UTILIZATION OF RECLAIMED ASPHALT PAVEMENT (RAP) IN JORDAN ROADWAYS

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Using Reclaimed Asphalt Pavement (RAP) in asphalt mixes has become a common practice in many countries as experience indicated that the recycling of asphalt pavements is very advantageous from different perspectives. Some of the advantages of utilizing RAP include conservation of asphalt and aggregate resources, conservation of energy, and reduction in life-cycle cost. In this study, the suitability of asphalt mixes using RAP was investigated. Two hot asphalt mixes were prepared following gradations recommended by Ministry of Public Works & Housing (MPWH/ Jordan). Marshall mix design procedure was used to determine the optimum asphalt content. The first mix composed of 100% fresh aggregate and virgin asphalt and the second mix composed of 30% RAP and 70% fresh aggregates and virgin asphalt. Marshal stability, loss of Marshall Stability, water sensitivity, indirect tensile strength, dynamic creep, and fatigue tests were performed on samples of the two mixes. Comparing the results of the conducted tests indicated that the use of RAP in hot mix asphalt was advantageous in all properties measured except for the fatigue test where shorter fatigue life was observed. The mix containing RAP showed less reduction in both loss in stability and loss in indirect tensile strength, improved stripping resistance, and better creep performance than the mixture with fresh aggregates. Therefore, it is preferred to use mixes containing RAP in highways, where fatigue is not the predominant distress type.

Key words: HMA, Recycling, RAP, Fatigue, Rutting, ITS, Marshall, Stability.

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OVERVIEW

When roadways asphalt mixes are removed during maintenance, rehabilitation, and reconstruction the resulting material is usaully known as Reclaimed Asphalt Pavements (RAP). RAP is normally produced by milling an existing asphalt pavement or by crushing the broken material resulting from partial or full removal of old pavements (*1*,*2*). Generally, the broken material is collected and transported to a central plant for processing, such as crushing, screening, conveying, and stacking. Properly crushed and screened RAP consists of high-quality, well-graded aggregates coated by asphalt cement (*1*,*2*). Most of the time, the recycling process takes place at central plants inspite the fact that cold in-place and hot in-place recycling can be performed on site using appropriate mahinery (*1*,*2*).

RAP can be used in many highway construction applications. “It can be used as an aggregate substitute and asphalt cement supplement in recycled asphalt paving (hot mix or cold mix), as a granular base or subbase, stabilized base aggregate, or as an embankment or fill material” (*1*). Using RAP in asphalt mixes has become a common practice in many countries especially when knowing, by experience, that recycling of asphalt pavements is very advantageous from different perspectives (*2*,*3*,*4*,*5*,*6*). Some of these advantages include:

- Maintaining existing roadway profile,
- Conserving asphalt and aggregate resources,
- Saving of energy,
- Reducing construction and life-cycle cost,
- Providing asphalt mixes that are equal to or better than mixes with virgin asphalt and aggregates

- Effective rehabilitation techniques can be achieved since old, distressed pavements are milled and removed which will warrant that severe cracks will not be reflected through the new surface layer.
- Environmental benefits that include reducing amount of asphalt binder needed; reusing valuable or scares aggregates; and preserving valuable landfill space from unnecessary disposal of old pavement materials.

Due to the various and obvious advantages of using RAP, many state highway agencies have been moving toward rising the percentages of RAP in their hot-mix asphalt pavements (*7*). RAP has been used in hot mix asphalt pavements in various percentages that reached in some cases up to 80% (*7*), and most usually from 20-50% (*4,8, 9*).

Over the past three decades, The Hashemite Kingdom of Jordan has invested considerable amount of money in constructing roads according to international standards. Due to the cruel environmental conditions and traffic loading, roads in Jordan have shown early signs of distresses (*10*). Developed distresses in early stages will shorten the pavement service life and accelerate the need for major maintenance and rehabilitation. These operations will generate massive amount of RAP that can be consider a waste if not utilized in an appropriate way. Based on the statistics of MPWH/ Jordan, it is estimated that 10,000 tons of RAP materials are produced yearly during maintenance activities on roads, but unfortunately slight percent of it is being reused in some applications but not in re-asphalting jobs. While in the United States, for example, and according to documents published by the National Asphalt Pavement Association (NAPA), The Federal Highway Administration (FHWA) estimates that out of the 90 million tons of hot mix asphalt (HMA) that are milled and removed each year, 90% is reused in highway applications in one form or another, including pavements, subbase and fill. About 1/3 of the 90 million tons is recycled into HMA (*4*).

