Implementation of Safety Edge and Warm Mix Asphalt Technologies in Puerto Rico and US Virgin Islands

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ABSTRACT

The Every Day Counts (EDC) program is a national initiative conceived by the Federal Highway Administration (FHWA) of the United States Department of Transportation (USDOT) designed to identify and deploy the latest technologic innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment. The Commonwealth of Puerto Rico, through its Department of Transportation and Public Works (DTPW), the Highway and Transportation Authority (HTA), and the Virgin Islands Department of Public Works (VIDPW) has identified several innovative initiatives to be considered for implementation in Puerto Rico and in the US Virgin Islands. This technical paper will describe the success stories associated with the deployment of two (2) of these initiatives, namely Safety Edge and Warm Mix Asphalt.

A description of the major components of the specifications that were developed and adapted to Puerto Rico and USVI conditions will be described. Furthermore, the statistical analysis and other pertinent findings of the effectiveness of the Safety Edge and Warm Mix Asphalt implementation in selected projects in the Puerto Rico state highway network and in Virgin Islands are also discussed.

The findings of experimental study comparing the effectiveness of the TransTech model Shoulder Wedge Maker and the Advant-Edge model Ramp Champ safety shoes, as part of the transition in implementing Safety Edge technology, are also discussed in the paper.

1.1 INTRODUCTION

The Federal Highway Administration (FHWA) designed and organized the Every Day Counts (EDC) initiatives with three different goals in mind: Shortening project delivery, improving the safety of our highways, protecting our environment. EDC is divided into two different categories **Accelerating Technology and Innovation Deployment** and **Shortening Project Delivery**. Within the first pillar, there are five initiatives that focus on the safety of highways and the sustainability of our planet, which are Adaptive Signal Control Technology, Geosynthetic Reinforced Soil, Prefabricated Bridge Elements Systems, Safety Edge and Warm Mix Asphalt.

The Safety Edge, one of the EDC initiatives, is aimed at improving the safety on highways. It is a simple initiative that could have overwhelming benefits. Changing to 30° the current vertical drop-off of pavement edges, which occurs when there are height differences between a paved road and the adjacent graded material has the potential to save many lives by providing a smooth transition for vehicles that are re-entering the roadway. Conventional paving techniques result in vertical or nearly vertical pavement edges, which can cause safety concerns when they are exposed. It is proven that drivers leave the paved road for many reasons, leading them to the vertical drop-off of the pavement edge. Some drivers may have the need to avoid a drunk driver or a roadway obstruction. Others drivers are asleep or distracted by a phone call, a text message, a GPS device, or even a passenger. Also, it is easy to leave the paved road when visibility is low. A driver who doesn't slow down before attempting to steer back onto the pavement can easily lose control of the car leading them to an accident. Research studies found that drop-off crashes are four times more likely to include a fatality than other types of crashes on similar roads.

Figure 1. Safety Edge angle at PR-184 Yabucoa, PR

According to the Fatality Analysis Reporting System (FARS 2009), from 33,808 fatalities that occurred on U.S highways, 53% were due to roadway departures. This statistic shows how vital it is for a vehicle to be able to re-enter the pavement safely. Without the Safety Edge, the vertical edge will be exposed to the drivers, which will create tire scrubbing by attempting to return to the road. The side of the tire may scrub along the drop-off and it often leads the driver to overcorrect with a greater steering angle than desired. The implementation of Safety Edge (figure 1) will provide a strong and durable transition for all vehicles that are particularly vulnerable due to their weight and size, such as smaller, lighter cars or motorcycles. Even at relatively high speeds, vehicles can return safely to the paved road smoothly and easily.

It is proven that the Safety Edge shoe (Figure 2) is easy to install and any maintenance crew of the asphalt producers can perform the installation procedure. The Safety Edge shoe is commercially available and it can be mounted as an attachment to the screed unit plate of the asphalt resurfacing equipment. Although generic devices that provide a 30° angled shape can also be used, they typically only cut the pavement into the correct angle, but do not consolidate the asphalt, which will leave the edge more open to breaking off. Changing the vertical drop-off of the pavement edge to 30° is an actual proven solution that requires minimal cost and time to the asphalt producers. Including the Safety Edge detail in the paving process is a proven countermeasure that can be implemented system-wide at a very low cost.

