International Journal of Structural and Civil Engineering Research

ISSN 2319 – 6009 www.ijscer.com
Vol. 3, No. 4, November 2014

Research Paper

STUDIES ON MARSHALL AND MODIFIED MARSHALL SPECIMENS BY USING CRMB

Sk. Wasim Anwar[1]*

*Corresponding author:**Sk. Wasim Anwar** ✉ wasimanwar16@yahoo.com

This study compares the mix properties such as Marshall Stability, flow and indirect tensile strength obtained on 100 mm and 150 mm diameter specimens. Both Marshall and Modified Marshall method of mix design were used to compact the specimens of these two sizes. The maximum aggregate size used here is 37.5 mm. In the present study, the adopted aggregate gradation is as per MoRT and H (IV revision) specification. The binder used is Crumb Rubber Modified bitumen (CRMB-55). The mix design is conducted as per Marshall Method of mix design for 100 mm diameter specimen and MS-2 guidelines are used for 150 mm diameter specimen (Modified Marshall Method). It was observed that the Modified Marshall Method satisfies the mix properties such as Marshall Stability, flow and indirect tensile strength and can be used for testing the large stone aggregate mixes. Indirect tensile tests were conducted on the Marshall and Modified Marshall specimens of Crumb Rubber Dense Graded Bituminous Macadam Grading-1 mixes varying stress levels at 10%, 15%, 20%, 25% and 30% respectively. Laboratory studies on the behavior of Marshall and Modified Marshall specimens were carried out in terms of optimum bitumen content, Indirect Tensile Strength.

Keywords: Optimum bitumen content, Indirect tensile strength, Marshall Mix design, Crumb Rubber Modified bitumen

INTRODUCTION

Increasing traffic growth in terms of both volume and axle loads is a world-wide phenomenon. This has resulted in traffic loading on some of the major highways in excess of the current design classes. There is also currently a strong lobby to increase the legal axle load limit from 8.2 tons to approximately 10 tons. In addition, higher tyre pressures due to new tyre types exacerbate the situation. Due to this heavy loads the pressure on pavements increases and suffer from different types of distress such as fatigue cracking, bleeding and rutting.

Premature rutting of heavy duty Hot Mix Asphalt (HMA) pavements has been a significant problem in recent years. High tire pressures and increased wheel loads are believed to be the primary causes of this phenomenon. Although the HMA has served

[1] Department of Civil Engineering, West Bengal University of Technology, Kolkata, India.

reasonably well in the past there is a need to reexamine its design to withstand the increased stresses. Most asphalt technologists believe that fundamental changes in the aggregate component of the HMA (such as, size, shape, texture, and gradation) must be made. There is a general agreement that the use of large size stone in the binder and base courses will minimize or eliminate the rutting of heavy duty pavements. Marshall Mix design procedures are used by 76% of the states in the United States according to a survey conducted in 1984. The equipment specified in the Marshall procedure (ASTM D1559) consists of a 100 mm (4-inch) diameter compaction mould which is intended for mixtures containing aggregate up to 25.4 mm (I-inch) maximum size only. This has also inhibited the use of HMA containing aggregate larger than one inch (25.4 mm) because it cannot be tested by the standard Marshall Mix design procedures. Hveem mix design procedures (ASTM D1560) used by 20% of the states in the United States also uses 100 mm diameter specimens thus restricting the maximum aggregate size to 25.4 mm. There is a need to use larger diameter (such as 6-inch) specimens for testing large stone asphalt mixes because in Marshall Method, which is currently used by many agencies all over the world have many shortcoming such as:

1) The maximum size of aggregate is limited to 25.4 mm.

2) The method of compacting Marshall Specimens is by impact, which is different from the one actually taking place in field by rollers.

3) The thickness of Marshall Sample is almost constant, and it does not take into consideration the different layers thickness in field.

4) The aggregate orientation in Marshall mould is different from that actually occurring in field.

5) Marshall Mix design method does not take into consideration resistance of mix to many types of distress such as fatigue and rutting. Stability and flow are used which are measured at 60°C. Therefore, the method ignores the effect of temperature.

