SEMINAR ON ROAD PAVEMENT RECYCLING
OCTOBER 10^{TH} – 11^{TH}, 2002
WARSAW (POLAND)

IN SITU RECYCLING WITH CEMENT
THE BELGIAN EXPERIENCE

Jasienski André, Head of the Department Promotion, Research and Development
Rens Luc, Engineer – Infrastructure
Federation of the Belgian Cement Industry – FEBELCEM
Voltastreet 8
1050 Brussels (Belgium)

ABSTRACT

This paper presents the progress to date of various worksites in Belgium where stabilisation by recycling in situ with cement has been applied. The main operations of this method are present in the summary of the «Guidelines», a clear, precise and practical document that has existed in the South of Belgium (Walloon) since 1995.
The use of this method over the last years in Belgium has produced satisfactory results. For a recent worksite, the use is elucidated and tests before, during and after works are discussed.
For some years now, specifications have been introduced in Belgium containing technical provisions and the requirements to which the recycling results must satisfy. These are also summarised.
In spite of the progress made, more effort must be made to promote this technique and provide financial stimuli in order to accelerate the development of in situ recycling in Belgium.

KEY WORDS

Recycling, in situ, cement, stabilisation, Belgium.

1. INTRODUCTION

In situ pavement recycling using cement is a well-tested technique now. The first experiences with this method in other countries, i.e. USA and France, were made in the fifties. Since 1985, it has been gaining importance and has been considerably improved.

Despite the fact that recycling is one of the important questions in Belgium, few applications have been carried out. As remainder, this method consists of mixing on site cement with the already available aggregate. Thus is an excellent recycling method. It requires little or no transport except for a generally very small quantity of added aggregate, cement and water.

The first Belgian worksite was at Vaux-sur-Sûre in 1989. Now, some 13 years later, it seems that the advantages and feasibility conditions of recycling need to be discussed again and the conclusions drawn.

2. GUIDELINES

To facilitate the growth of in situ recycling with cement technique, in 1995, the Division des Infrastructures subsidiées of the General Administration for Local Authorities of the Ministry of the Walloon Region published detailed guidelines for engineers. These guidelines are clear, exact and practical. The force lines of this document and the main recycling operations are summarised below.

2.1 Feasibility study

Preliminary studies must be carried out rigorously. This is an essential condition for the success of recycling. The feasibility study aims at:

- verifying the feasibility of recycling ;
- determining the mechanical characteristics of the material to be recycled ;
- enabling special specifications to be prepared ;
- estimating the cost and yield of the project.

The feasibility study consists of several steps :

- searching the history of the road to determine the nature and the thickness of the layers making up the pavement ;
- visual examination, based on which any heterogeneity and structural defects can be observed on the pavement and based on which it can be decided on the removal sites and connected works ;
- sampling in order to establish the profile across type of pavement ;
- granulometric analysis to determine whether in situ crushing is necessary and to estimate the calibre and quantity of aggregate to be added ;
- a quick stabilisation test on the 0/4 fraction of the mixture to control the ability to the setting of the cement.

2.2 Materials

The material to be recycled must comply with certain granulometric criteria. The ideal granulometric curve is a curve of the Talbot equation:

$$y = 100 \text{ x } (d/D)^{0,4}$$

In which y is passing through sieve d in %, d is the mesh of the sieve in mm and D is the dimension of the largest particle in mm. Generally, a tolerance of more or less 5 to 10 % is admitted on this curve on the percent of passing through sieve d. The comparison between the sieve curve of the material removed and that of the Talbot enables the deposit quality to be evaluated and the quantity and granulometry of the added aggregate can be determined.

If the pavement to be recycled contains more than 10 % of elements greater than 80 mm, crushing of the material may be technically and even economically interesting.
The recommended binder is cement of the type CEM I LA or CEM III A LA of strength class category 42.5 (or 32.5) dosed at 6 % of the entire layer to be recycled.
Generally, before execution, contractors should carry out studies to determine the exact percent of water, cement and aggregate to be used to obtain a mixture satisfying the requirements of the specifications.

