



EFFECTIVE USE OF RECYCLED ASPHALT SHINGLES FOR GRANULAR MATERIALS

MacEachern, Matthew^{1,2}, Sanchez-Castillo, Xiomara¹ and Oh, Won-Taek¹

¹University of New Brunswick, Canada

².mmaceac1@unb.ca

Abstract: The province of Prince Edward Island (PEI) imports 20,000 to 100,000 tons of aggregates per year for construction purposes. It is estimated that close to 8000 tons of tear-off shingles (end of life roofing shingles) are sent to local landfills annually. To reduce aggregate import costs and to utilize Recycled Asphalt Shingles (RAS), the University of New Brunswick (UNB) has been working closely with the province to investigate the use of RAS as a partial replacement of high quality quarried aggregates (Granular Class A) for its potential use as a granular base in pavements. The main objective of the present study is to suggest an optimum combination of RAS and Granular Class A. The individual gradation curves for each material were obtained and the theoretical design indicated that a replacement of up to 30% of RAS by weight could meet provincial specifications. Three suitable combinations of Granular Class A/RAS were selected (90/10, 80/20, and 70/30) for testing and quantifying the impact of RAS in the mechanical properties of the material. Proctor tests were conducted to determine the Optimum Moisture Content (OMC) for each combination. Based on the standard proctor test results, California Bearing Ratio (CBR) tests were then carried out for the mixtures compacted at OMC. Results showed that the addition of RAS significantly reduced CBR results by making the material up to 85% weaker than that of just Granular Class A material alone.

1 INTRODUCTION

The province of Prince Edward Island (PEI) decided to explore the possibility of using recycled materials as an additive to their granular material that is used for road construction and backfilling. The province has reached out to the University of New Brunswick (UNB) to study the effects of the addition of Recycled Asphalt Shingles (RAS) to their granular material. A full testing plan has been laid out to potentially put to use some of the approx. 8000 tonnes of shingles being disposed of in local landfills annually. It is the goal of this research to find an optimum mixture of shingles that meets the physical requirements that the current granular A performs at; as well as assuring the mixture meets all material characteristics outlined in the provinces contract specifications. As a first step of this research, this paper focuses on the California Bearing Ration (CBR) testing results with the addition of 10, 20 and 30% RAS to the currently used granular material.

2 BACKGROUND AND LITERATURE REVIEW

The recycling and subsequent use of old asphalt shingles have been gaining more popularity in the past few years. RAS is recently being incorporated into hot mix asphalt designs across North America. This is

mainly because the incorporation of RAS can reduce not only cost but also conserves significant amounts of materials without sacrificing the strength and quality of the asphalt material. However, increased asphalt hardness and the extra amount of money spent on cleaning and preparing the asphalt shingles for use are considered as concerns with using RAS in asphalt mixes. According to Soleimanbeigi et al. (2012), RAS has great potential to be used as structural fill due to its better dust control and reduced maintenance requirements. However, its current use is restricted to field testing and research due to it being a relatively new material for fill applications. RAS has a potential application to improve roadbeds; however, their effectiveness will depend on the characteristics of the granular material and the percentage of replacement.

Warner et al. (2012) discussed the possible use of recycled asphalt shingles (RAS) in aggregate base (AB) and aggregate subbase (ASB) in roadway construction. In this research, different ratios of RAS and soils native to Wisconsin, US were blended and tested for characteristics such as California Bearing Ratio, Proctor, Resilient Modulus along with others. The addition of fly ash and asphalt emulsion to attempt to improve test results was also discussed. The results of the study found that there are large inconsistencies in the RAS depending on the source as there was no mandatory method to create the RAS in the US at the time of the study. It was also found that just the simple addition of RAS to the aggregate proved to be insufficient for AB; however, a 50:50 ratio of backfill material and RAS proved to be acceptable for backfilling applications. Results found that even though the addition of fly ash to help stabilize the RAS showed improvement in the resilient modulus, it was still not enough to deem the mixture acceptable.

Yang et al. (2014) investigated the use of RAS in combination with recycled asphalt pavement (RAP) to form hot mix asphalt (HMA). The investigation looked at different combinations of RAS and RAP and their effects on such asphalt characteristics as stiffness, resilient modulus, fracture temperature, air void percentage, surface characteristics and life expectancy. It was found that the addition of RAS and RAP caused the asphalt to perform more stiffly at higher temperatures. The resilient modulus was lowest when the mix contained 12% RAP and 3% RAS. In the end, it was determined that mixtures containing RAS and RAP performs well in the short term.

