Rubber Modified Bitumen For Hot Mix Asphalt Concrete

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Abstract:

Waste throughout materials the world are causing costly disposal problems. Some are by-products of industrial production processing, while others are waste materials from day to day usage by consumers. Disposal of waste material is a difficult task because the government and public agencies are becoming more environmental conscious. It is found that using tire rubber instead of other waste materials in pavement construction is less expensive.

The objective of this study is to examine the effects of adding tire rubber to asphalt cement. The methodologys consist of mixing crumbs of tire rubber with two different penetration grades of asphalt cement; determining the rheological properties of the mixes; and performing a series of Marshall tests to determine the optimum modified bitumen content of the asphalt-rubber hot-mix.

Test results indicate that mixing certain percentages of rubber with asphalt cement will provide modified bitumens that are within the specification limits of asphalt cements that can be used in pavement construction.

Introduction:

There are many waste materials resulting from manufacturing operations. As the generation of waste materials continues to increase, the capacity to handle them decreases. Many landfills have closed, and new facilities are often difficult to site due to economic and environmental constraints.

There are three techniques for waste disposal: recycling, incineration with and without generation of energy, and burial. The management of these waste materials is becoming very challenging due to improper disposal facilities and processes, as well as environmental considerations. The use of a variety of waste products in highway construction has been looked into to find an alternative source of material supply to offset the rising cost of quality natural aggregates, waste disposal, and energy. For the past several years, there have been limited studies to incorporate some of these waste materials into Hot Mix Asphalt (HMA). Materials involved to date include ground rubber tires, ground glass, incinerator ash, and various kinds of waste polymers. There may also be other waste materials that could be included in similar studies in the future [1].

There are two primary factors that must be taken into account when incorporating waste materials into HMA is considered. One consideration is cost, there needs to be a balance between disposal of the waste material in the normal manner as compared to incorporation into the HMA. A second consideration is the effect on quality and performance of the HMA. It would be poor economics indeed to incorporate a waste material that substantially increases the cost of the HMA and at the same time shortens the service life or increases maintenance costs. The objectives of using waste materials in hot mix asphalt can be summarised as [2]:

To determine how waste materials should be processed and handled,
To determine how various waste materials can be physically added to the asphalt mix,
To determine the effects on mix and performance, and
To determine the resultant cost increase in the finished products.

One of these waste materials is tire rubber; reports indicate that in the United States, there are about 3 billion tires currently in scrap heaps with about 240 million tires added each year. With the increasing problem of disposing of more than 200 million tires per year, several State Departments of Transportation (DOTs) are investigating the use of these materials in asphalt mixtures in their effort to identify materials with improved physical and mechanical properties [2].

Objective:

This research aims to study the characteristics of tire rubber modified hot mix asphalt for use in road surfacing. A series of Marshall tests were performed to determine the optimum bitumen content of the mix.

Materials:

Two types of asphalt were used in this study, 60-70 and 120-150 penetration grades. Table 1 shows the properties of these asphalt.

Rubber used in this study was reduced in size by mechanical shearing to particle sizes less than 4.75 mm. The gradation of tire rubber is shown in Table [2]. The specific gravity of tire rubber was found to be 1.130.

The aggregate used in this study was crushed limestone obtained from Be_Üarmak quarries in North Cyprus. The aggregate was graded to the Turkish Highway Standard for binder course, Type1 [3]. Table 3 shows the gradation of aggregate used for binder course. The physical properties of the aggregate fractions were evaluated, and the average bulk specific gravity was found to be 20561.

Laboratory Testing:

Asphalt rubber binder produced by wet process represents binder where fine tire rubber crumb is incorporated into hot asphalt cement. At a temperature of 20 °C, the crumb rubber was added in different percentages (16, 18, 2., and 22% by weight of asphalt) and the binder was kept at this temperature for one hour [4]. Then the rheological properties of the binder such as penetration, softening point, and specific gravity were tested according to ASTM Standards.

The conventional mixtures were prepared according to ASTM Standards 1999 [5]. The aggregate heated at 177°C (35°F) was mixed with the asphalt for producing samples at 400, 405, 500, 505, and 600 % binder content by weight of mix. The samples, 101.6 mm (4 inch) in diameter by 63.5 mm (2.5 inch) in height, were compacted at 150°C (300° F) with 50 blows (medium traffic) on both sides. The samples were then left to cool inside the molds overnight before extraction to avoid specimen damage or deformation. The same procedure was followed for the modified mixture (asphalt-rubber mix). Then according to ASTM Standards the Marshall characteristics such as bulk specific gravity, stability, flow, density, and voids were determined.

Test Results:

Binder Evaluation:

The two types of asphalt binders and their modifications were evaluated by two tests: penetration and softening point. The effect of tire rubber on the penetration and softening point are shown graphically in Figures 1 and 2 repectively.

Figures 1 show that as the percentage of tire rubber increases the penetration values of the asphalts also increase. The reason of increasing penetration values may be due to some oil extracting from rubber. These results indicate that the modified mixtures will be less stiff than the conventional ones, and therefore the rutting resistance of the modified mixtures is expected to be less.

