AMERICAN Journal of Engineering,
Mechanics and Architecture
*Volume 02, Issue 07, 2024 ISSN (E): 2993-2637*

# The Utilization of Various Types of Waste as Modifiers in Asphalt and Asphalt Mixtures

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**Abstract.** The study reports the usage of waste materials such as mixed sand, rubber powder, and recycled plastic to modify the properties of bitumen used in road construction. The demand for bitumen is increasing amidst a scarcity of resources, prompting the road industry to look for sustainable solutions.

The results show that introducing waste as additives in modified bitumen can improve performance without negatively affecting the technical properties. The thermal and mechanical performance of modified bitumen using recycled plastic, which has low melting points, was studied, making it suitable for use in asphalt mixtures.

These initiatives contribute to achieving social, economic, and environmental benefits by reducing pollution from plastic waste and saving natural resources. These strategies also contribute to enhancing sustainability in the construction industry, ensuring the continued development of road infrastructure.

**Keywords:** florarium, plants, nature, succulents, vessel, cultivation

**Introduction.** One of the well-known waste materials aimed at the substitution of asphalt mixtures is plastic waste. Most of the waste plastics used for the modification of asphalt are preferred for their high ductility, elasticity and for their cheap price. It is general knowledge that waste plastics have a positive effect on the physical, mechanical and/or longer-lasting properties of asphalt mixtures. However, some disadvantages of using waste plastics as the only modifier such as reduced low-temperature susceptibility, aging, and the economic burden related with material recycling are important obstacles to their broadened applications. Possible solutions include the use of waste plastics as an independent additive with other construction materials, and their use in a modified form with other materials joined as an aggregate-asphalt system not only in bitumen substitution. In addition modified plastics gave improvement in rutting resistance, dynamic creep stability, stiffness and fatigue life of asphalt mixtures.

The disposal of increasing amounts of waste materials is one of the significant environmental problems. One of the solutions to tackle this issue is the integration of waste materials into various industry sectors, primarily in construction. Many materials used in the construction sector, such as asphalt mixtures used as road pavement layers, are produced in large volumes, making them responsible for a significant part of the waste being generated [1]. On the other hand, many waste materials are suitable for the modification of asphalt mixtures, which can be applied to construct objectively less burdensome and durable variants of asphalt roads. Waste materials suitable for asphalt modification include materials such as by-products of industrial processes, waste from energy-producing industries or post-consumer recycled aggregates [2]. Waste can modify asphalt via different pathways, such as filler replacement, bitumen partial replacement or as an independent additive.

1.2. Objective of the Study
The main idea of this work is to search for a cost-effective manner in which to utilize the huge amount of polyethylene terephthalate (PET) waste which accumulates annually. This can be achieved by using recycled polyethylene terephthalate (rPET) as an asphalt modifier. Filler fly ash, a waste product of the combustion of coal, may also be applied to asphalt mixtures with the intention to create more favorable conditions for placing them in the ground and minimize their negative impact on the environment. Taking the advantages of fly ash modification into account (lowering of the asphalt mixture's aging process, improvement of its durability and water resistance, increase in elasticity and fatigue life) this study aimed to investigate the feasibility of combining these methods of waste utilization [3]. For this purpose, the study was planned in two steps: in the first step, the influence of rPET on the selected parameters of the physical properties of asphalt binders and mixtures was analyzed and in the second step, the effect of rPET on bitumen in synergy with fly ash was evaluated. Modifications of these materials were realized in accordance with the idea of the sustainable development approach, following the rule of converting something that would be thrown away into valuable materials that take into account the development of the economy, society, and environment.
The main objective of this study is to investigate the feasibility of using two waste materials, namely recycled polyethylene terephthalate (rPET) and filler fly ash (FFA), as modifiers for road-asphalt mixtures. The rationale for researching these two materials lies in: the fact that PET is the most widely used plastic material for packaging and it is necessary to find an effective way of their management [1], especially bearing in mind the impending restrictions on the use of virgin materials and the European Waste Framework Directive 2008/98/EC, which obliges an annual target of recycling 55% of plastics by 2030. On the other hand, the ways of managing the waste generated from the combustion of coal are also of great importance. It should be done in accordance with the principles of a circular economy in order to minimize its impact and to obtain new valuable products from it. Roads are the most suitable space in the urban and rural environment for the exploitation of such old materials as asphalt mixtures. What is more, susceptible to modification, they can be made more sustainable thanks to the recovery of waste materials. Additionally, introducing them into the road infrastructure involves reducing the environmental load because the emitted CO2 from applied waste materials is nullified by newly obtained waste products. The disposal of waste materials and the huge demand for new asphalt mixtures are the foundations on which the idea of this work is based.
2. Types of Waste Materials
The available evidence indicates that new modified bituminous mixtures improved rutting, fatigue cracking, and thermal cracking resistance. Generally, the use of polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) attributed significant positive expectations to the mechanical properties of the bituminous mixtures. The reuse of waste materials thus offers opportunities to increase our sustainability and should be considered for helping to reduce global waste volumes. Some of the possible areas of use include the construction of embankments, erosion control, backfill, and primarily the improvement of various properties in bitumen and bituminous mixtures, including rheological, adhesion, fatigue

