Performance Evaluation of Household Waste Plastic as Additive in the Bituminous Mix Design

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Abstract— Recently the frequency of traffic in the road has been augmented day by day. That's why the strength of bituminous road should be increased. To increase the strength of bituminous mix design, many additives such as sulphur, rubber, organic polymer and plastic are added with the bitumen. In this study the household waste plastics were used as an additive in bituminous mix, as huge amount of non-biodegradable plastics have been wasted in every day. It is not possible to recycle all of these plastics. However the waste management operation for these waste plastic is also very difficult due to insufficient land and poor system. Thus the soil is polluted in a great extent as well as the environment. The aim of this study is to reuse these plastic as an additive of bituminous mix design. Also another aim of this study is to justify the strength of bituminous mix design by using these plastic. In this study household waste plastics were mixed as a percentage of 15, 20, 25 and 30 with the bitumen content of percentage 4.5, 5, 5.5, 6 and 6.5 of total aggregates. As a result, the optimum bitumen content have increased for 15%, 20% and 25% plastic but slightly decreased when 30% plastic is used. It is found that the amount of bitumen content is declined with the increase of plastic content with good strength. It is also found that the fire and flash point, penetration, ductility value has decreased but the softening point value and specific gravity are increased due to the increase of plastic in mix design. The flow value is increased up to 25% plastic then it started to decrease. The Marshall Stability value is amplified gradually with the increase of plastic content. Hence it can be used in warmer region for better durability and strength of road surface. It will minimize the cost of road construction and environmental pollution.

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Index Terms— Marshall Stability, bitumen, Mix design, plastic additives, compressive strength, flow value.

1 INTRODUCTION

The traffic volume has increased in a great extent in the road all over the world in present year. But the strength of the road surface are not sufficient to carry this heavy load of traffic. As a result the road surface has less serviceability, because the roads are carrying more traffic load then the designed value. So the strength of the bituminous road surface should be increased. But it is expensive and time consuming and it is also indefinite that when does the traffic volume will increase in a specific road. Hence it is required to increase the strength of road surface. From this point of view different studies have performed to increase the strength of road surface by using different materials like sulphur [1, 2] organic polymer [3, 4], polyethylene, and plastic with bitumen as additive. The waste plastic that used for modification of bitumen for paving purposes is generally styrene-butadiene-styrene copolymer styrene-butadiene-rubber [5]. Most of these polymers are not available found. For this reason everyone have to choose the materials which are found easily.

From this point of view high density waste cover plastic of television remote, television, radio, computer have been used for modification of bitumen.

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At present many investigations are performed for improving the properties of bitumen by using styrene-butadiene-styrene or commonly known as rubber. The main source of rubber is rejected tire of various vehicles. In Turkey an investigation is done for increasing the moisture susceptibility of hot mix asphalt [6]. In this investigation penetration test and softening test are performed. In our investigation we have tried to performed penetration test, softening point test, flash and fire point, ductility test, specific gravity test to show the improvement of properties of bitumen after mixing with plastic.

Polymer materials are also used to improve the properties of bitumen. Waste polymer is used for improving the properties of bitumen in India [7]. Some kinds of polymers are costly, that's why it increases the construction cost. Polymer materials are generally shellac, amber, wool, silk and natural rubber. Synthetic polymers are generally synthetic rubber, phenol formaldehyde resin (or Bakelite), neoprene, nylon, polyvinyl chloride (PVC or vinyl), polystyrene, polyethylene, polypropylene, PVB, silicone. Among these some are costly and some are not easily found. Polystyrene also improves the properties of bitumen. Expanded polystyrene is widely used in the industry, as a packaging material, construction material and in house hold appliances [8]. But for the developing country like Bangladesh it is not easily available all over the country especially in non-industrial area.

