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IMPACT OF LDPE ON THE PROPERTIES OF BITUMEN

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ABSTRACT

*Since the beginning of time, bitumen has been put to use as a binder in the creation of flexible pavements. The number of people living in an area as well as the total number of automobiles has led to steadily rising traffic levels on the highways. Therefore, roads that are made of unaltered bitumen experience a number of significant downsides over the course of time, including rutting, heat cracking, fatigue cracking, pothole formation, and other similar issues. As a result, it is essential to incorporate a modifier into the bitumen in order to improve the binding property of later. The high usage of polyethylene, which is a substance that cannot be broken down by natural processes, results in the creation of waste and contributes to pollution. This polyethylene, which has a melting point that ranges from 120 to 180°*C *and degrades thermally above 400 degrees Celsius, has a character that causes it to become sticky when it is in liquid form and can therefore function as a binder. Additionally, as the primary components of polyethylene and bitumen are both hydrocarbons, leftover polyethylene (both LDPE and HDPE) can be combined with bitumen in order to alter its properties and make it a more effective binder. Degradation of other polymeric wastes is similarly difficult, much as degradation of polyethenes, and it can be put to use for various purposes in order to reduce waste and improve the overall quality of items that are currently on the market.*

Keywords*- waste plastic; PET; HDPE; LDPE; penetration; DSR; ageing.*

INTRODUCTION

Asphalt is a composite material that is frequently utilised for the surfacing of roadways, parking lots, and airports, in addition to serving as the central component of embankment dams. In North America, it is also referred to as blacktop or pavement, whereas in the United Kingdom and Ireland, it is referred to as tarmac or bitumen macadam.

In its most basic form, asphalt may be broken down into three components: aggregates, binder, and filler. Bitumen, which performs the same function as cement does in concrete, is used as the binder to hold the aggregates together. This accomplishes the same goal as cement does in concrete.

The quality of the bitumen, which is a key component of asphalt, is extremely important since it plays a significant role in determining the asphalt's strength and its capacity to last for a long time. Over the years, people have been urged to improve the quality of the bitumen while bearing in mind the financial repercussions of their actions. It has been possible for many years to incorporate virgin polymers into bitumen with the goal of improving the properties of the polymer modified bitumen that is produced as a result. In recent times, there has been growing interest in the possibility of replacing virgin industrial materials with recycled polymers. It was pointed out by the author that when recycled polymers are utilised as bitumen modifying agents, the resulting mixture may show performance that is comparable to that of mixtures that comprise virgin polymer.

The alteration of bitumen is not a recently discovered phenomenon. Patents have been issued for naturally occurring and manufactured polymer modifications of bitumen as far back as 1923. The 1930s saw the construction of a number of experimental projects around Europe. The fact that polymers were first included into bituminous mixtures in Australia in the middle of the 1980s is evidenced by the country's current national asphalt requirements. In, it was proposed that the construction of roads in Malaysia could benefit from the use of rubberized bitumen. It was claimed in that bituminous materials acquired from different sources have varying amounts of different elements and, as a result, varied qualities. These differences in attributes can be attributed to the presence of distinct constituents. Tests including flash point, softening, and penetration tests need to be carried out on the materials in order to determine whether or not they are suitable for use as binders.

It has been discovered that polyethylene is one of the polymer additives that is the most effective. Polyethylene is by far the most common type of plastic used everywhere. Plastic is a material that has several uses. Plastic was produced on such a massive scale during the industrial revolution that it gave the appearance of being a more cost-effective and reliable raw material. The use of plastics has nearly changed every essential industry in the modern economy, beginning with agricultural and continuing through the packaging, automotive, electronic, and electrical industries, as well as the building construction industry. Several studies have shown that incorrect disposal of plastic wastes poses a significant risk to human and animal health, including reproductive issues in both humans and animals, genital anomalies, and other conditions. A complete prohibition on the use of plastic cannot be envisaged in the context of the current way of life; nonetheless, discarded plastic can be recycled and reused. As a result, the goal of this study is to investigate the feasibility of employing the waste polyethylene material (clean water sachet) as a bitumen modifier. Specifically, this will be done by looking into the possibilities.

