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Title : Towards a global, environmental evaluation of pavement materials and techniques in France

Abstract : This work takes places in the context of the creation of a new research team at LCPC, performing studies in the field of sustainable development applied to roads. The present on-going projects - a recycling road works using hot-mix reclaimed asphalt pavement and a data base on material recycling in roads – are leading to the collection of significant environmental data. These projects also include the application of LCA methodology to roads, and display a territorial approach. Finally the research work is focused on a modular analysis of road infrastructures, which should be extended in the future to both economical and social spheres.

1. INTRODUCTION

LCPC (Central Laboratory for Roads and Bridges, a French public research institution) mainly used to deal with the construction of new infrastructure involving materials and structures. More recently attention has been focused on better management of the existing stock of infrastructures. The aim is to maintain and to adapt the existing structures to the evolution of requirements concerning environment and safety. Therefore, it has obviously become important to optimise the maintenance policies, to control natural risks and environmental impacts of infrastructures over their whole life cycle. On the other hand, recycling has to increase, especially in road pavement because of increasing care about environment and in order to meet the new 2002 French legislation, which greatly limits landfill. Hence, only "ultimate" waste products (i.e. products which cannot be recycled with the available technology) will be allowed in waste disposals.

Besides, at the international scale, sustainable development recently gathered industrial countries at Johannesburg, 2002 on topics such as resource preservation and pollution reduction. There is now a growing demand for decision-making tools, which take into account not only the various environmental factors but also economic and social ones.

In this framework, a research team, called "sustainable development", has been created with the idea to contribute to a global approach of road infrastructures, considering not only technical parameters but also environmental, economical and social criteria. The team concentrated first on environmental analysis, with the goal to develop and then propose decision making tools in this framework, which is characterized by a lack of environmental data.

This paper presents the two main projects of the team, mainly focused on recycling. The first project deals with the application of Life Cycle Analysis (LCA) methodology to roads made of reclaimed asphalt pavement. Hence, since the early eighties LCA has been used in a lot of industries, in order to improve knowledge of the studied industrial processes. The interest for LCA is growing in building industry, while it is not broadly used in road construction, especially in France. A LCA based approach, as it is a standardized tool, can be considered as the first step of the decision making tool elaboration regarding environmental cares. As for the second project, the objective is to collect data concerning different secondary raw materials and their use in road civil engineering among the various French regions. After the projects presentation, the way to perform a global analysis of road infrastructure environment is discussed.

2. RESEARCH WORK IN PROGRESS

2.1 An experimental road site

Today, asphalt production and asphalt road paving are well known from a technical point of view, up to high recycling rates. However, increase of recycling in the future leads to perform predictive studies, in particular environmental ones, allowing technical option optimization, in each local road work context. Such an approach implies to develop and to validate global tools for environmental assessment, as precise as possible.

According to a LCPC proposal, the French "Direction des Routes" (Ministry of Transportation) asked the SETRA (a department of "Direction des Routes") to prepare an experimental and research program. The aim was to apply Life Cycle Analysis (LCA) to road construction using new aggregates and recycled ones, for environmental impact evaluation (air, water, energy and workers). As a result of a strong collaboration between the DDE41 (local agency of ministry of transportation), LCPC and SETRA, the experiment was carried out on the RN76 national road, close to the city of Romorantin . Road works were thus performed in 2001 by the Parc Routier (local road public operator), including a specific program for environmental impact assessment of the pavement construction. Finally, three divisions of LCPC as well as the Parc Routier of Blois (DDE 41), and Romorantin subdivision, the regional laboratories of Blois, Saint-Brieuc, Angers, Autun and CETE of LYON were involved.

As a first step, existing methodologies like LCA were applied. LCA is divided into four steps: objectives definition (ISO 14040), life cycle inventory (ISO 14041), impact assessment (ISO 14042) and interpretation (14043). Uncertainties are to be analyzed during the final step, that is interpretation.

The environmental study was performed as follows: a first part was devoted, in 2002, to life cycle inventory of the pavement (data collection and pollutant fluxes determination), and a second part, in 2003, deals with environmental impact analysis for pavement construction. Only the results of the first part are available (LCI of pavement construction).