Figures 2 shows softening point test results for the two types of asphalt and their modifications. These results show that for the 136-penetration asphalt, softening points increase by approximately 5 to 12 °C by the addition of up to 18 percent tire rubber and then start decreasing when more tire rubber is added. For the 60-penetration asphalt, the trend is similar. It is important to note that, for both asphalt types, rubber modified asphalts have higher softening points. These results indicate that asphalt-rubber concrete pavements should be less susceptible to traffic-induced deformation distress at high pavement temperatures compared to conventional asphalt pavements.

Evaluation of Asphalt Mixtures:

Figures 3 and 4 show the variations of Marshall Stability by using different rubber contents for two types of asphalt (60-penetration and 136-penetration). These figures show that as the rubber content of the mix increases, its stability decreases. The addition of rubber increases the penetration value of the asphalt (see Figure 1), this results in decreased viscosity, and hence the stability of the mix decreases. Stability values of all mixes prepared with rubber-modified asphalts are found to be above the specification minimum.

Figures 5 and 6 show that mixes prepared with modified asphalts have higher flow values than those prepared by unmodified asphalts. This indicates that modified mixtures are less stiff. Flow values of some modified mixtures fall within specification limits while others do not. Flow is an important factor in designing hot mix asphalt mixtures. It is not desirable to have high flow values because the mix becomes more plastic, and this tends to create stability problems. However, low flow values may indicate a mix with higher than normal voids and insufficient asphalt for durability, which cause brittle mixes, and therefore cracks can occur on the pavement surface under loads.

Figures 7 and 8 show the variation of Unit Weight with different rubber contents for the two asphalt grades. Figure 7 shows that the asphalt-rubber mixtures for all percentages are less dense than the conventional asphalt mixture. As the asphalt becomes softer and the asphalt content increases, thicker films are produced around the aggregates, thereby pushing the aggregate particles further apart and resulting in lower density. Figure 8 shows that when the asphalt content is close to the optimum asphalt content (~5.5 % AC), asphalt-rubber mixtures for all percentages are less dense than the conventional asphalt mixture.

Figures 9 and 1. show the variation of Air Voids with different rubber contents for the two asphalt grades. Figure 9 shows that rubber asphalt has higher air voids than conventional asphalt. Figure 1. shows that there is not too much difference between air voids values of modified and unmodified asphalt, the asphalt content corresponding to 4 % air voids ranges from 5% to 5.5 %.

Figures 11 and 12 show the variation of Voids Filled with Asphalt (VFA) with different rubber contents for the two types of asphalt grades. Figure 11 shows that rubber asphalt mixtures have less VFA values than that of conventional asphalt, because VFA is dependent on the values of VMA and air voids. All values fall within specification. In the case of the 6.-penetration asphalt (see Figure 12), the values of modified and unmodified asphalt are very close to each other, all values fall within specification.

Conclusions:

Asphalt–rubber binders produced with mixing different percentages of tire rubber (16, 18, 20, and 22 %) to the two types of conventional asphalt cements (60 and 136-penetration) are less resistant to permanent deformation at high temperatures compared to conventional asphalts. This conclusion is supported by the penetration tests shown in Figure 1. This indicates that asphalt- rubber binders are much more temperature sensitive than the conventional asphalts they are produced from.

Marshall test results show that the asphalt-rubber mixtures have some characteristics that are different from those of the conventional asphalts. These can be summarized as follows:

1) Asphalt-rubber mixtures present lower stability, higher flow, and lower density than the conventional asphalt for both soft and stiff types of asphalt.

2) The use of asphalt rubber provides the most improvement in susceptibility to traffic-induced deformation distress at high pavement temperatures compared to conventional asphalt.

3) The Marshall optimum binder contents for the conventional and modified mixtures are very close to each other.

4) The use of softer asphalts such as 120-150 penetration grade for the asphalt-rubber are not suitable in dense graded mix design because asphalt-rubbers which have rubber contents between 16 to 22 % have higher flows than the maximum allowable value given by standards. However, the 60-70-penetration grade asphalt can be mixed with tire rubber to provide a binder that can be used in dense graded hot mixes for highway pavement construction.

References:

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Table 1 - Properties of the 60-70 and 120-150 Penetration Grade Asphalt Cements

Penetration, ..1 mm	60	136
Sofening Point, °C	4903	60
Specific Gravity	100364	100240

Table 2 - Gradation of Tire Rubber

Sieve Size	% Passing (by weight)
4.75 mm, No 4	10000
2036 mm, No 10	9002
00425 mm, No.40	2506
0.180 mm, No.80	802
00.75 mm, No. 200	300

Table 3 - Gradation of the Aggregate Used

Size	Range (%)	% Passing
25mm, 1 (inch)	100	10000
19mm, ¾	82-100	10000
1205mm, ½	68-87	8600
905mm, 3/8	60-79	5905
4075mm, No.4	46-65	5505
2036mm, No.10	34-51	4205
0.425mm, No.40	17-29	2300
0.18.mm, No.80	9-18	1305
00.75mm, No.200	2-7	405
Pan	0	000