Townsend et al (2007) investigated the effects of using RAS in construction materials on the environment regarding asbestos contents in the shingles. The paper looked at samples taken from several states in the US. It was found during an asbestos case study that out of 27,694 samples taken from across six states, an average of 1.48% contained asbestos. However, in that study, it showed that some states had no samples containing asbestos while others had up to 16.7% of samples containing asbestos. This shows that although there is a low chance of encountering asbestos there is still a chance; therefore, RAS manufacturers need to continue testing samples for asbestos. It was discussed that asbestos was found more in roll out shingles than tabbed shingles. Aside from the focus being on asbestos contents, the study also found that RAS has been used in Iowa in combination with gravel to be used on unpaved roads. The mixture was proven to yield less dust and have a longer life than regular gravel roads.

Shrestha et al. (2008) investigated not only combining RAS with granular materials but also selecting the size of the RAS particles. The study focused on two grades of RAS: a fine sample that had all particles passing the 4.75mm sieve and the other which had a nominal aggregate size of 75mm with only 40% passing the 4.75mm sieve. This unique research looked at using the RAS for more than just the replacement of fine particles. The RAS was tested while being mixed with five different aggregate materials. The materials used were three types of recycled concrete aggregate (RCA), quarried crushed limestone as well as crushed gravel containing 72% crushed rock particles. The study focused mostly on how the different mixes performed in the CBR tests. During CBR testing, the study looked at mixing the five granular materials with 0, 3, 5, 8, 10 and 15% RAS contents. CBR testing, proved that the RAS had no benefit and, in some cases, reduced the CBR of the material. However, the reduction of the CBR was not significant in any case and still passed necessary requirements for the Ontario standard. It was also found that with the addition of 5% and 8% in certain cases made the material more stable. As well, the drainage capability of the different materials was not deemed to be significantly altered with the addition of RAS.

Lee et al. (2010) analyzed a road project in Wisconsin focusing on how the use of recycled materials saved in both the environmental and economic aspects. The study found that the use of recycled material in the base and subbase layers during road construction could result in a 20% reduction in the potential for global warming. Aside from that, reductions in energy use, water consumption and hazardous waste generations

were all said to be reduced by 16%, 11% and 6% respectively. The study showed that the use of recycled materials could result in a 21% reduction in the overall life-cycle cost.

3 MATERIALS AND TESTING METHODS

For this research, PEI supplied UNB with the necessary materials to be tested. The granular material was a sample of their current stock being used on the island classified under their specifications as Granular A. The sample of RAS was supplied by a local island contractor that was importing samples from a produced in the Unites States. All testing was performed under the assumption that the RAS acted as a granular material, so the same testing standards were used for both the granular and RAS material. The following sub sections explain the different stages of testing performed in order to complete CBR testing.

3.1 Mixing Combinations

Based on the individual size distribution of the materials it was determined that a maximum theoretical percentage of replacement of up to 30% RAS could be incorporated and still meet the specified requirements for granular A. In order to evaluate the optimum mix percentage of the combination of granular and RAS particles, three different mixing combinations by weight were used in the present study (Table 1).

Table 1: Mixing Combinations (by weight)

Test Condition Number	Granular A Material (%)	Recycled Asphalt Shingles (%)
1	100	0
2	90	10
3	80	20
4	70	30

3.2 Particle Distribution

Sieve analysis was conducted following ASTM C136/C136M (2014). Figure 1 shows the grain size distribution curves of Granular A and RAS. After sieve analyses, necessary amounts of Granular A and RAS were taken and then blends were prepared based on the predetermined percentages shown in Table 1. Blends were hand mixed thoroughly to maximize the uniformity and consistency in the samples used for standard proctor and CBR tests. Blended samples can be seen in Figure 2.

