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Rutting Performance of Asphalt Layers Mixtures with Inclusion RAP Materials

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ABSTRACT

Asphalt is the most recycled materials around the world and the amount of RAP materials can be significantly increased with the application of good RAP management applications. In Iraq, the real inclusion of RAP materials in asphalt mixtures has not been applied yet in the field. It is therefore that there is a need to characterize the effect of inclusion RAP materials in asphalt mixtures with particular reference to permeant deformation/rutting resistance. The aim of this study is to evaluate the best layer of pavement structure; base, binder, and surface layers for inclusion (RAP) materials. In addition, highlight the best percentage that can be added from RAP to achieve positive results and better than that associated reference mixture in terms of rutting resistance. RAP materials collected from different sources Karbala and Fallujah, were adopted in this study at percentages of 20%, 30%, and 40% by weight of the asphalt mixture. Two scenarios of incorporating RAP materials have been adopted. The first is considered that RAP as a black rock in which the effect of aged binder surrounding the aggregate of RAP is neglected while, the letter is not considered RAP as black rock and the influence of aged binder in RAP materials has been taken into consideration. Dora bitumen has adopted in the current study which is used in common in Iraq. It has been highlighted the best layer in which RAP can be incorporated is the base layer, with a percentage up to 40% that RAP without considering RAP black rocks regardless the sources of RAP.

1. Introduction

Paving is considered one of the important layers for the construction of the road because it is directly related to the traffic loads as well as being exposed to climatic conditions. Therefore, asphalt mixtures must be prepared an adequate manner which can carry the constructed traffic loads and climatic circumstances. In this regard, the process of recycling the waste of the old paving is a good step from an economic and environmental point of view. The use of old paving residues RAP began in 1915, but its use spread in 1970 during the Arab oil embargo, which led to an increase in the cost of virgin bitumen and this is the main reason for the increase in the use of RAP in large quantities **(Kandhal, 1997)**. There are other reasons, including economic, environmental and social **(Willis, 2014).**RAP is considered one of the best alternatives (for aggregates) for the construction of asphalt pavement by hot, cold or warm mixing method. RAP can also be recycled in the work site or using plants. The results indicate that the inclusion of RAP in manufacturing asphalt mixture gives better mechanical properties than that of the conventional mixture **(Tabaković, 2013)**. The old asphalt can be recycled by up to 100%, meaning that the virgin aggregate can be dispensed which could lead to great benefit from an economic and environmental point of view **(Zaumanis et al., 2014).** It is therefore that the use of RAP in the

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manufacture of asphalt mixtures has become more common in many countries, including America, Holland, Spain, France, India, Australia, China, Japan and other countries. Can RAP be considered as black rocks? is the old bitumen found in RAP can be effective and rejuvenated and mixed with the new bitumen? This question has not been answered definitively, even after 30 years of submitting the application **(Shingles, 2014)**. Most US agencies specify that adding 15% or less of RAP to the asphalt mixture does not change the degree of added bitumen, i.e. RAP is considered black rocks , but if the proportion of RAP exceeds (15%) here, the degree of bitumen must be modified, which means that RAP cannot be considered as black rocks **(McDaniel and Anderson, 2001).**

(Oliver, 2001) produced an asphalt mixture containing 50% of RAP and 50% virgin materials and made a hot asphalt mixture but added the proportion of bitumen half the calculated percentage assuming that the RAP contained pre-bitumen to evaluate the performance of asphalt mixtures containing RAP materials. **(Abd et al., 2018)** used advanced technique, Nanoindentation to investigate level of blending between RAP and virgin materials for mixtures incorporating some warm additives such; Sasobit, Rediset WMX and Rediset LQ and concluded that RAP cannot be considered as black rocks even with inclusion RAP materials up to 40%. Furthermore, a novel protocol was reported to fine a complete blend between RAP and virgin materials. **(Miró et al., 2011)** manufactured three high moduli of asphalt mixtures containing different percentages of RAP materials 15, 30, 50% as well as a reference mixture which does not contain RAP martials. It was concluded that the rutting depth of high modulus asphalt mixes containing RAP had better performance in terms of rutting resistance than that of reference mix.

