Testing Terminal Blend Tire Rubber Asphalt Performance for Safety, Ride Quality and Cost in Colorado Springs, Colorado

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CITY OF COLORADO SPRINGS

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BEYOND ENGINEERING

City of Colorado Springs, Colorado Tests Terminal Blend Tire Rubber Asphalt to Improve Safety, Enhance Driving Conditions and Reduce Maintenance Costs

Like many cities across the nation, Colorado Springs, Colorado has faced a variety of complex challenges related to maintaining its roadways. Surging growth in population, escalating cost of materials, roadway safety and pavement life are issues commonly shared with other communities. However, Colorado Springs has two additional distinctive factors to contend with: climatic extremes, which impact roadway durability, and mandated limits on government spending enacted by voters more than a decade ago, impacting state and local government's ability to keep pace with growth.

Based on these complexities, the City of Colorado Springs Street Division determined that new thinking was required to determine how best to utilize resources in meeting both current and future demands. This led to the development of a plan of action to experiment with different paving materials to address these challenges. The first experiment implemented was the use of Terminal Blend Tire Rubber Asphalt (TBTRA).

A Growing City Leads to Growing Challenges

As the second largest city in Colorado, Colorado Springs has experienced a 51 percent growth in population since 1990, expanding from 281,740 to 426,535 people. It has also added approximately 1,500 lane miles of new roads for a total network of 4,710 lane miles of paved streets, a 32 percent increase. During the same time span, the City Street Division's workforce has been reduced by 14 percent, with significant decreases in the operating budget, despite inflation and growth.

Although the city has added preventive maintenance treatments, such as chip and slurry seals to its toolbox of roadway maintenance practices, the result of years of inadequate funding in its roadway infrastructure has become more and more obvious each year. Colorado's harsh winter of 2006 – 2007 highlighted the negative impact of continued deferred maintenance. The city's Pavement Management System suggests an average pavement quality index below 6.0, reflecting this degradation and requiring sustainable alternatives that will perform well under extreme and variable climatic conditions.

Funding Source

In November of 2004, the voters of four neighboring communities: the City of Colorado Springs, El Paso County, the City of Manitou Springs and the Town of Green Mountain Falls, approved the formation of a Transportation Authority known as the "Pikes Peak Rural Transportation Authority" (PPRTA). This authority collects a 1 percent sales tax that specifically funds capital improvement projects, roadway maintenance and expanded transit services.

Additional roadway maintenance funds provided by the PPRTA are allowing the city to expand its current pavement maintenance program, while giving the Street Division the opportunity to investigate different techniques to improve pavement surfaces and ride quality. The use of Terminal Blend Tire Rubber Asphalt is one such technique.

Product Research

Asphalt mixes modified with tire crumb rubber have been in use for decades on resurfacing projects in several states, including California, Arizona, Texas, Rhode Island, Connecticut, New York and

Maine. Significant information and research are available that address the benefits of tire rubber modified asphalt mixes; however, there is very limited experience with this product in the conditions found along Colorado's Front Range. Based on its successful use in other parts of the country, the city was extremely curious to find out how well tire crumb rubber asphalts would perform in Colorado Springs.

The City Street Division, along with Nolte Associates, began researching and developing specifications for the use of tire rubber asphalt for the 2006 paving season. Saleem Khattak, the Street Division Manager and Bob Syme, Nolte Pavement Manager, traveled to Arizona in the summer of 2005 to visit several projects using rubberized asphalts. A stop was also made at the Arizona Department of Transportation (ADOT), where they were introduced to the "wet", "dry", and "terminally blended" tire rubber asphalt manufacturing processes.

Prior to visiting Arizona, local Colorado Springs contractors expressed concerns about using the "wet or dry methods", due to the excessive smoke and smell that would be expelled into the atmosphere during the manufacturing process of this material at their asphalt plants. The contractors were so concerned about losing their state environmental certifications that they indicated they would not use the "wet or dry methods" without some assurances that their operating permits would not be jeopardized.