The society currently suffers from two significant issues: (a) waste made of“non-degradable polyethylene, which remains in the environment for extended periods of time” (posing a significant threat to the wellbeing of living things as well as contributing to environmental issues), and (b) the requirement that bitumen be modified in order to lengthen the time that roads can remain in use. “Now, both polyethylene and bitumen are non-polar in their natural states, and the melting point of polyethylene is within a range that allows it to be mixed with bitumen. The” exploitation of waste polyethylene (and other polymeric) materials in the alteration of modified bitumen is therefore a single-line approach that can address both of these issues. Polymers are the most prevalent type of modifiers that are utilised in bitumen. Polyethylene terephthalate (PET), low density polyethylene (LDPE), high density polyethylene (HDPE), polystyrene (PS), and other types of polymers have all been the focus of studies as potential modifiers for bitumen. Among other polymers, polystyrene (PS) has also been investigated. According to Ho et al. (2006), one of the most crucial factors for LDPE to have in order for it to function as an effective bitumen modification is its molecular weight and how it is distributed. “The Marshal Stability test, the water absorption test, the bulk density test, and the extraction test were used to evaluate the modified bitumen/plastic blends that were" created by mixing waste LDPE with bitumen in percentages of five, ten, and fifteen percent. It was determined that the modified bitumen made using LDPE had increased strength in addition to improved performance. For the purpose of creating polymer modified bitumen, combined maleated bitumen with recycled LDPE rather than using pure bitumen. In previous studies it was shown that combinations of "maleated bitumen and recycled LDPE have higher softening point and greater elastic recovery, along with improved performance during storage and application in the field. In order to alter the properties of the bitumen made use of gamma-irradiated recycled low density polyethylene". According to the findings of the research, - LDPER has a stiffening effect on bitumen, which results in a reduction in the temperature susceptibility of the bitumen and an improvement in its performance grade. As a modifier for the bitumen, employed recycled polyethylene that was generated through the processing of plastic waste materials. When bitumen is modified, it becomes less sensitive to variations in temperature and the rate of thermal ageing, as well as the pace at which moisture damage can occur. The study demonstrated "that the internal structure of the polymer-modified bitumen can be determined with the help of a few straightforward tests; as a result, the optimal polymer-bitumen blend can be chosen".

In the current investigation, recycled low-density polyethylene (LDPE) served as a partial replacement for virgin polymers in the polymer-modified bitumen. LDPE is an abbreviation for low-density polyethylene. It is not possible to improve the low-temperature flexibility of bitumen simply by adding recycled polymers to it. In order to achieve this behaviour, a recoverable bituminous composition with recycled LDPE and styrene–butadiene–styrene (SBS) combination was formulated. The goal of this composition was to satisfy the minimum specified level of softening point (60°C) and elastic recovery. To accomplish this, the composition was made with recycled LDPE (50 percent at 15°C). The excessive quantity of SBS copolymer that is required makes this method prohibitively expensive despite the fact that it offers benefits in terms of the enhancement of the property.

OBJECTIVE OF STUDY

The aims "of the study are":

- "To prevent the loss of stability due to submergence in bitumen pavement".
- "To produce road which has relatively longer service life".
- "To lower the cost of construction of bituminous pavement by employing LDPE as the partial replacement of bitumen".

RESEARCH METHODOLOGY

A Stepped Approach to Grading Aggregates Aggregates was chosen according to the MORTH grade, which was provided in Table 1, for the purpose of preparing bituminous mix, also known as dense bituminous macadam. Following the selection of the aggregates and the gradation of those aggregates, the proportioning of the aggregates was carried out. The practice of trial and error, the graphical method, and the analytical method are all common methods used in the proportioning of aggregates. For the aim of grading, the graphical method was utilised in this investigation. The method developed by Rothfuch was utilised in the graphical method. The outcomes obtained using "Rothfutch approach is presented in table 1".