In addition to the advantages of using RAP that previous studies have pointed out, this study intends to show the local pavement community in Jordan and the surrounding countries that using RAP can be also advantageous to our roadways as it is for the developed countries.

OBJECTIVES

The objective of the study is to investigate the suitability of asphalt mixes using Reclaimed Asphalt Pavement (RAP). Measuring and comparing some properties of two asphalt mixes, one is composed completely of fresh aggregate and virgin asphalt and the other one contains RAP as percent of total mix, is considered the base for examination the suitability of asphalt mixes using RAP.

STUDY APPROACH AND METHODOLOGY

In order to achieve the objective of this study, the following suggested approach was performed. Following gradations recommended by Ministry of Public Works & Housing (MPWH/ Jordan), two hot asphalt mixes were prepared and compared. The basis of assessment is to measure some properties, based on standard procedures described by the American Society of Testing and Materials (ASTM) (*11*), and the American Association of State Highway and Transportation Officials AASHTO (*12*), for the two asphalt concrete mixes and to compare their performance. The proceeding text provides detailed description for the adapted procedure.

Tests on Reclaimed Asphalt Materials

Reclaimed asphalt material was brought from a project site where milling operations are conducted to perform maintenance of some roadways in Amman/ Jordan. Representative samples of reasonable sizes from site were selected following the (ASTM C-702) test procedure. This procedure is crucial to reduce bias due to unforeseen factors that would affect measurements. In order to estimate the amount of asphalt in the RAP material, extraction test (ASTM D2172-95) was performed followed by sieve analysis for the clean aggregate using standard sieves as recommended by the Ministry of Public Works & Housing (MPWH/ Jordan) for heavy traffic loads wearing course. The asphalt content of RAP was found to be 5.9%. Figure 1 shows the gradation of RAP aggregate. It can be noticed that RAP aggregate gradation is finer than the median recommended gradation by MPWH for heavy traffic loads wearing course. This is due to the milling process and due to the breaking of the aggregate that occurs during mixing, compaction, and trafficking of the asphalt concrete mix. Specific gravity and absorption of the RAP aggregate were calculated according to ASTM C127-88 (for coarse aggregates) and ASTM C128-97 (for fine aggregates) test procedures.

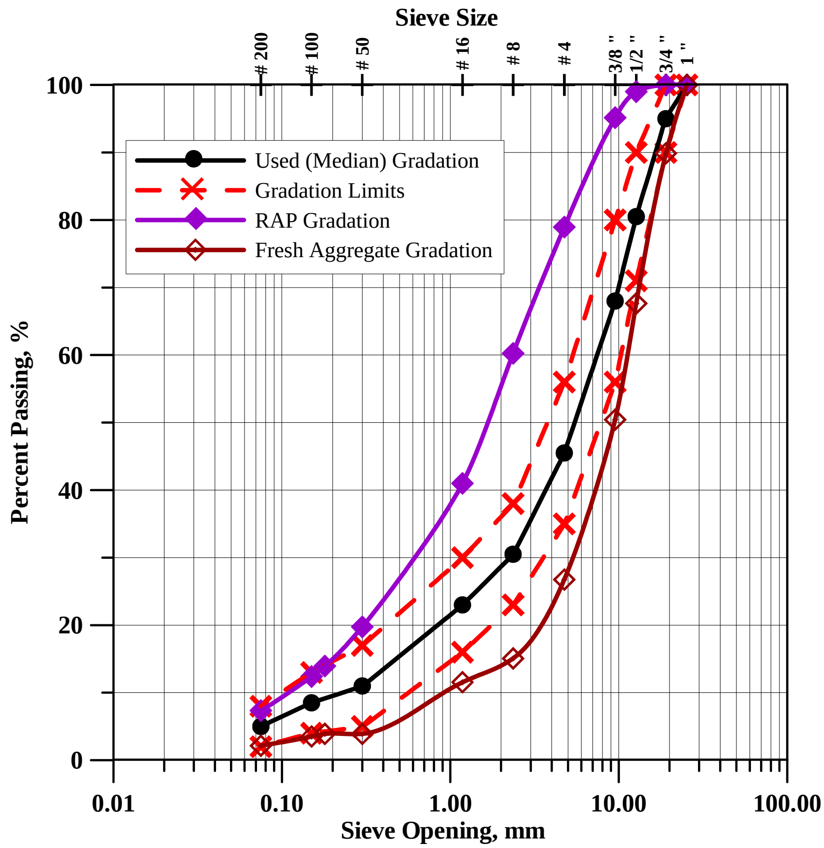

Fig. 1. Ministry of Public Works & Housing specified gradation limits for heavy traffic loads wearing course, median gradation, RAP aggregate gradation, and added fresh aggregate gradation.