Modern traffic levels and tire pressures have resulted in increased stress on modern pavements. Brown (1987) in a paper presented at an AASHTO/FHWA Symposium in Austin, Texas in 1987 and listed several conditions which may be aggravated by these stresses and which may result in rutting. The potential problems causing rutting failure listed by Brown included excessive asphalt content caused by improper laboratory procedures, excessive use of natural sand and improperly crushed aggregate. Maximum size coarse aggregate that was too small, and density obtained in the field that was too low.

A study of rutting in Canada by Huber and Heiman (1987) analyzed the condition of asphalt concrete as it was designed, after it was constructed and as it existed at the time of their study. They used cores from between the wheel paths to represent conditions immediately after construction. The condition after traffic was represented by cores taken from the outer wheel path and the characteristics of the mixes as they were designed were obtained from historical data and from construction records.

Huber and Heiman concluded that rutting resistance could not be separately related to traffic level or mix properties of the asphalt mixes. When rutting was analyzed according to deformation per number of single axle loadings, however, Huber and Heiman found a strong correlation with air voids, voids filled, asphalt content, and Hveem stability. Performance was directly affected if voids filled were greater than 70%, air voids were less than 4%, or asphalt content was greater than 5.1%. They found that fractured faces, VMA, and Hveem stability seemed secondary and Marshall Stability, flow, penetration, and viscosity showed little correlation to rutting resistance.

A British study of roadway bituminous base material by Brown and Cooper (1984) used various gradations with maximum aggregate size up to 40 mm (1.57 inch) to analyze elastic stiffness, fatigue life, and rutting resistance. They used four full scale field trials and laboratory work in this study. Testing methods included a repeated load tri axial test, tri axial creep, uniaxial creep and Marshall Stability. The creep results obtained by Brown and Cooper indicated that asphalt mixes prepared with 100 and 200 penetration grade asphalt showed no significant difference in permanent deformation.

In a 1986 ASTM paper, Brown *et al.* (1986) presented results which implied the advantages of larger aggregate while not analyzing larger aggregate specifically. Their test results showed that both stability and tensile strength decreased as Voids in the Mineral Aggregate (VMA) increased. Since VMA is generally higher for smaller aggregate, stability and tensile strength decreased as aggregate size decreased.

Kennedy has analyzed the indirect tensile test and its use in determining many aspects of asphalt concrete performance. Based on both static and dynamic loading, Kennedy concluded that the indirect tensile test may provide information on fatigue, elastic modulus, Poisson's ratio, and permanent deformation. His conclusions regarding permanent deformation were based on his work and that of others.

An interesting result of Kennedy's research was the variability of the Poisson's ratio. For static loadings, the majority of values ranged from 0.08 to 0.36, while the majority of instantaneous resilient Poisson's ratios (ratios derived from repeated loadings) ranged from 0.10 to 0.70. A Poisson's ratio of 0.50 indicates no volume change in the test specimen. Values greater than 0.50 indicate an increase in volume and thus may be suspect. Kennedy, however, indicated that values greater than 0.50 were often achieved after a "relatively large number of load applications." Thus, the repeated loading produced strain in the horizontal direction (the direction of stress that causes a tensile failure along a vertical plane) larger than the strains in the vertical direction (direction of loading) as the specimens approached fatigue failure. The ratio increased with increased load applications with a rapid increase at about 70 to 80% of fatigue life.

MATERIALS AND METHODS

In the present investigation the aggregate Gradation adopted was Dense Graded Bituminous Macadam mix Grading-1. Basic engineering tests on aggregates and bituminous binders are conducted in the laboratory to assess their properties and to check their suitability to be used as road construction materials. Marshall Method of Bituminous Mix design was adopted to carry out mix design using Crumb Rubber Modified bitumen for 100 mm specimen and Modified Marshall Method of Bituminous Mix design was adopted to carry out mix design using Crumb Rubber Modified bitumen for 150 mm specimen. Indirect tensile strength tests were conducted by varying temperatures from 15^{0}C, 25^{0}C and 35^{0}C).

Main Constituents of a Mix

Aggregates

- Coarse aggregates: Offer compressive and shear strength and shows good interlocking properties. Material retained on 2.36 mm IS sieve is taken as coarse aggregates.
- Fine aggregates: Fills the voids in the coarse aggregate and stiffens the bitumen. Material passing 2.36 mm IS sieve and retained on 0.075 mm or 75 micron IS sieve is taken as Fine aggregates.
- Mineral Filler: Fills the voids between the fine aggregates, stiffens the bitumen and offers permeability. Cement was used as mineral filler in the present study.