The Arizona DOT staff was able to explain the differences between the manufacturing methods. Khattak and Syme determined that **terminally blended** tire rubber asphalt could be the most efficient and environmentally-friendly option available and selected it for testing.

Technical Process - Terminally Blended Closed-System Manufacturing
TBTRA is produced in a closed-system plant which prevents particulates from entering the atmosphere. Raw tire crumb rubber is delivered to the processing plant. The tire crumb rubber is introduced into the SBS polymer-modified asphalt (70TR28) in a wetting vessel, where both products are precisely blended by weight with the use of computer-controlled scales. The material is then "cooked" for approximately 16 hours under great pressure at temperatures as high as 425 degrees Fahrenheit. This method of blending the materials produces a more consistent and smooth homogenous blend of tire crumb rubber, assuring the complete breakdown of the crumb rubber into the asphalt.

In the next step in the process, the Terminal Blend material is loaded into tanker transports and shipped directly to the contractor's storage tanks where the material is required to be heated to 325 degrees Fahrenheit and constantly agitated until it is ready to be introduced into the aggregates at the asphalt plant.

By contrast, in the "wet method", crumb rubber and asphalts are only blended for 45 minutes at 425 degrees Fahrenheit. The potential exists for the crumb rubber to fail to break down completely into a homogenous liquid form, which could jeopardize the quality of the final product. Also, because of the portable nature of the operation, large amounts particulates are released into the atmosphere during the manufacturing process.

Additional advantages of using the terminally blended process in lieu of the wet or dry methods at the contractor's plant include:

- No need for costly specialized equipment.
- No portable plants required for blending of crumb rubber with asphalts.
- No additional holding areas for storing the crumb rubber product.
- Easiest for the contractor to incorporate into their traditional manufacturing process.
- Completely eliminates potential problems with heating and blending of crumb rubber and asphalt products.
- Eliminates smoke and particulates from entering the atmosphere.

Percentage of Rubber

In the initial 2006 experiment, the City of Colorado Springs used a 10 percent content of crumb rubber in the TBTRA and will be using a 15 percent content in 2007. Both formulas will be monitored to assess potential advantages.

Aggregate Gradation Selection

The City of Colorado Springs was looking for a product that could be placed over existing asphalts, to achieve both a durable wearing surface, as well as provide a quieter and safer traveling surface. It was decided to use an "open graded" permeable friction course. This gradation (see below) provided an exceptionally smooth surface, which would also drain water quickly away from the surface, dramatically reducing the "splash back" of surface waters. The open graded mix also assisted in the reduction of noise created by vehicles. Arizona DOT testing has shown that the rubber, combined with an open graded mix has the ability to absorb or deaden certain frequencies sensitive to the human ear.

Target Voids 15% to 18%

The aggregates were crushed, screened and then washed to achieve the cleanliness required.

Advantages Over Traditional Dense Graded Asphalt Pavements

Smoother

- Extremely smooth surface finish due to the gradation of aggregates.
- Material is capable of filling in underlying surface irregularities ("self-leveling").

Quieter

- External noise found to be reduced by 3 to 4 dBA over existing asphalt surfaces (using 10 percent crumb rubber formulation).
- Perceived noise from inside the vehicle is also noticeably reduced.

Better Safety During Rain Storms

- Better drainage, less 'ponding' of water, reduced splash back, better visibility of pavement markings, and faster drying surface.
- Potentially better traction and skid resistance.