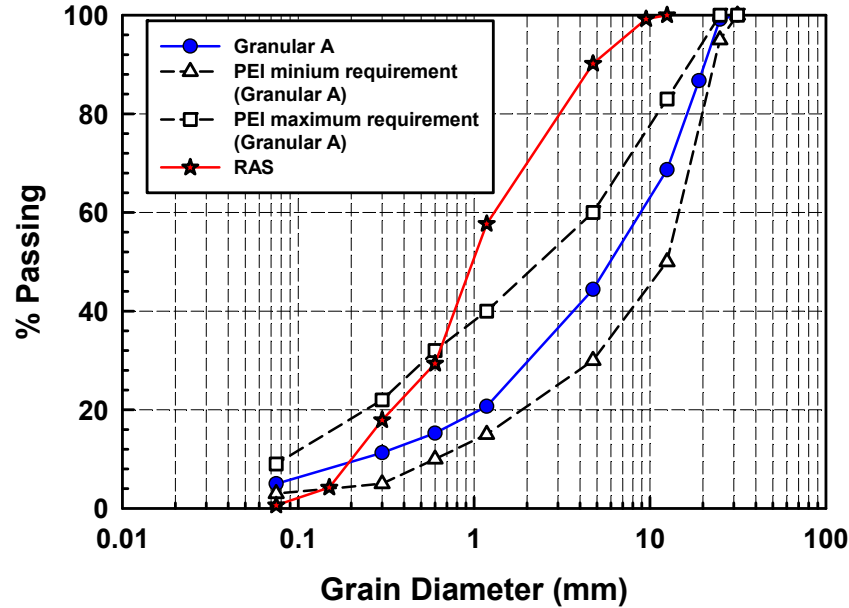


Figure 1: Granular A Particle Distribution



Figure 2: Samples Left to Right (Granular A - RAS) 100-0, 90-10, 80-20, 70-30

3.3 Specific Gravity

Specific gravity tests were performed following ASTM C127 (2015) and ASTM C128 (2015) for coarse and fine particles, respectively. This test was necessary to determine correction factors for oversized materials in standard proctor tests. The granular material supplied by PEI was already estimated to meet their specifications for construction purposes. Summary of test results for Granular A and RAS are shown in Table 2 and Table 3, respectively. Average apparent specific gravity was determined to be 2.64 and 1.84 for Granular A and RAS, respectively.

Table 2: Summary of Specific Gravity Test Results for Granular A

Sample No.	Oven dry	Saturated-surface dry	Apparent specific gravity
1	2.59	2.61	2.64
2	2.60	2.62	2.65
3	2.59	2.61	2.64
Average	2.59	2.61	2.64
Standard Dev.	0.00696	0.00656	0.00605

Table 3: Summary of Specific Gravity Test Results for RAS

Sample No.	Oven dry	Saturated-surface dry	Apparent specific gravity
1	1.55	1.70	1.81
2	1.55	1.72	1.86
3	1.50	1.69	1.84
Average	1.54	1.70	1.84
Standard Dev.	0.023	0.013	0.018

3.4 Standard Proctor Test

Standard proctor tests were carried out following ASTM D698 (2012) to determine optimum moisture content (OMC). Figure 3 shows uncorrected proctor test results for each blend. The OMC and maximum dry density ($\gamma_{d(max)}$) in Figure 3 were then corrected for oversized granular materials as shown Table 4. Corrected maximum dry density linearly decreases with increasing RAS content used in the present study (Figure 4). However, as shown in Figure 4, corrected OMC converges to constant value (approximately 7.33%) as RAS content approaches 20%.