Binder: The type of binder plays a very important role in the performance of Dense Graded Bituminous Macadam Mix. In the present study, the effect of these two types of binders on Dense Graded Bituminous Macadam Mix has been investigated. The binder used is Crumb Rubber Modified Bitumen (CRMB – 55)

Aggregate Gradation

The aggregate Gradation for Dense Graded Bituminous Macadam Mix *(Grading-1) used for the study was as per Table-500-11, of MoRT&H (IV* revision) specification using MS-2 as in Table 1

Laboratory Testing of Materials

Aggregate

In the present study, the Granite stone chips are used. Crusher run Stone dust is used as Filler. Ordinary Portland cement is used as Mineral Filler. The aggregates are subjected to laboratory investigations in accordance with specified test methods for determining the Physical Properties. Results of the same are shown in Table 2.

Filler

Filler may originate from fines in the aggregate or be added in the form of cement, lime or ground rock. Filler has an important effect on the voids content and the stiffness of the bitumen-fines matrix. The specific gravity of filler must be taken into account. The filler material used in the study is cement. The filler shall be free from organic impurities and have plasticity index less than 4%. The specific gravity test was conducted in the lab and results are presented in Table 3.

Bitumen

The desirable properties of bitumen depend on the mix type and construction. In general, bitumen should posses following desirable properties.

- The bitumen should not be highly temperature susceptible, i.e., during the hottest weather the mix should not become too soft or unstable, also during cold weather

Table 1: Typical Grading Requirements for DBM-1 as per MoRT&H Specifications

IS Sieve Size(mm)	Cumulative percentage by weight of total aggregates passing	Percentage Passing(mid limits)
45	100	100
37.5	95-100	97.5
26.5	63-93	78
13.2	55-75	65
4.75	38-54	46
2.36	28-42	35
0.3	7-21	14
0.075	2-8	5

Table 2: Physical Properties of Aggregates

Property tested	Test methods	Test results	MoRT&H specifications (IV revision 2001)
Aggregate impact value, %	IS:2386(IV)	14.1	27% maximum
Los angeles abrasion value, %	IS:2386(1V)	19.1	35% maximum
Water absorption value, %	IS:2386(IV)	0.50	2% maximum
Specific gravityCourseFineFiller	IS:2386(III)	2.662.702.78	2.5-3.0
Combined flakiness and elongation index, %	IS:2386(I)	29.85	30% maximum
Aggregate crushing value, %	IS:2386	18.8	30% maximum

Table 3: Specific Gravity of Cement

Mineral Filler	Specific Gravity
Cement	3.10

the mix should not become too brittle causing cracks.

- The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing.
- There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.

Properties of Modified Bitumen

Modified bitumen are generally recommended for the roads with heavy traffic and located in extreme climatic areas. The selection of modified bitumen will be based on climatic, traffic performance reports and life cycle cost analysis.

Conventional binder tests such as penetration, ductility, softening point, specific gravity test and flash point tests were carried out on Crumb Rubber Modified (Grade-55) and the Results presented in Table 4

RESULTS AND DISCUSSION

General

Tests were carried out on Dense Graded Bituminous Macadam Grading-I prepared using Crumb Rubber Modified Bitumen. The optimum binder content was determined by Marshall and Modified Marshall method of mix design for both the mixes. Static Indirect Tensile Strength test was carried out on Crumb Rubber Modified bitumen for Dense Graded Bituminous Macadam Grading-I mix at 15°C, 25°C to 35°C.

Marshall Test

The purpose of the Marshall Test is to determine the optimum binder content for a particular blend of aggregates and bitumen. The optimum binder content is determined by the ability of a mix to satisfy the mechanical properties and volumetric properties. The test data are used to plot the Marshall properties versus Bitumen content for crumb rubber modified bitumen by using Marshall and Modified Marshall methods. The Marshall Stability value versus bitumen contents, Flow versus bitumen contents, Bulk density versus bitumen contents, Percent voids in Total mix versus bitumen contents and Percent voids filled with bitumen versus bitumen contents were also plotted for Crumb Rubber Modified bitumen Dense Graded Bituminous Macadam mix were presented.

