HMA Longitudinal Joint Construction & Preservation
Pathway to Resilient & Sustainable Highways
HMA Longitudinal Joint Construction & Preservation

Michael Durante, ENV SP

Longitudinal joint construction quality and maintenance is critical to the performance and lifecycle of asphalt pavements. While some states have added joint specifications based on construction-time density, distress also is tied to air and water permeability at the surface and through the wearing course of the structure. So, it is paramount for agencies to expand requisite testing for sustainable joints to include density and permeability (and repeated over time in service) for both the longitudinal joint and the surface area adjacent and through the wearing course.

The premature failure of centerline joints, lane-to-lane joints, and especially rumble strips is generally recognized by pavement preservation managers to be a grave threat to the sustainability of our federal interstate highway system. Longitudinal joints are a systemic design flaw in paving installation created where single lane paving mats meet at different temperatures making bonding difficult. The edge(s) of newly laid asphalt also tend to have reduced compaction as part of the paving process.

Poor bonding and compaction lead to top-down moisture intrusion in the wearing surface and accelerate deterioration. HMA pavements typically have air voids reaching 10% or higher directly at the longitudinal joint. Most highways begin to degrade along these various construction joints first, leading to premature failure of the entire pavement. A high percentage of road system maintenance costs hence are exhausted by an inherently flawed and unattended confined area less than 10% of a lane width.

Additionally, road construction plays a crucial role in our society’s goal to reduce carbon. America alone has seven million lane miles of paved road, enough to drive oneself to the Moon and back more than fifteen times. The maintenance of that roadway system requires in excess of 350 million metric tons of virgin asphalt annually (emitting two hundred million tons of carbon) and its demands are as

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1 Calvert J., Longitudinal Joints: Sealing Road Seams for Pavement Preservation.
2 Williams R.C. and Kamau J, Use of J-Band to Improve the Performance of The HMA Longitudinal Joint, Iowa State University; presented to the Minnesota Department of Transportation, May 2022.
3 Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
4 Ninety-four Percent (94%) asphalt: U.S. Department of Transportation, Federal Highway Administration (FHWA).
5 Federal Highway Administration (FHWA) and National Asphalt Paving Association (NAPA).
endless, as they are insatiable. Preserving our road systems is perhaps the lowest hanging fruit for the highway construction industry in the fight against climate change.

The weighted average life cycle (LCA) of the U.S. roadway system is a mere 12 years,\(^6\) worth in net present value (NPV) well over $2 trillion in replacement cost. If agencies and taxpayers do not already struggle to meet this perpetual financial burden, the NPV of the system’s carbon footprint just for maintenance (embodied carbon)\(^7\) approaches another $100 billion in carbon equivalents (CO\(_2\)e).\(^8\)

Longitudinal joint construction and maintenance are critical to both financial and environmental costs. Poorly constructed joints contribute to as much as 40% shorter overall pavement structure life.\(^9\) To mitigate the problems associated with premature failure requires a combination of best-practice construction and established preventive maintenance strategies.

**Systemic Construction Flaw**

Longitudinal joints are constructed one lane at a time. So, the first paved lane has cooled prior to the second lane placement. When the first lane is rolled, the outside edge(s) lack confinement and produce areas of low density. The second paved lane has the first lane for support and adequate density is more attainable albeit not generally successful.

HMA with low density will experience more rapid aging of the asphalt binder due to oxidation and will become more susceptible to fatigue and thermal cracking.\(^10\) When density is poor along a longitudinal joint, voids on both sides tend to be larger and “interconnected” making the joint highly vulnerable to air and water intrusion, which will accelerate oxidation, moisture damage, cracking, raveling, and even separation. Another problem plaguing paving joints is differential caused by settlement between the lanes after post installation cracking begins.\(^11\) Vertical

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\(^6\) National Center for Pavement Preservation at Michigan State (NCP); FHWA; and NAPA.
\(^7\) Embodied carbon means all the CO\(_2\)e emitted in producing materials.
\(^9\) National Center for Asphalt Technology (NCAT) Report #94-01, Auburn University.
\(^11\) NCAT Report #94-01.
differentials appear as a depression along the joint and further collect and store water.

