

SHRP-ID/UFR-92-610

## **The Use of Conversion Residue as a Component in Asphalt Cement**

Richard E. Root, P.E.  
Chicago Testing Laboratory, Inc.  
3360 Commercial Avenue  
Northbrook, IL

Richard B. Moore  
Shell Development Company  
P.O. Box 1380  
Houston, TX



**Strategic Highway Research Program**  
National Research Council  
Washington, DC 1992

SHRP-ID/UFR-92-610  
Contract ID-020

Program Manager: *Edward Harrigan*  
Project Manager: *Rita Leahy*  
Production Editor: *Amy Gray Light*  
Program Area Secretary: *Juliet Narsiah*

June 1992  
Reprint December 1993

key words:  
asphaltic concrete  
conversion residue  
thermal cracked residues  
thermal cracking

Strategic Highway Research Program  
2101 Constitution Avenue, N.W.  
Washington, D.C. 20418

(202) 334-3774

The publication of this report does not necessarily indicate approval or endorsement of the findings, opinions, conclusions, or recommendations either inferred or specifically expressed herein by the National Academy of Sciences, the United States Government, or the American Association of State Highway and Transportation Officials or its member states.

© 1993 National Academy of Sciences

# **Acknowledgments**

The research described herein was supported by the Strategic Highway Research Program (SHRP). SHRP is a unit of the National Research Council that was authorized by section 128 of the Surface Transportation and Uniform Relocation Assistance Act of 1987.

# Contents

Abstract .....	1
Executive Summary .....	2
Related Research .....	4
Binder Preparation .....	4
Binder Evaluation .....	5
Methodology of Binder Evaluation .....	5
Arabian Heavy .....	7
California Heavy .....	7
Binder Evaluation in Bituminous Mixture .....	8
Arabian Heavy .....	9
Georgia Aggregate .....	9
Maryland Limestone .....	10
Texas Chert .....	10
Comments .....	10
California Valley .....	10
Conclusions and Recommendations .....	11
Appendix A List of Figures .....	12
Appendix B List of Tables .....	24
References .....	104

# **Abstract**

Thermal cracking of distilled residues was a popular refining practice in the 1920s that helped double the production of gasoline from a given quantity of crude oil from 1919 to 1935. Thermal cracked residues, a by-product of thermal cracking, were used as paving materials in the 1920s and '30s, although they ultimately proved unsatisfactory for this purpose.

A conversion residue generally used as a blending component in heavy fuel oils or as a refinery fuel, was discovered to successfully blend into paving grade asphalt to provide superior resistance to moisture-induced damage, and to provide similar hardening characteristics as conventional specification asphalt.

Although conversion residue is seldom used in the United States, the preliminary findings of this material compared to conventional asphalt form the basis of this SHRP IDEA study.

## **Executive Summary**

Thermal cracking of distilled residues became a popular refining practice in the 1920s. The primary benefit of thermal cracking was to increase the production of gasoline and other light products from a given quantity of crude, and decrease the volume of asphaltic residue. As a result of the introduction of thermal cracking, the production of gasoline from a given quantity of crude oil was practically doubled during the period of 1919 to 1935 (ref 1).

Thermal cracked residues (TCR), a by-product of thermal cracking, were used as paving materials in the 1920s and '30s. Most of the TCR, however, was volatile (not highly vacuum distilled), and proved to be unsatisfactory in terms of age hardening (partially due to high volatility losses during the hot mix process to make asphaltic concrete). This led to some premature failures (primarily thermal and fatigue cracking) of pavements.

The Oliensis spot test (ref 2), developed in 1933 as a means of identifying TCR, was later used as a specification standard to ensure that TCRs were not used in paving asphalts. (This test is still mandatory in eight states and optionally enforced in 21 states--AASHTO M226, Table 2) (ref 3). The thin film oven test (TFOT), developed in 1941, gave a more accurate prediction of age hardening during plant mixing to produce hot mix asphaltic concrete (ref 4). A majority of states today no longer run the spot test, while all use the TFOT, or rolling thin film oven test.

Conversion Residue (CR) is a visbroken material (lightly thermal cracked, typically exposed to temperatures between 420C and 480C) that is subjected to a high vacuum to remove volatile materials (ref 5). CR is produced according to the scheme illustrated in Figure 1, page 13. If the material exiting the visbreaking reactor is not exposed to a high vacuum unit, the resulting residue would be volatile, a poor aging material, and would be classified as visbroken residue--not CR.

CR is generally used as a blending component in heavy fuel oils or as a refinery fuel, and it has a relatively low value when compared to other refinery streams. If CR were to be blended into paving grade asphalts, it would not increase the overall cost of the asphalt. Presently, CR is seldom (if ever), used in paving grade asphalts in the United States. However, previous preliminary findings (ref 6) show that when CR is used in small percentages, (<20 percent) with the remainder being a conventional distilled asphalt, the resultant material in limited testing displayed superior resistance to moisture-induced damage (Modified Lottman Test) and similar hardening characteristics

(TFOT) when compared to conventional specification asphalts. These preliminary findings are the basis of this SHRP IDEA study.

For this study, two different CR materials, two sources of vacuum distilled asphalt, and three sources of aggregate were evaluated. The asphalts and their blends were tested using standard specification binder tests, and the asphalt-aggregate mixtures were tested using ASTM-D-4867 (ref 7) to assess moisture-induced damage.

## RELATED RESEARCH

The reduction of moisture-induced damage by using CR or TCR is not widely known or practiced in the United States. However, in the 1955 Proceedings of the Association of Asphalt Paving Technologists (AAPT) there is a paper entitled "Waterproofing Aggregates with Cracked Road Oils" (ref 8). The authors concluded "that certain cracked road oils are better waterproofing agents than any other commonly used asphalt products".

In the 1988 Proceedings of AAPT a paper entitled "Hydrocracking Residues--The Potential Source of Road Binders" by Zanzotto et al (ref 9) showed dramatic improvement in percent of retained Marshall stability after a 24-hour soak with as little as 3% hydrocracked residue. Zanzotto also showed lower aging index values with 20% or less hydrocracked residue in the blend when compared to the straight run asphalt. At percentages above 30% the hydrocracked residue increased the aging index significantly.

In work done at Shell Development (ref 6) findings similar to Zanzotto's were reached when CR was used. A blend containing 17.6% CR had a lower aging index than the original vacuum distilled AC-5 blending base. Also, a blend having 20% CR had a higher Tensile Strength Ratio (51.2% vs. 36.1%) when compared to the control (using the Modified Lottman Test procedure as run by the Texas State Department of Highways and Public Transportation).

## BINDER PREPARATION

Two CR materials were chosen. One sample (W-834) is a Tia Juana Pesado (TJP) CR. TJP is Venezuelan crude. The other (W-840) is a Middle East CR. Asphalt sources chosen from the SHRP Materials Reference Library (SHRP MRL) were Arabian Heavy (AAS) and California Valley (AAG). West Texas Intermediate (solvent deasphalting) (AAM) was originally chosen, but proved to be incompatible with both CR materials. This was determined by viewing thin films of the blends under a microscope at 200X. Instead of being a homogenous honey color (compatible), these blends contained a network of visible black structures (flocculated asphaltenes). All subsequent blends used in this study were compatible using the 200X microscopic technique.

It was the aim of the study to have CR blended at 0, 5, 10, 20 and 40% by weight of the total binder with the base asphalt; and the resultant blends have a consistency of AC-20. The AC-20 blends (18 in all) were then tested using common asphalt specification tests along with a minimum of other tests that have shown some correlation to field performance.

Because both CR materials were more viscous than AC-20, it was necessary to use a soft asphalt to give the resultant blends the proper consistency. The softest California Valley available from the SHRP MRL was an AR-2000 and for the Arabian Heavy an AC-10. In a few of the higher % CR blends, soft asphalts were not sufficient, and a heavy non-volatile distillate from a Mexican/West Texas Sour crude was used to attain AC-20 consistency.

## BINDER EVALUATION

Binder tests results are found in Tables 1A through 4A. Calculated properties of the binders are found in Tables 1B through 4B. It should be noted that all blends did meet AASHTO M-226 specifications for either AC-20 Table 1 or Table 2, except (in some cases) for the optionally specified Spot Test.

## METHODOLOGY OF BINDER EVALUATION

The following calculated properties and test data are considered important in predicting binder performance:

Bitumen Temperature Susceptibility (BTS)  
Estimated Thermal Cracking Temperature (ETCT)  
Penetration at 4C (60 seconds, 200 grams)  
Viscosity at 60C  
% of Original penetration  
Aging Index  
Exudation Droplet Tests (EDT)

It is more meaningful to evaluate these properties or data on TFOT residue (where applicable), because TFOT residue closely matches the short-term aging that occurs during construction of a hot mix asphalt pavement (ref 10). Unfortunately, at the time of this study there was no standard long-term aging test available (Pressure Air Vessel test under development in SHRP). Each of the above properties and test data in relation to performance are discussed below.

BTS is identical to the Penetration Index (PI) as developed by Pfeiffer and Van Doormaal (ref 11) when penetrations are used. Heukelom (ref 12 & 13) extended the PI concept to include viscosities. However, PI based on viscosities is a contradiction in terms, and authors de Bats and van Gooswilligen (ref 14) developed the term BTS—which will be used in this report. From a rheological standpoint it would be advantageous to have a relatively stiff binder at high service temperatures (high viscosity at 60C) and a relatively soft binder at low temperatures (high penetration at 4C). This type of material would have a high BTS value. BTS can be represented graphically using the Bitumen Test Data Chart (BTDC) developed by Heukelom (ref 12). An example of the BTDC is given in Figure 2. Three classes of asphalt are shown: Type W (waxy), Type S (straight line) and Type B (blown). The slope of the line in the performance region (typically 60C and below) is of most concern. Viscosities (and BTS) at temperatures above the performance region are important during the construction of the pavement, but once properly constructed, they have no correlation to performance.

ETCT is based on findings of low temperature thermal cracking from the ST. Anne's Test Road (ref 15). A relatively simple chart (see Figure 3) and penetrations at 5C and 25C are all that is needed to determine the ETCT. Penetrations (5 seconds and 100 grams) were run at 4C and 25C in this study. The penetration at 5C was interpolated (using BTDC) and used in calculation of the ETCT.

The Pacific Coast Conference on Asphalt Specifications has adopted the 60 second-200 gram penetration test at 4C on Rolling Thin Film Oven Residue in their 1990 Performance Based Asphalt Specifications. It is felt that this test is better

from a precision standpoint than the 5 second -100 gram test at 4C. The apparent problem with the 5 second test at low temperatures is the depth of penetration is small, and it is on the highly tapered portion of the needle. Goodrich (ref 16) evaluated the 60 second penetration test at 4C as a performance based test, and found that it correlated with low temperature creep testing on mixtures (limiting stiffness temperature) better than any other binder test in his study.

Viscosity at 60C is the basis of our country's present Viscosity Graded Asphalt Cement Specifications. It is intuitively obvious that the higher the viscosity of the asphalt cement--the stiffer the mixture, and the more resistance the mix is to permanent deformation (rutting). The Shell Pavement Design Manual (ref 17) has input parameters for asphalt cement stiffness, and this factor directly affects predicted mix stiffness and rutting.

Percentage of original penetration (25C) after the TFOT is a specification requirement for Penetration Graded Asphalt Cements (ref 18). AASHTO M-20 requires a minimum of 58%, 54% and 50% for 40-50, 60-70, and 85-100 penetration grades. If the % is less than these minimums, then it is inferred that the material is prone to excessive aging and the resulting pavement will prematurely crack.

Aging index is the ratio of TFOT viscosity @ 60C / viscosity @ 60C. AASHTO M-226 limits this ratio to a maximum of 4.0. If the aging index is above 4.0, then (similar to % of original penetration) it is inferred that the material is prone to excessive hardening during aging and the resulting pavement will prematurely crack. However, pavements do not crack at 60C--they crack at lower temperatures; and the fallacy of the aging index was discussed by Moore (ref 19). In this discussion it was pointed out that some aged asphalts develop high 60C viscosities, but they have excellent low temperature properties (high 4C penetrations--soft and resistant to cracking). It was concluded that judging how an asphalt will perform after age hardening cannot be adequately assessed by only comparing relative aging indexes based on viscosities at 60C.

The exudation droplet test (EDT) was proposed by van Gooswilligen, de Bats and Harrison (ref 20). It has been found that exudative hardening may contribute to premature fracture of pavements, which occurs more frequently with lean mixes. Exudative hardening is the loss of oily material that exudes from the binder into the mineral aggregate. Shell Method Series 2697 was the test procedure followed. Weighed quantities of asphalt are placed in drilled recesses of a marble plate of a specific Italian origin. The plates are heated to 60C for four days under a nitrogen blanket. During this period oily rings develop which are measured with a microscope under ultraviolet light. For AC-20 materials a ring width of less than 2.0mm is an indicator good performance. All blends in this study were 1.2mm or less.

The following two sections will discuss how the two CRs affected the Arabian Heavy and California Valley asphalts.

## ARABIAN HEAVY

Arabian Heavy is recognized as an asphalt with low temperature susceptibility, and because of this is generally considered a good performer. It easily exceeds AASHTO M-226 Table 2 requirements for temperature susceptibility (minimum 60 penetration at 25C and 1600 to 2400 poise at 60C). The Arabian Heavy AC-20 has a 25C penetration of 81 and a 60C viscosity of 2041 poise (Table 1A) and a BTS of -0.73 (Table 1B). It can be seen that both CRs had little effect on the BTS (25C pen. & 60C visc.) for original properties (Table 1B & 2B). However, in all cases CR improved the BTS after the TFOT when compared to the control AC-20.

BTS (4C pen & 60C visc.) for the control AC-20 (Table 1B & 2B) were slightly better than the CR blends. However, after the TFOT the higher percentages (20 & 40% CR) exhibited better BTS. Similar trends are evident in the Estimated Thermal Cracking Temperature (ETCT) on TFOT residue—which show lower ETCT (more resistant to thermal cracking) for high % CR blends.

The aging index increased with increased amounts of CR (Figure 4), however, percent of original penetration at 25C showed no significant change with increased CR (Table 1A & 2A). TFOT penetrations at 4C generally increased with increasing amounts of CR (Figure 5)—which is beneficial for low temperature properties of the pavement.

Based on binder evaluation of the two CRs in Arabian Heavy, there is little evidence of reduced performance. With the exception of spot test results, all Arabian Heavy-CR blends tested meet current AASHTO M-226 Table 2 requirements.

## CALIFORNIA VALLEY

California Valley is recognized as an asphalt with high temperature susceptibility, and because of this is generally considered a marginal performer in areas with large seasonal temperature changes. It easily exceeds AASHTO M-226 Table 1 requirements for temperature susceptibility (minimum 40 penetration at 25C and 1600 to 2400 poise at 60C), but fails to meet more stringent requirements found in Table 2. The California Valley AC-20 control has a 25C penetration of 50 and a 60C viscosity of 2059 poise, (Table 3A) and a BTS of -1.51 (Table 3B).

It can be seen that both CRs had a positive effect on the BTS (25C pen. & 60C visc.) for original properties and TFOT properties (Tables 3B & 4B). The 20 and 40% TJP and the 40% Middle East CR blends improved the temperature susceptibility to the point that these blends meet AASHTO M-226 Table 2 (Tables 3A & 4A).

Low temperature properties were improved significantly with CR. For example, the ETCT for the control after TFOT was -21C while the 40% TJP and Middle East CRS were -28 and -33C respectively (Table 3B & 4B).

The aging index did not increase with increased amounts of CR until 40% CR was used (Figure 6). Percent of original penetration at 25C did decrease with increasing CR, but this is probably a function of increased penetration (Table 3A & 4A). As previously discussed AASHTO M-20 allows for a lower percent of

original for a high penetration grade. Penetrations at 40 on the TFOT aged material in both cases increased with the higher amounts of conversion residue (Figure 7).

The improvement in BTS was primarily a function of the two CR crude sources as compared to the California Valley. However, Giavarini (ref 21) shows an increase in asphaltenes during the CR process. In this study six different residues from distillation and their corresponding CRs were analyzed for asphaltenes. In all cases the % weight asphaltenes increased. The average asphaltene content for the six distilled residues was 11.0%, and for the corresponding CRs it was 15.0% Two main reactions occur in visbreaking (ref 5 & 21). The primary reaction is the removal of Alkyl side chains (paraffins) from the molecules of the distilled residue. The secondary reaction is condensation of ring structures—increased molecular weight. Simpson et al (ref 22) found that the temperature susceptibility of an asphalt decreases with increasing molecular weight; and Corbett (ref 23) found that asphaltenes decrease the temperature susceptibility and are a desirable component of asphalt. Thus based on the above, a possible benefit from the CR process appears to be an improved BTS.

Based on binder evaluation of the two CRs in California Valley, there is strong evidence of improved performance (BTS). With the exception of some spot test results, all California Valley-CR blends tested meet current AASHTO M-226 Table 1 requirements; and the higher % of CR improved the resultant blends so they could meet Table 2.

#### BINDER EVALUATION IN BITUMINOUS MIXTURE

Three sources of aggregate were chosen from the SHRP Library in order to evaluate the effect of the various CR binders in the performance of mixtures in the presence of moisture. The aggregates selected for this phase of the evaluation were:

RA	Lithonia Granite Vulcan Materials Co. Grayson, Georgia
RD	Limestone Genstar Stone Product Frederick, Maryland
RL	Gulf Coast Gravel Fordyce Inc. Sullivan City, Texas

It was known from previous studies that the RA was prone to severe stripping, the RL to moderate stripping and the RD to little stripping.

Preliminary supplies of each aggregate were obtained from the SHRP Library and evaluated for gradation. Calculations indicated that satisfactory mixture

designs could not be prepared without additional fine aggregate. A supply of natural sand (FA-2) was obtained from SHRP source:

RF                   Glacial Gravel  
                     Vulcan Material  
                     Crystal Lake, Illinois

Marshall Mixture designs were prepared with each aggregate (RA, RD and RL) incorporating 30% of the natural sand (RF) using Arabian Heavy AC-20 (W 831). The designs were prepared in essential conformity with the procedures in the Asphalt Institute Manual MS-2. Optimum asphalt content was chosen at 4.0% air voids. This design data and blends are shown on Tables 5-7.

In order to evaluate the effect of the conversion residue to reduce moisture damage a series of fifty-four moisture induced evaluations were conducted. Each of the three aggregates were tested with two control asphalts AC-20 Arabian Heavy and AR-4000 California Valley. Each aggregate was also tested with blends of the above control asphalts and each conversion residue in concentrations of 5, 10, 20 and 40%.

The testing was conducted in accordance with ASTM Method D-4867. The data on these tests is summarized in Tables 1C through 4C. Individual Data on each test is in the Appendix.

#### ARABIAN HEAVY

The test results for the original Arabian Heavy AC-20 indicate that all three aggregates have moisture damage potential (Table 1C & 2C). The data indicates that the Georgia aggregate (RA) has the greatest damage potential as expected. However, the order of the Texas and Maryland aggregate was reversed from the expected performance. Both Tensile Strength Ratio (TSR) and the visual evaluation of stripping confirmed the ranking of the laboratory performance of the aggregates. The fact that the high percentage of natural sand (RF) from Illinois was needed for the mixture design could have confused the comparison of the laboratory versus field performance of the aggregates.

Georgia Aggregate (RA) - The test results for the Georgia Granite showed the greatest improvement of the study when the Arabian Heavy was blended with the Middle East CR. The TSR values increased from 20 with 0 percent CR to 69 with 40 percent CR. This is a statistically significant increase when testing precision reported in the ASTM Method is considered. When the Tia Juana Pesado CR was used, an increase in the TSR values was noted as the percentage of CR was increased. The blend of 40 percent Middle East CR with the Arabian Heavy brings the TSR values up to a marginal area. All other blends as well as the mixture without CR would need some additive to enhance the moisture damage potential of the mixtures. However, for all blends with this asphalt the TSR properties were equal to or better than the results on the mixtures without CR. The test results for the three aggregates and two CRs are shown on Figures 8&9. Visual evaluation confirmed that the stripping for the control and eight blends in this part of the study occurred in the coarse aggregate fraction.

Maryland Limestone (RD) - The test results on Tables 1C & 2C indicate that the 40 percent blends of both CRs brought the retained strengths for the Maryland limestone up to a value which would meet most state specifications. Both results are significantly different than the control results according to the ASTM precision statement.

In all cases, the CR blends were again equal to or better than the control tests with this aggregate. These results are in Figures 8&9.

Visual examinations of the moisture treated specimens again confirmed that the coarse aggregate fraction was the cause for the loss of strength.

Texas Chert (RL) - The test results given in Tables 1C & 2C show a general increase in the TSR values for increased percentages of CR. These results are compared on Figures 8&9 for all three aggregates. None of the values are significantly different from the control tests. However, they are equal to and there appears to be a trend of better performance with more CR.

