DEVELOPED COUNTRIES - DEVELOPING COUNTRIES: CONVERGENT INTERESTS IN THE FIELD OF ROADS?

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INTRODUCTION

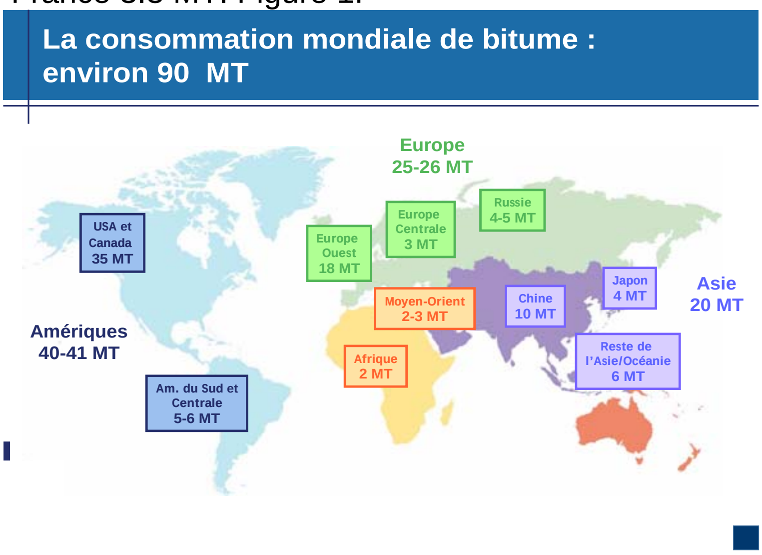
People are becoming increasingly aware that we must change our way of living. The report written by Madame Brundtland to the U.N.'s World Commission on Environment and Development, the very document that sparked the notion of sustainable development, dates back to 1987, some 20 years ago. At that point in time, the French-English translation was already the source of debate: should development be "durable" (lasting, *durable* in French) or "sustainable" (*soutenable* in French). Diplomacy made its choice. As we all know, it was sustainable development, an expression with a clear double meaning. We must remember that this means "development that meets the needs of the present without compromising the ability of future generations to meet their own". When we hear that there will be no more oil in forty years (even with the most sophisticated techniques) or that the availability of oil products will begin to decline in 15 or 20 years, now is high time to start asking ourselves questions.

Over the next 20 years, mankind will grow from 6 to 8 billion individuals that will need to be properly nourished, with what and how?

In this paper, I will highlight how our professions can positively contribute to this ineluctable evolution. Can we already start replacing oil and bitumen in our projects, at least partially? The sources I have based my work on are indicated, the figures are published but must be put into perspective because the disciplines covered have not been studied with strict statistics on a local or global scale.

1. OIL AND ENERGY IN ROAD WORK

Our lines of business consume bitumen: roughly 90 MT per year with the geographical breakdown featured on the map below. The world's leading road construction company consumes 3.5 MT, France 3.3 MT. Figure 1:



When translated into asphalt mixes or surfacing, the consumption figures are approximately as follows:

Chart 1: asphalt mix worldwide

United States *	500 MT	(30)
Canada *	40 MT	(2)
Europe (27 member states)	320 MT	(18)
Rest of world	640 MT	(35)
Total	**1500 MT**	(85)

* excluding recycling and reclaiming

The worldwide tonnage of bitumen emulsion is estimated at 8 MT according to the following breakdown:

Chart 2: Emulsions worldwide

Europe (27 member states)	2.65 MT
US / Canada	2.75 MT
Brazil	0.40 MT
Mexico	0.65 MT
Other - South America	0.50 MT
Rest of world	1.05 MT

We estimate that the above is used as follows:

Chart 3: Applications of emulsions

Surfacing	Surface dressing	2.4
	Cold micro asphalt	0.8
	Other	3.6
Cold mixes		1.2

We estimate that 240,000 T of fluxing agents were consumed in the above.

As for the fuel used in worksite equipment and vans, it is not easy to carry out an accurate inventory. We chose to take into consideration the consumption of the Colas Group and to extrapolate (which is a bit risky) as per Colas' weight in our profession. We obtained an annual average number of roughly 6,000 M liters of light fuel. For coating, a similar approach led us to calculate the equivalent of 7,500 liters of heavy fuel. Application amounts to less than 10% of manufacturing (let's say roughly 6%), i.e., 450 M liters of fuel out of the 6,000 cited above.