To properly construct a longitudinal joint, the joint must be smooth and tight, of course. Joint density is affected by the poor compaction along the unconfined edge(s) of the cold lane; compaction of material in the joint itself; and compaction of material on the hot side. In most cases and despite sound construction placement mitigation practices, an asphalt surface course mat will condense to a final compacted lift density that is only 80% or less of thickness behind the screed.\textsuperscript{12} This is why longitudinal joints unavoidably fail prematurely from the top down.

Premature distresses which often begin at the longitudinal joint necessitate costly repairs and maintenance both on the pavement and on our environment.

\textbf{“Mechanical” Joint Construction Techniques}

Traditional longitudinal joint construction methods can be grouped into several categories:

\textbf{Echelon Paving}

Echelon paving involves placing multiple lanes simultaneously by staggering multiple pavers. The strategy can be effective at improving joint density and permeability but is rarely feasible due to construction sequencing and traffic management.

\textbf{Joint Heater}

The premise is that by heating-up the cold lane prior to the second lane install, adhesion will improve. The downside to improved performance is that managing the heat is contractor quality intensive and often results in damaging the cold lane binder integrity by “scorching” it.\textsuperscript{13}

\textsuperscript{12} Brown E., Transportation Research Board (TRB) paper #E-C105; Factors Affecting Compaction of Asphalt Pavements, September 2006.

\textsuperscript{13} Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
**Cutting Wheel**

A cutting wheel can be deployed to remove low density material at the cold side edge. It is both expensive, rarely successful at improving overall density and is highly operator quality dependent, in part, due to roller bridging.

**Forced (Hot) Overlap**

Rolling can be employed to force the overlapping mix from the second lane into the joint to improve density, but still has only varied success given the temperature and bonding hurdles described. The technique is affected by placing the balance of the weight of the roller on the hot side and using a vibrating drum. The technique may reduce initial vertical differential. But not effective at improving compaction.\(^{14}\)

![Hot Overlap Rolling Pattern](image)

**Hot Pinch**

Hot pinch is similar to forced overlap but is affected in two passes. The first pass positions the roller further away from the joint to create a ridge or “hump” which is then rolled to “pinch” excess hot material into the joint. The method has shown better results than simple forced overlap, but the creation of the hump creates low density in the bridged areas. So, secondary cracks often develop along the pinch line.\(^{15}\)

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\(^{15}\) Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
Cold Rolling

A cold roll simply reverses the position of the roller to favor the cold lane and hence the drum must remain in static (non-vibratory) mode. The method improves vertical differential but wastes valuable compaction energy in static mode reducing overall compaction effectiveness.\textsuperscript{16}

Joint Adhesives and Sealants

Crack fillers (CF) have shown to improve permeability within longitudinal joints though tend to not last long (>50\% failure rate).\textsuperscript{17} Critically, adhesives and sealants do not improve density in the surrounding (permeable) area of the longitudinal joint (Figure 4) essential to a thoroughly resilient structure.\textsuperscript{18}

\textsuperscript{16} Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
\textsuperscript{17} FHWA: Sealing and Filling Cracks in Asphalt Pavements, November 1999.
\textsuperscript{18} National Center for Asphalt Technology (NCAT) Report #94-01, Auburn University.
VRAM is a crack sealer only applied to the base layer at time of construction to improve adhesion and stability from the bottom-up. In theory and if perfectly timed, as the top layers or wearing course of a new road build are installed, the sealant material will be squeezed up into the lower part of the surface course joint. The bottom-up approach is expected to permeate 50% or so.

The limiting factors are cost, new construction timing constraints, and the inability to improve surface course joint area density and permeability (Figures 4, 5).

While pavement base adhesion and stability improvements are potentially valuable in mitigating loading stress on a joint, directly addressing atmospheric air and water intrusion damage from the top-down of the pavement are the most critical to joint and wearing course preservation. A recent site survey by Iowa State University of a VRAM project after the first winter noted that “material loss limited to the top layer of rock 1 inch wide and 0.5 inch deep” appears to support the bottom-up limitation.

