# RECYCLING - A LABORATORY STUDY

by

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## ABSTRACT

With the current trend towards preserving the environment and the country's natural resources the asphalt industry as a whole has committed itself to the use of recycling.

This paper contains data from a laboratory study done by McAsphalt Engineering Services on laboratory prepared recycled hot mix designs with the major emphasis on the asphalt cements used. HL 4 mixes conforming to Ontario's OPSS Form 1150 were designed using two different recycling materials combined in nine different recycling percentages with six different grades of asphalt cement. The extracted asphalt cement was recovered by Abson recovery and the basic asphalt cement testing was performed on each sample. The two different recycling materials had recovered penetration values of 22 and 37.

The study examines the effects of asphalt cement grade (85/100, 120/150, 150/200, 200/300, 300/400 and 500+) in combination with the different percentages of recycled material (15% to 50%). Blends of the recovered asphalt from the recycle materials and the six virgin asphalt cements were made and the standard asphalt tests done on each blend.



## SOMMAIRE

Dans le cadre de la tendance actuelle à vouloir préserver l'environnement et les ressources naturelles du pays, l'industrie de l'asphalte dans son ensemble s'est engagée à utiliser le recyclage.

Ce document contient des données provenant d'une étude en laboratoire effectuée par McAsphalt Engineering Services. Cette étude porte sur des mélanges à chaud d'asphalte recyclé préparés en laboratoire et met l'accent principalement sur les ciments d'asphalte utilisés dans ces mélanges. Les mélanges HL 4, conformément au formulaire OPSS 1150 de L'Ontario, ont été conçus à l'aide de deux matériaux de recyclage différents, combinés, selon 9 différents pourcentages de recyclage, avec 6 ciments d'asphalte de degrés de pénétration différents. Le ciment d'asphalte extrait a été récupéré au moyen de la technique de récupération Abson et le test de base pour le ciment d'asphalte a été effectué pour chaque échantillon. Les deux matériaux différents de recyclage ont retrouvé les valeurs de pénétration de 22 et de 37.

L'étude analyse les effets de la combinaison de ciments d'asphalte possédant un degré de pénétration de 85/100, 120/150, 150/200, 200/300, 300/400 ou 500 et plus avec des matériaux de recyclage de différents pourcentages (15 à 50%). L'asphalte récupéré à partir de matériaux de recyclage a été mélangé aux six ciments d'asphalte vierges, et chaque échantillon a été soumis à des tests standard afin de vérifier le degré de pénétration de l'asphalte.

## INTRODUCTION

With the improved technology in processing recycled materials and state of the art hot mix plants the quality of recycled hot mix has been greatly improved since the early days of the recycling business. As well, improved mix design methods for recycled pavements have resulted in better quality recycled hot mixes. The proper application of good pavement mixture design using the proper aggregates and asphalt cement can greatly improve the quality of paving mixes and increase the service life of paved roads made from recycled materials.

Hot mix recycling is extremely popular throughout Canada and the rest of the world as evidenced by the number of papers and reports which have been published on the subject (1-7). All the reports talk of good mix design practice and recycled binder quality to achieve a successful pavement.

As part of this trend in recycling technology McAsphalt Engineering Services initiated a research study into the factors affecting the design of recycled hot mixes. The major concern in the past has been to redesign the hot mix using a softer grade or the same grade of asphalt cement and return the old pavement to its original consistency. The main thrust of this study was to determine the effect different grades of asphalt cement (85/100 to 500+) would have on the finished properties of the recycled mix. The study was designed to provide information which would allow an engineer to determine with a satisfactory degree of confidence when a certain grade of asphalt cement should be used and the level of recycled material which could be used with that asphalt cement to meet user agency specifications.

## MIX DESIGNS

The Marshall method of design was used to obtain the laboratory data on the mixes. An HL 4 type mix conforming to Ontario's OPSS Form 1150 was selected as the basis for the designs. The following design criteria was used:

| | | |
|---|---|---|
| Traffic Volume | > | 5000 vpd |
| Marshall Stability | | 8900 N min. |
| Air Voids % | | 3 - 5 |
| VMA % | | 14.5 min |
| Mixing Temperature | | 150 C |
| Compaction Temperature | | 140 C |

The coarse and fine aggregates used in the study are aggregates which McAsphalt has used for many years for various research projects because of their consistent physical properties. In order to meet the design criteria using the high recycle percentage (50%), the sand aggregate was screened on the 1.18 mm sieve to create a fine blending sand. The data on the virgin aggregates as well as the two recycle materials (RAP and Millings) used in the study are shown in Table 1. The terms RAP (Recycled Asphalt Pavement) and Millings have been used to differentiate between the two recycle materials used in the research project. The RAP material has been processed

through a crusher, whereas the Millings is the material that has been produced by a milling machine.

Mix designs were obtained on the eight different recycle percentages (15 to 50%) for each of the two recycle materials. A control mix containing only virgin materials was also designed using the same virgin aggregates as used in the recycle mixes. In order to simplify the design process all the designs were based on the use of 85/100 virgin asphalt. Once the nine designs were done, the six different grades of asphalt cement were substituted and the designs redone. The physical data on the six grades of asphalt cement used as well as the test data on the two recycled asphalt cements are as shown in Table 2. In order to eliminate variables and to simplify the design procedure, the same mixing (150°C) and compaction (140°C) temperatures were used on all mixes regardless of the percentage recycle, type of recycle material or grade of asphalt cement used. Tables 3 and 4 contain the gradation data on the various recycle designs done using both the RAP and the Millings.

After the Marshall tests were performed on the mixes the asphalt cements were recovered from the briquettes by the Abson recovery method (ASTM D1856). The penetration at 25°C, the kinematic viscosity at 135°C and the PVN were measured for each recovered asphalt cement.

## ASPHALT BLENDING STUDY

In conjunction with the mix design work involving the various grades of asphalt cement and recycling percentages, a blending study was done to produce asphalt cement blends, which incorporated the various grades of virgin asphalt cement with the asphalt recovered from the two recycling materials (RAP and Millings).

A large volume of recovered binder was required for the blending study. In order to extract sufficient recovered binder, large supplies of recycle materials were obtained from the stockpiles at two different Ontario contractors.

These materials were representative of the stockpiles and were the same recycle materials which were used in the mix design portion of the research study. In order to achieve a large enough amount of recovered binder, an extraction procedure similar to the method that Robertson and Adams (1) described in their 1988 CTAA paper was used. The procedure used for the study involved the following steps:

1. A sufficient amount of recycle material (20 kg) was placed in a suitable container, covered with trichloroethylene and stirred to ensure thorough mixing. The material was left covered for a number of days with occasional stirring each day.

2. The extract solution was decanted and collected. The solution was centrifuged using an SMM centrifuge to remove the fines. The standard Abson recovery test (ASTM 1856) was run and the recovered binder was collected in fractions.

3. The penetration at 25°C, the kinematic viscosity at 135°C and the PVN value were obtained on each fraction and compared to the other fractions.

After an adequate amount of recovered binder was collected, the blending study was started. In the case of the Millings, sufficient recovered binder was obtained for the complete blending study. The use of a higher penetration recycle material (37 Pen) was added to the research project after a large proportion of the project had been completed. The RAP material was in limited supply and the quantity of recovered binder was not sufficient to complete the entire asphalt blending study. To maximize the data obtained from the blending study, the pertinent blending percentages were used with each grade of virgin asphalt cement.

The asphalt cement blending study involved the blending of the six virgin asphalt cements with various percentages (15 to 50%) of the recovered asphalt from the two recycled materials. The blends using the Millings material were then tested for the following:

Penetration at 25°, 10° and 4°C
Kinematic Viscosity at 135°C
Absolute Viscosity at 60°C
Softening Point
PVN

Due to the limited supply of the higher penetration RAP material the asphalt blends for this study were tested for only the following:

Penetration at 25°C
Kinematic Viscosity at 135°C
PVN

Thin Film Oven Tests were carried out as well on the blended samples and the above tests were repeated on the residues.

## DISCUSSION OF THE MIX DATA

The Marshall briquettes produced for each recycle mix blend were extracted to obtain the asphalt content and the asphalt cement for testing. All the samples were recovered by the standard Abson recovery method (ASTM D1856).

In order to determine the percentage of recycle asphalt cement present in each mix the recovered asphalt content was assumed to be the true asphalt content in the mix (i.e. 100% recovery). Since the percentage of virgin asphalt cement added to each mix is known, the percentage of recycle asphalt in the mix is equal to the difference between the total percentage of asphalt cement in the mix and the percentage of virgin asphalt added to the mix. Once the percentage of recycle asphalt cement is determined, graphs of the recovered penetration versus the percentage of recycle asphalt cement can be plotted. Figures 1 through 6 show the plots for the various virgin asphalt cements and the two recycle materials.

The test data shown in Figures 1 through 6 illustrate the impact that the penetration of the recycle material can have

on the final penetration of the mix. Depending on the penetration of the recycle material the quantity of recycle material which can be incorporated into the mix can be varied significantly. This effect has the greatest influence when the harder grades of virgin asphalt cement are used (Figures 1 and 2). An interesting observation of this study is that soft grades of virgin asphalt cement (500+, Figure 6) appears to negate the influence that the penetration of the recycle material has on the final penetration results of the mix.

Based on the test data generated in the laboratory study, the use of 85/100 penetration grade asphalt cement as a virgin asphalt cement for recycling should be monitored very closely. The likelihood of a hot mix which has a low percentage of recycle material (20% or 25%) having a marginal recovered penetration during actual construction is high.

With the looming implementation of end result specifications (ERS), contractors, should use the next grade higher than 85/100 for all low recycle percentage mixes.

## DISCUSSION OF THE ASPHALT CEMENT BLENDING

As mentioned earlier, a blending study was done to produce asphalt cement blends which incorporated the various grades of virgin asphalt cement with the asphalt cement recovered from the two recycling materials.