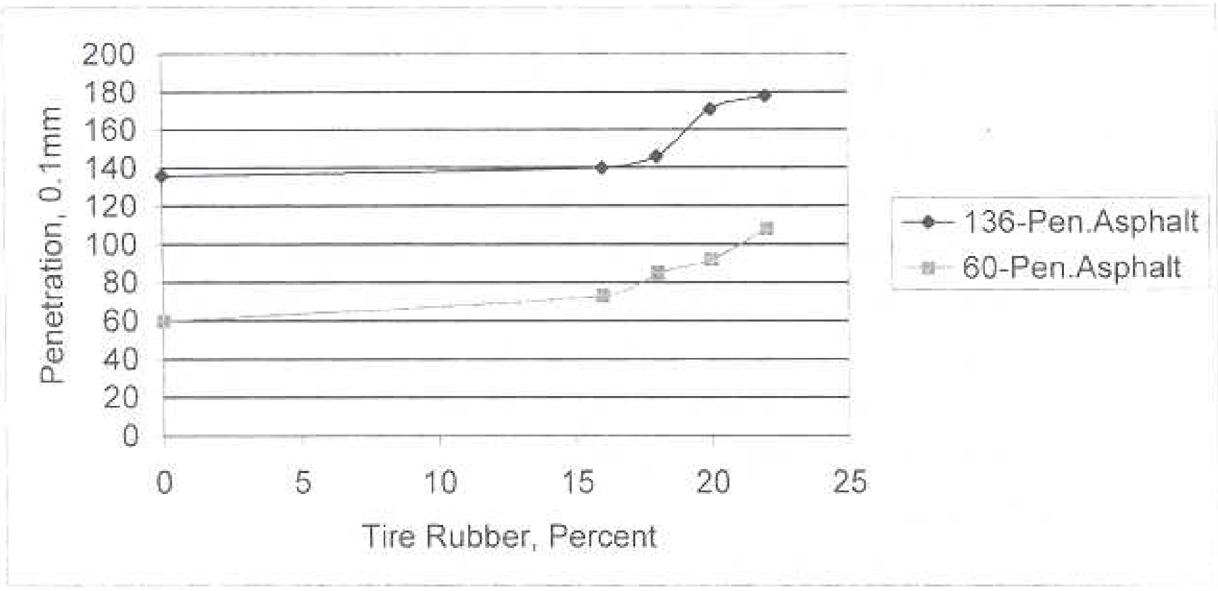

Figure 1 – Variation of Penetration by Rubber Content

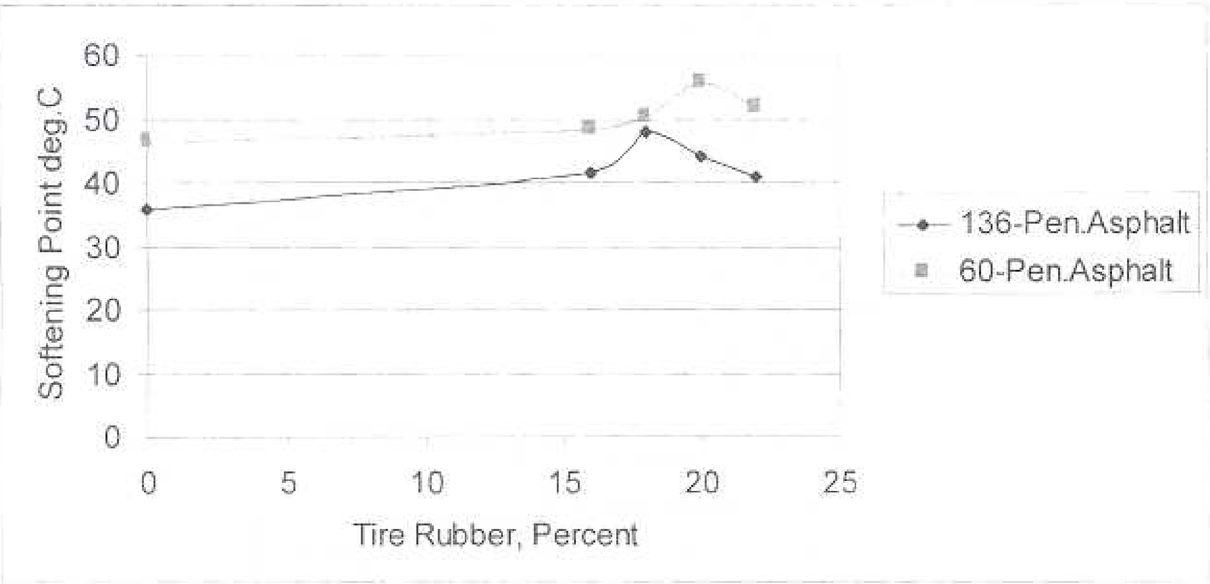

Figure 2 – Variation of Softening Point by Rubber Content

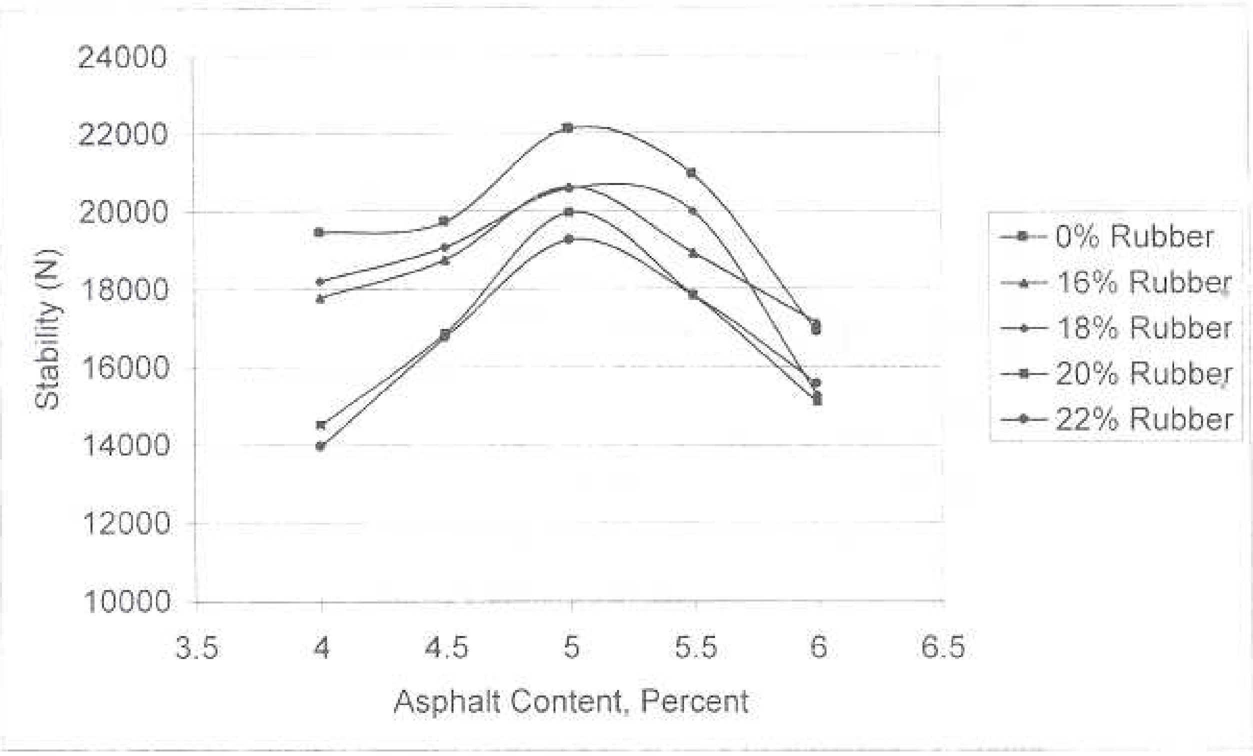