resistance, rutting resistance, and thermal cracking resistance functionality, as well as the side beam properties of the prepared mixtures [4].

Pavement engineering is a process for the design, construction, and maintenance of road and pavement. The primary purpose of pavements is to provide vehicles with a relatively smooth surface and a durable base to assure traffic functions with safety and comfort conditions. With the significant role that roads play in sustainable development, it is crucial to consider recycling waste materials to reduce obtaining new resources. In light of resource savings, the currently available road construction and maintenance tools that reduce the price of pavement materials while still meeting quality criteria are of great interest. These new materials provide an avenue for the building of sustainable and quiet road infrastructure, have the ability to minimize the use of natural resources, and play a critical role in the sustainable construction and maintenance of road infrastructure [5].

2.1. Plastic Waste

As part of research conducted at the Institute of Roads and Bridge Engineering, West Pomeranian University of Technology in Szczecin, and as part of scientific research projects, valuable new asphalt modifications have been obtained, which can be a response to the increasing problems of the road industry and the waste management industry. Among the suggestions, interesting proposals include the use of both commercially available modified asphalt Modified Rubber) MR6 and MR10(, as well as modified Styrofoam asphalt, polypropylene, rubber, and terephthalate asphalt (;).[1]& [6] Plastic waste has become a significant obstacle to the environment, waste logistics, and waste management. Therefore, various solutions are sought to extend the life cycle of such polymers, including the context of the construction industry—in particular, the road sector in which the end user is an asphalt mixture. There are several ways to dispose of waste plastics, including incineration, recycling (i.e., closed-loop, open-loop, upcycling), and dumping. Cooperation between scientific, production, and implementation institutions has led to a modification technology based on the utilization of plastic waste in the construction industry, in particular in bituminous mixtures [5].

2.2. Tire Rubber

There are different used tires rubber disposal techniques. Crumb Rubber and Tire oils, relocating the waste from the tires, have not only improved the framework but also increased durability and price performance of the roads. A cyclical development occurs with tire natural rabbit material which contains of steps as collecting, investigation or planning, assessment, presentation and lastly arrangement. When the correct aspect of each step is employed in well-arranged period as per the condition, the costs are getting very small while the produced wheel lasts a long period. This aspect motivates the analysis of Rubber tires in some ways to protect the bird life.

The use of tire rubber in the asphalt industry has grown in recent decades [7]. The addition of crumb rubber to bitumen improves mechanical properties, aging resistance, rutting, and cracking resistance of the resultant modified binders and asphalt mixtures (ARMs) [8]. In addition, CR modification also is beneficial in developing binder, which improves moisture resistance in bituminous mixtures [9]. Rubber in asphalt mixture usually leads to significant benefits in terms of performance, sustainability, and also environment.