Preparation of the Asphalt Concrete Mixes

The gradation results of the RAP materials (Figure 1) suggested that fresh aggregates should be mixed with the RAP material to meet MPWH standards. Thus, it was decided that two asphalt mixes would be used to achieve the goals of this study. The first mix, called "Control Mix", composed of 100% fresh aggregate and virgin asphalt. While the second mix, called "Rap Mix", composed of 30% RAP (aggregate and asphalt), and 70% fresh aggregates and virgin asphalt. Marshall mix design procedure (ASTM D1559), which is currently used in Jordan for asphalt concrete mix design, was used to determine the optimum asphalt content (that produce 4% air voids) for the asphalt mixes used in the study. The Job Mix Formula results suggest that the optimum asphalt content would be 5.5% of the total mix. Marshall Stability, flow, voids filled with asphalt, and voids in mineral aggregate values were checked to verify that they meet the specification limits of MPWH for heavy traffic loads wearing course.

Suggested Tests for Comparison

In order to examine the suitability of asphalt mixes using RAP the following tests were performed on samples of the two mixes.

- *Marshal stability*
- *Loss of Marshall stability*
- *Water sensitivity*
- *Indirect tensile strength*
- *Dynamic creep tests*

For consistency reasons, Superpave Gyratory Compactor was used to compact the test samples at 4% air voids.

DATA ANALYSIS AND RESULTS

Marshall Stability and loss of Marshall Stability Test Results (ASTM D1559)

Six compacted samples from each mix were placed in a water bath at 60°C. After 30 minutes immersion in the water bath, three samples were tested for Marshall Stability as described by (ASTM D1559) standard procedure. The other three samples were tested for Marshall Stability after 24 hours immersion to find loss of Marshall Stability. Figure 2 presents the difference in Marshall Stability and loss of Marshall Stability between the Control and Rap mixes. Figure 2 clearly shows that the inclusion of the RAP aggregates and asphalt in the RAP Mix has improved the Marshall Stability and reduced the loss of Marshall Stability over the Control Mix. It is believed that this can be attributed to the fact that RAP contains hardened asphalt which will lead to increased stability, and when subjected to immersion, the mixture RAP Mix will be less affected by hot water than the mixture completely made of fresh asphalt.

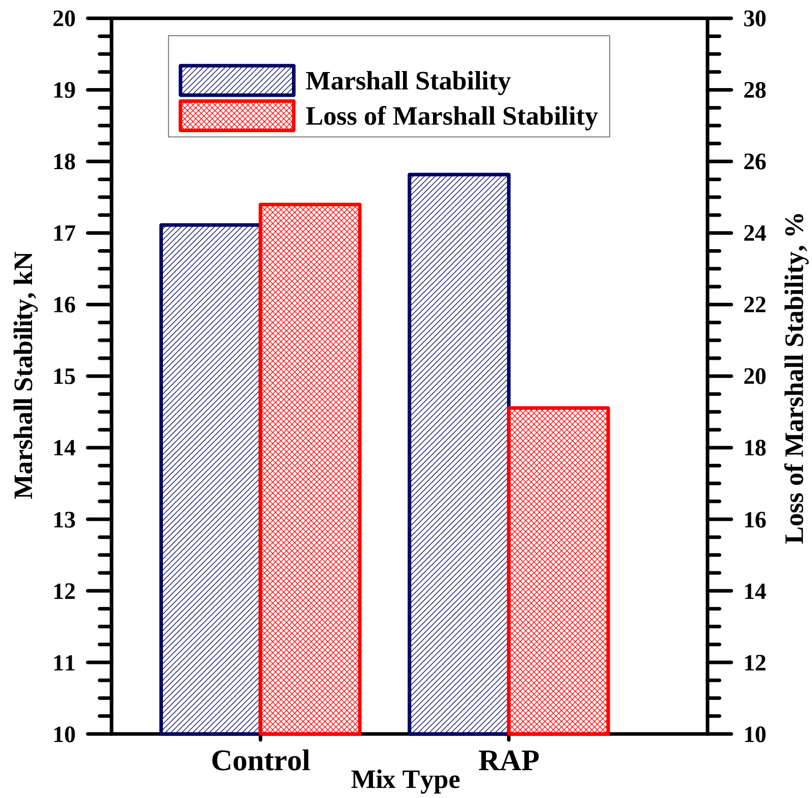

Fig. 2. Marshall Stability and Loss of Marshall Stability between Control and Rap mixes.

