

## **CONTRIBUTION OF GREEN ADDITIVES AND TECHNOLOGIES TO ASPHALT SUSTAINABILITY**

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### **ABSTRACT**

Due to the increasing awareness of “Environment and Sustainability”, the impact and enforcement of these issues are becoming very important factors for every industry in the recent years. They also apply to planning of road construction and road repair. To be able to control and manage it, the European Commission (EC) has published some directives and regulations that should be followed by the industry. The road sector is concerned about the environment and is trying to make it as sustainable as possible.

The enforcements of the EC are forcing industries to limit the use of natural resources and increase the re-use of materials. For this reason “recycling” is an important topic regarding sustainability. However, the “recycling of the additives” which are used on road construction, is mostly underestimated until now. The additives that can be found on the market are either “virgin” (originally produced) or “recycled” (green). The “green” additives are introduced and their technical properties are compared with the “virgin” ones. The technical and environmental properties are also compared and their contribution to the “sustainability of asphalt” is discussed.

**Keywords:** Sustainability, asphalt additives, green products, re-use, recycling

## 1. INTRODUCTION

As a result of recent global challenges like “Global Climate Change and Carbon footprint”, the asphalt industry is taking care of its share regarding these developments. The asphalt industry is now also addressing “sustainability” whose general definition is: *‘Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.’* [1.].

To be effective the European Commission (EC) intends to focus on the two environmental key issues that are mentioned in their action plans called “Towards a sustainable industrial policy”:

- Climate change and a low-carbon economy;
- Sustainable and efficient use of natural resources, energy and materials.

The two Action Plans fully take into account competitiveness, energy, environmental and social aspects. Their aims are: improving the way materials are produced, improving the products available on the market and the way they are consumed. Regarding contribution of asphalt industry to sustainability, the sustainability themes and policies at the EC level affecting asphalt industry are the following:

- Energy consumption (during production, construction and use)
- Use of materials/ re-use / recycling / efficient construction
- Minimising waste
- Environment (Warm Mix Asphalt)
- Living environment (Noise reduction, Traffic safety, Cool cities)
- Nature and landscape

Asphalt industry, like other sectors, should be responsible for sustainability in front of future generations and should build the roads by optimizing the use of the limited natural resources and by re-using and recycling available materials as much as possible.

## 2. RE-USE OF MATERIALS IN ASPHALT

New concepts are coming regarding the re-use of materials and the use of sources.

One of them is called “Cradle to Cradle”, which is related to sustainable design, mentioning the use of environmentally safe and healthy materials; the design for material reutilization, such as recycling; the use of renewable energy and energy efficiency; the efficient use of natural sources and instituting strategies for social responsibility.

The other one is “Environmental Product Declaration”(EPD). This is related to “Sustainability of Construction Works” standards for the delivery of environmental information on construction products, and to assess the environmental performance of buildings, and more generally the integrated performance of buildings in a framework document. The objective is to cover all kinds of building products and buildings, new and existing ones, possibly other construction works, and the development of a technical report describing processes and scenarios related to the building's life cycle, in order to complement the whole concept.

The asphalt industry which is developing a wide range of new and improved products, has to optimize the use of materials, reducing the use of new minerals and promoting the recycled and secondary materials, used in asphalt mixes too.

Asphalt is 100 % recyclable and can be used to produce new hot mix asphalt. In some countries Reclaimed Asphalt Pavements (RAP) is the most recycled product. The techniques that are being developed now are not only related to the recycling of asphalt but also to other materials/additives with the aim to reduce energy and costs by keeping/increasing the technical performance.

Besides, secondary materials have also been used for the production of asphalt.

The use of secondary materials reduces the need for natural sources, provided that [3.]:

- *There are no disadvantages for health and safety of workers in the asphalt industry*
- *There are no environmental impacts, now or in the future*
- *Future recyclability and reuse of asphalt remains*
- *There is no negative impact on the technical product performance of asphalt*

There are also many types of additives/chemicals that are being used in the asphalt industry, as anti stripping agents, rejuvenators, flux oils, polymers for mix modification, fibres, WMA additives, etc.

The paper gives an overview of the green practices which can be adopted in road construction.