References:

19 Williams R.C. and Kamau J, Use of J-Band to Improve the Performance of The HMA Longitudinal Joint, Iowa State University; presented to the Minnesota Department of Transportation, May 2022.
20 Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
21 Williams R.C. and Kamau J, Use of J-Band to Improve the Performance of The HMA Longitudinal Joint, Iowa State University
Wedges

Paver “shoes” or “boots” can be employed to create a graduated edge on the cold side to reduce transverse migration during compaction. A “notch” is typically placed at the top of the edge to mitigate dragging out the material which promotes less voids. However, compacting the wedge itself is difficult and aggregate particles tend to remain large and irregular.²²

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²² NCAT Report #94-01, Auburn University.
Edge Restraint

Edge restraint is an addition to a wedge where a temporary restraint is placed on the low side of the wedge to reduce material dragging. It is an improvement to a wedge but requires additional skill by the paving contractor and still provides poor relative compaction results along the wedge.\(^{23}\)

Joint Replacement

The failed joint can be sawed out and replaced with new hot mix asphalt. The limitations are cost, and the new joint now has replaced one longitudinal joint vulnerability with two.\(^{24}\)

Asphaltic Emulsions

Rapid penetrating asphalt emulsions (RPE) are a misnomer. They are actually rapid setting emulsions and typically are 30% to 40% asphalt. They set-up above the surface and act like a micro-surface addition that can improve permeability for about a year or so before they wear or oxidize away. So, not very cost efficient.

Natural, Binder-Based Joint Preservation

Molecular Density Restoration

At the road surface, pavement oxidation begins immediately, opening a direct pathway for water in intrusion and exponential oxidative deterioration of the binder, the primary factors shortening lifecycles for most roads. A fifty-year proven approach is to remedy this by spray-applying a natural or maltene-based rejuvenator.

Maltene Replacement Technology (MRT) reintroduces to the aged asphalt binder, exact molecular components (maltene fractions) lost to manufacturing related thermal stress and in-service oxidation, naturally restoring flexibility and in-place density thereby and extending road life by years (Figure 7).\(^{25}\) The method cuts both paving budgets and avoids asphalt manufacturing emissions by 50% or more by significantly stretching-out repaving cycles.

\(^{23}\) NCAT Report #94-01, Auburn University.
\(^{24}\) Ibid.
\(^{25}\) Multi-year MRT Sustainability Study: Charleston County (SC): Pavement Technology, Inc.; APART.
The technique has been successfully repurposed to restore natural properties to longitudinal joints and offset the systemic shortfalls in highway construction related to poor compaction and bonding. Key advantages of Molecular Density Restoration (MDR) include the ability to address and redress both new and aged longitudinal joints with minimal traffic stoppage multiple times throughout the pavement lifecycle and at minimal cost.

MDR is a proven solution to restore longitudinal joint area integrity and securing the intended service life of highways. MDR may be used on its own or as a complement to traditional or mechanical longitudinal joint construction techniques.

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26 Reclamite® is a trademark of Ergon, Inc.
27 The poise (symbol P) is the unit of dynamic viscosity (absolute viscosity) in the centimeter-gram-second system of units.
Methods for Assessing Joint Performance

Density

Longitudinal joints have been considered to be the root cause of HMA pavement deterioration for a long time, when the surface area surrounding the joint was first identified as having low density.28

In simple terms, density is the “degree of compactness of a substance.” A well-constructed joint should have only 1 to 2 percent lower density than the mat, but a poorly constructed joint can have 5 to 10 percent lower density.29

Density can be measured using a non-destructive field gage (nuclear or non-nuclear) or by obtaining cores from the pavement and measuring density in the laboratory.30 Density is a critical qualitative indicator of joint quality, but the parameter alone is not adequate in the case of joint adhesives or sealants 31 as they fail to address asphalt density. Proper density (surrounding the joint area) is critical for achieving desired strength and achieving adequate resistance against moisture damage.32

Permeability

The fundamental mechanism of failure is also directly related to permeability of the joint area because of the entrance of air and water directly contribute to the distress of oxidation and moisture damage that lead to cracking, raveling, and joint separation.33 The definition of permeability is the “state or quality of a material or membrane that causes it to allow liquids or gases to pass through it.”

