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APPLICABILITY OF LOW DENSITY WASTE POLYTHENE (LDPE) WITH BITUMEN IN TERMS OF ROAD CONSTRUCTION

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ABSTRACT

Significant amount of waste polythene is increasing day by day either by getting mixed with MSW (Municipal Solid Waste) or thrown over habitable land area causing environmental pollution. To confront this trend, molten polythene has been used as a modifier of bitumen as it possesses the binding property that can be used for road construction. To investigate the effect of waste polythene on the properties of bitumen, routine tests were performed on bitumen and modified bitumen as per AASHTO. The value of penetration, specific gravity, ductility, solubility decreased with the increase of polythene content with bitumen by 5 to 45% indicating the constant volume in hot weather, higher viscosity, resistance to heat, and also temperature susceptibility. The flash point and softening point increased with the increase of polythene content by 25 to 105 % indicating the reduction tendency of getting soft in hot weather and more susceptibility to temperature. The bulk specific gravity, stability, flow and OBC (Optimum Bitumen Content) of asphalt mixtures are affected by the addition of waste polythene. Due to higher elasticity of waste polythene, the stability and flow decrease with the increase in waste polythene contents. The values of stability and flow are both satisfied with the Marshall criteria. Addition of polythene with bitumen considerably increases the load carrying capacity and aggregate interlock with the decrease of pavement deflection. So polythene can be a good modifier of bitumen.

Key Words: *LDPE; Modifier; OBC; AASHTO; Pavement.*

1. INTRODUCTION

Population, urbanization and industrialization of asian developing countries have increased in which contribute to solid waste (SW) generation. For example, in India it was between 0.2 kg/capita/day and 0.5 kg/capita/day with 217 million people (Rajendra, 2012). Most of the wastes are non-biodegradable polythene. The common problems are lack of collection coverage, and open dumped landfill as the final disposal method. This disposal method gave the environmental pollution, such as the pollution of soil, surface and groundwater caused by leachate and GHGs emission caused by the waste decomposition process. An estimate of the future generation rate of waste in Dhaka indicates that the present generation rate of 3500 tons/day may exceed 30 thousand tons/day by the year 2020. The mixed waste dumped at dumping sites is characterized with high organic content and high moisture content (about 80% and 50-70%by weight, respectively) (JAEBS,2012) (Hai, F. Ibney. & Ali, M. 2005). Data were collected through pre-tested questionnaire from selected 21 BSCIC industries erected at different places of Mymensingh, Bogra and Rangpur districts. It was found that the waste generation from metal, plastic, aluminium, packaging polythene, LDPE and Soap industries varies from 2 to 9% of their total production capacity and 74.28%, 2.61%, 3.52%, 0.26%, 1.83% and 17.49% of total generated waste respectively (BSCIC, 2010) (Md. Mofizul Islam,June, 2006). Investigations in India and countries abroad have revealed that properties of bitumen and bituminous mixes can be improved to meet requirements of pavement with the incorporation of certain additives or blend of additives. (Biswanath Prusty, 2012). These additives are called “Bitumen Modifiers” and the bitumen

premixed with these modifiers is known as modified bitumen. Modified bitumen is expected to give higher life of surfacing depending upon degree of modification and type of additives and modification. Bituminous pavement are subjected to a variety of loading conditions which result in the development of internal tensile stresses. This source of failure which is likely to be induced in bituminous mixtures as a result of this inherent tensile characteristics in bituminous mixtures is cracking. A number of researchers have experimented with the use of various materials as additives and modifiers in bituminous mixtures. One of the major problems of Bangladeshi Roads is formation of Pot holes which usually occurs when vehicular loads induce shear stresses that exceed the shear strength of the materials contained in the pavement structure. This depends on vehicular loads and the visco-elastic properties of the bitumen binder. Bitumen binders are required to have high stiffness at high temperatures to resist rutting while talking to environmental pollution. In recent years, numerous waste materials result from manufacturing operations, service industries and households in which several millions of plastics are produced and plastics are not being readily biodegradable will persist in the environment in a more or less unchanged state of a considerable time. The need of the hour is to use the waste plastic in some beneficial purpose.

In this study an attempt was made to find solution to overcome above discussed problems. The aim of the project is to study the performance of Low Density Waste Polythene (LDPE) in modified bitumen. By doing this, we will be able to reduce the cost and also improve the performance of flexible pavement for future highways construction due to the involvement of a more environmental friendly materials. Here 80/100 garde bitimen has been used. Penetration Grade 80/100 is a standard penetration grade bitumen usually used as a Paving grade bitumen suitable for road construction and for the production of asphalt pavements with superior properties. Here 80 indicates minimum and 100 indicates maximum penetration value in milimeter.