We would like to recall the fact that the global production figures for oil oscillate at around 29 G bbls/day i.e., 4,700 G l/year. Our line of business thus consumes roughly 3‰ of global production. In light of this, one can wonder if we actually need to make an effort. But we can cite the most famous authors of antiquity by saying "Small streams feed big rivers".

2. DOES GLOBAL FARMING HAVE ENOUGH ROOM TO ALLOW FOR NEW CROPS?

It must first be noted that, before looking for plant-based fuel substitutes, mankind must first and foremost eat, in light of estimates that show growth in populations from 6 to 8 billion people, excluding Europe and North America, whose populations remain stable.

We will calculate our evaluations with the idea in mind that in the future, on a "human"-scale, i.e., 30 to 50 years, the surface area of the planet will maintain the same ratio between land and sea, and climate changes will not have any impact on this.

UN studies (FAO) give us an idea of the surface area available for new crops.

Chart 4: Breakdown of land surface area (2003 / 2004)

Zone in billions of hectares (G. Ha)	Land	Forest	Farmland	Remainder (estimate)
World	13.041	3.869	5.017	4.155
Developed countries	5.383	1.720	1.744	1.919
Developing countries	7.658	2.149	3.273	2.236
Asia / Pacific	2.014	0.512	1.029	0.473
South America and central America	2.018	0.964	0.784	0.270
Africa – Near East	1.263	0.029	0.455	0.779
Sub-Sahara Africa	2.363	0.644	1.005	0.714
	7.658	2.149	3.273	2.236
Europe (27 member states)	0.420	0.150	0.200	0.070
USA	0.916	0.226	0.411	0.279
Canada	0922	0.245	0.075	0.602
Australia	0.768	0.155	0.455	0.158
Russia	1.689	0.851	0.217	0.621
	4.715	1.627	1.358	1.730
Other	0.668	0.093	0.386	0.189
China (including Asia)	0.929	0.163	0.554	0.212
Brazil (including South America)	0.846	0.544	0.263	0.039

Before going any further with this line of thought, we would like to indicate several examples of the use of fertilizers and some results of crop yields.

Chart 5: Fertilizers

Wheat	240 kg/Ha in France	25 kg/Ha in Russia
Corn	257 kg/Ha in USA	12 kg/Ha in Tanzania
Rice	320 kg/Ha in South Korea	4 kg/Ha in Cambodia
Cotton	461 kg/Ha in Tajikistan	41 kg/Ha in Benin

This data shows the enormous disparity in the use of fertilizers worldwide and the slow progress of yield. The figures do raise questions: do we need to increase yield by using fertilizer (hence energy) or put the issue of feeding future populations aside for now?

One conclusion is certain: by mobilizing research and technical progress, farming can become more productive with fertilizers that comply with sustainable development requirements or with more productive types of plants.

What was our goal? To find out if farming could offer sufficient capacity to feed mankind and become a substitute for oil products in the upcoming 40 to 50 years. We could say that the situation isn't hopeless, yet.

Can global farming face these multiple challenges, often contradictory and controversial? Let's bet the answer is yes.

The graphs below show that over the last few years during which the global population increased 20% (+ 1 billion people), the yield per capita for farming is maintained. We bet that the same will be true in the future and that Governments will find the appropriate solutions for GMOs, pesticides and fertilizers on the whole.