Keeping all these things in mind as a guideline for further renewal of bitumen to increase the strength, modification of bitumen is necessary for the present investigation and this

modification is made by using waste plastic

2 MATERIALS AND METHODOLOGY

2.1 Plastics

Particular type of household waste plastic, purchased from the salvage yard where the unused waste household plastics are collected and smashed into small pieces. Most of these plastics possessed high density and generally black in color. After smashing these small pieces are sent to the recycle factory to recycle them for further uses. In general these plastics are chemically known as acrylonitrile-butadiene-styrene. Basically these types of plastics are used to made remote case, cover of radio and television computer monitor case, toys and other household materials. General properties of these plastics are given below:

i) Specific gravity: 1.00 to 1.06

ii) Density: high

iii) Maximum service temperature: 80-95˚C

iv) Softening point: 100˚C

v) Size: 0.5 to 2 cm

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2.2 Bitumen

In this experimental research the bitumen have used contain the following properties

i) Penetration grade: 80/100
i) Specific gravity: 1.024
ii) Ductility value: 100+
iii) Flash point: 260˚C
iv) Fire point: 295˚C
v) Softening point: 48˚C
vi) Solubility. 97.84%

2.3 Fine aggregates

The grade of fine aggregate are 2.36 mm passing and 600 µm, 300 µm, 150 µm and 75 µm retained. Specific gravity of fine aggregate was 2.476.

2.4 Coarse aggregates

At first the larger pieces of stone were broken into small pieces as experimental requirement. These aggregates then passed through 20 mm sieve and retained through 12.5 mm, 9.5 mm, 4.75mm, and 2.36 mm sieves consequently. Specific gravity of coarse aggregate was 2.892.

2.5 Mineral filler

The residuals obtained after sieving the fine aggregate in soil lab by mechanical shaker was the mineral filler. These filler passed through the 75 µm sieve. Specific gravity of mineral filer was 2.457.

2.6 Working Principle

The samples were prepared by adding plastic with bitumen. The addition of plastic with pure bitumen is done on the basis of weight percentage of pure bitumen. Different samples were prepared for different percentages of weight.

At first fresh bitumen, without any debris and adulterants was collected. The properties of pure bitumen were justified. Then for the preparation of samples, required five bowls were taken and weighted. These bowls were filled with hot bitumen. Then the combined weights of bitumen with bowls were measured. After that weight of bitumen was calculated. Equivalent weights of plastic were measured for 15%, 20%, 25% and 30% of bitumen respectively. For each percentage of plastic, samples were prepared. The prepared samples then started to heat until the samples liquefied fully and at the same time plastic was reached into dissolved state. The soften form of plastic were floating on the hot bitumen. But after continuous stirring by steel spoon it was thoroughly mixed with bitumen. Then the mixtures were kept in room temperature a duration of 24 hours for cooling. After that the flash and fire points of the mixtures were determined. There was no change in color of bitumen as the plastic was black. These mother samples were kept for further experiments. Thus five samples were prepared with variable plastic content. The preparation of specimen and the heating process was done simultaneously. The proportion of five samples were given below,

- Sample 1: 0% plastic + 4.5%, 5%, 5.5%, 6%, 6.5% pure bitumen
- Sample 2: 15% plastic + 4.5%, 5%, 5.5%, 6%, 6.5% pure bitumen
- Sample 3: 20% plastic + 4.5%, 5%, 5.5%, 6%, 6.5% pure bitumen
- Sample 4: 25% plastic + 4.5%, 5%, 5.5%, 6%, 6.5% pure bitumen
- Sample 5: 30% plastic + 4.5%, 5%, 5.5%, 6%, 6.5% pure bitumen.