Visual evaluation of the moisture treated specimens confirmed that the strength loss was a result of coarse aggregate stripping.

Comments - The test results for the Arabian Heavy indicate in some cases a significant improvement in the moisture damage properties of the three aggregates studied. No detrimental performance was indicated with regard to moisture damage by this data. In all cases, the visual evaluation confirmed that the moisture damage occurred in the coarse aggregate fraction. This indicates that the natural sand (RF) used in the mix design did not have a detrimental effect on the performance of the aggregate blends. This is confirmed by the reasonable agreement between the laboratory data and the field performance history of the aggregates.

#### CALIFORNIA VALLEY

The moisture damage test results with the control asphalt indicate that the Georgia aggregate was approximately equal to if not better than the Maryland material and the Texas aggregate showed to be the worst. As previously indicated, this does not agree with previous field or laboratory experience. The Georgia material is a known stripper with TSR values expected to be in the 20 to 30 range if the material doesn't fall apart during testing.

A further factor which confused this issue is the fact that none of the CR blends showed any significant benefit as experienced with the Arabian Heavy Study.

The visual evaluation of all the mixtures with the California Valley asphalt indicated that the vast majority of the stripping occurred in the fine aggregate fraction. This is totally different from the Arabian Heavy data and indicates that instead of evaluating three aggregates, only the natural sand RF from Illinois was studied.

Because of the concern over the major switch in data in this part of the study, an independent sample of California Valley asphalt was obtained (Not part of SHRP

MRL). The results of a new set of TSR tests on the Georgia aggregate are shown on Table 8. With this sample of asphalt, the TSR values decreased from 70 percent to the more common value of 28 percent with the coarse aggregate showing the stripping.

A study was undertaken to determine the differences in the asphalts which could cause such a major change. The results of a X-Ray fluorescence indicated that the SHRP MRL sample of California Valley asphalt contained 2400 parts per million of calcium compared to less than 50 parts per million for the check sample obtained independently. Other elements were present in virtually the same concentrations in each sample. Following is the data obtained on the two California Valley asphalts.

<u>Element</u>	SHRP <u>% Wt.</u>	Independent <u>% Wt.</u>
Al	0.06	0.08
Si	0.03	0.03
S	1.2	1.2
Ca	< 50 PPM	0.24
Fe	< 0.010 PPM	< 0.010 PPM

Based on this information, it appears that a form of processing was used in the manufacturing of the SHRP MRL asphalt which introduced calcium into the material.

It appears that the calcium benefitted this asphalt such that when tested with the aggregates and CR in this study it masked the results. For this reason, the results of the California Valley asphalt moisture damage tests were not used to derive the conclusions to this study.

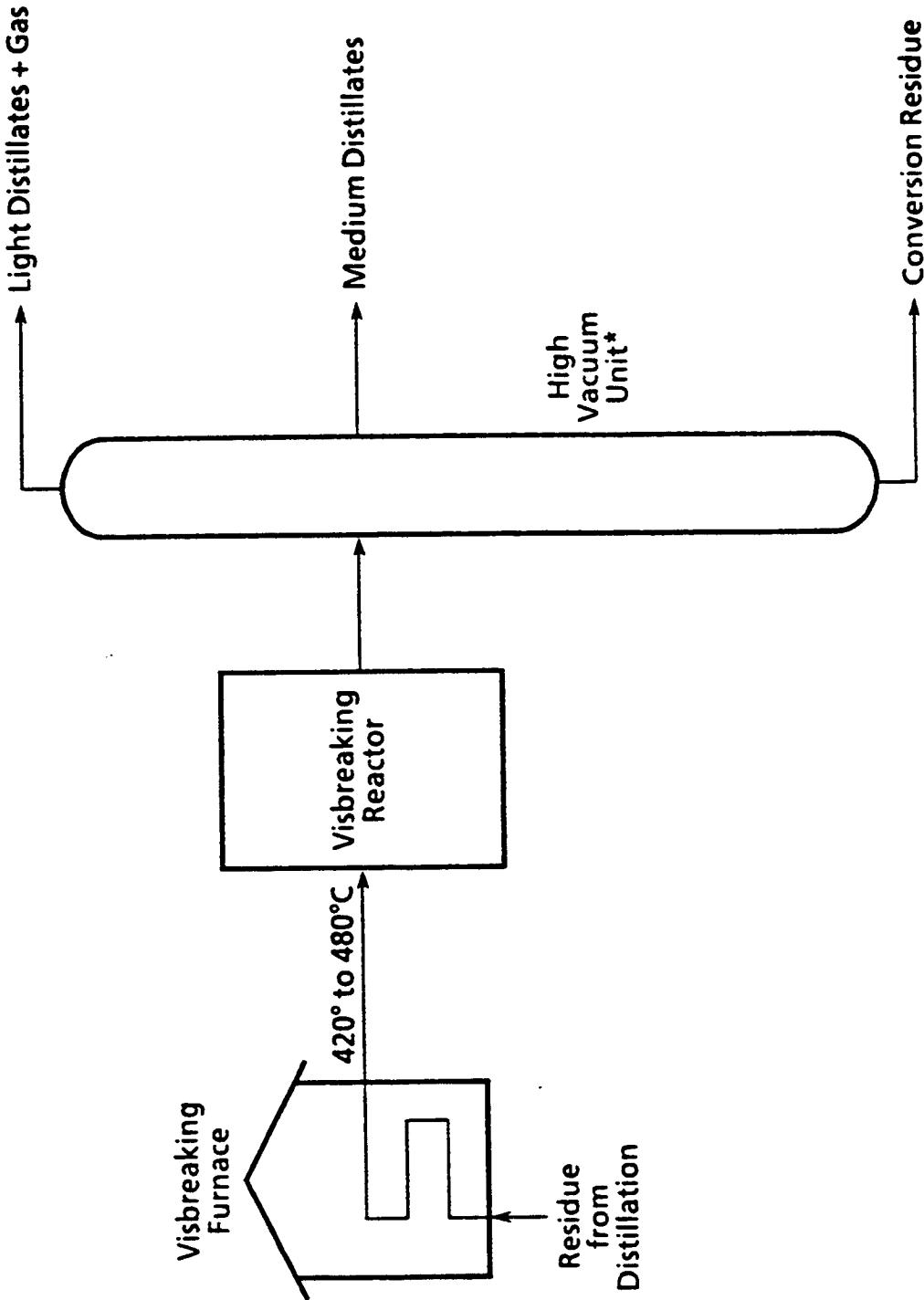
## CONCLUSIONS

All the tests conducted in this study showed that conversion residue can be used in limited quantities with current asphalts. The data indicates a significant improvement in asphalt properties and moisture performance for a number of conditions. None of the tests indicated any adverse effect of the CR on the asphalt except for the spot test.

## RECOMMENDATIONS

Based on the results of this study, it is recommended that several of the CR blends be shipped to other SHRP contractors for evaluation under the new binder tests being developed. If those results prove satisfactory, it is recommended that several test sections be built as part of the Long Term Pavement Performance Studies.

## **Appendix A**



\*Vacuum Distillation Column or Vacuum Flash Chamber

### Production Scheme for Conversion Residue

013194-1

FIGURE 1

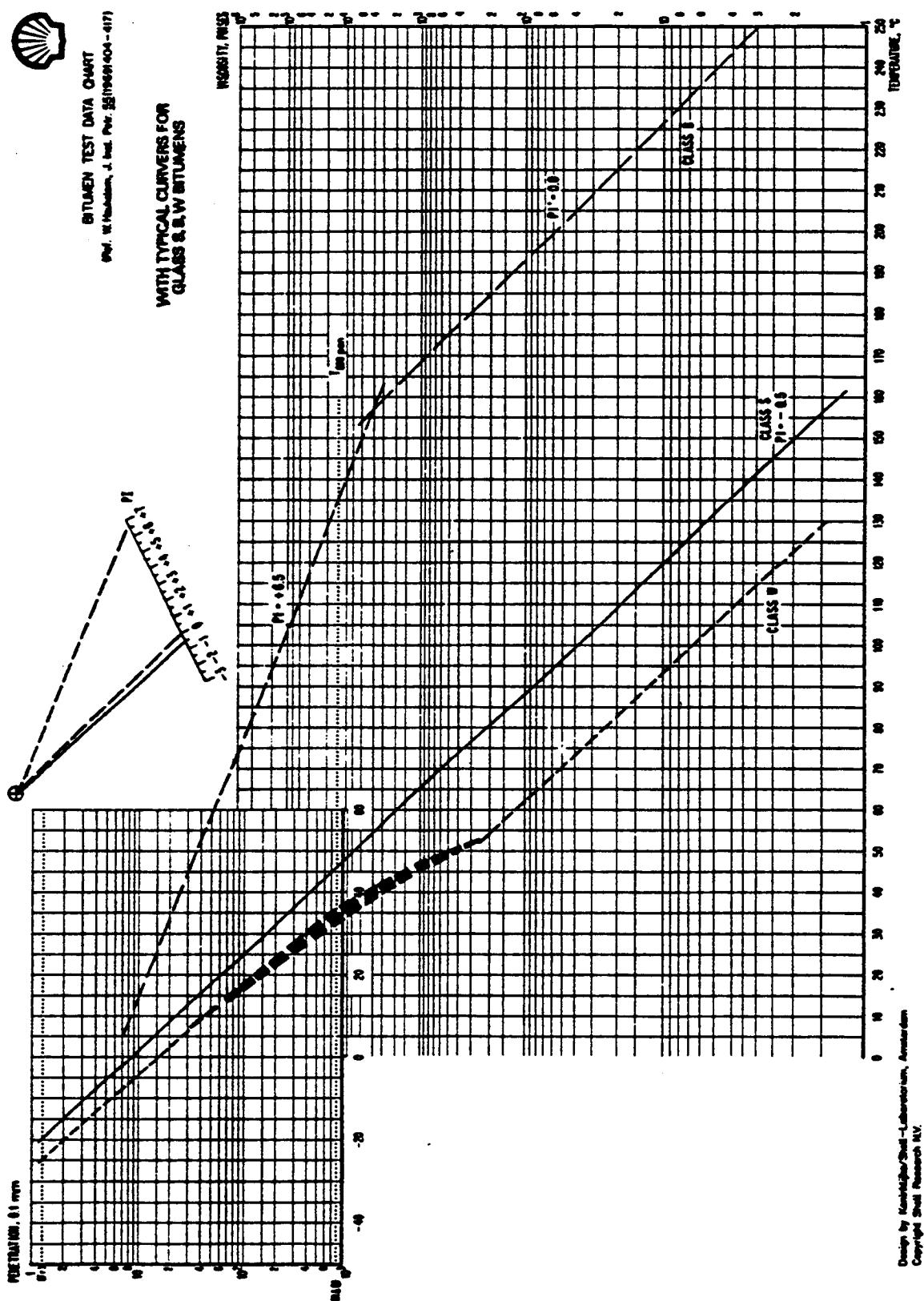
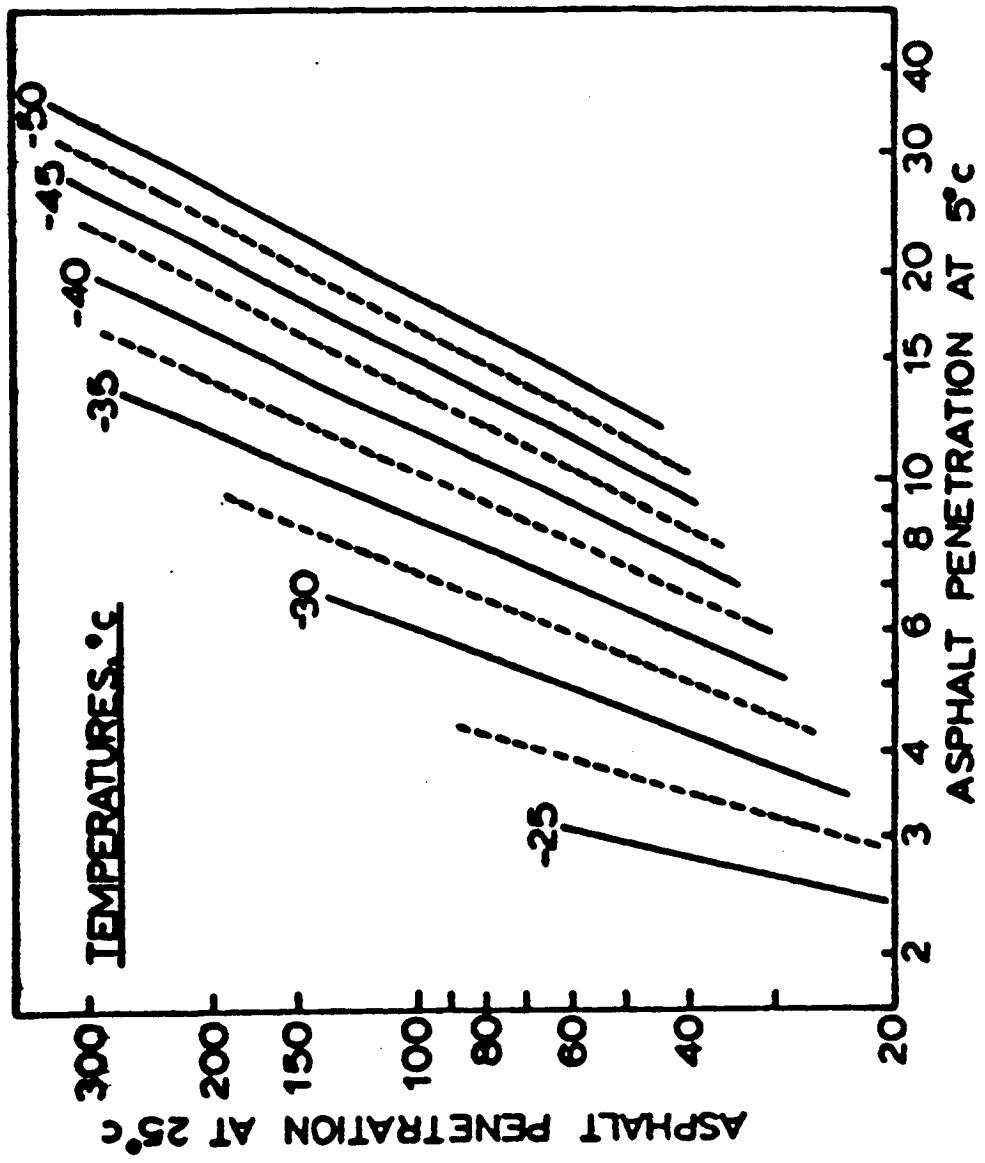


FIGURE 2

FIGURE 3



-Nomograph for predicting cracking temperatures in °C from asphalt penetrations.

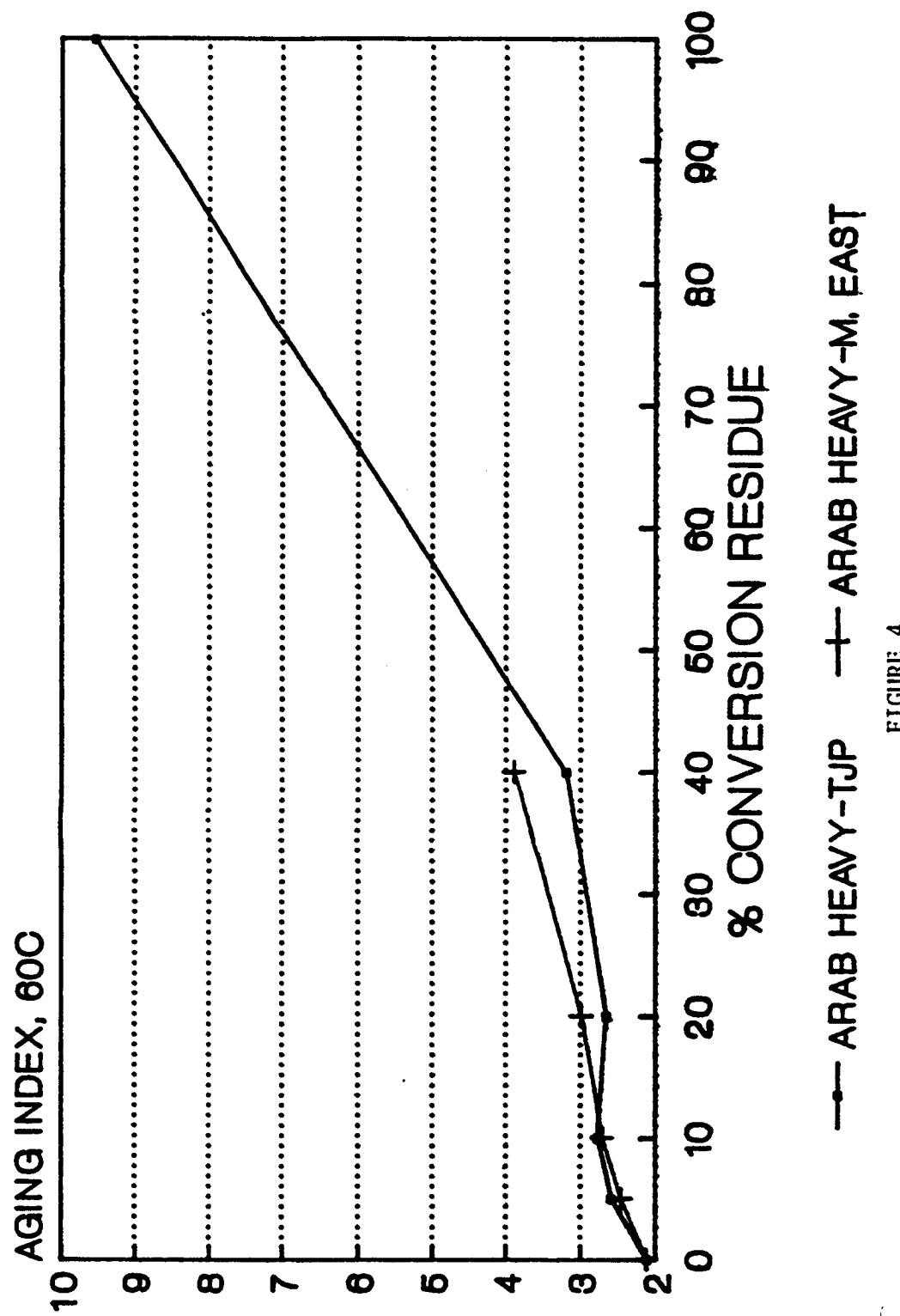
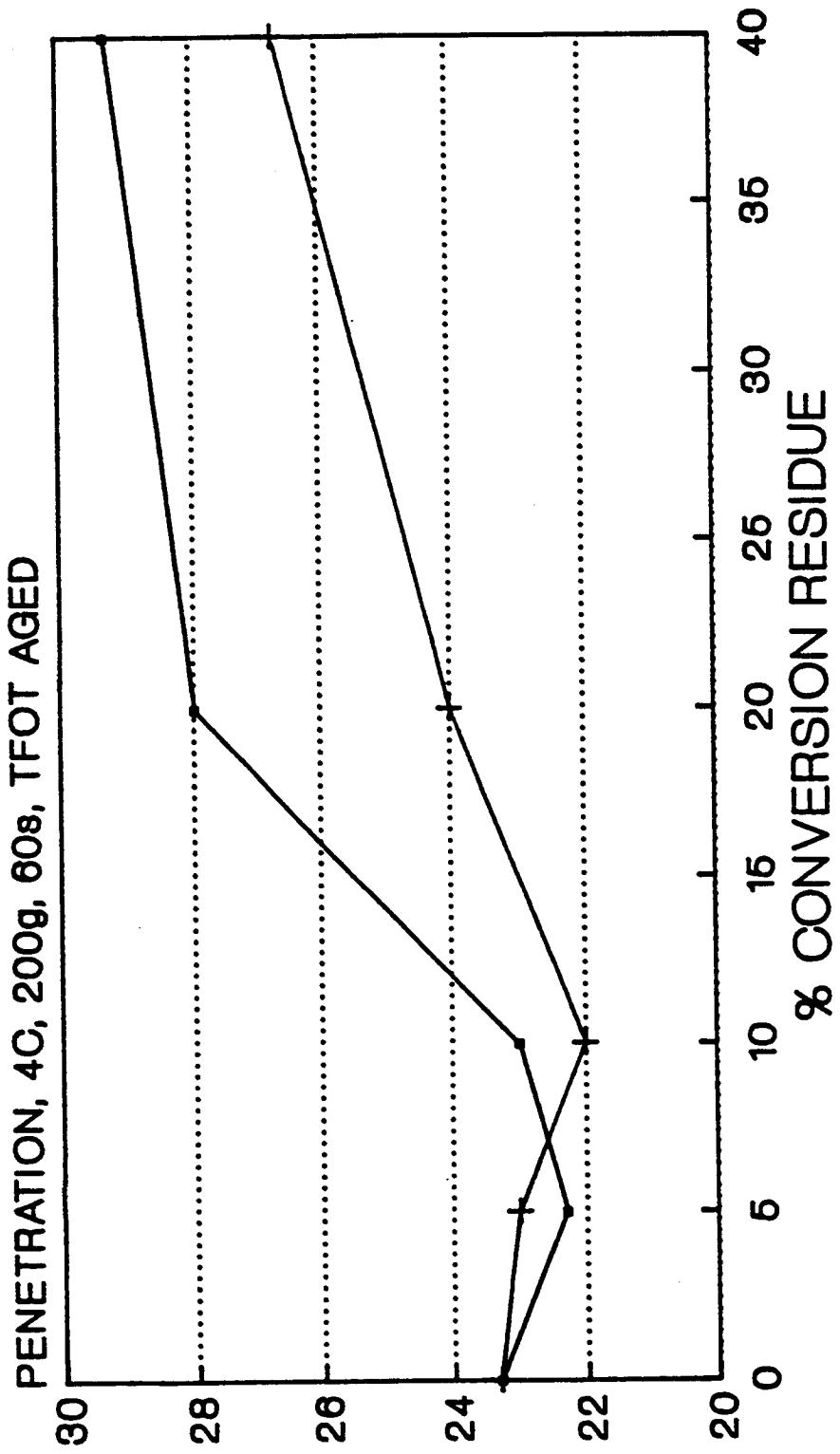