The initial research project involved the use of the six different grades of virgin asphalt cement and one recycle material (Millings, Pen = 22). As a result the volume of test data collected on this recycle material is quite substantial (Tables 5 - 10), whereas the results obtained on the second recycle material (RAP, Pen = 37) are limited in volume due to the lack of available RAP material. Tables 11 through 16 contain the test data on the higher penetration recycle material. Although there is less data on the second recycle material, similar trends in test results have been observed for both recycle materials.

Figures 7 through 18 present the test data from the tables in graph form. The plots show that the penetration values obtained on the recovered asphalt cement lie between the penetration values of the virgin blends and the penetration results of the thin film oven test (TFOT) on those virgin asphalt blends for the same percentage of recycle asphalt cement. The penetration numbers from the TFOT were the lowest penetration values observed in all cases.

When designing a recycle mix, blends of the recovered asphalt from the recycle material and softer grades of virgin asphalt cement, which might be used, should be made. The Thin Film Oven Test should be run on these blends and based on the TFOT test results, the proper grade or penetration of virgin asphalt cement can be determined. By using the results from the TFOT the likelihood of low penetration results occurring in production would be negligible.

The quantity of recycle which can be used in a new mix can be influenced not only by the penetration, but by the percentage of asphalt cement present in the recycle material as well. The ratio of virgin asphalt to the recycle asphalt

can aid in the determination of the grade of virgin asphalt cement necessary to meet the specified requirements.

## FUTURE RESEARCH

As part of the continuing research at McAsphalt Engineering Services on recycling technology a number of factors which have not been answered by the present study should be examined. These are as follows:

1. The use of modified asphalt cements in recycling should be investigated.

2. The use of rejuvenating oils in conjunction with asphalt cements should be examined.

3. The development of a design method to simulate the aging process that occurs in the field is required.

## CONCLUSIONS

1. When 85/100 Penetration grade asphalt cement is used for recycling, the penetration of the recycle material should be monitored closely. The penetration of the recycle material should dictate the virgin grade used.

2. The use of the Thin Film Oven Test as a design criteria for final penetration should be considered in the determination of the percentage of recycle material in the mix and the penetration grade of virgin asphalt cement to be used.

3. The grade of virgin asphalt cement used should also be based on the final penetration desired as well as the ratio of percent recycle asphalt to virgin asphalt cement.

4. The effect of the penetration of the recycle material disappears as the penetration of the virgin asphalt used increases. Above a penetration of approximately 400 the recycle material penetration has no influence on the penetration of the final blend.

5. With the implementation of end result specifications (ERS) all parties involved in the design and production of recycled hot mix will have to become keenly aware of the pitfalls of recycle mixes.

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TABLE 1

DATA ON AGGREGATE SAMPLES
WASHED SIEVE ANALYSIS

| AGGREGATE TYPE | STONE | SAND | BLEND SAND | RAP 37 PEN | MILLINGS 22 PEN |
|---|---|---|---|---|---|
| SIEVE SIZE | % PASS | % PASS | % PASS | % PASS | % PASS |
| 26.0 mm | | | | 100 | 100 |
| 19.0 mm | 100 | | | 99.0 | 99.0 |
| 16.0 mm | 99.5 | | | 98.0 | 96.6 |
| 13.2 mm | 97.0 | | | 95.0 | 94.0 |
| 9.5 mm | 77.4 | 100 | | 85.0 | 86.8 |
| 4.75 mm | 10.7 | 98.8 | | 65.0 | 66.9 |
| 2.36 mm | 1.4 | 89.7 | 100 | 48.0 | 55.7 |
| 1.18 mm | 1.1 | 72.3 | 97.0 | 33.0 | 47.3 |
| 600 um | 0.9 | 40.5 | 54.5 | 21.0 | 37.7 |
| 300 um | 0.8 | 20.5 | 29.0 | 14.0 | 23.7 |
| 150 um | 0.7 | 8.1 | 9.5 | 9.0 | 12.3 |
| 75 um | 0.6 | 1.0 | 2.0 | 5.6 | 7.6 |
| Bulk Specific Gravity | 2.682 | 2.632 | 2.666 | 2.658 | 2.666 |
| % Water Absorption | 1.37 | 1.63 | 1.19 | 0.79 | 1.00 |
| % Asphalt Content | | | | 4.30 | 4.63 |

TABLE 2

PROPERTIES OF ASPHALT CEMENT

| | ASPHALT CEMENT GRADES | | | | | RAP MATERIALS | | |
|---|---|---|---|---|---|---|---|---|
| TESTS | 85/100 | 20/150 | 150/200 | 200/300 | 300/400 | 500+ | 22 PEN | 37 PEN |
| Pen @ 25°C | 88 | 123 | 156 | 275 | 335 | 537 | 22 | 37 |
| @ 10°C | 19 | 31 | 37 | 67 | 90 | 103 | 6 | - |
| @ 4°C | 10 | 16 | 18 | 33 | 41 | 56 | 2 | - |
| Kin.Vis @ 135°C | 423 | 325 | 285 | 207 | 175 | 121 | 1215 | 586 |
| PVN | -0.28 | -0.30 | -0.22 | -0.01 | -0.01 | 0.00 | -0.29 | -0.70 |
| Abs.Vis. @ 60°C | 2023 | 1098 | 943 | 924 | 265 | 177 | 32559 | 9151 |
| Soft.Pt. R&B °C | 44.2 | 45.3 | 41.9 | 39.7 | 35.0 | 29.6 | 63.1 | 60.0 |
| TFOT | | | | | | | | |
| % Loss by Wt. | 0.166 | 0.318 | 0.205 | 0.342 | 0.817 | 0.667 | 0.681 | 0.354 |
| % Ret. Pen | 62.5 | 61.8 | 59.6 | 57.5 | 49.6 | 57.9 | 77.3 | 83.8 |
| Pen @ 25°C | 55 | 76 | 93 | 158 | 166 | 311 | 17 | 31 |
| @ 10°C | 12 | 16 | 26 | 50 | 42 | 69 | 2 | - |
| @ 4°C | 6 | 10 | 14 | 27 | 20 | 37 | 0 | - |
| Kin.Vis @ 135°C | 599 | 505 | 432 | 304 | 301 | 167 | 1739 | 845 |
| PVN | -0.30 | -0.19 | -0.19 | -0.09 | -0.05 | -0.22 | -0.21 | -0.41 |
| Abs.Vis. @ 60°C | 5334 | 3395 | 2181 | 1052 | 805 | 396 | 87613 | 21068 |
| Soft.Pt. R&B °C | 52.2 | 49.4 | 47.8 | 41.7 | 40.0 | 34.8 | 68.6 | 62.2 |

TABLE 3

ASPHALT MIX BLENDS - 22 PEN

| BLEND | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % RAP MATERIAL | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 |
| % COARSE AGGREGATE | 37.5 | 35.0 | 32.5 | 27.5 | 24.0 | 21.5 | 20.0 | 17.5 |
| % FINE AGGREGATE | 47.5 | 45.0 | 42.5 | 42.5 | 41.0 | 38.5 | 0.0 | 0.0 |
| % BLEND AGGREGATE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 35.0 | 32.5 |
| % VIRGIN ASPHALT | 4.66 | 4.45 | 4.13 | 4.02 | 3.61 | 3.56 | 3.13 | 2.90 |
| % TOTAL ASPHALT | 5.30 | 5.30 | 5.20 | 5.30 | 5.10 | 5.40 | 5.20 | 5.20 |
| **SIEVE SIZE** | | | | | | | | |
| 1 INCH 26.5 mm | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3/4 INCH 19.0 mm | 99.9 | 99.8 | 99.8 | 99.7 | 99.7 | 99.6 | 99.6 | 99.5 |
| 5/8 INCH 16.0 mm | 99.3 | 99.4 | 99.0 | 98.8 | 98.7 | 98.5 | 98.4 | 98.2 |
| 1/2 INCH 13.2 mm | 98.0 | 97.8 | 97.5 | 97.4 | 97.2 | 97.0 | 96.7 | 96.5 |
| 3/8 INCH 9.5 mm | 89.5 | 89.5 | 89.4 | 89.9 | 90.0 | 89.9 | 89.5 | 89.4 |
| NO. 4 4.75 mm | 60.8 | 61.4 | 62.0 | 64.8 | 66.3 | 66.9 | 67.2 | 67.8 |
| 8 2.36 mm | 51.1 | 51.6 | 52.2 | 54.9 | 56.3 | 56.8 | 60.3 | 60.6 |
| 16 1.18 mm | 40.6 | 41.2 | 41.8 | 44.1 | 45.4 | 46.0 | 56.5 | 56.3 |
| 30 600 µm | 26.5 | 27.3 | 28.1 | 29.9 | 31.1 | 31.9 | 38.9 | 39.2 |
| 50 300 µm | 15.3 | 15.8 | 16.4 | 17.5 | 18.3 | 18.9 | 22.9 | 23.2 |
| 100 150 µm | 7.0 | 7.3 | 7.7 | 8.3 | 8.7 | 9.0 | 10.9 | 11.1 |
| 200 75 µm | 2.6 | 2.9 | 3.2 | 3.5 | 3.8 | 4.1 | 4.8 | 5.1 |