Surface permeability of the longitudinal joint area is a key measure of quality, as a less permeable upper area joint matrix will not allow the intrusion of water and foreign matter that lead to premature distresses.34

30 Mallick RB and Daniel JS, Development and evaluation of field permeameter as a longitudinal joint quality indicator, Worcester Polytechnic Institute and University of New Hampshire, 2005.
32 Mallick RB and Daniel JS.
33 Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
34 Mallick RB and Daniel JS.
Voids

In general, permeability values are expected to increase with an increase in voids or decrease in density, of course. However, permeabilities can be extremely low despite having air void content greater than even 6% with certain sealers, so the use of void measurement may be less instructive than density and permeability. 35 36

Field Survey

Pavement condition surveys provide exceptionally valuable information as to the long-term performance of the pavement, albeit these measures are employed after the pavement has been in service for quite some time.

Spray-Applied Longitudinal Joint Stabilizer – Molecular Density Approach

Pavement Technology, Inc. has fifty years of experience in the pavement preservation industry, serving America’s largest public works agencies and transportation administrators.

Agencies have utilized PTI’s core technology – maltene replacement 37 for decades to extend asphalt pavement life through molecular revitalization. PTI has applied MRT to more than 600 million square yards (85,000 miles) of road.

MRT has shown to extend pavement life by 50% or more, cutting both repaving budgets and asphalt manufacturing emissions by the same through materially stretching-out repaving cycles.

Maltene replacement is the only 100% natural approach to asphalt binder rebalancing as is considered by asphalt technicians to be “settled science”. Every center lane mile of MRT treated pavement saves our environment a net 7,500 tons of embedded carbon.38 39

JOINTBOND® asphalt joint stabilizer products build upon the MRT success by bringing proven molecular revitalization chemistry to the critical longitudinal joints on highways. A breakthrough approach to mitigating pavement fatigue originating

35 Ibid.
36 NCAT Report #94-01, Auburn University.
37 GotMaltenes?: www.pavetechinc.com/got-maltenes/.
38 BlackwallPartners LLC,
from systemic longitudinal joint failure with JoINTBOND® has over fifteen years of field performance testing. Select agencies that deploy the technique include the Ohio Turnpike Commission, Ohio Department of Transportation (ODOT), Summit County (OH), Tennessee Department of Transportation (TDOT), Hawaii Department of Transportation (HDOT), and Montana Department of Transportation (MDOT) et al.

Designed to be an economical, yet robust technology for both new build and existing asphalt pavements, JoINTBOND® is a top-down application proven to materially improve both density and permeability in the longitudinal joint and the critical surrounding surface area.

JoINTBOND® asphalt joint stabilizer is a post installation applied polymerized maltene-based (no asphalt) emulsion and developed to inhibit the premature deterioration of construction joints by penetrating the pavement and molecularly combining with the existing asphalt binder.

The product penetrates the pavement’s surface and affects the chemistry of the in-place asphalt binder upper matrix to help prevent joint deterioration and separation. Typical application rates are 0.07 to 0.10 gallons per square yard, covering up to three feet of surrounding permeable area, and costs between $0.50 and $0.75 per linear foot of joint.

Comparative Testing 40 –

University of Arkansas, Department of Civil Engineering

In general, the joint heater (JH), joint stabilizer (JB) [JoINTBOND®], and notched wedge (NW) methods were the most successful at limiting the potential for deterioration at the longitudinal joint. This was evident for both the density-related responses and the water-related responses. In terms of density, some of the methods could be reasonably expected to significantly affect density (i.e., joint heater and notched wedge) because the very nature of the techniques involved additional efforts to increase density. Other methods, such as the application of joint adhesives, serve primarily to seal the joint without seeking to affect the actual density. Interestingly, the JointBond® (JB) product appeared to both increase density and decrease permeability.