FIGURE 4



— ARAB HEAVY-TJP    + ARAB HEAVY-M. EAST

FIGURE 5

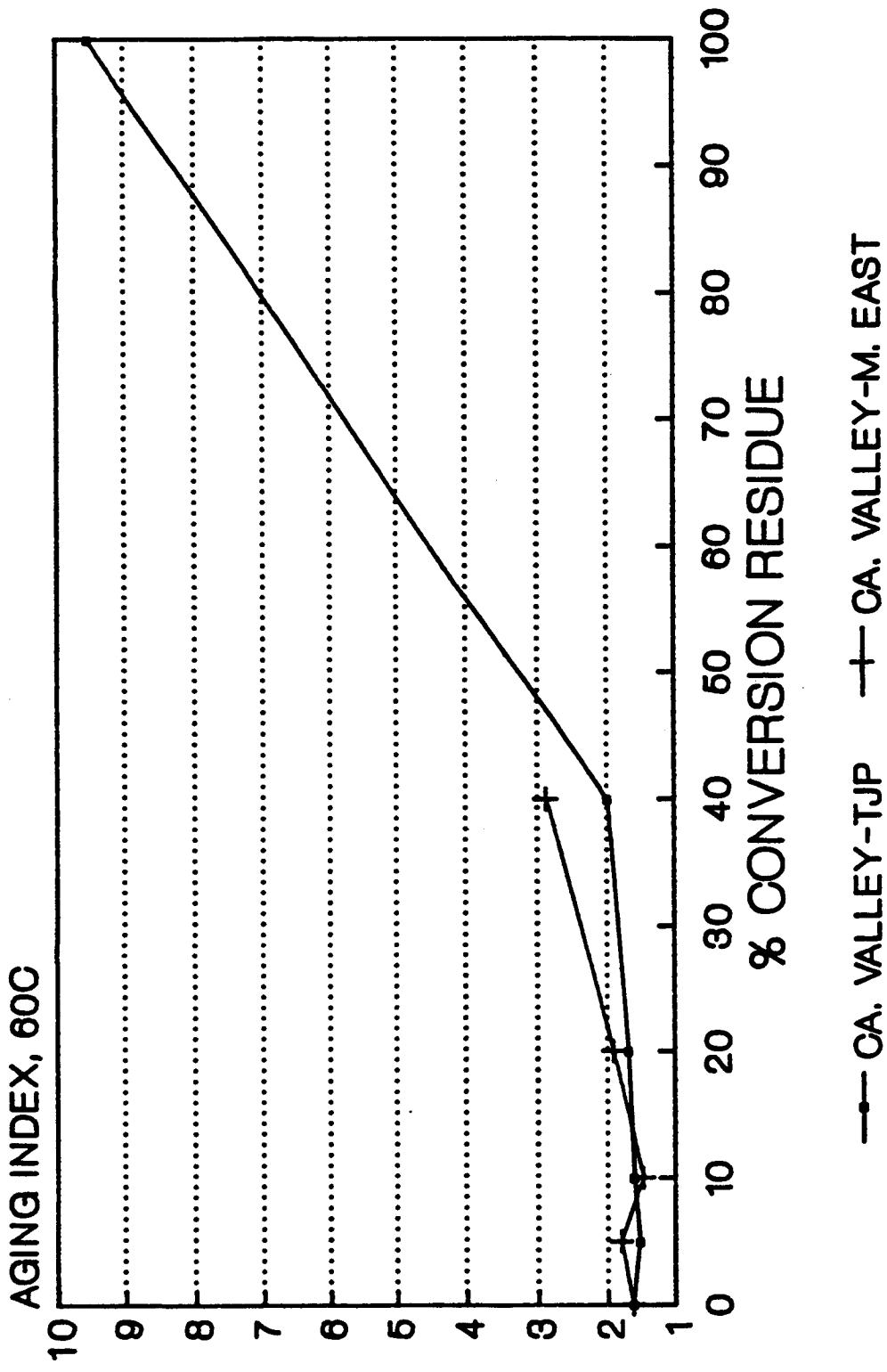


FIGURE 6

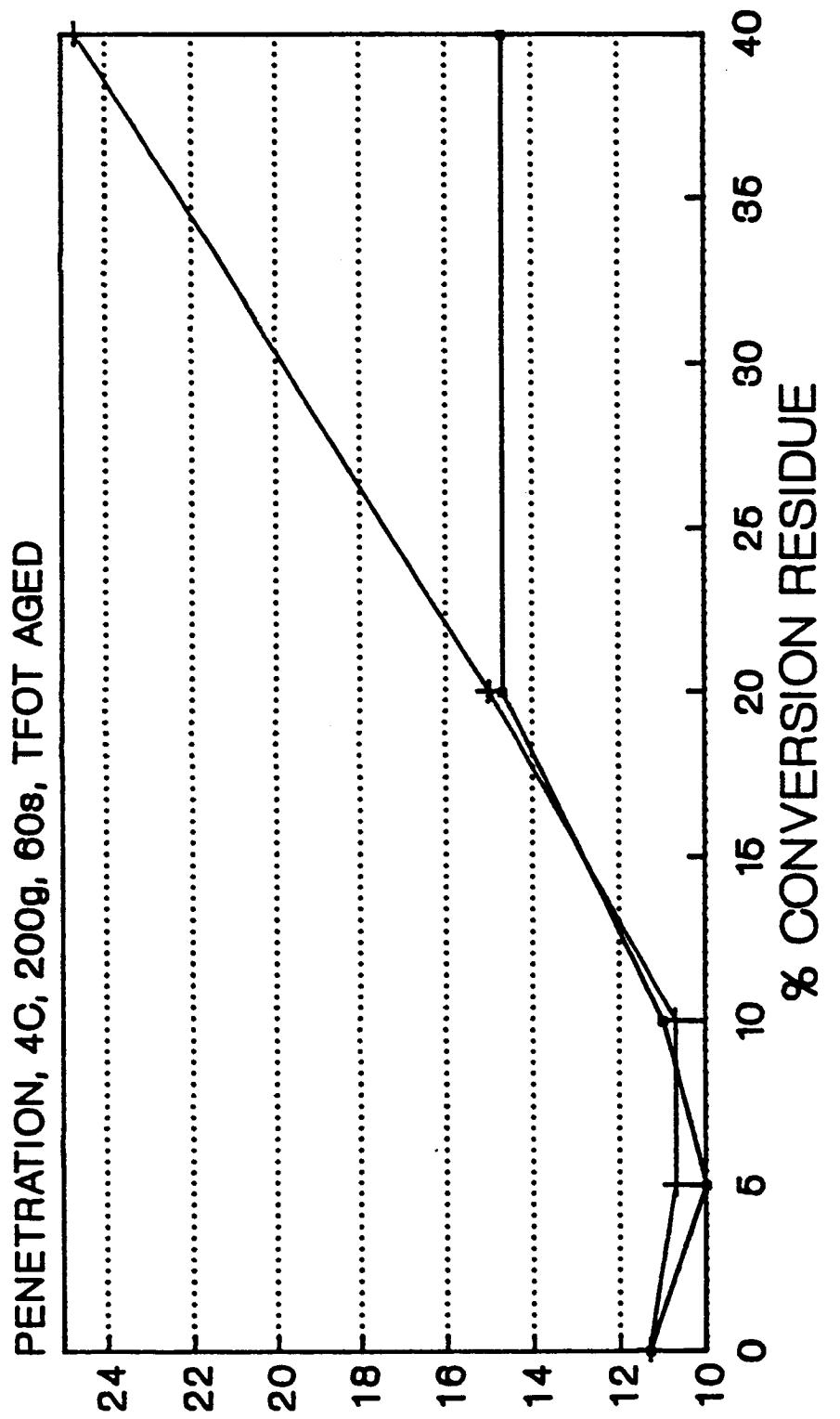


FIGURE 7

ARABIAN HEAVY ASPHALT BASE  
WITH TJP CONVERSION RESIDUE

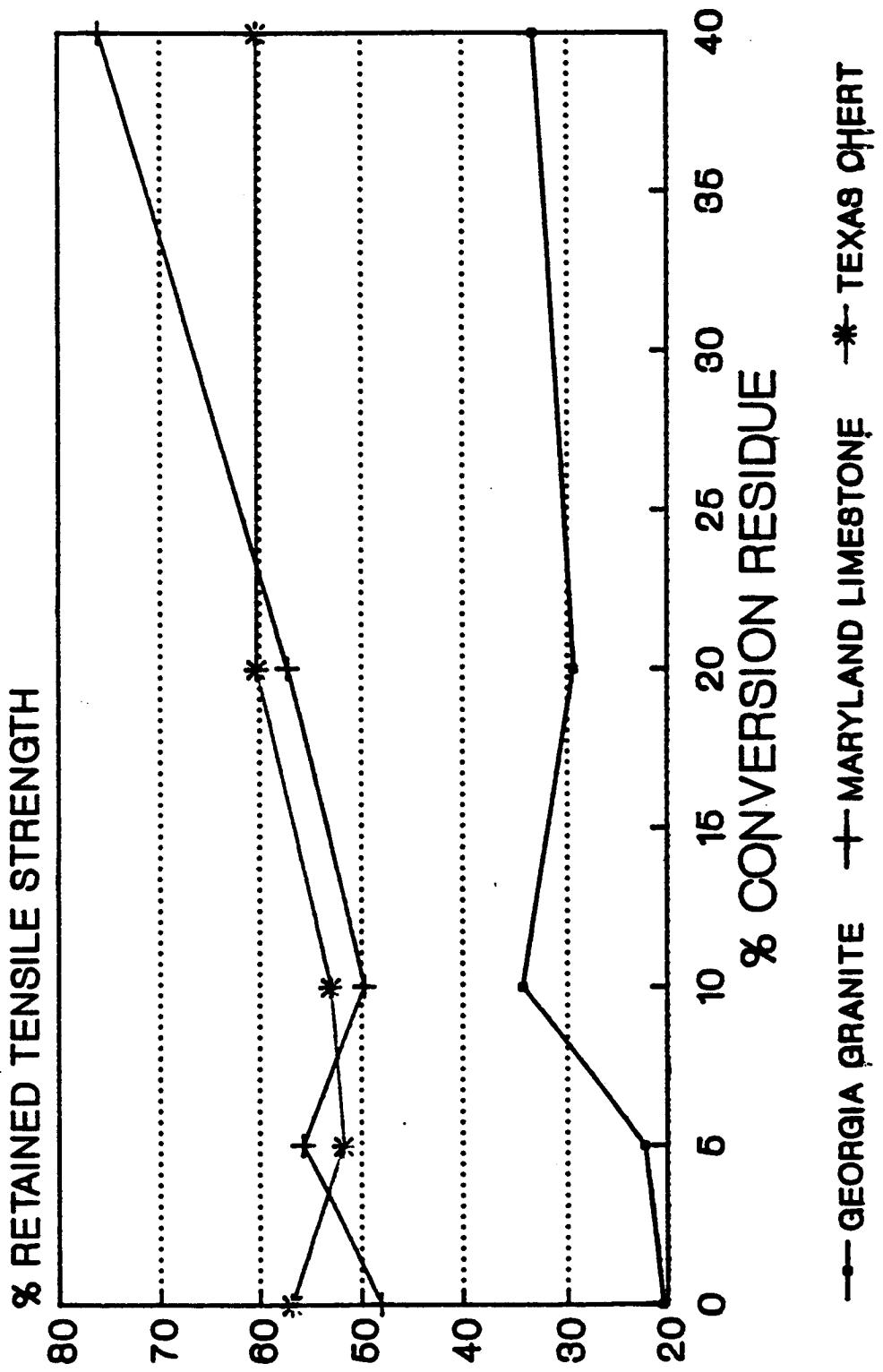
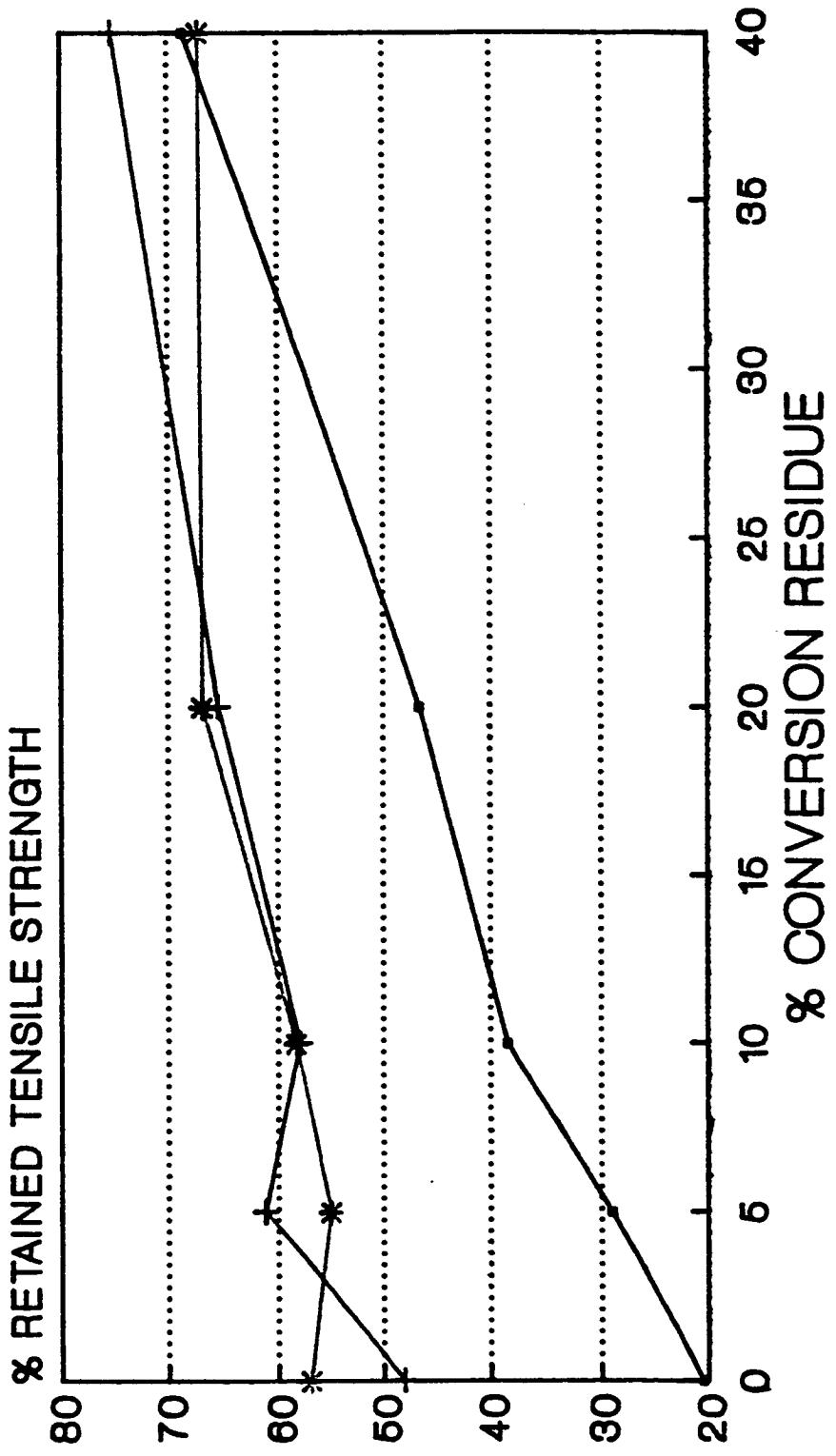