In this study 80/100 grade bitumen were used. The aggregates and filler are mixed together in the desired proportion as per the design requirements and fulfilling the specified gradation. Approximately 1200g of aggregates and filler are taken and heated to a temperature of 170˚C to 190˚C. The mixing temperature for 80/100 grade bitumen was kept around 154˚C. Preparation at each trail of bitumen content started from 4% and o.5% increments up to about 6.5%. Firstly the bitumen having 0% plastic are used. Then 15% plastics were used 5% increments up to 30% plastic. The study is performed for medium traffic. Every specimen required 50 blows in each side. The specimens to be tested are kept immersed under water in a thermostatically controlled water bath maintained at (60±1)˚C for 30 to 40 minutes. The specimen are taken out one by one, placed in Marshall Stability test head and the Marshall Stability value (maximum load carried in KN before failure) and the flow value (the deformation of specimen undergoes during loading up to the maximum load in 0.25 mm units) are noted. The corrected Marshall Stability value of each specimen is determined by applying the appropriate correction factor

3 RESULT AND DISCUSSION

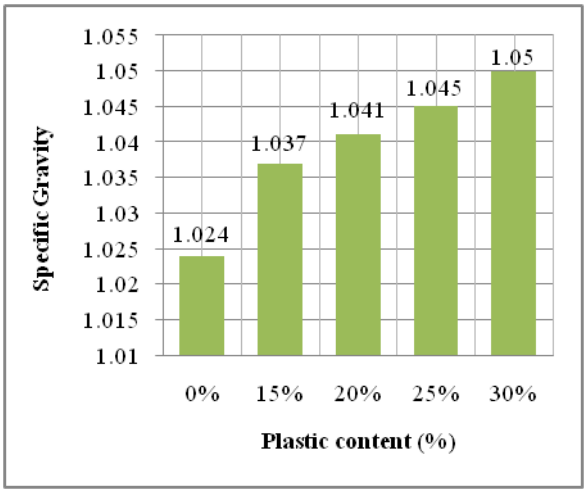

Figure 01: Variation of specific gravity with respect to plastic content

Figure 01 shows that the specific gravity gradually increased with the increase of plastic content in the bituminous mix as the plastic has high density than the pure bitumen.

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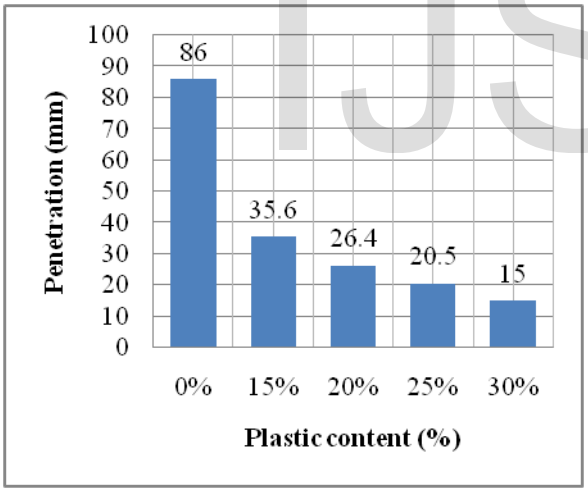

Figure 02: Variation of penetration value with respect to plastic content

From figure 02 it is clearly seen that the penetration value is gradually decreased with the increase of plastic content in bituminous mix as a result plastic mixed bitumen became harder than the pure bitumen.

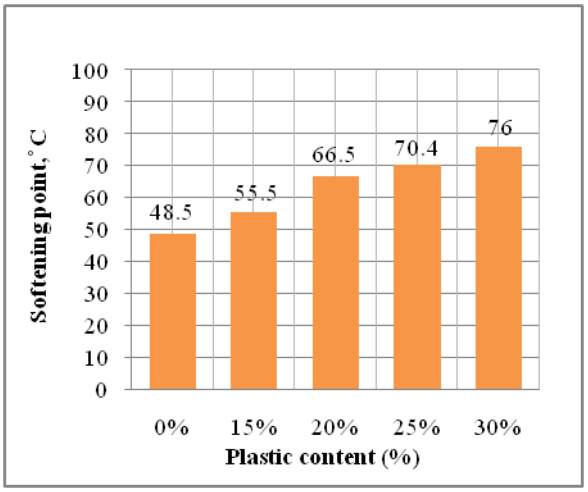

Figure 03: Variation of softening point with respect to plastic content

Figure 03 represents that softening point is increased with the increase of plastic content in bituminous mix. Hence it required high temperature for liquefied. As a result it can be used in warmer region.