There are several objectives that need to be achieved when completing this project. The objectives are, to compare, under controlled laboratory conditions, the performance of the bitumen modified with an optimum percentage of waste polythene using the standard 80/100, to evaluate the behavior of bituminous mix when added with waste polythene and compare the result with conventional bituminous mix, to assess the different engineering implications and physical characteristics with the addition of waste materials into the binder mixture, to evaluate the economical implication with the use of waste polythene modified bitumen mixture as compared with the standard mixture.

2. METHODOLOGY

For the binder the standard bitumen of 80/100 garde were used. The waste polythene were collected from the roadside waste garbage collectors and also from the domestic waste and dustbins. The polythene that has been used as modifier here is LDPE (Low Density Waste Polythene). This LDPE has been used because of some specific reasons. The LDPE is easily getable, very low costly, can be used very easily and less activities are needed to process it to use as modifier. Again HDPE (High Density Waste Polythene) is to some extent not properly available. That's the reaon why LDPE has been used here. The collected polythene wastes were washed, cleaned and dried. The polythenes were then shredded into very tiny pieces with klnife. The required quantities of polythene to be added with specified amount of bitumen for preparation of different percentage of polythene-bitumen. The blend were weighted and added in required percentage by weight of bitumen to the hot bitumen and the mixture was stirred well for about 30 minutes under temperature around 170-180°C. Clean waste polythene was shredded to 2-3 mm size which was used as recycled polythene. To investigate the effect of waste polythene on the properties of bitumen, five types of modified bitumen (MB) designated as MB_5, MB_{10}, MB_{15}, MB_{20}, MB_{25} by addition of 5, 10, 15,

20 and 25% of waste polythene in bitumen respectively. Routine tests and Marshall stability Test were performed on bitumen and modified bitumen as per AASHTO and test results were compared.

3. RESULTS AND DISCUSSION

Regular tests that were performed on conventional bitumen and modified bitumen and results of the tests are as follows:

Table 1: Conventional Test result performed on modified bitumen with different LDPE content

Types of Bitumen	Specific Gravity At 25/25^0 C	Penetration Test Value (mm)	Softening point Test Value (^{0}C)	Ductility Test Value (cm)	Solubility Test Value	Flash Point (^{0}C)
Conventional bitumen	1.01	81	45.2	79.6	96.7	340
5% LDPE	1.00	75	72	74.6	88.2	355
10% LDPE	0.99	69	68.8	65	83.5	365
15% LDPE	0.99	65	76	54.3	75.2	380
20% LDPE	0.98	57	84	49	69.2	400
25% LDPE	0.95	53	93	44	60.5	420

Table 1 shows the different test results performed on bitumen. From Table 1 it's been shown that the values were reduced from the roughly 100 mm of penetration to an average of 70 mm for LDPE. By norm the lower the penetration grade will imply a high viscosity, thus the modified bitumen has higher viscosity compared to standard bitumen. Another point to note would be the difference in terms of storage stability factor. This result shows that the modified bitumen has a large tendency for separation towards the top. The higher penetration value indicates the higher range of consistency. The softening point is generally higher for the polythene modified than the standard 80/100 grade bitumen. This phenomenon indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of polythene the modified binder will be less susceptible to temperature changes. The results show that the ductility decreases with the increases of polythene content. No correlations could be found to indicate the relevance of the ductility in terms of fatigue or rutting resistance of asphalt. Specific gravity result indicates that the resistance of the binder to the effect of heat is decreased and it will reduce its tendency to increase its volume in hot weather. Thus, with the addition of LDPE, the modified binder will be susceptible to temperature changes. The solubility is generally lower for the LDPE modified and the standard 80/100 bitumen due to the increase of impurities. This phenomenon indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather. Thus, with the addition of LDPE the modified binder will be less susceptible for pavement construction. The flash point is generally higher for the modified bitumen and the standard 80/100 bitumen. This indicates that the resistance of the binder to the effect of heat is increased and it will reduce its tendency to soften in hot weather.

