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# Environmental acceptability of beneficial use of waste as construction material—State of knowledge, current practices and future developments in Europe and in France

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**Abstract**

Since a decade, numerous industrial and public initiatives have been launched in order to make knowledge, practices and mentalities evolve in relation to the acceptability of using waste instead of raw material as construction product. The objectives of these initiatives have been to evaluate current practices and to make new solutions and beneficial use channels emerge.

At the same time scientific and standardisation communities have developed methodologies and tools to fit with the assessment needs expressed by industrialists and public decision-makers.

In spite of that, some factors, some of them being cross-linked, make the perpetuation of beneficial use channels or even the concretisation of research projects difficult.

To cope with this situation, in the framework of sustainable development applied to natural and alternative material, the French Directorate of Road has launched a project aiming at providing public contracting authorities with a document gathering both technical and environmental requirements that they can prescribe in public market tender calls to promote the use of waste and out-of-technical-specifications-material.

This paper deals with the presentation of this project focusing more specifically on the approach to assess both technical and environmental acceptability of waste and out-of-technical-specifications-material to be used as alternative material in road construction in France. The current European situation is first described and this paper finally discusses briefly the other key aspects – than environmental acceptability – that have to be taken into account to succeed waste beneficial use.



*Keywords:* Waste; Environmental assessment; Acceptability; Criteria; Beneficial use; Road construction

## 1. Introduction

Since a decade, throughout Europe, environmental risk assessment emerges as a key issue in the decision process between different waste management options. At the same time, waste producers have tried to find alternative solutions to disposal in landfill for different reasons: the never ending rise of landfill cost, the regulatory frame encouraging recovery as much as possible under safe health and environmental conditions, the growing social pressure, the environmental commitment in a continuous improvement cycle such as EMAS or ISO 14001, etc.

For some historically re-utilised waste as construction material in pavement or in cement, such as blast furnace slag or coal fly ash, for which no environmental risk assessment have been realised ever, this general environmental awareness could have been a good opportunity to know more about those practices.

This trend has however not been arising on sound harmonised basis. Due to the lack of regulatory guidelines at a European level, various inconsistent initiatives have popped up even if some regulatory frames have been elaborated and applied at Member states level.

All this pleads for the elaboration of a harmonised framework for assessing the environmental acceptability of utilising waste as construction product. By initializing the work of taking into account hygiene, health and environment in the next generation of construction product standards according to the Construction product Directive 89/106/EEC [1], the European Community (hereafter EC) gives a sound impulse in that perspective.

Focusing on France, the public market law has recently evolved by considering environmental aspects as a selection

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Table 1
Quantification of waste production and beneficial use channels as construction material in France

| Waste (except "natural aggregate") | Production | | Beneficial use channels | |
|---|---|---|---|---|
| | Mt/y | Year | Percentage | Channel |
| Surface layer demolition aggregate | 4.34 | 1997 | 50 | Road construction |
| MSWI BA | 3.2 | 2000 | 70 | Road construction |
| Coal fly ash | 2.2 | 1997 | 60/30 | Cement/road construction |
| Blast furnace slag | 3.8 | 2002 | Unknown | Cement/road construction |
| Building C&D waste | 20 | 2001 | 60 | Road construction |
| Public works C&D waste | 380 | 2001 | 66 | Road construction |
| Natural aggregate | 399 | 2000 | – | – |

criterion. Moreover, the French Directorate of Roads has reinforced its concern about sustainable development applied to construction material due to the risk of lowering aggregates resources, especially due to the policy of quarry closure without opening of new capacities. Come on top of that, the duty of reducing the consumption of alluvial aggregate that represents 22% of the French consumption of aggregate. This has allowed starting again the methodological work jointly engaged in 2001 by the French ministries of Equipment and Environment concerning the beneficial use of waste as road construction material [2].

This paper firstly describes the current situation in Europe regarding waste production and management options, regulation, standardization, practises and environmental assessment approaches developed. Then, the French project to provide the way to assess both technical and environmental acceptability of waste and out-of-technical-specifications-material to be used as alternative material in road construction is presented. Finally, the other key aspects than environmental acceptability that have to be taken into account to succeed waste beneficial use are briefly discussed.