Water Sensitivity Test (Lottman Test AASHTO T-283-89)

The improvement in stripping resistance (water susceptibility) of the asphalt concrete mixes due to RAP usage in asphalt mixes was evaluated by measuring the loss or reduction of the indirect tensile strength (ITS) after immersion in water for 24 hrs at 60° C, according to AASHTO T-283 test procedure. Six samples of each mix were used. Three samples were tested for their initial ITS values. the other three samples were immerses in water for 24 hrs @60°C, and then immersed in 25°C water bath for 2 hrs before their final ITS values were obtained. Comparison of loss in ITS between fresh mixture and mixture containing RAP is presented in Figure 3. Figure 3 shows clearly that the loss in ITS for mixtures containing RAP is much lower than mixtures containing no RAP. This is attributed to the fact that RAP contains hardened asphalt that became more viscous as time passes. Thus, mixtures with more viscous materials will perform better under tension, which will lead to smaller reduction in tensile strength when exposed to sever conditions of high temperatures and moisture.

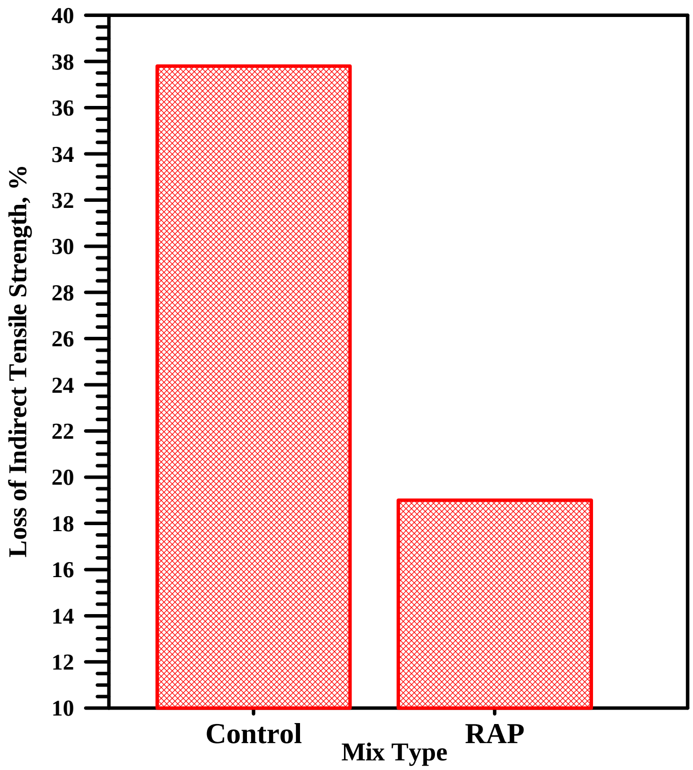

Fig. 3. Loss of Indirect Tensile Strength (ITS) between mixture with fresh aggregates and asphalt, and mixture containing RAP.

Dynamic Creep Test

The Dynamic Creep Test is a test that applies a repeated pulsed uni-axial stress on an asphalt specimen and measures the resulting deformations in the same direction using Linear Variable Differential Transducers (LVDT's). The test was performed in accordance with the protocol developed by NCHRP 9-19 Superpave Models, Draft Test Method W2 (Witczak et al. 2001). The applied stress on the specimen was a feed back haversine pulse. The pulse width duration was 100 milliseconds (ms), and the rest period before the application of the next pulse was 900 ms. The deviator stress during each loading pulse was 207 kPa, and the contact stress that was applied so that the vertical loading shaft does not lift off the test specimen during the rest period was 9 kPa. The test was performed at 40°C. The specimen’s skin and core temperatures during the test were monitored by two thermocouples which were inserted in a dummy specimen and located near the specimen under test. The testing was continued until the maximum axial strain limit reached 10000 micro-strains, or until 10000 cycles, whichever occurred first. Three samples from each mix were tested. Figure 4 shows the relationship between the number of cycles and the axial accumulated permanent deformation for the mix. It can be noticed that mix samples containing RAP showed better creep performance than samples of mix made of fresh aggregate and virgin asphalt. This behavior difference is attributed to the higher asphalt viscosity in the RAP mixture.