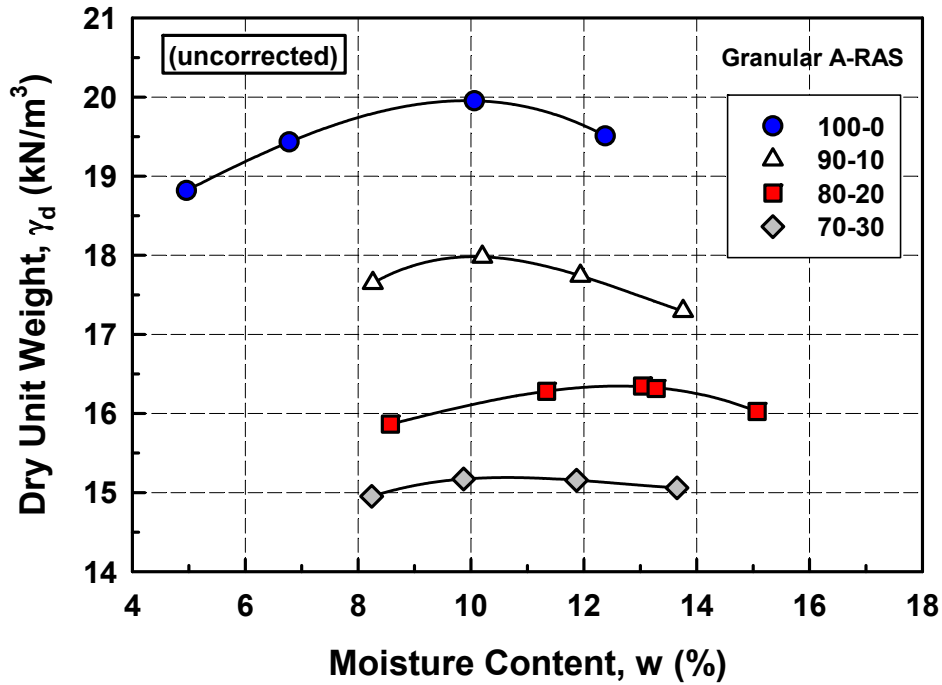


Figure 3: Proctor test results (uncorrected)

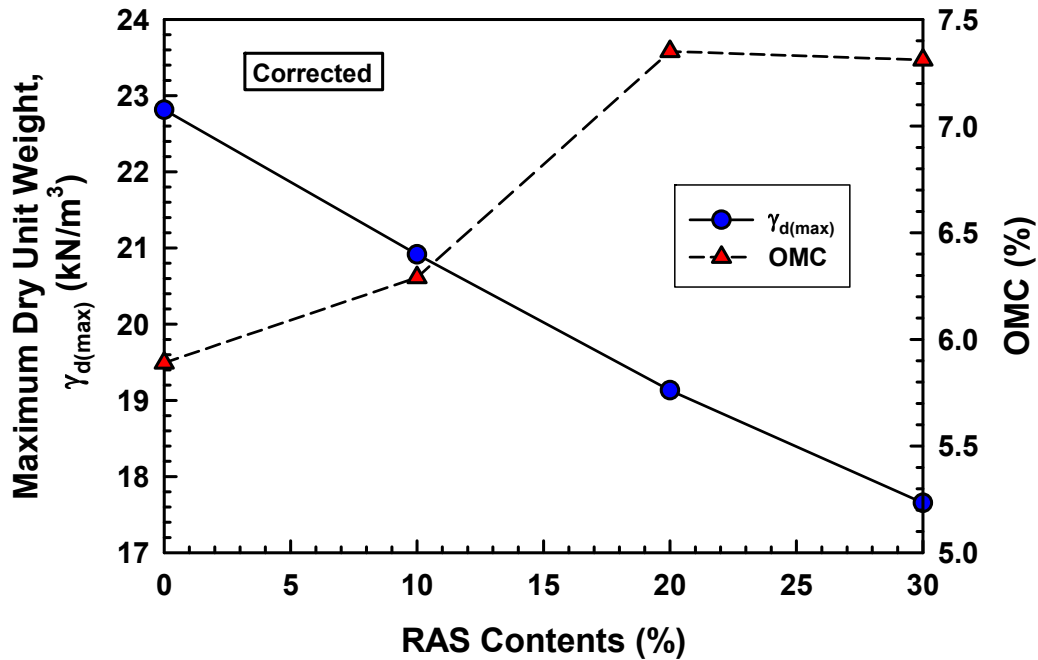


Figure 4: Proctor Results

Table 4: Corrected OMC and $\gamma_{d(max)}$

Mix (Granular A-RAS)	Corrected OMC	Corrected $\gamma_{d(max)}$
100-0	5.89%	22.81
90-10	6.29%	20.91
80-20	7.35%	19.13
70-30	7.31%	17.65

3.5 California Bearing Ratio Tests

For the purposes of these tests, both the granular and RAS materials are considered to behave the same, which leads to the same standards being used for both material. ASTM D1883 (2016) standard was followed in conducting CBR tests for each blend compacted at the corrected OMC. Due to the characteristics of the materials used, the compacted materials fell while flipping the CBR mold. Hence, a different metal base plate was attached to the mold prior to flipping the CBR mold to remove the spacer disk (Figure 5). Load was applied on the penetration piston at the rate of 1.27 mm/min. The stress levels at 2.54mm and 5.08mm were determined for each test scenario. The stress values of 2.54mm and 5.08mm were divided by 6.9 MPa and 10 MPa, respectively. The larger value is chosen for the final CBR result.



Figure 5: Modified CBR Test Assembly

4 CBR TEST RESULTS AND ANALYSIS

Figure 6 shows the uncorrected stress on piston versus penetration curves for each blend from CBR tests. Based on the results in Figure 6, corrected CBR values were determined as shown in Table 5. It was observed that the CBR decreases exponentially with the increase of RAS replacement (Figure 7).