(Pradyumna et al., 2013) reported that adding 20% of RAP to the hot asphalt mixture of surface layer with the addition of a regeneration agent of 10% by weight of bitumen resulted in higher rutting resistance than the reference mixture, as the rutting depth of the mixture containing 20% of RAP was (7.6) mm, while the rutting depth of the reference mixture was (8.2) mm after (20000) passes which made the mixture containing RAP had higher resistance to rutting than the reference mixture. In Iraq, RAP has not been used in road construction or maintenance yet, but there are laboratory studies from a number of researchers in Iraq to support the use of RAP and to get a benefit from it applying these research outcomes. **(Hasan, 2012)**, through his work and research used RAP with a recycling agent to create a hot asphalt mixture for a surface layer. Based on the results, RAP recommended to be used up to 60% and this percentage is very useful, especially from an economic and environmental point of view, Therefore, it is recommended to check the use of a better recycling agent as well as study the mixing blending case between raw materials and recycled materials. **(Mohammed 2019)** also conducted a laboratory study to evaluate the applicability of inclusion of RAP materials in the mixtures of surface and base layers but with limited results and scenarios. Recommendation was also reported also to investigate different source of RAP and its regenerating. **(Ismael 2018)** studied the possibility of using RAP materials in cold asphalt mixture. In fact, the improving in the moisture resistance could be due to the presence of cement with presence of water. Therefore, further investigation is needed.

Accordingly, this research addresses the possibility of using RAP materials in the layers of asphalt mixtures of pavement structure taking into account the scenario of inclusion such materials either black rock scenario or not black scenario.

2. Materials

Materials were collected locally from inside Iraq. Laboratory tests for these materials were conducted as shown below.

2.1 Binder

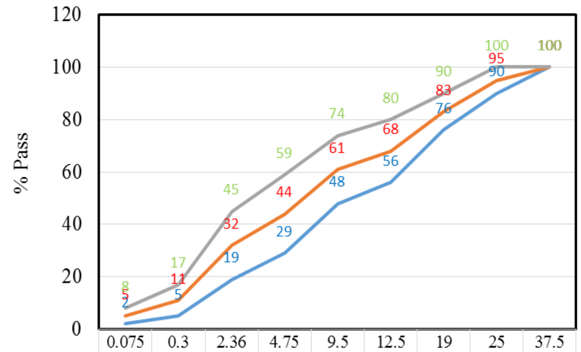
One source of bitumen was used in the current research, namely Dora, which is commonly used in Iraq nowadays in constructing pavement and was brought from Dora refinery directly. Basic laboratory tests in terms of penetration, softening point and viscosity were conducted in order to find the raw properties of bitumen, as shown in Table 1.

Table 1: Physical properties of Dora bitumen

Property	Value
Penetration at 25°C (0.1 mm)	48
Viscosity c.P at 135°C	525
Softening point°C	47
Specific gravity	1.03

2.2 Aggregate

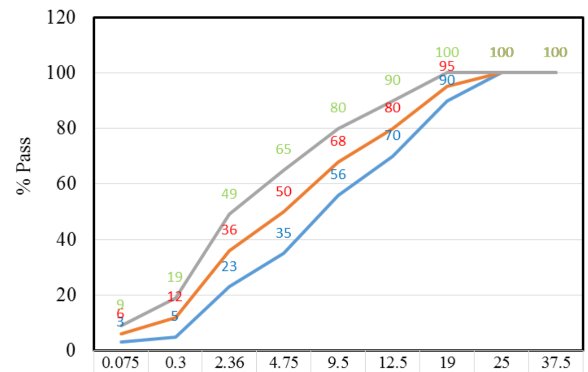
Coarse aggregate was brought from the Tigris arm quarry which is located north-east of Ramadi, while fine aggregate was brought from Hammurabi Company which is a governmental company worked in the field of construction at Governorate of Anbar. Physical properties of both aggregate were performed in the Roads Laboratory at University of Anbar, College of Civil Engineering as shown in Table 2. It should be noted, as previously mentioned, three asphalt mixtures were adopted in the current study, surface, binder and base. **Figures** 1, 2, and 3 show the gradation of those mixtures.