Storm Water Filter

- Studies performed by the University of Texas at Austin show that the concentration of roadway pollutants running into the roadside ditches were significantly reduced compared to storm water running off of a dense graded asphalt pavement. (*Source*: Dale A. Rand, P.E., Environmental Benefits of Permeable Friction Courses, Texas Asphalt Magazine, May 2007)

Production and Application of TBTRA Permeable Friction Course Material

Production of the TBTRA material at the asphalt plant matches the production of typical asphalt mixes, combining the aggregates with the terminally blended tire rubber asphalt in a continuous double drum mixer. No special equipment is necessary or required at the plant. Once the material has been properly mixed and heated it is transferred to a standard heated silo. No materials are allowed to be stored overnight in the silo. The material is then deposited into haul trucks for delivery to the jobsite the same day. Typically the material is heated to approximately 310 degrees Fahrenheit so that when it is discharged from the paving machine, it is a minimum temperature of 300 degrees Fahrenheit, five feet behind the screed on the paver.

When the material is deposited into the hopper of the paving machine, it has the appearance of a "flowing mass" instead of the typically stiff look of normal asphalt. The material also has a "sticky/gooey" appearance where it might spill out over the front of the hopper. This is the effect the tire rubber gives to this gradation of material.

When tying this material into existing asphalt surfaces or concrete cross pans it is important to create a proper “butt” joint to assure a smooth transition for traffic as well as protect the edge of the material from snow plows “hooking” the material and possibly tearing or pealing the material. This is achieved by milling a depth of 1.5 inches at the butt joint and tapering the milled surface back a minimum of 15 feet to 0 inches to create a smooth transition. Entrapment of moisture can occur at these butt joints but with a standard 2 percent cross slope on most streets, this moisture is confined to the outer edges of the roadway.

Prior to placement of the TBTRA it is imperative the surface is smooth, clean and completely dry for a minimum of 12 hours to assure proper bonding. If it rains, the operation should be shut down until the following day to allow proper drying of the surface. Power pickup brooms and kick brooms are needed to assure a clean surface is achieved. Butt joints require “hand cleaning” to assure no loose materials are packed next to the vertical joint. Once cleaned, the surface will require the application of a tack coat (SS-1h) at an application rate of approximately 0.20 gallons per square yard. The emulsion should be 60 percent emulsion to 40 percent water. Once the tack has broken, placement of the TBTRA can begin.

Paving Considerations

Typical paving equipment and traditional methods are used to place the TBTRA. A standard paving machine distributes the mix approximately 1.0 to 1.25 inches in thickness and from 8 to 12 feet in width. It is critical that the TBTRA be at a minimum temperature of 300 degrees Fahrenheit, five feet behind the screed of the paver, to assure proper spreading and compaction. Two, eight-ton, smooth drum static rollers are used to compact the material.

The first roller will make two static passes directly behind the paving machine, prior to the material cooling below 230 degrees Fahrenheit. The second static roller will make one final pass to assure all roller marks are eliminated. This final pass with the roller must be completed prior to the material surface cooling to 180 degrees Fahrenheit. It is imperative these temperatures are maintained during the paving operation to assure that proper bonding and compaction occurs. Awareness of the environment is essential, as ambient temperatures must be at least 70 degrees Fahrenheit and rising prior to placement.

Other Temperature Factors

Haul distances must be considered at each site and adjustments made at the plant to assure proper temperatures are achieved behind the paving machine. Shaded areas on the surface to be overlaid can cause the surface temperatures to drop as much as 40 degrees Fahrenheit compared to areas in direct sunlight! Wind will cause rapid cooling of the material and make it difficult to maintain proper temperatures when rolling the newly paved surfaces. These temperatures are required to be monitored on a continual basis using hand-held infrared temperature gauges. Two inspectors are required, one directly behind the paving machine and the other back with the final rolling operation, to assure proper temperatures are maintained at all times. All gauges must be calibrated each day by comparing all gauges to one another and assuring all gauges are within 2 degrees Fahrenheit of each other. If they are not within 2 degrees Fahrenheit of each other, the gauge indicating the lowest temperature must be used.