Figure 2. Safety Edge Shoe-TransTech: Shoulder Wedge Maker

Besides Safety Edge, EDC integrates initiative that helps with the sustainability of our planet. Warm Mix Asphalt (WMA) is a result of the addition of an additive (water-based, organic, chemical, or hybrids) intended to lower the temperature of the asphalt mix between 30 to 120°F lower that the conventional Hot Mix Asphalt (HMA). It first started as a European experiment between 1995-1996 as a measure to reduce greenhouse gas emissions, lower fuel consumption and reduced exposure of workers to asphalt fumes (WMA-Best Practices). Between 1997-1999, Europe constructed their first pavement using WMA. By 1995, Europe conducted their first experiments and in 1997 they constructed the first pavements in Europe (Brian D. Prowell, Graham C. Hurley). Since Europe already had test results on WMA, in 2002 NAPA decided to start the study tour to Europe (Brian D. Prowell, Graham C. Hurley) in order "to gather any information on technologies used to produced WMA" (WMA-European Practice), technologies such as: Aspha-min®, WAM Foam and Sasobit (WMA-Best Practices).

Later on, with the purpose of maintaining such practice, the Federal Highway Administration (FHWA) started a program with three primary goals in mind: Shortening project delivery, improving the safety of our highways, and protecting our environment. Such program took the name of Every Day Counts (EDC), in which WMA was included as an accelerating technology that will help to improve the conventional HMA. In order to produce WMA mixes, additives were added with the intention of reducing the viscosity of the asphalt mix, which will be helpful during the compaction and mixing of the material due to the lack of friction between the aggregates.

Figure 3. WMA Section, Yauco, PR

In addition to the viscosity reduction of the asphalt mix, WMA is proven to be efficient in certain areas of the paving process such as the ease of compaction of the paving mixture, paving in colder weather due to the decrease in the mix temperature, haul distances of the asphalt mixture are increased, a greater percentage of Reclaimed Asphalt Pavement (RAP) can be used and there is a significant reduction in roller compaction. Fuel and emissions reduction are also accomplished while improving the working conditions of the paving crew at job site. Also, it is know that the WMA offers a chance to the asphalt producers to improve the performance of the mix, the efficiency in which the roads are constructed and provides a better environmental care. Due to the benefits described above and as part of the implementation of the FHWA's EDC initiatives, the Puerto Rico Highway and Transportation Authority (PRHTA) has started implementing this technology in their projects.

1.2 SAFETY EDGE EQUIPMENT

The primary objective of the following experiment is to compare the effectiveness of the Safety Edge shoes, TransTech model Shoulder Wedge Maker and the Advant-Edge model Ramp Champ. The performance of each device was tested to verify the following attributes that each one of them have.

Figure 4. TransTech Shoulder Wedge Maker

Figure 5. Advante Edge Ramp Champ

Table 1. Safety Edge Shoes Comparison, TransTech: Shoulder Wedge Maker and Advant-Edge Ramp Champ

ID	Attributes	TransTech Shoulder Wedge Maker (SWM)	Advant-Edge Ramp Champ (RC)	Comments/Remarks
1	Adjustable angle	No. It has a fixed angle of 30°	Yes. The wedge can be adjusted from 5° to 30°	Current FHWA standard is set to 30°
2	Adjustable sides	No. It requires a match pair for each side of the paver	Yes. It has a removable shoe that allows it to be used on either the left or the right side of the screed unit of the paver	The adjustment process of for the RC requires technical skills
3	Edge profiles	No. Fixed Safety Edge profile	Yes. Creates a tapered Safety Edge or a longitudinal center lane joint	The RC contains a removable shoe that allows various edge profiles
4	Simple installation process	Yes. The installation process requires no technical training	Yes. The installation process requires no technical training	Each Safety Edge shoe requires a drill, standard bolts, nuts, and washers
5	Self-adjustable during paving process	No. Requires continuous adjusting for changing surface profiles	Yes. Designed to automatically follow the shoulder elevation	SWM: A trained technician is required at all times RC: The radial force cylinder component requires no technician
6	Weight	50 lbs. (Light)	115 lbs. (Moderate to heavy)	(www.transtechsys.com) (www.advantedgepaving.com)
7	Initial Cost	$4,200	$4,600	(www.transtechsys.com) (www.advantedgepaving.com)

1.3 SAFETY EDGE EVALUATION

In order to demonstrate the effectiveness and performance of both Safety Edge shoes, field tests were executed in Yabucoa, Patillas and Ponce, PR (Figure 6). To perform the evaluation, Betteroads Asphalt Corp. provided a Blaw-Knox paver for the installation of both Safety Edge shoes, which was carried out in one of the plants in Cayey, PR. The next phase in the evaluation of Safety Edge was to verify the integrity of the angle that will be created with both Safety Edge shoes in an experimental segment in the highway network in Puerto Rico.

Betteroads Asphalt Corp. selected two job site locations in Puerto Rico to perform a trial test and the first experiment to study the performance of both shoes.

Figure 6. Job site location of Safety Edge projets in Puerto Rico

The first trial test was conducted in the municipality of Yabucoa, PR in PR-182 with the purpose of comparing both Safety Edge shoe. PR-182 was design as a two lanes road, one in the westbound direction and one in the eastbound direction with an approximated Average Daily Traffic (ADT) of 8,922 (PRHTA). The Advant-Edge Safety Edge shoe and TransTech Shoulder Wedge Maker were tested with six dump trucks containing approximately 24.5 tons of asphalt mixture each one.

