# Evaluation of an Improved Rotavapor Aging Apparatus Using a Morton Flask for Simulation of Hot-Mixing on Modified Asphalts

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## ABSTRACT

A modified Rotavapor apparatus and method had been previously developed at the University of Florida for simulation of short-term aging of modified asphalts. Due to the great potential of this aging procedure, further refining of this procedure had been undertaken. This paper presents the evaluation of an improved Rotavapor aging apparatus using a Morton flask. It was observed that greater temperature uniformity was obtained in the oil bath when the Morton flask was used. The equivalent aging severity between the modified rotavapor aging process and the standard short-term aging methods (TFOT and RTFOT) was established.

## INTRODUCTION

Only two methods which simulated hot-mix plant aging of asphalt have been adopted as standard methods by ASTM and AASHTO. These are the Thin Film Oven Test [(TFOT), ASTM D1754, AASHTO T179 ] and the Rolling Thin Film Oven Test [(RTFOT), ASTM D 2872, AASHTO T240 ]. Both TFOT and the RTFOT processes are intended to simulate aging which occurs during hot mixing in a hot-mix plant operated at 150 °C. These two standard processes have been successfully used to age conventional asphalts for years. However, problems have been reported [1, 2, 3] with these two standard processes when modified asphalts are used.

Due to the increasing use of GTR-modified asphalts and potential use of other modified asphalts in Florida, it is necessary that a laboratory process be developed to replace TFOT or the RTFOT, so that the aging characteristics of these modified asphalts could be properly determined. To solve the problems with TFOT and RTFOT processes when modified asphalts are used, an alternative short-term aging method using a Rotavapor apparatus was developed to simulate hot-mix plant aging of modified asphalts at the University of Florida [4]. Further refining of the developed aging method was undertaken. This paper presents the evaluation of the aging characteristics of an improved Rotavapor aging apparatus using a Morton flask.

## BACKGROUND

Due to the shortcomings of the TFOT and the RTFOT processes with modified asphalts, studies were conducted by the researchers to develop alternative short-term aging procedures for modified asphalts. Bahia et al. [5] modified the RTFOT process to solve the problem of highly viscous asphalts. In this method, RTFOT was modified by using some steel rods inside the RTFOT bottles to spread the thin films uniformly. In a previous study at the University of Florida [4], rotavapor apparatus, which is commonly used for the recovery of asphalts from solutions and as an aging device in a German standard test (DIN 52016) for determining changes in mass and changes in the properties of asphalt due to heating, was modified to be used for simulating hot-mix plant aging of modified asphalts. The schematic representation of the modified rotavapor aging apparatus is shown in Figure 1. In the previous study, asphalt binder was aged in a standard distillation flask. However, it was observed that there were some advantages of using a Morton flask in place of the standard distillation flask in the modified rotavapor aging process. The Morton flask has two advantages over the standard distillation flask, as follows:

1. It provides better agitation of thin films inside the flask.
2. It reduces the temperature variation by stirring the oil in the oil bath.

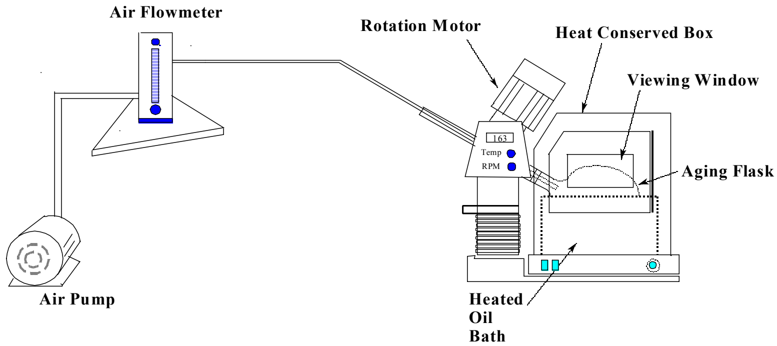


Figure 1 Schematic Representation of Modified Rotavapor Aging Apparatus

To evaluate the effects of the Morton flask on the temperature distribution within the oil bath of the modified rotavapor apparatus, a RTD thermal probe was used to measure temperature at different depths in the oil bath when the Morton flask was used. Similar measurements were also made when the standard distillation flask was used. The plot of temperature versus vertical distance from the surface of the oil bath for both conditions is shown in Figure 2. It can be seen that the temperature in the oil bath varied from 175 to 151 °C when Morton flask was used. When the standard distillation flask was used, the temperature varied from 175 to 144 °C. This clearly indicates that the use of Morton flask reduces the temperature variation within the oil bath.