Cooling Intersections

When passing cross streets that need immediate access for traffic, the new pavement must be cooled to a minimum of 135 degrees Fahrenheit prior to allowing traffic to cross in order to avoid new TBTRA material from "sticking" onto the tires of the vehicles. This is achieved by the use of 1 to 2 water trucks with spray nozzles on the truck or with the use of a hose with an adjustable nozzle. A 0.7 percent solution of lime (by weight) may be mixed in with the water. The lime acts like a talcum powder and reduces the tackiness of the material. Areas that become wet with this solution, or even with plain water, cannot be paved over until the following day to assure the pavement is thoroughly dry. If it is not dry and material is placed over moisture, the material will not bond to the old surface.

Corners and Joints

When working in tight corners or narrow areas where the paving machine cannot place the mix directly on the surface, laborers can work the material with shovels as long as the temperature of the material is at least 270 degrees Fahrenheit. Above this temperature the material can be easily shoveled or raked into place. When temperatures fall below this mark, the material begins to stiffen, becoming impossible to move with any hand-held tools.

When beginning work the following morning, cold joints are achieved by a full depth, vertical cut with a flat saw through the previous day's material. Once a straight vertical cut is made, a backhoe is usually required to "peel off" the TBTRA material from the existing asphalt surface. This area is then cleaned with the front-end loader of the backhoe and the surface is "broomed" clean. After thoroughly cleaning this joint, a tack coat is required prior to the placement of new TBTRA material. Cold joints, during daily paving operations should be avoided as much as possible. If, for example, a turn lane requires an overlay, the contractor may try stopping the mainline paving operation for a very brief time and leave a small pile of new TBRTA material (approximately 2 feet in depth) while paving the turn lane. When the paving machine returns to the small pile, it is required to maintain at least 250 degrees Fahrenheit in order to create a smooth joint, avoiding a vertically saw-cut joint. If the material is below 250 degrees Fahrenheit, removal of the pile will be necessary. Usually there is enough temperature at the existing surface to allow the contractor to continue paving operations.

One type of cold joint *not* allowed is a "thin lift" cold joint, where the paving machine spreads whatever remaining material is in the hopper into a thin layer by lowering the screed to the thickness of the aggregate. Two problems occur: First, the screed can and normally does partially crush the aggregate, loosing the asphalt coating; and second, it is very difficult to lay another lift of TBTRA on this surface and achieve a smooth finish, since your total thickness is only 1 to 1.25 inches.

Hauling

Hauling of the TBTRA material is accomplished with normal smooth bottomed trucks in various sizes. One type of trailer that can have difficulties is a flowboy. These trailers have continuous belts that pull the material to the end of the trailer bed, depositing it into the paving machine. The problem incurred with this type of trailer bed is that the TBTRA material is exposed to cool air along the edges of the continuous belt and will start to solidify toward the rear of the bed. Small pieces of the cooled material will break off from the bed of the truck and pass through the paving machine and become lodged below the screed, creating small ditches in the newly placed mat. This in turn requires the contractor to stop the paving machine while the crew hand carries additional shovels full of material to "fill in" the small ditches, reducing production rates and compromising quality. When the haul trucks are finished dumping their loads into the paving machine, they must "clean their tailgates" in an area not receiving an overlay. This waste material will harden and create problems in the new mat, as it will be solid by the time the screed passes over the discarded material.

Testing

It is imperative to have qualified testing staff and a lab available at all times during paving operations. After the mix design has been created it is important to stay strictly within the limits of the gradation and asphalt content of the design. Gradations are checked a minimum of twice daily, once after the third load is dispensed from the silos, and then again approximately half way through the day's paving. This is accomplished with the use of an ignition oven, which can verify gradation as well as the asphalt content.