From these plots bitumen contents are determined corresponding to maximum stability, maximum bulk density and 4% air voids in total mix. The optimum bitumen content of the mix is the numerical average of the three values for bitumen contents determined as above.

Marshall Properties and results are shown in Tables 5 to 8 and Figure 1 to 10.

Static Indirect Tensile Strength

Indirect Tensile Strength tests of Marshall and Modified Marshall specimens of Dense Graded Bituminous Macadam grading-I by using crumb rubber modified bitumen by varying the temperatures from 15°C, 25°C and 35°C results are presented in Table 9 and 10.

Table 4: Physical Properties of Crumb Rubber Modified Bitumen (Grade-55)

Test conducted	Test Results	Requirements as per IRC SP:53-2002
Penetration at 25°C, 100gm, 5 Seconds, 0.1mm	55	Maximum 60
Softening Point (Ring & Ball), °C	57	Minimum 55
Flash point, °C	290	Minimum 220
Elastic Recovery of Half Thread in Ductilometer at 15°C, %	57	Minimum 50

Table 5: Marshall Properties of DBM-I mix for Marshall Method (100mm diameter) specimens using CRMB-55

Bitumen Content(%)	Marshall Stability Kg	Flow mm	Bulk density g/cc	Total air voids (%)	Voids filled by bitumen (%)	Voids in mineral aggregates (%)
3.50	1013.33	1.55	2.34	5.68	58.84	13.80
4.00	1120.00	2.42	2.36	4.40	69.22	13.55
4.50	1301.33	2.98	2.38	3.80	76.48	13.36
5.00	1205.33	3.52	2.37	3.50	82.56	14.29
5.50	1152.00	3.90	2.36	3.15	85.73	15.02

Table 6: Marshall Properties of DBM-I mix by Modified Marshall method (150mm diameter) of mix design using CRMB-55

Bitumen Content(%)	Marshall Stability Kg	Flow mm	Bulk density g/cc	Total air voids (%)	Voids filled by bitumen (%)	Voids in mineral aggregates (%)
3.50	2560.00	5.07	2.33	6.00	57.41	14.08
4.00	2720.00	6.09	2.35	4.56	67.15	13.88
4.50	3146.67	6.54	2.37	3.88	75.74	13.92
5.00	3093.33	7.02	2.36	3.08	79.25	14.75
5.50	2848.00	7.26	2.35	2.65	83.03	15.46

Table 7: Marshall Properties at OBC for mid limit Gradations of DBM-I mix by Marshall Method using CRMB-55

Marshall Property	CRMB-55	Requirement of Dense Graded Bituminous Macadam (Grading 1) as per Table 500-10 of MoRT&H Specifications
Optimum Binder Content, %	4.42	Min 4.0
Marshall Stability (75 Blows) At 60^0 C, Kg	1290	Min 900
Marshall FlowAt 60^0 C, mm	3.4	Min 2.0
Total Air Voids (Vv),%	4.2	3 – 6
Bulk Density (Gb), G/Cc	2.37	—
VMA, %	13.5	Minimum 11 %
VFB, %	74.92	65 – 75 %

Table 8: Marshall Properties at OBC for mid limit Gradations of DBM-I mix by Modified Marshall method CRMB-55

Marshall Property	CRMB-55	Requirement of Dense Graded Bituminous Macadam (Grading 1) as per Table 500-11 of MoRT&H Specifications using MS-2
Optimum Binder Content, %	4.45	Min 4.0
Marshall Stability (75 Blows) At 60^0 C, Kg	3120	Min 2025
Marshall FlowAt 60^0 C, mm	6.3	Min 3.0
Total Air Voids (Vv),%	4.1	3 – 6
Bulk Density (Gb), G/Cc	2.36	—
VMA, %	13.90	Minimum 12 %
VFB, %	74.00	65 – 75 %

Table 9: Results on Static Indirect Tensile Strength for Dense Graded Bituminous Macadam grading-I using CRMB-55 binder

Gradation	Static Indirect Tensile Strength in N/mm^2	
DBM-I	**Marshall specimen(100 mm dia)**	**Modified Marshall specimen(150 mm dia)**
1) FOR 15^0C		
Trial 1	1.059	1.001
Trial 2	1.165	1.021
AVERAGE	1.112	1.01
2) FOR 25^0C		
Trial 1	0.953	0.811
Trial 1	0.878	0.877
AVERAGE	0.916	0.844
3) FOR 35^0C		
Trial 1	0.744	0.615
Trial 1	0.860	0.665
AVERAGE	0.802	0.640