2.3 Execution
The different operations to carry out are:
- spread the added aggregate and lightly compact it ;
- spread the cement if it is not incorporated in the form of grout in the mixer ;
- fractionate the layers of pavement into usable granulate ;
- moisture the product to ensure hydration of the cement and so that the mixture can be compacted under optimum conditions ;
- mix the product obtained and the different additional materials to prepare a homogenous product ;
- thoroughly level and compact the new material in order to obtain a stable pavement support ;
- protect the material against desiccation .

Generally, fractionating, moistening and mixing of the products are done with the same specific machine. Many constructors, having understood the advantages of this method, have developed engines that can perform these activities under good conditions. As purely indication, we cite some here : RACO – CATERPILLAR – WIRTGEN – BJD – ARC 700 – BOMAG etc …

3. REALISATIONS IN BELGIUM

Except for the very first worksites, where lack of experience, inadequate material sometimes used and non compliance with certain stipulations and recommendations, notably with respect to compacting and protection against desiccation have resulted in some local defaults, the global results obtained are excellent and both on rural roads and on regional and communal networks.
The mean compressive strength obtained at different worksites show that the results are satisfactory and comply with imposed stipulations : the standard specifications impose an mean strength of 8 MPa at 90 days on 200 cm² cores. The resistance obtained at 90 days on 100 cm² cores is given below for certain worksites:

- Vaux-sur-Sûre: 9.2 N/mm²
- Lavaux-Ste-Anne: 8.7 N/mm²
- Francorchamps: 13.5 N/mm² (on 200 cm² cores)
- Philippeville: 17.9 N/mm²
- Messancy: 11.2 N/mm²
- Bierset 12.1 N/mm² (on cubes 20x20x20)
- Waimes: 15.0 N/mm² (on cubes 20x20x20)
- Attert: 10.6 N/mm²
- Marche-en-Famenne 11.7 N/mm²

Nevertheless, relatively considerable dispersions have been observed, which are due to the heterogeneity of the sand, gravel and stones in place. these differences are acceptable with respect to an on site recycling technique.
The frost resistance of the renovated structures is ensured by adequately dosing cement and good compacting. On the other hand, immersion resistance tests have shown that the relationship of resistance of specimens subjected to immersion and control specimens as described in the specifications reach 80 %, higher than the 70 % normally stipulated.

4. THE WORKSITE AT MARCHE-EN-FAMENNE : A GLIMPSE AT THE TESTS BEFORE, DURING AND, AFTER THE WORKS

In 1997, the communal authorities of Marche-en-Famenne, a city in Southern Belgium, inspired by a project in a neighbouring town, planned the development of an agricultural road using on site recycling. The different phrases in the conception and execution of works will be presented below. The road was about 2.5 km long and 4 m wide, which has been increased to 5 m for a part of the route. The asphalt surface layer and the subbase (15 cm of gravel) were in very bad condition.
Material was removed on site four times to determine the granulometric composition and to carry out a feasibility test with respect to stabilisation with cement. Granulometric analysis by sieving produced four similar curves, of which the average is presented in Figure 1, compared with the Talbot curve.