40 Williams S., AHTD Transportation Research Committee: HMA Longitudinal Joint Evaluation and Construction, University of Arkansas Department of Civil Engineering, February 2011.
In terms of nuclear density, all techniques except the joint adhesive (CF) and hot overlap (HO) were effective in increasing in-place density over that of the hot pinch (HP) method, with the greatest average increase of 2.3 percent being achieved by the notched wedge (NW) method. For density of cores tested by AASHTO T166, the joint stabilizer (JB), joint heater (JH), and notched wedge (NW) were able to provide greater densities than the traditional hot pinch (HP) method, with the greatest increase of 1.5 percent being produced by the joint heater (JH). The joint adhesive (CF), hot overlap (HO), and tack coat (TC) methods were not as effective as the hot pinch (HP), while the cold roll (CR) method produced the same average core density.

...the joint stabilizer (JB), joint heater (JH), and notched wedge (NW) methods appear to generate similar densities at and away from the joint, while the joint adhesive (CF), hot overlap (HO), cold roll (CR), hot pinch (HP), and tack coat (TC) methods exhibit practically significant differences at various distances from the joint.
The highest joint densities were obtained for the joint heater (JH) and joint stabilizer (JB) methods, while the lowest densities were associated with the joint adhesive (CF) and tack coat (TC) methods. The largest differences between densities at and away from the joint were noted for the hot overlap (HO), hot pinch (HP), and tack coat (TC) methods. Densities on the hot side of the joint were greater than those on the cold side, and more closely approximated the mat density.

The water-related responses generated similar results, with the joint stabilizer (JB) being the most effective at reducing absorption, permeability, and infiltration levels, followed by the joint heater (JH) and notched wedge (NW) techniques. The joint adhesive (CF) and hot overlap (HO) were least effective, and the cold roll (CR) and tack coat (TC) techniques were similar to the hot pinch (HP).

41 AASHTO T166.
Figure 9 – Absorption

Source: University of Arkansas, Department of Civil Engineering

(Figure 9) The joint stabilizer (JB) and joint heater (JH) methods were most successful at limiting absorption at the joint, while the hot overlap (HO) method was least successful.

Figure 10 – Field Permeability

Source: University of Arkansas, Department of Civil Engineering
Field permeability results indicated a more varied performance among the various joint construction methods than most other parameters. Overall, the joint stabilizer (JB), joint heater (JH), and notched wedge (NW) methods were the best performers, creating joints with levels of permeability that were fairly similar to that away from the joint. Larger deviations were present for the joint adhesive (CF), cold roll (CR), hot overlap (HO), and hot pinch (HP) methods. Permeability on the hot side of the joint was closer to the mat permeability… the joint stabilizer (JB) and joint heater (JH) methods most nearly approximated the permeability values exhibited for the mat.

Figure 11 – Infiltration

Infiltration results were very similar to permeability results, which is reasonable given the fact that infiltration is simply another way to represent the same type of information. The joint stabilizer (JB), joint heater (JH), and notched wedge (NW) methods were the better performers, while the joint adhesive (CF) and hot overlap (HO) methods were least successful.

Source: University of Arkansas, Department of Civil Engineering
Table 1 – Average Difference in Response to Hot Pinch