2.3. Glass Waste

Another possible solution can be the usage of waste glass in the field of building materials, for example as an aggregate in asphalt mixtures. Prudil et al. tried to analyze the effect of waste and powder glass on selected properties of concrete mixtures [4]. The aim of the study was to verify an assumption that the use the glass waste in the crushed or powder form as an aggregate in the composition of a concrete seal, complies with the requirements.

Currently over 50% of waste glass is used for recycling in Slovakia, which corresponds approximately to 150,000 tons a year. At the same time, glass processing companies generate

4000–8000 tons of waste glass a year [10]. According to available information, it is crushed or prepared to be used for manufacturing glass–ceramic materials [11].

2.4. Construction and Demolition Waste

Composite modification, that is a combination of a waste plastic with another modifier, have become a popular recent approach to improve asphalt properties. Researchers have found that blends of waste plastics, common polymers, and other materials are effective for these purposes [1]. Another interesting trend in asphalt studies is the incorporation of waste materials. There are numerous materials that could be successfully used to modify the asphalt. Building demolition waste is one of the most often used waste materials as a modifier in the asphalt and asphalt mixtures [4]. Fibers, which are common modifiers of the asphalt, are found in demolition waste. Their content in building materials is optimal. They are responsible for enhancing the results of a lot of tests. Several mechanical characteristics are also better than for a sample with a bitumen. This makes the modified asphalt more elastic and durable. Chemical properties of bitumen are also improved such as softening point, rutting susceptibility. Obviously, the obtained mixtures qualify for use in road construction [12]. It is shown that there is a possibility to use these materials instead of modified bitumen.

3. Modification Techniques

The chemical structure of bitumen could be altered by incorporating electronic arc furnace EAF slag, which is a result of steel manufacturing, and thereby benefits could also be observed for mechanical and durability properties of the final pavement material. Some of the waste materials have pozzolanic activity and many of them have been tried as an active mineral filler in hot mix asphalt. The growing problem of disposing red soil waste that is being produced when niobium is extracted was solved by the addition of the red soil in bitumen as a filler to produce red soil–asphalt mixture. E-glass fibers, rubber, tire powder, nanoparticles, waste cooking oil, and palm oil fuel ash, as well as polymer and plastic waste materials, were extensively researched with the aim of improving the physical, chemical, and rheological properties of asphalt and bitumen [6]. There are plenty of waste materials and by-products that can be applied to improve the quality of an asphalt mixture. The potential waste materials for bitumen modification includes gypsum, electronic arc furnace (EAF) slag, marble powder, limestone dust, steel slag, petroleum sludge, granite waste, copper tailings, and fly ash. LBMs containing fly ash as mineral additives have higher initial stiffness as well as better rutting, fatigue, and moisture resistance [12].

Researchers world wide are exploring the use of waste materials for improve the pavements sustainability. The reuse of the crushed concrete as fine aggregates in the asphalt mixture are provide many financial and environmental benefits. Waste marble chips waste material obtained from the stone cutting industries and quantities of waste materials such as carbonate powders result from the grinding and dressing of granites were also used as fillers to produce 'marble–asphalt' concrete mixtures in asphalt road pavement applications [4]. Waste marble powder is obtained from the marble industry. The particles are very fine and dust fraction is too much. By using these waste materials many problems can be reduced such as problems regarding to disposal, environmental problems, employing and loss of revenue.