NB: this paper focuses only on mineral waste and beneficial use as road construction product.

## 2. Current situation

### 2.1. Waste production, stocks and disposal channels

The quantification of waste production and re-utilisation or disposal channels is not a simple issue as far as no database not even collection organism are in charge of doing it. All the same it is a critical issue to clearly have in mind what we are talking about and what are the stakes.

This is why ADEME tried to do in late 2003 at the French level and in a less extent to the European level based on data collected in literature or on the Web site of the French Monitoring Office of Recycling in Road Infrastructure (OFRIR, [3]) launched the same year. A part of this gathering work is shown in Table 1 (for more information see the ADEME Web site [4]).

Some waste fluxes are more used, especially in public works, in France as in the rest of Europe. For instance we can quote blast furnace slag, foundry sand, Municipal Solid Waste Incineration Bottom Ash (MSWI BA hereafter) or construction and demolition waste (C&D waste hereafter). A overall look at the data, shows that in France, the beneficial use of waste as aggregate, without counting public works C&D waste, represents an average of 5% ($20.10^6$ t/y) of the quantity of natural aggregate used in road construction.

This could only be seen as a little part but 20 000 000 t is not a little figure! And as far as these uses imply a direct contact with the environment in a potentially long timeframe, environmental and health security requirements are basic and justified expectations.

### 2.2. European regulatory frame and standardization

The European Community encourages, by the waste framework directive 75/442/EC (hereafter WFD) [5], the prevention, recycling and recovery of waste. Although the subsequent European waste legislation grown during the past 30 years, regulatory re-utilisation objectives and requirements have only concerned specific waste stream such as tyres or electronic waste. For others waste such as those mentioned in Table 1, there was no environmental regulation providing guidelines to go through this policy of recovery of waste for use as material in construction.

The effort of the EC and of the Member States were put on the development of disposal directives (landfill directive 1999/31/CE [6] and incineration directive 2000/76/EC [7]) in order to modernise waste management and practices. Waste standardization process has mainly followed the same route since the creation of the waste standardization technical committee CEN/TC292 which dates back to the early discussions on the elaboration of the landfill directive in 1992.

Nevertheless, one work item has provided an opening by explicitly referring to both disposal and utilisation in its scope. This work item, based on a French experimental standard, has been turned into a Standard in 1997, prEN12920 [8], specifies a methodology for the determination of the leaching behaviour of a waste under specified conditions.

### 2.3. Beneficial use of waste as construction product in European countries

While harmonised European guidelines were lacking, several Member States have taken the initiative to develop specific or harmonised regulations up. A recent joint-meeting held in the framework of waste standardization (WG2 "leaching" and WG6 "leaching behaviour" of CEN/TC292) has shown the broad

Table 2
Existing regulation in European Members States concerning beneficial use of waste as construction material

| Country | Regulation | Source of information |
|---|---|---|
| Belgium | Regulation based on the BMD (see "The Netherlands") approach in the Flemish part of Belgium and also in the Walloon part, for different kind of waste | [12,13] |
| Denmark | Regulation on recycling of residual products and soil in building and construction work | [9] |
| France | Circular for the disposal and re-use of MSWI BA in road-based applications and order relative to foundry sands for different beneficial use | [10,11] |
| Germany | "LAGA" technical rules concerning the use of material from waste and mineral by-products | [14] |
| Italy | Regulation for re-use of waste based on technical parameters and, for some waste in some applications (e.g. coal fly ash in road construction) on leaching tests | Internal CEN/TC292/WG6 document |
| The Netherlands | Building Material Decree – BMD – covering the use of raw material and waste | [15] |

range of situations regarding the re-utilisation of waste as material in construction throughout Europe. This range concerns both the existence of regulation and the acceptance procedure (elaboration, content) for utilisation. When available, acceptances procedures are systematically based on the association "leaching test" – "limit values".

