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APPLICATION OF PLASTIC AGGREGATES IN ASPHALT MIX PAVING FOR SUSTAINABLE ENVIRONMENT

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Abstract- Flexible pavements use bitumen as a binder and aggregate as filler. One of the key elements of a road structure is aggregate. Researchers are looking towards alternatives to natural aggregates due to the depletion of natural resources. In this approach, plastic aggregate can be quite useful. The results of tests on asphalt mixtures using plastic aggregate derived from electronic waste as a partial replacement at 0-15% with 5% intervals demonstrate a significant result. Testing in this area revealed that while marshal stability gradually declines, performance against rut resistance significantly improves, leading to a decrease in rutting depth to from 4.78mm to 1.89mm, which demonstrated the best results at 10% partial substitution of Electronic waste plastic aggregate. Using that much percentage of Electronic waste in Flexible pavement will gradually decrease the pollution created from the Electronic waste and also contributes to the sustainability of Natural aggregates to some extent.

Keywords- Plastic aggregate, Electronic waste, modified asphalt mix, artificial aggregate.

1 Introduction

Flexible pavements use bitumen as a binder in addition to aggregates. The cost, usability, and durability of every road project depend on the caliber of the materials used and how evenly the different layers are spaced in accordance to the expected traffic loads. Aggregate is one of the essential components of a road structure. Their grade, quantity and quality play a key role in the entire service life of a pavement. Researchers are investigating innovative alternatives to natural aggregates due to the depletion of natural resources, such as reusing natural aggregates utilized in prior projects, recycling concrete waste, and creating aggregates from collected plastic.[1]

The disposal of huge quantities of poisonous and non-biodegradable waste materials poses a serious threat to the ecosystem. Many of these waste products can be adequately controlled in the construction sector by being recycled or reused. Recycling waste is important from a number of angles. It reduces environmental pollution, aids in energy conservation and recycling throughout production operations, and supports the continued use of nonrenewable natural resources.[2]

The explosive development of electronic materials over the past few decades has improved human living by revolutionizing communication, defense, and medical scientific lifestyles but presently electronic trash (Electronic waste) is developing into an unavoidable environmental concern. By using these waste products, we can maintain a healthy and sustainable ecosystem. Electronic waste is primarily produced as a result of new electronic appliance sales, including those of laptops, monitors, TVs, LE/CDs, and TVs. Additionally, the demand for aggregates in the concrete building sector is rising daily. Additionally, concrete products are depleting natural resources for aggregates. Therefore, steps should be done to recover recyclable components from Electronic waste residues in order to promote the development of sustainable Aggregate and prevent environmental contamination. Therefore, one of the potential options to ensure the sustainability of the environment is to mix Electronic waste. The electronic waste items are heated in the heating kiln below their melting point to create the electronic waste aggregates. Electronic waste aggregates are created by crushing this hot electronic debris through a particular filter size.[3]

Ahmed and Qureshi replaced 30% of the volume of NA in concrete with Electronic wastes. Additionally, concrete was strengthened by the addition of 0.75% polypropylene macro synthetic fibers. The inclusion of 0.75% macro synthetic fibers increased the compressive strength and split tensile strength values of concrete with Electronic wastes by 30% and 75%, respectively. Due to the inclusion of macro synthetic fibers, the density of concrete containing Electronic wastes somewhat increased.[4], [5]

Bituminous-mix design entails combining aggregates of varied sizes and bitumen concentrations in the best possible ratios. The wasted electronic products that are intended for reuse, resale, recycling, or disposal are referred to as electronic waste. Due to the lack of governmental control of the processing of electronic waste in poor nations, this practice may have major negative effects on public health and the environment. The utilization of recovered Electronic waste in place of coarse particles in bitumen is the subject of the current investigation.[6]

2 Problem Statement

Due to the rising demand for aggregates, natural resources are being depleted quickly, which is raising the cost of substitute materials. Aggregate availability suffers greatly as a result. Consequently, in order to stop the depletion of natural aggregates, artificial aggregates created from waste plastic, which pose a major environmental risk because it does not rapidly disintegrate naturally, should be used in place of natural aggregates.