	0.075	0.3	2.36	4.75	9.5	12.5	19	25	37.5
Lower Limit	2	5	19	29	48	56	76	90	100
mid point	5	11	32	44	61	68	83	95	100
Upper Limit	8	17	45	59	74	80	90	100	100

Seive Size

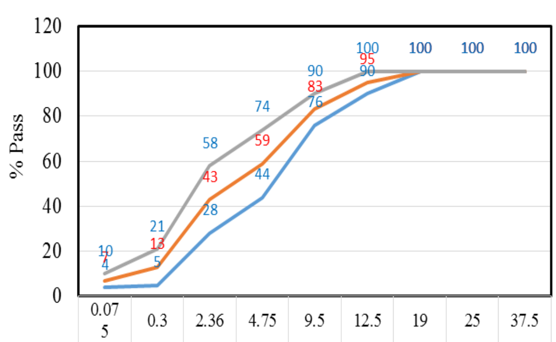
Figure 1: Gradation of aggregate for Base coarse mixture



	0.075	0.3	2.36	4.75	9.5	12.5	19	25	37.5
Lower Limit	3	5	23	35	56	70	90	100	100
mid point	6	12	36	50	68	80	95	100	100
Upper Limit	9	19	49	65	80	90	100	100	100

Seive Size

Figure 2: Gradation of aggregate for binder course mixture



	0.075	0.3	2.36	4.75	9.5	12.5	19	25	37.5
Lower Limit	4	5	28	44	76	90	100	100	100
mid point	7	13	43	59	83	95	100	100	100
Upper Limit	10	21	58	74	90	100	100	100	100

Seive Size

Figure 3: Gradation of aggregate for surface course mixture

Table 2: Physical properties of aggregate

Laboratory Test	Coarse aggregate	Fine aggregate
Bulk Specific Gravity	2.611	2.513
Apparent Specific Gravity	2.626	2.628
Water absorption%	0.2	1.7

2.3 Filler

The used filler is locally manufactured dust limestone collected from Fallujah. Laboratory tests were performed in order to measure some properties as presented in **Table 3**

Table 3: Physical properties of limestone filler

Property	Test Result
Bulk specific gravity	2.770
Passing sieve% No.200 (0.075 mm)	75

2.4 Reclaimed asphalt pavement materials

RAP is one of the most important materials that are widely used in recycled asphalt mixtures, especially in Europe, America and Canada. It is used as a substitute for aggregates as it contains raw materials and binder. In the current study, two sources of RAP were adopted. The first was brought from Governorate of Karbala (Karbala Cement Factory Road), with the help of the Andi Company. The RAP age was more than 10 years. The second type was brought from the city of Fallujah (Service Street to Tharthar- bypass Street) and was used by Wasit Company. The RAP age was 3years. The physical properties of both RAP sources present in **Table 4**.

Table 4: Physical properties of RAP bitumen

Property	RAP (Karbala)	RAP (Fallujah)
% binder	4.7	3.7

2. Mix Design

According to the Marshall method, **(ASTM-D6926, 2010**), asphalt mixtures were designed for each type of three layers (base, binder, and surface). The optimum bitumen ratio was found by mixing five asphalt mixtures according to the (mid-point) method. Each mixture contains three samples. In order to design the base layer mixture, bitumen ratio was added as follows; 3.5% ,4% ,4.5%, 5% and 5.5 respectively. While for the binder and surface layer, the range was as follows; 4%, 4.5%, 5%, 5.5% and, 6 respectively. The required weight each sieve was determined. After that, the aggregate was mixed with the filler and heated in an oven at a temperature of 160°C. The bitumen is also heated 160°C and mixed with the heated aggregate and filler until the bitumen completely coats aggregate and filler.

After that the mixture was placed in a Marshall mold (4-inch diameter, 2.5-inch height) and compacted with 75 blows for each face using an electric hammer that falls free from a height of 457.2 mm. Then after 24 hours, the samples were de-molded. The volumetric properties in terms of bulk density and air voids were measured according to **(ASTM-D3203, 2017, ASTM-D2726, 2012)** respectively. **Table 5** shows optimum binder content for designed mixes.

After determining the optimum bitumen ratio for each mixture layer and for both binders, RAP materials were at three percentages 20, 30, and 40% by weight of aggregate and filler. The same previous steps in preparing the bitumen ratio were adopted in order to manufacture asphalt mixtures with addition of RAP

Two scenarios were adopted in the process of incorporating RAP materials. The first considered the RAP as black rock (Neglecting the bitumen ratio in RAP). While in the second scenario, the bitumen ratio in RAP was considered in the total weight of bitumen prior to mixing. The mixing process was carried as mentioned previously in preparing control mixes.