The SAMARIS (Sustainable and Advanced Materials for Road Performance) project [9] is aiming at providing information of the situation in Europe regarding recycling and beneficial use of waste in pavement including the newly accepted EU countries. This information is not fully available yet.

Some countries possess specific environmental regulation for some waste, such as France for using MSWI BA in road-based applications [10] or foundry sands for different beneficial use [11], and some others have implemented more or less recently a specific one for different kinds of waste (see Table 2).

It seems nevertheless that beneficial use is more likely to be done as a matter of opportunity more than as a real sustainable process.

### 2.4. Methodologies and approaches

A beneficial consequence of this situation, if I could say so, is that research has been a huge field of investment for a lot of actors: scientists, producers of waste, environmental agencies, contracting authorities, etc. Indeed, the above-mentioned regulations have set limit values that are not really based on sound environmental impact assessment. A lot of research projects have then been conducted in order to assess or demonstrate the feasibility of using waste as construction material in road-based applications or in fewer cases in buildings. In some of them, environmental acceptability has been studied for different purposes and by different approaches. In support or as a result of these projects, assessment methodologies, methods and tools have been proposed by scientists or a step further by standardisation bodies since 1997. The ADEME "Ecocompatibility" method ([16,17]), the tiered approach proposed by Kosson et al. [18] – an alternative to the TCLP-based waste management, regulatory implemented in the USA –, the one jointly proposed by the French ministries of Equipment and Environment and reported by Domas et al. [2] and the approach led by the Norwegian Directorate of Roads [19] are relevant examples.

A looking at these approaches shows a real methodological convergence in the assessment of the emission of components from the waste material, as far as they are all based on or they refer to the prEN12920 standard.

In 2003, ADEME launched two projects in order to make a state-of-the art of the implementation of the prEN 12920 methodology and of the practices of technical and environmental acceptability assessments or waste re-use in France. These projects are now at a finalising stage. The first one called BILENV [20,21] and led by the French National Institute of Applied Science of Lyon, has consisted in a critical analysis of the implementation of the prEN12920 methodology during the 1997–2003, which was particularly used for some of the cases studied in the CAREX project. This critical analysis has allowed to identify what are the benefits of implementing it, what kind of difficulties were met and what can be the content of a guidance document in order to enhance its applicability and enhance its implementation by stakeholders. The second one, called CAREX [22] and lead by LCPC (French Public Works Research Laboratory), is aiming at evaluating what has been done during the previous years concerning the assessment of the use of alternative materials in road construction by different stakeholders such as, waste producer, contractors, consulting engineers, scientists, etc., in terms of approach, methodology or testing procedures. A link with SAMARIS is ensured by the LCPC.

Another project called LIMULE [23] and led by BRGM, the French Geological Survey Office, is focusing on a better understanding of scale effects between lab and in situ situation for percolating scenarios like pavement. The issues of scales effects and of hydrodynamics and their influence on alteration and release mechanisms are of main importance for the improving the resort to lab tests (e.g. percolation test) for instance in the frame of environmental risk assessment for beneficial use of waste.

Some other projects or studies might have been carried out in European countries but identify or even describe them should requires a dedicated survey which is not the aim of this paper.

## 3. French initiative

### 3.1. Objectives and description

At the beginning of 2005, the French Directorate of Roads from the Ministry of Transportation and Equipment (MTETM) set up a working group (see Table 3) in order to address the issue

Table 3
List of organisms involved in the project launched by the French Directorate of Road

| Acronym | Name | Role and/or skill |
|---|---|---|
| MTETM | Ministry of Transportation and Equipment | Contracting authorities |
| MEDD | Ministry of Ecology and Sustainable Development | Environmental regulation |
| ADEME | Agency for Environment and Energy Management | Environmental acceptability criteria/secretary of the WG |
| BRGM | Geological Survey Office | Environmental acceptability criteria |
| CETE | Technical Studies Equipment Centre | Technical acceptability criteria |
| INERIS | Environment and Industrial Risks National Institute | Environmental acceptability criteria |
| LCPC | French Public Works Research Laboratory | Technical acceptability criteria |
| SETRA | Road and Highway Technical Research Department | Technical acceptability criteria |

of waste and out-of-technical-specifications-material acceptability as alternative material in road construction.