3 Research Objectives

- Determination of Optimum bitumen Content of traditional HMA
- Optimization of Aggregates made from Electronic waste for best performance in rutting

4 Research Methodology

Electronic waste is collected from Gujranwala after a thorough review of the literature and then crushed to size range of 4.75mm-19mm with the help of crusher, and both traditional asphalt mix and modified asphalt mix with partial replacement of plastic aggregate have been put to marshal stability test and wheel tracking test. The plast, and the best replacement dosage for the plastic aggregate is identified. Electronic waste aggregate is used partially in place of natural aggregate in our study up to 15% with 5% intervals. Below figure 1 is a visual representation of the research methodology:

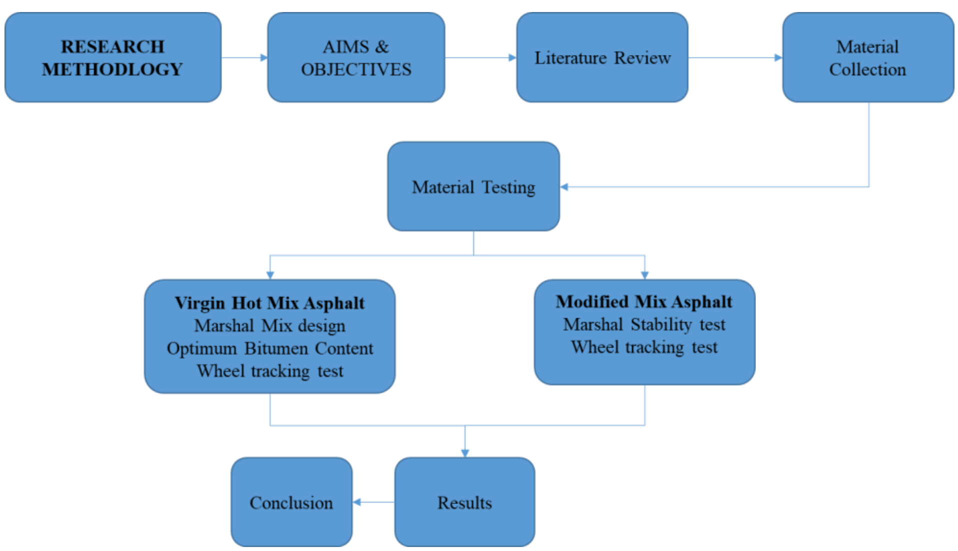

Figure 1: Research methodology

5 Results

With Hot Mix Asphalt, binder and aggregate are blended in a very specific method. The HMA's physical characteristics, which are ultimately governed by the relative proportions of these components, will determine how effectively it functions as a paved surface. As a means of testing the efficiency of modified HMA mixes, this research substitutes partially Electronic Waste plastic aggregates for natural aggregates in varying percentages (as measured by aggregate weight) in many different concrete mixes for HMA.

5.1 Sieve Analysis

To determine the particle size distribution, also known as gradation of granular materials, a sieve analysis, also known as a gradation test, is a method or procedure used in civil engineering that measures the amount of material that is stopped by each sieve as a percentage of the total mass. Gradation used in this research is NHA class B, whose gradation is shown in figure 2.