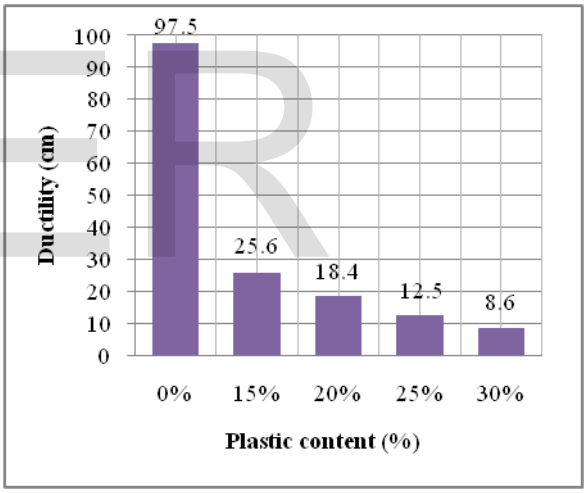

Figure 04: Variation of ductility value with respect to plastic content

For bituminous mix design the ductility value should be between 5 to 100 mm. But for pure A 65 to 200 grades bitumen the minimum ductility value should be obtained is 15 cm [10]. But in this investigation it is decreased gradually with the increase of plastic content which shows at figure 04. Hence for road surfacing or mix design up to 25% plastic can be used safely with bitumen content.

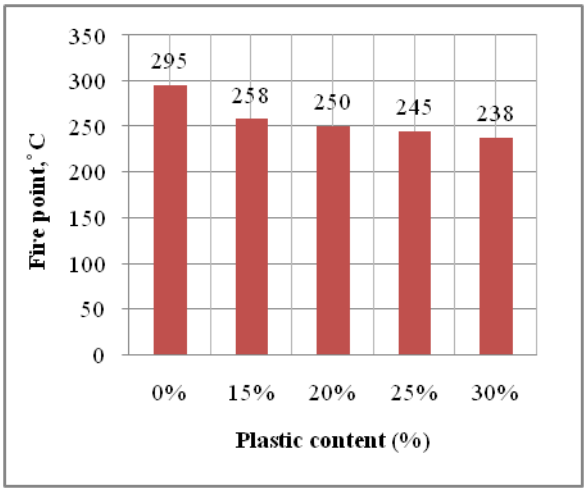

Figure 05: Variation of fire point with respect to plastic content

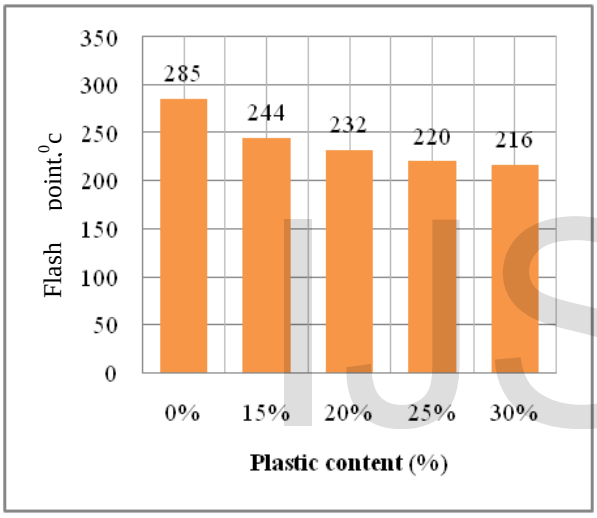

Figure 06: Variation of flash point with respect to plastic content

Figure 05 and 06 indicates that Flash and fire point is decreased with the increased of plastic content as a result the vapour will comes in the form of flash and fire in a lower temperature than the pure bitumen.

