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Asphalt application according to DAT Evotherm process

## Development of the Tempéra®/Evotherm DAT™ Process in Europe: A Collaboration Between Eurovia and MeadWestvaco

Since 2003, EUROVIA has been producing warm mix asphalt with its ASPHA-MIN process, which enables asphalt mix temperatures to be reduced by about 30°C.<sup>1,2</sup> ASPHA-MIN is a synthetic zeolite, sodium alumina silicate, containing about 21% crystallized water by weight. When injected into asphalt mixing operations, the water is released as steam thereby creating an asphalt foam. With this process, EUROVIA has become the leader in the field with more than 700,000 tons of total warm mix asphalt applied - more than 200,000 tons for 2008 alone.

Today, the family of EUROVIA products has expanded with the creation of the TEMPERA line, which brings together all the warm processes used by EUROVIA. The TEMPERA line of asphalt mixes retains the same wide range of characteristics possible with conventional hot mix, in terms of mix plant, aggregate mineralogy, overall mix type, etc., while reducing mix temperatures up to 50°C. By eliminating fumes and odors, these new asphalt mixes guarantee a more pleasant environment for residents and work crews while using up to 40% less energy.

At the heart of this new line is the EVOTHERM DAT process, a product of MEADWESTVACO under exclusive commercial development by EUROVIA in France and several other European countries.

This collaboration between the two companies has now been in place for over two years. Numerous validation tests have been carried out by the EUROVIA Research Centre in Mérignac and the European MeadWestvaco asphalt laboratory in Villeneuve d'Ascq. Several job sites in France and Spain, using different types of asphalt mix, have confirmed the viability of the process.

This article presents the EVOTHERM DAT process in greater detail and show the performance characteristics obtained in the laboratory and in the field using several types of asphalt mixes.

## **EVOTHERM OVERVIEW**

### **History**

EVOTHERM is a process developed by Asphalt Innovations , a MEADWESTVACO business. The first patents and project sites date from the end of 2003.<sup>3,4</sup> A world leader in the field of surfactants and additives for asphalt emulsions, MEADWESTVACO quite naturally developed its first generation of warm mix asphalt (EVOTHERM ET) based on the use of asphalt emulsions. The project binder was first converted into a high-residue asphalt emulsion (70% binder residue) in an emulsion plant, and then this emulsion was injected in place of liquid binder at the mix plant. The water and MEADWESTVACO warm mix additives present in the emulsion enabled the company to manufacture asphalt mixes 100°F below conventional hot mix while guaranteeing mix properties and pavement performance.

Since 2005, various studies and evaluations have been carried out (mainly in the USA) by a wide range of universities, transportation agencies, and other research organizations, which have demonstrated the outstanding performances of EVOTHERM mixtures compared with their hot mixes equivalents.<sup>5,6,7</sup> One example is the experiment conducted at NCAT (the National Center for Asphalt Technology) in Auburn (AL, USA) where two sections of EVOTHERM pavement (sections numbered E9 and E10) constructed on the NCAT Pavement Test Track have been in place since 2005. After being subjected to more than 10 million equivalent single-axle loads (ESAL's), the rutting measured was less than 3 mm on the two test sections.<sup>8</sup>

Always concerned with optimizing the cost and performance of its products, MEADWESTVACO subsequently patented the EVOTHERM DAT process (Dispersed Asphalt Technology) in 2006 and the first job was undertaken in the state of Texas in February 2007 and in France in July 2007.

The core concept behind EVOTHERM DAT is to start with the same additives and concentrate them in an aqueous phase. This aqueous phase is then injected directly into the asphalt line (5% w/w asphalt) when the materials are coated. This does away with the cost of processing and transporting the emulsion, reducing further the environmental impact of the EVOTHERM process.

Perfecting this direct injection process allowed the EVOTHERM process to move aggressively to full-scale projects, with more than 150 jobs completed during 2008 throughout the world (USA, Canada, Mexico, China and Europe) for a total of more than 400,000 tons of mix.