Table 2: Marshall Test Result

LDPE (%)	Engineering Properties					
	Unit weight (lb./ft³)	Air voids (%)	VMA (%)	Stability (lb.)	Flow (0.01 in.)	OBC (%)
5	135.4	59	22.0	950	1.5	5
10	136.7	46	21.5	1022	1.7	
15	137.9	38	21.7	955	2.1	
20	138.2	32	22.2	750	2.7	
25	136.2	29	23.0	550	3.7	

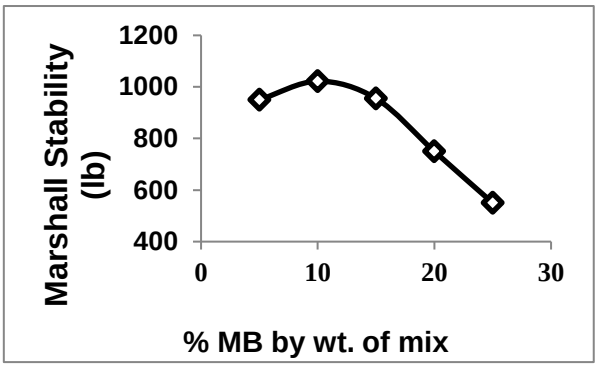

Figure: 1: Marshall Stability Vs. % MB wt. of

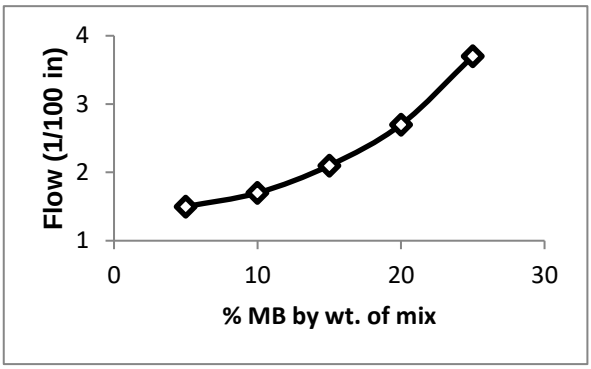

Figure: 2: Flow Vs. % MB wt. of mix

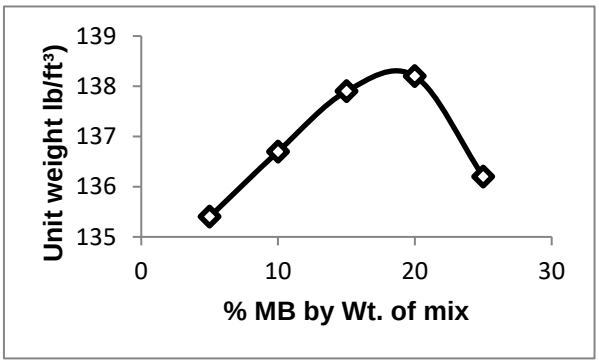

Figure: 3: Unit Wt. Vs. % MB wt. of mix

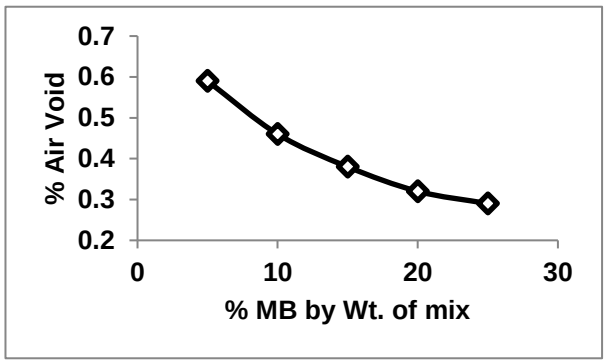

Figure: 4: % Air void Vs. % MB wt. of mix

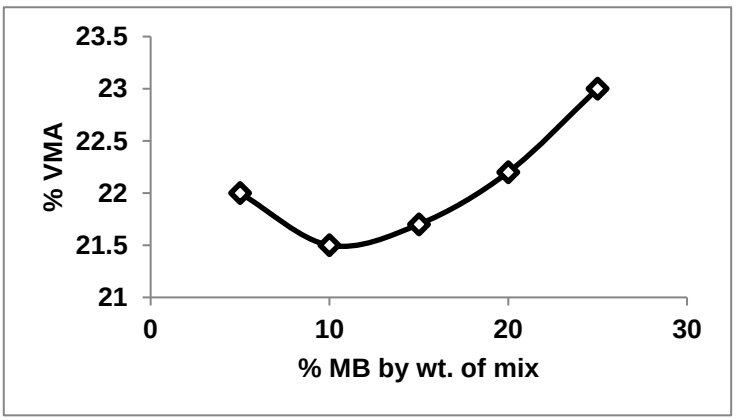

Figure: 5: % VMA Vs. % MB wt. of mix

From the figures 1,2,3 & 4 above, it was determined that maximum specific gravity is obayined at 5% of LDPE so as the other values decreasing from the tope with the addition of LDPE with bitumen. Thus, if average is taken of the values of LDPE the optimum bitumen content for the bituminous mixture is found as 5%. Table 2 shows the Marshal Test result where teh values for modied bitumens are provided. Marshal test was conducted on modified bitumen only and the variations of results were observed for differnet percentages of LDPE in bitumen. From table 2, it was found that the unit weight, stability, flow and OBC of bitumen mixtures are affected by the addition of waste polythene. Because the specific gravity of LDPE is far less than that of aggregate, the bulk specific gravity of LDPE modified asphalt mixtures decrease with the increase in waste polythene. Due to lower compressive strength and higher elasticity of waste polythene, the stability and flow decrease with the increase in waste polythene contents. The values of stability and flow are both satisfied with the Marshall criteria. The values of stability and flow are both satisfied with the Marshall criteria. The stability, VMA (%), and air void varied by 14%, 3.8%, and 39 % respectively. The same trend can be observed for Voids in Mineral Aggregate (VMA). With the addition of LDPE into the binder, the VMA reduced by 0.4% respectively. These variation were detemined by simple arithmatic calculation as the table shows the variations of results in case of stability, flow, % Air void and % VMA. Addition of polythene has considerably increased the load carrying capacity and aggregate interlock with the decrease of pavement deflection.

4. CONCLUSIONS

From the study, the following can be concluded that-

The incorporation of LDPE affects the properties of the conventional bitumen. This can be seen through the penetration and ring and ball test whereby the binder properties are observed to undergo changes due to the addition of the LDPE. From the penetration test results, the penetration values of LDPE modified bitumen are lower than the conventional bitumen. The penetration values decreased from around 100 mm for conventional bitumen to around 70 mm for LDPE modified bitumen respectively. This means that the incorporation of both additives results in the increase in stiffness of the conventional bitumen. The same trend can be observed for the ring and ball test. The test results show that the softening point value increased from 43°C for conventional bitumen to around 50°C for LDPE modified bitumen respectively. Hence, the inclusion of both the additives into the conventional bitumen increases the viscosity of the conventional bitumen. Besides that, in terms of storage, it can be concluded that modified bitumen are not suitable for long-term storage. After mixing with additives, modified bitumen should not be stored temporarily because separation process will occur between the bitumen and the additives. This is due to the fact that the LDPE did not dissolve fully in the mixing process and thus after it was stored for one day, separation process occurred.