A very wide range of environmental data was collected during road maintenance works for the chosen functional unit, dealing with air, water, smell, noise, resource and energy spending. The

main studied parameter in the context of decision making was the recycling rate for hot-mix plant material. Hence asphalt is the main material used in road construction and road maintenance in France. Figure 1 shows for the RN76 pavement the dimensions and positions of experimental road sections. Recycling rates of the binding course ranged from 0 % (control section) to 10 %, 20% et 30% of reclaimed asphalt pavement (RAP) obtained from milling the old pavement. Old wearing (3cm) and binding courses (4cm) were deconstructed and rebuilt into one single new binding course (7 cm). In order to minimize experimental errors, road sections were adjacent and road works were carried out on the same day. The functional unit consisted in 100 tons of asphalt, equivalent to one hour of hot-mix plant production, or one binding course pavement section of 150x3.80x0.07 (in meters).

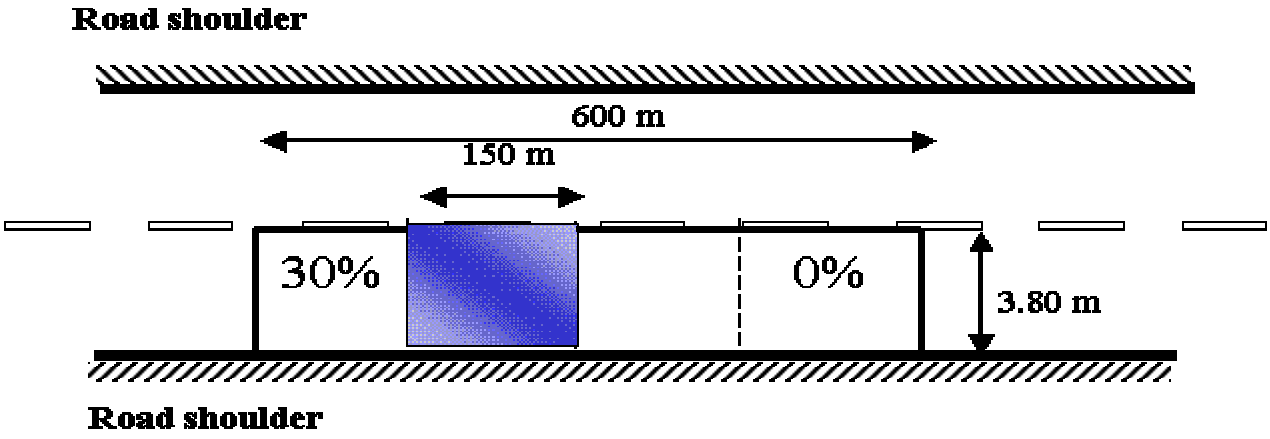


Figure1 : road sections of RN76 subjected to experimental road works.

Figure 2 gathers elements which were considered for the experimental road works, including different geographical sites for the various tasks (constitutive materials production, mixes elaboration, asphalt laying and rolling...), and the subsequent sub-systems linked to road life cycle and road works.