## **EVOTHERM DAT**

Thus, EVOTHERM DAT is a warm mix asphalt production procedure relying on the use of an aqueous solution of additive. The EVOTHERM DAT provides the mix with the rheological properties needed during production and construction, while ultimately improving adhesion between the binder and aggregate.

An aqueous solution with between 10 to 15% in weight of additive (e.g., EVOTHERM E1) is produced then adjusted to pH 2.0 +/- 0.3. [Other EVOTHERM DAT products do not require pH adjustment.] This solution is then injected directly into the asphalt line at a rate of between 5 to 10% w/w asphalt. [The solution also may be injected directly into a pug mill of a batch plant.]

In this way, the coating plant does not require any modification, except for a branch connection fitted to the asphalt line and the addition of a pump (and a flow meter) to regulate the EVOTHERM additive injection.

**Photo 1: Metering kit**



**Photo 2: Staking on bitumen line**



## **THE BENEFITS REALIZED:**

The benefits in temperature reduction realized with the EVOTHERM DAT technology are on the order of 50 to 60°C compared to the reference hot mixes. Thus, the various construction projects completed with this process [and discussed herein] used mix produced between 105°C and 120°C depending on the aggregate materials, the grade of asphalt, and the type of asphalt mixes produced.

The first obvious benefit is the reduction in the consumption of energy when manufacturing the asphalt mixes, as the job materials need to be heated less than when manufacturing the conventional hot mix. Various job sites have shown a savings of around 40% in energy, with measured gains from 35% to 55% depending on the moisture content of the aggregate materials and the ambient weather conditions.

The second direct consequence of this reduction in temperature is a significant drop in the emission rates of stack gases and particulates at the mix plant. Measurements highlighted the following levels:

- 48% reduction in greenhouses gases
- 58% reduction in nitrogen oxides,
- 41% reduction in sulphur dioxide, which is responsible for acid rain.

Finally, the work of the paving crew has become much less difficult, since the warm mixes are generally compacted at between 80°C and 110°C, compared to 120°C to 140°C for the hot mix. Also, the drop in nuisance odors makes working in an urban environment or a confined environment (underground parking, tunnels, etc.) much easier.

## **LABORATORY STUDIES OF VARIOUS TYPES OF MIX**

The close collaboration between the two enterprises, Eurovia and MeadWestvaco, made it easy to execute the first laboratory validation of the properties and performance characteristics of the Evotherm warm mix asphalt process. Described below are some examples of typical results.

### ***TWO BBSG 0/10 DENSE WEARING COURSE MIX FORMULATIONS WITH AGGREGATE MATERIALS FROM MAZIERES AND DONIA AND GENUILLAC QUARRIES (DIORITES)***

The EUROVIA Study and Research Centre, based in Mérignac, carried out two, level III formulation studies for each formula of BBSG 0/10 used, in each case comparing the EVOTHERM mixture with its hot mix reference.

The EVOTHERM mixtures were manufactured at 110°C and the specimens for the various tests were compacted at 100°C. The hot reference bituminous mixes were manufactured and compacted at 160°C.

The aggregate gradation curves of the mixtures conformed to the European Norm NF EN 13108-1.

In both cases, the bitumen content is 5.8 % total.

The different results of the formulation studies for each of the bituminous mixes are summarized in Tables 1 and 2.