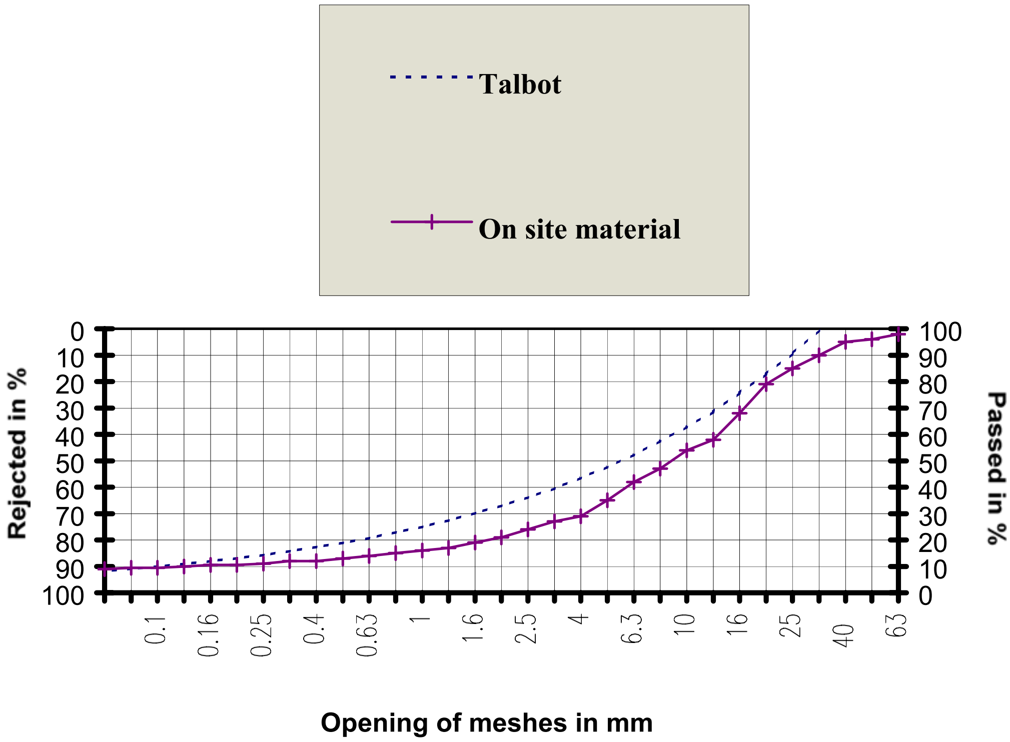

Figure 1 : Marche-en-Famenne – sieve curve of the on site material compared with the Talbot curve

To control stabilisation, mixtures were prepared from the 0/4 fraction of material removed on site to 4 samples and from crushed limestone sand according to the following composition:

Table 2 : Marche-en Famenne –composition of the 0/4 mixture fraction

Limestone sand	0 / 3,15	50 %
Sand taken on site	Sample 1	12.5 %
	Sample 2	12.5 %
	Sample 3	12.5 %
	Sample 4	12,5 %

The quantity of CEM III/A – 42.5 LA cement added to the mixture corresponded to 15 % by weight of the inert substances.

Different Proctor Standard specimens were compacted with different water contents. After a storage period of 7 days in a humid chamber at 20° C and 95 % relative humidity, the compressive strength was determined. The results, which were satisfactory are presented in Table 3.

Table 3 : Marche-en Famenne – results of quick stabilisation test

Water content (%)	6	7	7,5	8	9
Compressive strength after 7 days (N/mm^2)	13.0	21.0	20.8	15.5	17.5

On the basis of the composition of the on site material, 0/32 crushed limestone, limited in fine material, was chosen as added aggregate. A sample was taken on site before the recycling machine and a granulometric analysis was performed. Before recycling, these materials were spread into a 15 cm thick layer (compacted).

CEM III/A 42.4 LA was used as cement (blast furnace cement with limited alkalis content). The cement and water to be added were added automatically in the form of a grout. The cement was added at a rate of 6 % of the inert materials ; water added corresponded to around 3 % of the dry material (inert + cement), since it was expected that the water content of the on site material was around 4 %. Milling of the lower layer of 10 cm thickness of the on site material and mixture of the different additional materials were executed in one operation by the recycling machine:

- thickness of the recycled layer : $\pm$ 25 cm
- total width is 4 m (2 passages of the machine with overlap, the width of the machine is 2.44 m).

The mixed material was compacted by a vibratory roller and from the second day, smoothened by the leveller. A last passing of the roller finished the surface.

