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Full-scale experimentations on alternative materials in roads: Analysis of study practices

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ABSTRACT

In France beginning in the 1990s, the topic of road construction using various alternative materials has given rise to several studies aimed at clarifying the technical and environmental feasibility of such an option. Although crucial to understanding and forecasting their behaviour in the field, an analysis of feedback from onsite experiences (back analysis) of roads built with alternative materials has not yet been carried out. The aim of the CAREX project (2003–2005) has been to fill this gap at the national scale. Based on a stress-response approach applied to both the alternative material and the road structure and including the description of external factors, a dedicated standardised framework for field data classification and analysis was adopted. To carry out this analysis, a set of 17 documented field experiments was identified through a specific national survey. It appears that a great heterogeneity exists in data processing procedures among studies. The description of material is acceptable while it is generally poor regarding external factors and structure responses. Structure monitoring is usually brief and mechanical loads too weak, which limits the significance of field testing. For future full-scale experiments, strengthening the realism within the testing conditions would be appropriate.

1. Introduction

In the field of road engineering, building and monitoring a test section represents an essential step in the usual validation procedure for a new technique. Regarding the engineering and the environmental assessment of alternative materials (such as slag, fly ash, bottom ash, shale, sand, etc. originating from different processes) for road use scenarios, such an approach is also necessary in order to improve the correlation between laboratory testing and the field behaviour (Reid et al., 2001). For that purpose, dedicated trial sections can be built and monitored (Åberg et al., 2006; Hjelmar et al., 2007; Lidelöw and Lagerkvist, 2007), whereas actual roads originally built with such materials can be examined at different ages (Lind et al., 2001; Flyhammar and Bendz, 2006).

Many types of alternative materials are available in France, and in some areas some of them have been used in road construction for a long period of time (OECD, 1997; Schimmoller et al., 2000; François and Jullien, 2009). However, site traceability of their use has only recently and partially been introduced, and the feedback from onsite experience with these materials (back analysis) appears to remain scarce (Jullien and de Larrard, 2005). This situation constitutes a drawback to understanding their field behaviour. Yet, driven by environmental objectives (European Commission, 2001), the interest in alternative materials for road construction is extending today into greater numbers of areas, materials and applications, while, as well as in some other countries, the need for information sharing in that field continues to grow (NCHRP, 2000; TEKES, 2000; CROW, 2001).

2. Objective of the study

In addition to a limited inventory of field studies, one key outcome of the French shared database OFRIR (http://ofrir.lcpc.fr) initiated in 2001 by the French Road Institute (LCPC) (Jullien and de Larrard, 2005), was the necessity to create a dedicated standardised framework for back analysis. In considering the road structure as a system subject to the influence of various external factors, such a data collection and classification framework was developed on the basis of a stress-response approach at both the alternative material and road structure levels (François and Jullien, 2009). The data to be collected have been identified from typical characteristics of road construction materials (MELT, 1997, 2000), as well as from the current state of knowledge on alternative material properties.

The aim of the CAREX project (2003–2005) initiated by the French Agency for the Environment and Energy Management (ADEME) and coordinated by LCPC, was to conduct a back analysis of the use of alternative materials in road construction at the national scale (Chateau, 2007). The first objective of the project was to gather the majority of documented field experiments in France

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in order, as a second objective, to derive general behavioural laws for different alternative materials. In this pursuit, a set of varied and complementary case studies had to be identified by means of a national survey. The project's third objective consisted of analysing study practices to assess their efficiency and possibly improve future experiments. Within the scope of the project, information forms were created to classify and process the data necessary to the back analysis. The information to compile due to these various forms, as well as the national survey results and the global analysis of study practices, are presented and discussed below.

3. Information compilation

The information compilation was designed to inventory the general characteristics of each case study: general information; description of materials and structures; characteristics of materials and external factors; and responses observed at both the road structure and material scales in terms of engineering and environmental behaviour.

3.1. General information

Experiments involving alternative materials in road construction may pursue a number of objectives, which in turn determine the use of different means and study methods. As a consequence, the goals of each study are initially indicated, as they appear in the original documents. The same applies to the various study partners, who represent the range of competences necessary to manage the experiment. All documentary references analysed to gain feedback from the experience are compiled. Apart from the classical road structure monitoring (denoted SM below), studies can consist in observations carried out during the construction phase of roads (denoted CP) or can be diagnostic studies on preexisting structures (denoted DS).