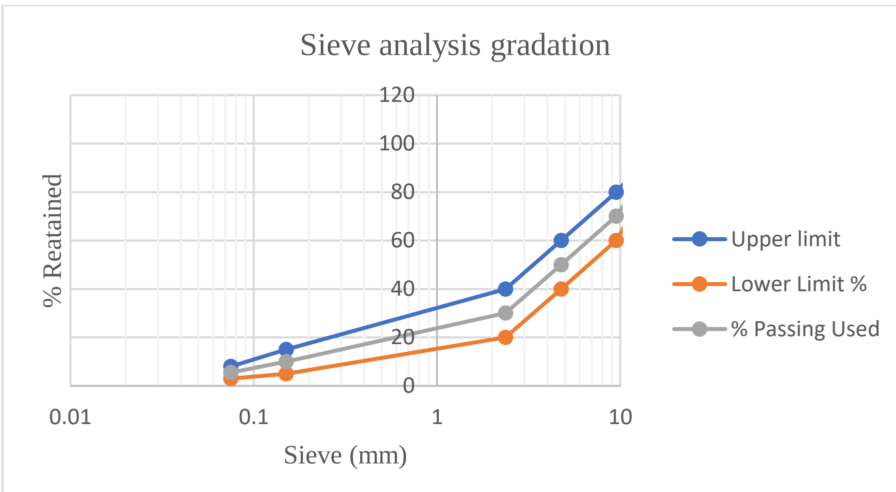

Figure 2: Sieve analysis of NHA class B

5.2 Properties of Plastic Aggregate Made from Electronic Waste

Properties of plastic aggregates characterize them and aids in understanding the behaviour of plastic aggregates made from electronic waste. Further testing is performed after knowing the specific gravity, water absorption and melting point of these aggregates. Table 1 shows the findings.

Table 1 Properties of plastic aggregates

Sr. No.	Properties of Aggregates	Test Results (Electronic waste)
1	Specific Gravity (g/cm^3)	1.34
2	Water Absorption (%)	0.15
3	Melting Point (°C)	255

5.3 Determination of Optimum Bitumen Content

Optimum bitumen content is the prime factor for designing the HMA. For determining the OBC, 3 compacted samples and one loose sample at each percent of bitumen content (3.5%, 4%, 4.5%, 5% & 5.5%) are made. Test method employed for determination of OBC is Marshal Stability Method for mix design ASTM-D6927. Table 2 below shows the average value of Optimum Bitumen Content.

