12 Mar 1998, 10:30 am - 12:00 pm

An Ecotechnical Alternative: An Embankment of Incinerated Municipal Solid Waste

Ph. Gotteland
L.I.R.I.G.M. University of Grenoble, France

G. Bossonney
Général Council of Savoi, France

D. Coulon
Genove S. A., France

Proceedings: Fourth International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, March 9–12, 1998.

AN ECOTECHNICAL ALTERNATIVE : AN EMBANKMENT OF INCINERATED MUNICIPAL SOLID WASTE

Ph. GOTTELAND
L.I.R.I.G.M. University of Grenoble
Grenoble,38041 France

G. BOSSONNEY
Général Council of Savoie
Chambery,73000 France

D. COULON
Geonove S.A
Chagny, 71150 France

9.04

ABSTRACT

Incineration seems to be one of the best solutions to solve the problem of household refuse disposal. In compliance with European legislation, part of this incinerated refuse, could be used in public works. The authorities are fully aware of the high economic stakes involved, and this is the reason why they would like to control and define the conditions of use of such incinerated refuse. An innovative alternative is presented in this paper, involving the use of slag from Municipal Solid Waste Incineration (I.M.S.W.R.), lightened by the inclusion of old tyres, and strengthened with a layer of geosynthetics, in order to build a retaining wall for a road embankment. With the possibility of seeding the wall facing, the structure can be blended harmoniously into the site. This reinforced structure was monitored in order to check its behaviour, especialy its thermal behaviour.

KEYWORDS

Lightened road embankment, Incinerated Municipal Solid Waste Refused (I.M.S.W.R.), Geogrid Reinforcement, Monitoring

INTRODUCTION

Every year, France produces some 20 Mt of household waste. About 7 Mt are processed in 160 household waste incineration plants. Through this incineration process, the volume of the waste material is reduced by a factor of ten; the weight of the solid residues from incineration (slags) represents 25% of the initial weight of the refuse. Consequently, 2Mt of slag are produced each year in France and it seems likely that this production will continue to increase in the years to come.

At the present time, most of these slags are conveyed to storage centres (at a cost of about 40FRF/tonne and this prices continues to rise), while a small part is put to productive use in public works projects: this residual material is still considered for the most part as a waste product.

In accordance with European legislation, the use of storage centres will no longer be authorised after 2002.

Conscious of the economic stakes involved, the French Ministry of the Environment distributed a circular defining the environmental conditions under which productive use can be made of this material for public works projects, in accordance with current legislation on incineration plants.

The slag produced as residual waste from authorised plant, would seem to have a promising future in road building schemes, especially in major cities or, as is the case in question here, in mountainous regions. It forms an economically advantageous alternative to the extraction of natural mineral resources.

The French *département* of Savoie has been a trail-blazer for several years in environmental questions, in particular in giving incentives for public works alternatives involving recycled waste products. Such ecologically-friendly technical alternatives - "dubbed ecotechniques" - are economically very attractive. In this context, the roads department of Savoie's General Council, when faced with road grading and reinforcement requirements, opted for an innovative alternative for retaining road embankments composed of slag from waste incineration, lightened by the inclusion of old tyres and strengthened with layers of geosynthetics.

Photo 1: General view of the structure

THE SITE

The works described here were situated on the RD 202 minor road, in the commune of Chateauneuf in Savoie. The road had been seriously damaged by landslides due to storms at the end of 1991, and had to be enlarged and redesigned.
The foundation materials were quite fine grained: the site is located in a morainic formation from the Wurm ice age (sandy moraine, sandy marl silt). The geotechnical investigations were carried out during spring 1992. After interpretation of the pressure meter tests, the following characteristics were determined for the foundation ground: cohesion 5 kPa $< c' <$ 20 kPa, angle of friction $29° < \phi' < 35°$, mean dry density γ = 18 to 19 kN/m^3.
This "fairly loose" ground is relatively easy to deform and its properties are fairly poor.
The slope is quite wet and most of the flows are concentrated at the interface of the impermeable marl substratum and the permeable sandy moraine.