FIGURE 8

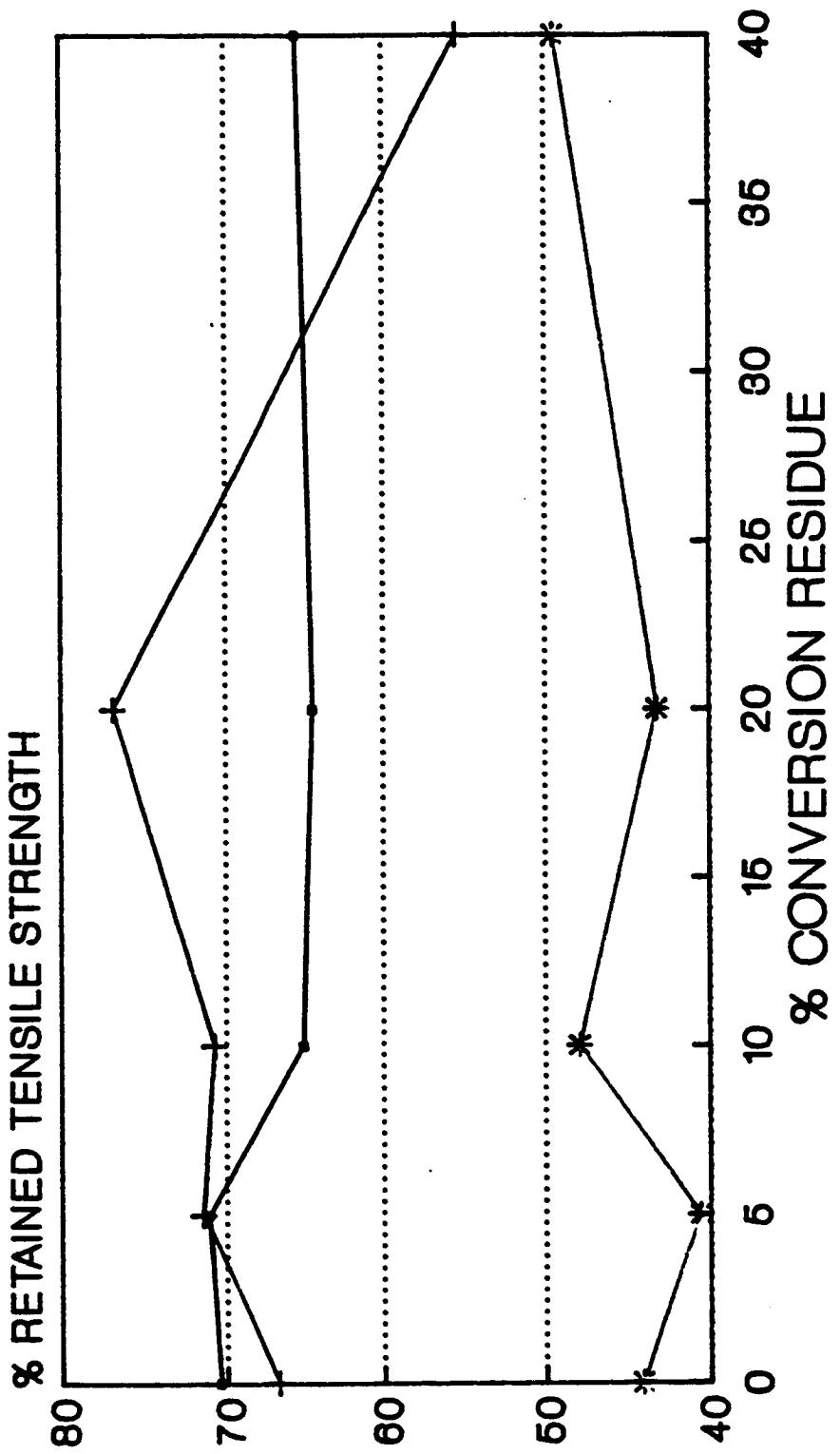
ARABIAN HEAVY ASPHALT BASE  
WITH M. EAST CONVERSION RESIDUE



—●— GEORGIA GRANITE    —+— MARYLAND LIMESTONE    -\*— TEXAS QUARTZ

FIGURE 9

CALIFORNIA VALLEY ASPHALT BASE  
WITH TJP CONVERSION RESIDUE



—●— GEORGIA GRANITE    +— MARYLAND LIMESTONE    -\*— TEXAS CHERT

FIGURE 10

CALIFORNIA VALLEY ASPHALT BASE  
WITH M. EAST CONVERSION RESIDUE

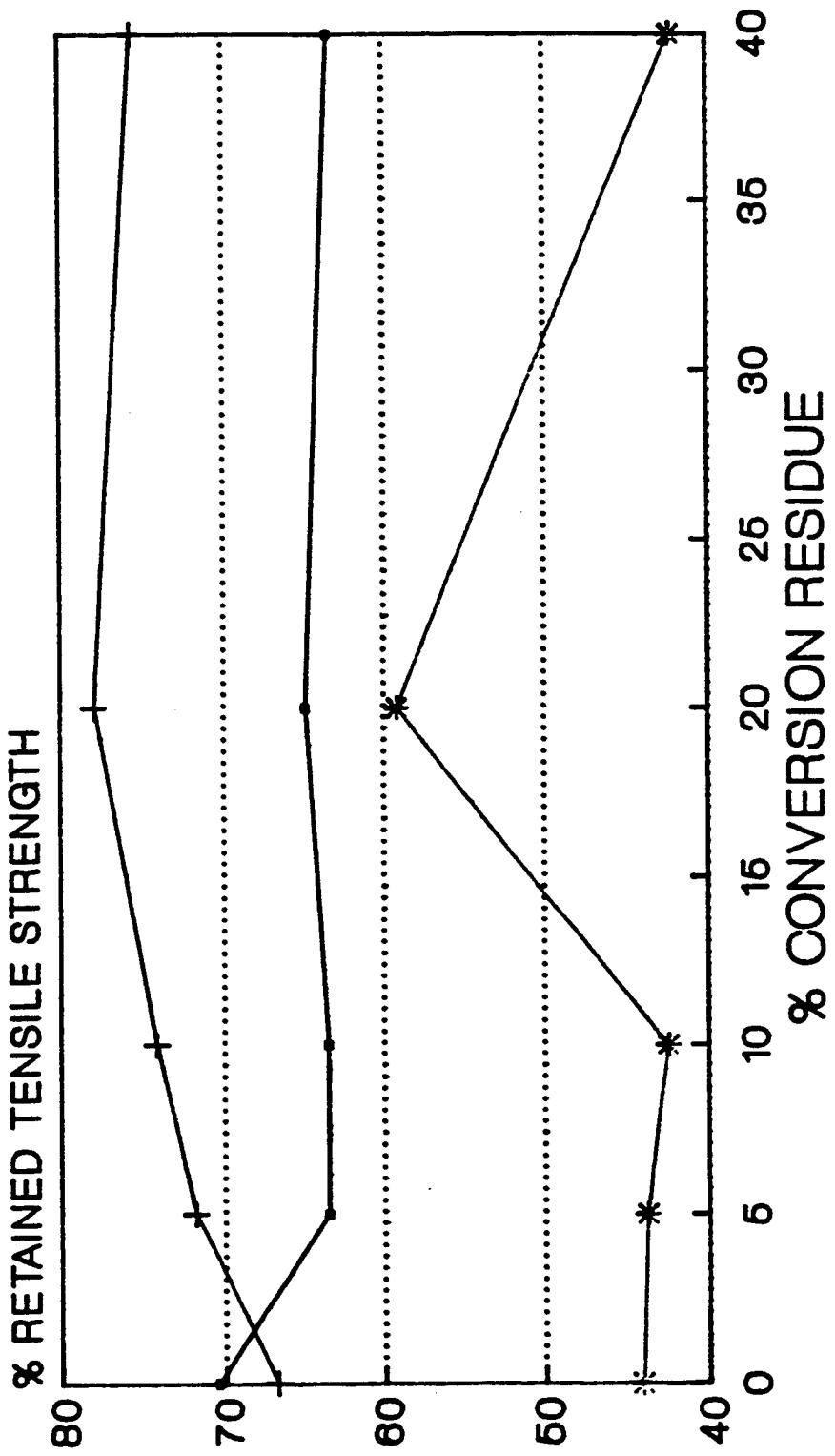


FIGURE 11

## **Appendix B**

TABLE - 1A

Laboratory Number	4207	4208	4203	4204	4205	4206
Component Number	1	2	3	4	5	—
Blend Number	—	—	—	—	—	8
Conv. Residue (W-834) x Tia Juana Pasada	100	—	—	—	5.0	10.0
AAS AC-20 (W-831), x Arabian Heavy	—	100	—	—	93.0	86.0
AAS AC-10 (W-829), x Arabian Heavy	—	—	100	—	2.0	4.0
XHFD (W-754), x	—	—	—	100	—	—
Penetration:						
200 gm, 60 Sec, 4C	30.3	37.3	—	—	36.0	34.3
100 gm, 5 Sec, 4C	8.0	11.0	—	—	9.3	9.0
100 gm, 5 Sec, 25C	42.7	80.7	—	—	80.3	79.7
Absolute Viscosity at 60C, P	10590	2041	—	0.8	2036	2070
Kinematic Viscosity at 135C, cst	478	470	—	—	441	435
Specific Gravity at 77F	1.052	1.028	—	—	1.029	1.033
Spot Test (65% Heptane, 35% Xylenes)	Pos.	Neg.	—	—	Neg.	Neg.
Spot Test (x Xylene for Negative Spot)	70	20	—	—	20	25
Eudation Droplet Test, mm	—	0.3	—	—	0.3	0.3
Flash Point (COC) °C	263	310	—	—	307	299
Solubility in TCE, %	99.76	99.73	—	—	99.99	99.94
Thin Film Oven Loss, % wt.	0.23	0.02	—	—	0.05	0.06
Tests on Residue:						
Penetration:						
200 gm 60 Sec, 4C	18.7	23.3	—	—	22.3	23.0
x Original	61.7	62.4	—	—	61.9	67.1
100 gm 5 Sec, 4C	4.7	7.7	—	—	6.0	6.3
x Original	58.7	70.0	—	—	64.5	70.0
100 gm 5 Sec, 25C	24.3	52.0	—	—	49.7	48.3
x Original	56.9	64.4	—	—	61.9	60.6
Absolute Viscosity at 60C, P	101, 160	4330	—	—	5276	5760
Aging Index (Abs. Vis. After 1FOL/orig.)	9.55	2.12	—	—	2.59	2.78
Ductility at 25C, 5/60, Cm	9.0	150+	—	—	150+	150+
Kinematic Viscosity at 135C, cst	2868	700.8	—	—	661.5	624.7

TABLE - 2A

Laboratory Number	7017	4208	--	--	8229	8230	8231	8232
Component Number	7	2	3	4	--	--	--	--
Blend Number	--	--	--	--	13	14	15	16
Conv. Residue (W-840)%	Middle East	. . . . .	. . . . .	. . . . .	5	10.00	20.00	40.00
AAS AC-20 (W-831), %	Arabian Heavy	. . . . .	. . . . .	. . . . .	--	--	--	--
AAS AC-10 (W-829), %	Arabian Heavy	. . . . .	. . . . .	. . . . .	95	84.84	63.52	23.25
XHFD (W-754), %	. . . . .	. . . . .	. . . . .	. . . . .	100	5.16	16.48	36.75
<b>Penetration:</b>								
200 gm, 60 Sec, 4C	. . . . .	0	37.3	--	28.0	28.7	32.7	35.7
100 gm, 5 Sec, 4C	. . . . .	0	11.0	--	5.7	6.3	7.7	9.7
100 gm, 5 Sec, 25C	. . . . .	1.7	80.7	--	79.0	77.0	80.0	77.0
<b>Absolute Viscosity at 60C, P</b>								
Kinematic Viscosity at 135C, cSt	. . . . .	*	2041	--	2113	2077	2178	1916
Specific Gravity at 77F	. . . . .	*	470	--	477	444	384.6	653.4
Spot Test (65% Heptane, 35% Xylene)	. . . . .	1.140	1.028	--	1.034	1.035	1.038	1.044
Spot Test (X Xylene for Negative Spot)	. . . . .	Pos.	Neg.	--	Neg.	Pos.	Pos.	Pos.
Exudation Droplet Test, mm	. . . . .	**	20	--	30	**	**	**
Flash Point (COC) °C	. . . . .	0.3	--	--	0.3	0.3	0.6	1.2
Solubility in TCE, %	. . . . .	349	310	--	321	316	313	310
Thin Film Oven Loss, % Wt.	. . . . .	97.67	99.73	--	99.81	99.54	99.38	97.96
<b>Tests on Residue:</b>								
Penetration:	. . . . .	. . . . .	. . . . .	. . . . .	--	23.0	22.0	26.7
200 gm 60 Sec, 4C	. . . . .	0	23.3	--	82.1	76.7	73.3	74.8
% Original	. . . . .	0	62.4	--	5.3	5.3	6.7	8.3
100 gm 5 Sec, 4C	. . . . .	0	7.7	--	93.0	84.1	87.0	85.6
% Original	. . . . .	0	70.0	--	50.0	47.0	44.7	50.0
100 gm 5 Sec, 25C	. . . . .	0	52.0	--	63.3	61.0	55.9	64.9
% Original	. . . . .	0	64.4	--	--	5198	5622	6510
Absolute Viscosity at 60C, P	. . . . .	*	4330	--	--	2.46	2.71	2.99
Aging Index (Abs. Vis. After TFOL/Orig.)	. . . . .	*	2.12	--	--	89.0	28.3	3.89
Ductility at 25C, 5/60, Cm	. . . . .	0	150+	--	--	621.5	634.3	7.0
Kinematic Viscosity at 135C, cst	. . . . .	*	700.8	--	--	--	--	732.8

\* Material is too hard to determine these viscosities  
 \*\* Spot is positive with 100% Xylene

TABLE - 3A

Laboratory Number	4207	8233	--	6076	6077	6078	6079
Component Number	1	5	6	4	9	10	11
Blend Number	--	--	--	--	--	12	12
Conv. Residue (W-834)% Tia Juana Posada	100	--	--	--	5.0	10.0	20.0
AAG AR-4000 (W-842),% Calif. Valley	--	100	--	--	93.0	86.0	80.0
AAG AR-2000 (W-841),% Calif Valley	--	--	100	--	2.0	4.0	--
XHFD (W-754),%	--	--	--	100	--	--	--
<b>Penetration:</b>							
200 gm, 60 Sec, 4C	30.3	13.0	--	--	11.3	21.3	24.3
100 gm, 5 Sec, 4C	8.0	1.0	--	--	2.0	3.0	6.0
100 gm, 5 Sec, 25C	42.0	49.7	--	--	55.3	57.3	67.7
Absolute Viscosity at 60C, P	10590	2059	--	0.8	1874	1810	1779
Kinematic Viscosity at 135C, cSt	478	252	--	--	256	255	256
Specific Gravity at 77F	1.052	1.017	--	--	1.022	1.022	1.024
Spot Test (65% Heptane, 35% Xylene)	Pos.	Neg.	--	--	Neg.	Neg.	Pos.
Spot Test (% Xylene for Negative Spot)	70	10	--	--	20	30	50
Exudation Drop Test, mm	--	0.2	--	--	0.2	0.2	0.2
Flash Point (COC) °C	263	313	--	--	318	316	285
Solubility in TCE, %	99.76	99.89	--	--	99.86	99.85	99.84
Thin Film Oven Loss, % Wt.	0.23	0.12	--	--	0.08	0.08	0.07
<b>Tests on Residue:</b>							
Penetration:	--	--	--	--	10.0	11.0	14.7
200 gm 60 Sec, 4C	18.7	11.3	--	--	90.9	97.3	69.0
% Original	61.1	86.9	--	--	2.0	2.0	60.5
100 gm 5 Sec, 4C	4.7	1.0	--	--	100	100	2.3
% Original	58.7	100	--	--	40.3	41.7	3.3
100 gm 5 Sec, 25C	24.3	35.0	--	--	72.9	72.8	55.0
% Original	56.9	70.4	--	--	--	--	42.7
Absolute Viscosity at 60C, P	101, 160	3326	--	--	2867	2913	3677
Aging Index (Abs. Vis. After 1FOL/orig.)	9.55	1.62	--	--	1.53	1.61	2.00
Ductility at 25C, 5/60, Cm	9.0	150+	--	--	150+	150+	150+
Kinematic Viscosity at 135C, cSt	2868	324.7	--	--	363.5	359.6	390.4

TABLE - 4A

Laboratory Number	7017	7013.	7014	7015	7016
Component Number	7	—	—	—	—
Blend Number	—	5	4	—	—
Conv. Residue (W-840)% Middle East	100	—	—	—	—
AAG AR-4000 (W-842),% Calif. Valley	—	100	—	—	—
AAG AR-2000 (W-841),% Calif. Valley	—	—	100	—	—
XHFD (W-754),%	—	—	—	100	—

## Penetration:

200 gm, 60 Sec, 4C	0	13.0	—	—	17.7
100 gm, 5 Sec, 4C	0	1.0	—	—	3.0
100 gm, 5 Sec, 25C	1.7	49.7	—	—	50.3
Absolute Viscosity at 60C, P	*	2059	0.8	—	1760
Kinematic Viscosity at 135C, cst	*	252	—	248	231
Specific Gravity at 77F	*	1.140	1.017	—	1.028
Spot Test (65% Heptane, 35% Xylene)	Pos.	Neg.	—	—	1.031
Spot Test (% Xylene for Negative Spot)	**	10	—	—	Pos.
Exudation Drop Test, mm	—	0.2	—	—	**
Flash Point (COC) °C	349	313	—	—	0.2
Solubility in TCE, %	97.67	99.89	—	—	0.2
Thin Film Oven Loss, % wt.	0.01	0.12	—	—	0.15

## Tests on Residue:

Penetration:	—	—	—	—	10.7
200 gm 60 Sec, 4C	0	11.3	—	—	60.4
% Original	0	86.9	—	—	1.0
100 gm 5 Sec, 4C	0	1.0	—	—	33.3
% Original	0	100	—	—	36.0
100 gm 5 Sec, 25C	0	35.0	—	—	71.5
% Original	0	70.4	—	—	3169
Absolute Viscosity at 60C, P	*	1.62	—	—	1.80
Aging Index (Abs. Vis. After TfOL/Orig.)	*	3326	—	—	1.47
Ductility at 25C, 5/60, cm	0	150+	—	—	150+
Kinematic Viscosity at 135C, cst	*	324.7	—	—	354.6

\* Material is too hard to determine these viscosities

\*\* Spot is positive with 100% Xylene

TABLE - 1B

Laboratory Number	4207	4208	--	--	4203	4204	4205	4206
Component Number	1	2	3	4	--	--	--	--
Blend Number	--	--	--	--	5	6	7	8
Conv. Residue (W-834)% Tia Juana Posada	100	--	--	--	5.0	10.0	20.0	40.0
AAS AC-20 (W-831),% Arabian Heavy	--	100	--	--	93.0	86.0	46.4	--
AAS AC-10 (W-829),% Arabian Heavy	--	--	100	--	2.0	4.0	33.6	58.4
XHFD (W-754),%	--	--	--	100	--	--	--	1.6
Bitumen Temperature Susceptibility Pen at 4°C, Absolute Viscosity at 60°C	+0.56	-0.54	-0.73	-0.75	-0.73	-0.75	-0.89	-0.74
Original Sample	+1.83	-0.29	-0.42	-0.29	-0.33	-0.26	-0.22	+0.22
After Thin Film Oven Loss	.	.	.	.	.	.	.	.
Bitumen Temperature Susceptibility Pen at 25°C; Absolute Viscosity at 60°C	+0.33	-0.73	-0.74	-0.73	-0.73	-0.71	-0.71	-0.74
Original Sample	+2.33	-0.51	-0.33	-0.26	-0.26	-0.18	-0.18	-0.09
After Thin Film Oven Loss	.	.	.	.	.	.	.	.
Fraass Breaking Point °C	.	.	.	.	.	.	.	.
Original Sample	-19	-19	-16	-15	-16	-16	-16	-16
After Thin Film Oven Loss	-13	-16	-12	-13	-14	-14	-14	-20
Estimated Thermal Cracking Temperature °C	-42	-43	-39	-39	-37	-37	-41	-41
Original Sample	-37	-39	-35	-37	-37	-37	-37	-37
After Thin Film Oven Loss	.	.	.	.	.	.	.	.

**TABLE - 2B**

Laboratory Number . . . . .	7017	4208	--	--	8229	8230	8231	8232
Component Number . . . . .	7	2	3	4	--	--	--	--
Blend Number . . . . .	--	--	--	--	13	14	15	16
Conv. Residue (W-840)% Middle East . . . . .	100	--	--	--	5	10.00	20.00	40.00
AAS AC-20 (W-831),% Arabian Heavy . . . . .	--	100	--	--	--	--	--	--
AAS AC-10 (W-829),% Arabian Heavy . . . . .	--	--	100	--	95	84.84	63.52	23.25
XHFD (W-754),% . . . . .	--	--	--	100	--	5.16	16.48	36.75
Bitumen Temperature Susceptibility								
Pen at 4°C; Absolute Viscosity at 60°C								
Original Sample . . . . .	-0.54				-1.23	-1.13	-0.88	-0.73
After Thin Film Oven Loss . . . . .	-0.29				-0.58	-0.31	-0.11	+0.29
Bitumen Temperature Susceptibility								
Pen at 25°C; Absolute Viscosity at 60°C								
Original Sample . . . . .	-0.73				-0.72	-0.79	-0.65	-0.90
After Thin Film Oven Loss . . . . .	-0.51				-0.34	-0.35	-0.25	+0.17
Fraass Breaking Point °C								
Original Sample . . . . .	-19				-8	-10	-12	-17
After Thin Film Oven Loss . . . . .	-16				-9	-13	-15	-18
Estimated Thermal Cracking Temperature °C								
Original Sample . . . . .	-43				-33	-34	-36	-41
After Thin Film Oven Loss . . . . .	-39				-33	-37	-38	-42

TABLE - 3B

Laboratory Number . . . . .	4207	8233	--	--	6076	6077	6078	6079
Component Number . . . . .	1	5	6	4	—	—	—	—
Blend Number . . . . .	--	--	--	--	9	10	11	12
Conv. Residue (W-834) % Tia Juana Posada .	100	--	--	--	5.0	10.0	20.0	40.0
AAG AR-4000 (W-842), % Calif Valley .	--	100	--	--	93.0	86.0	80.0	60.0
AAG AR-2000 (W-841), % Calif Valley .	--	--	100	--	2.0	4.0	--	--
XHFD (W-754), % . . . . .	--	--	--	100	--	--	--	--
Bitumen Temperature Susceptibility Pen at 4°C, Absolute Viscosity at 60°C								
Original Sample . . . . .	+0.56	-2.68			-2.22	-2.24	-1.92	-1.27
After Thin Film Oven Loss . . . . .	+1.83	-2.42			-1.96	-1.95	-1.81	-1.34
Bitumen Temperature Susceptibility Pen at 25°C; Absolute Viscosity at 60°C								
Original Sample . . . . .	+0.33	-1.51			-1.46	-1.44	-1.34	-1.16
After Thin Film Oven Loss . . . . .	+2.33	-1.49			-1.44	-1.37	-1.33	-1.06
Fraass Breaking Point °C								
Original Sample . . . . .	-19	+5			+1	+1	-2	-10
After Thin Film Oven Loss . . . . .	-13	+5			+1	+1	0	-4
Estimated Thermal Cracking Temperature °C								
Original Sample . . . . .	-42	-21			-23	-23	-27	-33
After Thin Film Oven Loss . . . . .	-37	-21			-23	-23	-24	-28

TABLE - 4B

Laboratory Number	7017	8233	--	7013	7014	7015	7016
Component Number	7	5	6	4	--	--	--
Blend Number	--	--	--	--	17	18	19
Conv. Residue (W-840), %	Middle East	100	--	--	5.00	10.00	20.00
AAG AR-4000 (W-842), %	Calif. Valley	--	100	--	19.26	--	--
AAG AR-2000 (W-841), %	Calif. Valley	--	--	100	75.74	88.22	71.22
XHFD (W-754), %	--	--	--	--	--	1.78	8.78
Bitumen Temperature Susceptibility							
Pen at 40°C, Absolute Viscosity at 60°C							
Original Sample		-2.68		-1.93	-1.82	-1.54	-1.00
After Thin Film Oven Loss		-2.42		-2.44	-2.46	-1.79	-0.61
Bitumen Temperature Susceptibility							
Pen at 25°C; Absolute Viscosity at 60°C							
Original Sample		-1.51		-1.67	-1.39	-1.45	-0.93
After Thin Film Oven Loss		-1.49		-1.50	-1.46	-1.27	-0.44
Fraass Breaking Point °C							
Original Sample		+5		-2	-2	-6	-13
After Thin Film Oven Loss		+5		+5	+5	+1	-9
Estimated Thermal Cracking Temperature °C							
Original Sample		-21		-27	-27	-30	-37
After Thin Film Oven Loss		-21		-21	-21	-24	-33