Table 5: Obtained optimum binder content of the designed mixes

Source of Binder	(%)base course	(%)binder course	(%)surface course
Dora	4.5	5	5

3. Testing

The resistance against permeant deformation was measured according to the method developed by Kim **(Kim et al., 2010, Kim et al., 2011, Kim et al., 2013)**.It should be noted that the samples were immerged in water bath at temperature of 60°C for 30 minutes. Moreover, the size of samples was 100mm in diameter and 62mm in highest. Kim device includes a constant loading rate of 50.8 mm / min as shown in the **Figure.4**. Three samples were tested for each mixture. The load and time were recorded using associated software and displacement was calculated through the following equation:

$$v = \frac{d}{t} \quad (1)$$

where is:
v= a constant rate of loading of (50.8) mm/min
d= displacement (mm)
t = time (sec.)

Moreover, the relationship between the load and the displacement was plotted to find the highest load and the displacement that corresponds to the highest load was determined. Then after, **equation 2** was used to calculate the deformation strength resistance of each sample and mixture. **Figure.5** shows examples of samples after failure

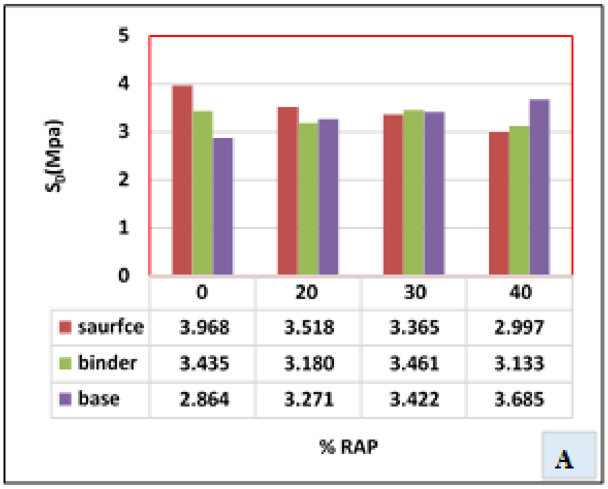
$$S_D = \frac{0.32\,P}{(10+\sqrt{20y-y^2})^2} \qquad (2)$$

Where is :
S_D: deformation strength (MPa)
P: Maximum load at failure (N)
y: vertical deformation (mm)

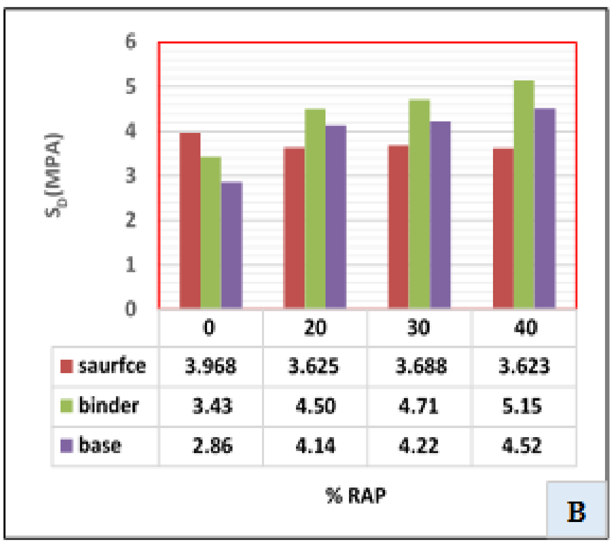
Figure 4: Sample testing process with a Kim's device

Kim's test has been used to measure the strength deformation of asphalt mixtures under static loading. This test indicates the ability of asphalt mixture to resist the permeant deformation. **Figure.6.a** shows deformation resistance results (S_D) of reference mixtures and mixtures containing RAP of Fallujah considering that the RAP as black rocks. It is clear that the deformation resistance of the surface layer decreased with increasing the addition of RAP ratios. This was agreed in case of binder layer when the value of (S_D) also decreased with increasing in RAP materials, apart from at 30% of RAP. The value of (S_D) increases and is higher than the value reference. On the other hand, an opposite trend has been noted in the base layer where the deformation resistance increased with increasing more RAP materials. In fact, the S_D of RAP-asphalt mixtures for base layer increased approximately by 14%, 19 % and 28% in case of inclusion 20% , 30% , and 40% RAP materials respectively.

In another scenario when RAP was not considered as block rocks, **Figure 6.b** presents the results of the resistance to deformation of asphalt mixtures. In case of surface mixture, the resistance against permeant deformation was almost same to that of control mix for all RAP ratios 20%, 30% and 40%. While in case of binder and base mixtures, there was a significant improvement in the deformation resistance with increasing in RAP ratios and in all percentages of RAP, resistance against permeant deformation was higher than that of corresponded reference mixtures.