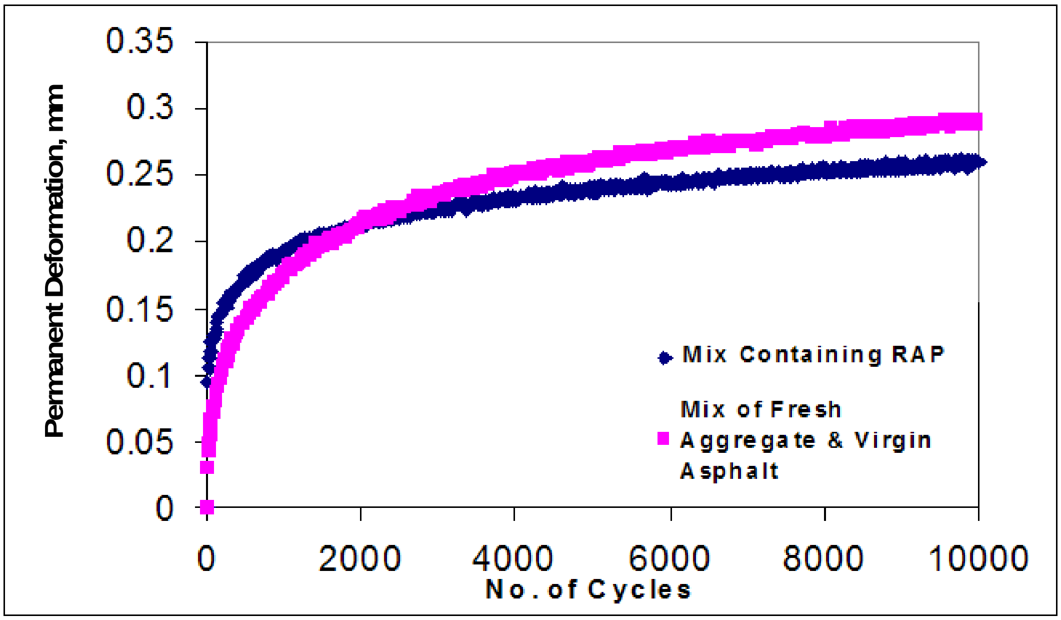

Fig. 4 Average creep results of mixture with fresh aggregates and asphalt, and mixture containing RAP.

Fatigue Performance

Samples from both mixes were tested diametraly under repeated pulsed uni-axial loading to determine the number of loading cycles required to fail the sample. To have a wide range of failure cycles, test samples were tested at different initial tensile strain levels. At least nine samples from each mix (three at each initial tensile strain level) were tested at 40°C. Figure 5 shows the results of these tests. In this Figure, regression lines were drawn through the mean of samples at each strain level. The results show a normal linear relationship between the logarithm of applied initial tensile strain and the logarithm of fatigue life (number of applied load repetitions until failure). Figure 5 implies that mixtures not containing RAP will have longer fatigue life than mixtures containing RAP which can be attributed to the existence of the aged asphalt the RAP material.