**TABLE 1**

Properties of 0/10 Semigranular Asphalt Mix Using Mazières Quarry Aggregate

| Test                                 | BBSG 0/10 Mazières |              | Specifications<br>(NF EN 13108-1) |
|--------------------------------------|--------------------|--------------|-----------------------------------|
|                                      | Hot Mix Control    | EVOTHERM DAT |                                   |
| PCG (NF EN 12697-31)                 |                    |              |                                   |
| V10                                  | 16.3               | 16.9         |                                   |
| V60                                  | 9.7                | 9.7          | 5-10                              |
| Duriez (NF EN 12697-12)              |                    |              |                                   |
| % Air Voids                          | 7.6                | 6.8          |                                   |
| Compressive Strength dry, Cd (MPa)   | 11,700             | 12,400       |                                   |
| Compressive Strength wet, Cw (MPa)   | 10,000             | 9800         |                                   |
| I/C = 100* Cd/Cw                     | 86                 | 79           | > 75                              |
| ITSR (NF EN 12697-12)                |                    |              |                                   |
| Indirect Tensile Strength, air (kPa) | 1356               | 1063         |                                   |
| Indirect Tensile Strength, wet (kPa) | 1091               | 860          |                                   |
| ITSR, Tensile Strength Ratio         | 80.5               | 80.9         | > 70                              |
| Rutting (NF EN 12697-12)             |                    |              |                                   |
| % at 30,000 cycles                   | 5.5                | 3.9          | < 7.5 (class 2)                   |
| % Air Voids                          | 6.9                | 8            | 5 – 8                             |
| Modulus (NF EN 12697-26)             |                    |              |                                   |
| % Air Voids                          | 7.9                | 7.8          | 5 – 8                             |
| Modulus at 15°C, 10 Hz (MPa)         | 13,298             | 14,232       | >7,000                            |

**TABLE 2**

Properties of 0/10 Semigranular Asphalt Mix Using Donia-Genouillac Quarry Aggregate

| Test                                 | BBSG 0/10 Donia-Genouillac |              | Specifications<br>(NF EN 13108-1) |
|--------------------------------------|----------------------------|--------------|-----------------------------------|
|                                      | Hot Mix Control            | EVOTHERM DAT |                                   |
| PCG (NF EN 12697-31)                 |                            |              |                                   |
| V10                                  | 16.2                       | 15.1         |                                   |
| V60                                  | 9                          | 7.5          | 5-10                              |
| Duriez (NF EN 12697-12)              |                            |              |                                   |
| % Air Voids                          | 8.8                        | 6.7          |                                   |
| Compressive Strength dry, Cd (MPa)   | 12,600                     | 11,700       |                                   |
| Compressive Strength wet, Cw (MPa)   | 9900                       | 9200         |                                   |
| I/C = 100* Cd/Cw                     | 78.5                       | 78           | > 75                              |
| ITSR (NF EN 12697-12)                |                            |              |                                   |
| Indirect Tensile Strength, air (kPa) | 1478                       | 1186         |                                   |
| Indirect Tensile Strength, wet (kPa) | 1154                       | 842          |                                   |
| ITSR, Tensile Strength Ratio         | 78.1                       | 71.0         | > 70                              |
| Rutting (NF EN 12697-12)             |                            |              |                                   |
| % at 30,000 cycles                   | 4.7                        | 5.5          | < 7.5 (class 2)                   |
| % Air Voids                          | 6.9                        | 6.2          | 5 – 8                             |
| Modulus (NF EN 12697-26)             |                            |              |                                   |

These results show the outstanding behavior of the EVOTHERM mixtures compared to their hot mix references. With these two mixes, the use of EVOTHERM DAT enables the warm mix asphalt to exhibit identical performance characteristics as the hot mix control.

### **STUDY OF A BBSG MIX USING RAP**

To illustrate the performance possibilities enabled by the Evotherm DAT technology, another study was undertaken using RAP materials. Conserving natural resources and preserving the environment has compelled Eurovia more and more to use recycled asphalt pavement (RAP) materials in their asphalt mixes. The development of warm asphalt techniques will realize its true potential only if performance demonstrated with RAP mixes (containing up to 30% RAP).

The research center of Eurovia tested the performance properties of a BBSG 0/10 containing Thiviers virgin aggregate plus 30% RAP. The combined aggregate and RAP materials formulation conformed with the European standard NF EN 13108-1. The binder utilized was a traditional asphalt with pen 35/50 dosed at a total of 5.7% by weight of mix.

The hot mix controls were made and compacted at 160°C, while the Evotherm warm mixes were produced at 110°C and compacted at 100°C.

Table 3 shows the properties of the mixes obtained in this study.