Figure 3-Variation of Stability with Rubber Content (6.-Penetration Asphalt)

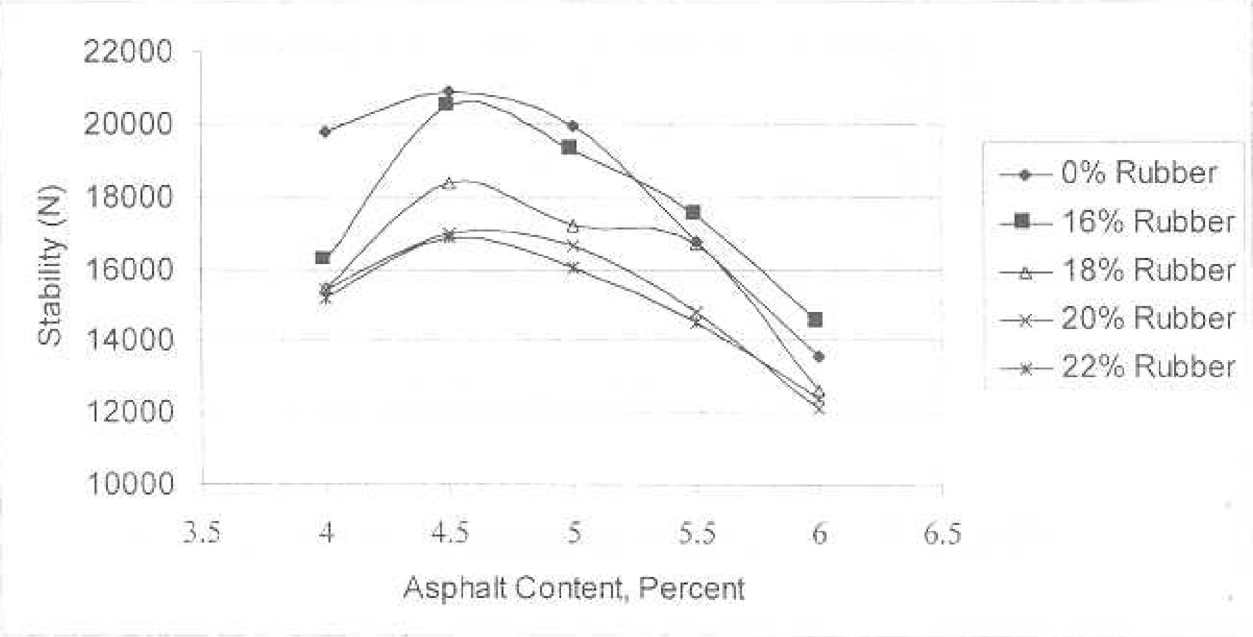

Figure 4- Variation of Stability with Rubber Content (136-Penetration Asphalt)