For this study the mixture components selection were done in accordance with JKR recommendations. The mixture components consist of granite as the coarse aggregate, the river sand as the fine aggregate and the Ordinary Portland cement (OPC) as the filler. For the binder the standard bitumen 80/100 were used. One waste materials that have been identified are LDPE. The properties of the bituminous mixtures were determined from the results of the Marshall.

From the results the following conclusions can be drawn:

- The stability load increased extremely with the addition of LDPE. This is due to the formation of a stronger binder proving the formation of the binding gel.

- For LDPE modified mix has the lowest value of flow but the difference is roughly around 0.5mm compared to the conventional mix which is not that significant.
- The porosity of the binder is reduced with the addition of LDPE. The proportion of voids decreases with addition of LDPE which is justified by a courser binder resulting from the partial digestion of the crumb LDPE in the reaction with bitumen.

The result of Marshall Test that the influence on engineering properties of the LDPE modified bituminous mixture are not that significant except for the stability where the stability of the bituminous mixture improves tremendously after LDPE is added as additive into the bitumen.

4.1 Issues Identified & Recommendations for Further Research

This study presents laboratory findings of the influence of incorporating LDPE as additives to the binder and investigates the effect on the binder properties and the performance of the bituminous mixture. However, for a better assessment on their influences as additives to the binder as well as to verify and validate the results obtained in this investigation, the following recommendations are suggested:

In terms of modification of binder, there are other aspects affecting the performance of binder such as:

- The Type of Polythene – different polythene have different properties. For example, LDPE, HDPE etc.

- The proportion of LDPE added to the standard bitumen – Previous investigations have shown that the amount of additive added can cause adverse effect if too much or too less amount is added to the bitumen. Hence, further study need to be conducted using different percentage of additive to know the optimum content.

- The Temperature – The influence of temperature is known to be one of the factors to influence fatigue response of material. In this study, the performance test was only carried out at only one temperature. Therefore, in order to better understand the performance, test should be carried out at various temperatures preferably between the lowest and highest temperature the pavement may be exposed.

- The compatibility between the LDPE with the bitumen – It was mentioned earlier that the additives failed to dissolve completely in the bitumen after mixing. One thing that can be done to improve this is to conduct study by adding certain solvent such as extender oil or maybe gasoline to ensure the additives can dissolve completely. It is reported that the addition of extender

- Storage stability – Further study can be conducted to see how long a modified binder can last before separation process occur prior to mixing of bituminous mixture. It would be beneficial if the optimum storage can be estimated for economic purpose.

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