	0	20	30	40
saurfce	3.968	3.518	3.365	2.997
binder	3.435	3.180	3.461	3.133
base	2.864	3.271	3.422	3.685

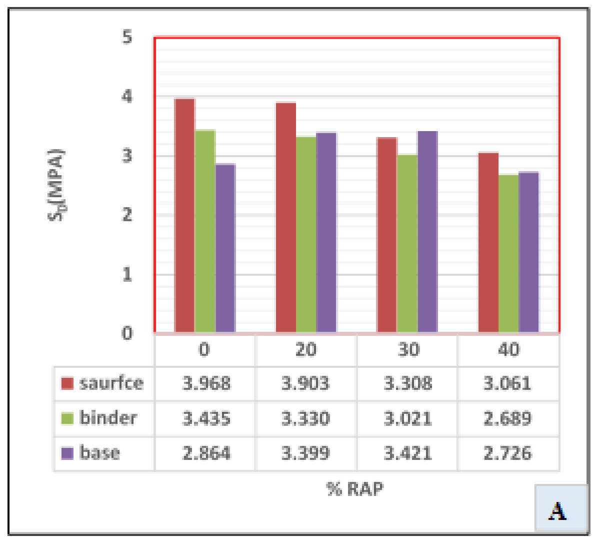


	0	20	30	40
saurfce	3.968	3.625	3.688	3.623
binder	3.43	4.50	4.71	5.15
base	2.86	4.14	4.22	4.52

Figure 6: Effect of adding RAP of Fallujah on (S_D) of the three layers (a) RAP is considered as black rocks (b) Not considering RAP as black rocks

Figure 7.a shows the deformation resistance of reference mixtures and mixtures containing RAP of Karbala, but without considering RAP as black rocks. The deformation resistance results of the surface and binder layer decreased slightly with increasing the addition of RAP ratios and all results were less than that of reference mixtures. However, in case of mixtures of the base layer, there was increase in the resistance of deformation associated with adding RAP at 20% and 30% respectively moreover, the deformation resistance of those mixture was higher than that of control mixture. However, there was a quick decrease when the addition of RAP materials increased to 40%.

In fact, considering the effect of aged bitumen in the RAP on the deformation resistance of asphalt mixtures is potential as shown **in Figure 4-12.b** when RAP was not considered as black rocks. Asphalt mixtures manufactured using RAP of Karbala has a superior performance in terms of rutting compared to that of control mixtures at all of RAP ratios 20%, 30% and 40%. The reason behind that is because there was a blend between RAP and virgin materials in which the engineering properties such elastic modulus of matrix and mastic phases can be enhanced as highlighted by **(Abd, 2017**).



	0	20	30	40
saurfce	3.968	3.903	3.308	3.061
binder	3.435	3.330	3.021	2.689
base	2.864	3.399	3.421	2.726

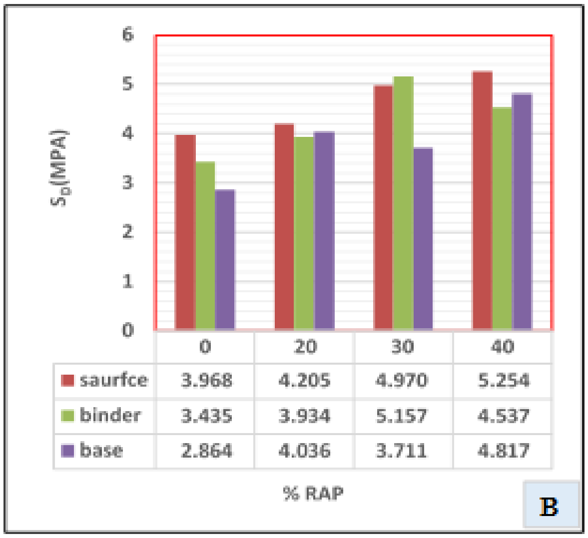


Figure 7: Effect of adding RAP of Karbala on (S_D) of the three layers (a) RAP is considered as black rocks (b) Not considering RAP as black rocks

3. Conclusion

The study was aimed to evaluate the best layer of pavement structure; base, binder, and surface layers for inclusion (RAP) materials as well as the best scenario of inclusion such materials. Based on the funding of this study, it can be concluded as follows:

- The best percentage of incorporating RAP of Fallujah depends on deformation resistance test is 40% is without again considering RAP as black rocks by using Dora bitumen and to manufacture a base layer, which is better than that of the reference value by about 57.8%.
- The best percentage of inclusion RAP materials of Karbala based on deformation resistance test is 40% without considering RAP as black rocks by using Dora bitumen to manufacture asphalt mixture a base layer, which is better than that of reference value by approximately 68%.