3.1. Physical Modification

Articles have been subjected to various forms of improvement when dealing with polymers and ashes that have already been used in mixtures. In order to use other forms of domestic waste it is necessary to perform mechanical and physical studies of not only ashes but also waste polymeric materials and used car tires. The following chapters will attempt to evaluate the suitability of tested waste materials for potential use in mixtures and the likely suitability of these materials as key materials in the applicable mixtures. EXPERIMENTAL STUDIES The generally established reduction (e.g., in the value of penetration, as 9ae126e8-dd2e-4bcd-a6c6-6cc953b8e1e5) of storage modules of bituminous asphalt mixtures is a correct way of increasing their resistance to permanent deformation at high temperatures (e.g., during the summer period) but also at lower temperatures. This paper investigates the state and changes of two types of bituminous asphalt mixtures using modified binders, Foster Quartz Type I and PG 76_22, which contain two types of a construction and demolition waste (ashes and powder of waste polymeric materials in the shape of sterile and common sheets). Tests based on the four points bending test (4PB) were performed at +40 and -15 ◦C and dynamic modulus tests in a temperature range from 20 ◦C to -20 ◦C using a DMA (dynamic mechanical analysis) device. Increment values of bending stiffness from both types of mixtures are presented in this paper. The highest values of the angular coefficient from both types of mixtures are met at −15 ◦C. From the PRINT2D tests of both types of mixtures at −15 and +40 ◦C, they show the good behavior in the permanent and changeable area. The decreased values of storage modules at 20 ◦C of Foster Quartz Type I mixtures proved that these modifies are effective also at lower temperatures such as −15 ◦C[1, 2, 3] ,[13] [6].

3.2. Chemical Modification

The viscoelastic behavior of unaged unmodified petroleum asphalt binder did differ considerably from the modelled viscoelastic behavior of organoclay modified binder, similar from the one for C60 modified as well as different from the one of nanotube modified asphalt binder. The differences in the viscoelastic behavior for non-aged and fully aged bitumen mixture were through the different degradation of the base binder and incorporated modifier. The best improvement of the viscoelastic properties at low frequencies and high temperatures was achieved by using multi wall carbon nanotube with the chemical vector and the highest mole fraction of graphene in the multi wall structure [1]. However, the best improvement of the viscoelastic properties at high shear temperatures/frequencies in the binder sublayer of the mixture was achieved with the functionalization of the binder by the liquation resin polymers with the lowest average molecular fraction. Furthermore, styrene butadiene and polypropylene functionalization did not affect the blend of polymer directly.

The enhancement of the asphalt properties by the chemical modification of asphalt has brought attention to many researchers and experts in the scientific communities. Commonly used modifiers in asphalt are polymers that are elastomer of natural rubber, or synthetic material such as styrene-butadiene-styrene (SBS), styrene-butadiene rubber (SBR), Ethylenevinylacetate (EVA), Polyethylene, and Polypropylene, which improve one or few properties of the asphalt. Polypropylene is degrading during the preparation of the asphalt mixture, because degradation begins at the temperature of 180°C and destruction of the base component of the asphalt mixture is 160°C [6]. The functionalization of petroleum, coal, pyrolytic, and bio-base asphalt to organic binders can be achieved by mixing of different carbon nanostructured additives which are fullerenes (C60), single wall carbon nanotube (SWCNT), multiwall carbon nanotube (MWCNT), nano clay organoclay, graphite nanoplatelets, graphene, and graphene oxide carbon particulates. Negligibly preparation temperature effects for all unaged organic binders were observed. Nevertheless, very significant rheometric differences between different types and contents of nanostructured additives were noticed. Moreover, rather high shear deformation at the preparation stage negatively influence the asphalt mixture complex modulus and phase angle at low and intermediate shear temperature intervals, and possibly also rutting resistance [14].

4. Impact on Asphalt Properties

Modifying asphalts with new types of modifiers presents technical challenges in terms of changes in performance properties. The articles reviewed display only the potential of modifiers to determine the most important properties of asphalt materials, which include asphalt viscosity, temperature susceptibility, and fatigue life. These only illustrate whether the modifiers affect stiffness, fatigue properties, and the fracture (thermal) susceptibility of the asphalt mixture [6]. Coefficients of thermal expansion between zero and 60 °C are key input parameters for the Finite

Element Model of asphalt-soil interaction, whereas a complex viscoelastic modulus model is necessary to describe the asphalt material's response to compacting, temperature, and aging. Entering the asphalt-soil interaction model is a result of obtaining interrelationships, including the porosity of the asphalt mixture, its temperature, and its mechanical resistance.