TABLE 4

ASPHALT MIX BLENDS - 37 PEN

| BLEND | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % RAP MATERIAL | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 |
| % COARSE AGGREGATE | 37.5 | 35.0 | 32.5 | 27.5 | 24.0 | 21.5 | 20.0 | 18.0 |
| % FINE AGGREGATE | 47.5 | 45.0 | 42.5 | 42.5 | 41.0 | 38.5 | 35.0 | 32.0 |
| % BLEND AGGREGATE | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| % VIRGIN ASPHALT | 4.61 | 4.38 | 4.05 | 3.92 | 3.49 | 3.56 | 3.29 | 3.07 |
| % TOTAL ASPHALT | 5.30 | 5.30 | 5.20 | 5.30 | 5.10 | 5.40 | 5.20 | 5.20 |
| **SIEVE SIZE** | | | | | | | | |
| 1 INCH 26.5 mm | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3/4 INCH 19.0 mm | 99.9 | 99.8 | 99.8 | 99.7 | 99.7 | 99.6 | 99.6 | 99.6 |
| 5/8 INCH 16.0 mm | 99.5 | 99.4 | 99.3 | 99.3 | 99.2 | 99.1 | 99.0 | 98.9 |
| 1/2 INCH 13.2 mm | 98.1 | 98.0 | 97.8 | 97.7 | 97.5 | 97.4 | 97.2 | 97.0 |
| 3/8 INCH 9.5 mm | 89.3 | 89.1 | 88.9 | 89.3 | 89.3 | 89.1 | 88.7 | 88.4 |
| NO. 4 4.75 mm | 60.5 | 61.0 | 61.5 | 64.3 | 65.7 | 66.2 | 65.8 | 65.9 |
| 8 2.36 mm | 50.0 | 50.1 | 50.2 | 52.6 | 53.6 | 53.7 | 53.0 | 52.7 |
| 16 1.18 mm | 38.4 | 38.3 | 38.2 | 39.8 | 40.4 | 40.2 | 39.4 | 39.0 |
| 30 600 µm | 24.0 | 24.0 | 23.9 | 24.9 | 25.3 | 25.2 | 24.8 | 24.5 |
| 50 300 µm | 13.8 | 13.9 | 14.0 | 14.6 | 14.9 | 15.0 | 14.9 | 14.8 |
| 100 150 µm | 6.5 | 6.7 | 6.9 | 7.3 | 7.5 | 7.7 | 7.8 | 7.9 |
| 200 75 µm | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 |

TABLE 5

ASPHALT BLENDING
85/100 - 22 PEN

| GRADE | 85/100 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 423 | 467 | 492 | 527 | 571 | 574 | 579 | 652 | 752 |
| Pen @ 25°C | 88 | 69 | 67 | 60 | 57 | 52 | 49 | 44 | 39 |
| @ 10°C | 19 | 14 | 12 | 12 | 11 | 10 | 9 | 8 | 6 |
| @ 4°C | 10 | 7 | 5 | 5 | 4 | 3 | 3 | 3 | 2 |
| PVN | -0.28 | -0.41 | -0.37 | -0.37 | -0.27 | -0.42 | -0.47 | -0.41 | -0.39 |
| Abs Vis @ 60°C | 2023 | 2966 | 3324 | 3909 | 4525 | 5012 | 6323 | 6966 | 9505 |
| Soft.Pt. R&B°C | 44.2 | 48.6 | 48.9 | 50.0 | 51.4 | 51.9 | 52.8 | 54.2 | 55.0 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.166 | 0.259 | 0.213 | 0.282 | 0.275 | 0.369 | 0.319 | 0.361 | 0.389 |
| % Ret. Pen | 62.5 | 68.1 | 71.6 | 71.7 | 71.9 | 71.2 | 73.5 | 75.0 | 76.0 |
| Kin Vis @ 135°C | 599 | 683 | 626 | 753 | 737 | 854 | 848 | 873 | 988 |
| Pen @ 25°C | 55 | 47 | 48 | 43 | 41 | 37 | 36 | 34 | 29 |
| @ 10°C | 12 | 11 | 10 | 8 | 7 | 6 | 7 | 7 | 5 |
| @ 4°C | 6 | 6 | 5 | 4 | 4 | 3 | 3 | 2 | 2 |
| PVN | -0.30 | -0.28 | -0.38 | -0.24 | -0.32 | -0.42 | -0.27 | -0.28 | -0.21 |
| Abs Vis @ 60°C | 5334 | 6824 | 6033 | 8535 | 9736 | 11335 | 12063 | 14600 | 17542 |
| Soft. Pt. R&B°C | 52.2 | 54.4 | 54.2 | 55.6 | 56.7 | 57.5 | 58.1 | 59.4 | 60.0 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 5.7 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED | 5.60 | 5.17 | 5.11 | 5.11 | 5.05 | 4.94 | 5.24 | 5.25 | 5.16 |
| Kin Vis @ 135°C | 482 | 552 | 606 | 641 | 653 | 667 | 708 | 710 | 782 |
| Pen @ 25°C | 70 | 63 | 54 | 52 | 52 | 46 | 44 | 42 | 38 |
| @ 10°C | 17 | 15 | 13 | 12 | 11 | 11 | 10 | 10 | 9 |
| @ 4°C | 9 | 9 | 8 | 7 | 7 | 6 | 7 | 6 | 5 |
| PVN | -0.36 | -0.27 | -0.29 | -0.26 | -0.34 | -0.34 | -0.30 | -0.34 | -0.32 |
| Abs Vis @ 60°C | 3670 | 4432 | 5393 | 5572 | 6010 | 6218 | 7647 | 8024 | 8437 |
| Soft. Pt. R&B°C | 50.6 | 51.4 | 51.9 | 51.9 | 53.9 | 54.7 | 55.0 | 56.1 | 56.9 |

TABLE 6

ASPHALT BLENDING
120/150 - 22 PEN

| GRADE | 120/150 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 325 | 380 | 440 | 500 | 521 | 550 | 530 | 569 | 630 |
| Pen @ 25°C | 123 | 83 | 71 | 65 | 64 | 60 | 56 | 50 | 43 |
| @ 10°C | 31 | 16 | 18 | 17 | 16 | 15 | 9 | 6 | 5 |
| @ 4°C | 16 | 8 | 9 | 6 | 6 | 6 | 4 | 3 | 2 |
| PVN | -0.30 | -0.46 | -0.46 | -0.38 | -0.33 | -0.33 | -0.45 | -0.47 | -0.48 |
| Abs Vis @ 60°C | 1038 | 2208 | 3157 | 3535 | 4003 | 4424 | 4769 | 5605 | 6554 |
| Soft.Pt. R&B°C | 39.2 | 45.3 | 47.7 | 49.4 | 50.0 | 51.1 | 51.7 | 53.3 | 54.7 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.235 | 0.318 | 0.323 | 0.328 | 0.295 | 0.338 | 0.391 | 0.446 | 0.392 |
| % Ret. Pen | 61.8 | 67.0 | 70.4 | 72.3 | 68.8 | 68.3 | 71.4 | 74.0 | 79.1 |
| Kin Vis @ 135°C | 505 | 544 | 653 | 690 | 716 | 794 | 750 | 831 | 854 |
| Pen @ 25°C | 76 | 59 | 50 | 47 | 44 | 41 | 40 | 37 | 34 |
| @ 10°C | 16 | 13 | 14 | 13 | 12 | 10 | 10 | 9 | 8 |
| @ 4°C | 10 | 6 | 7 | 6 | 6 | 5 | 5 | 5 | 4 |
| PVN | -0.19 | -0.36 | -0.22 | -0.27 | -0.29 | -0.22 | -0.32 | -0.26 | -0.31 |
| Abs Vis @ 60°C | 3395 | 4577 | 6705 | 7710 | 7764 | 8716 | 8920 | 11222 | 12281 |
| Soft. Pt. R&B°C | 49.4 | 51.4 | 54.4 | 54.7 | 55.0 | 55.3 | 55.0 | 55.8 | 56.7 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.83 | 5.04 | 5.29 | 5.11 | 5.17 | 5.14 | 5.16 | 5.04 | 4.95 |
| Kin Vis @ 135°C | 379 | 465 | 498 | 518 | 525 | 568 | 605 | 621 | 658 |
| Pen @ 25°C | 103 | 74 | 73 | 71 | 66 | 62 | 55 | 51 | 47 |
| @ 10°C | 20 | 19 | 19 | 18 | 17 | 16 | 11 | 12 | 10 |
| @ 4°C | 10 | 8 | 9 | 7 | 7 | 7 | 6 | 5 | 4 |
| PVN | -0.27 | -0.34 | -0.25 | -0.23 | -0.29 | -0.25 | -0.28 | -0.33 | -0.33 |
| Abs Vis @ 60°C | 1966 | 3008 | 3443 | 3157 | 3253 | 4639 | 5439 | 6367 | 7707 |
| Soft. Pt. R&B°C | 44.7 | 48.6 | 49.2 | 48.9 | 49.4 | 51.1 | 53.3 | 53.9 | 54.7 |