Table 1: “Results obtained from Rothfutch graph”

IS Sieves	% used	Wt. of Materials (g)
20 mm	25	300
12.5 mm	30	360
6 mm	25	300
S Dust	17	204
Filler	3	36
Bitumen	-	-
Total	100	1200

Marshall Stability Test

The Marshall stability of a compacted specimen of bituminous mix reveals the material's resistance to deformation when an incremental load is applied to it. This flow value represents the extent of the material's deformation that occurs as a result of loading or the material's flexibility. This evaluation is carried out on cylindrical samples of compacted bituminous mixture with diameters of 101.6 millimetres and thicknesses of 63.5 millimetres. The Marshall test that was used in this investigation “was carried out primarily in two distinct stages”:

- Preparation of Marshall samples
- Tests on samples

Preparing Marshall's representative samples

“This method requires the production of a number of specimens with varying bitumen levels, ranging from 3% to 7%, in increments of 0.5 percent, so that the test data curves can disclose clearly defined results. In order to deliver reliable results we produced two test specimens for every % of asphalt that was present. During the course of this research, two distinct types of asphalt concrete, namely unmodified bituminous concrete and modified bituminous concrete, were manufactured. In this context, unmodified samples refer to those samples in which there is no substitution of bitumen with plastic, while modified bitumen samples refer to those samples in which bitumen has been replaced with plastic (by weight of bitumen)”.

“Mixing and sample preparation”

“The mixing of ingredients was done as per the following procedure”:

- The aggregates and the filler were combined in the necessary proportions before being mixed together in order to meet the requirements of the design and achieve the desired gradation. Under controlled conditions, approximately 1200 grammes“of the sieved aggregates and the filler material were taken and heated to a temperature ranging from 175 to 190°C.
- The temperature of the bitumen binder was raised to anywhere between 120 and 165°C. When the aggregate was heated, the measured amount of bitumen, which would be equivalent to 3.5 percent of the aggregate's weight, was applied.
- “After that, it was thoroughly mixed at the temperature of 160 degrees Celsius, which is the optimum temperature for VG30 (60/70 penetration grade) grade bitumen. The

mixture was then poured into a casting mould and crushed using a rammer with 75 blows on either side of the sample at a temperature of 149 °C using VG 30 grade bitumen".

- "After allowing the specimens to reach room temperature in the mould, the compacted samples were extracted from the mould using a specimen extractor".
- The weight of the specimen was measured both when it was in air and when it was in water.
- The specimens were maintained submerged in water for 30 to 40 minutes in a thermostatically controlled water bath set at a temperature of 60°C plus or minus 10°C.

The Marshall examination of the samples

The resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is determined using this approach. The specimen is loaded diametrically at a deformation rate of 50 mm/min, and the measurement is taken while the specimen is under stress. The current research looked into "the Marshall qualities, such as stability, flow value, unit weight, and air voids". Using a graph that was very well defined, the data that were acquired were used to establish the optimal amount of binder to employ. Fresh asphalt mixes were created utilizing the optimal value once it had been determined what the optimal asphalt composition should be. After that, these samples were submerged in water for a period of time that ranged from one to four days. "Each compacted test specimen is put through the following battery of examinations and investigations as part of the Marshall technique of mix design".

a. Bulk specific gravity (Gb)
b. Stability and Flow test
c. Density and Void analysis

a. Bulk specific gravity (GB):

It was possible to determine the "bulk specific gravities of saturated surface dry specimens".

b. Stability and flow tests:

Following the completion of the bulk specific gravity of the test specimens' determination, the tests for flow and stability were carried out. After 30 to 40 minutes in the controlled water bath, the specimens were removed from the container, and the testing apparatus was then prepared. After then, the specimen was transferred to the Marshall Test head. The flow meter had its initial setting of zero when it was first used. The load was applied at a steady rate of 51 millimeters per minute of deformation while it was being exerted. Recordings were made of both the Marshall Stability Value, which is the greatest load that can be applied before the specimen breaks, and the associated flow value, which is the amount of deformation that the specimen undergoes up to the maximum load. It should not take more than a minute and a half to complete the entire testing procedure, which begins with the removal of the specimen from the bath and ends with the measurement of the flow and stability. While the stability test is being carried out, you have to firmly hold the flow meter above the guide road and make a recording.

"The process described above was carried out on a series of specimens for bitumen contents ranging from 3% to 7%, with increments of 0.5 % for each successive specimen. In this particular research project, the Marshall properties, which include stability, flow value, unit weight, and air voids, were investigated in order to determine the optimal binder amount".

Samples of modified bitumen will need to be prepared.