THE STRUCTURE

A flexible solution was proposed consisting of "lightened" fill, reinforced with layers of geosynthetics.
Under the measures to encourage the development of ecotechniques, the specifications for the project required the use of slag from refuse incineration.
Two alternatives were proposed.
The first was an embankment of incinerated refuse slag reinforced with layers of geotextiles and a facing formed from truck tyres (Pneutex alternative).
However, the unsightly facing prompted a proposal for a second alternative to the Environment and Development Group at the General Council. In this alternative, the structure's body was made of slag but the facing could be seeded.
The Textomur technique was used, a Swiss patented technique marketed by the firm Geonove (Gripond 93). Furthermore, old tyres were incorporated into the embankment, which considerably lightened the structure.
This second alternative, blending the embankment into the landscape, was approved.
The embankment was built between July and October 1994. Its total length is approx. 360 m, and its height varies with a maximum close to 7 m; its width goes from 2.5 m to 4 m and the facing is sloped at approximatly 60° (typical cross-section shown in Fig. 1).

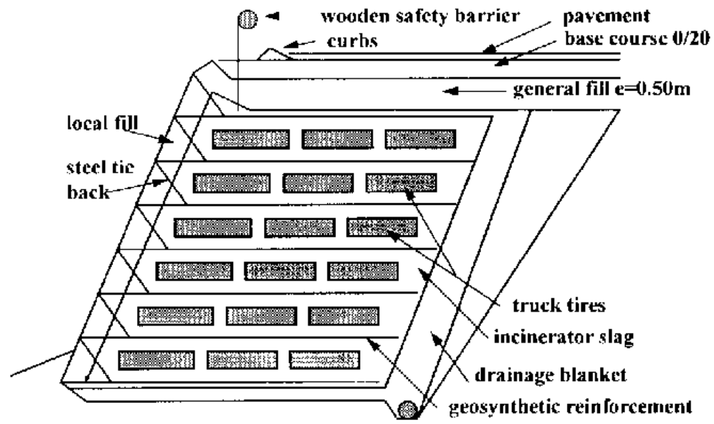

Fig. 1: Typical cross-section of the wall

Construction material

The material used for construction was slag from incineration of household refuse, in this specific case from the waste incinerator operated by the *Syndicat Intercommunal de l'Agglomération de Chambéry* (S.I.A.C.).
This intermediate incineration residue, in compliance with European regulations of 13 July 1992, can be used for public works in accordance with the instructions of the French Ministry of Equipment circular (GTR 92) and the instructions of the French Ministry of the Environment, issued on 9 May 1994 .
These instructions define the conditions under which IMSWR can be used in public works. Three quality classes are defined in relation to the results of leaching tests:

- classe V: Productive use ex-works,
- classe M: Productive use after a maximum maturing period of 12 months
- classe S: No productive use possible, destined to be conveyed to storage centre.

The thresholds (table 1) correspond to environmental characteristics.
The technical provisions drawn up by the Ministry of Equipment are based mainly on the specifications corresponding to geotechnical characteristics.

	classe V	classe M
Hg	< 0.2 mg/kg	0.4 mg/kg
Pb	< 10 mg/kg	< 50 mg/kg
Cd	< 1 mg/kg	< 2 mg/kg
As	< 2 mg/kg	< 4 mg/kg
Cr6+	< 1.5 mg/kg	< 3 mg/kg
SO42-	< 10000 mg/kg	< 15000 mg/kg
COT	< 1500 mg/kg	< 2000 mg/kg

Table 1: Definition of class thresholds (French Ministerial circular dated 09 May 1994)

The main inconvenience with this material is that its heavy metal content can be very high and, through leaching, it can therefore be environmentally harmful. Heavy metal content, obtained from the standard French leaching test (NFX 31-210), is nonetheless strictly regulated and regular tests are required; the results must be submitted to the government department in charge of granting permits for the reuse of waste materials

(D.R.I.RE. = *Direction Régionale de l'Industrie ,de la Recherche et de l'Environnement*).
The properties of such materials vary quite widely depending on the production site and they can be considered as light. The optimum Proctor maximum dry density is (mean $\gamma_{OPN} \simeq 16$ to 17 kN/m^3). It has very satisfactory geomechanical qualities, especially the angle of friction ϕ' which is approximately 40° (Gotteland and Milanov 93).

Before transport to the site, the material is first stored on a specially prepared site for a maturing period, during which it pre-stabilises chemically. No fixed time has been defined for this period, but in the case at hand, it was between 4 and 8 months.
Slag from household refuse incineration is an alkaline material with a fairly high hydrogen potential ($9 < pH < 12$);
The project under study used approximately 8000 tonnes of slag, i.e. almost 6 months' production from the Chambery incinerator.
The material was provided to the contractor free of charge, and even transport costs were borne by the local authority (SIAC) running the incinerator, under an agreement between that authority and the Savoie General Council.