The objective is to elaborate a document that public contracting authorities can prescribe in public market tenders call in order to promote the utilisation of waste – and of natural material currently not used due to their lower characteristics than those generally required, so-called "out of specifications material" – as construction material instead of raw material in road applications. This document defines both technical and environmental requirements for a proper assessment in beneficial use conditions. It will also provide explanations on the content and the methodological approach in order to enable users to judge the quality of each proposed solution.

The requirements definition is based on prEN12920 approach and takes benefit of the different initiatives and actions presented previously in this paper especially BILENV, CAREX, LIMULE and SAMARIS results and knowledge. Implementing the requirements of this document' will allow achieving the following goals:

- identify and characterize the out-of-specifications-material or the waste in terms of properties, reactivity, variability (environmental and geotechnical expertise),
- justify the interest and the usefulness of the sought solution,
- know and specify the scope and the utilisation limits (demonstration of the feasibility of the intended use),
- demonstrate the lack of incompatible emissions for the respect of water quality criteria which are set up in the document,
- provide the specifications for an intended use and as a corollary the quality control procedure.

For these purposes, a 5-step tiered approach is proposed (see Fig. 1).

The beneficial use is considered as followed: the alternative material made from out-of-specifications-material or of waste shall possess a useful function, that is to say present a geotechnical interest and ensure a sufficient level of environment protection.

### *3.2. Assessment of environmental acceptability: criteria, referential*

This chapter presents the criteria and referential that are currently worked out in order to assess the environmental acceptability of a out-of-specifications-material or of a waste and of the alternative material elaborated from it to be used as a road construction product. The presentation follows the 5-steps described in Section 3.1:

- description of the deposit/stream of out-of-specifications-material or of waste.

As far as waste is concerned, the first point is the status of the waste according to the European waste list. Only non-hazardous waste is eligible. The second criteria is the content of organic pollutants (e.g. PAHs, PCBs). Next is the position relative to the acceptance in landfill [6,24]. Non-hazardous waste has to be described more in detail than inert waste in terms of reactivity and content:

- description of the alternative material made from out-of-specifications-material or of waste and description of the beneficial use (road application).

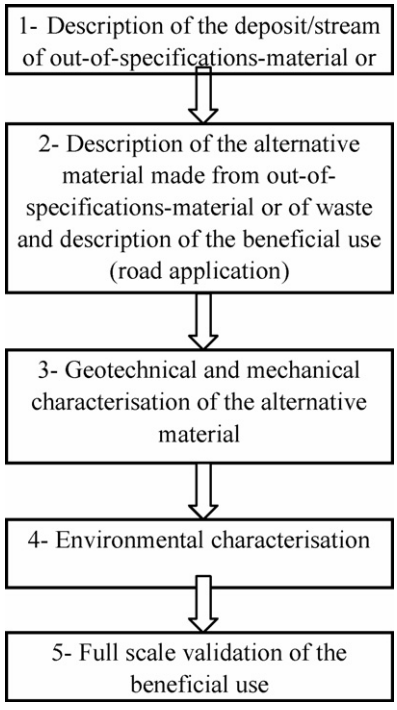


Fig. 1. A 5-step tiered approach to assess technical and environmental acceptability of waste and out-of-technical-specifications-material in road construction.

The key point here is, on the environmental point of view, to clearly present first the elaboration process of the alternative material from out-of-specifications-material or of waste and second, the road construction product that is to be put in the pavement (the road construction product is the alternative material untreated or treated with hydraulic or bituminous binder). It is important to understand what is done, why and what the potential consequences on the characteristics are.

The description of the road application also allows knowing what will be the exposure conditions in field and their possible consequences on the material behaviour:

- geotechnical and mechanical characterisation of the alternative material.