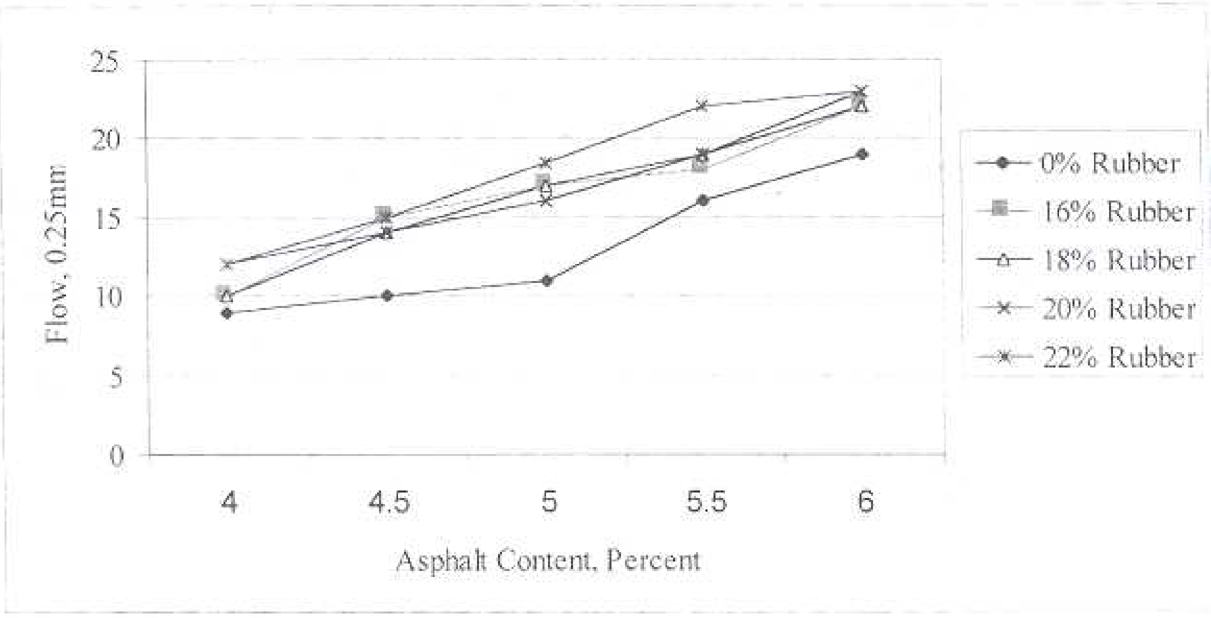

Figure 5 - Variation of Flow with Rubber Content (136-Penetration Asphalt)

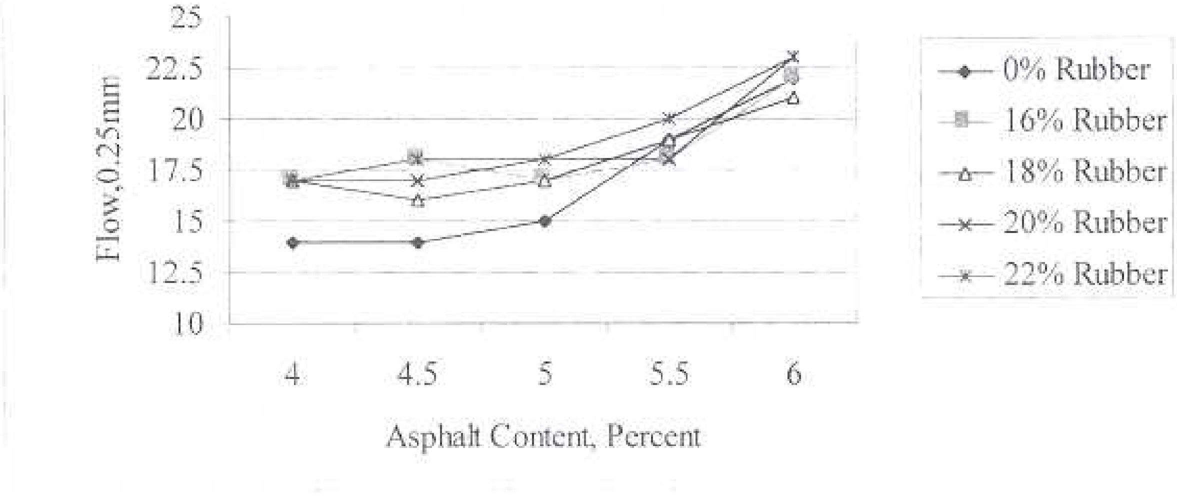

Figure 6 - Variation of Flow with Rubber Content (6.-Penetration Asphalt)