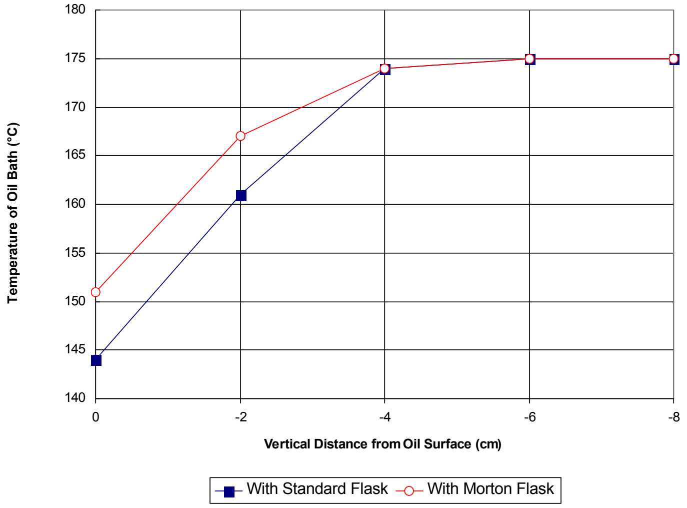


Figure 2 Plot of Temperature versus Vertical Distance from Surface of Oil Bath of Modified Rotavapor Aging Apparatus with Standard and Morton Flasks

## EXPERIMENTAL

A parametric experimental study was conducted to evaluate the aging effects of the modified rotavapor aging apparatus using a Morton flask. Test variables used in the parametric study were as follows:
Two asphalt binders – AC-30 and AC-30+12%GTR with a nominal size of No.80 sieve
Three sample weights – 125, 200 and 275 g
Two process temperatures – 163 and 176 °C
Five process durations – 110, 135, 160, 185 and 210 minutes
Rotating speed – 20 rpm
The flow of air – 4000 ml/min
Three samples per condition for the process temperature of 163 °C and only one sample per condition for the process temperature of 176 °C were tested. Samples were aged in the modified rotavapor aging process and compared with those subjected to TFOT and RTFOT processes.
The following tests were run on all aged asphalt residues:
Standard Penetration Test at 25 °C
Brookfield Viscosity Test at 60 °C
Dynamic Shear Rheometer Test at 25 and 64 °C
Mass change determination

## TEST RESULTS AND DISCUSSION

The comparison of the penetration values of asphalt residues after various rotavapor aging processes with those of the TFOT and RTFOT residues were plotted in Figure 3. For both conventional and modified asphalts, the modified rotavapor process at 163 °C for 160 minutes and using a sample weight of 200 g is closest to TFOT, while the modified rotavapor process at the test configuration of 163 °C, 210 minutes and 200 g is closest to RTFOT.

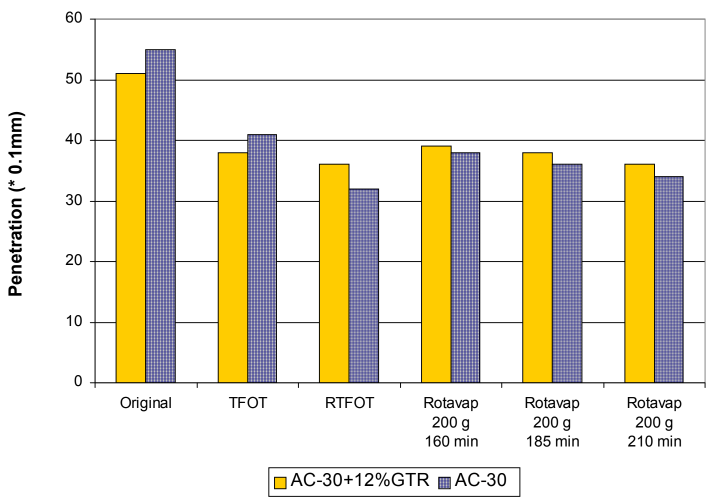


Figure 3 Comparison of penetration of asphalts after different aging processes

The comparison of the Brookfield viscosity of aged residues under various aging conditions are shown in Figure 4. On the basis of Brookfield viscosity at 60 °C, the modified rotavapor process at 163 °C for 160 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT process in aging severity for both conventional and modified asphalts.