A common aspect between this characterisation level and the environmental one is the content of reactive minerals such as lime, dolomite, sulphides, aluminium, etc. These minerals can react under the exposure conditions of the road application and lead to change in release and in pavement performance and subsequently to potential incompatible impact on the environment:

- environmental characterization.

This level concerns both the alternative material and the road construction material (note: if the latter consists only of the alternative material untreated, it is not characterised). The release of the alternative material has to be compared to values of reference, which are currently worked out. If the release exceeds these values, a specific risk assessment study based on prEN12920 for the source term has to be performed. If the release of the alternative material is below these values, a further characterisation is done. This characterisation aims at evaluating the effect of the elaboration process on the characteristics of the waste. If the alternative material has been elaborated from a out-of-specification material, this characterisation provides an "identity card" of this material that has not been fully characterised at the first level.

If the alternative material is treated before its use as road construction product, it has also to be tested treated. The way the results have to be compared with the ones obtained with the untreated material is currently worked out. In case the results are not satisfactory, a specific risk assessment study based on prEN12920 for the source term has to be performed. If not, the material is not acceptable.

In case the results are satisfactory, a full-scale experiment has to be performed:

- full scale validation of the beneficial use.

The last step is the construction and the follow-up of a real pavement made with the road construction product. Detailed requirements are included in the document regarding the construction and the follow-up of the structure. For instance, this pavement has to be exposed under real conditions (climatic, traffic, etc.). All these conditions have to be monitored. The percolation water through the pavement has to be collected during at least one climatic cycle (four seasons).

A reference structure is also constructed and followed in the same way for comparison purposes.

The results are expressed both in terms of concentrations collected as a function of time (and of liquid to solid ratio) and of fluxes. The thorough definition of criteria is under progress. At this stage, the following rules are planned: first to fix a criterion based on the evolution of concentrations/fluxes as a function of time in order to ensure that the release is at a "steady state"; second to fix a criterion of comparison between the results of the "test" pavement and of the "reference" one; finally to fix criteria to ensure that the concentrations respect the local water quality criteria. These last criteria will be fixed according to the requirements of the water framework directive [25].

When these requirements are available, all suitable information will be in the hands of waste producer and contracting authorities to go through waste utilisation route. This will be a great step towards beneficial use but only a part of a wider set of requirements covering different aspects in terms of social acceptability, communication, consultation and global waste management at local scale.

It seems important to remind them hereafter.

## 4. Other key factors to manage waste beneficial use

The previous section has described key technical and environmental aspects that are envisaged in France to assess the acceptability of waste beneficial use as road construction material. Hereafter are briefly discussed other aspects that are of main importance in order to manage and perpetuate a valorisation route.

### *4.1. Design product from waste*

Producers have to make up their mind and think "product" instead of "waste". And this has to be translated into action. The "waste"/"not waste" status is generally put forward by waste producer as the main curb to beneficial use development. The "economic value" is a current argument to justify that a material is not waste. As defined in the WFD, "waste" means "*any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force*".

The European Court of Justice has given further explanation to that definition several times by judgement. Those cases-laws state clearly that the concept of waste, within the meaning of Article 1 of the WFD, is not to be understood as excluding substances and objects which are capable of economic reutilization. The concept does not presume that the holder disposing of a substance or an object intends to exclude all economic reutilization of the substance or object by others [26].

It can be given a "product" status to a waste if its characteristics, with or without treatment, meet the specifications established by the user. In such a case, waste has a use value and not necessarily an economic one. This has to be rigorously demonstrated carrying out a qualification methodology. But generally waste does not fit with the requirements of an

intended use and has to be tailored. This has to be done on specific, clearly identified facilities, even if they are located where waste is generated. Such facilities, which are the missing link between waste channel and construction channel, could show the professional aspect and the necessary know-how to design product from waste.

### 4.2. Market

Elaborate a product from a waste can turn expense into income, the added value of the product depending on the level of elaboration of the waste. Then industrialists have to consider re-utilisation as a real channel instead of temporary outlets or random opportunities without future. This can be achieved with a market approach enabling to propose a set of products covering the different needs of the clients, suitable for the local market and for its fluctuation while complying with price, quality, quantity and time allowed.