TABLE 7

ASPHALT BLENDING
150/200 - 22 PEN

| GRADE | 150/200 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 285 | 327 | 416 | 464 | 472 | 522 | 520 | 524 | 552 |
| Pen @ 25°C | 156 | 113 | 93 | 83 | 76 | 69 | 64 | 58 | 52 |
| @ 10°C | 37 | 27 | 18 | 15 | 14 | 13 | 13 | 12 | 9 |
| @ 4°C | 18 | 15 | 10 | 8 | 7 | 6 | 6 | 7 | 6 |
| PVN | -0.22 | -0.39 | -0.25 | -0.21 | -0.31 | -0.25 | -0.34 | -0.43 | -0.47 |
| Abs Vis @ 60°C | 943 | 1543 | 2641 | 3082 | 3200 | 3604 | 3641 | 4206 | 5003 |
| Soft.Pt. R&B°C | 41.9 | 44.7 | 46.4 | 47.8 | 48.3 | 49.2 | 49.4 | 50.3 | 51.4 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.205 | 0.374 | 0.408 | 0.328 | 0.320 | 0.334 | 0.337 | 0.411 | 0.467 |
| % Ret. Pen | 59.6 | 65.5 | 81.8 | 79.5 | 76.9 | 82.8 | 81.3 | 63.3 | 69.2 |
| Kin Vis @ 135°C | 432 | 462 | 619 | 637 | 644 | 650 | 685 | 700 | 733 |
| Pen @ 25°C | 93 | 74 | 65 | 58 | 55 | 53 | 49 | 38 | 36 |
| @ 10°C | 26 | 18 | 16 | 13 | 13 | 10 | 9 | 8 | 8 |
| @ 4°C | 14 | 6 | 8 | 7 | 6 | 5 | 4 | 3 | 3 |
| PVN | -0.19 | -0.35 | -0.07 | -0.16 | -0.20 | -0.23 | -0.24 | -0.46 | -0.45 |
| Abs Vis @ 60°C | 2181 | 2972 | 5948 | 6289 | 6195 | 6877 | 7833 | 8156 | 10142 |
| Soft. Pt. R&B°C | 47.8 | 51.4 | 52.2 | 53.1 | 53.3 | 53.9 | 55.0 | 55.3 | 56.4 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.90 | 5.21 | 5.25 | 5.23 | 5.38 | 5.07 | 5.39 | 5.01 | 4.93 |
| Kin Vis @ 135°C | 327 | 377 | 411 | 474 | 506 | 515 | 518 | 525 | 564 |
| Pen @ 25°C | 131 | 103 | 89 | 79 | 74.5 | 69 | 68 | 61 | 54 |
| @ 10°C | 29 | 21 | 19 | 14 | 13 | 13 | 13 | 14 | 12 |
| @ 4°C | 16 | 12 | 11 | 9 | 7 | 6 | 6 | 8 | 6 |
| PVN | -0.21 | -0.28 | -0.32 | -0.24 | -0.21 | -0.27 | -0.28 | -0.37 | -0.39 |
| Abs Vis @ 60°C | 1599 | 2094 | 2375 | 2769 | 3080 | 3382 | 3216 | 4380 | 5167 |
| Soft. Pt. R&B°C | 43.1 | 45.0 | 46.4 | 47.8 | 48.3 | 49.3 | 49.2 | 50.3 | 51.4 |

TABLE 8

ASPHALT BLENDING
200/300 - 22 PEN

| GRADE | 200/300 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 207 | 245 | 285 | 314 | 303 | 379 | 418 | 440 | 488 |
| Pen @ 25°C | 275 | 167 | 149 | 130 | 117 | 94 | 83 | 78 | 68 |
| @ 10°C | 67 | 32 | 25 | 23 | 26 | 21 | 17 | 15 | 14 |
| @ 4°C | 33 | 25 | 19 | 17 | 13 | 10 | 8 | 7 | 7 |
| PVN | -0.01 | -0.38 | -0.27 | -0.29 | -0.47 | -0.38 | -0.37 | -0.36 | -0.36 |
| Abs Vis @ 60°C | 478 | 924 | 1098 | 1302 | 1438 | 2208 | 2585 | 2809 | 3838 |
| Soft.Pt. R&B°C | 39.7 | 37.5 | 38.9 | 40.6 | 43.6 | 45.6 | 46.1 | 47.5 | 48.9 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.342 | 0.386 | 0.463 | 0.370 | 0.399 | 0.621 | 0.417 | 0.358 | 0.350 |
| % Ret. Pen | 57.5 | 56.9 | 61.7 | 66.2 | 70.9 | 68.1 | 71.1 | 70.5 | 70.6 |
| Kin Vis @ 135°C | 304 | 342 | 394 | 408 | 409 | 554 | 560 | 587 | 670 |
| Pen @ 25°C | 158 | 95 | 92 | 86 | 83 | 64 | 59 | 55 | 48 |
| @ 10°C | 50 | 23 | 20 | 18 | 20 | 18 | 15 | 13 | 13 |
| @ 4°C | 27 | 13 | 10 | 8 | 9 | 8 | 7 | 7 | 6 |
| PVN | -0.09 | -0.52 | -0.34 | -0.37 | -0.40 | -0.25 | -0.31 | -0.33 | -0.29 |
| Abs Vis @ 60°C | 1052 | 1662 | 2182 | 2476 | 2452 | 4286 | 4853 | 5489 | 7383 |
| Soft. Pt. R&B°C | 41.7 | 43.3 | 44.4 | 45.6 | 46.1 | 51.1 | 52.2 | 53.1 | 54.2 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.81 | 5.15 | 5.19 | 4.88 | 5.25 | 5.07 | 5.47 | 5.21 | 5.32 |
| Kin Vis @ 135°C | 228 | 291 | 303 | 341 | 342 | 382 | 389 | 414 | 447 |
| Pen @ 25°C | 214 | 152 | 136 | 116 | 114 | 95 | 90 | 84 | 79 |
| @ 10°C | 41 | 31 | 28 | 24 | 23 | 21 | 18 | 16 | 14 |
| @ 4°C | 24 | 17 | 16 | 14 | 14 | 10 | 8 | 7 | 7 |
| PVN | -0.18 | -0.21 | -0.29 | -0.29 | -0.31 | -0.35 | -0.39 | -0.37 | -0.38 |
| Abs Vis @ 60°C | 708 | 1020 | 1039 | 1586 | 1778 | 1952 | 2034 | 2040 | 2925 |
| Soft. Pt. R&B°C | 38.9 | 40.8 | 42.5 | 43.1 | 44.4 | 45.6 | 46.7 | 48.6 | 50.3 |

TABLE 9

ASPHALT BLENDING
300/400 - 22 PEN

| GRADE | 300/400 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 175 | 208 | 219 | 252 | 282 | 310 | 351 | 377 | 414 |
| Pen @ 25°C | 335 | 209 | 200 | 150 | 133 | 118 | 108 | 98 | 82 |
| @ 10°C | 90 | 38 | 39 | 31 | 28 | 25 | 25 | 22 | 17 |
| @ 4°C | 41 | 22 | 23 | 17 | 15 | 13 | 14 | 12 | 9 |
| PVN | -0.01 | -0.38 | -0.34 | -0.47 | -0.43 | -0.43 | -0.33 | -0.34 | -0.40 |
| Abs Vis @ 60°C | 265 | 648 | 701 | 1009 | 1235 | 1477 | 1737 | 2067 | 2635 |
| Soft.Pt. R&B°C | 35.0 | 36.9 | 38.3 | 39.4 | 40.6 | 42.2 | 44.4 | 45.8 | 47.2 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.817 | 0.694 | 0.647 | 0.617 | 0.629 | 0.599 | 0.612 | 0.518 | 0.457 |
| % Ret. Pen | 49.6 | 60.3 | 64.0 | 66.7 | 67.7 | 66.1 | 74.1 | 69.4 | 74.4 |
| Kin Vis @ 135°C | 301 | 302 | 321 | 375 | 400 | 448 | 446 | 496 | 552 |
| Pen @ 25°C | 166 | 126 | 128 | 100 | 90 | 78 | 80 | 68 | 61 |
| @ 10°C | 42 | 32 | 30 | 24 | 23 | 21 | 19 | 18 | 17 |
| @ 4°C | 20 | 14 | 15 | 12 | 11 | 11 | 9 | 9 | 9 |
| PVN | -0.05 | -0.39 | -0.27 | -0.32 | -0.34 | -0.34 | -0.31 | -0.34 | -0.30 |
| Abs Vis @ 60°C | 805 | 1352 | 1378 | 2169 | 2266 | 2953 | 2727 | 3911 | 5003 |
| Soft. Pt. R&B°C | 40.0 | 41.4 | 43.9 | 46.1 | 46.9 | 47.8 | 50.0 | 50.8 | 51.7 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.76 | 5.18 | 5.34 | 5.05 | 5.18 | 5.10 | 5.40 | 5.22 | 5.25 |
| Kin Vis @ 135°C | 206 | 246 | 259 | 270 | 305 | 344 | 359 | 377 | 423 |
| Pen @ 25°C | 266 | 188 | 169 | 150 | 139 | 113 | 109 | 97 | 85 |
| @ 10°C | 54 | 38 | 34 | 30 | 27 | 23 | 25 | 22 | 17 |
| @ 4°C | 29 | 20 | 17 | 15 | 13 | 11 | 14 | 12 | 9 |
| PVN | -0.05 | -0.21 | -0.29 | -0.29 | -0.31 | -0.35 | -0.39 | -0.35 | -0.32 |
| Abs Vis @ 60°C | 523 | 685 | 911 | 930 | 1083 | 1411 | 1737 | 2067 | 2635 |
| Soft. Pt. R&B°C | 35.6 | 38.6 | 40.3 | 40.6 | 43.1 | 44.7 | 45.0 | 45.8 | 47.2 |

TABLE 10

ASPHALT BLENDING
500+ - 22 PEN

| GRADE | 500+ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 116 | 160 | 175 | 194 | 218 | 236 | 270 | 305 | 341 |
| Pen @ 25°C | 537 | 356 | 297 | 239 | 198 | 177 | 143 | 114 | 96 |
| @ 10°C | 103 | 65 | 58 | 48 | 40 | 34 | 30 | 22 | 18 |
| @ 4°C | 56 | 37 | 32 | 27 | 17 | 19 | 14 | 14 | 13 |
| PVN | 0.00 | -0.10 | -0.20 | -0.32 | -0.37 | -0.37 | -0.42 | -0.49 | -0.51 |
| Abs Vis @ 60°C | 177 | 313 | 385 | 494 | 667 | 778 | 790 | 1416 | 1795 |
| Soft.Pt. R&B°C | 29.6 | 32.2 | 33.9 | 36.9 | 39.2 | 40.6 | 42.5 | 44.7 | 46.4 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.667 | 0.743 | 0.629 | 0.719 | 0.607 | 0.592 | 0.588 | 0.581 | 0.597 |
| % Ret. Pen | 57.9 | 57.0 | 61.9 | 63.2 | 65.2 | 65.0 | 69.9 | 72.8 | 68.9 |
| Kin Vis @ 135°C | 167 | 219 | 227 | 280 | 293 | 329 | 346 | 417 | 460 |
| Pen @ 25°C | 311 | 203 | 184 | 151 | 129 | 115 | 100 | 83 | 66 |
| @ 10°C | 69 | 43 | 37 | 35 | 25 | 28 | 25 | 18 | 16 |
| @ 4°C | 37 | 23 | 20 | 17 | 15 | 14 | 14 | 8 | 8 |
| PVN | -0.22 | -0.32 | -0.39 | -0.29 | -0.41 | -0.36 | -0.44 | -0.37 | -0.48 |
| Abs Vis @ 60°C | 396 | 685 | 782 | 1050 | 1227 | 1510 | 1686 | 2676 | 3363 |
| Soft. Pt. R&B°C | 34.8 | 38.9 | 40.8 | 42.2 | 42.8 | 43.9 | 45.0 | 48.3 | 50.3 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.87 | 5.29 | 5.16 | 5.18 | 5.14 | 4.88 | 5.28 | 5.15 | 5.05 |
| Kin Vis @ 135°C | 136 | 171 | 175 | 209 | 211 | 235 | 259 | 288 | 291 |
| Pen @ 25°C | 455 | 308 | 290 | 238 | 227 | 194 | 166 | 137 | 126 |
| @ 10°C | 87 | 61 | 55 | 48 | 42 | 38 | 36 | 29 | 27 |
| @ 4°C | 44 | 30 | 27 | 24 | 22 | 20 | 16 | 13 | 11 |
| PVN | -0.03 | -0.19 | -0.24 | -0.19 | -0.27 | -0.26 | -0.30 | -0.36 | -0.45 |
| Abs Vis @ 60°C | 235 | 357 | 396 | 514 | 533 | 689 | 932 | 1033 | 1186 |
| Soft. Pt. R&B°C | 29.4 | 32.5 | 35.8 | 36.9 | 37.5 | 39.2 | 41.4 | 42.8 | 43.6 |