Figure 2: Cereals: Production/capita according to group of country, 1961 - 2000

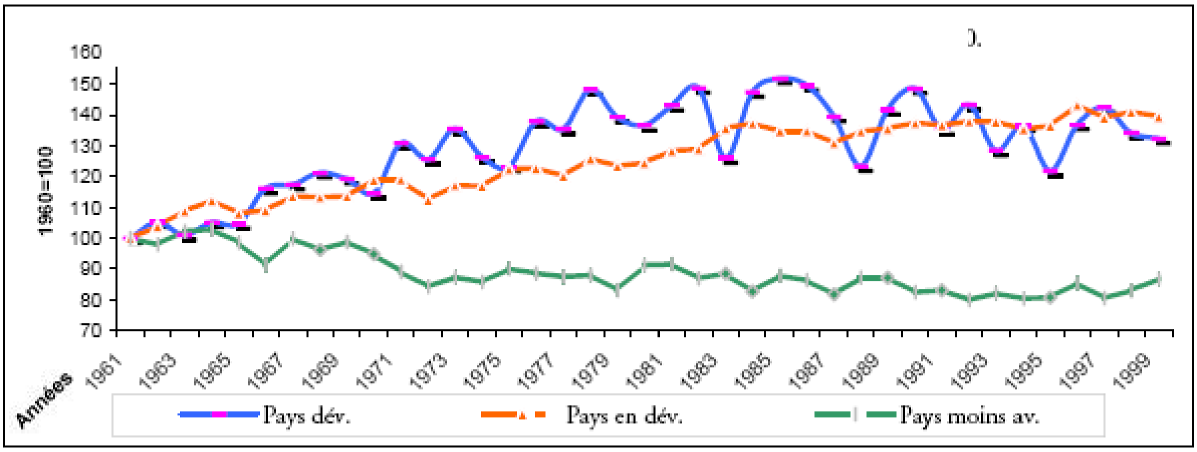
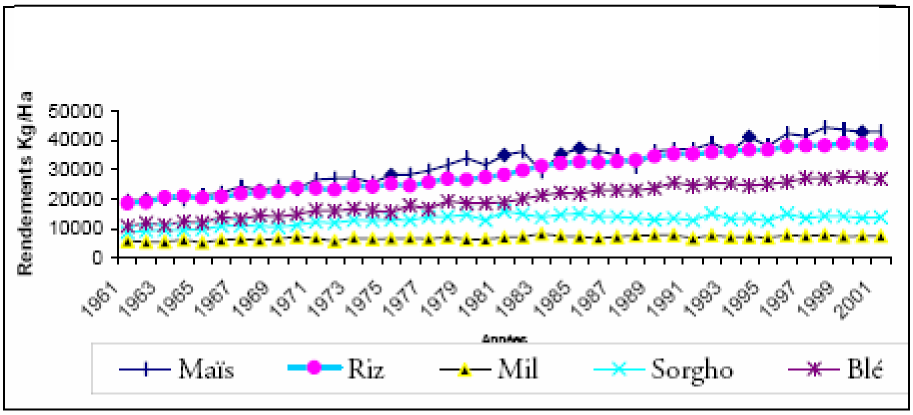


Figure 3: changes in yield of main cereal types per hectare



It must be noted that some countries such as Brazil do not hesitate to increase the amount of land dedicated to farming, to the detriment of the forest. Countries such as France are evolving inversely: there is a slow decrease of the amount of farmland (due to European agriculture policy) in favor of slow progress in the amount of forest land.

Once again, this can be a source not only of debate but also of new farming capacity. For a country such as France, its land is divided up as follows:

Chart 6: Situation en France

	in M Ha
Forests and hedges	17.0
Farmland	16.6
Prairies and heaths	15.2
Roads	1.1
Towns, cities and constructions	1.6
Inaccessible	1.8
Other	1.5
Total	**54.8**

There is little room left, but we can still find a few percentage points.

3. AGRO-RESOURCES OR BIO-RESOURCES

Where can substitutes for petroleum and its derivatives come from? We now fully master the process used to treat certain sweet plants or oil-producing plants to obtain fuel:

Figure 4: EMHV Chain: a 3 stages process

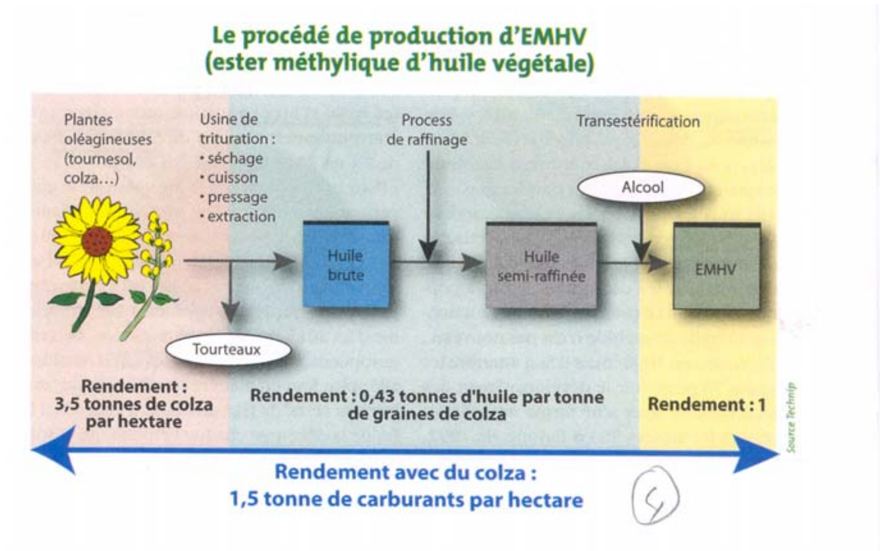


Figure 5: ETBE chain: a 3 stages process

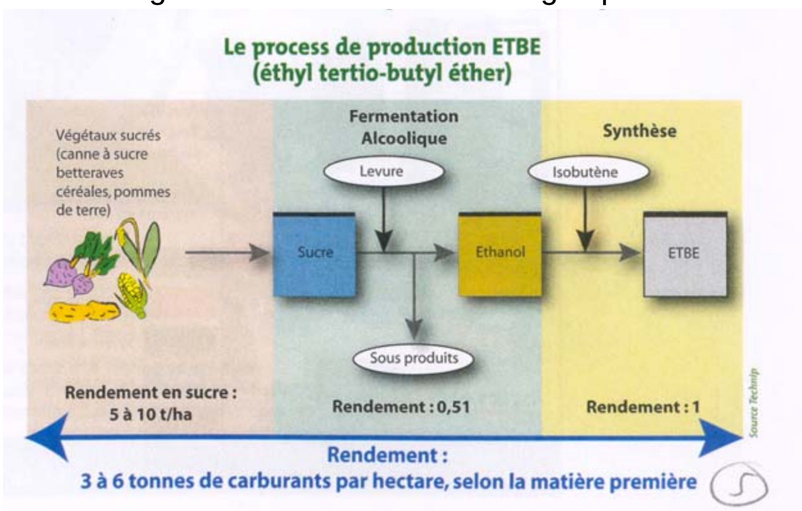
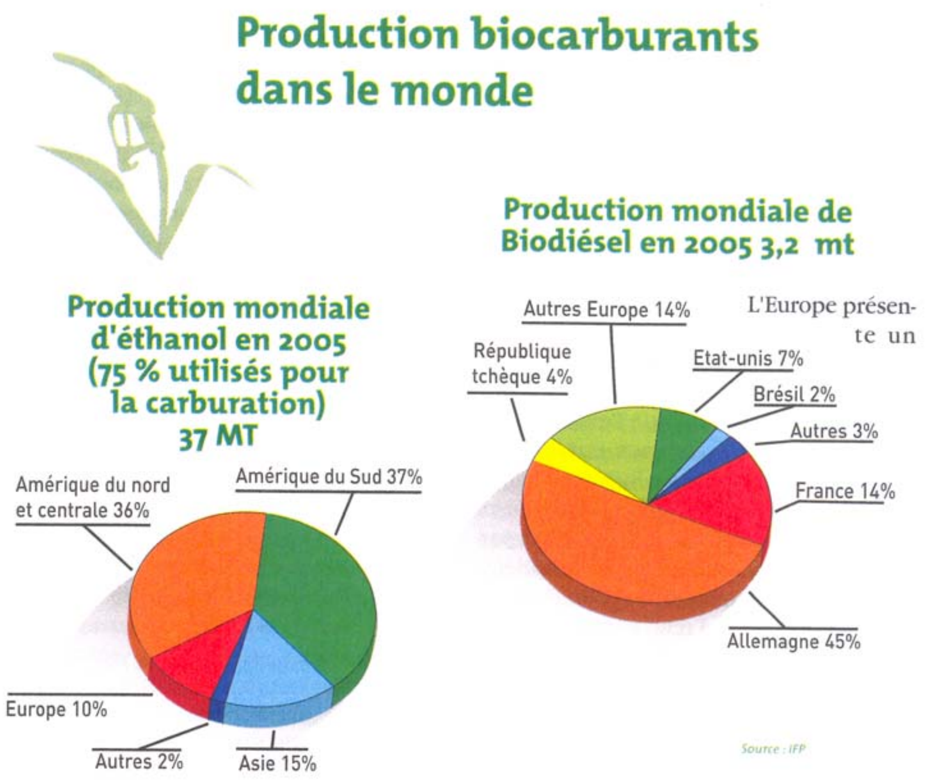


Figure 6:



In Europe, there are support programs but with rather clear disparities.

Given crop yields, we can easily evaluate the surface area that needs to be farmed to keep bio-ethanol and bio-diesel plants running.

