

Use of Reclaimed Asphalt Pavement in Puerto Rico

Pamela Díaz Martínez

Master of Engineering in Civil Engineering

Christian A. Villalta Calderón, Ph.D.

Civil and Environmental Engineering and Land Surveying Department

Polytechnic University of Puerto Rico

Abstract — *This paper is an investigation of the use of recycled pavement in Puerto Rico. RAP or Reclaimed Asphalt Pavement is the pavement material extracted from existing roads and recycled by introducing it as part of new asphalt mixes' materials. The introduction of RAP on asphalt mixes is a practice used by the United States of America (USA) several years ago. Nowadays the USA is implementing the use of high percent of RAP in their asphalt mixes allowing the 30 and 40 percent or more, of RAP in some states. At the meantime, Puerto Rico has a maximum percent of RAP allowed of 20% on certain asphalt mixes. But the production of asphalt mixes on the island still falls under this percent for state projects, making the implementation of RAP in Puerto Rico too low in comparison with other states. This investigation pretends to find out the reasons why the asphalt industry on the island is not moving forward on the use of RAP, and bring some recommendations which could help to impulse the production of high RAP mixes.*

Key Terms — *RAP, Reclaimed Asphalt Pavement, Recycle Asphalt, Puerto Rico.*

INTRODUCTION

Reclaimed Asphalt Pavement, known as RAP, is the asphalt pavement which is removed from existing roads or parking lots as part of pavement rehabilitation projects. This pavement is ripped off thru the process of cold milling and is then transported and stored on stockpiles. Usually it can be used as filled material, to make paths for equipment, stationary areas, and repair potholes, among others. But after this pavement material is processed, usually crushed into a single size, it can be re-used on asphalt mixes as a material which contains valuable asphalt binder and aggregates;

reason why since the early 90's RAP have been incorporated as part of the materials used in new asphalt mixes. This material is introduced as an aggregate on the design and production of hot and warm asphalt mixes, bringing economic and environmental benefits to the asphalt industry, the states, and the commonwealth.

RAP Benefits

Among the benefits the use of RAP brings to the environment, the most important could be that substituting the virgin aggregates of the asphalt mix for RAP, allows less impact to the earth crust. The exploitation of the earth crust for the extraction of virgin aggregates can be reduced with the use of RAP, which could also elongate the service life of several pits and quarries. The use of RAP also reduces the amount of landfill used to waste or store this material. After the contractor performs the cold milling, the generated material (RAP) turns into property of the contractor in the majority of the states (including P.R.), as seen on Figure 1 [1]. This makes the contractor responsible for this material's storage or disposal. Usually they transport the material to their own terrains and store it on huge stockpiles as shown on Figure 2, for a long time until somebody needs it for the purposes mentioned above. Contractor can pay for its disposal, or nowadays they can sell it to a landlord which processes it and sells it back as RAP (not in P.R.). This material is occupying landfill space and sometimes can represent a storage problem to the contractors which do not have a lot of space on their plants. Using this material reduces the space and occupied landfill problem.

The economic benefits that the use of RAP brings to the asphalt industry can include transportation and disposal savings for the material

generated thru milling and the savings they have in substituting virgin aggregates for RAP. This material is basically free for them and when it is introduced into the mix, it contributes in its majority with the fines aggregates and with a percent of binder in the mix. Considering that these two are specifically the most expensive materials needed for asphalt mixes, the economic contribution that this material produces to the asphalt industry is well valuable. These advantages allow the asphalt contractors to have more competitive prices which result on benefits for the state and the commonwealth.

are incorporating higher percent of RAP on their mixes.