TABLE 11

ASPHALT BLENDING
85/100 - 37 PEN

| GRADE | 85/100 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 423 | | 414 | | 424 | | 463 | | |
| Pen @ 25°C | 88 | | 76 | | 68 | | 61 | | |
| @ 10°C | 19 | | 17 | | 15 | | 14 | | |
| @ 4°C | 10 | | 8 | | 7 | | 7 | | |
| PVN | -0.28 | | -0.50 | | -0.56 | | -0.55 | | |
| Soft.Pt. R&B°C | 44.2 | | 48.1 | | 50.0 | | 50.8 | | |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.166 | | 0.223 | | 0.241 | | 0.253 | | |
| % Ret. Pen | 62.5 | | 71.1 | | 70.6 | | 72.1 | | |
| Kin Vis @ 135°C | 599 | | 506 | | 634 | | 630 | | |
| Pen @ 25°C | 55 | | 54 | | 48 | | 44 | | |
| @ 10°C | 12 | | 12 | | 12 | | 14 | | |
| @ 4°C | 6 | | 4 | | 4 | | 5 | | |
| PVN | -0.30 | | -0.55 | | -0.36 | | -0.46 | | |
| Soft. Pt. R&B°C | 52.2 | | 49.4 | | 52.8 | | 53.9 | | |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (Target) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (Extracted) | 5.78 | 5.18 | 5.36 | 5.20 | 5.32 | 5.16 | 5.48 | 5.24 | 5.38 |
| Kin Vis @ 135°C | 482 | 513 | 500 | 536 | 547 | 551 | 570 | 560 | 575 |
| Pen @ 25°C | 70 | 66 | 63 | 58 | 56 | 55 | 53 | 51 | 49 |
| PVN | -0.36 | -0.32 | -0.41 | -0.40 | -0.41 | -0.41 | -0.47 | -0.47 | -0.49 |

TABLE 12

ASPHALT BLENDING
120/150 - 37 PEN

| GRADE | 120/150 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 325 | | 337 | | 380 | | 409 | | |
| Pen @ 25°C | 123 | | 91 | | 82 | | 72 | | |
| @ 10°C | 31 | | 19 | | 17 | | 16 | | |
| @ 4°C | 16 | | 12 | | 9 | | 8 | | |
| PVN | -0.30 | | -0.59 | | -0.52 | | -0.56 | | |
| Soft.Pt. R&B°C | 39.2 | | 45.8 | | 48.3 | | 48.9 | | |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.235 | | 0.258 | | 0.284 | | 0.335 | | |
| % Ret. Pen | 61.8 | | 74.7 | | 75.6 | | 77.8 | | |
| Kin Vis @ 135°C | 505 | | 484 | | 517 | | 571 | | |
| Pen @ 25°C | 76 | | 68 | | 62 | | 56 | | |
| @ 10°C | 16 | | 14 | | 16 | | 17 | | |
| @ 4°C | 10 | | 8 | | 6 | | 5 | | |
| PVN | -0.19 | | -0.37 | | -0.38 | | -0.35 | | |
| Soft. Pt. R&B°C | 49.4 | | 48.9 | | 50.8 | | 53.6 | | |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.83 | 5.32 | 5.37 | 5.05 | 5.17 | 5.11 | 5.41 | 5.26 | 5.36 |
| Kin Vis @ 135°C | 379 | 398 | 417 | 421 | 450 | 470 | 494 | 509 | 516 |
| Pen @ 25°C | 103 | 87.5 | 82.5 | 79 | 75 | 68 | 67 | 63.5 | 58.5 |
| PVN | -0.27 | -0.38 | -0.38 | -0.41 | -0.37 | -0.42 | -0.36 | -0.37 | -0.44 |

TABLE 13

ASPHALT BLENDING
150/200 - 37 PEN

| GRADE | 150/200 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 285 | | | 318 | | 371 | | 371 | |
| Pen @ 25°C | 156 | | | 110 | | 92 | | 85 | |
| @ 10°C | 37 | | | 22 | | 20 | | 16 | |
| @ 4°C | 18 | | | 15 | | 12 | | 10 | |
| PVN | -0.22 | | | -0.47 | | -0.43 | | -0.52 | |
| Soft.Pt. R&B°C | 41.9 | | | 43.3 | | 45.6 | | 47.8 | |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.205 | | | 0.395 | | 0.421 | | 0.378 | |
| % Ret. Pen | 59.6 | | | 67.3 | | 70.7 | | 68.2 | |
| Kin Vis @ 135°C | 432 | | | 463 | | 512 | | 536 | |
| Pen @ 25°C | 93 | | | 74 | | 65 | | 58 | |
| @ 10°C | 26 | | | 19 | | 16 | | 15 | |
| @ 4°C | 14 | | | 5 | | 7 | | 9 | |
| PVN | -0.19 | | | -0.35 | | -0.34 | | -0.40 | |
| Soft. Pt. R&B°C | 47.8 | | | 48.3 | | 50.7 | | 51.7 | |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.84 | 5.07 | 5.21 | 5.07 | 5.20 | 5.16 | 5.40 | 5.22 | 5.38 |
| Kin Vis @ 135°C | 327 | 340 | 375 | 364 | 398 | 428 | 415 | 430 | 483 |
| Pen @ 25°C | 131 | 109 | 97 | 94 | 85.5 | 78 | 78.5 | 73.5 | 67.5 |
| PVN | -0.21 | -0.35 | -0.35 | -0.44 | -0.41 | -0.40 | -0.44 | -0.46 | -0.38 |

TABLE 14

ASPHALT BLENDING
200/300 - 37 PEN

| GRADE | 200/300 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 207 | | | 238 | | 295 | | 304 | |
| Pen @ 25°C | 275 | | | 156 | | 120 | | 99 | |
| @ 10°C | 67 | | | 29 | | 26 | | 21 | |
| @ 4°C | 33 | | | 17 | | 14 | | 11 | |
| PVN | -0.01 | | | -0.52 | | -0.48 | | -0.65 | |
| Soft.Pt. R&B°C | 39.7 | | | 42.8 | | 46.4 | | 46.7 | |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.342 | | | 0.445 | | 0.406 | | 0.386 | |
| % Ret. Pen | 57.5 | | | 65.4 | | 68.3 | | 73.7 | |
| Kin Vis @ 135°C | 304 | | | 270 | | 320 | | 367 | |
| Pen @ 25°C | 158 | | | 102 | | 82 | | 73 | |
| @ 10°C | 50 | | | 23 | | 19 | | 17 | |
| @ 4°C | 27 | | | 10 | | 10 | | 8 | |
| PVN | -0.09 | | | -0.80 | | -0.78 | | -0.70 | |
| Soft. Pt. R&B°C | 41.7 | | | 45.0 | | 46.9 | | 48.1 | |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.73 | 5.35 | 5.03 | 5.18 | 5.11 | 5.08 | 5.53 | 5.16 | 5.37 |
| Kin Vis @ 135°C | 228 | 272 | 267 | 291 | 293 | 305 | 313 | 333 | 340 |
| Pen @ 25°C | 214 | 153 | 146.5 | 136 | 130.5 | 111.5 | 104.5 | 102 | 96.5 |
| PVN | -0.18 | -0.32 | -0.40 | -0.35 | -0.39 | -0.52 | -0.55 | -0.48 | -0.51 |

TABLE 15

ASPHALT BLENDING
300/400 - 37 PEN

| GRADE | | | | 300/400 | | | | |
|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 175 | | | | 218 | | 262 | | 287 |
| Pen @ 25°C | 335 | | | | 180 | | 144 | | 115 |
| @ 10°C | 90 | | | | 36 | | 30 | | 24 |
| @ 4°C | 41 | | | | 18 | | 15 | | 11 |
| PVN | -0.01 | | | | -0.50 | | -0.46 | | -0.58 |
| Soft.Pt. R&B°C | 35.0 | | | | 38.6 | | 41.7 | | 43.3 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.817 | | | | 0.445 | | 0.441 | | 0.396 |
| % Ret. Pen | 49.6 | | | | 66.7 | | 66.7 | | 73.0 |
| Kin Vis @ 135°C | 301 | | | | 312 | | 347 | | 501 |
| Pen @ 25°C | 166 | | | | 120 | | 96 | | 84 |
| @ 10°C | 42 | | | | 26 | | 23 | | 20 |
| @ 4°C | 20 | | | | 11 | | 12 | | 12 |
| PVN | -0.05 | | | | -0.39 | | -0.49 | | -0.09 |
| Soft. Pt. R&B°C | 40.0 | | | | 45.3 | | 46.1 | | 46.9 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.71 | 5.23 | 5.29 | 5.15 | 5.23 | 5.15 | 5.44 | 5.09 | 5.24 |
| Kin Vis @ 135°C | 206 | 220 | 231 | 237 | 261 | 272 | 285 | 317 | 356 |
| Pen @ 25°C | 266 | 211 | 194.5 | 177.5 | 158 | 139.5 | 138 | 114 | 97.5 |
| PVN | -0.05 | -0.26 | -0.29 | -0.36 | -0.35 | -0.43 | -0.37 | -0.43 | -0.43 |

