Proceedings of the
International Conference on Engineering Research, Innovation and Education 2013
ICERIE 2013, 11 - 13 January, SUST, Sylhet, Bangladesh

Experimental Behavior of Waste Polyethylene and PVC on the Compressive Strength of Bituminous Mixes

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Keywords:
Modified bitumen, optimum bitumen content, compressive strength, moisture susceptibility, index of retained strength

Abstract: As a binding material, bitumen is widely used for the construction of wearing course of flexible pavement. The durability of the bituminous mix can be enhanced by use of a binder formed by modifying available bitumen with certain additives like sulphur and organic polymer. The modified binder also improve temperature susceptibility and viscosity characteristics and help alleviating some common problems like bleeding of binder during peak summer temperature and stripping of aggregate in moisture prone areas. The aim of this study is to use of polyethylene and PVC as admixture to bitumen to introduce high quality bituminous mixes for the road construction. This investigation presents some of the experimental results regarding the effect of water on the compressive strength of compacted bituminous mixes with waste polyethylene and PVC. In this investigation 10% waste polyethylene and 7.5% waste PVC was added to the pure bitumen as an admixture to study the compressive strength of the mix. Marshall mix design procedure specified by AASHTO T245-82 was followed in the design and testing of bituminous mixes. On the basis of experimental results of this investigation, optimum bitumen content (OBC) for pure bitumen, polyethylene modified bitumen and PVC modified bitumen were 5.3%, 5.2% and 5.27% respectively. To investigate the effect of water on the compressive strength of bituminous mixes with modified bitumen, specimens were prepared and tested according to the procedures specified by AASHTO T165-86. In this study, the index of the retained strength for both polyethylene and PVC modified bitumen were 89.89% and 85.06% respectively which satisfy the limiting value 75% specified by the ASTM.

1. INTRODUCTION

Properties of bituminous mixtures depends upon the quality of binder and the amount and mineral composition of aggregates, the grading and shape of the grains, micro coarseness and activity of filler. Continuous increase of wheel load, tire pressure and change in climate condition severely affect the performance of bituminous mix pavements. The performance of the bituminous mix can be improved by modification. The polymer can be used as a modifier in bituminous mixture (Shbeeb and Awwad, 2007). Many investigations show that addition polymer like styrene-butadiene-styrene (SBS), copolymer styrene-butadiene, ethylene vinyle accetate (EVA), rubber latex, polypropylene etc. increase adhesion and cohesion, strength properties, stiffness, rutting, fatigue, and impact resistance of the mix. The addition of polymers typically increases the stiffness of the bitumen and improves its temperature susceptibility. Increased stiffness improves the rutting resistance of the mixture in hot climates and allows the use of relatively softer base bitumen, which in turn, provides better low temperature performance (Catt, 2004, Coplantz. et al., 1993, Newman K., 2004). Several polymers are avoided due to its high cost. In this investigation, waste polyethylene and PVC is used as admixture to bitumen which are locally available at negligible cost in our country. Rahman et al. (2012) and Rasel et al. (2011) recommended that, 10% waste polyethylene and 7.5% waste PVC can be mixed as admixture to bitumen for construction of flexible pavements respectively.

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Waste polyethylene and waste PVC are used as the modifiers in this investigation. This investigation is to carry out the comparative study of behavior of the bituminous mixes with 10% waste polyethylene and 7.5% PVC. The main aim of this study is to make comparison of compressive strength of modified bitumen with pure bitumen and to check the effect of water on the compressive strength whether the waste polyethylene and PVC are applicable or not.

2. LABORATORY STUDY AND TEST RESULTS

A bituminous mix is normally composed of aggregates and bitumen. Aggregates are generally divided into coarse, fine and filler fractions according to the size of individual particles. Aggregates have to bear load stresses occurring in the roads and have to resist wear due to abrasive action of traffic. Bitumen content in mix ensure proper bond together with durable pavement under suitable compaction. Thus the properties of aggregates and bitumen are of considerable significance for proper bituminous mix design.

