LOW EMISSION & LOW ENERGY ASPHALTS FOR SUSTAINABLE ROAD CONSTRUCTION: THE EUROPEAN EXPERIENCE OF LEA PROCESS

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ABSTRACT
Different proprietary low-energy asphalt techniques at 90°C, labelled LEA, have been recently developed by LEA-CO (low energy asphalt company) on standard asphalt plants as a real alternative to HMA (hot mix asphalt) which is usually produced above 150°C. LEA can be used as a relatively cheap way to minimize impacts during the manufacturing, transport, paving and compacting stages. In plant, this innovative eco-process enables a reduced binder ageing and a reduction of both energy consumption and greenhouse gases ranging from 30 to 55%. At the job site, fumes are reduced and the release to traffic is almost immediate after compaction. This illustrative article proposes practical examples and case studies that deal with how building owners, prime contractors, asphalt producers and even equipment manufacturers can seek to realise sustainable environmental, economic and social policies and solutions for roads by turning to fostering and using low-energy asphalt for roadway construction and maintenance. After a brief reminder of the objectives and the anticipated energy-related and environmental impacts, the innovative nature of the LEA process is described in relation to the state-of-the-art of classical HMA. The possible re-use of high reclaimed asphalt pavement (RAP) contents is highlighted. Eventually, a specific study focused on the evaluation of the possible moisture damage susceptibility of such half-warm mix asphalts (<100°C) using water-sensitive aggregates is presented, according to three main factors: i) the initial aggregate humidity, ii) the RAP content and iii) the binder penetration.

Keywords: low energy asphalt, half-warm mix asphalt, energy saving, CO₂ emissions, greenhouse gases emissions
1. INTRODUCTION

In connection with the environmental and sustainable development policy of the EIFFAGE Travaux Publics and the FAIRCO groups, different low-energy coating patented techniques were developed over the past few years. Since 2006, EIFFAGE Travaux Publics and FAIRCO have been sharing their respective patents within a joint subsidiary company named LEA-CO. LEA makes it possible, thanks to its specific manufacturing process, to lower asphalt manufacturing temperature on standard HMA plants by approximately 70°C (according to the considered asphalt formula and plant configuration). The final LEA mix temperature is approximately 90°C.

2. BACKGROUND

2.1 Terminology

The different types of asphalt mixes can be defined in relation with their coating temperature and corresponding consumed heating energy, as described in the literature [1]:

- Cold mix asphalt (CMA), produced at ambient temperature from asphalt emulsions or foams,
- Half-warm mix asphalt (HWMA), produced at temperatures below water vaporization,
- Warm mix asphalt (WMA), manufactured at approximately 130°C,
- Hot mix asphalt (HMA), usually produced at 150-180°C in relation with the used binders.

2.2 Sustainable development stakes

Both HWMA (90°C) and WMA (130°C) make it possible to save fossil energy in plants but in different proportions. WMA enables temperature gains of 20°C generally with an excess cost of production due to the use of additives or to a more complex manufacture and/or a somewhat lower rhythm. Energy savings are of the order of 15%. HWMAs lead to as much as 50% energy savings. When employing either an emulsion-type binder or a foam-type one, the saving is slight. Indeed, the emulsion and the foam respectively contain about 35% and 5% of water, which implies a stronger heating of the aggregate, hence the use of anhydric bitumen in the LEA process for simplicity and economic reasons.

Lower coating temperatures also mean that greenhouse gas emissions (GGEs) will also be reduced. As the reduction in CO$_2$ emission is about 9 kgCO$_2$/ton through the LEA process, in Europe (resp. in the USA), the CO$_2$ emissions could decrease by 3 million tons/year (resp. 5 million tons/year).

3. SHORT REVIEW OF THE EXISTING WARM AND HALF-WARM TECHNOLOGIES

These technologies are based on at least one of the four following possible principles:

- Modification of the asphalt mixing process (without changing the mix components)
- Addition of substances which decrease the viscosity of bitumen
- Introduction of water causing in-situ foaming of the bitumen
- Use of low-viscosity vegetable binder

Except the viscosity reducing organic additives (e.g. Fischer-Tropsch (FT) wax [2]) which are currently used more for extending paving season and making the compacting stage easier than for significantly reducing the asphalt temperature, the water-based technologies are more and more used all over the world in order to greatly decrease the production and paving temperatures of asphalt mixtures. The common principle is the generation of water steam which increases the volume of the binder and decreases its apparent viscosity.