Table 10: Comparison of results on Static Indirect Tensile strength of Marshall and Modified Marshall specimens of DBM-I Mix prepared by using CRMB-55

Temperature	Marshall specimen(100 mm dia)	Modified Marshall specimen(150 mm dia)
^{0}C	N/mm^2	N/mm^2
15	1.112	1.01
25	0.916	0.844
35	0.736	0.640

Figure 1: Graph showing Marshall Stability v/s Bitumen content (CRMB-55) of Marshall specimen

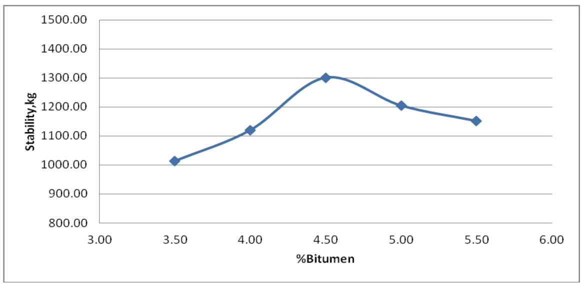


Figure 4: Graph showing bitumen content v/s flow (CRMB-55) of Marshall specimen

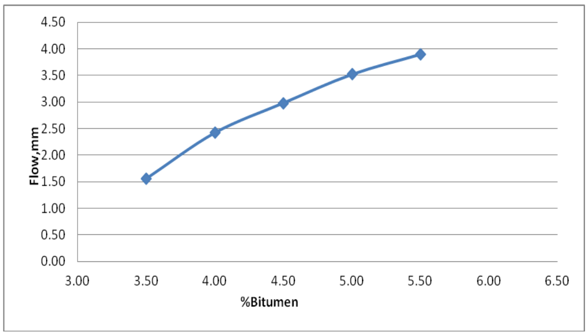


Figure 2: Graph showing bitumen content v/s bulk density (CRMB-55) of Marshall specimen

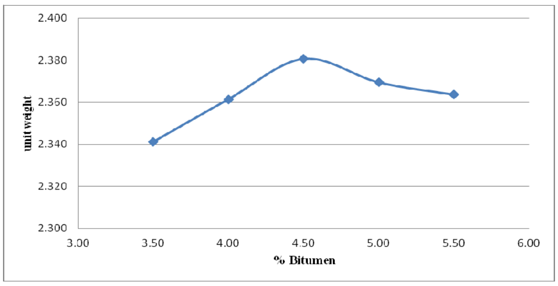


Figure 5: Graph showing VFB v/s bitumen content (CRMB-55) of Marshall Specimen

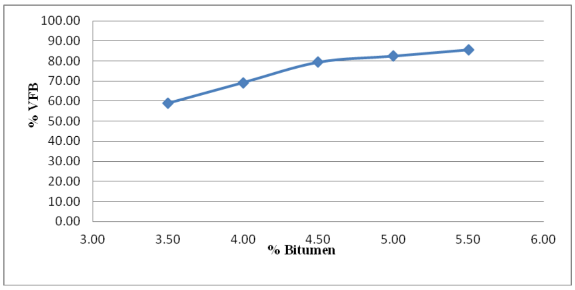


Figure 3: Graph showing bitumen content v/s air voids (CRMB-55) of Marshall specimen

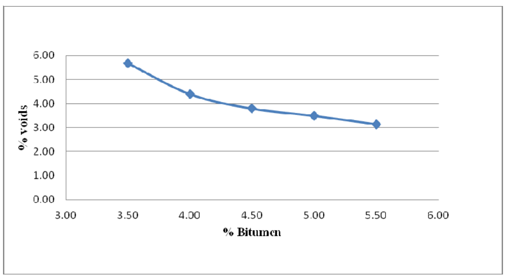


Figure 6: Graph showing Marshall Stability v/s Bitumen content (CRMB-55) of Modified Marshall specimen