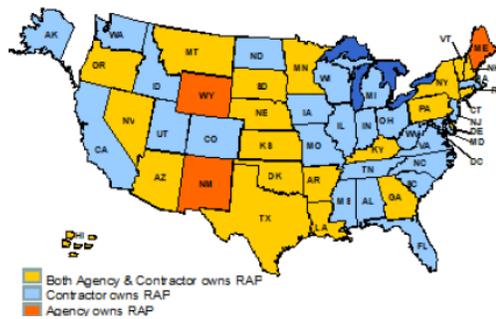


Figure 1
Ownership of RAP by State Highway Agency



Figure 2
RAP Stockpile

JUSTIFICATION

After evaluating the benefits that the RAP can bring, Federal and State agencies have been encouraging the use of RAP on new asphalt mixes thru investigation, analysis, technical recommendations and specifications, and even by law. In the last years, 2007 to present, as seen on Figure 3 [1] number one is the reference? Below, the percent of RAP reused or recycled into new asphalt mixes have been increasing and more states

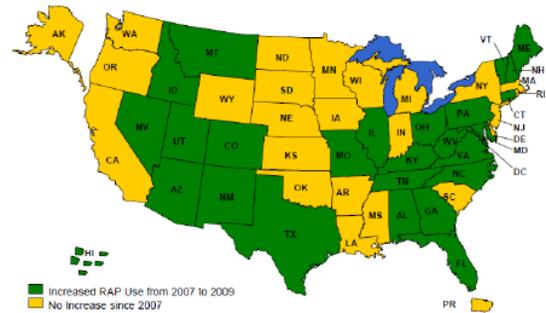


Figure 3
States with Increase RAP Use Since 2007

Puerto Rico is one of the states looking to increase the percent of RAP actually used on their asphalt mixes. Even there are local asphalt mix designs with 20% of RAP already approved, and a recent law staying that 20% RAP shall be used on asphalt mixes, this mix and higher percent RAP mixes still have not reach the production stage on the island. While at the same time, other states, as shown on Figure 4 [1], are already repaving roads with 20% and more percent of RAP in their mixes.

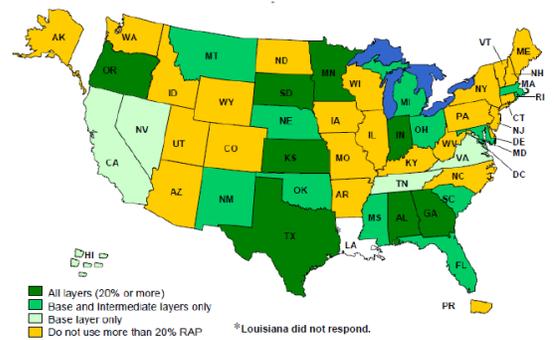


Figure 4
States that Use more than 20 percent RAP in HMA Layers

METHODOLOGY

Looking for the reasons why Puerto Rico is still caught using just from 5% to 15% of RAP on their asphalt mixes, this investigation takes place. A set of questions was developed to interview and visit the facilities of the three main companies of the asphalt industry on the island. The agency or state sector as the Puerto Rico Highway and Transportation Authority and the Puerto Rico

Division of the Federal Highway Administration were also consulted and interviewed. Puerto Rico's and other states' specifications, regulations, practices and recommendations regarding the use of RAP were evaluated and compared. All of these, including some studies and publications, were evaluated in order to determine in which stage is Puerto Rico planted regarding the use of RAP, and compare it with other states; which are the limitations that do not allow this island to advance in the production of mixes with 20% or more of RAP; and what should be done in order to move forward to the use of 20 or higher percent of RAP on asphalt mixes.