Two main classes of water-based warm technologies (>100°C) are currently used:

- The WAM (Warm Asphalt Mix)-Foam process uses a two-component binder system which needs a modification of the plant [3]. First, the aggregates are coated with a soft binder (penetration from 160 to 400) and then foamed, harder bitumen (penetration from 35 to 100) is added. The dry aggregates are coated with the hot anhydric soft bitumen before the water is introduced; this is supposed to ensure a good adhesion of the binder on the aggregate. Trials and applications are mainly located in Norway where the process has been developed.
Zeolites substitute a part of the filler and are added into the plant equipped with an additional storage silo and a feeding system. The structure of this synthetic mineral contains 21wt. % water in small pores which is released upon heating within 2-3 hours. The evolving water steam causes an in-situ foaming of the bitumen. Zeolite is in use in Europe and in the USA [4].

Three main classes of water-based half-warm technologies (<100°C) are currently used:

- Emulsion technology: This technology applies a special emulsion with 30% water content which is delivered and fed into the mixer at around 90°C [5] [6]. The 30% water content in the emulsion is partially liberated in the form of steam when it is mixed with hot aggregates, which makes the mix temperature swiftly decrease below 100°C. The heating and drying of aggregates above 100°C somewhat limit the in-plant energy savings. Trials and applications are mainly located in North America where the process has been developed.

- Foam technology: despite possible energy savings of 20-40%, the quality of this mixes appeared in the literature as lower than that of traditional HMAs [7].

- LEA process [1] [8] [9] [10] [11]: its originality lies in the ability of hot anhydric binder to foam or to emulsify when in contact with the residual water of warm aggregates just below the water vaporization point at 100°C, thus allowing aggregate coating at lower temperatures. The spontaneous volume expansion of bitumen leads to a thicker binder film around aggregate, which fosters good mixture workability even at the processing temperatures of about 80 to 95°C. More details of this process are given hereafter.

4. THE BASIC PRINCIPLE OF THE LEA PROCESS

This process is based on the ability of hot bitumen to foam/emulsify when in contact with the residual humidity of aggregates just below the water vaporization point, thus allowing aggregate coating at lower temperatures (in the range of 90 to 105°C). The volume expansion of bitumen (Figure 1) leads to a thicker binder film around aggregate and thus fosters good mix workability. As a matter of fact, different possible sequential drying and coating processes can be used in lab or on site in relation to the asphalt plant configuration (see Figure 2):

- LEA method 1: the drying stage only affects a first part of the aggregates, then coated by the whole bitumen. The remaining cold and wet part is then added. All the constitutive elements of the mix are then mixed, or
- LEA method 2: the drying stage only affects a first part of the aggregates, which is then mixed, before the coating stage, to the remaining moist part, or
- LEA method 3: all the aggregates are partially dried, then coated by the hot bitumen.

Figure 1: a) Bitumen auto-expansion during the LEA® process at the EIFFAGE central laboratory, b) & c) Microscopic evidence about the dispersion state of water (liquid or steam) inside bitumen [6]. Craters correspond to water already evaporated or to fine droplets, the diameter of which being between 2 and 50µm.
Figure 2: Schematic representation of the three main LEA methods.
5 PRINCIPLES OF LEA PRODUCTION IN PLANTS
Any plant can produce LEAs once the license is obtained from LEA-CO. Plants however need to be equipped with in-line water and additive dosage systems and automation system is modified, which necessitates training of the plant crew for this new know-how. No fume emissions during the discharge of mix in trucks (cf. Figure 3). The follow-up of the in-plant consumption and CO₂ emission confirms the theoretical savings by a factor 2 (Figure 4, [12-13]).

Figure 3: LEA process on a continuous drum mix plant with introduction of cold and wet sand or RAP into the pugmill (Cortland, NY State). Example of extra water addition system for controlling the initial moisture of cold aggregates (Bischoffsheim, France).

Figure 4: Environmental impacts measured on a batch plant in Monthyon (France), drawn from [12-13]. EE: Energy equivalent, GWP: Global Warming Potential.
6. WORKSITE VALIDATION

6.1 Improved working conditions
Asphalt mix temperature is almost halved, hence enhanced working conditions for plant workers and the paving crew as well. The residual moisture of 0.5% in the final mix is also favorable for equipment cleaning. Indeed, less soiling is observed due to the presence of fine water droplets condensed on equipment surfaces (drum, paver-finisher, lorry tipper) thus facilitating cleaning and reducing the use of solvents. Worth noting, an accidental cool rain on LEA may cause far less steam and a strong reduction in thick fog, which can then be a notable safety factor.

6.2 References of the Years 2005-2010
More than 400,000 tons of LEA were manufactured to date on 40 plants (continuous drum plants or batch plants) and with any kind of bitumen (pure bitumens and PMB’s) and aggregate nature and formula (dense or open-graded formulas). In most cases, some specific multifunctional additives were used to improve the foamability and the coating ability of the binder, along with the workability of the mixture at temperatures below 100°C. The reference roadworks were conducted successfully mainly in France (by EIFFAGE and FAIRCO) and in the USA (by Suit Kote) and to a least extent in Spain (by EIFFAGE Infraestructuras), the UK (by PetroPlus) and New-Zealand (by Fulton Hogan).