After the first trial test, the two devices were tested in the municipality of Patillas, PR in PR-184 between kilometer 5 and 7. Even though the project has two kilometers long, the Safety Edge shoes were tested in only one kilometer from 5 to 6. The PR-184 was constructed with two lanes, one in the northbound direction and the other one in the southbound direction having an approximate ADT of 12,170 (PRHTA). Betteroads Asphalt Corp. used almost 1,400 tons of asphalt from kilometer 5 to kilometer 7 to produce a layer of a thickness of 1.5 in. Density readings and slope measurements were taken on site every 10 meters for statistical purposes.

Figure 7. Slope measurement of 38.5 at PR-184, Patillas, PR

R & F Asphalt Unlimited Inc. was the responsible for executing the second Safety Edge shoe experiment inside their plant located in Ponce, PR. The same drilling procedure was applied to the installation of both Safety Edge shoes to the Blaw Knox paver (Figure 14) and mounted at the exact location as the first experiment conducted with Betteroads Asphalt Corp. R & F Asphalt Unlimited Inc. decided to conduct the Safety Edge experiment inside their facility in Ponce in order to demonstrate a Safety Edge angle of 30°. Cold wash sand with a 10% of humidity was used instead of an asphalt mix to perform a test trial with the Safety Edge shoes: Advant-Edge

Ramp Champ and the TransTech: Shoulder Wedge Maker. A surface layer of approximately 4 1/2" and 50' long was produced for each Safety Edge Shoe, which were installed in the screed unit plate of the paver. Temperature and Slope measurements were taken on site every 5 feet for statistical purposes. Photographs and videos clips were also taken to record the progress that was achieved during the experiment.

Figure 8. Slope measurement of 30.3 at R & F Asphalt Unlimited trial test

Heading to the next level to implement the Safety Edge technology, a third project was conducted in St. Croix, USVI with the help of Virgin Island Paving (VIP) and the contractor, which provided the paver for the Safety Edge shoe installation. The highway project was located in Route 70, Queen Mary Highway in St. Croix, USVI. The project located in route 70 in St. Croix (Figure 9), which was performed with the TransTech: Shoulder Wedge Maker, was the phase I of a section of the project with a total distance of 2.2 miles using the same mixture design Marshall having a total estimated cost of $4.9 millions.

Figure 9. Angle of 27.6 achieved at the edge of the road

1.4 STATISTICAL ANALYSIS OF SAFETY EDGE EXPERIMENTS

After experiment #1 with Betteroads Asphalt Corp. was conducted, the variables % compaction and slope of the edge were used to calculate descriptive statistics using the software Minitab 16, which was used to summarize the set of data that was taken at site. For the Shoulder Wedge Maker shoe (Table 2), a total of 18 measurements were taken in the northbound direction at PR-182 in Patillas, PR and for the Ramp Champ (Table 3) 8 measurements were taken in the southbound direction.

Table 2. Shoulder Wedge Maker descriptive statistic

Variable	Mean	Std. Dev.	Minimum	Median	Maximum
% Compaction (%)	93.49	0.98	92.3	93.3	95.1
% Compaction (%)@ 1 ft.	82.90	2.56	78.2	83.1	86.8
Slope (°)	25.8	5.69	13.8	27.15	36.4

The table above represents a TransTech SWM summary of the descriptive statistic of the set of data taken in Beteroads Asphalt Corp. experiment at PR-184 in Yabucoa, PR. By all means, it is proven that the TransTech SWM does not performed as it was built for, since the mean value of slope measurements was 25.8°<30°. The table below represents an Advant-Edge RC summary of the descriptive statistic. Like the TransTech SWM, it can prove that the Advant-Edge RC does not performed in this experiment as it was built for, since the mean value of slope measurements was 26.27°<30°, which is the target value for the edge.

Table 3. Ramp Champ descriptive statistic

Variable	Mean	Std. Dev.	Minimum	Median	Maximum
% Compaction (%)	94.31	1.29	92.60	94.10	96.0
% Compaction (%)@ 1 ft.	83.60	3.38	79.10	85.20	87.40
Slope (°)	26.27	5.21	16.80	29.00	29.80

A second experiment with Robles Asphalt was done with sand at 10% of humidity at their plant in Ponce, PR in order to test each Safety Edge shoe. A set of 11 slope and temperature measurements for each shoe was taken at a distance of 5 ft between measurements to calculate descriptive statistics of the data.