Chart 7: example of France

Type of fuel	Initial Farm Products	Gross energy produced per Ha (eq tons of. oil)	Energy required for fertilizers, farming, distillation (per ha)	Net energy produced per Ha (eq. tons of oil).	Minimum number of km² mobilized to produce Mtep	in % of French territory	in % of farmland 1997
Oil	Colza	1,37	0,50	0,87	**574.000**	**104%**	**365%**
Oil	Sunflower	1,06	0,29	0,77	**648.000**	**118%**	**413%**
Ethanol	Beets	3,98	3,22	0,76	**660.000**	**120%**	**420%**
Ethanol	Wheat	1,76	1,72	0,04	**14.800.000!**	**2700%**	**9400%!**

We quickly reach the conclusions that developed countries, even with the best yield figures, will not be able to modify their farming to both feed the population and replace petroleum products.

But, let us come back to our lines of business: Every year we consume roughly 6,000 M liters of fuel to run our machines. This means, without modifying our engines and adding 30% bio-fuel that we need roughly 2,000 M liters i.e., 1 to 2 M hectares.

To substitute the fuel in our asphalt mix plants: 7.5 M m^3 of fuel used, i.e., less than 7 MT of biofuel.

As for fluxing agents, it is very simple to forbid the used of petroleum-based flux agents and replace tehm with plant-based flux. Only 150,000 hectares of oil-producing plants are required (with 1.5 T per hectare of yield).

As for bitumen substitutes, and in light of yield figures at one ton for one and a half per hectare, we need some 60 M hectares. This does seem more difficult, but we are told that bitumen reserves are greater than those of oil…

4. CONCLUSIVE EXPERIENCE IN THE ROAD INDUSTRY

We will stick to the recent experience acquired by Colas to imagine, test and manufacture substitutes for petroleum-based fuel, flux and bitumen.

Over the last few years, research teams, joined now by development teams, have been working on the design of plant-based flux (bio-fluxing agents). Their work has opened up several paths of development: a substitute for bitumen (research is still underway); a plant-based bio-flux and derivative products such as bio-cleaners; bio-road marking. We will now take a look at our experience in bio-flux and bio-coating binders.

4.1 Research on bio-fluxing agents:

One of the goals set for the research teams in the design of substitution products was to comply with sustainable development criteria.

- **Renewal of natural resources**
- **Energy savings**
- **Reduction of greenhouse gas**
- **Safety: people and natural environment**

Their work follows the **principles of green chemistry** because it aims to reduce, even eliminates, the use or the formation of dangerous substances during design, production and use of chemical products, and decrease the amount of waste produced and energy consumed, while still providing improved performance in the end product.

The initial research work focuses on:

- **Bio-fluxing agents**, designed to reduce viscosity of bitumen in road applications,
- **Bio-cleaners** designed to protect equipment from becoming dirty or to clean it once it has become dirty.

In a second phase, the project may (in light of the very positive results of lab tests) spread out to cover the design of **bio-emulsifiers** and road safety **bio-marking** products in the same plants.

It is interesting to underline the fact that the plants that are used to manufacture bio-products for the road industry can also be used to manufacture bio-diesel fuel for internal use in our construction equipment (if approved by the authorities). An investment of 300 to 400 Euros per ton of production capacity is required on an average plant.

Bio-fluxing agents are designed to replace volatile oil or organic chemistry-based fluxes, which, when used, give off compounds that are potentially harmful to people’s health and to the environment, and are a loss of fossil fuel energy.

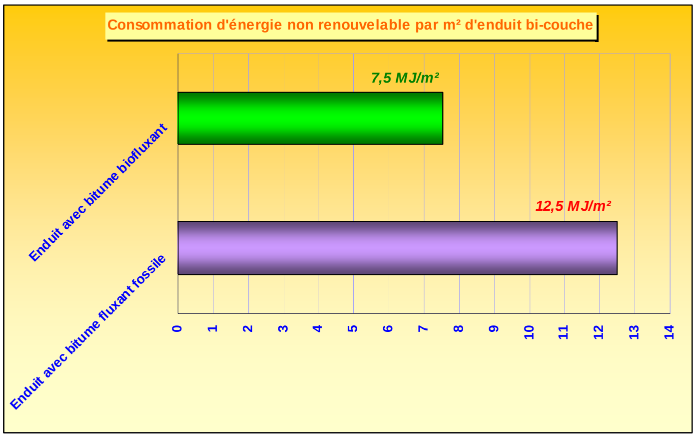
Bio-flux for bitumen was obtained using derivatives of renewable natural fat: derivatives of vegetable oil or fatty acids such as tall oil.