The performance properties of asphalt mixes significantly affect road behavior and safety [12]. The modification of asphalts with non-conventional modifiers is becoming increasingly popular as it helps to improve the performance and cost-effectiveness of the asphalt. Increasing environmental awareness has led to urgent necessity of researching the opportunities to use various types of waste as modifiers in asphalt and asphalt mixtures [1].

4.1. Rheological Properties

This solution is broad and complex, because the modifier is used in an unconventional way; therefore, it is necessary to predict its impact on long-term asphalt behaviour. However, it seems that such a concept provides excellent opportunities for the use of modified mixtures, especially recycled mineral waste aggregates. On the basis of the research presented, it was shown that it is necessary to study the influence of the kaolin content in the modifier mass on the properties of bituminous mix and asphalt mixtures. Certain studies have shown that the possibility of using taphole clay and kaolin as a pigment in KAC seems to be particularly justified. In the light of the obtained results, presented in the tables and by means of selected figures and values characterizing the functional properties of the developed fashionable asphalt mixtures, it has been demonstrated that taphole clay and kaolin can be used as fillers in asphalt mixtures.

Vanadium slag solid waste has been used as a filler [12] in porous asphalt concrete as a substitute for fine aggregate. The analysis showed that utilization of this type of waste as fillers in porous asphalt mixtures can improve the consistency of the bitumen and bitumen/filler mixture and reduces softening of the bitumen by temperatures rise observed in the AASHTO TP 102 Standard test. Solid waste was also used as a binder in bitumen transparent pipes [7], reducing the amount of traditional binders, and in rubber-modified asphalt mixtures to improve rheological properties, increase resistance to fatigue, and improve resistance to permanent deformation [6].

4.2. Mechanical Properties

The aim of this research is to present the possibility of using different plastic products to improve the effectiveness of the recycling process. The plastic waste modifiers were used as an additional component in the conventional asphalt mixture. The results of the tests indicate that the modification of bitumen with waste plastics improves the viscous and elastic properties. In addition, the modified binder in the stationary temperatures has greater resistance to permanent deformation. The addition of LDPE leads to an increase in the value of stiffness as well as reduced ability to relax stress compared to the asphalt containing unmodified bitumen. From both binder and asphalt mixture tests it was found that the use of the modifier has a beneficial effect on the asphalt-rubber mixture, on the elastic and viscous properties of asphalt and its resistance to permanent strain, contributes to obtaining the desired mechanical properties.

Asphalt industry is growing and utilizes a ton of raw materials and resources. Also in recent years, the issue of waste processing and new materials has come to the fore a lot. In this article, using waste plastics as an additive in asphalts and asphalt mixtures is presented. To sum up the state of art of the knowledge on the subject, which in most cases is advanced to the highest possible level, the authors of the article [1] have looked closely at this issue. The addition of plastics to asphalt is intended to improve its performance characteristics. Schema of macromolecular chains of asphalt after modification. Scheme of the influence of modifiers on the adhesion and cohesion of asphalt are shown. Map with the impact of plastic waste on environmental pollution is illustrated.

5. Environmental and Economic Benefits

Replacement of fossil resources with renewable alternatives to produce the PMB may support environmental and energy policies and contribute to sustainable development of the road spread. A considerable number of effective approaches have been developed to produce PMB by modifying base bitumen with waste materials such as oleochemicals, polymeric waste, agro-industrial by-products, and waste cooking oil. Oleochemical waste is produced by the palm oil industry, in acid, ester, hydroxyl, and polymer forms, and degrades the properties of asphalt mixtures. A rapid increase in polymer production and the use of packaging materials in the packaging sector led to adopting a waste management strategy for polymer waste. Over the years, many studies detailed the use of different polymer types for this purpose, including linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE) and low-density polyethylene (LDPE), poly acrylonitrile (PAN), flexible polyvinyl chloride (PVC) and recycled polyethylene terephthalate (RPET), polyurethane (PU), polystyrene (PS), and tire polymer waste [1]. Despite the fact that PMBs significantly improve the engineering properties and promote a sustainable response of asphalts to changing temperatures and heavy traffic loads, the fact that they are formed from synthetic linear begins to challenge environmental and economic sustainability policies in life cycle assessments. What measures to take in wasting a large-scale polymer production in the daily economy in the event of extensive R & D effort for a possibly novel waste management strategy, what actions to take in the possible optimization of the properties of the usage materials accordingly, and what the possible effects of these measures are on the cost of the polymer are also issues to be analyzed.