TABLE 16

ASPHALT BLENDING
500+ - 37 PEN

| GRADE | | | | 500+ | | | | |
|---|---|---|---|---|---|---|---|---|
| % RECYCLE | 0 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| TESTS | | | | | | | | | |
| Kin Vis @ 135°C | 116 | | | | 174 | | 207 | | 237 |
| Pen @ 25°C | 537 | | | | 236 | | 180 | | 141 |
| @ 10°C | 103 | | | | 43 | | 34 | | 28 |
| @ 4°C | 56 | | | | 23 | | 19 | | 14 |
| PVN | 0.00 | | | | -0.54 | | -0.58 | | -0.65 |
| Soft.Pt. R&B°C | 29.6 | | | | 35.6 | | 38.9 | | 41.9 |
| TFOT | | | | | | | | | |
| % Loss by Wt. | 0.667 | | | | 0.610 | | 0.660 | | 0.498 |
| % Ret. Pen | 57.9 | | | | 65.7 | | 66.7 | | 70.9 |
| Kin Vis @ 135°C | 167 | | | | 249 | | 278 | | 319 |
| Pen @ 25°C | 311 | | | | 155 | | 120 | | 100 |
| @ 10°C | 69 | | | | 32 | | 27 | | 22 |
| @ 4°C | 37 | | | | 18 | | 14 | | 11 |
| PVN | -0.22 | | | | -0.45 | | -0.58 | | -0.57 |
| Soft. Pt. R&B°C | 34.8 | | | | 40.0 | | 43.1 | | 47.8 |
| DATA ON ABSON RECOVERED AC | | | | | | | | | |
| % AC (TARGET) | 6.0 | 5.3 | 5.3 | 5.2 | 5.3 | 5.1 | 5.4 | 5.2 | 5.2 |
| % AC (EXTRACTED) | 5.75 | 5.38 | 5.18 | 5.16 | 5.32 | 5.13 | 5.39 | 5.14 | 5.25 |
| Kin Vis @ 135°C | 136 | 163 | 164 | 181 | 183 | 206 | 214 | 217 | 266 |
| Pen @ 25°C | 455 | 316 | 291 | 263 | 242 | 188 | 164 | 160 | 124 |
| PVN | -0.03 | -0.25 | -0.36 | -0.31 | -0.41 | -0.53 | -0.64 | -0.64 | -0.61 |

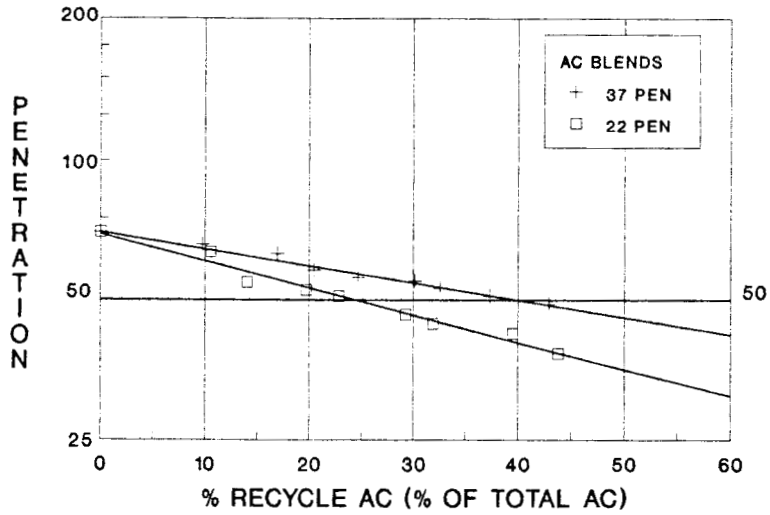


FIGURE 1 EFFECT OF THE PROPORTION OF AGED ASPHALT CEMENT (AC) ON THE PENETRATION OF THE MIX AC AFTER RECYCLING WITH 85/100 AC

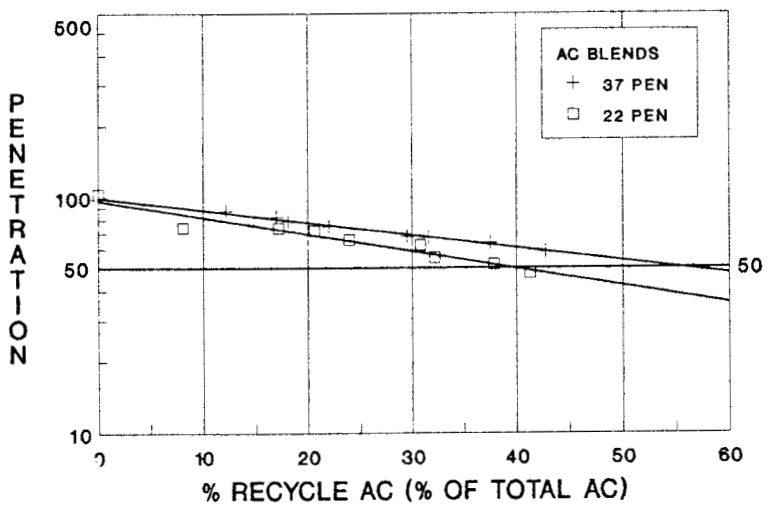


FIGURE 2 EFFECT OF THE PROPORTION OF AGED ASPHALT CEMENT (AC) ON THE PENETRATION OF THE MIX AC AFTER RECYCLING WITH 120/150 AC

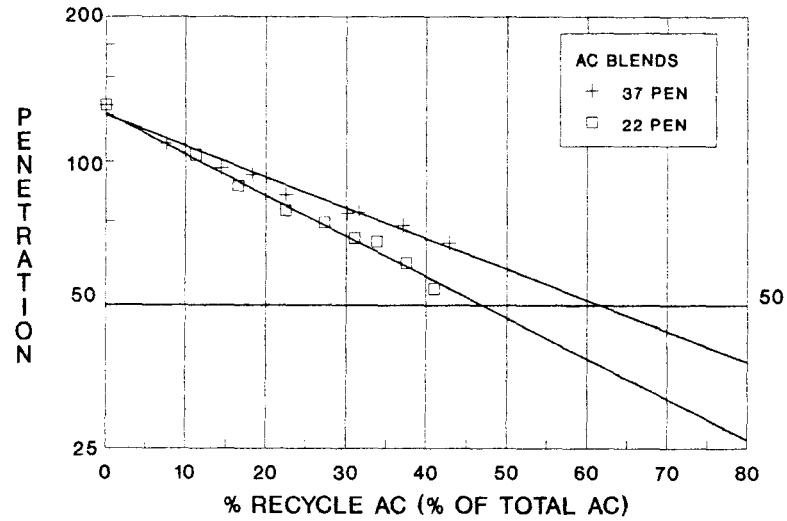


FIGURE 3 EFFECT OF THE PROPORTION OF AGED ASPHALT CEMENT (AC) ON THE PENETRATION OF THE MIX AC AFTER RECYCLING WITH 150/200 AC

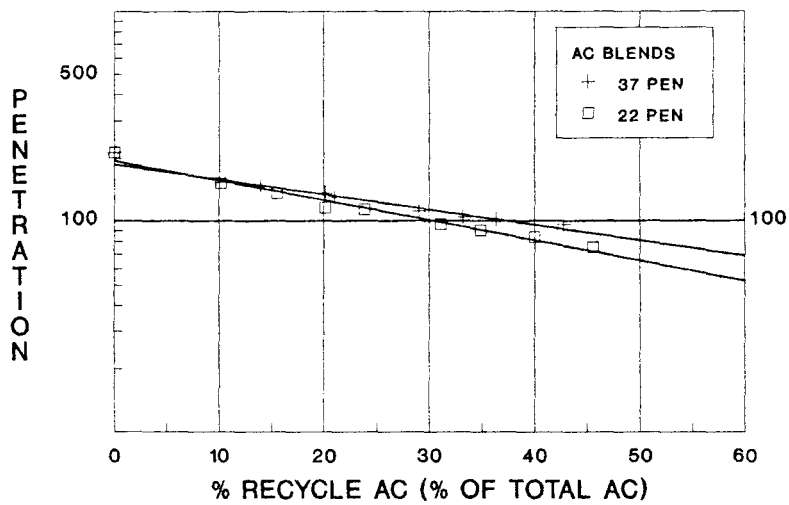


FIGURE 4 EFFECT OF THE PROPORTION OF AGED ASPHALT CEMENT (AC) ON THE PENETRATION OF THE MIX AC AFTER RECYCLING WITH 200/300 AC