Recycled material, not yet compacted, was removed for testing, directly behind the machine:

- determination of the humidity in microwave oven produced the following values :

Table 4 : Marche-en Famenne – water content and bulk density

	Mean value	Standard deviation
Humidity (%)	7,19	1,21
Bulk density (kg/m^3)	2370	33

- fabrication of 20 cm edge control cubes for the compression tests after 7, 28, and 90 days, which produced the following results :

Table 5 : Marche-en Famenne- compressive strength on cubes 20x20x20 cm^3

	Mean value	Standard deviation
Compressive strength after 7 days	12.56	6.3
Compressive strength after 28 days	20.1	9.5
Compressive strength after 91 days	24.9	11.8

- control of the inert substances of the re-treated material is given in Figure 2:

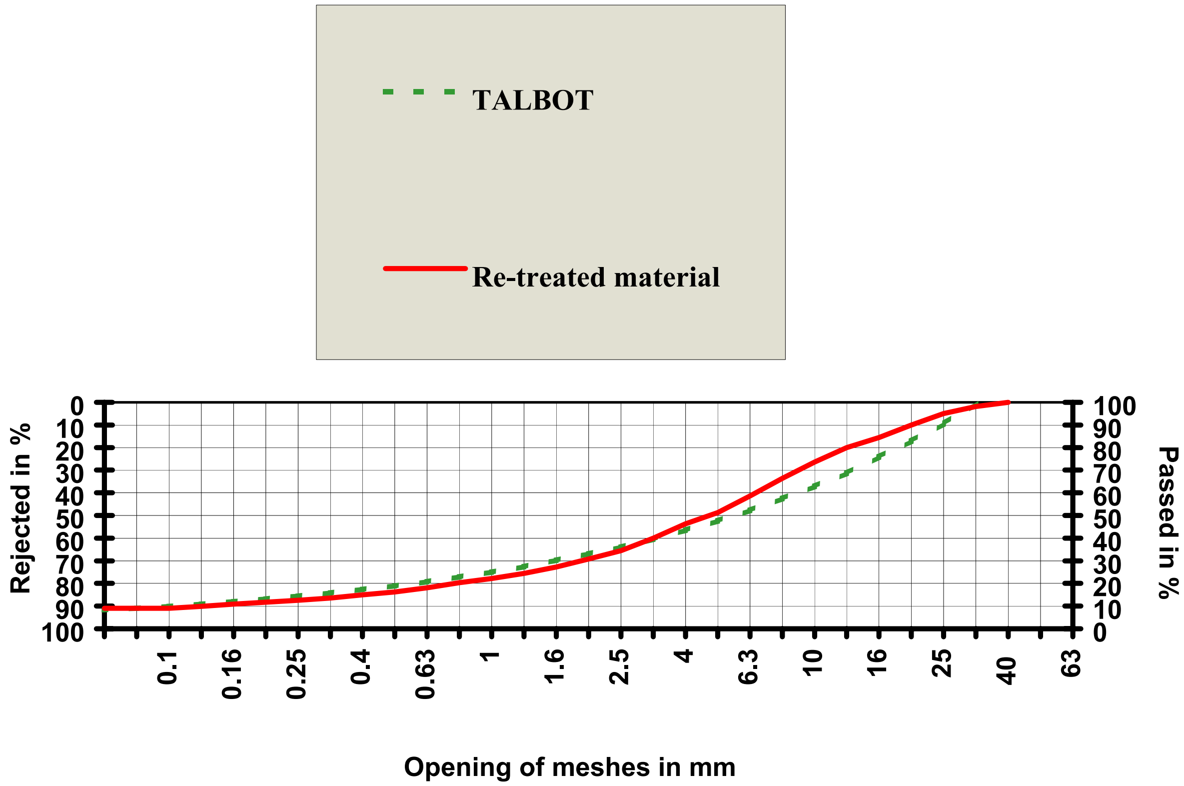

Figure 2 : Marche-en Famenne – inert substances of the retreated material compared with the Talbot curve

Five months after execution of works, 11 cores were removed, distributed uniformly over the length of the road. The cores had a 100 cm² section. The thickness of the asphalt layer and the layer of the recycled material were measured. In view of the irregular character of the lower surface of the layer of re-treated material, the measurement of the thickness of this layer is given only as indication but it was not controlled contractually.