TABLE - 1C

Laboratory Number	4207	4208	--	--	4203	4204	4205	4206
Component Number	1	2	3	4	--	--	--	--
Blend Number	--	--	--	--	5	6	7	8
Conv. Residue (W-834) %	T1a	Juana Pasada	--	--	5.0	10.0	20.0	40.0
AAS AC-20 (W-831), %	Arabian Heavy	--	--	--	93.0	86.0	46.4	--
AAS AC-10 (W-829), %	Arabian Heavy	--	100	--	2.0	4.0	33.6	58.4
XHFD (W-754), %	--	--	--	100	--	--	--	1.6
Georgia Aggregate (RA)								
Retained Tensile Strength	--	20.5	--	--	22.3	34.3	29.4	33.3
Visual Stripping	--	5.0	--	--	5.0	5.0	5.0	4.5
Maryland Limestone (RD)								
Retained Tensile Strength	--	48.0	--	--	55.8	49.7	57.3	76.1
Visual Stripping	--	4.0	--	--	4.0	4.0	2.5	3.0
Texas Chert (RL)								
Retained Tensile Strength	--	56.9	--	--	51.8	53.1	60.3	60.3
Visual Stripping	--	3.5	--	--	4.0	4.0	3.5	3.5

TABLE - 2C

Laboratory Number	7017	4208	--	--	8229	8230	8231	8232
Component Number	7	2	3	4	--	--	--	--
Blend Number	--	--	--	--	13	14	15	16
Conv. Residue (W-840), %	Middle East	100	--	--	5	10.00	20.00	40.00
AAS AC-20 (W-831), %	Arabian Heavy	--	100	--	--	--	--	--
AAS AC-10 (W-829), %	Arabian Heavy	--	--	100	--	95	84.84	63.52
XHFD (W-754), %		--	--	--	100	--	5.16	16.48
Georgia Aggregate (RA)								
Retained Tensile Strength	--	20.5	--	--	29.1	38.5	46.6	68.7
Visual Stripping	--	5.0	--	--	5.0	5.0	4.0	2.5
Maryland Limestone (RD)								
Retained Tensile Strength	--	48.0	--	--	61.2	58.0	65.5	75.3
Visual Stripping	--	4.0	--	--	3.0	3.0	3.0	0.0
Texas Chert (RL)								
Retained Tensile Strength	--	56.9	--	--	55.0	58.3	66.9	67.2
Visual Stripping	--	3.5	--	--	3.5	3.5	3.0	0.0

TABLE - 3C

Laboratory Number . . . . .	4207	8233	--	--	6076	6077	6078	6079
Component Number . . . . .	1	5	6	4	--	--	--	--
Blend Number . . . . .	--	--	--	--	9	10	11	12
Conv. Residue (W-834)% T1a Juana Pasada .	100	--	--	--	5.0	10.0	20.0	40.0
AAG AR-4000 (W-842),% Calif. Valley .	--	100	--	--	93.0	86.0	80.0	60.0
AAG AR-2000 (W-841),% Calif. Valley .	--	--	100	--	2.0	4.0	--	--
XHFD (W-754),%	--	--	--	100	--	--	--	--
Georgia Aggregate (RA)								
Retained Tensile Strength . . . . .	--	70.4	--	--	71.1	65.1	64.5	65.5
Visual Stripping . . . . .	--	2.5	--	--	2.5	2.5	2.5	2.0
Maryland Limestone (RD)								
Retained Tensile Strength . . . . .	--	66.7	--	--	71.4	70.7	76.8	55.4
Visual Stripping . . . . .	--	2.5	--	--	2.0	2.0	1.0	0.0
Texas Chert (RL)								
Retained Tensile Strength . . . . .	--	44.1	--	--	40.6	47.9	43.2	49.4
Visual Stripping . . . . .	--	3.0	--	--	3.0	3.0	3.5	2.0

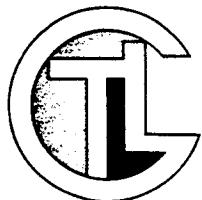
TABLE - 4C

	Laboratory Number	7017	8233	--	--	7013	7014	7015	7016
Component Number	7	5	6	4	--	--	--	--	--
Blend Number	--	--	--	--	17	18	19	19	20
Conv. Residue (W-840)%	Middle East	100	--	--	--	5.00	10.00	20.00	40.00
AAG AR-4000	(W-842),% Calif Valley	--	100	--	--	19.26	--	--	--
AAG AR-2000	(W-841),% Calif Valley	--	--	100	--	75.74	88.22	71.22	29.08
XHFD (W-754),%	--	--	--	100	--	1.78	8.78	8.78	30.92

**Georgia Aggregate (RA)**

Retained Tensile Strength	--	70.4	--	--	63.5	63.5	64.9	63.4
Visual Stripping	--	2.5	--	--	2.5	2.5	3.0	2.5
Maryland Limestone (RD)								
Retained Tensile Strength	--	66.7	--	--	71.8	74.1	77.9	75.5
Visual Stripping	--	2.5	--	--	2.0	1.0	0.0	1.0
Texas Chert (RL)								
Retained Tensile Strength	--	44.1	--	--	43.8	42.5	59.2	42.3
Visual Stripping	--	3.0	--	--	3.5	3.5	1.0	2.0

GENE ABSON, P.E. (1897-1963)  
WARD K. PARR, P.E. (1912-1985)  
CONWAY C. BURTON, P.E.  
(CONSULTANT)  
RICHARD E. ROOT, P.E.  
GEORGE J. GIROUX, B.S.  
EROL UNER, C.E.T.



# CHICAGO TESTING LABORATORY, Inc.

3360 COMMERCIAL AVENUE/NORTHBROOK, ILLINOIS 60062

FOUNDED 1912

(708) 498-6400 FAX: (708) 498-7232

TABLE 5A

Report  
No. 006039

September 28, 1990

National Research Council  
Strategic Highway Research Program  
Attention: Mr. Robert R. Kelley  
818 Connecticut Avenue, N.W.  
Washington, DC 20006

### SHRP IDEAS - Georgia Granite (RA) Contract No. SHRP 87-ID020

Samples of aggregate were received from SHRP-Reference Laboratory for testing. A Marshall mix design was conducted in essential conformity with the procedures in the Asphalt Institute Manual MS-2.

Specimens were prepared from multiple batches and held at compaction temperature for 1.5 hours to simulate field conditions. Compaction was accomplished with a mechanical hammer and the maximum density was determined in accordance with ASTM Method D-2041.

The test data is summarized on the attached Report of Bituminous Mix Design and has been plotted on the Marshall data curves.

The following data summarizes the recommended mix design for the materials submitted.

#### Aggregate Proportions (Cold Feed):

<u>Quantity</u>	<u>Material</u>	<u>Source</u>
20%	No. 7	Georgia Granite (RA)
15%	No. 890	Georgia Granite (RA)
35%	No. 810	Georgia Granite (RA)
30%	FA-2	Crystal Lake (RF)

#### Optimum Asphalt Content for 75 Blow Design:

(Percent by Total Weight of Mix)

<u>Grade</u>	<u>Amount</u>
AC-20 (W831)	6.0 %



TABLE 5B  
CHICAGO TESTING LABORATORY, INC

Report 006039

Marshall Properties at Optimum Asphalt Content:

Stability, at 140F, 1b . . . . .	2770
Flow, at 140F, 0.01" . . . . .	10.5
Unit Weight, lb/ft <sup>3</sup> . . . . .	145.4

Voids Analysis, %:	
Air Voids . . . . .	4.0
Voids Mineral Aggregate . . . . .	16.4
Voids Filled . . . . .	76

Job Mix Formula:

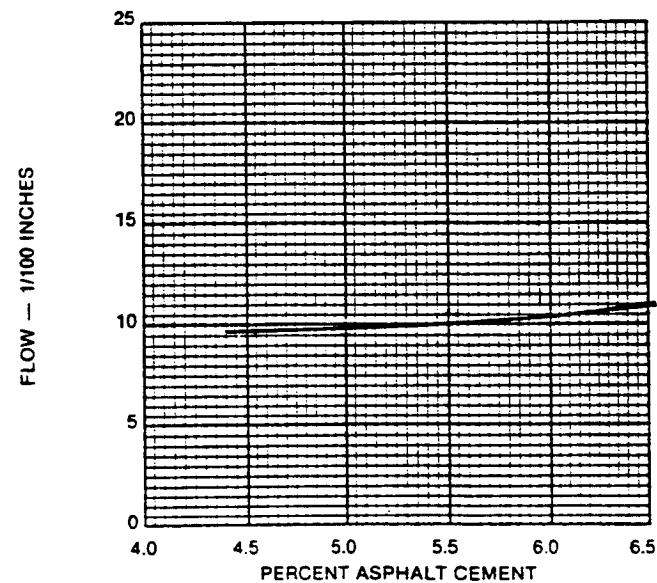
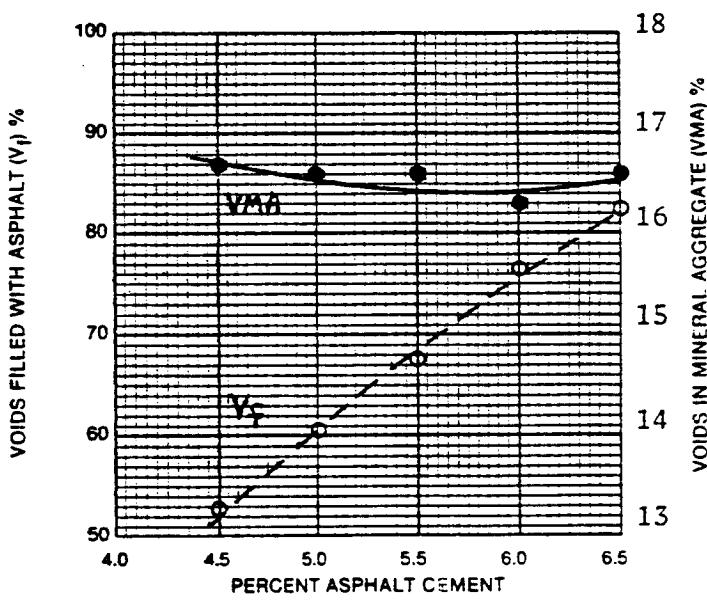
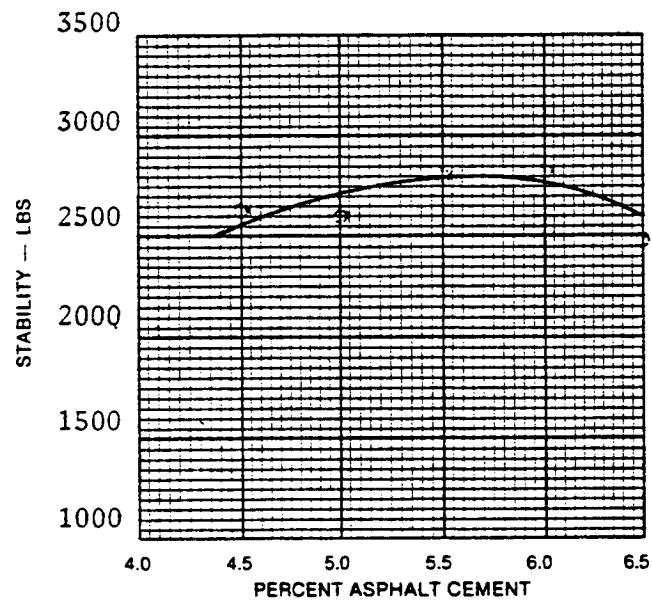
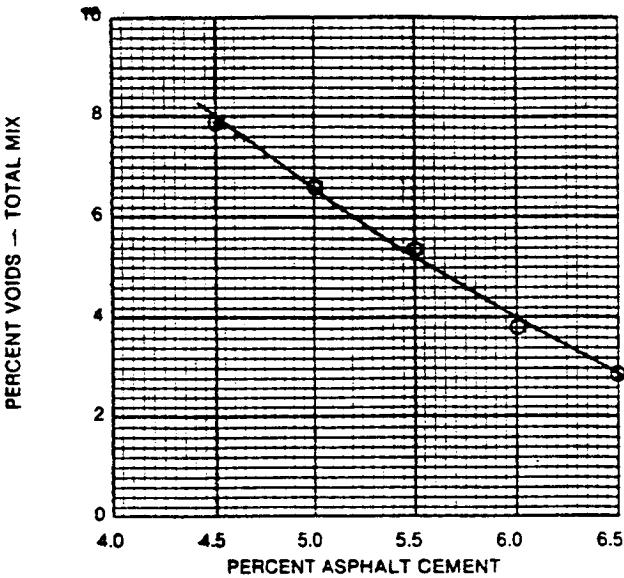
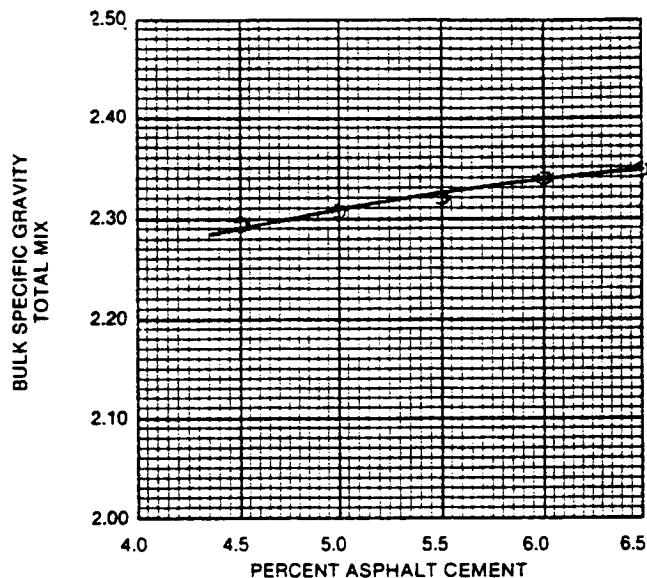
<u>Sieve Size</u>	<u>Percent Passing</u>
3/4"	100
1/2"	95
3/8"	87
No. 4	65
No. 8	54
No. 16	42
No. 30	30
No. 50	15
No. 100	7
No. 200	3.8
Asphalt Content, % . . . . .	6.0

Respectfully submitted,

CHICAGO TESTING LABORATORY, INC.

*Richard E. Root*  
Richard E. Root, P.E.

TABLE 5C



#### BITUMINOUS MIXTURE DESIGN By The MARSHALL METHOD

Lab. No. 006059	Date 9/28/90
-----------------	--------------

Materials Used

Georgia Granite

20%	No. 7
15%	No. 890
35%	No. 810
30	No. FA-2

CHICAGO TESTING LABORATORY, INC.

3360 COMMERCIAL AVENUE  
NORTHBROOK, ILLINOIS 60062

TABLE 5D

## REPORT OF BITUMINOUS MIX DESIGN

LAB. NO. 006039  
 DATE 9/28/90

TO: SHRP Ideas - Georgia Granite (RA)

TYPE: Surface

## MATERIALS SUBMITTED

CTL No	Agg	Source
004102	No. 7	Georgia Granite (RA)
004104	890	Georgia Granite (RA)
004103	810	Georgia Granite (RA)
007131	FA 2	Crystal Lake, Illinois (RF)

Sieve	AGGREGATE		GRADATION - PERCENT PASSING		Blend		
	No. 7	890	810	FA 2			
3/4"	100.0	100.0	100.0	100.0	100.0		
1/2"	75.7	100.0	100.0	100.0	95.1		
3/8"	37.0	97.5	100.0	100.0	87.0		
No 4	3.4	20.0	90.7	99.8	65.4		
No 8	2.0	2.6	77.2	85.9	53.6		
No 16	1.7	1.6	65.3	62.1	42.1		
No 30	1.4	1.2	50.2	39.1	29.8		
No 50	1.0	0.7	32.1	11.0	14.8		
No 100	0.7	0.5	18.0	2.1	7.1		
No 200	0.4	0.2	9.6	1.2	3.8		
Agg BSG	2.627	2.613	2.634	2.629	2.628		
Percent	20.0	15.0	35.0	30.0	100.0		
Type :	AC-20	Source:	'004208	SG :1.034			
TEMP.	MIX- 315	MARSHALL COMP.- 290	MIXTURE	DATA			
Bitumen	BSG	MSG	Voids	VMA	Vf	Flow	Stab
4.5	2.291	2.488	7.9	16.7	52.8	9.7	2620
5.0	2.306	2.469	6.6	16.6	60.2	9.8	2595
5.5	2.318	2.451	5.4	16.6	67.3	10.2	2800
6.0	2.339	2.434	3.9	16.3	76.2	10.2	2820
6.5	2.344	2.416	3.0	16.6	82.0	10.8	2470
Agg ESG	2.664			Asphalt Abs, %			0.5

COMMENTS:

TABLE 6A

Report  
No. 006040

September 29, 1990

National Research Council  
Strategic Highway Research Program  
Attention: Mr. Robert R. Kelley  
818 Connecticut Avenue, N.W.  
Washington, DC 20006

SHRP IDEAS - Maryland Limestone (RD)  
Contract No. SHRP 87-ID020

Samples of aggregate were received from SHRP-Reference Laboratory for testing. A Marshall mix design was conducted in essential conformity with the procedures in the Asphalt Institute Manual MS-2.

Specimens were prepared from multiple batches and held at compaction temperature for 1.5 hours to simulate field conditions. Compaction was accomplished with a mechanical hammer and the maximum density was determined in accordance with ASTM Method D-2041.

The test data is summarized on the attached Report of Bituminous Mix Design and has been plotted on the Marshall data curves.

The following data summarizes the recommended mix design for the materials submitted.

Aggregate Proportions (Cold Feed):

<u>Quantity</u>	<u>Material</u>	<u>Source</u>
15%	No. 7	Maryland Limestone (RD)
10%	1/2-4	Maryland Limestone (RD)
10%	Birdeye	Maryland Limestone (RD)
35%	10 Screening	Maryland Limestone (RD)
30%	FA-2	Crystal Lake (RF)

Optimum Asphalt Content for 75 Blow Design:  
(Percent by Total Weight of Mix)

<u>Grade</u>	<u>Amount</u>
AC-20 (W831)	5.5 %

R.G.J.  
R.G.W.