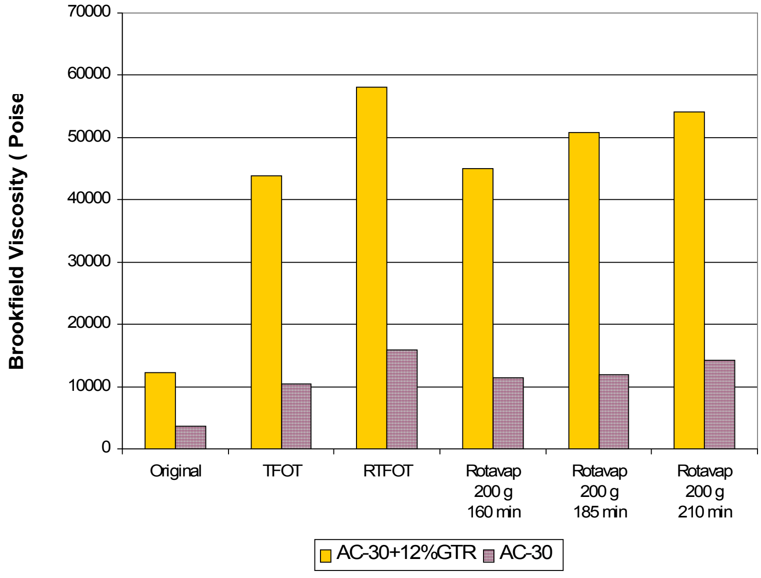


Figure 4 Comparison of Brookfield viscosity of asphalts after different aging processes

Figure 5 shows the dynamic shear modulus at 25 °C of aged residues after different aging processes. Based on G* at 25 °C, the modified rotavapor process at 163 °C, 160 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT process in aging severity for CR-modified asphalt. However, the modified rotavapor process at 163 °C, 185 minutes and 200 g is closest to TFOT and RTFOT for the conventional asphalt.

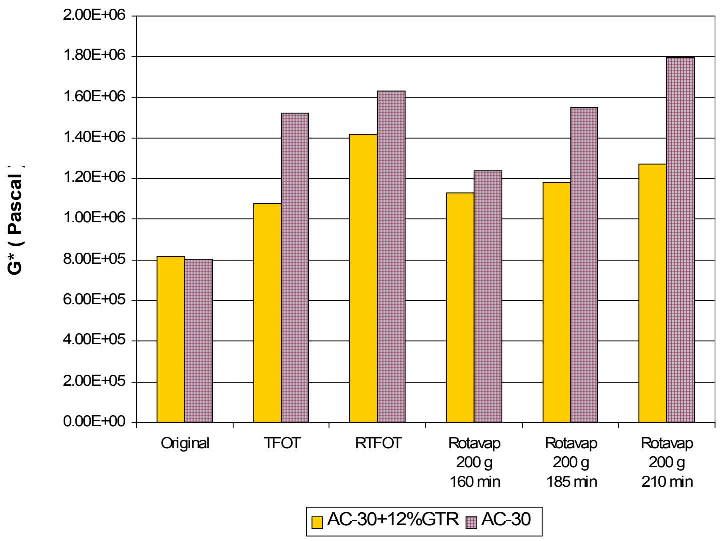


Figure 5 Comparison of dynamic modulus of asphalts at 10 rad/sec and 25 °C after different aging processes

The comparison of the δ values at 25 °C of the aged residues under different aging conditions are displayed in Figure 6. Based on δ values at 25 °C, the modified rotavapor process at 163 °C, 185 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT process in aging severity for the CR-modified asphalt. For the pure asphalts, the modified rotavapor process at 163 °C, 160 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT.