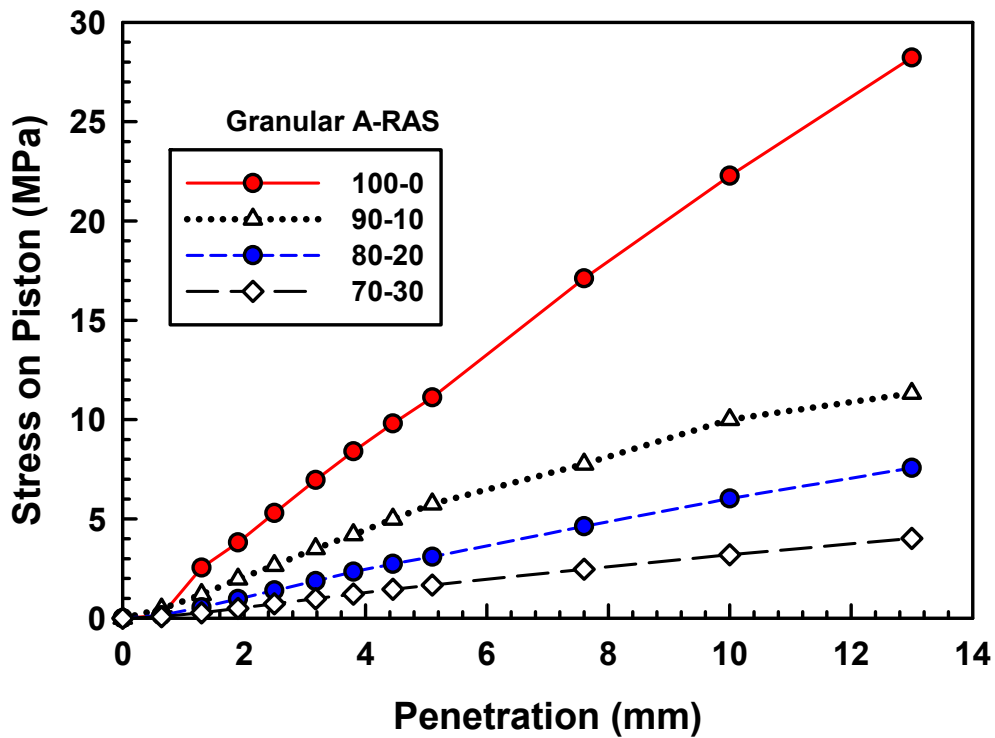


Figure 6: Stress on piston vs penetration Curves from CBR Tests

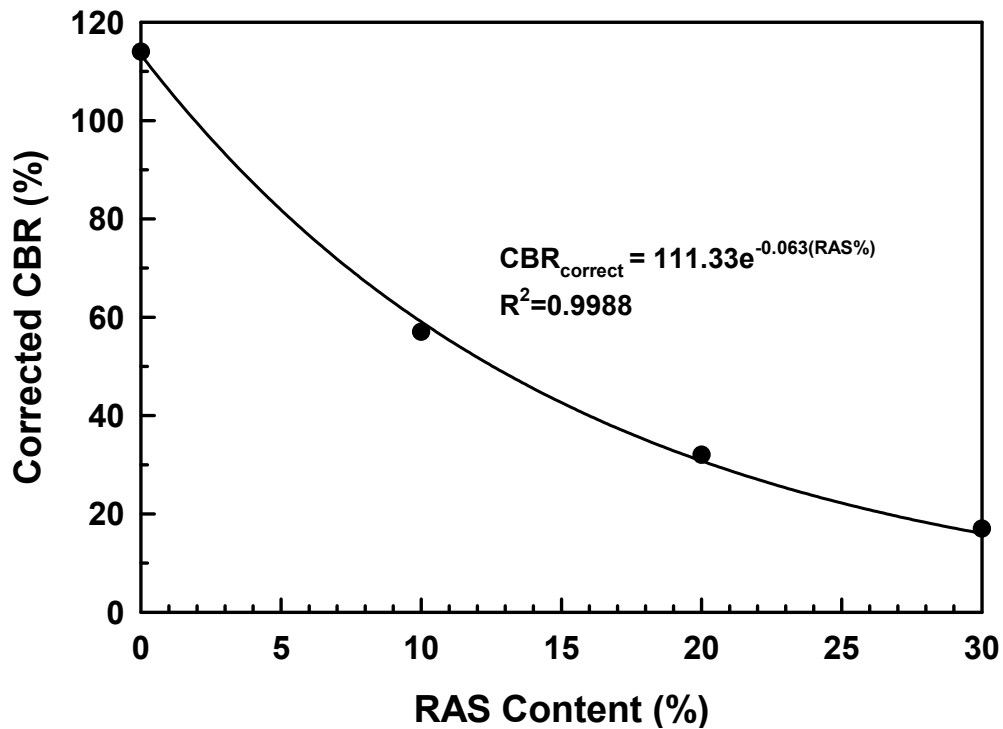


Figure 7: CBR vs Percentage of RAS Replacement

Table 5: California Bearing Ratio Test Results

Mix (Granular A-RAS)	CBR Uncorrected	CBR Corrected
100-0	111%	114%
90-10	57%	57%
80-20	31%	32%
70-30	17%	17%

5 CONCLUSION AND RECOMMENDATIONS

In the present study, a series of CBR tests were carried out for the mixtures of Granular A and RAS, compacted at the OMC. To investigate the variation of CBR with respect to the replacement of Granular A with RAS, three different mix combinations of the two materials were designed. Each mix combination was compared to how the granular material behaved on its own.

The results showed that the addition of RAS significantly decreases the strength of the soil compared to the currently used granular material. With the decrease in strength this would require a thicker layer of granular subbase in roadway construction to achieve similar strength and have the ability to withstand similar loading conditions. As the whole objective of using RAS is to decrease the cost of road construction, this is not ideal. Therefore, it is recommended that if a high percentage of RAS would like to be used, additives should be looked at to stabilize the blend to increase strength. These additives could include:

asphalt emulsion, lime like additives and geosynthetics. Additives come with a price and would need to consider a balanced design that optimizes the use of RAS and additives while still saving money.

This paper is based on the preliminary results of an ongoing study at the University of New Brunswick, aimed at evaluating the effective use of recycled asphalt shingles for granular materials. This paper focuses on the California Bearing Ratio of the granular material partially replaced with different percentages of RAS. One source of crushed stone (Granular A) from the province of Prince Edward Island and a single source of RAS with nominal maximum aggregate size of 4.75mm were used in this study. Hence, the results may vary depending of the quality of the materials, then a case by case analysis may be necessary.