Photo 2: Truck tyres before being covered

Photo 3: Geosynthetic reinforcement and framework Thermoelectric cells

Tyre inclusions

As part of the Savoie *département's* plan for waste disposal, old truck tyres were taken from a storage site about 15 km from the works site.
The tyres were unprepared and placed side by side before being covered with slag and then compacted (photos 1 & 2). Voids were not entirely filled in and thus the body of the embankment was considerably lightened (mean $\gamma \simeq 13$ kN/m^3).
With no link holding them together, the tyres play no mechanical role in maintaining internal stability within the embankment.

Geosynthetics

Layers of geosynthetics were used to reinforce the embankment.
The engineering firm Geonove selected HDPE SR 55 geogrids made by the firm Tensar, because of their high strength in aggressive environments with high pH and good mechanical interaction with the construction materials.
Two layers, of varying length depending on the profile, were spaced 60 cm apart (Fig.1) (photo 3).

Facing

The use of integrated « lost » Textomur coffering brings decisive advantages to the wall made of geosynthetic. Firstly, any and all geometrical figures, even very complex, are made possible be the simple shearing of the metal braces of the structure. Secondly, execution can proceed by distinct and successive instalments. This is very practical in difficult geotechnical contexts (I.E. work in montain site).

Photo 4: local view of the facing 8 months after

To garentee the landscaping , optimal conditions are used. Notably a suited geotextile backing and behind this, earth with enough fine particles to encourage root development and water retention. The geotextile facing should be dissociated from that of the reinforcement. It is useless to provide the same mechanical resistance when the charge put upon facing with a slope to 70 degrees is very light. On the other and it must be woven very finely (1 to 2 mm) to allow roots to pass through and can include an anti UV treatment that will determine the best period for growth.
Construction sites should be vigilantly overseen because geotextile masses are complex construyctions and rigourous controls are necessary to avoid undermining of the technique by negligence, even if the execution is apparently very simple.

MONITORING

This innovative embankment was monitored to check its behaviour.
The instrumentation installed was intended to follow any heat variations within the embankment body so that it could be correlated to any change that might occur in the mechanical properties of the materials over time.
Despite the maturing period, when the main chemical reactions occurred, slag behaviour had to be checked to see whether it would change once it was placed, since the setting process took place concomitantly with exothermal reactions. As this point was not well understood, the correlation of internal temperature with the results of pressure meter tests should furnish valuable information.
The Rhône-Alpes Regional Council provided financial support for the operation.
The LIRIGM laboratory was appointed to make and install the sensors, and to monitor them.

Thermal measurements

The thermal sensors consist of protected thermocouples capable of resisting the aggressive environment in which they are placed.
Twelve of the sensors (12 protected thermoelectric cells) consist of copper-clad, teflon-sheathed thermocouples with the wires also teflon-coated. The element generating the signal is a weld linking the ends of the thermocouple component wires. The weld is protected against chemical attack by an epoxy resin coating and against mechanical stress by a stainless steel tube. The wiring, protected by an associated metal strand, is further protected by being placed in a PVC sheath.
Twelve other sensors (12 unprotected cells) were made with more rudimentary protection: only a plastic sheath covering the thermocouple weld and no additional protection for the wiring
The sensors were installed as the works progressed.
Since October 1994, when the works were completed, the thermal sensors (12 protected thermoelectric cells and 12 unprotected cells), installed on two embankment profiles spaced approximately one hundred metres apart, have been regularly read.
Figure 2 shows the results of the thermal measurements.
It is worth noting that:

- no significant rise in temperature has occurred, indicating that the material is no longer subject to internal exothermal reactions,
- there is an attenuated cyclic variation in external temperature. This variation is greater at the facing compared to the back of the structure, and at the top compared to the bottom. This would seem to confirm the good heat-insulating qualities of the material.

So, no noteworthy change has been reported to date. However, it still seems too early to conclude that none will occur.