STATUS OF RAP IN PUERTO RICO

According to the interviews made to the private and public sector, between the late 90's and beginning of the 2000's the asphalt industry made the approach to the state and the transportation department in order to start using Reclaimed Asphalt Pavement on their mixes. This was driven in part by industrial funds available for the use of recycled materials on the construction industry. Since those days, the Puerto Rico Highway and Transportation Authority started to modify their specifications in order to allow some percent of RAP on asphalt mixes. By 2002 the PRHTA Specifications allowed 5% of RAP on surface asphalt mixes and a 10% on asphalt mixes used as base. But the use of RAP on the mixes was optional to the contractor. It is understood that these were the percentages the industry was capable to introduce on their mixes by that time. After this, some new technologies on the asphalt industry took place. These are the Superpave, the Warm Mix Asphalt (WMA), and the Rubber Asphalt. Specifications and projects were developed incorporating these new technologies on the island pavements. Federal Funds were assigned for Superpave asphalt projects, imposing this technology over the others. Eventually majority of the projects were specified again as HMA (Spec

401) and some were specified with Warm Mix Asphalt (WMA).

Technical Specifications

Up-to-date technical specifications [2] for pavement projects on the island still include the use of RAP as optional to the contractor and the maximum percent of RAP allowed depends on the kind of mix. [3] Supplemental Specification 401-Hot Plant Mix Bituminous Pavement (Rev. 2009) together with [4] Supplemental Specification 703-Aggregates (Rev. 2009) allows the use of a maximum of a 10% of RAP by total weight of mix in surface courses and a 15% of RAP on base and leveling courses. For Warm Mix Asphalt Pavement, [5] Special Provision- Specification 962 (2011) states a maximum of 20% of RAP by weight of total mix. As mentioned, and as the majority of the states, [6] Specification 403- Cold Milling of Bituminous Concrete Pavement, establishes that the pavement material removed from the cold milling of rehabilitation projects becomes property of the contractor.

Legislation

A recent law establishes that RAP shall constitute the 20% of the total asphalt to be used on state highways pavement projects. [7] This is the Law #114 of the 2014, known as the "Law for the use of recycled materials on the public infrastructure of the Commonwealth of Puerto Rico". It establishes the percent of RAP that should be used on asphalt mixes among other recycled materials used for the construction industry.

For the use of RAP, it just established a 20%, no more, no less, which at the mean time restricts any further advance in the use of this technology. Just with this fact it can be said that the development of this law never considered any technical aspect of the design and production of asphalt in the island. And in fact it did not even considered the state's current specifications which still fall behind the percent of RAP required by this law. There is no asphalt or aggregate study made in Puerto Rico in order to determine the percent of

RAP established. Not even the characteristics of the RAP available in the island were taken into consideration. All of these lead into faulty policy legislations that after being approved, they realize that they cannot be implemented as they said. The law even said that it will come into force 90 days after its approval, time which is not sufficient to develop mix designs or change the specifications, because these are matters that should be based on technical investigations, trials, performances, among others.

Asphalt Industry

Asphalt producers on the island have several years of experience on the investigation, design and production of mixes with Reclaimed Asphalt Pavement. The company that have been working for more time on this matter has around 15 years of experience on RAP, while the one with the less experience with RAP has around 5 years. Asphalt producers have already developed asphalt mixes designs including 10%, 15% and 20% of RAP. Two of these three asphalt producers have all of their mix designs with RAP approved by the PRHTA. But for state's pavement projects they are still producing asphalt mixes with up to just the 15% of RAP as the specification allows for hot plant mixes. One of the difficulties that asphalt producers might have is the requirement that establishes that PRHTA personnel must be present during the mix designs process. This consequently limits the time that the contractors can invest on these tasks.

Just one state project, a pilot project requiring complying with law #114 has been developed. The project was auctioned at the end of 2014 and comprehends the pavement rehabilitation of PR-613 from km 0.0 to km 6.1 in the municipality of Utuado. With this, one of the asphalt companies moves to the production and placement stages with their 20% RAP mix design on a state project, but this was the only one. Approximately 5,200 tons of surface and base asphalt pavement with 20% of RAP were deposited, complying with all testing

and quality requirements under hot mix asphalt specifications.