Acknowledgements

The authors would like to thank the province of Prince Edward Island's Transportation Department and its director, Steve Yeo, for the opportunity to complete this research. As well the authors would like to thank the technical staff at UNB including, Chris Forbes and Andrew Sutherland for their help with testing procedures.

References

- ASTM. 2015. C127 Standard Test Method of Relative Density (Specific Gravity) and Absorption of Coarse Aggregate. *ASTM Compass*.
- ASTM. 2015. C128 Standard Test Method of Relative Density (Specific Gravity) and Absorption of Fine Aggregate. *ASTM Compass*.
- ASTM. 2014. C136 Standard test method for Sieve Analysis of Fine and Coarse Aggregates. *ASTM Compass*.
- ASTM. 2012. D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort. *ASTM Compass*.
- ASTM. 2016. D1883 Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils. *ASTM Compass*.
- Lee, Edil, et al. 2010. Quantitative assessment of environmental and economic benefits of recycled materials in highway construction. *Transportation Research Record: Journal of the Transportation Research Board*, **2158**: 138-142.
- Shrestha, Narayan, et al. 2008. Use of Processed Tear-off Roof Shingles to Improve Performance of Roadbase Materials. *Recycled Materials and Recycling Processes for Sustainable Infrastructure Annual Conference of the Transportation Association of Canada*, Toronto, Ontario
- Soleimanbeigi, Ali, Tuncer B. Edil, and Craig H. Benson. 2011. Recycled asphalt shingles mixed with granular byproducts as structural fills. *Journal of ASTM International*, **9**(1): 1-19.
- Townsend, Timothy, Jon Powell, and Chad Xu. 2007. Environmental issues associated with asphalt shingle recycling. *Construction Materials Recycling Association, US EPA Innovations Workgroup*.
- Warner, J. D., and T. B. Edil. 2012. An Evaluation of Reclaimed Asphalt Shingles for Beneficial Reuse in Roadway Construction. *STP*, **1540**
- Yang, Ddamba, et al. 2014. Investigation on use of Recycled Asphalt Shingles in Ontario Hot Mix Asphalt: A Canadian Case Study. *Canadian Journal of Civil Engineering*, **41**(2): 136-143