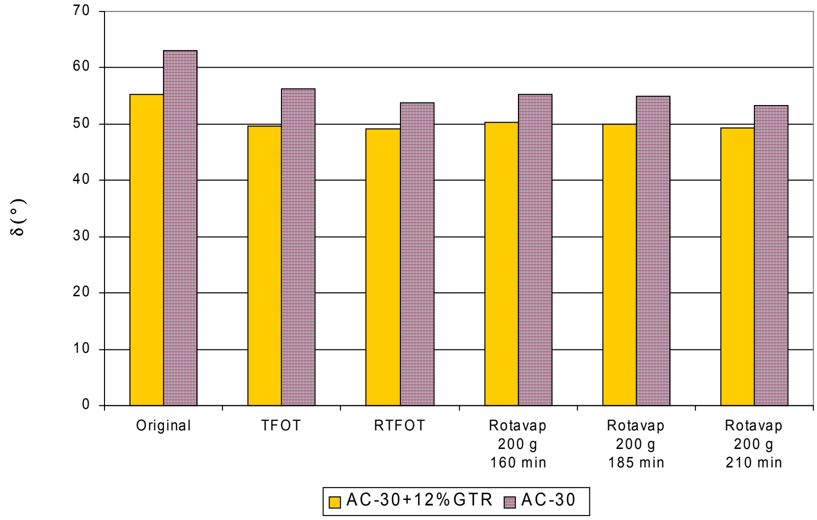


Figure 6 Comparison of phase angle (delta) of asphalts at 10 rad/sec and 25 °C after different aging processes

Figure 7 shows the comparison of G* values at 64 °C of the aged residues after different aging processes. It can be seen that the modified rotavapor process at 163 °C, 185 minutes and 200 g is closest to TFOT and RTFOT processes in aging severity for the CR-modified asphalts. For the conventional asphalts, the modified rotavapor process at 163 °C, 160 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT.

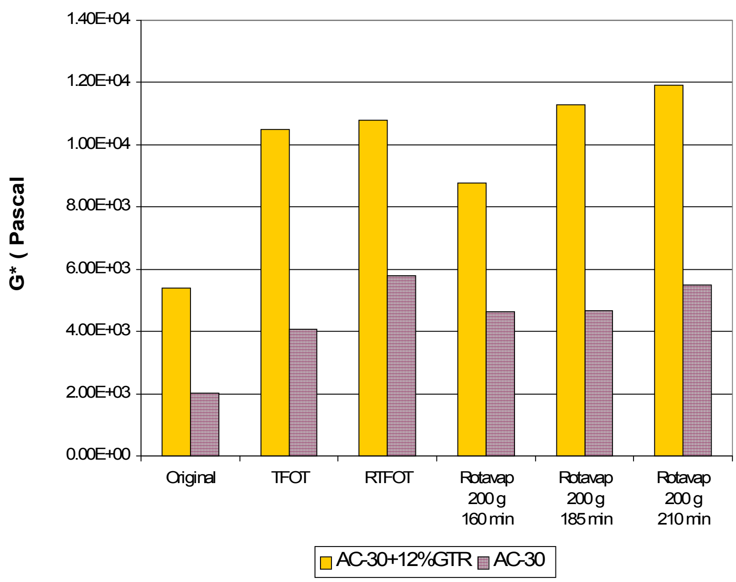


Figure 7 Comparison of dynamic modulus of asphalts at 10 rad/sec and 64 °C after different aging processes

Figure 8 displays the comparison of the δ values at 64 °C of the aged residues under different aging conditions. For the CR-modified asphalts, the modified rotavapor process at 163 °C, 135 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT. The modified rotavapor process at 163 °C, 160 minutes and 200 g is closest to TFOT, while the modified rotavapor process at 163 °C, 210 minutes and 200 g is closest to RTFOT for the conventional asphalts.