All of the main asphalt producers in Puerto Rico had sufficient RAP available at their yards; all have bought the equipment to process the RAP at one size, and all have made the adjustments needed in some of their plants in order to introduce the RAP into the mix. Mentioned adjustments include the incorporation of a crushing machine to crush the RAP into a single size, and the introduction of a new bin (as the one shown on Figure 5) on the assembly line in order to incorporate the RAP material. This bin has a screen that only allows material pieces of a specific nominal size and a conveyor which transports the screened material into the asphalt plant drum where all materials mix together in order to produce the final asphalt mix. Depending on the type of drum that the actual plant has, addition of a new drum could be needed in order to allow virgin aggregates to be dried and heated on one drum and then mixed with the asphalt binder and the RAP on the other drum.



Figure 5
Additional Bin for RAP at Plant

RAP material cannot be introduced in the drum where virgin aggregates are dried and heated, this could produce hydrocarbon emissions because it will burn the asphalt binder on the RAP and can affect the quality of the aggregates on RAP already oxidized by its initial process and its use on the original pavement. This is why the RAP shall be introduced in the mix at ambient temperature, which when mixed with the hot virgin aggregates, by the heat transfer, it considerably drops the mix temperature which is not good for the mix. All of

these entail to raise production temperatures over 30 to 40 degrees Fahrenheit more than normal, and overheating the virgin aggregates so that when they mix with the RAP, the mix temperatures can stay as required, and the binder can cover well all aggregates. To avoid that the quality of the virgin aggregates is affected by this over heat, anti-oxidant additives may be used on the mix. Temperature raises on production plants should be controlled; any plant equipment on the production assembly has its own temperature resistance limitation. As an example, a fire could be produced by these high temperatures on the baghouse which is the place where the bags or fabric filters used to control the dust generated during asphalt production are located. All of this means that the need of temperature raisings could be a limitation on the implementation of higher percent of RAP on the asphalt mixes production. But asphalt producers on the island assure that their plants are able to rise at least up to the temperatures needed to produce mixes with 20 to 30 percent of RAP. Beyond that, some adjustments on the plants and/or the use of additives which allow asphalt production at lower temperatures will be needed.

These additives are the ones used for the warm mix asphalt technology which is a technology already available on the island. These are chemical or organic additives that are incorporated either on the asphalt mix or directly into the binder, and allow the production of asphalt mixes at temperatures from 30 to 120 Fahrenheit degrees lower. This technology has the benefit of reducing the energy production costs and the emissions to the environment because of the reduction in temperature needed, among other benefits as the better working conditions and that during placement, the mix reaches its compaction with less time and effort. This is why it is said that warm mix technology is the perfect combination for the use of RAP and higher percent of RAP on asphalt mixes. But the costs of these additives are considerable, not allowing the asphalt producer to reduce its prices as much as expected for the lower energy consumption.

However, there is a technology to produce warm mix asphalt. It is the Foaming Technique in which the only additive to be used on the mix is water, making this technology one of the most cost effective forms of WMA production. In fact, in the United States, 95% of the Warm Mix Asphalt is produced with the foaming technology. Different methods to introduce small amounts of water into the hot bitumen are used. Reference [8] shows that “under the direct method of foaming, a small controlled amount of water is introduced to hot bitumen via a foaming nozzle which results in a large but temporary increase in the effective volume of the binder, which then facilitates coating at lower temperatures. Later, at cooling, the binder reverts to normal as the amount of water is insignificant.” In order to use this technique, some modification is needed on asphalt plants, but the technology for doing these modifications is already available at the island. The inconvenient to move to the use of this technology is that the Puerto Rico Highway and Transportation Authority Specification 962 (Rev. 2011) for WMA along with Specification 401-10 do not allow the use of foaming as an additive to produce WMA. Modification of this specification to allow the use of foaming on asphalt mixes can help a lot in the implementation of warm mixes and even more in the production of asphalt mixes in the island, with the 20 or higher percent of RAP.