Table 4. Shoulder Wedge Maker descriptive statistic for R & F Asphalt Unlimited experiment

Variable	Mean	Std. Dev.	Minimum	Median	Maximum
Slope	29.04	1.04	27.40	29.10	31.20
Temperature	88.96	0.86	87.00	89.00	90.00

Table 5. Ramp Champ descriptive statistic for R & F Asphalt Unlimited experiment

Variable	Mean	Std. Dev.	Minimum	Median	Maximum
Slope	30.80	1.63	26.40	31.10	32.40
Temperature	88.91	0.83	87.00	89.00	90.00

2. WARM MIX ASPHALT EVALATION

A SUPERPAVE mix design was used in Puerto Rico Highway and Transportation Authority (PRHTA) PROJECT #200240 IN YAUCO, PR. This mix design consists of a SPS mix with a 1/2-inch Nominal Maximum Aggregate Size (NMAS), classified as a Coarse-Graded mix and designed for a Traffic Level #4 that included 0.65% by weight of binder of Wetfix 312 anti-stripping additive. APPROXIMATELY 23,500 TONS PLACED AND COMPACTEDTRAFFIC LEVEL #4. The test section consisted of two days of production of approximately 367 tons each day for a total of 736 tons of WMA.

Table 6. Summary table of test results of the mix design

Acceptance Parameter (Quality Characteristics)	Target	Average	Standard Deviation
% Air Voids	4.0	3.76	0.542
% Asphalt Content	6.2	6.08	0.208
% In-Place Compaction	94	94.14	0.533

Table 7. Temperature comparison

Type of Mix	Plant Temperature (^{o} F)	Field Temperature (^{o} F)
Control HMA	315	295
WMA	280	270

The following sampling and testing was conducted to perform a WMA test section for the control mix design used in the first project in Yauco, PR:

1. AASHTO M 320- Standard Specification for Performance-Graded Asphalt Binder
   - BOTH BINDERS GRADED OUT 70-22.
   - PRHTA REQUIRES THE USE OF EITHER PG 64-22, PG 67-22 OR PG 70-22.
   - TYPICAL BINDER GRADE PROVIDED IS PG 64-22.
2. AASHTO T 283- Standard Method of Test for Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage
   - 6 SPECIMENS PER MIX
   - COMPACTED TO 7% ± 0.5% AIR VOIDS
   - 150 MM DIAMETER AND 95 MM IN HEIGHT.
3. AASHTO T 324- Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)
   - 4 SPECIMENS PER MIX
   - COMPACTED TO 7% ± 0.5% AIR VOIDS
   - 150 MM DIAMETER AND 95 MM IN HEIGHT.
4. AASHTO TP 79- Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Hot Mix Asphalt: (HMA) Using the Asphalt Mixture Performance Tester (AMPT)
   - 12 SPECIMENS
   - SPECIMENS ARE 150 MM DIAMETER BY 170 MM IN HEIGHT.
   - FINAL REPRESENTATIVE SAMPLE IS OBTAINED BY CORING A 100 MM DIAMETER CORE AND SAWING TO A 150 MM HIGH SPECIMEN FROM THE GYRATORY SAMPLE.
   - THE SPECIMEN HAS TO BE AT 7% AIR VOIDS ± 0.5%.

After successfully completing the trial laboratory test and the WMA project in Yauco, PR, the following Specifications and document were develop for WMA:

1. Instruction to bidders allowing the Contractor the options of using WMA and/or GTR technologies in Marshall and SUPERPAVE mixes
2. Pre-approved list of WMA additives (PRHTA W 401-10)
3. Special Provision 962 (WARM MIX ASPHALT (WMA) PAVEMENTS) - Marshall Mixes
4. Special Provision 964 (WARM MIX ASPHALT (WMA) PAVEMENTS) - SUPERPAVE Mixes

5. Special Provision 960 (GROUND TIRE RUBBER MODIFIED ASPHALT CONCRETE FRICTION COURSES)

3. CONCLUSIONS

WMA test section lived up to expectation and produces results such as the reduction in heat, smoke and odor. There were better working conditions for employees at plant and field. Also a reduction in energy consumption (fossil fuels) and reduction in CO_2 emissions was noticeable. At the time of compaction the asphalt mix, the employees realized that less compactive effort required, due to this benefit it increased rate of laid-down and compaction. In term of the finish of the pavement, it shows a uniform mat texture and no tender zone effect observed.

By successfully completing the Safety Edge implementation plan in Puerto Rico and USVI the target of pursuing a initiative that is progressing positively as expected was achieved. Due to the different projects conducted between Puerto Rico and USVI, effective communications between PRHTA, VIDPW, FHWA, and PR-T2 Center officials has been a key factor for this success. Also the collaboration of asphalt paving contractors in Puerto Rico and USVI has been instrumental in the EDC implementation process and the exchange of knowledge and experience gained by undergraduate and graduate students from UPRM and Purdue University has motivated them to continue their professional career in transportation, does increasing the workforce in highway and transportation engineering.

4. AUTHORIZATION AND DISCLAIMER

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