Bio-cleaners for site equipment (pavers, cold micro asphalt application units), trucks, and workshops are designed to replace oil solvents often used by application and workshop teams (solvents such as fuel oil) to clean their machines and equipment. The target of this research phase is to propose two types of products to replace fuel oil, which evaporates into the atmosphere once it has been used: a **bio-product that offers preventive action** (applied to protect machines from getting dirty) and a **bio-product with curative action** (used to clean dirty equipment). In both cases, **natural, plant-based raw materials were used to synthesize and/or formulate bio-cleaners** with the targeted characteristics.

Environmental standpoint: a partial life cycle analysis of bio-flux compared to fossil flux was done according to criteria including energy and greenhouse gas. Findings showed highly pertinent impact.

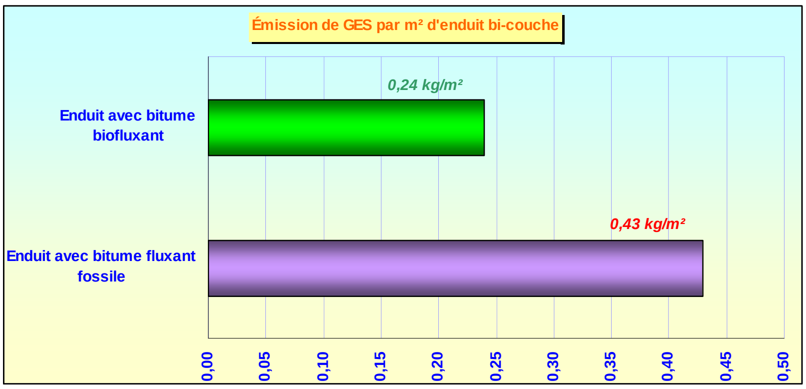
- 40% less non-renewable energy is consumed by fluxed bitumen compared to fossil fluxed bitumen.

Figure 7:



- Greenhouse gas emission (in equivalent CO_2) is some 12% less with bio-fluxing agents.

Figure 8:



Using bio-products offers an answer to questions raised by users, who are very motivated in this field, as is demonstrated by the success of the projects and the speed with which they were carried out.

As a complement to the partial analysis described above, the technical findings showed:

- **A gain in materials, thus additional savings in fossil resources, of some 5-10% of bitumen,**
- **A gain in spraying temperatures of some 20°C, thus in corresponding energy**
- **Savings of some 30% of flux in the mixes**

The manufacturing process for the products was tested in the laboratory and then in specially-built dedicated pilot manufacturing plant. The results are excellent.

- Development in the laboratory

Photo 1: example of synthesis of soy ethyl ester

- ***Selection of best products for in-situ testing***

Photos 2-3: surface dressing in the Gers region of southwestern France in October 2005.

Photo 4: surface dressing in the Indre region of central France in June 2006.

- ***Design and construction of pilot plant***

Photos 5-6: pilot plant

4.2 First findings on bio-fluxing agents:

Bio-products made from laboratory synthesis were tested in the design of road products, by replacing fossil fluxing agent commonly used with **bio-flux**. As for **bio-cleaners,** their properties were compared to petroleum solvents used and tested in-situ by our application teams.

The main characteristics measured were:
- **No VOC emission was detected; on the contrary, there was** even a gain due to the reaction of products with oxygen in the air (up to +1%)
- **For properties in use, the speed of rise to cohesion of the binder is equivalent if not faster** then that obtained with fossil binders,
- **There is a 30% reduction of the consumption of bio-flux products** compared to oil-based flux for the same use, thanks to improved solvent power.
- **Bio-cleaner** offered equivalent cleaning power compared to conventional petrochemical cleaners often used in the road construction business.

Additional research is already underway to study the substitution of fossil-based products with plant-based products in the following fields:

- **Road-marking products (bio-marking)** using resins and petroleum-based solvents,
- **Surfacing with heavy-duty skid-resistance (bio-surfacing)** using resins today,
- **Natural surfactants (bio-surfactants)**

The majority of these products will be able to be manufactured in industrial plant without requiring any modifications. Some coproducts can be reused for manufacture.