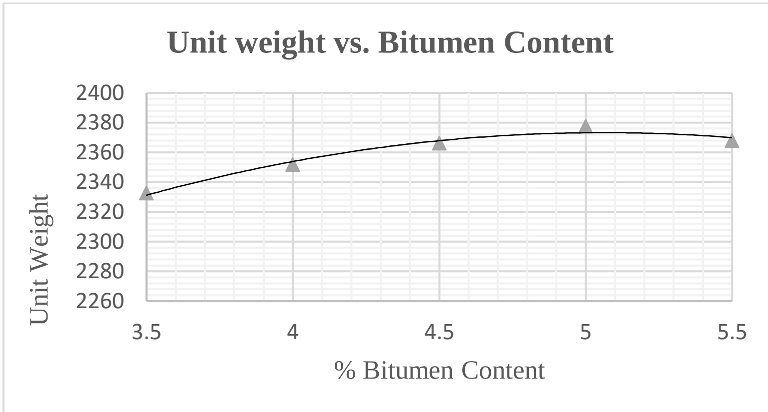

Figure 3: Unit weight vs Bitumen content

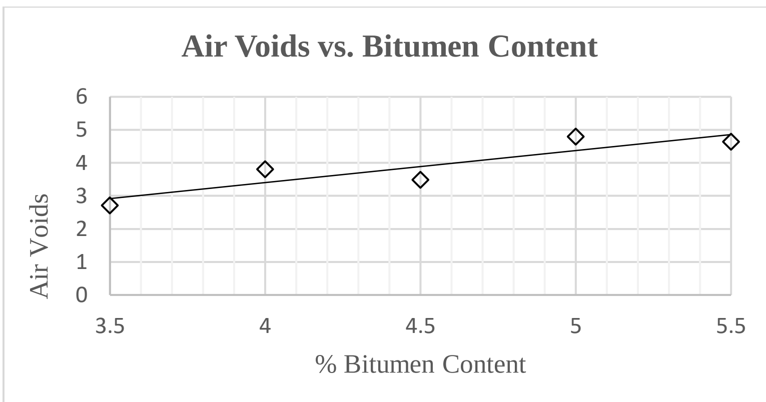

Figure 4: Air voids vs Bitumen content

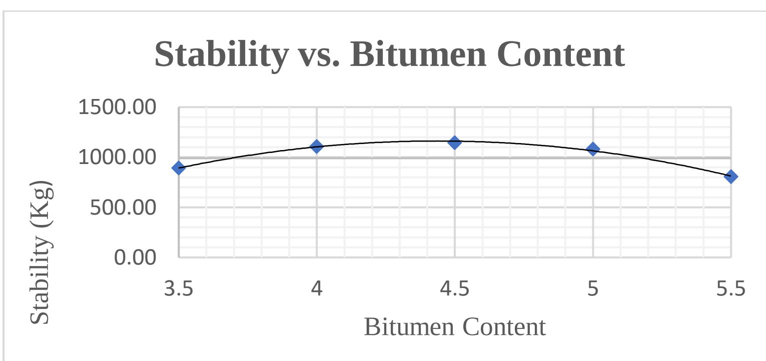

Figure 5: Stability vs Bitumen content

Table 2 Optimum bitumen content

Bitumen Content at Max Stability	4.5
Bitumen Content at 3% Air Void	3.6
Bitumen Content at Max Unit Weight	5
OBC (Optimum Bitumen Content)	4.3667

Based upon the Max. Stability, Air Voids and Max. Unit weight figure 3, figure 4 and figure 5 demonstrate the Maximum value of 4.5%, 3.6%, 5% bitumen content respectively. Computing the average of these three findings, gave the optimum bitumen content (OBC) of 4.36% as shown in table 2.

5.4 Effect of Electronic Waste on Marshall Stability

During constant deformation, the Marshall Stability load is the maximum load at which resistance occurs. Three replicates of each original and modified specimen undergone for a stability test. Plastic aggregates are partially replaced with natural aggregates ranging from 4.75mm-19mm sieve sizes. Asphalt concrete's load-resistance performance has been slightly decreased by the presence of plastic aggregate. Marshall Stability values, related to plastic content as a partial replacement of aggregates, can be seen in the table 3 below.

Table 3 Effect of Electronic waste on Marshall Stability

Marshall Stability (kg)							
0% Replacement		**5% Replacement**		**10% Replacement**		**15% Replacement**	
1337.7	Average Value= 1288.61	1314.69	Average Value= 1277.87	1222.64	Average Value= 1253.32	1107.59	Average Value= 1208.84
1245.66		1245.66		1280.17		1280.17	
1282.48		1273.27		1257.16		1238.75	

When plastic waste was added up to 5% by weight of natural aggregates, stability practically decreased with a drop of 0.8%, but if plastic content was increased up to 15%, stability was lowered by roughly 6.19%. Zero percent plastic content yields the best stability rating, while fifteen percent yields the lowest. In spite of a decline in stability with increasing plastic content (up to 15%), the value is still well within the Marshall Mix design parameters for large traffic loads (i.e., more than 1000 kg). The findings of the tests show that recycled Electronic waste plastic may be used in lieu of some of the natural aggregate in hot mix asphalt concrete. The aforesaid experimental findings are shown in the figure 6 below.