Another challenge that asphalt producers have in order to elevate the percent of RAP in their mixes, is the quality of the RAP available nowadays in the island. The material that is accumulated and available today as RAP is the product of asphalt mixes that were produced 15 years ago or more. And by that time the asphalt mix design and production was different than nowadays. Before the year 2000, asphalt mixes had a lot of fine aggregates, even mixes with approximately 50% of fine aggregates could be found. Fines can be good for densification and voids consolidation, but too much fines affect the quality of the mix. It increases the presence of humidity that could be in the mix and difficult the dust control on it. The

control of dust in asphalt mixes is very critical since it is one of the items evaluated by specification requirements for payment adjustments to contractors. Under PRHTA Specification 401, the control sieve #200, which is the one regarding dust material, has a tolerance of just +/- 3. If the dust material on the asphalt mix falls out of the parameters established in the Job Mix Formula for more than 3, automatically a reduction of the 50% is applied on the contractor payment. Another fact that difficults the dust control on asphalt mixes is the quality of the aggregates in the island. Quarries sell their aggregates with a lot of dust because they do not wash their aggregates. In Puerto Rico, unlike other states, the quality control of the aggregates is responsibility of the asphalt producer. It is the asphalt producer the one that has to wash the bought aggregates in order to have a better control of dust in their asphalt mixes production. This is an additional step to consider in the production of asphalt mixes with RAP, and even more to be able to produce with higher percent of RAP (20% or more).

Knowing that these factors are affecting the dust control in Puerto Rico's production of asphalt mixes with RAP, more effort should be put from all sectors on the study and analysis of the RAP and aggregates available in the island, in order to obtain better knowledge of its characteristics and behavior. A better understanding and knowledge of these could lead to reevaluate the equipment, procedures, additives and even the requirements and specifications used so far. Modifications to all of these can be made in a way they can suit the reality of the material conditions available in the island. If a 20 percent or more of RAP on asphalt mixes is wanted to be implemented on projects, some specifications requirements and tolerances may be changed in order to adapt them to what is really available in the island. But this should not be done without backup studies, and analysis of the RAP and aggregates materials and its performance as mentioned before.

Nowadays asphalt contractors only produce the asphalt mixes with 20% of RAP for private and

municipality projects. These include private projects as the road facilities inside housing developments, parking lots and minor municipality roads where the mentioned strict requirements do not apply. But even new state projects are not specifying or requiring the 20% of RAP on asphalt mixes as law #114 establishes. The few existing new asphalt state projects' still follow the PRHTA specifications where the use of RAP is still optional to the contractor and which establishes lower percent limits of RAP. This may be because these state projects are been financed by federal funds and when this happens, local laws not necessarily apply. In this case, federal laws have a major force. At present, Puerto Rico's local economy is in crisis, the government is in huge debt and has no money for rehabilitation or new construction projects. This is another obstacle for the development of RAP and other new technologies in the construction sector.

The lack of new projects financed by the state is another challenge for the production of asphalt mixes with 20% of RAP. If there are no projects, there is no market for the asphalt producers to implement their mixes designs with RAP. There are no incentives from the state for the use of RAP, neither economic nor by projects requirements. As mentioned before, the few existing projects are not requiring the use of RAP, not even the 20% established by a state law.

Even knowing that local asphalt producers are experimenting the economic benefits of the use of more RAP on their mixes (most of their private projects), they are not taking the risk to produce it for state projects where specification penalize them for requirements that where established without taking considering local RAP characteristics and behavior. And they are not experimenting nor even trying asphalt mix designs with higher percent of RAP (>20%) because there is no market for the 20%, even less opportunity would be for the 25% or more where additional quality control strategies should be taken into consideration. There are no projects to implement the asphalt mixes with the 20%, so contractors are not going to invest in the design of mixes with higher percent of RAP,

neither in the quality control and plant modifications that they should implement in order to produce it.