This test takes approximately four hours to run, and for this reason, the asphalt content needs to be verified more frequently by the use of a nuclear asphalt content gauge. This test only takes about 15 minutes and is very consistent and accurate due largely to the "clean" gradation of the mix. This test is usually taken four times daily at equal intervals of time during the day's paving. If the asphalt content is too low, the material will appear dull in color and have an appearance of "pulling or tearing" from under the screed of the paving machine. If the gradation becomes "dirty" (200 sieve is higher than 3 percent), you will see small "splotches" on the surface of the mix and small "globs" of material pealing off the smooth drum of the rollers. These are simply the fines attaching themselves to the rubberized asphalt. Again, it is imperative that both the gradation and asphalt content are monitored closely to assure the final product is both consistent and of good quality.

Colorado Springs Test Sites

In 2006, the testing of TBTRA began. Approximately 5 miles of arterial/collector roads that were originally scheduled to receive a traditional dense-graded overlay application were instead overlaid with terminally blended tire rubber asphalt. The four sections of roadway selected support different degrees of traffic and were treated with various combinations of milling, crack sealing and overlay techniques.

The first area selected was Wooten Road between Platte Avenue and Galley Road. This is a four-lane, industrial roadway section with low traffic volume. Wooten Road was divided into two sections, the first section, approximately 1,500 feet, was milled and overlaid with 1.5 inches of traditional Grading CX (0.5 inch) mix with a 1 inch layer of TBTRA placed on top of the newly resurfaced roadway.

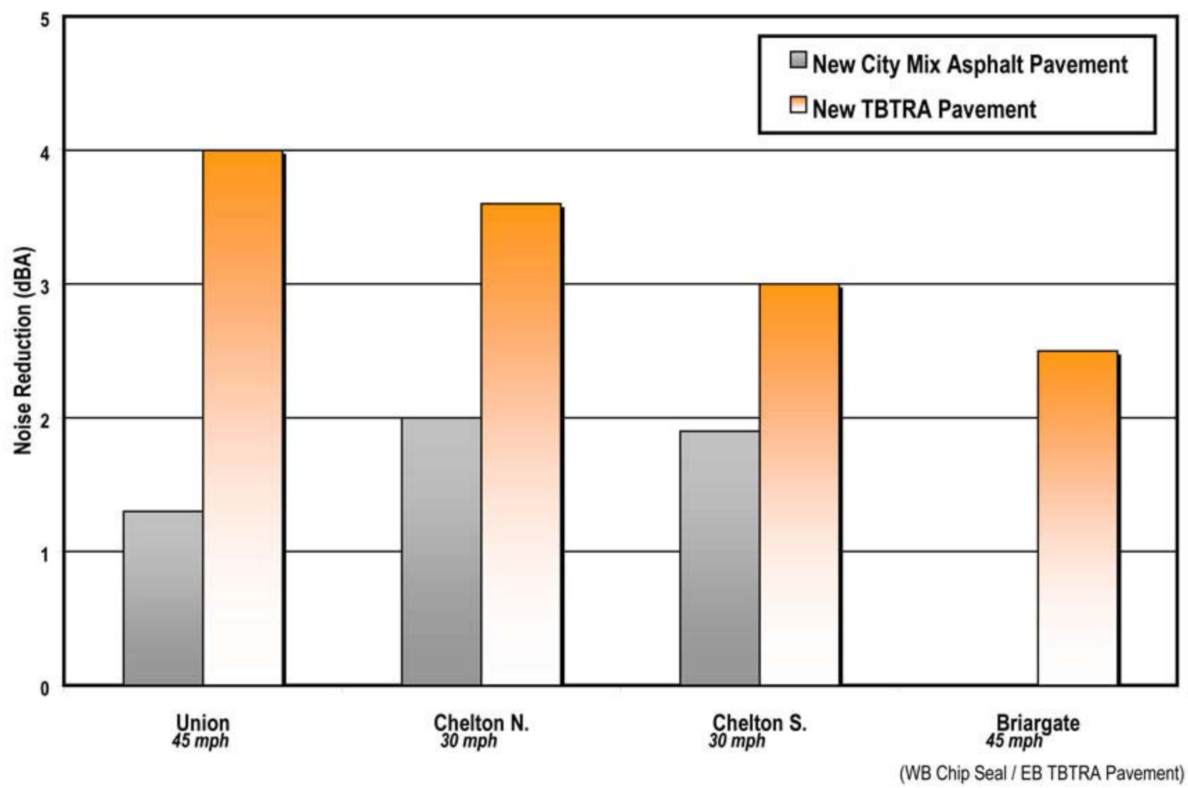
The remainder of the road, approximately 1,000 feet, was crack-sealed and 1 inch of TBTRA was placed directly on top of the old surface. This initial section was used as a test to better understand any construction problems or issues. The city then placed 4.5 miles of TBTRA on three additional streets:

- **Chelton Road**, between Airport Road and Marion Drive - a major collector roadway,
- **Union Boulevard** between Austin Bluffs Parkway & Academy Blvd - a heavily-traveled, major arterial roadway and
- the East Bound lanes of **Briargate Parkway** between Lexington Street and Union Boulevard, another major arterial.

As part of the test implementation of TBTRA, the City scheduled various performance-specific testing programs to learn what effect the Front Range environment has on the sustainable life of this new pavement. Once testing is complete, comparisons between TBTRA pavements and traditional asphalt mixes will be made. A request for proposal to create a pavement surface distress rating for TBTRA and traditional pavements has been finalized and the City is awaiting responses from local area pavement consultants before selection.

Noise Reduction Testing Results

One of the stated advantages of this product is noise reduction. Prior to the implementation of this test TBTRA project, the City retained a noise consultant, Hankard Environmental Inc., to conduct studies of the differences in noise levels between aged asphalt pavements, new asphalt pavements (both type C and CX mixes) and TBTRA pavements. These tests have been completed and they confirm what we have been hearing from our citizens, that “this new pavement (TBTRA) seems quieter.” The comparative review of noise measurements completed by Hankard Environmental has shown up to a 4 dBA reduction in noise over existing (old) asphalt with higher reductions on roadways with higher traffic speeds. Specific results of the noise study are illustrated in the table below. Follow up measurements will be conducted in the future to determine if noise reductions are maintained over time.



Safety Outcomes

Better safety is another observed advantage. Visual observation of splash back and spray during wet weather show a considerable improvement in visibility of pavement markings and splash back reduction for TBTRA pavements over the traditional dense-graded pavements. A reduction in ice build up was also noted. The City of Colorado Springs Street Division will be reviewing both routine and inclement weather traffic accident data and developing accident rate comparisons for the TBTRA versus traditional pavements. In addition, skid testing was performed by the Colorado Department of Transportation in 2007. Results indicate comparable traction between the TBTRA open graded mix and traditional dense graded mixes.

The picture at right was taken approximately 20 minutes into a storm on a typical dense graded pavement. The water is ponding and sheeting across the pavement with tremendous splash back and pavement markings are almost invisible.

The picture at left was taken approximately 24 minutes into the same storm. The driving surface of the TBTRA open graded mix seems dry with no splash back and pavement markings are clearly visible.

Cost Evaluation

As we evaluate the different aspects of TBTRA, cost is also an important factor. Using 2006 pricing, TBTRA added an approximately 22 percent cost increase to the City's normal mill and overlay operation and an approximately 61 percent increase when compared to chip seal. Given the City's experience with how long its traditional mill and overlay type rehabilitation lasts, it appears if TBTRA was to last two more years over traditional dense graded mixes, the extra costs will be mitigated, while providing the current and ongoing benefits of increased ride comfort, safety and sustainability.

On the Right Road

While short-and long-term testing results remain outstanding, the City of Colorado Springs is committed to seeking materials and processes that increase public safety and promote fiscal stewardship. Investing in new solutions is necessary and will benefit the community we are entrusted to serve.

For additional information, please contact the Colorado Springs Street Division office at: 719-385-5296.