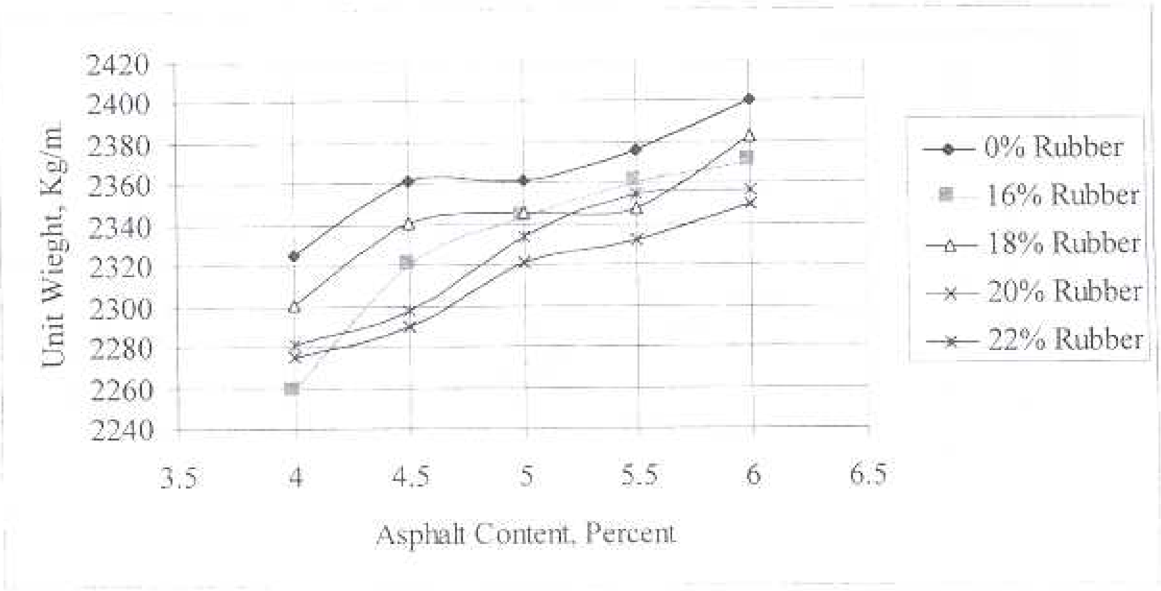

Figure 7 - Variation of Unit Weight with Rubber Content (136-Penetration Asphalt)

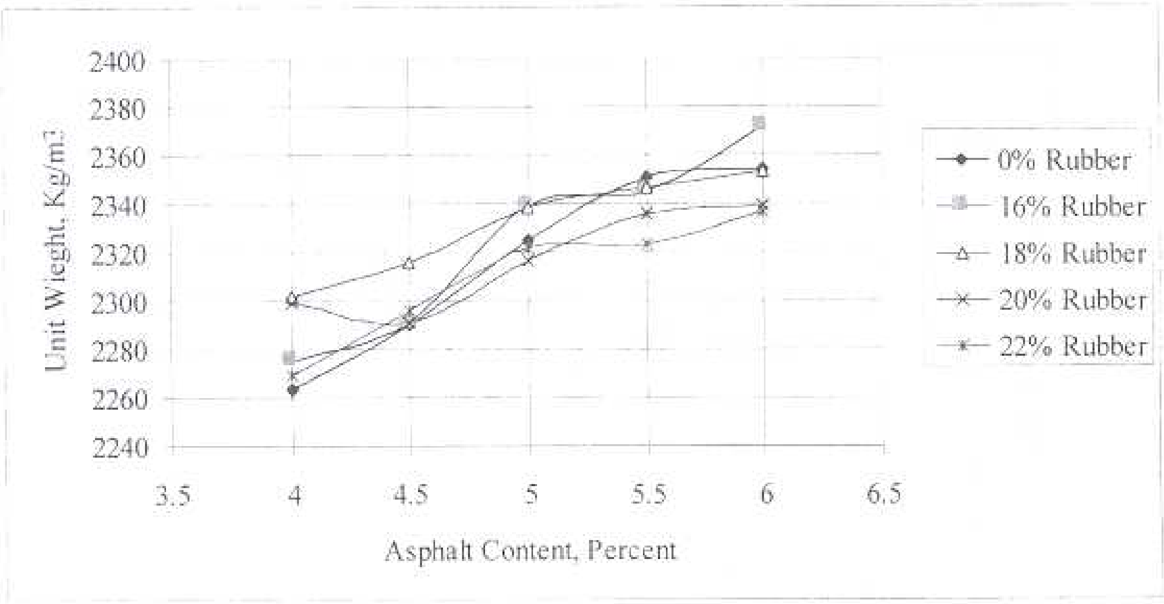

Figure 8 - Variation of Unit Weight with Rubber Content (6.-Penetration Asphalt)