TABLE 6B

CHICAGO TESTING LABORATORY, INC

Report 006040

Marshall Properties at Optimum Asphalt Content:

Stability, at 140F, 1b . . . . .	2550
Flow, at 140F, 0.01" . . . . .	10.8
Unit Weight, lb/ft <sup>3</sup> . . . . .	149.8

## Voids Analysis, %:

Air Voids . . . . .	4.0
Voids Mineral Aggregate . . . . .	15.0
Voids Filled . . . . .	75

Job Mix Formula:

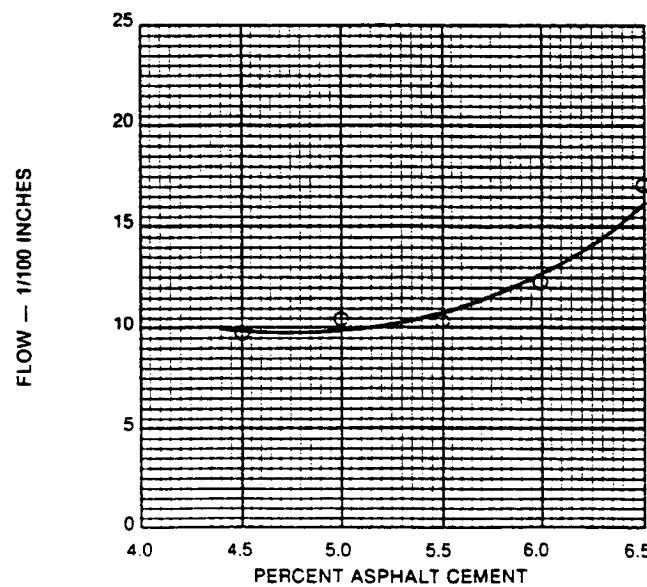
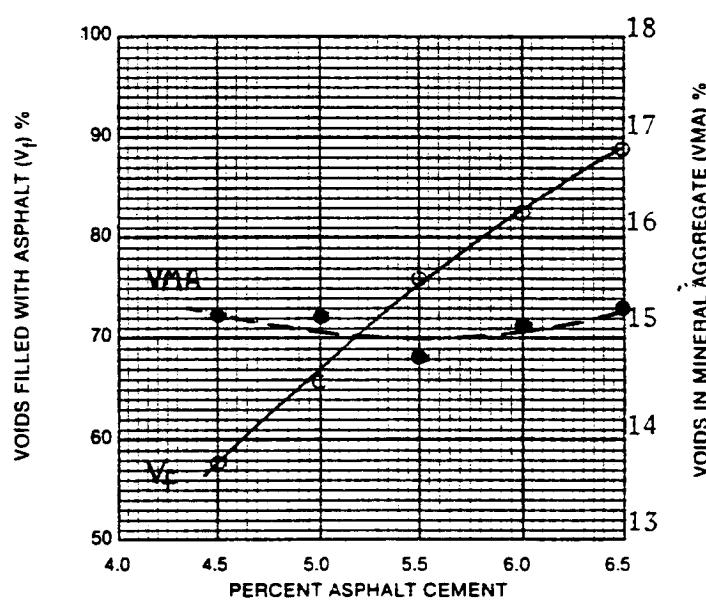
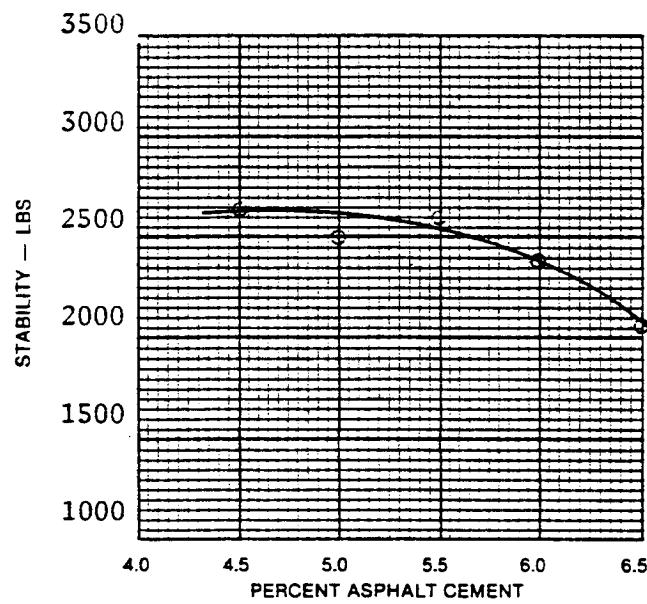
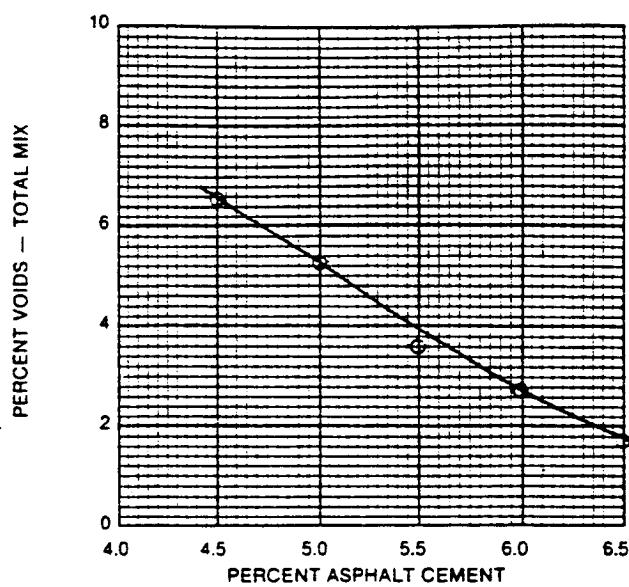
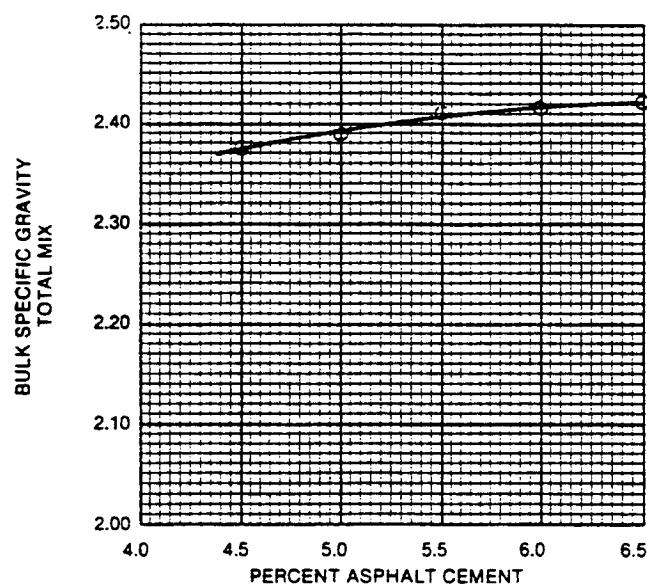
<u>Sieve Size</u>	<u>Percent Passing</u>
3/4"	100
1/2"	98
3/8"	93
No. 4	73
No. 8	52
No. 16	35
No. 30	22
No. 50	10
No. 100	6
No. 200	4.8
Asphalt Content, % . . . . .	5.5

Respectfully submitted,

CHICAGO TESTING LABORATORY, INC.

Richard E. Root  
Richard E. Root, P.E.

TABLE 6C



### BITUMINOUS MIXTURE DESIGN By The MARSHALL METHOD

Lab. No. 006040	Date 9/29/90
-----------------	--------------

Materials Used  
MARYLAND LIMESTONE

15% No. 7  
10% 1/2-4  
10% Birdeye  
35% 10 Screening  
30% FA-2

CHICAGO TESTING LABORATORY, INC.  
3360 COMMERCIAL AVENUE  
NORTHBROOK, ILLINOIS 60062

TABLE 6D  
REPORT OF BITUMINOUS MIX DESIGN

LAB. NO. 6040  
DATE 9/29/90

TO: SHRP Ideas - Maryland Limestone (RD)

TYPE: Surface

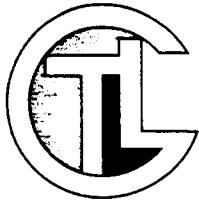
MATERIALS SUBMITTED

CTL No	Agg	Source
4111	No. 7	Maryland Limestone (RD)
4109	1/2-4	Maryland Limestone (RD)
4107	Birdeye	Maryland Limestone (RD)
4112	10 Scrn	Maryland Limestone (RD)
7131	FA-2	Crystal Lake, Illinois (RF)

Sieve	AGGREGATE		GRADATION - PERCENT		PASSING		
	No. 7	1/2-4	Bird	10 Scrn	FA 2	Blend	
3/4"	100.0	100.0	100.0	100.0	100.0	100.0	
1/2"	89.3	100.0	100.0	100.0	100.0	98.4	
3/8"	57.6	91.1	100.0	100.0	100.0	92.8	
No 4	8.5	14.0	67.6	95.7	99.8	72.9	
No 8	2.2	3.0	22.7	68.0	85.9	52.5	
No 16	1.3	1.2	6.6	43.1	62.1	34.7	
No 30	1.1	1.0	4.0	28.0	39.1	22.2	
No 50	1.1	0.8	3.1	19.0	11.0	10.5	
No 100	1.0	0.7	2.7	14.0	2.1	6.0	
No 200	0.9	0.7	2.6	11.4	1.2	4.8	
Agg BSG	2.710	2.691	2.699	2.663	2.629	2.673	
Percent	AGGREGATE		BLEND				
	15.0	10.0	10.0	35.0	30.0	100.0	
BITUMEN DATA							
Type :	AC-20	Source:	'004208		SG : 1.034		
TEMP.	MARSHALL MIXTURE DATA						
	MIX- 315		COMP.- 290		BLOWS- 75		
Bitumen	BSG	MSG	Voids	VMA	Vf	Flow	Stab
4.5	2.373	2.537	6.5	15.2	57.4	9.7	2625
5.0	2.387	2.518	5.2	15.2	65.6	10.3	2490
5.5	2.410	2.499	3.6	14.8	75.8	10.2	2590
6.0	2.414	2.481	2.7	15.1	82.2	12.2	2370
6.5	2.420	2.462	1.7	15.3	88.8	17.0	2050
Agg ESG	2.724				Asphalt Abs, %		0.7

COMMENTS:

GENE ABSON, P.E. (1897-1963)  
WARD K. PARR, P.E. (1912-1985)  
CONWAY C. BURTON, P.E.  
(CONSULTANT)  
RICHARD E. ROOT, P.E.  
GEORGE J. GIROUX, B.S.  
EROL UNER, C.E.T.



# CHICAGO TESTING LABORATORY, Inc.

3360 COMMERCIAL AVENUE/NORTHBROOK, ILLINOIS 60062

FOUNDED 1912

(708) 498-6400 FAX: (708) 498-7232

## TABLE 7A

Report  
No. 006041-A

February 5, 1991

National Research Council  
Strategic Highway Research Program  
Attention: Mr. Robert R. Kelley  
818 Connecticut Avenue, N.W.  
Washington, DC 20006

SHRP IDEAS - Texas Chert (RL)  
Contract No. SHRP 89-ID020

Samples of aggregate were received from SHRP-Reference Laboratory for testing. A Marshall mix design was conducted in essential conformity with the procedures in the Asphalt Institute Manual MS-2.

Specimens were prepared from multiple batches and held at compaction temperature for 1.5 hours to simulate field conditions. Compaction was accomplished with a mechanical hammer and the maximum density was determined in accordance with ASTM Method D-2041.

The test data is summarized on the attached Report of Bituminous Mix Design and has been plotted on the Marshall data curves.

The following data summarizes the recommended mix design for the materials submitted.

Aggregate Proportions (Cold Feed):

<u>Quantity</u>	<u>Material</u>	<u>Source</u>
30%	No. 4	Texas Chert (RL)
15%	No. 6	Texas Chert (RL)
24%	8-200	Texas Chert (RL)
30%	FA-2	Crystal Lake (RF)
1%	Dust	Texas Chert (RL)

Optimum Asphalt Content for 75 Blow Design:  
(Percent by Total Weight of Mix)

<u>Grade</u>	<u>Amount</u>
AC-20 (W831)	6.2 %



TABLE 7B

## CHICAGO TESTING LABORATORY, INC

Report 006041-A

Marshall Properties at Optimum Asphalt Content:

Stability, at 140F, 1b . . . . .	1860
Flow, at 140F, 0.01" . . . . .	9.1
Unit Weight, 1b/ft <sup>3</sup> . . . . .	143.3

## Voids Analysis, %:

Air Voids . . . . .	4.0
Voids Mineral Aggregate . . . . .	16.0
Voids Filled . . . . .	75

Job Mix Formula:

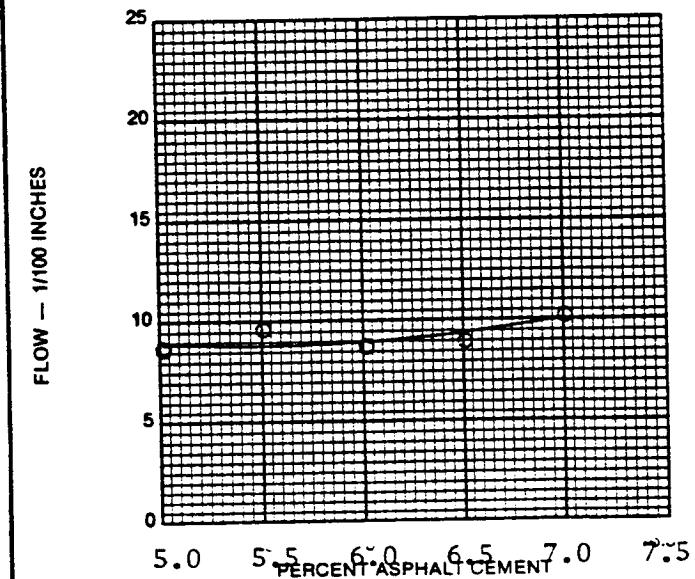
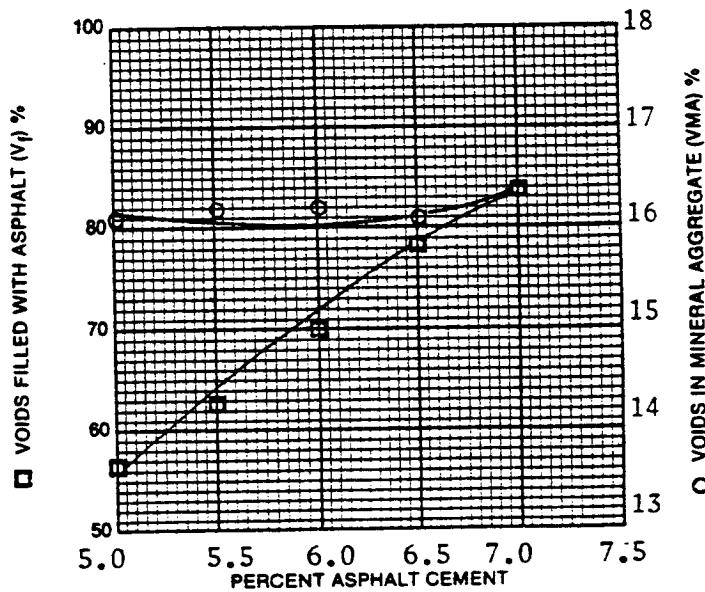
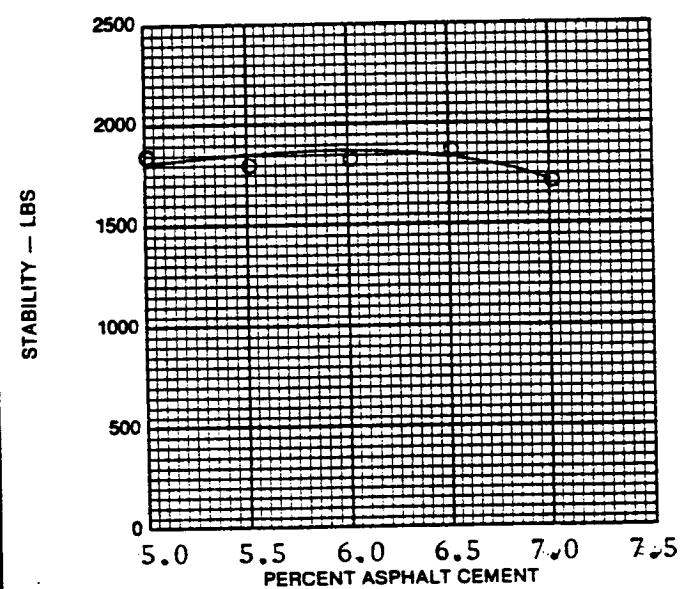
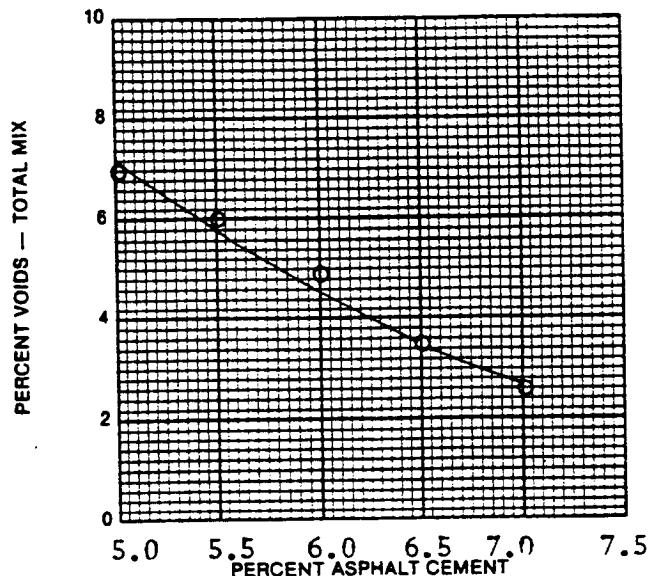
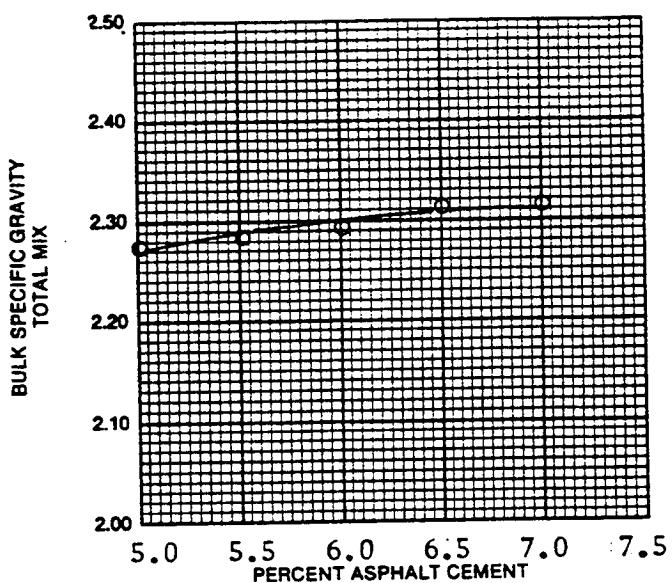
<u>Sieve Size</u>	<u>Percent Passing</u>
1/2"	100
3/8"	90
No. 4	67
No. 8	51
No. 16	38
No. 30	28
No. 50	17
No. 100	4
No. 200	2.4
Asphalt Content, % . . . . .	6.2

Respectfully submitted,

CHICAGO TESTING LABORATORY, INC.

*Richard E. Root*  
Richard E. Root, P.E.

TABLE 7C



### BITUMINOUS MIXTURE DESIGN By The MARSHALL METHOD

Lab. No. 006041-A Date 2/5/91

#### Materials Used

30% No. 4 (RL)  
15% No. 6 (RL)  
24% 8-200 (RL)  
30% FA-2 (RF)  
1% Dust

AC-20

CHICAGO TESTING LABORATORY, INC.  
3360 COMMERCIAL AVENUE  
NORTHBROOK, ILLINOIS 60062

TABLE 7D  
REPORT OF BITUMINOUS MIX DESIGN

LAB. NO. 006041A  
DATE 1/22/91

TO: SHRP Ideas - Texas Chert (RL)      TYPE: Surface

		MATERIALS SUBMITTED	
CTL No	Agg	Source	
4115	No. 4	Texas Chert (RL)	
4116	No. 6	Texas Chert (RL)	
2109	8-200	Texas Chert (RL)	
7131	FA-2	Crystal Lake, Illinois (RF)	
4117	Dust	Screened from -200 Material	

Sieve	AGGREGATE		GRADATION - PERCENT		PASSING	
	No. 4	No. 6	8-200	FA-2	Dust	Blend
3/4"	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	99.4	100.0	100.0	100.0	100.0	99.8
3/8"	67.0	99.8	100.0	100.0	100.0	90.1
No 4	1.7	79.1	99.9	99.8	100.0	67.3
No 8	0.3	7.8	94.5	85.9	100.0	50.7
No 16	0.2	0.6	76.4	62.1	100.0	38.1
No 30	0.1	0.2	65.6	39.1	100.0	28.5
No 50	0.1	0.1	51.7	11.0	100.0	16.8
No 100	0.1	0.1	10.9	2.1	100.0	4.3
No 200	0.0	0.0	4.3	1.2	100.0	2.4
Agg BSG	2.597	2.578	2.485	2.629	2.562	2.575

Percent	AGGRÉGATE		BLEND		1.0	100.0
	30.0	15.0	24.0	30.0		

BITUMEN DATA		
Type :	AC-20	Source: 004208
		SG : 1.034

TEMP.	MIX- 315	MARSHALL MIXTURE		DATA		
		COMP.- 290		BLOWS- 75		
Bitumen	BSG	MSG	Voids	VMA	Vf	Flow
5.0	2.275	2.447	7.0	16.1	56.2	8.7
5.5	2.283	2.430	6.0	16.2	62.8	9.7
6.0	2.295	2.413	4.9	16.2	70.0	8.8
6.5	2.311	2.396	3.5	16.1	78.1	9.0
7.0	2.316	2.379	2.6	16.4	83.9	10.2
Agg ESG	2.637				Asphalt Abs, %	0.9

COMMENTS:

CHICAGO TESTING LABORATORY, INC.