## 3. OVERVIEW OF RECYCLED CHEMICALS TO BE USED IN ASPHALT MIX PRODUCTION

A number of additives and modifiers are used in asphalt industry. They can be produced starting from virgin raw materials or by using recycled materials

### 3.1 Asphalt additives

Asphalt additives can be:

- *Anti stripping agents*
- *Rejuvenators*
- *Flux oils*

#### Anti stripping agents

The road surfaces can be subject to deterioration caused by a weak adhesion between aggregates and bitumen, especially when it occurs in the surface course. Such damage is highlighted by detachment and loss of surface aggregates and the consequent formation of cracks or potholes. In this way water will be in contact with every single layer of the pavement and will degrade the entire road section. Some types of asphalt pavement mixtures, including Porous Asphalt and those with a high content of RAP, or poorly sealed, are especially exposed to this phenomenon. Anti stripping products act as protective agents against these water disruptive effects. These kind of additives can be produced using up to 40% of spent luboils.

#### Rejuvenators

To reuse the RAP (Reclaimed Asphalt Pavement) with the technology of recycling either by hot or cold processes, it is necessary to regenerate the chemical and physical properties of the bitumen lost during ageing in service. This is the function of rejuvenators, which regenerate the oxidized bitumen, bringing back the binder volatile fractions gone due to aging process. The reasons to support recycling are different but equally important, starting from the point of environmental issues, as well as per the general guidelines of the OECD study (Organization for Economic Cooperation and Development) published in 1997, whose main points are focused on: a) the reduction of the use of raw materials, b) the reduction of the areas to be allocated to landfill, soil and air pollution containment, c) conservation of energy, affordability and technical advantages. The rejuvenators additives can be produced using up to the 70% of spent luboils.

#### Flux Oils

Flux oils are materials used to soften the bitumen in case of bond coat emulsions or in the process of pothole patching material, to release workability to the mixture. They can be of vegetal or mineral nature and produced by using up to the 90% of spent luboils.

#### Environmental benefits

The use of so-called green additives, composed of recycled oils, allows a reduction of environmental impact related to saving the use of raw materials. The environmental benefits are shown in table 3.

### 3.2. Asphalt modifiers

Asphalt modifiers can be:

- *Fibres*
- *Polymers*
- *Rubbers*

#### Fibres

Since the eighties, with the developments in the use of Porous Asphalt with acoustic and draining properties, together with high performances and long life cycles, the asphalt industry has considered new materials to be added to the mixes with the aim to increase its properties.

Porous Asphalt shows draining performances due to the open structure of the mix, which avoids the formation of dangerous puddles of water on the surface, avoiding the effect of "aquaplaning". The need to use a high percentage of modified bitumen in porous asphalt and to ensure the durability of high modulus pavement layers, has required the use of strengthening additives such as fibres, synthetic or natural, which generate an internal cross-linking in the bituminous structure. The fibres improve the mechanical properties of the conventional asphalt by increasing its durability. Thanks to their capability to create a thicker film of active binder, the fibres represent a valid solution to the problems of brittleness and displacement, especially in mixes with a high percentage of voids. In all related laboratory studies, the results obtained show an improvement of the mechanical properties of the mixture, expressed as an increase in the absolute value of complex modulus and an overall improvement of the deformation response of the material under static loads (see table 2).

The use of green fibres, made of 80% of cellulosic recycled material, allows a reduction of the environmental impact related to the raw materials' saving. The environmental benefits are shown in table 3.

## **Polymers**

Polymer additives are provided by the petrochemical industry. However, they can be obtained by using recycled plastic materials of various origin, providing that they are correctly blended.

The need for designing and constructing asphalt pavements that perform satisfactorily under severe climate and traffic conditions can be met by modifying traditionally produced asphalt with polymers. The selection and dosage of polymers, and the production of modified asphalt require expertise and polymer compounds.

These polymer compounds are a mix of selected recycled polymers, which are made of smooth and flexible granules. They are used to produce all types of bituminous mixtures where a modification of the bitumen is needed to improve the characteristics of the asphalt and to increase the mechanical resistance. These polymers can be added directly to the plant's mixer, avoiding the special equipment and tanks of the modified bitumen.

Moreover, there is no need to increase the production temperatures compared to the traditional mixtures: the addition can be made with a batching scroll, or manually through an opening in the mixer.

Advanced lab testing and various applications have shown that these polymers considerably reduce the plastic deformation (rutting) of asphalt surfaces at high temperatures. The service life of the road surface is thus appreciably increased.

The improved properties and prolonged wear resistance have been repeatedly demonstrated in road and airport projects we have carried out in Austria, Great Britain, Italy, Spain, Hungary, the Czech and Slovak Republics, Saudi Arabia, the USA, the Chinese People's Republic, Malaysia and a number of other countries.