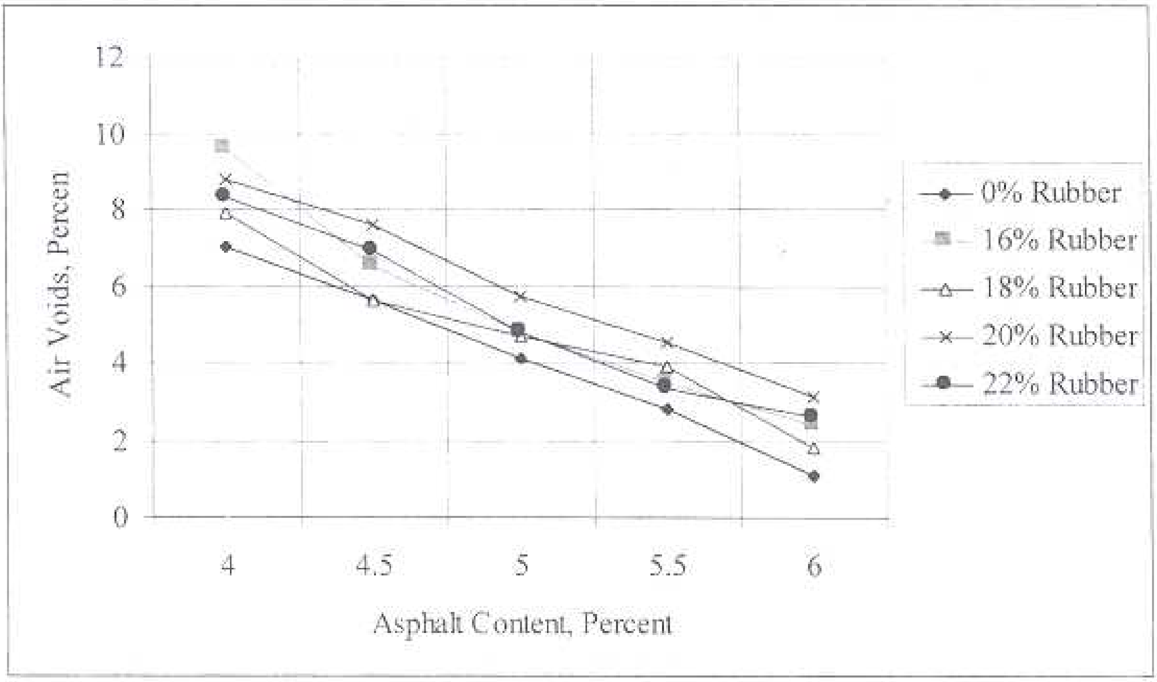

Figure 9 - Variation of Air Voids with Rubber Content (136-Penetration Asphalt)

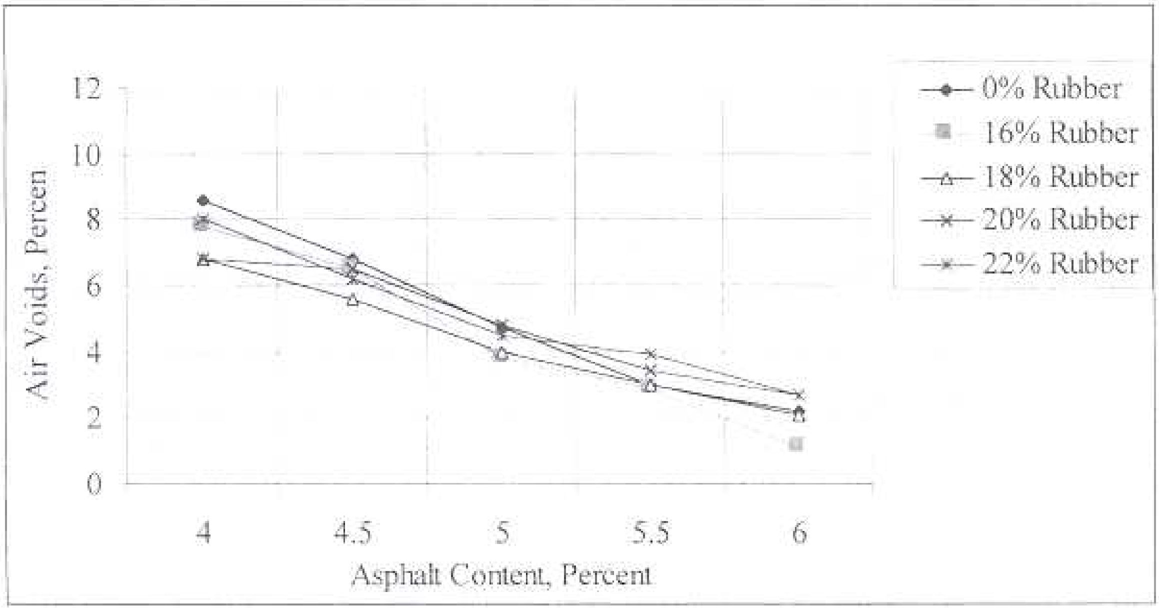

Figure 10 - Variation of Air Voids with Rubber Content (6.-Penetration Asphalt)