Polymer-modified bitumen (PMB) is gradually replacing conventional bitumen in transportation systems necessitated by concerns over high-temperature susceptibility and low-temperature cracking resistance due to climate change and increasing heavy traffic loads [7]. The considerable growth of polymer production has led to a higher concern of polymer waste and consequently has become a pertinent global issue. Studies showed that cooking oil added to virgin binder can increase the stiffness of the binder and does not create rutting. Therefore, it can potentially improve the load capacity of the road and reduce the number of asphalt road layers. After more than 20 years of intensive research and trial applications in field use, the time has come for PMB to be incorporated widely as a sustainable engineering requirement. Special binder uses in the future will test resistance to late mixture and pavement performance, long-term structural performance in relation to traffic loads and environmental conditions, and economic options minimizing costs and energy consumption in transport systems [15]. In recent years, new efforts to minimize environmental pollution have led to intensive studies for optimizing the properties of road asphalt mixtures, enhancing pavement life, and minimizing the rate of bituminous material.

5.1. Reduction of Waste in Landfills

On the other hand, in 2022 it is planned to reach 50% of RHSW landfills utilization, and in 2025 the goal of 70% [16]. This obliges Member States to search for industries that are the most polluting and to reduce the amount of waste sent to landfills by promoting recycling or other waste recovery processes. One of the main wastes that end up in RHSW landfills is used car tires, which is a major environmental problem due to the fact that tire degradation is a slow process, with the potential to contaminate water and air. Therefore, the possibility of using rubber-containing waste as a modifier to bituminous mix was found. In Poland annually more than 100,000 tons of used tires are generated, and almost half of them are stored in the open due to the lack of a way to utilize them. The recycling of these waste allows to improve the properties of the asphalt mix and, to a small extent, reduce water and air contamination with rubber. Such modification of the composition of the bituminous mixture is contrary to reducing the number of bituminous aggregates and replacing traditional bituminous aggregates with lightweight aggregates working as bearing, stopping any waste in the bituminous mixture on the heels of the goal of reducing the number of waste accumulated in landfills or preventing further depositing.

The amount of waste generates is growing continuously around the world, without following a proper track of recycling and reusing the waste materials. One of the most serious environmental problems is the waste of different types from which a significant part ends in landfills. By using different methods to improve the properties of waste, we can restore it to the chain of production and mitigate environmental pollution mentioned earlier. The asphalt industry, which is one of the largest consumers of material and energy, is interested in reducing the cost and the energy consumption in the production and laying the asphalt layer. By using waste wild rubber, it is possible to achieve the desired improvements in the performance of the asphalt mix. A significant part of the produced electricity and heat in Poland is generated based on coal combustion, and as a result, a large amount of fly ash is produced as a by-product. What can be seen in the literature is the potential possibility of using fly ash as filler in bituminous mixtures with significant possibilities to improve the bituminous mixture [4].

### 5.2. Energy Savings and Emissions Reductions

It is a well-known fact that asphalt production requires high energy costs and significant emissions into the environment. Production of an asphalt mixture takes place at 160–180 °C, and it is very crucial to lower the energy requirement and emissions during production and application by reducing the mixing and compaction temperature. Rubber modified asphalt helps recover some amount of waste rubber (WR) and reduce the requirement of new polymers (virgin binder), as well as improve economic aspects. In the literature, RPL refers to ground and/or granulated rubber that is produced as a result of depolymerization processes and does not contain added binders.