2.1 Material Properties

In this investigation, crushed basalts retained on 2.36 mm sieve were regarded as coarse aggregate (The Asphalt Institute, 1984). Fine aggregate portion of the aggregate blend (passes 2.36 mm and retained on 0.075 mm sieve) was taken from coarse sand. Non-plastic sand finer than 0.075 mm sieve was used as mineral filler. Properties of mineral matter were determined according to the test procedure specified by American Association of State Highway and Transportation Officials (AASHTO) and results are given in Table 1. Binder material was penetration grade bitumen that was collected from crude oil refinery. Routine tests as per AASHTO were performed on the bitumen sample used in this study and get the properties: Specific Gravity, 1.022; Penetration (0.1mm), 83; Solubility value, 98.55%; Ductility value, 100^+ cm; Flash point, 295°C; Fire point, 305°C; Softening point, 44°C; Loss on heating, 0.29%.

2.2 Mix Types

The following three bituminous mixes were prepared in this investigation:

Mix I: coarse aggregate+ coarse sand + fine sand (filler) + pure bitumen.
Mix II: coarse aggregate+ coarse sand + fine sand (filler) + bitumen with 10% polyethylene.
Mix III: coarse aggregate+ coarse sand + fine sand (filler) + bitumen with 7.5% PVC.

At least 3 specimens were prepared for each bitumen contents and at least 5 bitumen contents were used with increments of 0.5 percent for all mix types. The particle size distribution of this study is shown in Figure 1. This gradation was used for the preparation of bituminous mixes with above three mix types.

Table 1: Properties of mineral aggregate

Properties	*Coarse aggregate*	*Fine aggregate*	*Filler*
Unit weight, dense, (kg/m^3)	2640	2350	2300
Unit weight, loose, (kg/m^3)	2610	2342	2260
Bulk specific gravity	2.64	2.35	2.30
Apparent specific gravity	2.67	2.74	…
Absorption of water, %	0.33	5.94	…
Los Angeles Abrasion, %	30.86	…	…
Soundness($MgSO_4$,5cycle), %	20	…	…
10% fines value, kN	120	…	…
Aggregate Crushing value,%	16.59	…	…
Aggregate Impact Value,%	10.88	…	…

2.3 Laboratory Investigation

To ascertain the optimum bitumen content (OBC) for selected bituminous mixes, Marshall test specimens of 101.6 mm diameter and 63.5 mm thick were prepared for medium traffic requires 50 blows per side of the specimen as per AASHTO T245-82 by varying bitumen content. The number of blows for the preparation of specimen was selected corresponding to 690 kN/m^2 (100 psi) tyre pressure. The bulk specific gravity of compacted specimens were determined according to the test procedure specified by ASTM 2726. After determination of the bulk specific gravity, the specimens were then subjected to Marshall stability and flow tests as per AASHTO T245-82. Voids analysis was made for each series of test specimens after the completion of the stability and flow tests. The variations of bulk density, Marshall stability and air voids in total mix with bitumen contents were plotted and shown in Figure 2, 3 and 4 respectively. The bitumen content at maximum density and at maximum stability is determined from Figures 2 and 3 respectively. For bituminous concrete, bitumen content at 4 percent (median of 3-5 percent range) air voids in total mix is determined from Figure 4. The average of these three bitumen contents is taken as OBC. Optimum bitumen content (OBC) for Mix I, II and III were found 6.5 percent 8.5 percent and 10.5 percent by weight of total mix respectively.