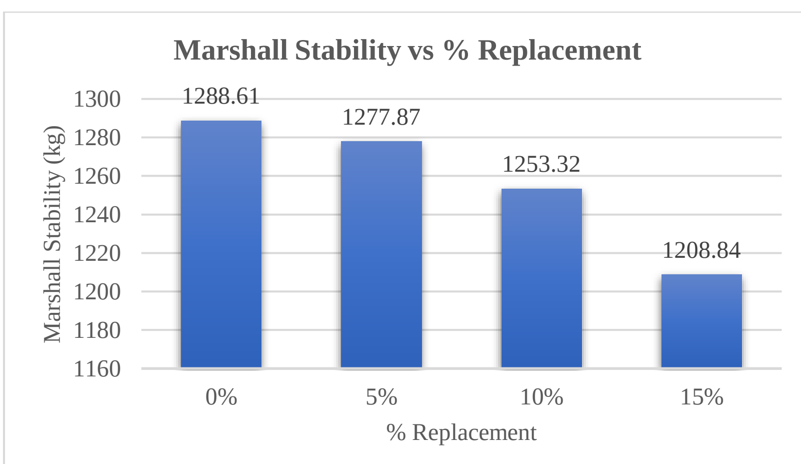

Figure 6: Effect of Electronic waste on Marshall Stability

5.5 Effects of Electronic waste on rut resistance performance

Rutting brought on by repeated loadings has long raised concerns about the performance of HMA pavement. Rutting's rate and intensity are influenced by behavioral as well as environmental factors. External factors include things like temperature, tire pressure, load, and the volume of truck traffic. Internal factors include mixture quality, bitumen, aggregate, and pavement depth. Here, 3 replicates are prepared for standard and modified HMA mixes (5%, 10% & 15%) at each percentage in which plastic aggregates are partially replaced with natural aggregates ranging from 4.75mm-19mm sieve sizes, both of which adhere to Marshall Properties are compared for their rut-resistance capabilities using wheel tracker test. Table 4 below displays the outcomes of this finding.

Table 4 Effects of Electronic waste on rut resistance performance

Rutting (mm) (10000 passes)							
0% Replacement		**5% Replacement**		**10% Replacement**		**15% Replacement**	
4.74	**Average Value = 4.78**	1.99	**Average Value =2.04**	1.91	**Average Value =1.89**	9.1	**Average Value =9.63**
4.9		2.08		1.87		10.1	
4.7		2.06		1.9		9.7	

Figure 7 demonstrates that the wheel tracking rate of modified HMA is lower than that of conventional HMA concrete. The maximum rut depth for conventional HMA mixes after 10,000 cycles at 55℃ is 4.78 mm, whereas the maximum rut depth for modified HMA mixes at 10% replacement using same test conditions is 1.86 mm. Consequently, a typical hot mix asphalt concrete's rutting depth may be decreased by 61.08% when employing the optimal dose of plastic aggregate component in the mix. However, the data showed that modified mix was much better at resisting ruts than regular mix.

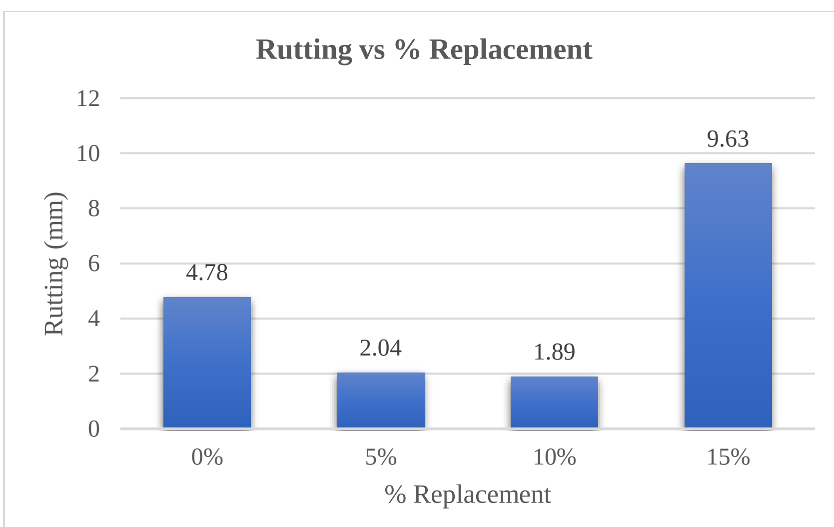

Figure 7: Effects of Electronic waste on rut resistance performance

6 Conclusions

Test results on asphalt mix with partial replacement of plastic aggregate made from Electronic waste at 0-15% replacement with 5% interval shows a considerable outcome. Testing conducted in this regard showed that marshal stability decreases continuously but performance against rut resistance increased considerably, as a result rutting depth decreased to 1.89mm, which showed the Optimum result at 10% of partial replacement of Electronic waste plastic aggregate. Beyond the 10 % content of partially replaced Electronic waste aggregate resistance to permanent deformation (rutting) reduces.

Research Study on this topic shows that with the depleting natural resources, Plastic aggregate can play an important role in sustaining the Natural aggregate to some extent, as it performed well against major problem like rutting.

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