Contractors are willing to produce and design mixes with 20% and more of RAP because they are benefiting economically with the savings the use of this material produces. With the percent of RAP used nowadays they have reach to save up to 20% of the mix costs. Because RAP not only substitutes some of the mix aggregates; it substitutes in its majority the fine aggregates which are the more expensive and they are in short supply on the island; and it not only brings asphalt binder to the mix, the amount of RAP introduced on the mix does not absorbs binder which leads to lesser new binder needed for the mix, knowing that this is the most expensive material on asphalt mixes.

To produce asphalt mixes with more than 20% of RAP, contractors need to invest in the additional quality control strategies and plant modifications. One of the quality control strategies they are very conscious and in agreement with, is the fractionation of RAP into different sizes. Nowadays contractors are fractionating to one size only. For multiple fractionations, the additional investments needed include new equipment, plant modifications and more space. Also software updates or new ones may be needed in order to operate the plant. Before investing on these changes contractors are asking for new or modified specifications that adjust more to the reality of RAP and aggregates in the island. These are: less rigorous specifications on payment adjustments and penalties when using RAP; projects that open up the market in which they can produce and place their mixes; and incentives that motivate them to take the risks for the implementation of higher percent of RAP in their mixes.

USE OF RAP IN OTHER STATES

As in Puerto Rico, some other states are struggling with the implementation of higher percent of RAP on their asphalt mixes. Even that in general, [1] DOT specifications bring the

opportunity to implement an average of 30% of RAP, the average percent of RAP use in the USA is approximately 12%. And the most common challenges to increase the use of RAP are the DOT Specifications' limits, the lack of processing, lack of RAP availability and past experiences. Nowadays RAP mixtures must comply with the same specifications used for virgin mixtures because states usually do not have additional means of acceptance.

The two major concerns of mixes with higher percent of RAP are the quality of the blended virgin and RAP binders, and the stiffening of the mix, which could lead into a cracking material. However, multiple performance tests have been made to pavements using from 10 up to 50 percent of RAP across the United States, including the FHWA, NCAT, California DOT, Florida DOT, among others. The studies where developed on pavements from one year old to approximately 17 years old, and basically all conclude that the performance of pavements with virgin aggregates versus pavements using RAP and high percent RAP do not have significant differences. RAP pavements can perform well and satisfactory as virgin pavements if designed properly.

As mentioned, some other states have already moved to implement on their specifications the use of 20% of RAP or more as shown on Figure 4. For example, [9] Georgia Department of Transportation Specifications allowed the use of up to a 40% of RAP, [10] Texas DOT is allowing a 30% of RAP by specification. From these and other states which are encouraging the production of asphalt mixes with high RAP percent, some recommendations for best practices have been developed [1]. The best practices on these states recommended to produce good quality asphalt mixes include: fractionation of the RAP, sampling and testing the RAP material, properly characterization of the RAP, selection of a softer asphalt binder grade for mixes with 25% or more of RAP, implementation of programmatic sampling and testing of mixture during production to verify mixture design assumptions, among others. Additional good practices that the majorities

on the asphalt industry are not following include: the separation of stockpiles of different sources because classifying the stockpiles requires a lot of space, and minimizing the moisture in RAP stockpiles.

Some of the mentioned good practices for higher RAP implementation are being followed in Puerto Rico, but some of them are not. For example, contractors are characterizing the RAP properly. Even when this requires sending the material to the U.S.A, they are fractionating at least at one size, washing the aggregates, among other practices mentioned. But asphalt producers are not classifying and separating the stockpiles by source, neither minimizing the moisture on RAP stockpiles by means of covers or sloped surfaces to aid draining moisture, among others. So better effort to follow more of the mentioned best practices recommendations shall be done by asphalt producers on the island, in order to maintain optimum quality standards on RAP and higher RAP asphalt mixes.

CONCLUSIONS

Puerto Rico is a small island with limited space and resources, reason why the state and industry should move forward to the use of recycled materials. Taking into consideration PRHTA data from year 2010 thru 2014 as seen on Figure 6, an average of approximately 500,000 Tons of asphalt mix are deposited on the island each year. If 20% of this asphalt could be recycled asphalt, it can be said that Puerto Rico could be recycling approximately 100,000 Tons of asphalt material per year.