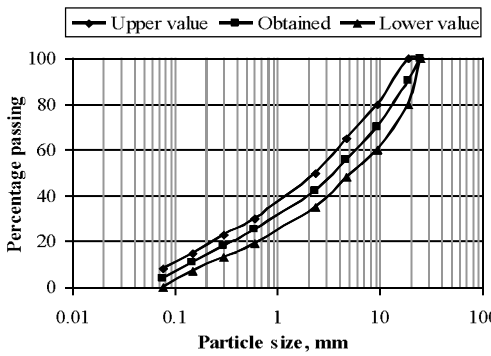

Fig. 1: Particle size distribution

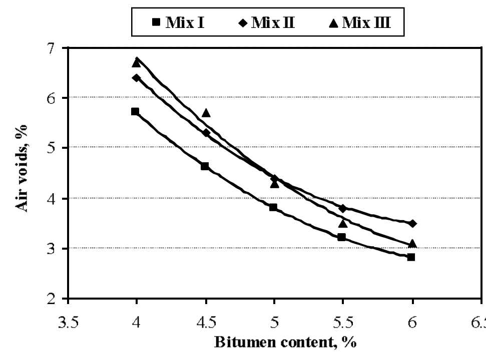

Fig. 3: Relationship between air voids and bitumen content

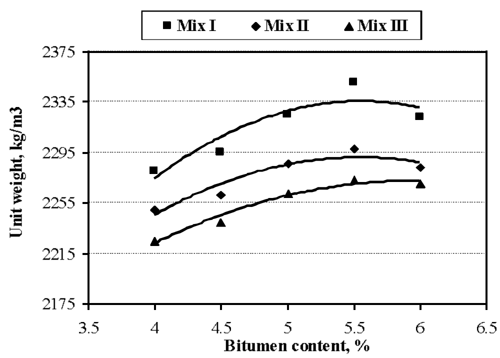

Fig. 2: Relationship between unit weight and bitumen content

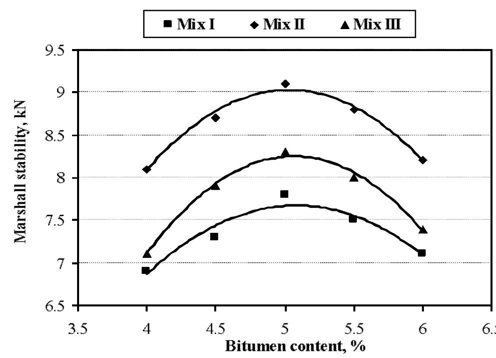

Fig. 4: Relationship between stability and bitumen content

To investigate the reduction of compressive strength of bituminous mixes with polyethylene and PVC for different soaking periods, compacted bituminous mix specimens of 100 mm diameter and approximately of the same height of 95 mm were prepared according to the procedures specified by AASHTO T167-84. Specimens were prepared for Mix I, II and III. Bitumen content was kept constant at OBC to give higher strength. Procedures specified by AASHTO T165-86 have been followed to investigate the effect of water on the compressive strength of bituminous mixes. The numerical index of resistance of bituminous mixtures to the detrimental effect of water (called Index of retained strength) is the ratio of compressive strength of immersed specimen to the compressive strength of dry specimen and expressed as percentage. Index of retained strength of three mix types is recorded in Table 2.

Table 2: Compressive strength and index of retained strength (IRS) for different mixes

Mix Type	*Dry compressive strength (kN/m^2)*	*Immersed compressive strength (kN/m^2)*	*Index of Retained Strength (IRS), %*
Mix-I	1810	1488	82.21
Mix-II	2375	2135	89.89
Mix-III	2109	1794	85.06

3. ANALYSIS AND DISCUSSION

Results shown in Figure 5 and Table 2 indicate that the index of retained strength decreases with the increase of soaking periods. With the increase of soaking periods, there is more opportunity for porous aggregates to absorb water and this absorbed water weakens the adhesive bonds between the bitumen binder and the aggregate surface rapidly. With the increase of soaking periods compressive strength reduction rate for polyethylene modifier is less than that for bituminous mix with pure binder and PVC modified binder.

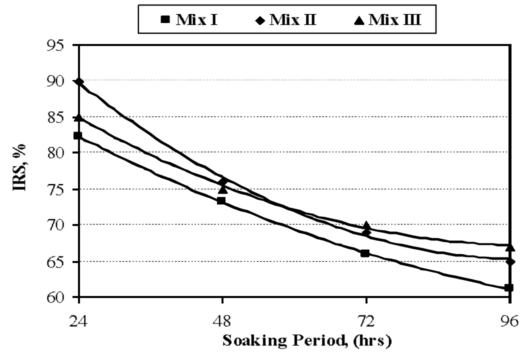

Fig. 5: Relationship between IRS and soaking period

The study reveals that the index of retained strength (the percentage of the original strength that is retained after soaking) of compacted bituminous mix specimens containing polyethylene and PVC as modifier for soaking periods of 24 hrs, 48 hrs, 72 hrs and 96 hrs were relatively higher compared with that values found for similar specimens prepared with pure binder. Some of these measured values for the bituminous mix with modifier in this study were above the acceptable recommended limit 75 percent, specified by the Asphalt Institute, 1981.

4. CONCLUSION

The compressive strength of the modified bitumen is higher than pure bitumen. Polyethylene modified bitumen shows higher compressive strength and moisture susceptibility than PVC modified bitumen. The polyethylene and PVC available from domestic and other waste are applicable to obtain a high strength bituminous mixes. The dense graded bituminous mixes with modified bitumen containing polyethylene and PVC is a feasible option for the road construction from the stand point of availability, stability, compressive strength and moisture susceptibility.

5. REFERENCES

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