In this particular investigation, low density polyethylene (LDPE), also known as low density polyethylene, was utilised to partially replace "bitumen in DBM. The LDPE films were cut up into little pieces after" being shredded. After determining the ideal values for the binder content, LDPE films were included into the mixture. In order to determine the optimal amount of LDPE to incorporate into the samples, different percentages, namely 2%, 3%, 4%, 5%, and 6%, were used in terms of the weight of the total binder content. The dry process and the wet process are the two primary methods that are utilised in the production of bitumen mix by making use of waste plastic. In the current experimental work, a wet procedure was used to partially replace bitumen with plastic. This replacement was carried out. During the wet process, waste plastic was first shredded before being combined with bitumen according to a predetermined proportion. The resistance of bitumen to high temperatures can be improved through the addition of plastic to bitumen in certain proportions. In order to complete the preparation of Marshall samples, this mixture is next applied to the heated aggregates as described earlier.

Submergence

Both the unmodified samples of bitumen and the modified samples of bitumen were submerged in water for a period of time ranging from one to four "days. The samples were loaded, and the stability value was determined and recorded after each day of curing. The values were recorded after each day of curing".

Index of the body's retained strength (RSI)

The amount of striping in the mix that is caused by moisture and the consequent loss of stability that occurs as a result of a weaker link between the aggregates and the binder are both measured by retained stability. The Marshall machine, together with both its unmodified and its modified Marshall samples, were put through their paces in the test. Before and after immersion, the samples' stabilities were evaluated so that comparisons can be made.

$$RSI = \frac{S_i}{S_0}$$

Where,

S_i = stability after immersion at time ti or stability of conditioned specimen.

S_o= stability before immersion or stability of unconditioned specimen

RESULTS

"Marshal test for obtaining optimum binder content"

Table 2: Marshall Flow and stability values for the control mix

Bitumen%	Stability in kg	Flow value in mm
3.0	2300.0	3.60
3.5	2650.0	3.65
4.0	2725.0	3.75
4.5	2825.0	3.80
5.0	2112.5	4.30
5.5	2100.0	4.80
6.0	2087.5	5.00

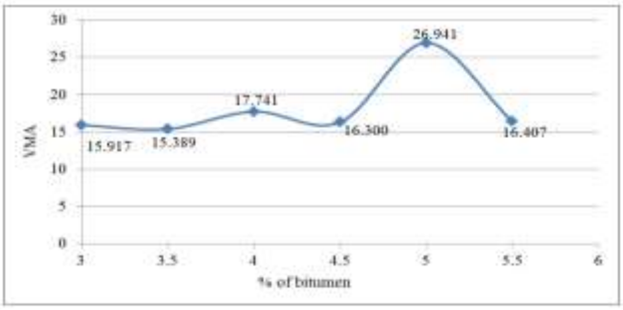

Fig. 1: VMA in Regular DBM

Table 3: Analysis of density and void volume for the control mix

Bitumen%	Gb	V	VMA	VFB
3.0	2.272	9.168	15.917	42.523
3.5	2.300	6.9120	14.925	53.688
4.0	2.249	7.9272	15.853	49.994
4.5	2.302	7.420	15.389	51.841
5.0	2.021	7.2905	16.347	55.402
5.5	2.327	10.3793	19.134	45.755
6.0	2.090	8.835	17.741	50.579

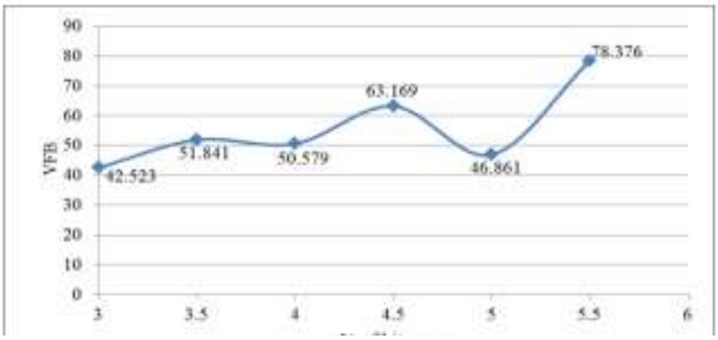

Fig. 2: "VFB in Regular DBM"

The Marshall test on the samples that were submerged

Two samples have been examined by the Marshall test to determine the proportion of LDPE present in each. Therefore, a score of 2 was chosen as the average. The table presents the values as their mean.