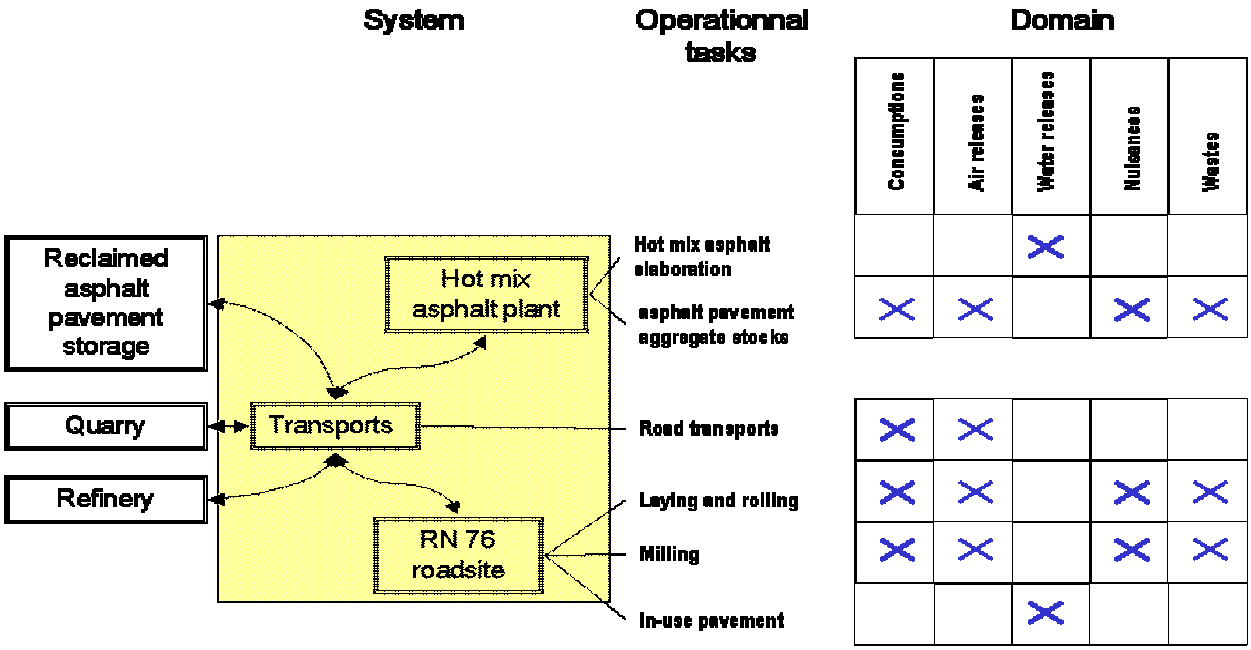


Figure 2 : sub-systems and types of collected data.

Considered elementary sub-systems for the inventory of spendings and environmental releases, were, for all recycling rates :

- reclaimed asphalt aggregates storage;
- asphalt production;
- transportation (material and equipment);
- old road deconstruction;
- new road building (binding and wearing courses);
- new road in service.

For each sub-system, for the partial inventory the following parameters have to be determined : i) consummations (electricity, gas, water, diesel oil...), ii) air releases (VOC, NOx, PAH, CO_2, solid particles...), iii) water releases (PAH, total hydrocarbons, heavy metals, suspended matter..), iv) nuisances (noise and smell), v) waste (reclaimed asphalt, asphalt sweepings …).

Figure 3 and 4 point out some results obtained respectively in terms of consumption (without gas, electricity being considered separately because linked to energy) and emissions. Water and steel consummations (figure 3) increase with recycling rate appear non-linear, as 10 and 20 % rates show quite similar results. Water spending derives from milling (mainly), sweeping and rolling. Steel spending is associated with the milling process as well. These results are then directly produced by equipment for road deconstruction and arise from road works scenarios. As for CO_2 emissions (figure 4) , variations exhibit an inverse trend in comparison with natural aggregates spending shown in figure 3.