Because of the extended service life and reduced maintenance cost the asphalt pavements, life cycle costs are substantially reduced.

## **Rubbers (worn out tyres)**

Worn out (end of life) tyres can be used to produce many types of crumb rubber. Added to the asphalt mix, such recycled rubber contributes to lower the noise produced by the rolling car tyres.

Special additives are made of about 80% crumb rubber and 20% compatibilizers.

Another system to reduce the pavement noise is the application of special porous asphalt made of polymer modified bitumen. The use of recycled rubber can replace the use of virgin polymers (SBS).

## **4. OVERVIEW OF GREEN TECHNOLOGIES USED IN ASPHALT MIX PRODUCTION**

Although in this case the additives are not made of recycled / natural material, the use of special additives, emulsions or techniques can help to lower the impact of road construction on the environment.

Besides the green additives, there are a number of techniques that not necessarily utilize green materials or additives, but are themselves green because they allow to reduce energy consumption and carbon emissions.

### **4.1. Cold recycling of milled materials**

The construction and the maintenance of roads in general, and of asphalt paving in particular, involve, in addition to high costs, also a high demand for high quality raw materials consisting of new aggregates from the quarry.

Many roads have been in use for over twenty years and have reached the limit of operation, requiring an increased maintenance in order to maintain acceptable levels of service. In addition, over the years, the average volume of vehicles has increased steadily. The increase of traffic, the stress due to vehicles, the larger load axles and the increased age are all factors that contribute to the deterioration of the roads. To address the related problems, the technique of recycling flexible pavements has become increasingly popular. The reasons supporting the need for recycling are numerous, and very important from the point of view of the environmental protection, as it was highlighted by the general lines of the OECD study (Organization for Economic Cooperation and Development) published in 1997:

- Reduced use of raw materials
- Less ground that need to be used as waste dumps;
- Less soil and atmospheric pollution caused by waste transportation;
- Energy saving;
- Cost-effectiveness;
- Technical advantages.

In this case, we are talking about cold recycling. Cold regeneration is carried out with suitable equipment that mixes the milled bituminous conglomerate (*RAP*) using a *special bituminous emulsion*, together with cement, water and, if necessary, newly added virgin aggregates. Depending on the situation, this production process can be carried out using fixed production plants or through the use of self-propelled equipment that move along the road to be regenerated, carrying out milling, mixing and application units.

The environmental benefits of this technique are shown in table 3.

#### **4.2. Warm-mix asphalt**

Environmental issues and problems in connection with safety and health of operators in charge of manufacturing and laying bituminous mixes have always raised long debates on the plausible harmfulness of fumes formed by the heating of mixes at the temperatures (160 – 180°C) required for their compaction.

If, on one hand, the effects on the operator's health are still undergoing clinical studies, on the other hand, the environmental impact of the emissions of harmful substances on the atmosphere is clear to everybody.

Warm-mix asphalt (WMA) application matches all the above mentioned requirements, guaranteeing the same performances of traditional hot mixes.

High processing temperatures have so far been an indispensable need for the mix in order to achieve the best characteristics, which are obtained if the following conditions are assured:

- Drying of aggregates, to remove the humidity.
- Bitumen binding the entire surface of aggregate.
- Workability and compactability of the mix.

The goal of reducing the production temperature can be reached by lowering the temperature of the aggregates, which are 94-95 % of the total mass of bituminous mixture.

It is important to underline that, to achieve this goal, a large number of studies have been carried out with the aid of the most advanced technologies and assisted by field tests. Under present conditions, these technologies provide the possibility to produce mixes at temperatures that are close to 110-120°C and allow them to be compacted at 70-90°C, depending on the different techniques.

The final characteristics of a WMA are comparable to the traditional asphalt laid at the normal working temperatures. Lab test results are shown in Table 1. The environmental benefits are shown in table 3.

#### **4.3. Antismog asphalt**

The catalytic properties of TiO<sub>2</sub> are well known. TiO<sub>2</sub> is the base of special antismog treatments which sensibly reduce the number of automotive pollutants such as NO<sub>x</sub> and SO<sub>x</sub>.

## 5. TECHNICAL COMPARISON BETWEEN TRADITIONAL AND GREEN PRACTICES

Romania is among the countries where the use of green additives is most diffused, especially recycled polymers and fibres. In the following table we consider a number of applications and experimental studies carried out in Romania.