Use of waste rubber powder (WRP) as an increased portion of recycled content in binder modification has the potential to reduce energy usage and emissions in producing road pavement mixtures, contributing to the fight against global warming. For instance, the high value of the asphalt mixing temperature (HMA) also has a considerable impact on the energy consumption in production and road pavement traffic noise, pavement durability, and environmental impact. The mechanical properties and temperature susceptibility of polymer-modified asphalt samples (PMA), modified by Barbero moulds in the laboratory, have been investigated in this article [1][3].

## 6. Challenges and Future Research Directions

In future research, we must specifical extend on the following topics: analyzing the properties variation of bitumen when the modifiers are properly used to impact the modulus-gradient, particularly in the bottom layer; deeply looking into the Ultraviolet radiation (UV) ageing mechanism and the change of the mechanical behavior of warm mix asphalt using this waste material; finding out the missing spectrum of the complex-cracking scenarios in the ageing mix that may occur when asphalt pavements are subjected to the combined glycolysis + HMA + fatigue degradation, etc.; evaluating the capability of selective/two-stage extraction protocols to describe the compatibility under service conditions and even changes in WMA film-morphology formation during its service life [1].

Challenges arise in recycling and utilizing waste materials. Among the most important is that the introduction of waste or recycled materials in asphalt mixtures might lead to degrading binder performance. Specifically, waste materials might compromise binder vision, and increased stiffness, fatigue, and rutting resistance. Generally speaking, a balanced way is to ameliorate the modified binder properties with a storage stability at the improvement in HMA performance. HMA performance can be improved by impasto emissions and establishing a strong bond between fillers and binder. Moreover, to date, the stiffness modulus can be guaranteed during service life, and the binder can withstand fatigue and rutting. The durability and prolonged usability of WMA can be enhanced by adding waste organic or inorganic particles as potential modifiers. Although recycling waste materials for asphalt modification are expected to become an efficient and environmentally benign solution, several obstacles exist including higher costs, lower quality, higher fragility, and irregular structure[17] [4].

6.1. Quality Control and Standardization

In road constructions using flexible pavement, the quality of the bitumen, the main raw material, and its deformational, adhesive, and cohesive characteristics with the aggregates are important as per the strength and performance of these types of pavements. Factors affecting bitumen like the crystallization effect is important for the endurance of infrastructure. Moreover, bitumen may not meet the desired level of quality for road works due to harsh weather conditions or other unexpected factors. Therefore, Waste Plastic Additives (WPA) used for the purpose of recycling the tribological plastic waste, non-recyclable plastics, bitumen modification, and increasing the atex discharge characteristics standardizing the airworthiness by obtaining different blend formulations in reaching the compatibility of the bitumen, preparation for the bituminous mixture can change directly the physical, mechanical, and chemical properties. Only 2% crosslinking and WPA substitution to bitumen gave the best performance value and this is acceptable for the usage of very suitable WPA in the road construction sector as the best single waste [15].

The loss of quality, pollution, waste, and waste management problems are becoming more and more complex day by day, as the population of people living on Earth increases and their consumption and production increase in parallel with it. Nowadays, about 30 percent of the waste that forms the bulk of the layers of asphalt pavements used in highway and road construction is produced by the construction industry. Recycling the resulting construction waste that has reached enormous dimensions and contributing to soil pollution by affecting human health, the environment, and the ecosystem in a negative way has become a compulsory and urgent necessity. small pieces of waste plastic, the most effective way to return them to the economy, is the transportation sector [1]. Using waste plastics, which accumulate in nature as pollutants, in asphalt mixtures as an independent modifier is a way to evaluate the replacement level of a product that provides good service in road construction practice and has high continuity life. Using plastic waste, which cannot be recycled easily and thus poses a problem in terms of the environment and the economy, to strengthen the bitumen in the asphalt mixture will ensure this rubbish meets the desired environmental, social, and economic requirements. The mixture formulations, recycling percentages, and percentage of bitumen substitution of waste plastic will be optimized utilizing artificial neural networks (ANN), Response Surface Methodology (RSM), and Adaptive Neuro-Fuzzy Inferences System (ANFIS) methods (standard between neural network and fuzzy systems) in case the compound element is based on less money and time [18].