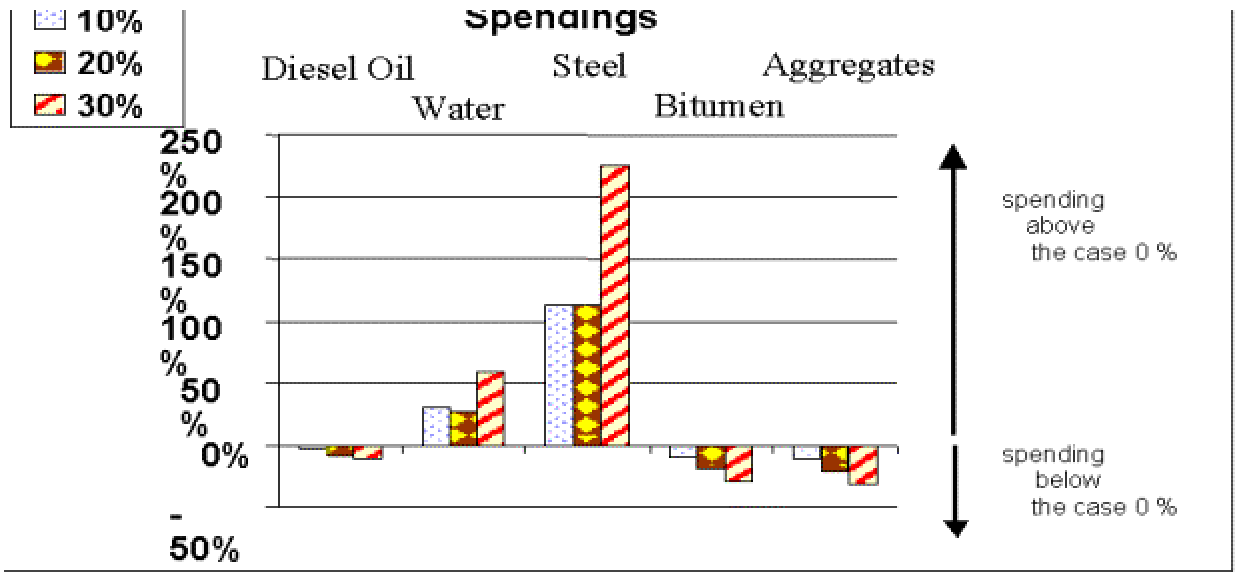


Figure 3 : relative resource spendings versus recycling rate for road works referred to the solution without recycling (0%).

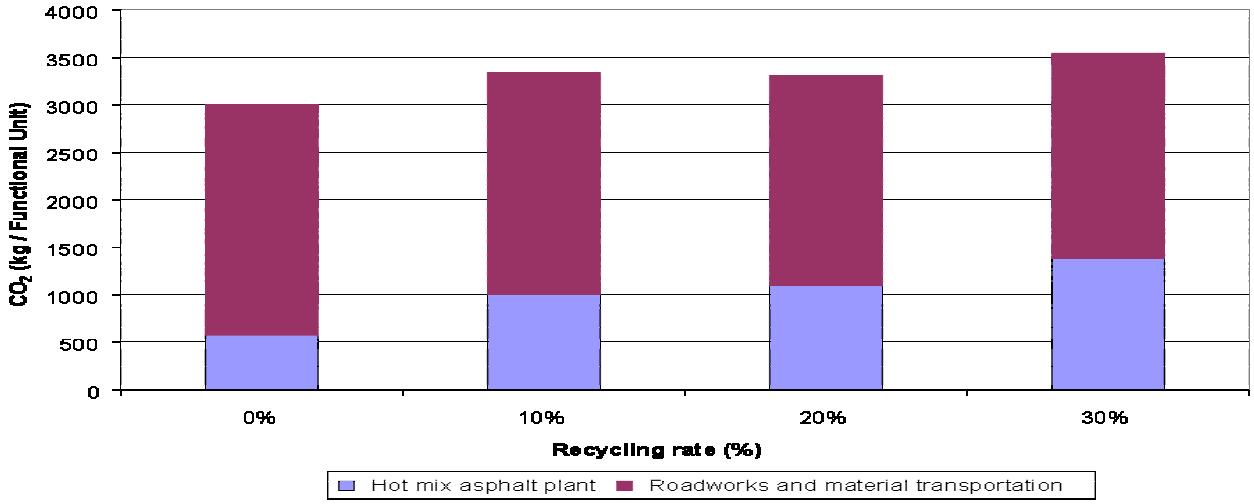


Figure 4 : CO_2 emissions inventory for each road section during the whole road works.

2.2 A national data base on recycling in road infrastructures

A second project began in 2002, dealing with a data base construction about materials that are recyclable in road infrastructures. Hence, for recycling development it is relevant to bring a reliable information to those - owners, site engineers, construction companies and material suppliers - who contribute to building. Environmental questions, usually considered as the most critical ones, are those for which transparency is the most necessary.