<table>
<thead>
<tr>
<th>Method</th>
<th>Nuclear Density (%)</th>
<th>T166 Density (%)</th>
<th>T331 Density (%)</th>
<th>Absorption (%)</th>
<th>Permeability (cm/s x 10^(-5))</th>
<th>Infiltration (cm/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Adhesive (CF)</td>
<td>-2.9</td>
<td>-1.2</td>
<td>-2.3</td>
<td>0.1</td>
<td>1672</td>
<td>286</td>
</tr>
<tr>
<td>Cold Roll (CR)</td>
<td>0.7</td>
<td>0.0</td>
<td>0.1</td>
<td>-0.2</td>
<td>147</td>
<td>31</td>
</tr>
<tr>
<td>Hot Overlap (HO)</td>
<td>-0.9</td>
<td>-0.2</td>
<td>-0.8</td>
<td>0.5</td>
<td>1789</td>
<td>328</td>
</tr>
<tr>
<td>Joint Stabilizer (JB)</td>
<td>1.1</td>
<td>1.0</td>
<td>3.3</td>
<td>-1.7</td>
<td>-2340</td>
<td>-424</td>
</tr>
<tr>
<td>Joint Heater (JH)</td>
<td>1.8</td>
<td>1.5</td>
<td>-0.9</td>
<td>-1.9</td>
<td>-1927</td>
<td>-339</td>
</tr>
<tr>
<td>Notched Wedge (NW)</td>
<td>2.3</td>
<td>0.6</td>
<td>2.6</td>
<td>-0.9</td>
<td>-1485</td>
<td>-261</td>
</tr>
<tr>
<td>Tack Coat (TC)</td>
<td>0.1</td>
<td>-0.9</td>
<td>-0.6</td>
<td>0.3</td>
<td>-103</td>
<td>-11</td>
</tr>
</tbody>
</table>

Source: University of Arkansas, Department of Civil Engineering

(Table 1) JOINTBOND® performed exceptionally across both density and water-related testing relative to control and the group. JOINTBOND® was a strong performing method for both nuclear density (%) and density (AASHTO T166), and the best performing method overall for absorption (%), permeability, and infiltration.

JOINTBOND® asphalt joint stabilizer extends the service life of longitudinal joints and adjacent areas in two ways:

• Improving the chemistry of the in-place asphalt binder
• Adding a physical in-depth seal to the construction joint, thereby sealing the joint and surrounding area against intrusion by air, water, and salt brine

Figure 12 – Full Road MRT: Delaware County (OH) After 3 Years

Source: Pavement Technology, Inc
Figure 13 – JOINTBOND® After 4 Years Post rain

Source: Pavement Technology, Inc.

Figure 14 – JOINTBOND® After 2 Years Post Rain

Source: Pavement Technology, Inc.
At the *Earthx2019* environmental symposium, PTI formally introduced our state-of-the-art mobile source pollution-reduction and solar reflective “photocatalytic pavement” solutions after years of both field and laboratory testing success.\(^{42}\)

Our **PlusTi\(^\text{TM}\)** family of road preservation products also build upon the MRT success by adding photocatalytic materials which promote certain decarbonization and other environmental benefits including direct pollutant removal, cooler pavements, and better pavement hydrophilicity in addition to pavement preservation.

We now have brought this additional technology to the asphalt joint stabilizer products to create **JOINTBONDTi\(^\text{®}\)**, the newest addition to our family of photocatalytic pavement sustainability and resiliency products.

**JOINTBONDTi\(^\text{®}\)** brings all the value of **JOINTBOND\(^\text{®}\)** and takes advantage of the **PlusTi\(^\text{TM}\)** benefits of improved water desorption and solar reflectance value afforded by the addition of photo-reactive titanium dioxide (TiO\(_2\)).

- **Super-Hydrophilic / Hydrophobic** surfaces, which provide a rapid water-desorbing (faster H\(_2\)O *sliding*) pavement surface, are self-cleaning to remove contaminants (e.g., mold) and staining (de-soiling); protects against water intrusion to extend pavement life; and are rain displacing / ice-build inhibiting for inclement weather-related safety improvements for roadways.\(^{43}\)

- **“Cool Pavement”** applications where TiO\(_2\) enhanced pavements provide a solar-reflective top boundary, which lessens pavement related radiative forcing (RF) by reducing pavement heat absorption and averting the convective re-release of solar radiation that leads to the undesired UHI impacts. Significantly lower absorption also extends the life-cycle assessment (LCA) of pavements by slowing-down oxidation.\(^{44}\)

**JOINTBONDTi\(^\text{®}\)** is the world’s first super-hydrophilic longitudinal joint stabilizer capable of revitalizing and correcting longitudinal joint density, sealing rumble strips and other critical roadway joints while improving sorptivity. The product combines two proven technologies - **Maltene Replacement Technology (MRT)** with **Photo Catalytic Technology (PCT)**. Together, they extend roadway life by

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improving asphalt density and solar reflectance values while accelerating water desorption for a *quick-drying surface* adding additional protection from water intrusion damage.