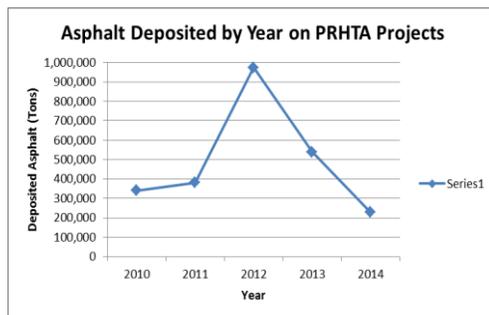


Figure 6

Asphalt Tons Deposited on the Island Yearly

The island, as many other states, is trying to implement the use of more RAP on new asphalt mixes and have had some progress, but there is a long way to go. Progress in the percentage of RAP used has reached only to the 20% in mix designs, but production of asphalt mixes with 20% of RAP has taken place just in the private sector. Main limitations for this are summarized next:

- Contractors understand that actual technical specifications are too strict under the payment parameters and tolerances of dust and volumetric gradations, considering how much a 20% or more RAP could affect these parameters.
- Time restrictions imposed by the state during the asphalt mixes design phase.
- Quality of the aggregates in the island.
- Quality of the RAP available nowadays in Puerto Rico.
- Temperature limits on asphalt plant equipment.
- Warm Mix technology restrictions under specifications.
- Faulty policy legislations.
- Economic situation of the island in the last years.
- There is no market or incentives for the use of RAP in the island.

Based on this investigation and its conclusions, the following are recommendations to consider in order to push forward the production of that approved mix design with 20% RAP for state projects, and the design and production of mixes with higher RAP percent:

- Amendments of Law and regulations based on technical studies and analysis. Revision of the existing law for all parts or amendment of it based on technical analysis on the island.
- Based on local technical analysis and results, consider the modification of certain parameters and tolerances for mixes designs with 20% or more of RAP.
- Make the use of specific percent of RAP mandatory by specification, not optional.

- Contemplate the possibility to add the Foam Technology for Warm Mix Asphalt under Specification 962.
- Quality Control of the aggregates, use wash aggregates.
- Keep RAP stockpiles classified and minimize moisture accumulation.
- Creation of incentive for the use of RAP on asphalt mixes including economics and by requirement.
- State should separate funds for asphalt projects with specific RAP percent; create the market.
- Performance analysis over time of the projects where 20% of RAP was introduced on the asphalt mixes.

REFERENCES

- [1] A. Copeland, "Reclaimed Asphalt Pavement in Asphalt Mixtures" in *Office of Infrastructure Research and Development FHWA*, McLean, VA, Rep. FHWA-HRT-11-021, 2011.
- [2] *Standard Specifications for Road and Bridge Construction*, DTOP PRHTA, 2005.
- [3] *Supplemental Specification 401-Hot Plant Mix Bituminous Pavement*, DTOP PRHTA, 2009.
- [4] *Supplemental Specification Revision to Specification 703-Aggregates*, DTOP PRHTA, 2009.
- [5] *Special Provision Specification 962- Warm Mix Asphalt (WMA) Pavement- Marshall*, 2011.
- [6] *Supplemental Specification Revision to Standard Specification 403-Cold Milling of Bituminous Concrete Pavement*, DTOP PRHTA, 2009.
- [7] *Ley #114, Ley para el uso de Materiales Reciclados en Infraestructura Pública del Estado Libre Asociado de Puerto Rico*, 2014.
- [8] "The Use of Warm Mix Asphalt", EAPA, Brussels, Belgium, 2010.
- [9] *Standard Specifications Construction of Transportation Systems*, GDOT, 2013.
- [10] *Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges*, TDOT, 2004.