All the properties of the mixes conformed to the norm NF EN 13108-1. Moreover, one will notice that despite the marked differences in production temperatures of the warm and hot mixes, the workability and the mechanical properties of the mixes were nearly identical.

The Duriez test for moisture resistance also met the specifications of the norm, which is remarkable when one considers the temperature reduction and the use of 30% RAP.

These performance results (with the Thiviers aggregate and 30% RAP) highlight the important contribution of the EVOTHERM additives with regard to two key points: warm mix compactability (workability) and warm mix moisture resistance. Two other key characteristics (rut resistance and strength) point directly to the sound intrinsic properties of the materials.

**TABLE 3**

Properties of 0/10 Semigranular Asphalt Mix Using Thiviery Quarry Aggregate with 30% RAP

| Test                                 | BBSG 0/10 Thiviery + 30% RAP |              | Specifications<br>(NF EN 13108-1) |
|--------------------------------------|------------------------------|--------------|-----------------------------------|
|                                      | Hot Mix Control              | EVOTHERM DAT |                                   |
| PCG (NF EN 12697-31)                 |                              |              |                                   |
| V10                                  | 14.7                         | 15.1         |                                   |
| V60                                  | 7.8                          | 8.3          | 5-10                              |
| Duriez (NF EN 12697-12)              |                              |              |                                   |
| % Air Voids                          | 7.3                          | 6.4          |                                   |
| Compressive Strength dry, Cd (MPa)   | 13,600                       | 12,700       |                                   |
| Compressive Strength wet, Cw (MPa)   | 11,000                       | 9800         |                                   |
| I/C = 100* Cd/Cw                     | 80                           | 77           | > 75                              |
| ITSR (NF EN 12697-12)                |                              |              |                                   |
| Indirect Tensile Strength, air (kPa) | 1513                         | 1387         |                                   |
| Indirect Tensile Strength, wet (kPa) | 1278                         | 1054         |                                   |
| ITSR, Tensile Strength Ratio         | 84.5                         | 76.0         | > 70                              |
| Rutting (NF EN 12697-12)             |                              |              |                                   |
| % at 30,000 cycles                   | 4.3                          | 4.8          | < 7.5 (classe 2)                  |
| % Air Voids                          | 6.3                          | 7.2          | 5 – 8                             |
| Modulus (NF EN 12697-26)             |                              |              |                                   |
| % Air Voids                          | 6.7                          | 6.3          | 5 – 8                             |
| Modulus at 15°C, 10 Hz (MPa)         | 13,567                       | 13,872       | >7,000                            |

**FORMULATION OF A BITUMEN 0/14 SAND-GRAVEL TYPE III MIX (GB)**

Another case study shows the formulation and performance properties of an Evotherm mixture based on a bitumen sand-gravel mix (GB) of type III.

As in the preceding examples, a level III study was conducted by the Eurovia Research Center. The composition and formulation of the mixes conformed to European norm NF EN 13108-1. The binder was a conventional 35/50 penetration asphalt, dosed at 4.5% by weight of mix.

The hot mix control was produced and compacted at 160°C, while the EVOTHERM mix was produced at 110°C and compacted at 100°C.

Table 4 shows that the properties of the both mixes conformed to the specification of NF EN 13108-1.

Moreover, the above three examples demonstrate and validate the performance capabilities of EVOTHERM with a variety of different mix types. Regardless of the mix type studies, the aggregate mineralogy utilized, or other material properties, the warm mix formulas conformed to all specifications of the hot mix controls.

In order to validate the above laboratory results, two projects were conducted in 2007. This article presents results obtained from two different field formulations, each containing RAP. For each of the two projects, a program of study was developed that involved analysis of field cores to determine in place performance.