Then, the samples, having a height of 10 cm were cut into the cores. A difference was made between the specimens taken in the upper part, lower part or middle of the core. The results are satisfactory but the dispersions of values are significant (see Table 5). Sometimes, they are due to local or temporary circumstances at the worksite. For example, to remedy a sub-grade, locally of very small load-bearing capacity, cement was added manually, this leading to very good results for the compressive strength, comparable to the results obtained with concrete.

Disregarding the results of the extreme values and the values obtained from the specimens from the lower part, the results obtained are much more coherent (see Table 6).

Table 6 : Marche-en Famenne – thickness of layers and compressive strength of the cores (100 cm²)

	Mean value	Standard deviation
Thickness of asphalt layer (cm)	4.98	0.67
Indicative thickness of layer of recycled material (cm)	22.7	4.4
Compressive strength (all specimens) (N/mm²)	11.7	7.8
Compressive strength (high parts)) (N/mm²)	15.0	9.2
Compressive strength (middle parts) (N/mm²)	11.8	7.2
Compressive strength (lower parts) (N/mm²)	7.1	3.4
Compressive strength (without lower parts, without extreme values) (N/mm²)	12.9	5.1

5. PRESCRIPTIONS IN THE STANDARD SPECIFICATIONS

The different experiences have allowed exact specifications to be included in the standard specifications of the three Belgian regions : Flemish Region, Walloon Region and Brussels –Capital Region. These different clauses are summarily compared below.

5.1. Walloon Region

The Walloon standard specifications –RW99 – foresee a very exact article titled “On site recycling using cement “.
In the description, the thickness of bituminous layer is limited to one third of that of the layer to be recycled and concrete and paving roads are excluded. Crushing before is foreseen, see § 2.2. The material must satisfy granularity criteria, described by the Talbot curve with a tolerance of ± 5 %. Otherwise, a corrective added aggregate is needed.
The composition of the mixture must be justified by a study certified by an approved laboratory. The contractors must provide the laboratory with samples of the material taken on site (at least 200 kg per sample) and the aggregate if there is to be used (at least 100 kg). Sampling is to be done at a rate of at least a drilling per 500 m of road and alternatively by half pavement.
The contents of the report are synthesised in Table 7 below:

Table 7 : RW 99 – Elements of the laboratory report concerning the composition of the mixture

Granularity of the material removed on site +content of elements smaller than 0,063 mm
Content of organic compounds
Granularity of any additional materials
Granularity of the mixture (in situ material + additional material)
Modified Proctor curve of the mixture with 6 % cement content of the dry mass
Quantity of cement needed to obtain a minimum resistance to compression after 7 days of 8 MPa on modified Proctor moulds (dosage fixed at 6 % if the method provides a lower value)
Resistance to immersion by comparison of a series of specimens immersed under water and a second series of specimens kept in a humid atmosphere. The average compressive strength of the first series must be greater than or equal to 70 % of that of the second series.

The paragraph concerning the execution describes in detail the procedure to be used. The most important elements are mentioned here:

- Preparation : the surface coating must be cleaned
- Distribution of additional materials, cement and water: the maximum deviations are foreseen for the quantities stipulated for the aggregate (2%), for the quantity of cement (5%) and for the optimum modified Proctor (1%).
- Fragmentation and mixing :minimum power for the recycling machine
- Compacting and finishing : for thickness less than or equal to 25 cm at least one vibratory roller with smooth rim, for thickness greater than 25 cm a roller with a type(> 2,7 tons per wheel)
- Protection against desiccation : moderate sprinkling with water immediately after the last passage of the roller followed at the end of the day by spreading bituminous emulsion and sand
- Putting into service : light traffic after 4 hours, normal traffic after the putting of the top layer

In the specifications paragraph, the desired load-bearing capacity is expressed by the compressibility coefficient, which must be treated to or equal to 110 MPa (plate test – 200 cm²). The minimum mean strength R'bm and the minimum individual strength R'bi of the cores, at least 90 days old on 200 cm² cores extracted from the stabilised layer are 8 MPa and 6.5 MPa respectively.