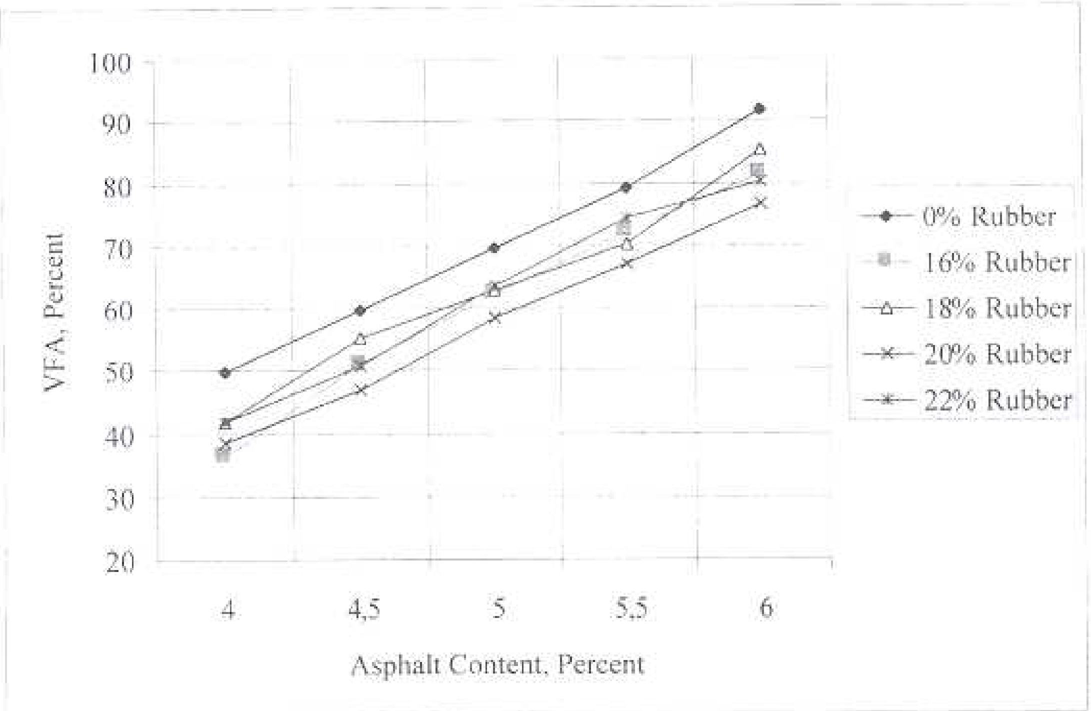

Figure 11 - Variation of Voids Filled with Asphalt (VFA) with Rubber Content (136-Penetration Asphalt)

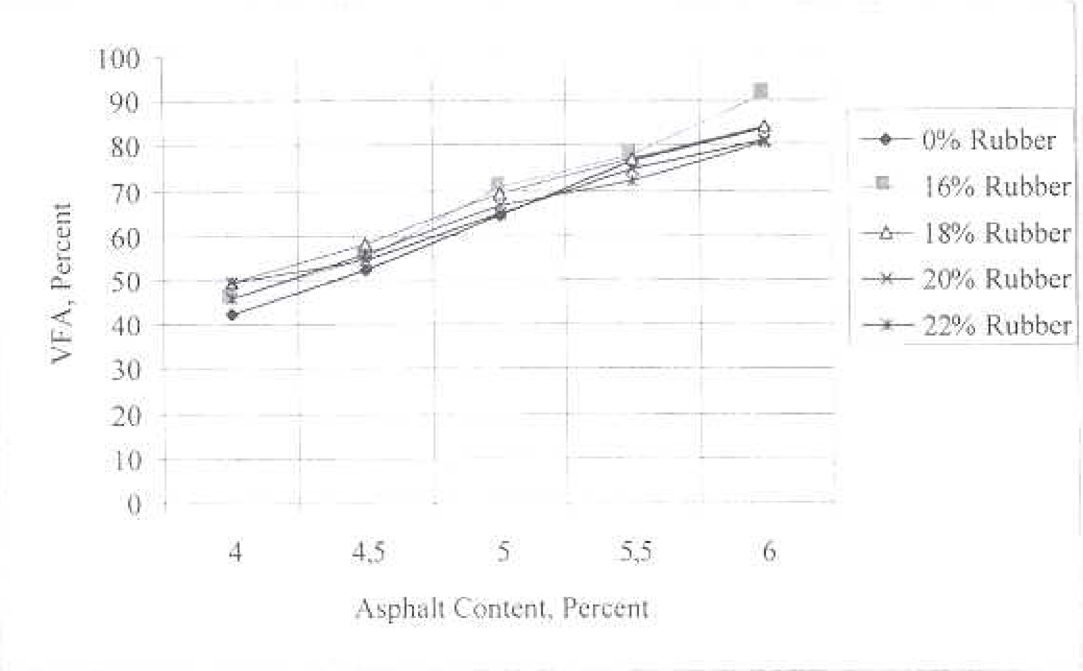

Figure 12 - Variation of Voids Filled with Asphalt (VFA) with Rubber Content (6.-Penetration Asphalt