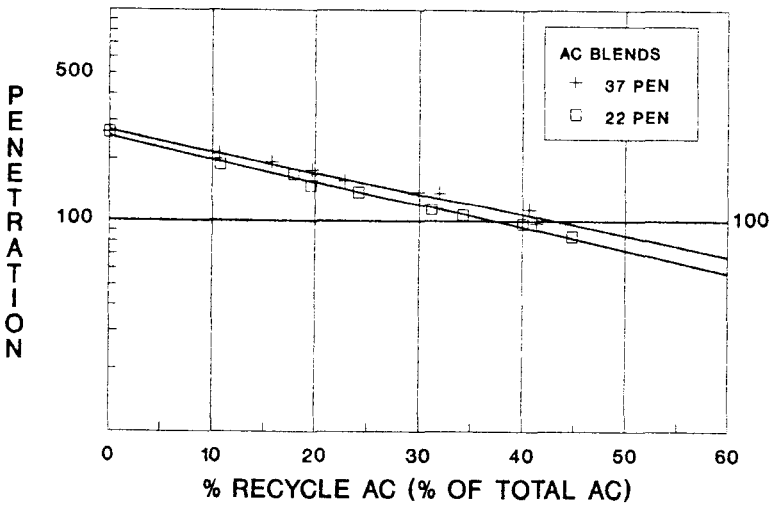


FIGURE 5 EFFECT OF THE PROPORTION OF AGED ASPHALT CEMENT (AC) ON THE PENETRATION OF THE MIX AC AFTER RECYCLING WITH 300/400 AC

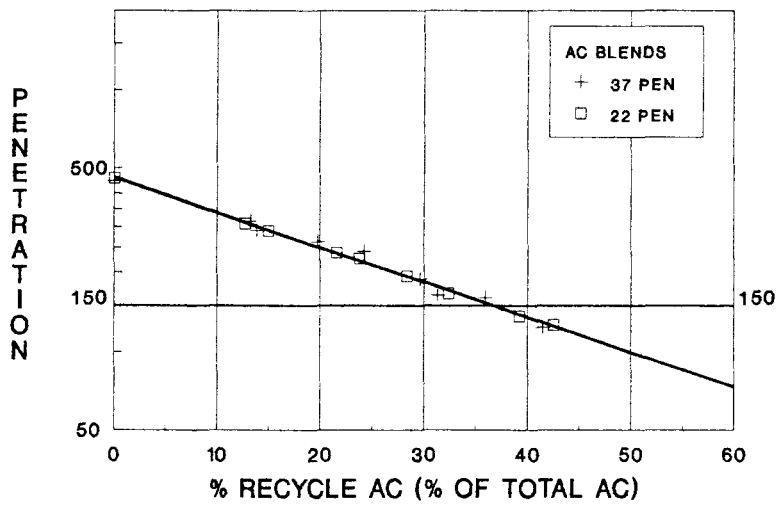


FIGURE 6 EFFECT OF THE PROPORTION OF AGED ASPHALT CEMENT (AC) ON THE PENETRATION OF THE MIX AC AFTER RECYCLING WITH 500+ AC

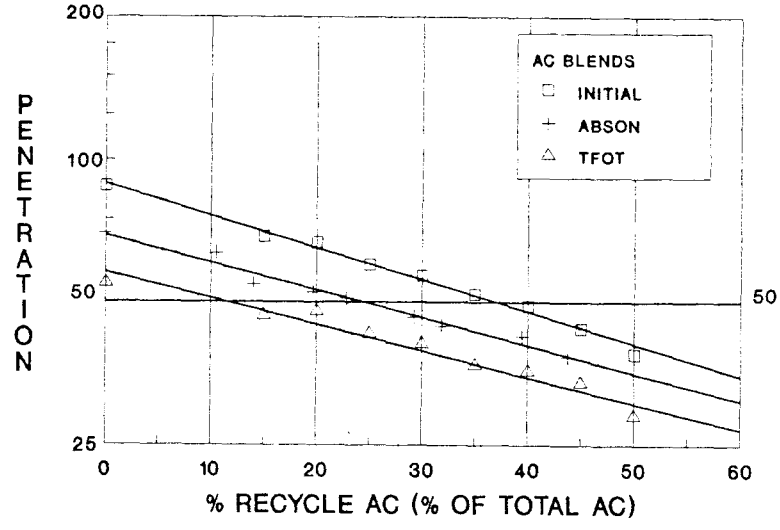


FIGURE 7 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (22 PEN AGED ASPHALT CEMENT AND 85/100 AC)

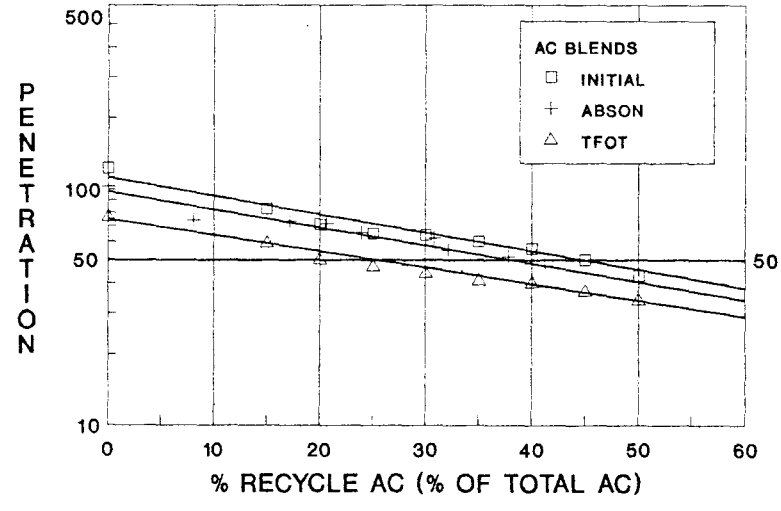


FIGURE 8 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (22 PEN AGED ASPHALT CEMENT AND 120/150 AC)

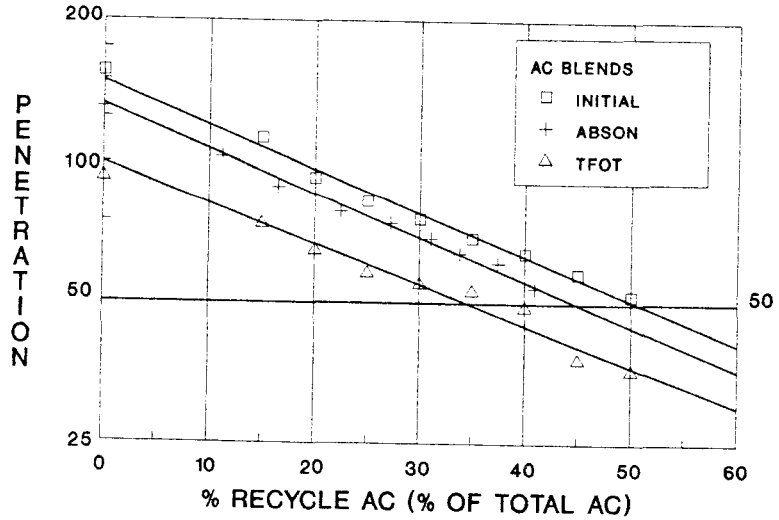


FIGURE 9 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (22 PEN AGED ASPHALT CEMENT AND 150/200 AC)

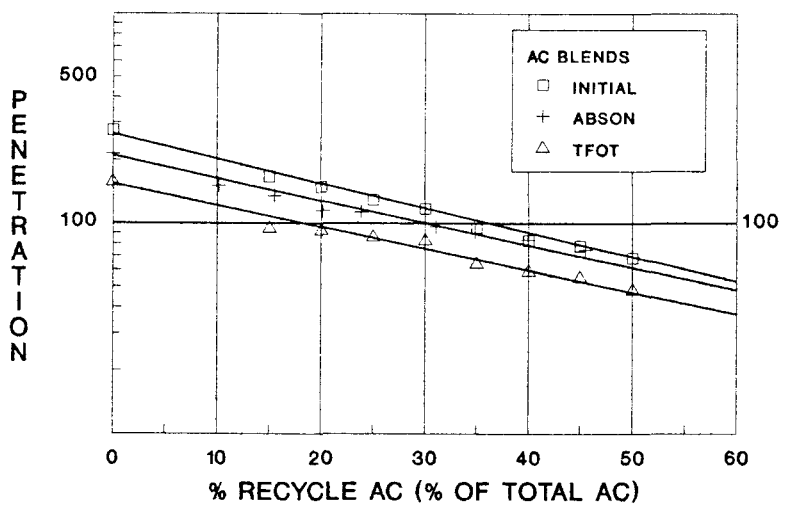


FIGURE 10 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (22 PEN AGED ASPHALT CEMENT AND 200/300 AC)

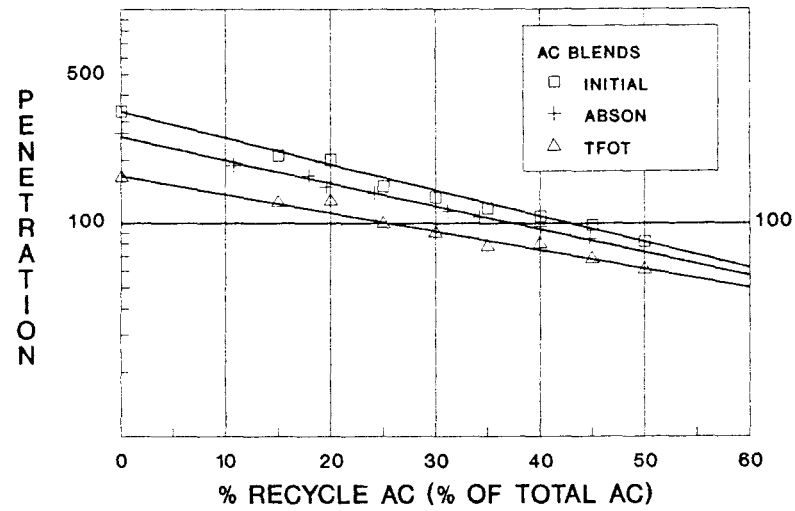


FIGURE 11 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (22 PEN AGED ASPHALT CEMENT AND 300/400 AC)