A fourth paragraph describes tests during execution and after execution and a fifth and last paragraph regulates the payment mode (measuring and reductions).

5.2 Flemish Region

The Flemish standard specifications are much less exact: the Talbot curve is not demanded, nor the laboratory report and the execution modalities are only succinctly described. The other specifications (compressive strength, cement content, load-bearing capacity, compressing, protection against desiccation, putting into service) correspond more or less to the Walloon standard specifications but are not formulated as strictly.

5.3 Brussels-Capital

The Brussels standard specifications (CCT 2000) do not talk about on site recycling but only treating the ground in order to obtain a load-bearing capacity of 17 MPa (plate test).

6. CONCLUSIONS

Stabilisation by recycling in situ with cement is an excellent recycling technique. It improves existing material without producing waste and limits the transport of new products. This technique has been well studied and it has a promising future.

Technical specifications in line with actual know how have been introduced in Belgian standard specifications.

In spite of the considerable efforts by the different Belgian regions and by research centres to make this technique known, there have been few applications in Belgium, slightly more than 300,000 m² in 10 years. Certain engineers, public administrations and contractors are not really willing to invest in innovative techniques even if they have provided positive results in the practice. The actual policies of the regions as regard environmental protection must provide a new and considerable stimulus in this respect.

Also, the necessity to perform laboratory tests at the very early stage to ensure the feasibility, absence of financial incitement or the absence of obligation does not encourage public administrations and contractors to use recycling methods still considered as not reliable enough.

And finally, particular effort must be made to promote this method with respect to building sponsors and designers. Besides the economic and ecological advantages inherent to this method, financial incitements can convince those responsible for projects to choose this completely manageable technique.

REFERENCES

1. M. Chomis, A. Jasienski
   Le retraitement en place des chaussées au moyen de ciment - Le chantier expérimental de Messancy (Belgique)
   7ème Symposium International des Routes en Béton
   Vienne, 3-5 octobre 1994, Session III, pp. 111-116

2. C. Ployaert
   Le retraitement au ciment des routes rurales
   Mémoire de fin d'études
   Faculté Universitaire des Sciences Agronomiques de Gembloux. Unité de Résistance des matériaux et constructions du génie rural
   Belgique, 1993, 94 p. et annexes

3. Le retraitement en place des chaussées au moyen de ciment. Economique - Ecologique - Performant - Code de bonne pratique
   Ministère de la Région wallonne - Direction générale des Pouvoirs locaux - Division des Infrastructures routières subsidiées
   Mars 1995

4. M. Chomis, A. Jasienski, C. Ployaert, P. Sion, J.C. Verbrugge
   L'expérience belge en matière de retraitement en place des chaussées au moyen de ciment
   XVIIIème Congrès belge de la route
   Bruges, 2-5 septembre 1997, Thème 3, pp. 240-244

5. S. Wirgot, C. Ployaert, P. Van Audenhove
   Rapports d'essais n° 83.294, 84.554, 84.555, 84.556 et 84.758.
   Centre de Recherche de l'Industrie Cimentière (C.R.I.C.)
   1999-2000

6. Risico-analyse en sanering van wegen bedekt met assen en slakken uit de non-ferro industrie.
   Verslag van een studie uitgevoerd in opdracht van de Openbare Afvalstoffenmaatschappij voor het Vlaamse Gewest.
   K. Van den Broeck, C. Vandecasteele - Katholieke Universiteit Leuven
   P. Berghmans, C. Cornelis, V. Dutré, J. Nouwen, P. Seuntjes – Vlaamse Instelling voor Technologisch Onderzoek
   Juni 2000