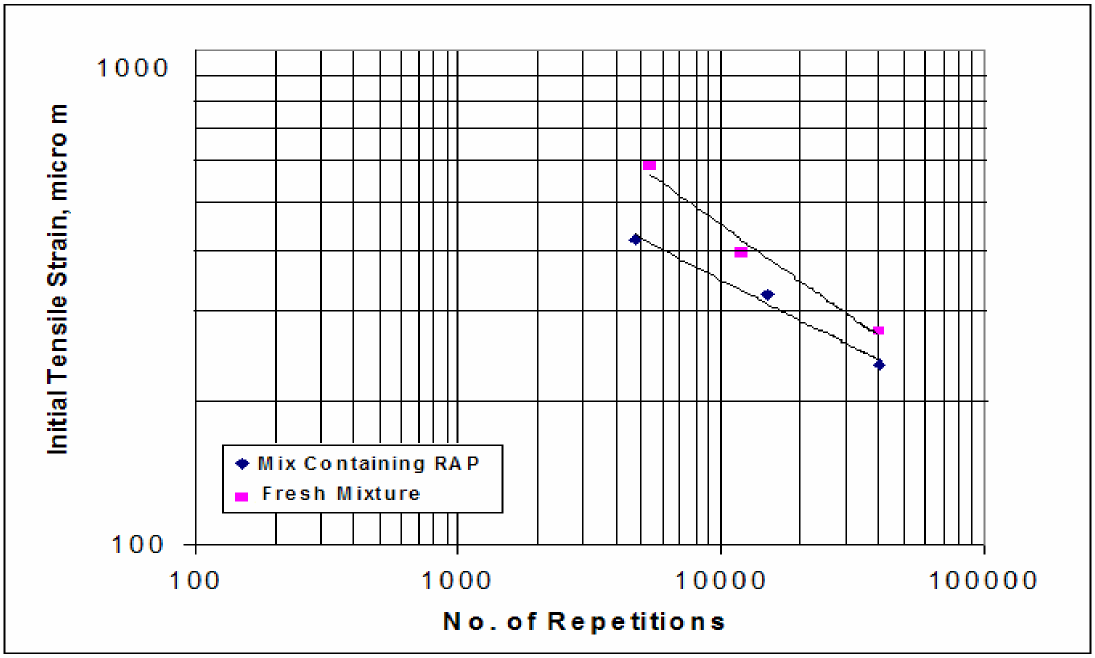

Fig. 5. Fatigue behavior for the two mixes @ 40°C

CONCLUSIONS

The main objective of this research was achieved through measuring and comparing some properties (Marshall Stability, Loss of Marshall stability, water sensitivity, dynamic creep, and fatigue tests) of two asphalt mixes, one is composed completely of fresh aggregate and virgin asphalt and the other one contains 30% RAP (asphalt and aggregate) as percent of total mix. The results of the conducted tests indicated that the use of RAP in hot mix asphalt was advantageous. The mix containing RAP showed less reduction in both loss in stability and loss in indirect tensile strength, improved stripping resistance, and showed better creep performance than the mixture with fresh aggregates. In the other hand, the study revealed that mixtures containing RAP may have shorter fatigue life due to aged asphalt that exists in the mix through RAP usage. Therefore, it is preferred to use mixes containing RAP in highways, where fatigue is not the expected predominant distress type.

REFERENCES

1. Federal Highway Administration. (2001). *Reclaimed Asphalt Pavement User Guideline: Asphalt Concrete (Hot Recycling).* Web page on the Turner-Fairbanks Highway Research Center web site.

   http://www.tfhrc.gov/hnr20/recycle/waste/rap132.htm.

2. http://www.asphaltwa.com/wapa_web/modules/02_pavement_types/02_recycled_hma.htm
3. Thomas W. Kennedy, Weng O. Tam, and Mansour Solaimanian (1998). “Effect Of Reclaimed Asphalt Pavement On Binder Properties Using The Superpave System.” Report No. FHWA/TX-98/1250-1, Center For Transportation Research, The University Of Texas At Austin.
4. Daniel C. Brown (2005), PUBLIC WORKS MAGAZINE, Publication date: 03/01/2005
5. Page, G. C. (1988) “Florida’s Experience in Hot Mix Asphalt Recycling,” *Hot Mix Asphalt Technology*.
6. Page, G. C., and K. H. Murphy (1987) “Hot-Mix Recycling Saves Florida DOT $38 Million,” *Asphalt*, Vol. 1, No. 1.
7. Environmental Protection Agency and Federal Highway Administration, (1993). “Recycling of Asphalt Pavements Using at Least 80 Percent Recycled Asphalt Pavement (RAP),” Engineering and Environmental Aspects of Recycled Materials for Highway Construction, Report No. FHWA-RD-93-088.
8. Flynn, L., (1992). “Three States OK More RAP in Recycling Specs: Asphalt Recycling and Reclaiming,” *Roads and Bridges*.
9. Solaimanian, M., and M. Tahmoressi, (1996) “Variability Analysis of Hot-Mixed Asphalt Concrete Containing High Percent Reclaimed Asphalt

Pavements,” Presented at the 75th annual meeting of Transportation Research Board, *Transportation Research Record, No. 1543,* National Research Council, Washington, D.C., pp. 89-96.

10. Suliman, M., Awwad, M. and Shbeeb, L. (2004). “Heavy Vehicles are Damaging our Highways.” Proc., *Jordan International Conference on Sustainable Development of Transportation Systems*, Amman, Jordan.
11. American Society of Testing and Materials ASTM. (2000). *Annual Book of ASTM Standards (03-04)*, West Conshohocken, PA.
12. American Association of State Highway and Transportation Officials AASHTO. (1988). *Standard specifications for transportation materials and methods of sampling and testing*, 19th Edition, Washington, D.C.