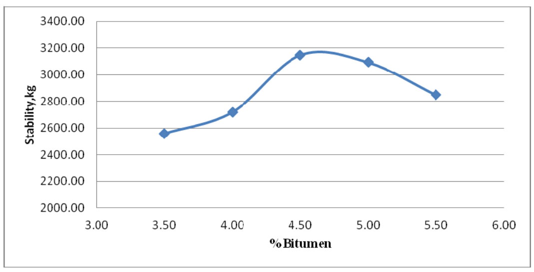


Figure 7: Graph showing bitumen content v/s bulk density (CRMB-55) of Modified Marshall specimen

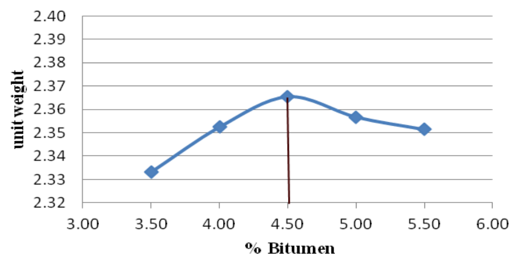


Figure 8: Graph showing bitumen content v/s air voids (CRMB-55) of Modified Marshall specimen

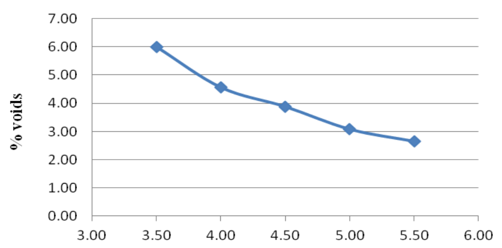


Figure 9: Graph showing bitumen content v/s flow (CRMB-55) of Modified Marshall specimen

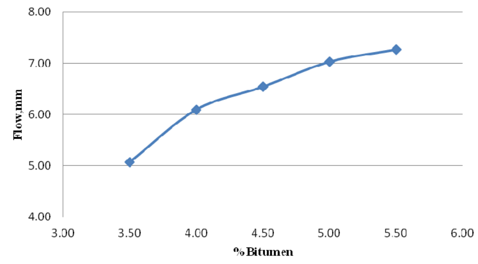
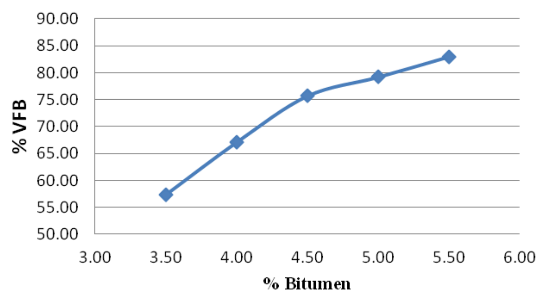


Figure 10 Graph showing bitumen content v/s VFB (CRMB-55) of Modified Marshall specimen



CONCLUSION

Based on the results and discussions of experimental investigation carried out on the behavior of Marshall and Modified Marshall specimens, prepared by using Crumb Rubber Modified Bitumen. In this experimental investigation, two types of specimens, i.e., Marshall (100 mm dia) and Modified Marshall (150 mm dia) are prepared by using CRMB. Properties behavior and Static Indirect Tensile Strength of these specimens have been tested at different stress level and temperature. Based on these test, it is concluded that specimens prepared by Modified Marshall method of mix design gives very good result than Marshall specimens and it can be used in flexible pavement

REFERENCES

1. Brown E R (1987), "Mix Design and Construction of Concrete to Support High Tire Pressures," paper prepared for presentation at AASHTO/FHWA Symposium on High Pressure Tires, Austin, Texas, February.

2. Brown E R, McCrae John L and Crawley Alfred B (1986), "Effects of Aggregates on Performance of Bituminous Concrete," paper presented for ASTM Symposium on the Implication of Aggregate in the Design, Construction, and performance of Flexible Pavements, December, New Orleans, Louisiana.

3. Brown S F and Cooper K E (1984), "The Mechanical Properties of Bituminous

Materials for Road Bases and Base courses," Proceedings, Association of Asphalt Paving Technologists, Vol. 53, pp. 415-439.

4. Huber G A and Heiman G H (1987), "Effect of Asphalt Concrete Parameters on Rutting Performance: A Field Investigation," Proceedings, Association of Asphalt Paving Technologists, Vol. 56, pp. 33-61.