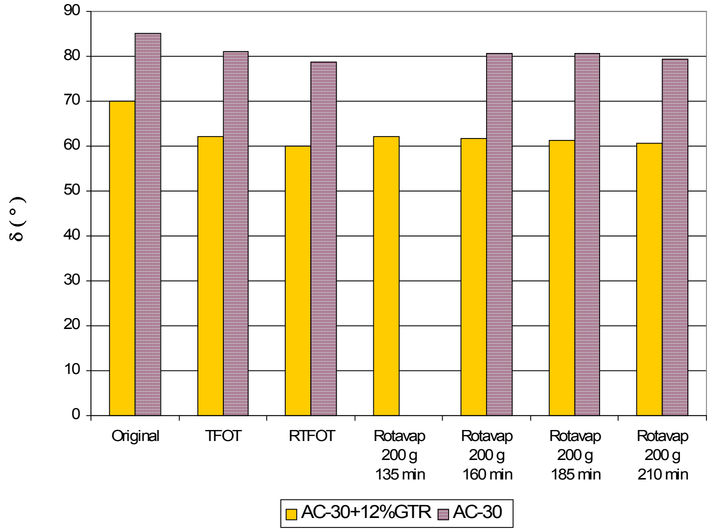


Figure 8 Comparison of phase angle (delta) of asphalts at 10 rad/sec and 64 °C after different aging processes

The average mass change of conventional and CR-modified asphalts after the modified process are compared with those of the TFOT and RTFOT residues in Figure 9. It can be seen that both conventional and CR-modified asphalt samples aged in the modified rotavapor aging process for 160, 185 and 210 minutes have experienced a mass loss very close to those aged in the TFOT and RTFOT processes. Figure 9 also shows that as the process duration increases in the modified rotavapor process, samples experience more mass loss. In other words, more volatiles are driven off as the process time increases.

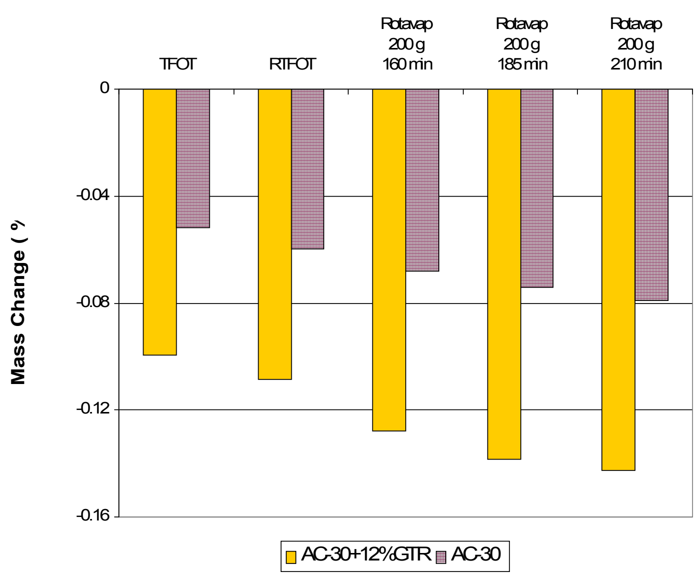


Figure 9 Mass change of residues after different aging processes

## STATISTICAL ANALYSIS

The Student t test was used to determine if the means of two sets of data were statistically different from one another. Brookfield viscosities of AC-30+12%GTR samples after the modified rotavapor process were compared with those of the TFOT and RTFOT processes. Table 1 displays the result of the t test performed on CR-modified residues. It can be seen that there is no statistical difference at $\alpha$ =0.05 level between CR-modified residues aged in the modified rotavapor process and those of TFOT. Also, no statistical difference was found at $\alpha$=0.05 level between CR-modified residues aged in the modified rotavapor process and those of RTFOT.

Table 1 T-test analysis of AC-30+12%GTR residues based on Brookfield viscosity values

| Brookfield Viscosity (Poise) | | | | | | |
|---|---|---|---|---|---|---|
| Rep. | Modified Rotavapor | TFOT | RTFOT | t | $t_{\alpha/2}$ | Comment |
| | | | | | $\alpha$=0.05 | |
| 1 | 45600 | 41507 | | | | |
| 2 | 41375 | 47695 | | | | |
| 3 | 47917 | 42315 | | 0.575 | 2.447 | No difference at $\alpha$=0.05 level |
| 4 | | 43869 | | | | |
| 5 | | 43704 | | | | |
| | | | | | | |
| Mean | 44964 | 43818 | | | | |
| S.D. | 3317 | 2379.4 | | | | |
| | | | | | | |
| 1 | 63613 | | 49395 | | | |
| 2 | 44218 | | 49299 | | | |
| 3 | 54361 | | 59240 | 0.614 | 2.447 | No difference at $\alpha$=0.05 level |
| 4 | | | 68706 | | | |
| 5 | | | 63936 | | | |
| | | | | | | |
| Mean | 54064 | | 58115 | | | |
| S.D. | 9700.9 | | 8675.8 | | | |