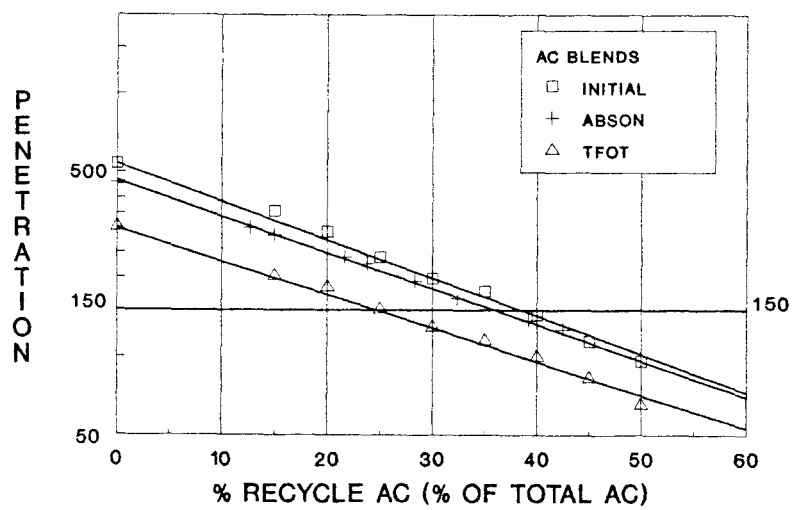


FIGURE 12 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (22 PEN AGED ASPHALT CEMENT AND 500+ AC)

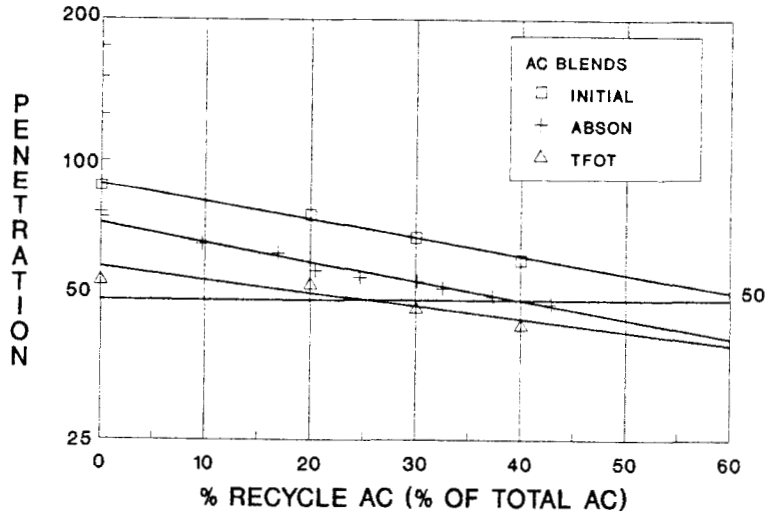


FIGURE 13 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (37 PEN AGED ASPHALT CEMENT AND 85/100 AC)

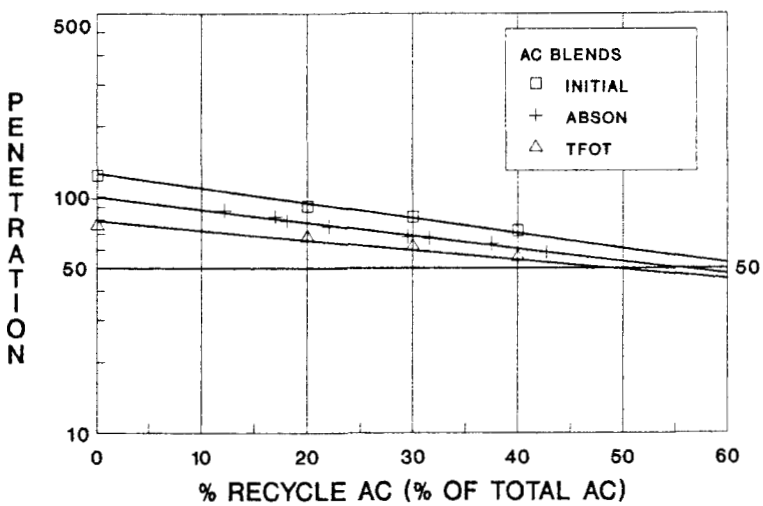


FIGURE 14 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (37 PEN AGED ASPHALT CEMENT AND 120/150 AC)

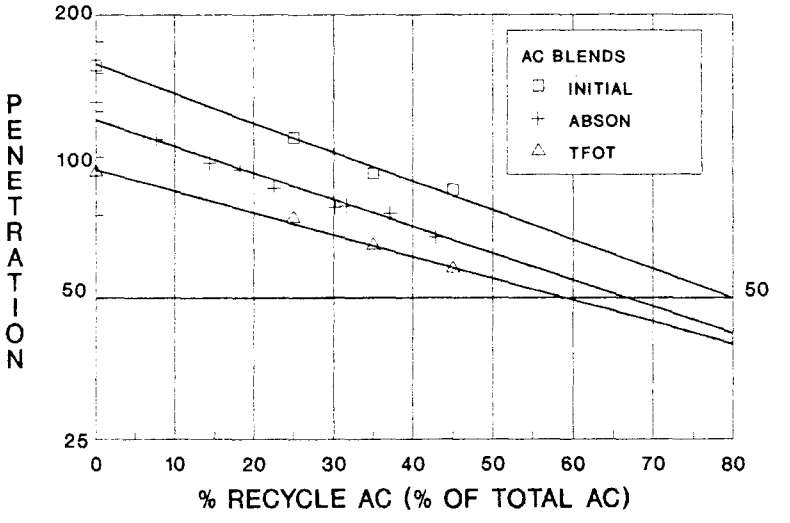


FIGURE 15 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (37 PEN AGED ASPHALT CEMENT AND 150/200 AC)

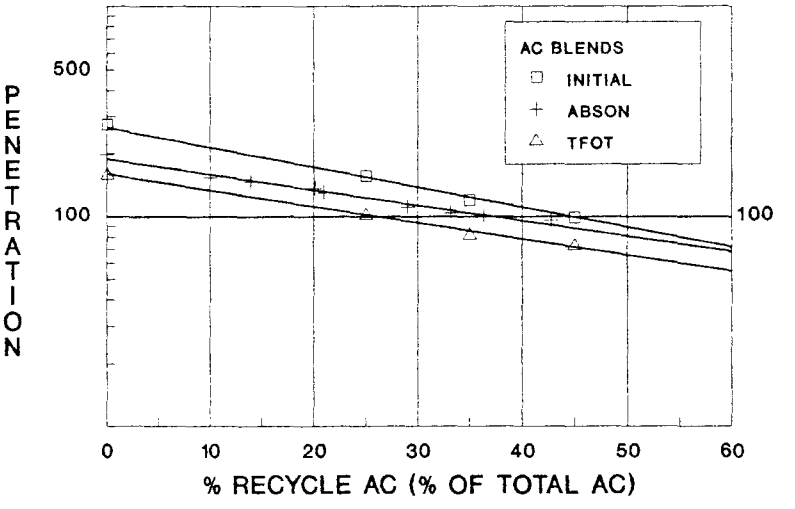


FIGURE 16 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (37 PEN AGED ASPHALT CEMENT AND 200/300 AC)

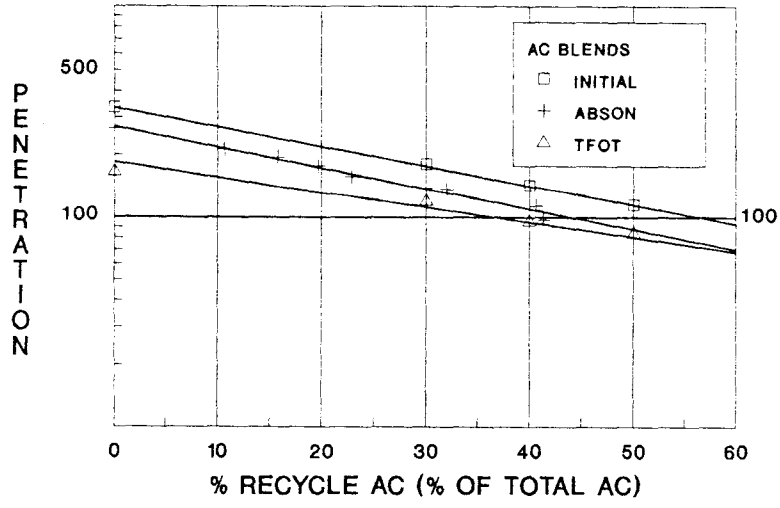


FIGURE 17 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (37 PEN AGED ASPHALT CEMENT AND 300/400 AC)

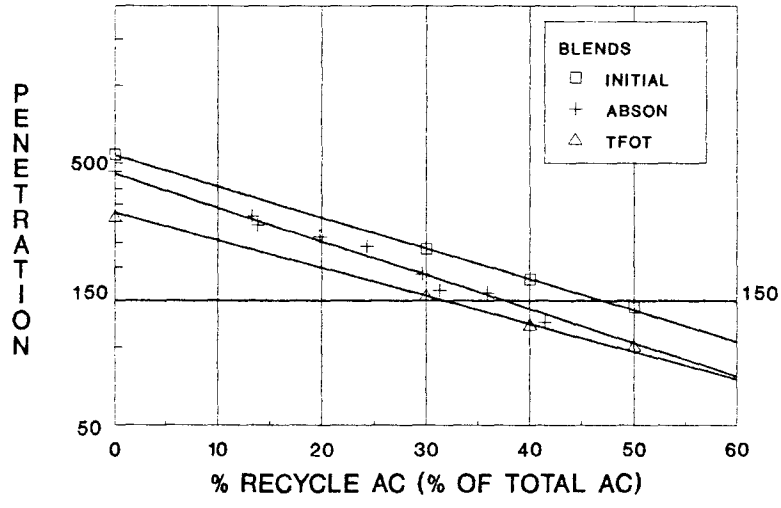


FIGURE 18 COMPARISON OF ASPHALT CEMENT BLENDS, BEFORE AND AFTER THIN FILM OVEN TEST (TFOT), WITH BINDERS EXTRACTED FROM RECYCLED MIXES (37 PEN AGED ASPHALT CEMENT AND 500+ AC)