**TABLE 4**

Properties of 0/14 Roadbase Asphalt Mix Using Thiviers Quarry Aggregate

| Test                                 | GB 0/14 cl III Thiviers |              | Specifications<br>(NF EN 13108-1) |
|--------------------------------------|-------------------------|--------------|-----------------------------------|
|                                      | Hot Mix Control         | EVOTHERM DAT |                                   |
| PCG (NF EN 12697-31)                 |                         |              |                                   |
| V10                                  | 15.3                    | 14.7         | >14                               |
| V60                                  | 6.4                     | 5.8          | <9                                |
| Duriez (NF EN 12697-12)              |                         |              |                                   |
| % Air Voids                          | 6.8                     | 5.7          |                                   |
| Compressive Strength dry, Cd (MPa)   | 13,500                  | 14,200       |                                   |
| Compressive Strength wet, Cw (MPa)   | 10,800                  | 10,800       |                                   |
| I/C = 100* Cd/Cw                     | 80                      | 76           | > 75                              |
| ITSR (NF EN 12697-12)                |                         |              |                                   |
| Indirect Tensile Strength, air (kPa) | 1950                    | 1978         |                                   |
| Indirect Tensile Strength, wet (kPa) | 1520                    | 1464         |                                   |
| ITSR, Tensile Strength Ratio         | 78                      | 74           | > 70                              |
| Rutting (NF EN 12697-12)             |                         |              |                                   |
| % at 30,000 cycles                   | 4.5                     | 5.5          | < 10                              |
| % Air Voids                          | 8                       | 7.5          | 7 – 10                            |
| Modulus (NF EN 12697-26)             |                         |              |                                   |
| % Air Voids                          | 5.2                     | 5.7          | 5 – 8                             |
| Modulus at 15°C, 10 Hz (MPa)         | 15,900                  | 15,200       | >9,000                            |

**FIELD PROJECTS USING EVOTHERM DAT**

Using the EVOTHERM DAT process, 800 tons of mix were produced and placed in June 2008. The mix plant was a continuous, Type 21 Ermont TSE plant.

The mix formulation was as follows:

- 0/6 (0 to 6 mm) dense-graded, calcareous aggregate 39%
- 6/14 (6 to 14 mm) dense-graded calcareous aggregate 41%
- RAP 20%
- 35/50 penetration asphalt 3.9%

(total asphalt, including RAP asphalt was 4.7%).

Production conditions for the Evotherm warm mix were as follows:

- exit temperature of the mix from the Ermont TSE 107-112°C
- production rate 180 tons per hour
- vapor temperature (bag house) 103°C
- Evotherm DAT feed rate (5% w/w total asphalt) 7 Liters / minute

Fuel consumption was measured and a reduction of 40% (compared to the HMA control) was observed on the day of Evotherm production, confirming results obtained internationally.

Placement of the mix presented no problems. Mix was laid at 12.5 cm thickness and compacted to a finished mat of 10 cm. Vibratory compaction (breakdown) was completed in four passes with a Hamm 110 in high amplitude (of class VT2) and with a Caterpillar PS 300 pneumatic compactor (of class PO).

Different temperature measurements were taken at the following points:

- temperature of the mix upon arrival at the job site 100 to 108°C
- temperature of the mix at extension (in the screed) 95 to 105°C
- temperature at compaction 85 to 100°C

Photographs 3 to 5 provide an idea of the quality of the mix in place. It is important to note the condition of the job site prior to the Evotherm application. A campaign of corings was undertaken to validate the performance of the mix. Table 5 shows the results of these core analyses.

### **PLACEMENT OF AN EME II MIX BASED ON CALCAREOUS AGGREGATE AND RAP**

EVOTHERM DAT technology was used to place 700 tons of high-modulus (EME) mix on July 30, 2008 south of RD 928 in Pas-de-Calais. The mix plant was a continuous Enmont TSE Type TSM 17XL.

The mix formulation was as follows:

- 0/4 (0 to 4 mm) dense-graded, calcareous aggregate 33%
- 4/6 (4 to 6 mm) dense-graded calcareous aggregate 12%
- 6/10 (6 to 10 mm) dense-graded calcareous aggregate 20%
- 10/14 (10 to 14 mm) dense-graded calcareous aggregate 24%
- RAP 11%
- 10/20 penetration asphalt 5%

(total asphalt, including RAP asphalt was 5.5%).