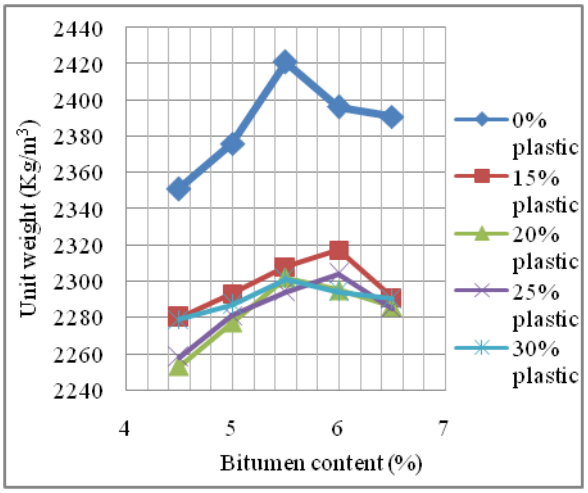

Figure 07: Combined variation of unit weight with respect to bitumen Content (%)

From figure 07 it is clearly seen that when 0% plastic are used, the unit weight is maximum which around 2421 Kg/m^3 and minimum for 20% plastic content which around 2253 Kg/m^3. The value of unit weight for 0% plastic curve increases with bitumen content up to 5.5%. After that with the increase of bitumen content the value of unit weight decreases. For 20% and 30% plastic the curves increase up to 5.5% and then decreases. Similarly for 15% and 25% plastic it increases up to 6% and then decreases.

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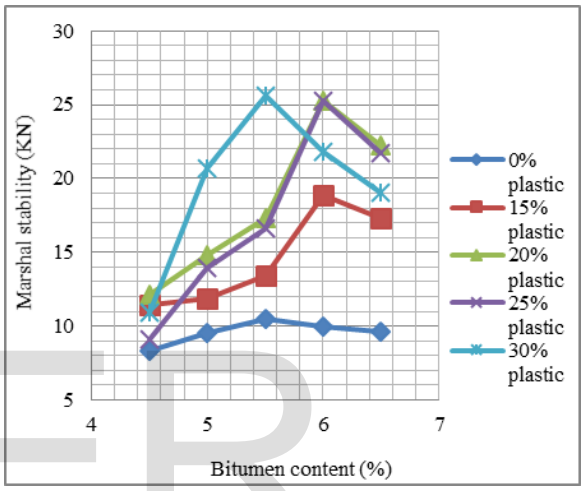

Figure 08: Combined variation of marshal stability with respect to bitumen content (%).

Figure 08 shows that the Marshall Stability curve is gradually increase with the increase of plastic content. When 30% plastic is used, the marshal stability is maximum which around 28.33 KN and minimum for 0% plastic which around 8.29 KN. For 30% plastic the value is increased gradually up to 5.5% bitumen content and after that the value was started to decrease. For 0%, 15%, 20% and 25% plastic the maximum value of OBC is obtained at 6%, 6%, 6% and 5.5% bitumen content respectively and after that the curves started to de-crease.

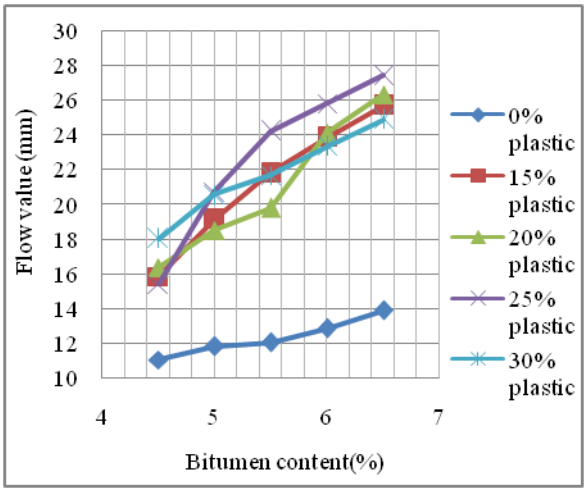

Figure 09: Combined variation of flow value with respect to bitumen Content (%)

The flow value is found to be maximum for 25% plastic content and it is 27.4 mm and minimum for 0% plastic which is around 11.04 and that is indicated by figure 09. The other flow value curve for 15%, 20% and 30% plastic content shows the similar change.