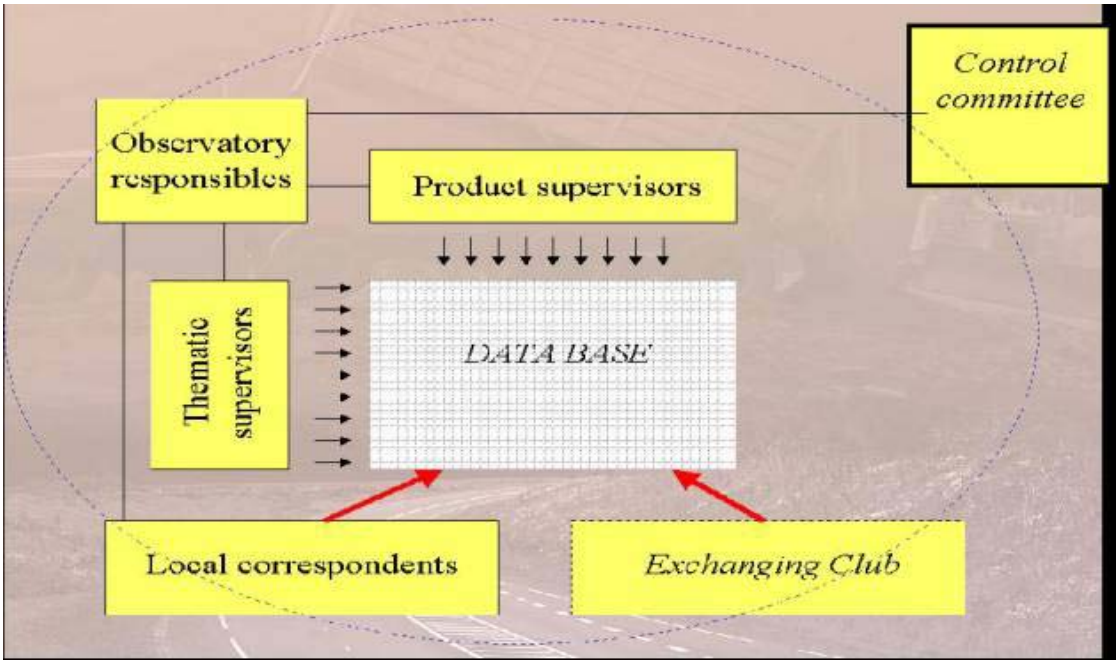
As for recycling in roads, nobody has the full skills in geotechnics, pavement technology, environment, economy, and legal issues necessary for an optimal use of material resources. It is only by gathering the various specialists, with the view of favoring exchange and discussions that relevant collective work can be carried out and sustainable long term policies can emerge.

Road always imposed real size experiments, using road sections, testing materials or new techniques. Unfortunately, road section monitoring with time is not always possible for several years, especially if local actors change. When the topic concerns material subject to environmental questions (the impact of which may arise either at medium or long term), such a turnover is very regrettable.

The **OFRIR** project ("Observatoire Français du Recyclage dans les Infrastructures Routières") started on the above considerations, after about one year before getting ready. It is an internet site (http://ofrir.lcpc.fr) for road national actors aiming at proposing classified, summarized and validated information in order to help recycling decisions, while noticing the different obstacles, especially the geotechnical and environmental ones.

Besides, LCPC and French technical network of road public ministry, BRGM (Bureau de Recherche Géologique et Minière) and INERIS (Institut National de l'Environnement Industriel et des Risques) also significantly contributed to this project supported by METLTM/DRAST and DR (Ministère de l'Equipement, des Transports, du Logement, du Tourisme et de la Mer/Direction des Affaires Scientifiques et Techniques et Direction des routes), by MEDD/DPPR (Ministère de l'Ecologie et du Développement Durable/Direction de la Prévention des Pollutions et des Risques), by ADEME (Agence De l'Environnement et de la Maîtrise de l'Energie) and finally by SETRA (Service d'Etudes Techniques des Routes et Autoroutes).