**Hydrophilic/Hydrophobic Pavements:** TiO₂ is naturally hydrophilic, so treated pavements are indicating better water desorption properties to create a more hydrophobic or quick drying pavement effect. Prevents water intrusion, ice build-up, and surface ponding to reduce inclement weather-related traffic accidents.

**Table 2 – PlusTi™ Water Contact Angle – FDOT OGFC Test Bartow (FL)**

<table>
<thead>
<tr>
<th>Site</th>
<th>Water Contact Angle°</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.R.A.-1 Ti²</td>
<td></td>
</tr>
<tr>
<td>Control Sample</td>
<td>81°</td>
</tr>
<tr>
<td>TiO2 1 Visible Light</td>
<td>82°</td>
</tr>
<tr>
<td>TiO2 1 UV Light</td>
<td>51°</td>
</tr>
<tr>
<td>TiO2 2 Visible Light</td>
<td>81°</td>
</tr>
<tr>
<td>TiO2 2 UV Light</td>
<td>50°</td>
</tr>
</tbody>
</table>

Source: Texas A&M Transportation Institute (TTI)

**Urban Heat Island Mitigation:** Asphalt pavements treated are consistently showing a 400% improvement in Solar Reflective Index (SRI) and qualify for U.S. Green Building Council LEED V4 Heat Island Reduction (HIR) and ISI ENV.

**Table 3 – PlusTi™ Solar Reflectance – Orlando International Airport**

<table>
<thead>
<tr>
<th>Compound / Substrate</th>
<th>Solar Reflectance Index Values (SRI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Sample</td>
</tr>
<tr>
<td>A.R.A.-1 Ti²/Asphalt</td>
<td>9              8</td>
</tr>
<tr>
<td>Litho1000 Ti²/Concrete</td>
<td>24            24</td>
</tr>
</tbody>
</table>

Source: Texas A&M Transportation Institute (TTI)

In combination with other PlusTi™ pavement products, JOINTBOND® can help agencies create a fully functional photocatalytic roadway system also capable of:

- **Depolluting near-pavement air cleaning applications,** where TiO₂ reacted surfaces are able to oxidize a variety of pollutants and contaminants such as those emitted by vehicles, especially NOₓ, CO₂, MPP (microplastic particles)
and VOCs, reducing air as well as oceanic pollution while mitigating acid rain formation.

Table 4 – PlusTi™ NOx Reduction – Texas A&M Center for Infrastructure Renewal (CIR)

<table>
<thead>
<tr>
<th>Application Rate</th>
<th>NO Reduction Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Sample</td>
</tr>
<tr>
<td>A.R.A.-1 Ti®</td>
<td>NEGL</td>
</tr>
<tr>
<td>Ti-introCME™</td>
<td>NEGL</td>
</tr>
</tbody>
</table>

Source: Texas A&M Transportation Institute (TTI)

- **Water Purification** - photocatalytic surfaces also are stormwater purifying as the combination of cooler pavements with depolluting properties are antibacterial, antiviral, and anti-plastic.

- **Microplastic Decomposition** is 98% efficient with TiO₂. Dangerous airborne and aquatic plastic pollution deposition into our environment estimated to be 85% sourced from roadway tire wear (RAMP_TWP), brake-pad wear (RAMP_BPW) and polymer modified asphalt (RAMP_PMA) degradation.

For more information, see your Pavement Technology Technical Representative or visit [www.pavetechinc.com](http://www.pavetechinc.com).

Other resources:

[www.pavetechinc.com/plusti/](http://www.pavetechinc.com/plusti/)

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