The results of the t test performed on pure asphalt residues are displayed in Table 2. Based on the Brookfield viscosities at 60 °C, there is no statistical difference at $\alpha$ =0.05 level between pure asphalt residues aged in the modified rotavapor process and those of TFOT. However, the results indicated that the mean values of pure asphalt residues aged in the modified rotavapor process and those of RTFOT were different at $\alpha$ =0.05 level. At $\alpha$ =0.01 level, there was no statistical difference.

Table 2 T-test analysis of AC-30 residues based on Brookfield viscosity values

| Brookfield Viscosity (Poise) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rep. | Modified Rotavapor | TFOT | RTFOT | t | $t_{\alpha/2}$ | $t_{\alpha/2}$ | Comment |
| | | | | | $\alpha$=0.05 | $\alpha$=0.01 | |
| 1 | 11131 | 9302 | | | | | |
| 2 | 11422 | 9160 | | 0.89 | 2.776 | | No difference at $\alpha$=0.05 level |
| 3 | 11713 | 12692 | | | | | |
| | | | | | | | |
| Mean | 11422 | 10385 | | | | | |
| S.D. | 291 | 1999.5 | | | | | |
| | | | | | | | |
| 1 | 14782 | | 15621 | | | | |
| 2 | 14773 | | 15780 | 2.868 | 2.776 | 4.604 | No difference at $\alpha$=0.01 level |
| 3 | 13162 | | 16123 | | | | |
| | | | | | | | |
| Mean | 14239 | | 15841 | | | | |
| S.D. | 932.7 | | 256.6 | | | | |

## CONCLUSIONS

Aging characteristics of an improved rotavapor aging apparatus using a Morton flask was evaluated in this study. The modified rotavapor aging process was improved by replacing the standard distillation flask with a morton flask in two ways:

1. Temperature variation in the oil bath was reduced
2. Thin films were agitated better inside the flask

Based on the Brookfield viscosity results at 60 °C of a parametric study, following conclusions were made.

For both conventional and CR-modified asphalts, the modified rotavapor aging process at 163 °C for 160 minutes and using a sample weight of 200 g is closest to TFOT process. The modified rotavapor aging process at 163 °C, 210 minutes and 200 g is closest to RTFOT process in aging severity for both conventional and CR-modified asphalts.
The modified rotavapor aging process appears to be an effective method for simulation of short-term aging of modified as well as conventional asphalts.

## REFERENCES

[1] Tia, M., Ruth, B.E., Chiu, C.T., Huang, S.C., Richardson, D., (1994) Improved Asphalt Cement Specifications to Ensure Better Performance, *Technical Report*, Department of Civil Engineering, University of Florida, Gainesville.

[2] Tia, M., Ruth, B.E., Huang, S.C., Chiu, C.T., Richardson, D., (1994) Development of Criteria for Durability of Modified Asphalt, *Technical Report*, Department of Civil Engineering, University of Florida, Gainesville.

[3] Zupanick, M., (1994) Comparison of the Thin Film Oven Test and the Rolling Thin Film Oven Test*, Journal of the Association of Asphalt Paving Technologists*, Vol.63, 346-372.

[4] Sirin, O., Shih, C.T., Tia, M., Ruth, B.E., (1998) Development of a Modified Rotavapor Apparatus and Method for Short-Term Aging of Modified Asphalts, *Transportation Research Record 1638*, TRB, National Research Council, Washington, D.C., 72-81.

[5] Bahia, H.U., Zhai, H., Rangel, A., (1998) Evaluation of Stability, Nature of Modifier, and Short-Term Aging of Modified Binders Using New Tests; LAST, PAT, and Modified RTFO, *Transportation Research Record 1638*, TRB, National Research Council, Washington, D.C., 64-71.