TABLE 8

SHELL DEVELOPMENT CO.  
TENSILE STRENGTH RATIO - ASTM D-4867  
GEORGIA GRANITE  
MIX DESIGN 006039

Asphalt fil Lap No.	102032	Asphalt W 625	Specimen	3	4	6	8	1	2	5	7	Average
Bulk Specific Gravity	. . . . .	2.267	2.288	2.274	2.276	2.285	2.276	2.261	2.261	2.282	2.282	
Maximum Specific Gravity	-----	-----	-----	-----	-----	2.434	-----	-----	-----	-----	-----	
Air Voids, %	. . . . .	6.9	6.0	6.6	6.5	6.1	6.5	7.1	6.2	6.5	6.5	
% Saturation	. . . . .	--	--	--	--	--	69.3	62.9	64.9	72.0	72.0	67.3
Dry Tensile Strength psi		176.8	181.5	184.7	189.5	--	--	--	--	--	--	183.1
Wet Tensile Strength psi		--	--	--	--	50.3	57.3	47.8	50.3	51.4	51.4	
Average Tensile Splitting Ratio, %	. . . . .											28.1

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 004208, Component 2

	1	2	5	7	3	4	6	8	Average
Specimen . . . . .									
Bulk Specific Gravity . .	2.351	2.347	2.337	2.343	2.354	2.358	2.337	2.335	
Maximum Specific Gravity					2.499				
Air Voids, % . . . . .	5.9	6.1	6.5	6.2	5.8	5.6	6.5	6.6	6.2
% Saturation . . . . .	--	--	--	--	66.2	64.4	66.8	65.6	65.8
Dry Tensile Strength psi	117.8	124.1	128.6	131.1	--	--	--	--	125.4
Wet Tensile Strength psi	--	--	--	--	65.3	63.0	57.3	55.4	60.3
Average Tensile Splitting Ratio, % . . . . .									48.0

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 008233, Component 5

	3	4	7	8	1	2	5	6	Average
Bulk Specific Gravity . . . . .	2.327	2.327	2.324	2.323	2.312	2.319	2.325	2.325	
Maximum Specific Gravity	-----	-----	2.499	-----	-----	-----	-----	-----	
Air Voids, % . . . . .	6.9	6.9	7.0	7.0	7.5	7.2	7.0	7.0	7.1
% Saturation . . . . .	--	--	--	--	74.9	70.7	65.1	69.1	70.0
Dry Tensile Strength psi	156.6	161.6	161.7	169.3	--	--	--	--	162.3
Wet Tensile Strength psi	--	--	--	--	106.6	106.6	109.8	109.8	108.2
Average Tensile Splitting Ratio, % . . . . .									66.7

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 004203, Blend 5

	3	4	5	8	1	2	6	7	Average
Bulk Specific Gravity . .	2.314	2.316	2.324	2.333	2.318	2.318	2.309	2.333	
Maximum Specific Gravity					2.499				-----
Air Voids, % . . . . .	7.4	7.3	7.0	6.1	7.2	7.2	7.6	6.6	7.1
% Saturation . . . . .	--	--	--	--	67.2	65.3	63.3	63.4	64.8
Dry Tensile Strength psi	89.1	96.1	95.5	101.2	--	--	--	--	95.5
Wet Tensile Strength psi	--	--	--	--	55.4	58.6	47.1	58.8	53.5
Average Tensile Splitting Ratio, % . . . . .								55.8	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 004204, Blend 6

	1	3	6	8	2	4	5	7	Average
Bulk Specific Gravity . .	2.292	2.316	2.319	2.318	2.308	2.315	2.313	2.316	
Maximum Specific Gravity					2.499				
Air Voids, % . . . . .	8.3	7.3	7.2	7.2	7.6	7.4	7.4	7.3	7.5
% Saturation . . . . .	--	--	--	--	64.6	64.7	71.7	76.5	69.4
Dry Tensile Strength psi	100.3	97.4	100.6	95.5	--	--	--	--	98.5
Wet Tensile Strength psi	--	--	--	--	50.9	50.9	46.5	47.7	49.0
Average Tensile Splitting Ratio, % . . . . .									49.7

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 004205, Blend 7

	1	2	5	6	3	4	7	8	Average
Bulk Specific Gravity . . . . .	2.302	2.307	2.306	2.296	2.294	2.314	2.297	2.308	
Maximum Specific Gravity . . . . .					2.490				
Air Voids, % . . . . .	7.1	7.1	7.1	8.1	4.2	7.4	8.1	1.8	7.8
% Saturation . . . . .	..	..	..	..	..	61.4	64.1	61.9	62.1
Tensile Strength psi . . . . .	110.4	114.4	101.0	110.0	--	--	--	--	110.6
Net Tensile Strength psi . . . . .	--	--	--	--	69.0	68.2	66.0	61.1	63.3
Average Tensile Splitting Ratio, % . . . . .								67.3	

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 004206, Blend 8

	3	4	6	7	1	2	5	8	Average
Bulk Specific Gravity . . . . .	2.324	2.328	2.319	2.325	2.313	2.310	2.320	2.325	
Maximum Specific Gravity . . . . .					2.498				
Air Voids, % . . . . .	7.0	6.8	7.2	7.0	7.4	7.2	6.4	7.0	7.1
% Saturation . . . . .	--	--	--	--	61.0	64.0	66.0	64.0	64.4
Dry Tensile Strength psi . . . . .	91.0	80.1	99.3	98.7	--	--	--	--	94.6
Wet Tensile Strength psi . . . . .	--	--	--	--	63.7	68.4	72.6	82.8	71.9
Average Tensile Splitting Ratio, % . . . . .								76.1	

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN 006040**

Asphalt CTL Lab No. 008229, Blend 13

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 008230, Blend 14

	1	2	5	6	3	4	7	8	Average
Bulk Specific Gravity . . . . .	2.313	2.325	2.314	2.314	2.318	2.329	2.310	2.312	
Maximum Specific Gravity . . . . .	-----	-----	-----	2.499	-----	-----	-----	-----	
Air Voids, % . . . . .	7.4	7.0	7.4	7.4	7.2	6.8	7.6	7.5	7.3
% Saturation . . . . .	--	--	--	--	64.8	63.6	64.4	64.8	64.4
Dry Tensile Strength psi . . . . .	105.0	103.8	105.0	105.0	--	--	--	--	104.7
Wet Tensile Strength psi . . . . .	--	--	--	--	61.1	61.1	61.1	60.8	60.8
Average Tensile Strength Ratio, % . . . . .									60.0

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN 006040**

Asphalt CTR Lab No. 008231 Blend 15

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 008232, Blend 16

	1	3	6	8	2	4	5	7	Average
Specimen . . . . .									
Bulk Specific Gravity . .	2.322	2.325	2.313	2.329	2.312	2.311	2.333	2.329	
Maximum Specific Gravity	-----	-----	2.499	-----	-----	-----	-----	-----	-----
Air Voids, % . . . . .	7.1	7.0	7.4	6.8	7.5	7.5	6.6	6.8	7.1
% Saturation . . . . .	---	---	---	---	64.3	64.2	67.0	66.6	65.3
Dry Tensile Strength psi	74.9	79.6	78.9	78.0	---	---	---	---	78.9
Wet Tensile Strength psi	---	---	---	---	60.0	60.0	60.0	61.1	60.6
Average Tensile Splitting Ratio, % . . . . .									76.3

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN 006040**

Asphalt CTL Lab No. 006076, Blend 9

**SHRP 09 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4990**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN 006040**

Asphalt CTL Lab No. 006077, Blend 10

	3	4	7	8	1	2	5	6	Average
Bulk Specific Gravity . . .	2.309	2.316	2.320	2.313	2.319	2.313	2.320	2.313	
Maximum Specific Gravity -----	-----	-----	-----	-----	2.499	-----	-----	-----	
Air Voids, % . . . . .	7.6	7.3	7.2	7.4	7.2	7.4	7.2	7.4	7.3
% Saturation . . . . .	--	--	--	--	--	65.2	66.1	65.7	64.0
Dry Tensile Strength psi	145.8	148.3	149.6	149.6	--	--	--	--	148.3
Wet Tensile Strength psi	--	--	--	--	105.7	106.6	106.6	100.3	104.8
Average Tensile Splitting Ratio, % . . . . .								70.7	

BHRP #9 ID 029  
**TENSILE STRENGTH RATIO - ASTM D-4907**  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 006078, Blend 11

	1	4	6	8	2	3	5	7	Average
Specimen . . . . .									
Bulk Specific Gravity . . .	2.316	2.308	2.315	2.311	2.309	2.315	2.305		
Maximum Specific Gravity	-----	-----	2.499	-----	-----	-----	-----	-----	
Air Voids, % . . . . .	7.3	7.6	7.4	7.5	7.5	7.6	7.4	7.8	7.5
% Saturation . . . . .	--	--	--	--	65.5	64.5	65.0	64.5	64.9
Dry Tensile Strength psi	140.1	136.9	138.5	140.7	--	--	--	--	139.1
Wet Tensile Strength psi	--	--	--	--	102.5	112.7	108.2	103.8	106.8
Average Tensile Splitting Ratio, % . . . . .									76.8

GHRP 89 IP 000  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN 006040

Asphalt CTL Lab No. 006070, Blend 12

	2	4	6	8	1	3	5	7	Average
Bulk Specific Gravity . . . . .	2.321	2.328	2.337	2.333	2.333	2.325	2.337	2.332	
Maximum Specific Gravity . . . . .	-----	-----	-----	2.499	-----	-----	-----	-----	
Air Voids, % . . . . .	7.1	6.8	6.5	6.6	6.6	7.0	6.5	6.7	6.7
% Saturation . . . . .	--	--	--	--	63.3	66.8	64.8	64.1	64.8
Dry Tensile Strength psi . . . . .	189.7	181.4	188.4	194.8	--	--	--	--	188.6
Wet Tensile Strength psi . . . . .	--	--	--	--	98.0	105.0	108.2	106.3	104.4
Average Tensile Splitting Ratio, % . . . . .									55.4

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN 006040**

Asphalt CTL Lab No. 007013, Blend 17

	3	4	6	8	1	2	5	7	Average
Bulk Specific Gravity . .	2.315	2.327	2.336	2.333	2.318	2.321	2.334	2.325	
Maximum Specific Gravity	---	---	2.499	---	---	---	---	---	
Air Voids, % . . . . .	7.4	6.9	6.5	6.6	7.2	7.1	6.6	6.7	6.9
% Saturation . . . . .	--	--	--	--	66.4	66.9	63.6	66.3	65.8
Dry Tensile Strength psi	160.4	169.3	172.5	165.5	--	--	--	--	166.9
Wet Tensile Strength psi	--	--	--	--	118.4	116.2	123.5	121.0	119.8
Average Tensile Splitting Ratio, % . . . . .									71.8

**0HHP Q9 ID Q2Q**  
**TENSILE STRENGTH RATIO - ASTM D-4667**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN QD6040**

Asphalt CTL Lab No. 007014, Blend 18

	2	3	5	7	1	4	6	8	Average
Specimen . . . . .									
Bulk Specific Gravity . .	2.320	2.322	2.323	2.313	2.325	2.315	2.325	2.312	
Maximum Specific Gravity				2.499					
Air Voids, % . . . . .	7.2	7.1	7.0	7.4	7.0	7.4	7.0	7.5	7.2
% Saturation . . . . .	--	--	--	--	63.9	63.3	63.5	67.2	64.5
Dry Tensile Strength psi	156.6	161.7	157.9	161.7	--	--	--	--	159.5
Wet Tensile Strength psi	--	--	--	--	120.3	117.8	118.4	116.2	118.2
Average Tensile Splitting Ratio, % . . . . .									74.1

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**MARYLAND LIMESTONE (RD)**  
**MIX DESIGN 006040**

Asphalt CTL Lab No. 007015 Blend 19

	3	4	6	8	1	2	5	7	Average
Bulk Specific Gravity . . . . .	2.313	2.311	2.311	2.315	2.310	2.316	2.319	2.303	
Maximum Specific Gravity . . . . .					2.499				
Air Voids, % . . . . .	7.4	7.5	7.5	7.4	7.6	7.3	7.2	7.8	7.5
% Saturation . . . . .	--	--	--	--	65.1	68.9	64.9	66.6	66.4
Dry Tensile Strength psi . . . . .	99.9	105.0	98.7	103.8	--	--	--	--	101.9
Wet Tensile Strength psi . . . . .	--	--	--	--	79.6	81.2	77.7	78.9	79.4
Average Tensile Splitting Ratio, % . . . . .									77.9

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 MARYLAND LIMESTONE (RD)  
 MIX DESIGN APP6040

Asphalt CT1 Lab No. 007016, Blend 20

	1	2	7	8	3	4	5	6	Average
Bulk Specific Gravity . . .	2.339	2.331	2.332	2.334	2.331	2.331	2.339	2.340	
Maximum Specific Gravity	-----	-----	2.499	-----	-----	-----	-----	-----	
Air Voids, % . . . . .	6.4	6.7	6.7	6.7	6.7	6.7	6.4	6.4	6.6
% Saturation . . . . .	--	--	--	--	64.5	64.9	65.9	64.9	65.1
Dry Tensile Strength psi	162.3	152.2	164.9	159.2	--	--	--	--	159.6
Wet Tensile Strength psi	--	--	--	--	115.9	115.2	125.4	125.4	120.5
Average Tensile Splitting Ratio, % . . . . .								75.5	

**SHRP 89-ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 004208, Component 2

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 008233, Component 5

	1	2	4	7	3	5	6	8	Average
Bulk Specific Gravity . . . . .	2.265	2.288	2.275	2.264	2.279	2.269	2.271	2.273	
Maximum Specific Gravity . . . . .	-----	-----	-----	2.434	-----	-----	-----	-----	
Air Voids, % . . . . .	6.9	6.0	6.5	7.0	6.4	6.8	6.7	6.6	6.6
% Saturation . . . . .	--	--	--	--	64.6	64.5	63.7	66.6	64.9
Dry Tensile Strength psi . . . . .	134.1	145.4	137.7	147.5	--	--	--	--	141.2
Wet Tensile Strength psi . . . . .	--	--	--	--	109.0	93.7	96.1	99.2	99.5
Average Tensile Splitting Ratio, % . . . . .								70.4	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 004203, Blend 5

	3	4	7	8	1	2	5	6	Average
Bulk Specific Gravity . . . . .	2.270	2.261	2.269	2.269	2.253	2.260	2.273	2.284	
Maximum Specific Gravity . . . . .					2.434				
Air Voids, % . . . . .	6.7	7.1	6.8	6.8	7.4	7.1	6.6	6.2	6.8
% Saturation . . . . .	--	--	--	--	67.0	70.6	65.3	66.8	67.4
Dry Tensile Strength psi . . . . .	91.8	94.9	102.2	95.5	--	--	--	--	96.1
Wet Tensile Strength psi . . . . .	--	--	--	--	23.9	22.0	21.4	18.4	21.4
Average Tensile Splitting Ratio, % . . . . .								22.3	

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 004204, Blend 6

	2	3	4	6	1	5	7	8	Average
Bulk Specific Gravity . . . . .	2.271	2.250	2.251	2.273	2.263	2.254	2.259	2.258	
Maximum Specific Gravity -----				2.434	-----				
Air Voids, % . . . . .	6.7	7.6	7.5	6.6	7.0	7.4	7.2	7.2	7.2
% Saturation . . . . .	--	--	--	--	65.5	65.6	66.7	65.8	65.9
Dry Tensile Strength psi	94.9	94.3	95.5	101.0	--	--	--	--	96.4
Wet Tensile Strength psi	--	--	--	--	34.3	34.3	31.8	31.8	33.0
Average Tensile Splitting Ratio, % . . . . .								34.3	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 004205, Blend 7

	3	5	6	7	1	2	4	8	Average
Bulk Specific Gravity . . . . .	2.259	2.266	2.273	2.255	2.264	2.263	2.259	2.263	
Maximum Specific Gravity . . . . .	-----	-----	-----	-----	2.434	-----	-----	-----	
Air Voids, % . . . . .	7.2	6.9	6.6	7.4	7.0	7.0	7.2	7.0	7.0
* Saturation . . . . .	--	--	--	--	65.2	64.4	63.6	63.7	64.2
Dry Tensile Strength psi . . . . .	90.3	96.7	90.3	100.4	--	--	--	--	94.4
Wet Tensile Strength psi . . . . .	--	--	--	--	23.0	33.1	26.9	28.2	27.8
Average Tensile Splitting Ratio, % . . . . .									29.4

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4861**  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 004206, Blend 8

	4	5	6	8	1	2	3	7	Average
Bulk Specific Gravity . . . . .	2.267	2.267	2.267	2.265	2.271	2.265	2.268	2.261	
Maximum Specific Gravity					2.434				
Air Voids, % . . . . .	6.9	6.9	6.9	6.9	6.7	6.9	6.8	7.1	6.9
% Saturation . . . . .	--	--	--	--	65.7	59.8	66.9	62.5	63.7
Dry Tensile Strength psi	88.8	82.6	82.6	91.8	--	--	--	--	86.5
Wet Tensile Strength psi	--	--	--	--	29.1	29.1	29.4	27.5	28.8
Average Tensile Splitting Ratio, % . . . . .							33.3		

SHRP 89 ID 020  
TENSILE STRENGTH RATIO - ASTM D-4867  
VULCAN GRANITE GEORGIA (RA)  
MIX DESIGN 006039

Asphalt CTL Lab No. 008229, Blend 13

	2	3	5	7	1	4	6	8	Average
Bulk Specific Gravity . . .	2.257	2.268	2.258	2.264	2.251	2.255	2.271	2.269	
Maximum Specific Gravity -----	-----	-----	-----	2.434	-----	-----	-----	-----	
Air Voids, % . . . . .	7.3	6.8	7.2	7.0	7.5	7.4	6.7	6.8	7.1
% Saturation . . . . .	--	--	--	--	68.8	69.0	65.5	63.8	66.8
Dry Tensile Strength psi	95.5	101.0	95.5	95.5	--	--	--	--	96.9
Wet Tensile Strength psi	--	--	--	--	24.8	26.0	29.4	32.4	28.2
Average Tensile Splitting Ratio, % . . . . .								29.1	

SHRP 89 ID 020  
TENSILE STRENGTH RATIO - ASTM D-4867  
VULCAN GRANITE GEORGIA (RA)  
MIX DESIGN 006039

Asphalt CTL Lab No. 008230, Blend 14

	1	3	5	6	2	4	7	8	Average
Bulk Specific Gravity . . . . .	2.264	2.270	2.259	2.257	2.260	2.260	2.265	2.260	
Maximum Specific Gravity . . . . .	-----	-----	-----	2.434	-----	-----	-----	-----	
Air Voids, % . . . . .	7.0	6.7	7.2	7.3	7.1	7.1	6.9	7.1	7.1
% Saturation . . . . .	--	--	--	--	67.7	68.4	71.4	68.4	69.0
Dry Tensile Strength psi . . . . .	93.0	94.3	88.8	90.3	--	--	--	--	91.6
Wet Tensile Strength psi . . . . .	--	--	--	--	36.1	37.0	33.7	34.3	35.3
Average Tensile Splitting Ratio, % . . . . .									38.5

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 008231 Blend 15

	3	4	5	7	1	2	6	8	Average
Bulk Specific Gravity . . . . .	2.269	2.264	2.267	2.268	2.274	2.263	2.271	2.255	
Maximum Specific Gravity . . . . .					2.434				
Air Voids, % . . . . .	6.8	7.0	6.9	6.8	6.6	7.0	6.7	7.4	6.9
% Saturation . . . . .	--	--	--	--	65.7	66.5	64.2	67.1	65.9
Dry Tensile Strength psi . . . . .	91.8	88.8	96.4	91.2	--	--	--	--	92.0
Wet Tensile Strength psi . . . . .	--	--	--	--	45.3	41.3	46.5	38.6	42.9
Average Tensile Splitting Ratio, % . . . . .								46.6	

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 008232, Blend 16

	3	4	6	8	1	2	5	7	Average
Bulk Specific Gravity . . .	2.266	2.264	2.258	2.263	2.264	2.254	2.273	2.254	
Maximum Specific Gravity					2.434				
Air Voids, % . . . . .	6.9	7.0	7.2	7.0	7.0	7.4	6.6	7.4	7.1
% Saturation . . . . .	--	--	--	--	64.0	64.1	68.8	65.2	65.5
Dry Tensile Strength psi	70.4	71.9	65.8	66.7	--	--	--	--	68.7
Wet Tensile Strength psi	--	--	--	--	47.4	44.7	48.4	48.4	47.2
Average Tensile Splitting Ratio, % . . . . .									68.7

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 006076, Blend 9

	2	4	5	8	1	3	6	7	Average
Bulk Specific Gravity . . .	2.272	2.262	2.270	2.263	2.267	2.265	2.268	2.263	
Maximum Specific Gravity	-----	-----	-----	2.434	-----	-----	-----	-----	
Air Voids, % . . . . .	6.7	7.1	6.7	7.0	6.9	6.9	6.8	7.0	6.9
% Saturation . . . . .	--	--	--	--	64.0	67.9	67.2	66.5	66.4
Dry Tensile Strength psi	132.2	140.8	129.2	131.0	--	--	--	--	133.3
Wet Tensile Strength psi	--	--	--	--	94.3	94.3	94.9	95.5	94.7
Average Tensile Splitting Ratio, % . . . . .								71.1	

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE GEORGIA (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 006077, Blend 10

	3	5	7	8	1	2	4	6	Average
Bulk Specific Gravity . . . . .	2.272	2.257	2.282	2.257	2.269	2.260	2.270	2.265	
Maximum Specific Gravity . . . . .	-----	-----	-----	-----	2.434	-----	-----	-----	
Air Voids, % . . . . .	6.7	7.3	6.2	7.3	6.8	7.1	6.7	6.9	6.9
% Saturation . . . . .	--	--	--	--	69.7	63.3	67.3	72.5	68.2
Dry Tensile Strength psi . . . . .	127.3	128.5	134.1	131.6	--	--	--	--	130.4
Wet Tensile Strength psi . . . . .	--	--	--	--	84.2	85.1	86.3	84.2	85.0
Average Tensile Splitting Ratio, % . . . . .									65.1