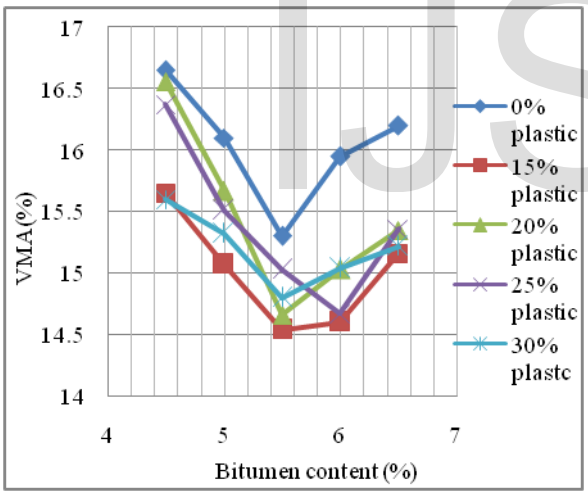

Figure10: Combined variation of VMA and bitumen content (%)

From figure 10 indicates that for 0% plastic curves VMA (%) is maximum which is around 16.65% for. The value of VMA (%) decreases with the increase of plastic content up to 5.5% of bitumen content. After that with the increase of bitumen content the VMA (%) is increasing. The minimum VMA (%) is obtained for 15% plastic which is around 14.6%. The obtained curve for 15% is decreases up to 5.5% bitumen content and after that it also increases with the increase of bitumen content. VMA (%) was started to increase. For 15%, 20% and 30% plastic curves the minimum value was obtained at 5.5% bitumen content and for 25 % plastic it was obtained at 6% respectively.

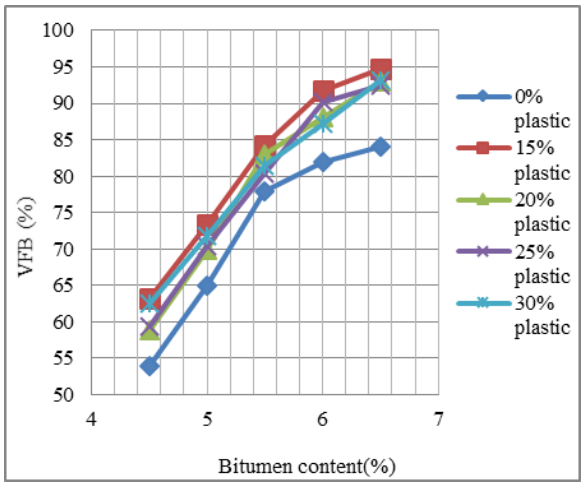

Figure 11: Combined variation of VFB with respect to bitumen content (%)

Figure 11 shows that among the 0%, 15%, 20%, 25% and 30% plastic graph maximum percentage of VFB (%) was found for 15% plastic and it was around 94.72%. Minimum VFB (%) was found for 0% plastic and it was around 54%. Similarly all other graph for different percentage of plastic shows the similar pattern of change.