As the difference with the ambient temperature is smaller for the LEAs than for their high-temperature counterparts, the drop in temperature with time is less significant. If the LEA mix in trucks is maintained at a temperature above 80°C a time of 4 or 5 hours between production and laying/compaction has turned out not to be a problem at all.

Figure 5: Example of a 3100-ton LEA® roadwork for an aerodrome near Montpellier (France).
7. LEA MIX DESIGN IN LABORATORY: CASE STUDY OF A PARAMETRIC STUDY WITH WATER-SENSITIVE AGGREGATE

The effects of the initial moisture content (before partial vaporization during foaming), of the RAP (reclaimed asphalt pavement) content and of the penetration of the neat binder were specifically investigated to mitigate the potential for moisture damage of a poorly water resistant mix formula: a dense BBSG 0/10 formula with ryolite aggregate—generally used as wearing course. Our results pointed out the values for the initial aggregate humidity, the RAP content and the penetration of the neat binder to be targeted in plant so that the LEA moisture resistance meets the current HMA specs. Indeed, the optimum r/R value (i.e. moisture resistance) is obtained for water content from about 0.9 to 1.3% and for a RAP content of 30% whatever the penetration of the neat bitumen. Regarding the other performances of LEA mixes (the compactability, rutting resistance, stiffness modulus and fatigue resistance) are very similar to those of their hot mix counterpart.

Figure 7: Optimisation of the moisture resistance (r/R ratio) of a LEA ryolite BBSG 0/10 according to the initial humidity, the RAP content and the penetration of the neat binder.
Besides, the optimized LEA mix design in lab thus seems as much important as that of any hot mix asphalt (HMA). From now on, should we still compare HMA and LEA with exactly the same aggregate formula or should we try to optimize our LEA formulas according to parameters such as the initial wetness, the RAP content or the nature or characteristics of the binder used? Indeed, in the case of the study with water sensitive aggregates, the use of a traditional 35/50 or 50/70 pen grade bitumen, the introduction of 20% RAP and the control of the initial water content of aggregates in a range from 0.9 to 1.6%, maximize the resistance to moisture.

8. LABORATORY EVALUATION OF TOTAL ORGANIC COMPOUNDS (TOC) Emitted During the Manufacturing Process: HMA VS LEA

8.1 TOC measurement sampling system

The French LCPC ("Laboratoire Central des Ponts et Chaussées") has recently developed an innovative laboratory procedure in order to discriminate the manufacturing processes (hot- Vs Warm- Vs half-warm processes) according to their emission potential of Total Organic Compounds (TOC).

The sampling and continuous analysis of TOC emitted during the laboratory manufacturing are carried out by portable and automatic total hydrocarbon equipment (model 901 MET-NMET/TOC Mercury) according to the French standard NF EN 13526. The evaluation and separation are performed by a flame ionization detector (FID). A sampling system makes it possible to collect the sample directly in the stack. The pump integrated with heated head, sucks up the fumes from sampling point towards the analyzer (see Figure 8).

![Mixer and stack for laboratory asphalt manufacturing](image)

**Figure 8:** Mixer and stack for laboratory asphalt manufacturing

8.2 Influence of manufacturing process upon bitumen aging and emission potential of TOC

Figure 9, drawn from [14-15], illustrates the correlation between manufacturing temperature and the TOC emissions, whereas Figure 10 shows the high correlation between emission potential of TOC and bitumen aging (aging was evaluated from the values of Penetrability and Ring&Ball Temperature after bitumen recovery). The former confirms in-situ measurements (see e.g. Figure 4), whereas the latter is of prime importance and very encouraging considering the durability issue of road materials and structures.
9. CONCLUSIONS & PROSPECTIVES

- The LEA® process is universal since different proprietary “partial” drying and coating methods enable us to adapt to drum plants as well as batch plants– as they exist nowadays.
- The use of high RAP contents (up to 50%) is compatible with the LEA® process.
- Unlike cold mix asphalts, LEAs have a performance tantamount to that of HMAs, but owing to the residual water (<0,5%) in the mix under 100°C, attention is to be paid to the evaluation of potential for moisture damage in lab.
- Even with water-sensitive aggregate, LEAs can meet the current European and US specifications used for the moisture resistance of HMAs.
- The influence of manufacturing process upon bitumen aging and emission potential of TOC may be evaluated in laboratory in order to discriminate processes and/or materials.
- Finally, implementation in other countries still needs to be realized to check the validity of the proposed low-energy asphalt process with other materials, climates and mix design methods.
10. REFERENCES


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