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 006078, Blend 11

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE GEORGIA (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 006079, Blend 12

	4	5	6	8	1	2	3	7	Average
Bulk Specific Gravity . . . . .	2.280	2.269	2.278	2.255	2.265	2.275	2.272	2.275	
Maximum Specific Gravity . . . . .					2.434				
Air Voids, % . . . . .	6.3	6.8	6.4	7.4	6.9	6.5	6.7	6.5	6.7
% Saturation . . . . .	--	--	--	--	63.3	65.3	65.2	66.3	65.0
Dry Tensile Strength psi . . . . .	133.1	139.3	131.6	120.0	--	--	--	--	131.0
Wet Tensile Strength psi . . . . .	--	--	--	--	82.6	88.1	86.9	85.7	85.9
Average Tensile Splitting Ratio, % . . . . .									65.5

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 VULCAN GRANITE GEORGIA (RA)  
 MIX DESIGN 006039

Asphalt CTL Lab No. 007013, Blend 17

	2	4	6	8	1	3	5	7	Average
Bulk Specific Gravity . . . . .	2.273	2.274	2.267	2.266	2.260	2.269	2.276	2.275	
Maximum Specific Gravity . . . . .					2.434				
Air Voids, % . . . . .	6.6	6.6	6.9	6.9	7.1	6.8	6.5	6.5	6.7
% Saturation . . . . .	--	--	--	--	66.0	66.8	66.2	67.6	66.7
Dry Tensile Strength psi . . . . .	152.3	166.0	152.4	166.0	--	--	--	--	159.2
Wet Tensile Strength psi . . . . .	--	--	--	--	99.2	103.5	93.6	108.0	101.1
Average Tensile Splitting Ratio, % . . . . .									63.5

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE GEORGIA (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 007014, Blend 18

	2	4	7	8	1	3	5	6	Average
Bulk Specific Gravity . . .	2.269	2.270	2.270	2.274	2.278	2.275	2.265	2.263	
Maximum Specific Gravity -----	-----	-----	-----	2.434	-----	-----	-----	-----	
Air Voids, % . . . . .	6.8	6.7	6.7	6.6	6.4	6.5	6.9	7.0	6.7
% Saturation . . . . .	--	--	--	--	64.7	64.2	63.9	66.3	64.8
Dry Tensile Strength psi	160.7	145.7	149.4	146.9	--	--	--	--	150.7
Wet Tensile Strength psi	--	--	--	--	99.2	98.6	95.5	89.4	95.7
Average Tensile Splitting Ratio, % . . . . .									63.5

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE GEORGIA (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 007015, Blend 19

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**VULCAN GRANITE GEORGIA (RA)**  
**MIX DESIGN 006039**

Asphalt CTL Lab No. 007016, Blend 20

	2	4	6	7	1	3	5	8	Average
Bulk Specific Gravity . .	2.268	2.264	2.268	2.274	2.273	2.274	2.259	2.261	
Maximum Specific Gravity					2.434				
Air Voids, % . . . . .	6.8	7.0	6.8	6.6	6.6	6.6	7.2	7.1	6.8
% Saturation . . . . .	--	--	--	--	65.2	64.7	65.5	66.0	65.4
Dry Tensile Strength psi	150.0	145.4	145.8	145.4	--	--	--	--	146.6
Wet Tensile Strength psi	--	--	--	--	92.9	99.8	85.7	93.4	93.0
Average Tensile Splitting Ratio, % . . . . .							63.4		

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 004208, Component 2

	1	3	5	7	2	4	6	8	Average
Specimen . . . . .									
Bulk Specific Gravity . . .	2.237	2.227	2.246	2.248	2.249	2.240	2.237	2.238	
Maximum Specific Gravity					2.406				
Air Voids, % . . . . .	7.0	7.4	6.7	6.6	6.5	6.9	7.0	7.0	6.9
% Saturation . . . . .	--	--	--	--	64.1	65.9	64.9	65.6	65.1
Dry Tensile Strength psi	89.1	86.6	89.1	91.0	--	--	--	--	89.0
Wet Tensile Strength psi	--	--	--	--	50.9	49.6	50.9	51.5	50.7
Average Tensile Splitting Ratio, % . . . . .									56.9

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 TEXAS CHERT (RL)  
 MIX DESIGN 008041-A

Asphalt CTL Lab No. 008233, Component 5

	1	2	5	6	3	4	7	8	Average
Bulk Specific Gravity . . . . .	2.246	2.241	2.233	2.244	2.238	2.244	2.244	2.235	
Maximum Specific Gravity -----				2.406					
Air Voids, % . . . . .	6.7	6.9	7.2	6.7	7.0	6.7	6.7	7.1	6.9
% Saturation . . . . .	--	--	--	--	64.2	65.4	64.6	66.0	65.1
Dry Tensile Strength psi	138.1	138.1	132.1	132.1	--	--	--	--	135.1
Wet Tensile Strength psi	--	--	--	--	58.9	62.4	62.4	54.7	59.6
Average Tensile Splitting Ratio, % . . . . .								44.1	

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**TEXAS CHERT (RL)**  
**MIX DESIGN 006041-A**

Asphalt CTL Lab No. 004203, Blend 5

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4887**  
**TEXAS CHERT (RL)**  
**MIX DESIGN 006041-A**

Asphalt CTL Lab No. 004204, Blend 6

	2	4	7	8	1	3	5	6	Average
Bulk Specific Gravity . . . . .	2.233	2.244	2.241	2.248	2.237	2.244	2.240	2.241	
Maximum Specific Gravity . . . . .					2.406				
Air Voids, % . . . . .	7.2	6.7	6.9	6.6	7.0	6.7	6.9	6.9	6.9
% Saturation . . . . .	--	--	--	--	65.1	65.9	66.3	66.0	65.8
Dry Tensile Strength psi . . . . .	89.8	86.0	91.7	94.9	--	--	--	--	90.6
Wet Tensile Strength psi . . . . .	--	--	--	--	43.9	46.5	52.5	49.7	48.2
Average Tensile Splitting Ratio, % . . . . .								53.1	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 004205, Blend 7

	1	4	6	8	2	3	5	7	Average
Bulk Specific Gravity . . . . .	2.245	2.237	2.241	2.243	2.247	2.244	2.245	2.237	
Maximum Specific Gravity . . . . .					2.406				
Air Voids, % . . . . .	6.7	7.0	6.9	6.8	6.6	6.7	6.7	7.0	6.8
% Saturation . . . . .	--	--	--	--	63.5	64.9	64.4	64.9	64.4
Dry Tensile Strength psi . . . . .	91.7	89.2	84.4	88.5	--	--	--	--	88.5
Wet Tensile Strength psi . . . . .	--	--	--	--	54.1	57.3	53.5	48.4	53.3
Average Tensile Splitting Ratio, % . . . . .								60.3	

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**TEXAS CHERT (RL)**  
**MIX DESIGN 006041-A**

Asphalt CTL Lab No. 004206, Blend 8

	1	4	7	8	2	3	5	6	Average
Bulk Specific Gravity . . . . .	2.236	2.228	2.245	2.247	2.248	2.234	2.236	2.238	
Maximum Specific Gravity . . . . .	-----	-----	-----	2.406	-----	-----	-----	-----	
Air Voids, % . . . . .	7.1	7.4	6.7	6.6	6.6	7.1	7.1	7.0	7.0
% Saturation . . . . .	--	--	--	--	64.3	63.8	64.8	64.8	64.4
Dry Tensile Strength psi . . . . .	84.4	83.4	87.6	85.4	--	--	--	--	85.2
Wet Tensile Strength psi . . . . .	--	--	--	--	54.1	50.3	49.4	51.6	51.4
Average Tensile Splitting Ratio, % . . . . .								60.3	

SHRP 89 10 020  
TENSILE STRENGTH RATIO - ASTM D-4867  
TEXAS CHERT (RL)  
MIX DESIGN 006041-A

Asphalt CTL Lab No. 008229, Blend 13

	1	3	5	8	2	4	6	7	Average
Specimen . . . . .									
Bulk Specific Gravity . .	2.242	2.233	2.222	2.226	2.233	2.229	2.229	2.230	
Maximum Specific Gravity				2.406					
Air Voids, % . . . . .	6.8	7.2	7.6	7.5	7.2	7.4	7.4	7.3	7.3
% Saturation . . . . .	--	--	--	--	63.4	65.3	63.8	64.2	64.2
Dry Tensile Strength psi	93.9	94.9	89.2	89.2	--	--	--	--	92.6
Wet Tensile Strength psi	--	--	--	--	49.4	47.8	54.1	52.5	51.0
Average Tensile Splitting Ratio, % . . . . .								56.0	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 008230, Blend 14

	2	3	4	8	1	5	6	7	Average
Bulk Specific Gravity . . . . .	2.248	2.242	2.243	2.247	2.261	2.244	2.237	2.239	
Maximum Specific Gravity	-----	-----	-----	2.406	-----	-----	-----	-----	
Air Voids, % . . . . .	6.6	6.8	6.8	6.6	6.0	6.7	7.0	6.9	6.7
x Saturation . . . . .	--	--	--	--	63.1	70.0	69.0	67.3	67.4
Dry Tensile Strength psi	90.0	92.4	94.9	92.4	--	--	--	--	92.4
Wet Tensile Strength psi	--	--	--	--	62.4	45.9	54.5	52.6	53.9
Average Tensile Splitting Ratio, % . . . . .								58.3	

SHRP 09 IP Q20  
 TENSILE STRENGTH RATIO - ASTM D-4861  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 008231, Blend 15

	3	4	5	6	1	2	7	8	Average
Bulk Specific Gravity . . . . .	2.238	2.239	2.238	2.243	2.242	2.248	2.227	2.246	
Maximum Specific Gravity					2.406				
Air Voids, % . . . . .	7.0	6.9	7.0	6.8	6.8	6.6	7.4	6.7	6.9
% Saturation . . . . .	--	--	--	--	64.9	65.3	65.3	65.5	65.3
Dry Tensile Strength psi	87.2	86.3	85.1	83.3	--	--	--	--	85.5
Wet Tensile Strength psi	--	--	--	--	59.7	58.2	54.5	56.3	57.2
Average Tensile Splitting Ratio, % . . . . .							66.9		

**SHRP B9 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4567**  
**TEXAS CHERT (RL)**  
**MIX DESIGN 006041-A**

Asphalt CTL Lab No. 008232, Blend 16

	3	4	5	6	1	2	7	8	Average
Bulk Specific Gravity . .	2.212	2.228	2.247	2.249	2.229	2.225	2.247	2.249	
Maximum Specific Gravity	-----	-----	2.406	-----	-----	-----	-----	-----	
Air Voids, % . . . . .	8.1	7.4	6.6	6.5	7.4	7.5	6.6	6.5	7.1
% Saturation . . . . .	--	--	--	--	65.1	66.8	67.1	66.1	66.3
Dry Tensile Strength psi	73.4	70.3	73.4	71.9	--	--	--	--	72.3
Wet Tensile Strength psi	--	--	--	--	44.3	45.9	50.5	53.5	48.6
Average Tensile Splitting Rat-Lo, % . . . . .								67.2	

SHRP 89 ID 020  
TENSILE STRENGTH RATIO - ASTM D-4867  
TEXAS CHERT (RL)  
MIX DESIGN 006041-A

Asphalt CTL Lab No. 006076, Blend 9

	3	4	7	8	1	2	5	6	Average
Bulk Specific Gravity . . . . .	2.250	2.244	2.241	2.245	2.238	2.245	2.247	2.244	
Maximum Specific Gravity -----	-----	-----	-----	2.406	-----	-----	-----	-----	
Air Voids, % . . . . .	6.5	6.7	6.9	6.7	7.0	7.0	6.6	6.7	6.8
% Saturation . . . . .	--	--	--	--	64.2	64.1	64.8	65.2	64.6
Dry Tensile Strength psi	129.9	130.6	131.2	132.2	--	--	--	--	131.0
Wet Tensile Strength psi	--	--	--	--	47.1	52.5	60.5	52.5	53.2
Average Tensile Splitting Ratio, % . . . . .							40.6		

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 006077, Blend 10

	2	4	5	7	1	3	6	8	Average
Bulk Specific Gravity . . . . .	2.245	2.230	2.239	2.242	2.239	2.244	2.241	2.236	
Maximum Specific Gravity . . . . .	-----	-----	-----	2.406	-----	-----	-----	-----	
Air Voids, % . . . . .	6.7	7.3	6.9	6.8	6.9	6.7	6.9	7.1	6.9
% Saturation . . . . .	--	--	--	--	65.3	65.2	64.2	63.7	64.6
Dry Tensile Strength psi . . . . .	117.8	115.3	117.8	117.8	--	--	--	--	117.2
Wet Tensile Strength psi . . . . .	--	--	--	--	52.5	58.9	58.9	54.1	56.1
Average Tensile Splitting Ratio, % . . . . .								47.9	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 006078, Blend 11

	1	2	6	7	3	4	5	8	Average
Bulk Specific Gravity . .	2.240	2.237	2.242	2.245	2.249	2.231	2.240	2.238	
Maximum Specific Gravity				2.406					
Air Voids, % . . . . .	6.9	7.0	6.8	7.0	6.5	7.3	6.9	7.0	6.9
% Saturation . . . . .	--	--	--	--	64.8	65.4	63.6	63.9	64.4
Dry Tensile Strength psi	121.0	119.4	120.4	123.6	--	--	--	--	121.1
Wet Tensile Strength psi	--	--	--	--	58.6	44.6	66.7	49.4	52.3
Average Tensile Splitting Ratio, % . . . . .								43.2	

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 006079, Blend 12

	1	3	7	8	2	4	6	6	Average
Bulk Specific Gravity . . .	2.240	2.238	2.244	2.241	2.243	2.235	2.243	2.239	
Maximum Specific Gravity	-----	-----	2.406	-----	-----	-----	-----	-----	
Air Voids, % . . . . .	6.9	7.0	6.7	6.9	6.8	7.1	6.8	6.9	6.9
% Saturation . . . . .	--	--	--	--	66.7	65.0	66.1	65.8	65.9
Dry Tensile Strength psi	123.6	121.7	122.6	116.2	--	--	--	--	121.0
Wet Tensile Strength psi	--	--	--	--	60.5	57.3	58.0	63.1	59.7
Average Tensile Splitting Ratio, % . . . . .								49.4	

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**TEXAS CHERT (RL)**  
**MIX DESIGN 006041-A**

Asphalt CTL Lab No.: 007013, Blend 17

**SHRP 89 ID 020**  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
**TEXAS CHERT (RL)**  
**MIX DESIGN 006041-A**

Asphalt CTL Lab No. 007014, Blend 18

	1	3	5	6	2	4	7	8	Average
Specimen . . . . .									
Bulk Specific Gravity . .	2.250	2.244	2.248	2.241	2.237	2.247	2.251	2.249	
Maximum Specific Gravity	-----	-----	-----	2.406	-----	-----	-----	-----	
Air Voids, % . . . . .	6.5	6.7	6.6	6.9	7.0	6.6	6.4	6.5	6.7
% Saturation . . . . .	--	--	--	--	64.1	64.0	64.2	66.3	64.7
Dry Tensile Strength psi	138.5	145.9	148.1	141.7	--	--	--	--	143.6
Wet Tensile Strength psi	--	--	--	--	58.0	60.5	63.7	62.1	61.1
Average Tensile Splitting Ratio, % . . . . .									42.5

SHRP 89 ID 020  
**TENSILE STRENGTH RATIO - ASTM D-4867**  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 007015, Blend 19

	2	4	6	8	1	3	5	7	Average
Specimen . . . . .									
Bulk Specific Gravity . .	2.243	2.240	2.246	2.241	2.235	2.246	2.248	2.241	
Maximum Specific Gravity					2.406				
Air Voids, % . . . . .	6.8	6.9	6.7	6.9	7.1	6.7	6.6	6.9	6.8
% Saturation . . . . .	--	--	--	--	66.8	66.2	65.8	65.5	66.1
Dry Tensile Strength psi	97.1	95.5	100.3	95.5	--	--	--	--	97.1
Wet Tensile Strength psi	--	--	--	--	54.8	60.5	58.9	55.7	57.5
Average Tensile Splitting Ratio, % . . . . .									59.2

SHRP 89 ID 020  
 TENSILE STRENGTH RATIO - ASTM D-4867  
 TEXAS CHERT (RL)  
 MIX DESIGN 006041-A

Asphalt CTL Lab No. 007016, Blend 20

	1	2	5	6	3	4	7	8	Average
Bulk Specific Gravity . . .	2.243	2.225	2.255	2.237	2.236	2.230	2.247	2.242	
Maximum Specific Gravity	-----	-----	2.406	-----	-----	-----	-----	-----	
Air Voids, % . . . . .	6.8	7.5	6.3	7.0	7.1	7.3	6.6	6.8	6.9
% Saturation . . . . .	--	--	--	--	66.7	66.6	66.6	66.4	66.6
Dry Tensile Strength psi	156.1	148.1	146.5	144.9	--	--	--	--	148.9
Wet Tensile Strength psi	--	--	--	--	60.5	57.3	66.9	67.5	63.1
Average Tensile Splitting Ratio, % . . . . .									42.3

## References

1. Shell International Petroleum Company Limited. *The Petroleum Handbook*. Fifth edition. 1966.
2. Oliensis, G. *American Society of Testing Materials*. Proceedings 33. 1933.
3. The Asphalt Institute, "State Specifications of Asphalt." July 1987.
4. Lewis, R. and Welborn, J. *Public Roads*. 22. 1941.
5. Hus, M. "Visbreaking Process Has Strong Revival." *Oil & Gas Journal*. April 13, 1981.
6. Root, R.E., and Moore, R.B. "The Use of Vacuum Distilled Conversion Residue as a Component to Reduce Moisture-Induced Damage in Asphalt Pavements." SHRP IDEA Proposal. July 10, 1989.
7. American Society for Testing Materials. *1990 Annual Book of ASTM Standards*. Volume 04.03. Philadelphia, PA.
8. Lettier, J.A., Tonne, C.D., and Wilson, N.B. "Waterproofing Aggregates with Cracked Road Oils." *Proceedings of the Association of Asphalt Paving Technologists (AAPT)*. 1955.
9. Zanzotto, L., Faber, A.J., Foley, D.P., and Jeffries, R.B. "Hydrocracking Residues - The Potential Source of Road Binders?" *Proceedings of the AAPT*. 1988.
10. SHRP. *Asphalt: A Strategic Plan--1990*. pg. 34. Washington, D.C.
11. Pfeiffer, J., and van Doormaal, P.M. "The Rheological Properties of Asphaltic Bitumen." *Journal, Institution of Petroleum Technologists*. No. 22. 1963.
12. Heukelom, W. "A Bitumen Test Data Chart for Showing the Effect of Temperature of the Mechanical Behavior of Asphaltic Bitumens." *Journal of the Institute of Petroleum*. November, 1969.

13. Heukelom, W. "An Improved Method of Characterizing Asphaltic Bitumens with the Aid of their Mechanical Properties." *Proceedings of the AAPT*. 1973.
14. de Bats, F.T., and van Gooswilligen, G. "Practical Rheological Characterization of Paving Grade Bitumens." *Fourth Eurobitume Symposium*. 1989.
15. Gaw, W.J. "Low Temperature Properties of Bituminous Materials and of Compacted Bituminous Paving Mixtures." *ASTM Symposium*. Chicago, IL. July, 1976.
16. Goodrich, J.L. "Asphalt and Polymer Modified Asphalt Properties Related to the Performance of Asphalt Concrete Mixes." *Proceedings of the AAPT*. 1988.
17. Shell International Petroleum Company. *Shell Pavement Design Manual*. London. 1978.
18. American Association of State Highway and Transportation Officials. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing--Part I Specifications*. Washington, D.C. 1986.
19. Moore, R.B. Prepared Discussion. *Proceedings of the AAPT*. pg. 232-234. 1989.
20. van Gooswilligen, G., de Bats, F., and Harrison, T. "Quality of Paving Grade Bitumen - A Practical Approach in Terms of Functional Tests." *Fourth Eurobitume Symposium*. 1989.
21. Giavarini, C., and Maregrande, S. "Characterization Studies on Visbreaker Residue and Bitumens." *Fuel Science and Technology International*. 7 (8). pg. 1121-1138. 1989.
22. Simpson, W.C., Griffin, R.L., and Miles, T.K. "Relationship of Asphalt Properties to Chemical Constitution." *Journal of Chemical and Engineering Data*. pg. 351. October 1959.
23. Corbett, L.W. "Dumbell Mix for Better Asphalt." *Hydrocarbon Processing*. April 1979.