The used fibres were made, up to 88%, by recycled material. Polymers were 100% recycled polyolefinic material, directly added into the plant mixer.

Table 1 shows the comparison between some asphalt mixtures made by using standard modified bitumens (BAD 25, BAD 16, etc.) and other mixes composed by green recycled additives, following the Romanian standards.

**Table 1 : Laboratory test results for different kind of asphalt mixtures, according to the Romanian standards**

No	Name of the asphalt mixture according to the Romanian standards	Laboratory test results					
		Dynamic creep		Stiffness modulus at 15°C (MPa)	Fatigue (cycles)	Wheel tracking	
		(µm/ m)	(µm/ m/cycle)			(mm/1000cycles)	( %)
1	BAD 25	17114	1.7	4730	309000	-	-
2	BA16a	18675	3.1	4590	-	0.3	16.8
3	MASF 16	16315	2.7	5774	-	0.5	15.2
4	BAD 25 m (Recycled LDPE)	10234	0.9	7939	415000	-	-
5	BAD 25 m (SBS)	14450	1.4	4832	405000	-	-
6	MASF 16 m (Recycled LDPE + recycled fibres 0.4%)	10457	1.5	8654	-	0.1	4.0
7	MASF 16 m(SBS)	10538	1.9	5128	-	0.2	4.2
8	BAD 25 m (Recycled LDPE)	6713	0.6	6675	418000	-	-
9	MASF 16 m (recycled LDPE + recycled fibres 0.4%)	12911	1.9	5400	-	0.1	4.6
10	MASF 16 m (recycled LDPE + recycled fibres 0.4%)	10611	0.9	6134	-	0.1	4.3
11	MASF 16 m (recycled LDPE + recycled fibres 0.5%)	14205	1.1	6432	-	0.07	4.2
12	MASF 16 m (recycled LDPE + recycled fibres 0.5%)	9675	0.2	8796	-	0.1	3.8

*Legend:*

*BAD 25 = open graded binder layer*

*MASF 16 = Romanian name for SMA (split mastic asphalt)*

*Points 1,2,3 = as per Technical Specifications*

*Points 4-12 = with type of use included in brackets ( )*

The results show that the performances of the mixtures containing green additives and those of the other mixtures are comparable.

**Table 2 : Results on warm mix asphalt compared to Hot Mix Asphalt**

Laboratory tests	HMA test results	WMA test results
Rutting (%)	3,8	4,8
Modulus ( MPa )	5774	5374
Fatigue ( cycles )	415000	422000

Table 2 shows a comparison between HMA and WMA with the same composition. WMA has been made using a chemical additive (Iterlow). Modulus and fatigue are similar.

Also in this case, the conclusion is that we can reduce the energy spent to produce and lay the asphalt mix (reducing in this way the atmospheric emissions) without affecting the mix performance.

## 6. EXAMPLES OF ENVIRONMENTAL BENEFITS USING GREEN ADDITIVES AND PROCESSES

Following the previous considerations and data, we can try to summarize the environmental benefits obtained by using green additives and technologies.

Table 3 shows for each green additive or technology the savings of raw material and the environmental impact (CO<sub>2</sub> reduction). The table also reports the expected saving (target) of virgin material or emissions when using the green additives, compared to the traditional products (traditional line).

**Table 3 Expected Environmental savings**

Product Category	Green Category		Target for green line savings vs. traditional line	Expected environmental impact Reduction in use of virgin raw materials/CO2 emissions reduction
	Virgin raw material savings	Minor environmental impact		
Recycled Fibres	cellulose	raw materials	80%	Virgin cellulose fibre
Recycled Flux Oils	mineral oils	raw materials	50%	Virgin mineral oils
Recycled Rejuvenators	mineral oils	raw materials	80%	Virgin mineral. The use of rejuvenators allows the recovery of road milled material
Recycled Anti-stripping agents	mineral oils	raw materials	80%	Virgin mineral oils
Recycled Polymers	SBS, EVA, polyolefin	raw materials	100%	Virgin polymers
Technology for producing warm mix asphalt	0	CO2 emissions	50%	Lowers the asphalt production temperature with 40°C , reduction of emissions at the workplace (up to -60%) and decrease of the use of energy sources and, indirectly, reduction of the total CO2 emissions (up to 50%). Reduced energy consumption up to 30% compared to the production of traditional Hot Mix Asphalt
Antismog products	0	CO2 emissions		SOx -NOx emission
Noise reducing additives	0%	Raw material/acoustic emissions	80%	Reduction of decibels compared to traditional road surfaces, use of recycled rubber from worn out tires.
Cold Recycling	Milled material	Raw materials / CO2 emission	100%	Virgin aggregates/new bitumen / low emissions

## 7. ADVANTAGES OF GREEN ECONOMY IN ROAD CONSTRUCTION



The latest world crisis is becoming the springboard for an economy that seemed like science fiction in the "Earth Summit" Rio de Janeiro, Brazil, 1992.