6.2. Long-Term Performance Evaluation

Enough amount of used natural rubber particles in the 64/100 road construction asphalt concrete mixtures improved their composite viscoelastic behavior in the short and even long terms and subsequently their rutting resistance and fatigue life. Also, their thermal and thermomechanical characteristics were improved according to the Thermoplastic Composite) TPC (and Thermogravimetric Analysis TGA [6].[19].

In the course of this study some important results were inferred and can be concluded as follows:

For the short-term analyses, the 64/100 asphalt concrete mixtures incorporating proper amount of natural rubber particles are suitable for in-service loadings on a heavy traffic asphalt road as the composite viscoelastic behavior was improved and consequently, the rutting resistance and fatigue life were also improved. This was in agreement with the recorded improvement in the thermomechanical properties of the asphalt binder. Plus, the results revealed that the introduced natural rubber particles improved the self-healing efficiency of the 64/100 asphalt concrete mixtures, which, however, needs much longer time than the related percent recoveries to express itself properly in the mechanical properties of the asphalt concrete. Thus, the particle size and type could not affect the cumulative self-healing efficiency of the studied asphalt concrete mixtures over 150 days of aging periods [15]. The long-term life-cycle analysis results showed that the 64/100 asphalt concrete mixtures incorporating up to 4% natural rubber particles could similarly lead to 15% and 20% reduction in the consumed energy to aggregate and total environmental impact, respectively. Furthermore, the optimal environmental point of the 100% virgin asphalt concrete mixtures turned from the control mixture to the 4% natural rubber asphalt concrete mixtures.

## Conclusion and Recommendations.

Bitumen is widely used in the construction of road-based transport infrastructure. It is the main raw material for paving, sealing, and maintenance layers in the road construction industry. The bitumen used in my country mainly relies on the tar resource reserve, which mainly used in chemical industry and urban heat supplying my country. As the work of the bitumen industry has shifted from a primary mining industry to a processing and manufacturing industry and the proportion of materials used in the road industry is gradually increasing, the continuous development of road construction has objectively required an increase in the bitumen demand of projects. Therefore, facing the increasingly severe shortage of resources, the road construction industry in my country has attracted attention to the reuse of waste materials such as waste slag sand, waste rubber powder, waste plastics, and waste heat from the economy, and the comprehensive utilization of waste materials. The concept discussed in this article is to comprehensively grasp the basic performance, mixing gradation structure, high and low temperature resistance, and other indicators of asphalt in the preparation formula of modified asphalt. Through a series of research and tests, it is determined the use of various kinds of The optimum content of waste materials without affecting the performance of the modified asphalt can effectively keep the technical indicators of the asphalt; through tests, such as the Marshal stability test of waste rubber asphalt concrete [3].

The waste used in these studies, such as waste plastics, waste slag sand, and waste rubber powder, etc., are all waste resources in my country. At the same time, with the increasing output of these waste resources, how to efficiently treat these waste resources has gradually become a hot spot for society. Therefore, using these waste resources as the original materials of the modified asphalt has great social benefits, economic benefits, and environmental benefits. The introduction of waste materials as the modifier content into the asphalt has adjusted the basic performance and high-temperature performance of the asphalt to different degrees. The Hainan waste plastic used in this article is a post-consumer plastic, and its softening temperature is lower (the softening points of LDPE, LLDPE, and HDPE are 107–114°C, 120–126°C, and 128–135°C, respectively). After rectification and separation treatment, the softening temperature range of the waste plastic is between 85 and 108°C, which means that it will have certain viscosity and dissolution temperature when added to the oil system. When the waste plastic passes the stepped rectification column, 0–180°C low boiling point gas is obtained as a resource and a solvent for mixing the stabilizer waste. According to statistics, tons of plastic waste can be recycled. The factories can save about tons of oil, reduce carbon dioxide emissions, effectively alleviate the environmental problems related to plastic waste, and lay a solid foundation for promoting the preparation and application of plastic waste modified asphalt road materi in my country.

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