### 4.3. Quality assurance plan

Traceability is one of the most important issues to insure stakeholders in waste re-utilisation process. A quality assurance plan (QAP) has then to be set up to ensure this traceability all along the re-utilisation route from the waste producer to the end user, passing by the trader and the product elaborator. This QAP should especially cover all the technical and environmental specifications the product should comply with and the test methods enabling to check this compliance. Those specifications should be set in regards of the results obtained by the implementation of the previously described procedure (see Section 3).

QAP can be completed by business contracts setting variability, price and deadline. All this will help turning waste valorisation professional.

### 4.4. Dissemination of good practices: development of technical guide

To facilitate the dissemination of good practices, experience and knowledge previously gained shall be clustered into dedicated documents such as the Regional Technical Guides (hereafter RTG) that exist in France. These documents are reference providing specifications and advices, especially scope and limits of use, based on experience and knowledge previously gained by all the participants in the construction action, from the contracting authority to the enterprise, passing by the producer and the laboratories.

Obviously, a lot of experience is required at different scales, from the laboratory to monitored construction site. Only sufficient background information will enable the codification of the practices subsequently allowing prescribing the scopes and the limits of a specific use.

### 4.5. Consultation, information, communication

The creation of a professional and responsible waste re-utilisation channel must not be done in the dark. As every issue concerning waste or every noticeable industrial project, a process of consultation with all the stakeholders shall be launched. This process shall be extended by periodical information and specific communication, especially in regards of the requirements of the QAP covering these aspects.

### 4.6. Risk awareness and acceptance, responsibilities

Stakeholders have to be aware that even in addressing all the here above issues, what we are talking about as input is waste which will always have a higher intrinsic heterogeneity than the one of raw material, even if elaborations steps will help to reduce this heterogeneity and even if this aspect is cover by the QAP. Waste reactivity is also a critical issue for numerous wastes such as LD steel slags, MSWI BA, etc. Knowledge shall also be further gained to enhance guidelines, for instance through the update of French RTG (see Section 4.4).

All this can lead to higher dysfunction probabilities of constructions works with waste compared to raw material. The end user has to be aware of the higher risks and to accept them. This shall not be understood by the waste producer or trader or product elaborator as an exemption of his responsibilities. And this is also one of the most important issues. The responsibilities between the different stakeholders are shared and have to be clarified for instance with the QAP and the business contracts.

## 5. Conclusions and perspectives

Until now, it had not been an easy way out to manage the issue of waste utilisation as construction product. Facing the lack of European specific framework, the development and the implementation of national regulations has been function of local criteria in terms of geology, policy or economy. In France also, the curbs set up by some French public contracting authorities have not encouraged practices.

The environmental acceptability of such utilisation has mainly been studied recently, especially based on the prEN12920 methodology for the source term characterization in France. Knowledge is currently clustered and state-of-the-art elaborated thanks to several European and national projects (e.g. OFRIR, CAREX, BILENV, SAMARIS) while further research are under progress to better take into account field complexity and reality to enhance assessment results (e.g. LIMULE project).

In France, an ongoing project launched by the Directorate of Roads is close to provide a long awaited harmonisation in the assessment of environmental acceptability of using waste as road construction product. It consists of a document that public contracting authorities can prescribe in public market tenders call in order to promote the beneficial use of waste as road construction material. Both technical and environmental requirements will be defined for a proper assessment ensuring durability and environmental protection.

This harmonisation will be useful for waste producer, contracting authorities and the other stakeholders to go through waste utilisation route. This will be a great step forward but only a part of a wider set of requirements covering different aspects in

terms of social acceptability, communication, consultation and global waste management at local scale that are discussed in this paper.

A key issue that is not discussed in this paper and that waste producers will have to address in the future remains the global environmental assessment of valorisation channels compared to current disposal practices to determine the potential global environmental benefit.

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