Table 4 shows the results of the Marshall Stability test on bituminous concrete after it has been soaked for one to four days at varied levels of LDPE substitution.

LDPE Content (%)	Marshall Stability Values (N) (average values)				
	Day-0	Day-1	Day-2	Day-3	Day-4
0	2800	1975	2287.5	1825	1050
2	2850	2400	2225	1900	1350
3	3175	2900	2450	2075	1625
4	3602.5	3325	3037	2690	2300
5	3000	3025	2625	2425	1950
6	2400	2012.5	1720	1595	1450

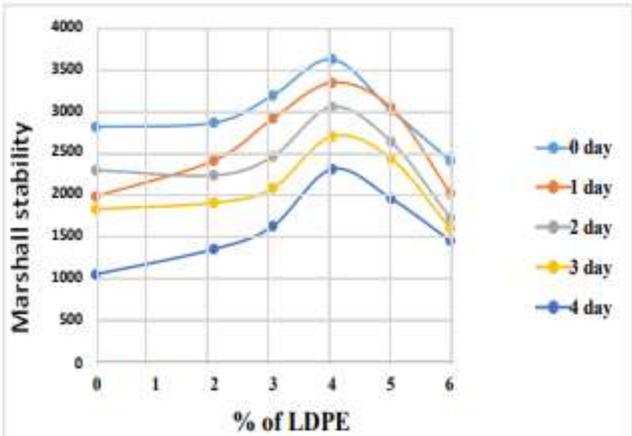

Fig. 3: Marshall stability vs. LDPE

DISCUSSIONS

The Marshall Stability value was shown to increase with an increase in bitumen concentration up to a specific bitumen content, beyond which it decreased. This was noticed from Fig. 1 to 3, where it was shown that the Marshall Stability value increases with an increase in bitumen concentration. The amount of bitumen in question is what's known as the "optimum binder content" (OBC). The results of this investigation indicated that the OBC for a standard DBM mix was 4.5 percent.

“It is possible to produce a reduction in the loss of stability of bituminous pavement by replacing some of the bitumen with low density polyethylene (LDPE). It was noted from the graph 5.9 that the Marshall Stability value steadily climbed from 0% to 4%, and then its value started declining. This was observed after the value had already started increasing. It was observed, based on the theory of retained Marshall Stability, that the addition of LDPE showed a reduction in loss in stability by increasing IRS value between 0 percent and 5 percent LDPE content; after that point, IRS value starts to decline. This was observed between the range of 0 percent to 5 percent LDPE content”.

When addressing concerns regarding the submergence of bituminous concrete, the index of maintain stability is one of the properties that is considered to be among the most significant. On the second day of soaking, the unmodified bituminous concrete had an IRS value of 84.80 percent, which was the highest percentage that could be produced. It was noticed, using graphs “5.09 and 5.10 that the modified bituminous concrete possesses” values that are significantly greater than those of the ordinary bituminous concrete. These observations were made. The maximum IRS values found for LDPE content ranging from 2% to 6% were 84.21 percent, 94.34 percent, 92.3 percent, 100.83 percent, and 83.85 percent, respectively. The addition of LDPE at a concentration of 5 percent produces the highest value of 100.83 percent, as shown in graph 5.10.

CONCLUSION

The findings of the studies that were carried out on bitumen that had been treated with low density polyethylene provide undeniable evidence that the addition of low density polyethylene to VG-30 bitumen leads to an improvement in the fundamental physical properties of bituminous binder. For the modification of VG-30 bitumen, the appropriate concentration of LDPE is four percent, measured as a percentage of the total mass of bitumen. It was investigated whether or not waste plastic may be utilised in Australian bitumen as a greener alternative to conventional modifiers. The findings point to the viability of including recycled plastic into the process of altering C320 bitumen. In compared to C320 bitumen, the waste PET samples that were aged for a longer period of time had a longer fatigue life, a lower rate of ageing, and a higher resistance to fatigue and cracking as shown by the findings of the long-term study. It has been shown that increasing the percentage of recycled PET plastic used, up to 8%, results in a considerable improvement in terms of the material's resistance to permanent deformation.

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