3.2. Material description

The evolution of the material status (i.e., waste or by-product, then alternative material, and finally road material) is described through its various preparation stages prior to use (dates and durations of these stages). In order to avoid any ambiguity relative to the multiple denominations certain materials can be assigned, as far as possible, the nature of the waste or by-product is specified with respect to the European Waste Catalogue code (OJEC, 2001). The material's origin, dates and duration of production are specified, along with its potential temporary deposit onsite before preparation. In the case of preparation, details regarding the operations carried out will be required, i.e., simple weathering or more thorough improvements consisting of mechanical, thermal and/or chemical processes (Chimenos et al., 2000, 2005; Eighmy and Eusden, 2004). In the event of treatment with a binder, the nature of the latter must be provided.

3.3. Structure description

The entire road structure (layers' thickness, materials) is specified, as well as the length, width and surface area of the studied section. These requests are not redundant since many documents only provide partial information. The longitudinal gradient and cross slope of the wearing course are required. The possible monitoring system is described with the actual geometric characteristics of the volume of alternative material undergoing experimentation, the existence of moisture and temperature probes, as well as sampling devices.

Studied structures may be trial sections (which by definition, are not submitted to traffic) or functional road structures: motorway segments; sections of trunk roads (RN), departmental roads (CD), urban roads (streets); private lanes; car parks; and embankments. The key dates to be input regarding the history of the structure are the beginning and end of alternative material implementation within the structure, and the monitoring dates. When diagnostic studies are carried out, the age of the structure at the time of diagnosis must also be indicated.

The site location is specified (city, department) as well as its altitude (with respect to France's geodetic reference datum – NGF). All details concerning the position and/or role of the road section are also accessible (e.g., the area's road traffic and urbanisation characteristics, distance to a major metropolitan area, other roads connected to this section, etc.). Should they be provided by means of the original documents or reconstituted from other sources, all drawings and photographs of the structure are important supplements to the description.

3.4. Material characterisation

Material characterisation includes a description of its composition, its leaching potential, grading, geotechnical characteristics, permeability and frost behaviour (resistance, heave). This requires specifying at which stage(s) the material characterisation actually took place: production, preparation or implementation. For characterisation carried out at the time of monitoring (SM) or as part of a diagnostic study, this information will be recorded as part of the material response (see Section 3.6.2).

Material composition includes its elementary analysis, identification of organic compounds, and mineralogy. Various experiments may rely upon different leaching protocols. Consequently, it is possible to provide the leaching characteristics of materials with respect to a number of standardised or original protocols, provided their descriptions are sufficient to interpret results and compare them with results from other studies.

Material grading is presented in its entirety and may be compared with standard envelop curves from the EN 13285 Standard (CEN, 2004). The fine (<80 μm) and sandy (<2 mm) fractions, as well as D_{max}, are specified and used for material positioning with respect to existing reference limits for classification, according to the NF P 11-300 and XP P 18–545 national standards (AFNOR, 1992a, 2004). The geotechnical characteristics of the material are expressed through cleanliness (sand equivalent and methylene blue values), mechanical strength (Los Angeles, micro-deval and friability of sand coefficients) and compaction references (immediate bearing index, California bearing ratio, CBR after immersion) in accordance with the standard and/or modified Proctor test. The plot of density (ρ_d) vs. water content (W) makes it possible to compare performance and moisture sensitivity of various materials.

3.5. Description of external factors

Identifying the external factors likely to act upon both the material and road structure, leads to describing the climatic and local hydrogeological contexts, in addition to gathering data relative to traffic and maintenance, as well as to the possible spillage of reactive and/or hazardous products during the study period.

The climatic context is described through precipitation and temperature. Under ideal conditions, this information is provided via local recording devices. Should these not be available, such information could be obtained from the nearest weather station, provided that the distance to the study site remains reasonable and that local topography is not too uneven. Data origin and the dates of monitoring initiation and completion must be specified. Total rainfall during the study period is to be inputted, along with