compressed blends (Gmb), air entrainment (VTM), voids filled with mineral aggregate (VMA) and voids filled with asphalt (VFA) were evaluated. Damage caused by moisture was assessed by a tensile test and a boiling water test. The results of the test show that the WMA mixtures respond to theproperties of the mixture. Furthermore, WMA blends were more resistant to moisture damage and met the minimum requirements of TSR. Furthermore, the dosage of WMA

additives had a significant effect on the Marshall Mix design and moisture-induced wound properties. The main objective of the authors study was to evaluate the performance of the bituminous conglomerate (BC) mixture using Sasobit Zycotherm a percentage ranging from 1% to 5% and 0.05 to 0.15% by weight of binder.

The author concluded that the optimal bitumen content for the HMA mixture at 160 ° C was 5.65%. The maximum stability of the 60/70 degree bitumen was reached at 135 ° C with an additional dosage rate of 3% of sasobit and 0.15% of cicoterma for the weight of the binder. The addition of additive sasobit and Zykotherm improves the apparent density of the mixture. It has been found that the percentage of air voids in the mixture decreases with the increase of the WMA additive with 5% and 0.15% Sasobit cycotherm at a minimum temperature of 135 ° C based on the conventional mixture or HMA.

Johnson Kwabena Appiah et al. (2017) Here, the author examines the effect of the waste mixture of thermoplastic polymers, in particular high-density polyethylene (HDPE) and polypropylene (PP), in conventional nominal AC-20 bitumen in various plastic compositions. The plastic materials were crushed and mixed with "in situ" bitumen with a cutting mixer in a temperature range of 160 ° C to 170 ° C based on rheological parameters such as penetration, ring

Softening and viscosity tests were performed to determine the resulting changes of the base bitumen. FTIR spectroscopy was also used to study the chemical functions present in the asphalt composite. It was found that unmodified bitumen properties were improved with changes in rheological properties of the modified bitumen polymer (PMB). The author noted that the polypropylene polymer has a strong influence on homogeneity and compatibility with a slight linear increase in the viscosity of the softening and penetration values, compared to the relatively high changes in bitumen modified with HDPE. C observed. For all modified binders prepared penetration values reduce when the polymer bitumen ratio increases, while the softening temperature generally increases as the polymer ratio increases. The most compatible and incompatible mixtures for HDPE were observed at polymer loads of 2% and 3%, respectively. The strongest mixture is obtained with 3% PP of polymeric load. Three main peaks have been identified in the unmodified bitumen spectrum, which appears in the infrared frequency range between 3000 and 2850 cm -1 and is typical of the balanced and unbalanced __C__H aliphatic alkanes. Curves of CH2 and CH3 were also observed at characteristic frequencies of 1465 cm -1 and 1375 cm -1, respectively. A low intensity peak of the order of 2400 cm -1 at 2100 cm -1 indicates the presence of a low group of CRC or CRN with only 0.12 extinction to improve the performance of conventional bituminous binders. This is an alternative option for plastic waste. use. Here the author concluded that the waste plastics containing modified bitumen was an alternative for recycling plastic waste in Ghana and non-traditional modified road-building binder. Further studies should be conducted to examine the long-term performance of the field test sections with PMB to assess the effects on storage, tension and crack resistance under various traffic conditions.

III. CONCLUSION

The researchers have tried to find the variation in H.M.A, W.M.A., and C.M.A. which occurs due to temperature effect, properties and admixture in a mix, following are the outcomes of literature review:

- Determine the effect of polythene in a mix.
- Determine that non degradable waste can be utilize in construction industry.
- Find out that LDPE doesn't have tensile strength
- Determine that H.M.A is comparatively more stable than others.
- Zykotherm is an admixture which can increase the binding properties of bitumen mix.

REFERENCES

[1] Reinke and Glidden year (2002) Effects of High density polythene on the permanent deformation of asphalt concrete. Indian Journal of Engineering and Material Science. 12: 456-460.
[2] Mohammad T et. al. year (2007)" Viscous properties and microstructure of recycled over modified bitumen. Fuel. 83(1): 31-38.
[3] Awwad and Shbeebyear (2007) "Influence of the processing conditions on the rheological behavior of polymer-modified bitumen. Fuel. 82(11): 1339-1348.
[4] Fernandes et al. year (2008)" Relation between polymer architecture and nonlinear visco elastic behavior of modified asphalts. Current Opinion in Colloid and Interface Science. 11: 230-245.
[5] Sabina et al. year (2009) "Warm Mix Asphalt Paving Technologies: a Road Builder's Perspective" Paper presentation of annual conference Transportation Association of Canada".

[6] Yousefiyear (2009)" Bitumen modification with reactive and non-reactive (virgin and recycled) polymers: A comparative analysis. Journal of Industrial and Engineering Chemistry. 15(4): 458-464.
[7] Bindu and Beenayear (2010) " Performance of Low-Carbon Environmental Warm Mix Asphalt", American Society of Civil Engineers".
[8] Albasheeret. al. year (2011) "Evaluation of Aspha-Min zeolite for use in warm mix asphalt." National Center for Asphalt Technology Report 05-04. Auburn University, Auburn, Alabama.