4.3 An innovative plant-based binder for asphalt mix:

The binder is manufactured by mixing several components from the transformation of plant-based raw materials. The invention is patented in France and Europe. During the manufacturing process, strict control is required regarding the proportions of ingredients, the temperature and mixing time, all of which guarantees that the asphalt mix made with the plant-based binder will have the cohesion and mechanical performance required for materials used in road techniques.

These binders can be used in emulsions. A variety of surfacing is possible, depending on the emulsion formulation: surface dressings, micro asphalt, cold mixes made in mixing plants.

We will present applications that have undergone sufficient development to date: hot mix asphalts using plant-based binder. Research led to the formulation of plant-based binders whose properties of use are perfectly suited to asphalt mixes in wearing courses or base courses.

Chart 1- Current classifications and main rheological characteristics before coating.

Classification	1	2	3
Initial viscosity (Pa.s) **Brookfield, (SC 4-27), 70 °C, 1.4 s^{-1}**	**33 to 45**	**16 to 24**	**11 to 14**
Pumpability temperature (°C)	**100**	**100**	**100**
Density at 25°C	**0.95 to 1.05**	**0.95 to 1.05**	**0.95 to 1.05**
Cleveland flash point(°C)	**> 210**	**> 210**	**> 210**
G* modulus (MPa) at 20 °C ; 7.8Hz	**>2.5**	**>0.8**	**>0.2**

- **Several interesting properties in plant-based binders**

The composition of plant-based binders can be selected to make the binder transparent in thin layers, in order to manufacture asphalt mixes that show the natural color of the aggregates or that can be colored as desired.

Photo 7 – asphalt mix with plant-based binder showing the natural color of the aggregates

As was said before, the hot mix process for plant-based binders is identical to that used for conventional HMA. **Hot, dry aggregates are used for mixing at temperatures that are 40 to 50°C lower, without any loss in handling capacity. Thus, less energy is used and greenhouse gas emissions are reduced.**

Photo 8 and 9 – loading a truck at a plant and application of the same mix on a heavily-trafficked country road.

- **Examples of projects and in-situ performance of asphalt mix with plant-based binder**

Photo 10 shows a project using white asphalt mix, applied in western France in 2002 (0/6 with 5.7 %; Bégard aggregates; batch plant). This was a delicate project to undertake, in light of the color of the mix.

Photo 10 – Application of the very first asphalt mix using plant-based binder (white)

Main surface characteristics of the asphalt mix

Sand patch tests showed that the surface's macro texture is correct, with an average of 0.71 mm.

Measured at 60 Km/H with the SCRIM apparatus (CETE in Lyon), the transverse friction coefficient is on the average 0.69 after 4 months. Evaluated by the ADHÉRA trailer (CETE Nord Picardie), after 6 and 30 months, the braking-force coefficient [3] findings are featured in chart 4.

Chart 4 – braking-force coefficient (BFC) at different speeds, ages

Age	**6 months**	**30 months**
BFC 40 Km/H	**0.65**	**0.61**
BFC 60Km/H	**0.53**	**0.45**

These findings show very satisfactory skid-resistance, similar to that found on surfacing using SBS elastomer bitumen.

- The Haut Rhin department in eastern France decided to renew, in 2003, the wearing course on an old section of roadway with T3 traffic, with many curves and a slight slope. Because it is located in the Alsatian Jura mountain range, the roadway undergoes extensive freeze-thaw cycles each year.

  The asphalt mix (0/6 aggregates from the Rhin; 5,7%) was manufactured in a batch plant at 110 to 120°C and was transported in tarped trucks for one hour. The mix was applied conventionally. During application, it began to drizzle slightly, but this had no negative impact on the project. The asphalt mix was very easy to handle, even at temperatures ranging from 80 to 90°C

Photo 11 - October 2003, application of 0/6 asphalt mix in Ligsdorf.

Photo 12 – view of the pavement after 30 months

- o Projects from 2004 to 2006

Photo 13 - RD 419 (Haut-Rhin) after 20 months under traffic

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Photo 14 - Bormes Les Mimosas and Luxembourg Gardens in Paris

CONCLUSION

In this brief overview, we were able to see that more farmland is available in developing countries than in developed countries.

We also saw that, if we take action quickly, we can find a share of natural resources to operate our site equipment and production plants.

We could also find solutions for the partial substitution of bitumen in surface courses, maybe even in part of asphalt mixes as a whole.

Of course, further studies are required to evaluate the real environmental impact of this type of change.

What on earth are we waiting for?

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