Production conditions for the Evotherm warm mix were as follows:

- exit temperature of the mixer 118-122°C
- production rate 170 tons per hour
- vapor temperature (bag house) 105°C
- Evotherm DAT feed rate (5% w/w total asphalt) 7 Liters / minute

A 35% reduction in fuel consumption was measured during mix fabrication (compared to the HMA control mix).

**TABLE 5**Results of Core Samples Taken *in situ* on 0/14 Roadbase Asphalt Using Limestone Aggregate

|                                 | NF EN 12697-7       | NF EN 12697-12      |                     |           | NF EN 12697-26    |
|---------------------------------|---------------------|---------------------|---------------------|-----------|-------------------|
|                                 | Average % Air Voids | ITS<br>dry<br>(kPa) | ITS<br>wet<br>(kPa) | ITSR<br>% | E* at 15°C, 10 Hz |
| EME-<br>Evotherm DAT            | 8.7                 | 983                 | 717                 | 73        | 11,531 MPa        |
| Specifications<br>NF EN 13108-1 | <9                  |                     |                     | >70       | >9000 MPa         |

**TABLE 6**Results of Core Samples on 0/14 High Modulus Asphalt (EME)  
Taken *in situ* on Highway RD 928

|                                 | NF EN 12697-7       | NF EN 12697-12      |                     |           | NF EN 12697-26    |
|---------------------------------|---------------------|---------------------|---------------------|-----------|-------------------|
|                                 | Average % Air Voids | ITS<br>dry<br>(kPa) | ITS<br>wet<br>(kPa) | ITSR<br>% | E* at 15°C, 10 Hz |
| EME-<br>Evotherm DAT            | 4.7                 | 2081                | 1901                | 91        | 19,500 MPa        |
| Specifications<br>NF EN 13108-1 | <5                  |                     |                     | >70       | >14,000 MPa       |

Vibratory compaction was carried out with six passes of a Bomag compactor in high amplitude (class V12) and using a Corinsa PS 300 pneumatic compactor over a range of temperatures from around 85°C to 110°C (see photos 6 and 7).

Core analyses from the job site confirmed the feasibility of using EVOTHERM DAT to reduce production temperatures of an EME mix 50 to 55°C from temperatures typically used for a conventional hot mix EME. The measured properties of the EVOTHERM EME cores met all specifications established in the European norm NF EN 13108-1 (Table 6), notably with regard to the in place air voids and the mechanical properties (indirect tensile strength) of the cores.

**Photo 3: Development of Tempera/Evotherm DAT process in Europe**



**Photo 4: Paver temperature**



**Photo 6: Compaction with a VT2**



**Photo 7: 99°C temperature during compacting**



## CONCLUSIONS

The very positive results observed in laboratory studies and confirmed at job sites attest to the performance capabilities of the EVOTHERM DAT technology. The feasibility of using this technology with a wide range of virgin aggregate and incorporating RAP into the mixes was demonstrated in the lab and field. By decreasing fumes and odors, the EVOTHERM DAT technology also improves air quality both for the paving crew and anyone in close proximity to the construction site, while simultaneously reducing fuel consumption by up to 40%.

Concurrent with ongoing field work, research and development continues in the laboratory. New EVOTHERM additives are being developed by MeadWestvaco. The Central Research Center of Eurovia is looking deeper into the rheology of EVOTHERM mixes and modeling the temperature-dependent behavior of these low-temperature mixes. This work will lead to the development of a practical guide to assist field personnel in production and lay down of EVOTHERM mix. This new generation of warm mix asphalt, while demonstrating great flexibility in the field, will clearly necessitate some adjustment to production and construction methods compared to conventional hot mix asphalt.

There is no doubt that the use of warm mix technologies will expand in the coming years given the rapid growth in sustainable technology initiatives, the increased focus of the engineering profession (USIRF) on this technology, the inevitable rise in fuel costs, and the ever-widening regulations aimed at reducing the environmental burden of industry and commerce. The flexibility and the performance obtained with this new technology will enable fast growth of the warm mix asphalt market in Europe.

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