This project aims at gathering all motivated people, through the exchange data club. Figure 5 presents OFRIR running-in principle. It will be a precious tool for literature surveying and for research results diffusion in the field of recycling. Transversality and "good governance", gathering all actors into a common consensus are expected from this project, the whole contributing to sustainable development approach.



igure 5 : principle of the OFRIR data base implementation

3. GLOBAL APPROACH OF ROAD ENVIRONMENT

3.1 LCA and roads

The RN76 experimental road works was focused on the analysis of environmental data, collected in the framework of LCA. Moreover, a literature review led to point out interesting points of view around this research field:

- at the scale of road projects, the impact studies (French regulations) which are an important information source are not focused on raw material, energy or rejects fluxes. Neither construction nor maintenance are studied, but territory as well as different decision criteria are considered. As for regulations, some authors think that they are not sot relevant for roads (Debièvre A 1997, Merle J.P, 2000);

- at the stage of final products, there is a wide literature about LCA, as defined in 14040-14043 ISO standards, which was been applied to various industries. Only few LCA studies were devoted to roads : Lundström K. (1998), Mroueh U.-M et al (2001), Schuurmans-Stehmann (1994), Stripple H. (2001). Among published data, part of them focused on the inventory of production of chosen bitumen, Blomberg et al (1999) and cement, (Vanderborght et Brodmann ,2001) or those of equipment, Landfield A.H. et Karra V. (2000). Besides, MEDD and ADEME proposed a methodological analysis of LCA (Ademe et Bio, 2002). INRETS is developing environmental evaluation tools using indicators in the field of transport. Such methodologies can be adapted to constitutive materials. Nevertheless, a global road approach cannot be undertaken with only LCA methods, Blanc A. (1999), mainly because of the functional unit concept which has not modular characteristics and of territory aspects which cannot be included.

3.2 Toward a specific approach for roads

Work already done showed that the key point would be to develop a specific methodology for roads, based on appropriate references and integrating in a specific way each pavement and roadway life cycle. Such a tool should take into account road environment integration, in particular areas around the infrastructure, before any opening to economical and social spheres.

Figure 6 proposes a new methodological frame that separately considers road layers (each with a given life cycle) and road structures. An Elementary Road Modulus is composed of different layers, initial construction and maintenance of which are evaluated through LCA methodology. Such a kind of modulus has its own material properties, thickness, as well as variable service conditions, based on defined scenarios. Then, from an assembling procedure, it can be gathered into a Global Road Modulus (GRM) placed inside a territory.

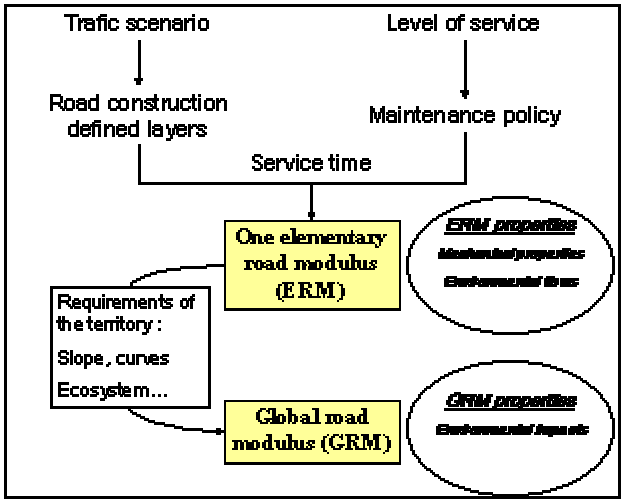


Figure 6 : principles of a tool integrating a multidisciplinary approach of road life.

4. CONCLUSIONS

Environmental measurements obtained since 2001, in the context of a new research theme at LCPC, will be used as a data base for road environmental evaluation tool. A global modular approach will be developed as well as life cycle analysis methodology applied to pavement layers. All life cycle

phases are taken into account, from resource extraction and material elaboration, up to recycling and final waste, integrating material processing, transport, distribution, use, reuse and maintenance. OFRIR data base will then allow for applying this approach to different recycling strategies in road filed. Indeed, the present projects have shown that it was useful to base this methodological tool upon specific road developments for environmental evaluation. However, a research theme focused on sustainable development of roads also must consider both economical and social fields. Thus, the idea that at the very beginning, the tool should be developed in order to integrate also these other fields, the study of which also began in 2002 by a PhD thesis. The purpose of the thesis is to carry out both environmental and economical assessment of road construction and maintenance, using different raw materials with natural aggregates and hydraulic/bituminous binders.

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