In general, the following points are recommended;

- laboratory results conducted to evaluate the performance asphalt mixtures confirm that RAP materials should not be considered as black rocks.
- In terms of resistance to deformation, 40% of RAP materials can be used safely in the mixture of base layer with a positive potential without considering RAP as black rocks.
- The inclusion of RAP materials in asphalt mixtures can be increased more than 40% without affecting the mechanical properties, provided that the optimum bitumen ratio is adequately set.

References

ABD, D. 2017. *Characterisation of Warm Asphalt Mixtures with Addition of Reclaimed Asphalt Pavement Materials.* PhD, University of Liverpool.

ABD, D. M., AL-KHALID, H. & AKHTAR, R. J. J. O. M. I. C. E. 2018. Novel methodology to Investigate and obtain a complete blend between RAP and virgin materials. 30.

ASTM-D2726 2012. Standard test method for bulk specific gravity and density of non-absorptive compacted bituminous mixtures.

ASTM-D3203 2017. Standard test method for percent air voids in compacted dense and open bituminous paving mixtures.

ASTM-D6926 2010. Standard test method for marshall stability and flow of asphalt mixtures. *Annual Book of ASTM Standards*.

HASAN, E. 2012. *Assessing performance of recycled asphalt concrete sustainable pavement.* University of Baghdad.

ISMAEL , A. D. 2018. Evaluation of Cold Asphalt Emulsion Mixtures (CAEMs) With Different Percentages of Recycled Aggregate.

KANDHAL, P. S. J. J. O. T. A. O. A. P. T. 1997. Recycling of asphalt pavements-an overview. 66.

KIM, K. W., AMIRKHANIAN, S. N., KIM, H. H., LEE, M. & DOH, Y. S. 2011. A new static strength test for characterization of rutting of dense-graded asphalt mixtures. *Journal of Testing and Evaluation,* 39**,** 59-68.

KIM, K. W., CHOI, J. S., YOO, M. Y. & KIM, H. H. 2010. An Approach to Characterization of High Temperature Deformation Resistance of Asphalt Concretes using SD and FCWT. *Proceedings, 11th ISAP, Nagoya, Japan***,** 8.1-5.

KIM, S. G., LEE, S. J., LEE, S. J. & KIM, K. W. Evaluation of rut resistance of polymer-modified

asphalt concretes. Advanced Materials Research, 2013. Trans Tech Publ, 282-288.
MCDANIEL, R. S. & ANDERSON, R. M. 2001. Recommended use of reclaimed asphalt pavement in the Superpave mix design method: technician's manual. National Research Council (US). Transportation Research Board.
MIRó, R., VALDES, G., MARTíNEZ, A., SEGURA, P., RODRíGUEZ, C. J. C. & MATERIALS, B. 2011. Evaluation of high modulus mixture behaviour with high reclaimed asphalt pavement (RAP) percentages for sustainable road construction. 25**,** 3854-3862.
MOHAMMED , H. H. 2019. Assessment of Sustainable Modified Asphalt Paving Mixtures.
OLIVER, J. W. 2001. The influence of the binder in RAP on recycled asphalt properties. *Road Materials and Pavement Design,* 2**,** 311-325.
PRADYUMNA, T. A., MITTAL, A., JAIN, P. J. P.-S. & SCIENCES, B. 2013. Characterization of reclaimed asphalt pavement (RAP) for use in bituminous road construction. 104**,** 1149-1157.
SHINGLES, R. A. 2014. Application of reclaimed asphalt pavement and recycled asphalt shingles in hot-mix asphalt. Citeseer.
TABAKOVIĆ, A. 2013. Recycled asphalt (RA) for pavements. *Handbook of Recycled Concrete and Demolition Waste.* Elsevier.
WILLIS, J. R. 2014. Life-cycle assessment of 2012 NCAT pavement test track green group mixtures.
ZAUMANIS, M., MALLICK, R. B., FRANK, R. J. R., CONSERVATION & RECYCLING 2014. 100% recycled hot mix asphalt: A review and analysis. 92**,** 230-245.