The theme of the new summit in Rio de Janeiro in 2012 will be "A green economy in the context of development and poverty eradication".

Taking the example of the relation of UNEP (United Nations Environment Program) "Towards a Green Economy Pathways to Sustainable Development and Poverty Eradication": for UNEP, the green economy is an economy that involves "An improvement of human welfare and social equity, while reducing significantly the environmental risks and the lack of resources".

By 2050 the world will produce more than 13 billion tons of municipal solid waste and other waste; currently only 25% of the total waste is recovered and recycled. An investment of 108 billion dollars a year in the greening of the waste sector could help to recycle almost 100% of electronic waste against the current 15%. Such an investment could triple the recycling of the waste by 2050 and decrease of 85% the amount of waste to landfill compared to the scenario of maintaining the status quo. By 2030 this would also result in additional savings, like a decrease of 20 to 30% of global emissions of greenhouse gases due to methane. The prevention and waste management remains a major challenge for the manufacturing industry. Approaches such as the "king manufacturing" and the redesigning of products and procedures can help to reduce waste and the use of resources. An elongation of the life of manufactured products of just 10% would result in an equivalent reduction of the volume of resources extracted.

To give a good example, the EU's 27 Member States dispose of five million km of paved roads, out of which 61,600 km are motorways.

The "greenroads" website reports that constructing and maintaining one lane mile of freeway pavement can use [5.]:

- between 7.000 and 12.000 tons of raw materials; equivalent to that used by 600 to 1.000 U.S. households for an entire year
- consume between 3 and 8 TJ (terra Joules) of energy; equivalent to that consumed by 75 to 200 U.S. households for an entire year
- emit 500 to 1,200 tons of CO<sub>2</sub> equivalent expressed as Global Warming Potential (GWP); equivalent to that produced from 70 to 160 U.S. households in an entire year.
- generate 2,500 tons of waste over its lifetime; equivalent to that generated by 1,250 U.S. households for an entire year.

If we make a simple multiplication we can estimate the savings in pollution and emission when we are trying to recycle the materials for road construction.

## 8. FINAL CONSIDERATIONS

**"Our roads are everywhere. Anywhere you turn, you're automatically on a road. We can't get away from them. We step outside of our house and we're on a road. If we go to a National Park, we take a road. People don't realize this but [building roads] is one of the highest impact things we do." – Shane Stathert, Think Green Roads**

The fundamental objective of this study was to explore some of the possibilities to recycle and to lower the CO<sub>2</sub> emissions in road construction in order to reduce the environmental impacts.

The purpose was to suggest the opportunity to think about the road as one of the best ways to save energy and CO<sub>2</sub> emissions and to reach the Kyoto protocol requirements.

The direct advantages for a massive recycling policy in road construction can be summarized as follows:

- road safety/social aspects: road accident reduction, improvement of working conditions, higher resistance to low temperatures, adherence increment, aquaplaning phenomenon reduction, road surface waterproofing, decrement of risks concerning the road workers' health, durability of the infrastructure.
- pollution: atmospheric pollutants decrease by considerably reducing toxic emissions, noise and soil pollution;
- savings/recycling: energy savings, less maintenance interventions, increment of the pavement life duration, saving virgin raw materials by using secondary raw materials and scrap.

Sustainability is very important and everyone and every industry should be aware of the consequences of its activities.

The asphalt industry already contributes in different ways to sustainability.

Durable asphalt roads and durable surface layers have been developed by the asphalt industry (and still improved) to reduce:

- road works
- less hindrance to the road users and the adjacent living people
- traffic jams and the environmental impacts of these traffic jams
- the use of (natural) resources and the transport of materials
- the use of energy.



In conclusion, previous studies and our experimental tests and applications have confirmed that the use of green technologies and materials can reduce appreciably both costs and environmental impact. Moreover, they can guarantee similar performances and characteristics of the application with respect to the traditional processes and materials.

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