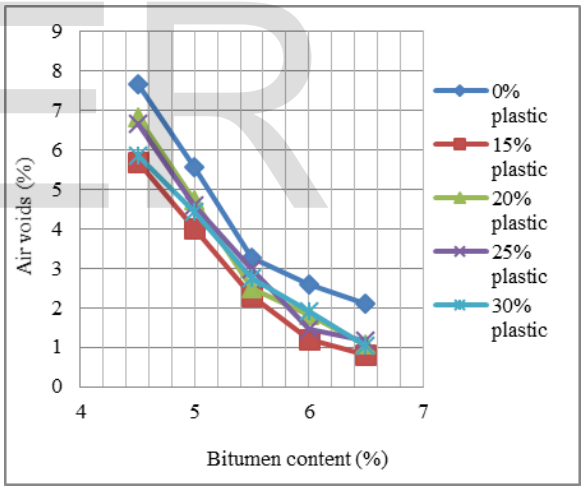

Figure 12: Combined variation of air voids with respect to bitumen content (%)

Figure 12 clearly shows that the minimum and maximum air voids (%) are obtained for 15% and 0% plastic curves, which were around 0.81% and 7.65% respectively. Other curves for different plastic content represent the same pattern of changing.

From overall result it was noticed that unit weight decreases with increased plastic content shown in figure 07.The Marshall Stability increases with increased plastic and the maximum value is obtained for 30% plastic content shown in figure 08.The flow value also increased with increase of plastic content and the maximum value is obtained for 25% plastic content shown in figure 09.For VMA and air voids the

maximum and minimum value is obtained in 0% and 15% plastic content respectively which shown in figure 10 and 12. The maximum and minimum value for VFB is obtained in 15% and 0% plastic content respectively as shown in figure 11. Hence from the above analysis it was easily observed that the strength of bituminous mix design is developed.

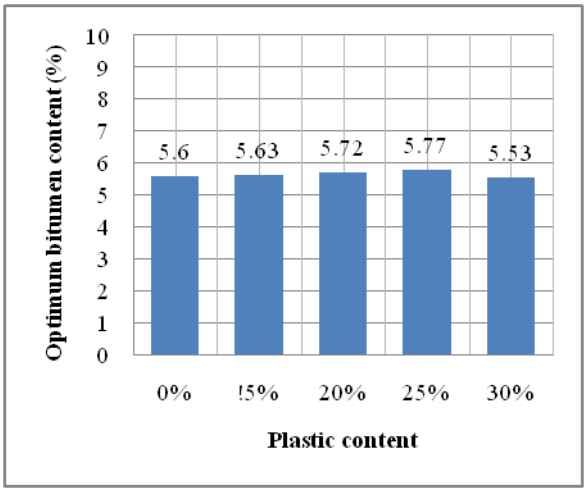

Fig13: Variation of optimum bitumen content with respect plastic content

From the analysis of graph, it has been observed that optimum bitumen content is increased with the increase of plastic content up to 25% plastic and for 30% plastic it decreases which is noticed in figure 13.

4 CONCLUSIONS

On the basis of the test results and subsequent discussions following conclusions have obtained.

i) The optimum bitumen content has been slightly increased when 15%, 20%, 25% plastic used but slightly decreased when 30% plastic content is added in mix. As a result the amount of bitumen content in mix is decreased as the plastic is used as an additive.

ii) Marshall Stability has increased with the increase of plastic content and Flow value has also increased with increasing plastic content up to 25% plastic.

iii) It is found that the value of penetration, ductility, flash and fire point have decreased but the softening point and specific gravity have increased with the increase of plastic content in bituminous mix. As a result the mix has become harder than pure bituminous mix due to presence of household waste plastic. As the ductility value is important for stability of road, so it can be possible to use 25% plastic content in bituminous mix. Besides, it is also suitable to use in warmer region like Bangladesh or Middle East country.

iv)) It is found that household waste plastics can be used with bitumen as an additive in bituminous mix design due to higher strength which lies between the standard value of strength.

ACKNOWLEDGMENTS

Authors want to show their utmost gratitude to Omnipotent Allah; without His clemency and blessing, nothing comes true, so does this research. The author are grateful to Dr. Md. Mahmud Sazzad who is the professor of Civil Engineering Department of RUET for his shrewd and sagacious demonstrations about the guide lines of writing this paper. The author also want to give thanks to laboratory technician of RUET for their kind full co-operation hands.

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