Geotechnical tests

Two comparative geotechnical test programmes were conducted in June 1997 in order to compare the behaviour of the material immediately after it was placed (St Baldoph site) and after a stabilisation period of 2.5 years in place (Chateauneuf site).
The St Baldoph site involved the construction of a motorway slip road ramp, made with IMSWR slag fill from the Chambery incinerator. The works were carried out in June 1997 after the IMSWR material had been left to mature for 4 to 6 months. The material was placed in homogeneous layers about 40 cm thick, without inclusions (tyres and geosynthetics). Bad weather disrupted the works to a certain extent, especially by increasing the water content of the material which, when taken from the storage site, was $w = 14\% = w_{opn}$
Pressuremeter tests and static penetrometer tests were performed. The results are given in Table 2.
No notable difference in behaviour was found between the two ages of the material. No hardening of the material placed would seem to have occurred in the Chateauneuf structure. this therefore confirms the fact that if the material is left to mature

during the temporary storage stage after leaving the plant, no additional reaction occurs during the lifetime of the structure. The hardening phenomenon linked to exothermal reactions occurs only during the maturing stage.

In the present case, no exothermal reaction occurred to compromise the mechanical behaviour of the reinforcing geosynthetic inclusions.

CONCLUSION

The structure presented in this paper, built with a mixture incinerated refuse slag and geosynthetics, is a first in the *département* of Savoie.

With the possibility of seeding the facing, the embankment can be blended into the site.

This opens up interesting prospects for employing large quantities of incinerated refuse slag, with a fairly easy-to-use technique and measuring its potential for any harmful effect on the environment.

	Chateauneuf Site		St Baldoph site	
	variation MPa	mean value MPa	variation MPa	mean value MPa
Pressuremeter tests				
limite pressure Pl	1.88 - 3.65	2.70	1.35 - 3.40	2.30
Modulus Em	30 - 65	42.5	16 - 50	29
Penetrometer test				
point resistance qc	3 - 10	6.5	3.7 - 10	6
lateral resistance Fl	0.1 - 1.35	0.5	0.15 - 0.9	0.49
FR = Fl / qc	2 - 15 %	6 %	2 - 20 %	8 %

Table 2: In-situ test results: comparison of the old placed (Chateauneuf site) and the new placed material (St Baldoph site)

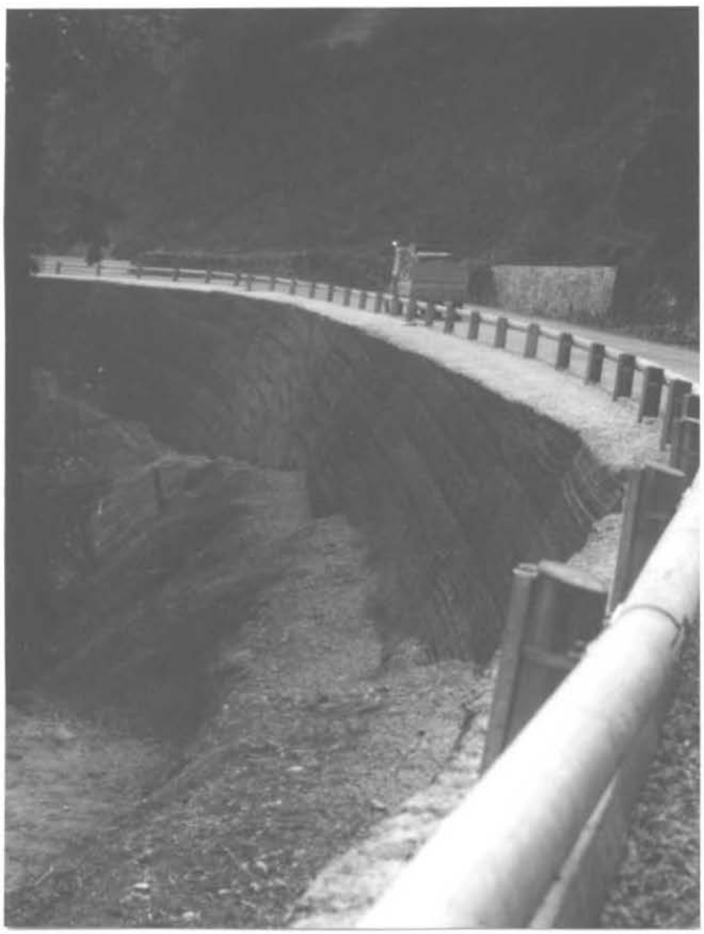

photo 5: The wall facing at the end of construction (10/94)

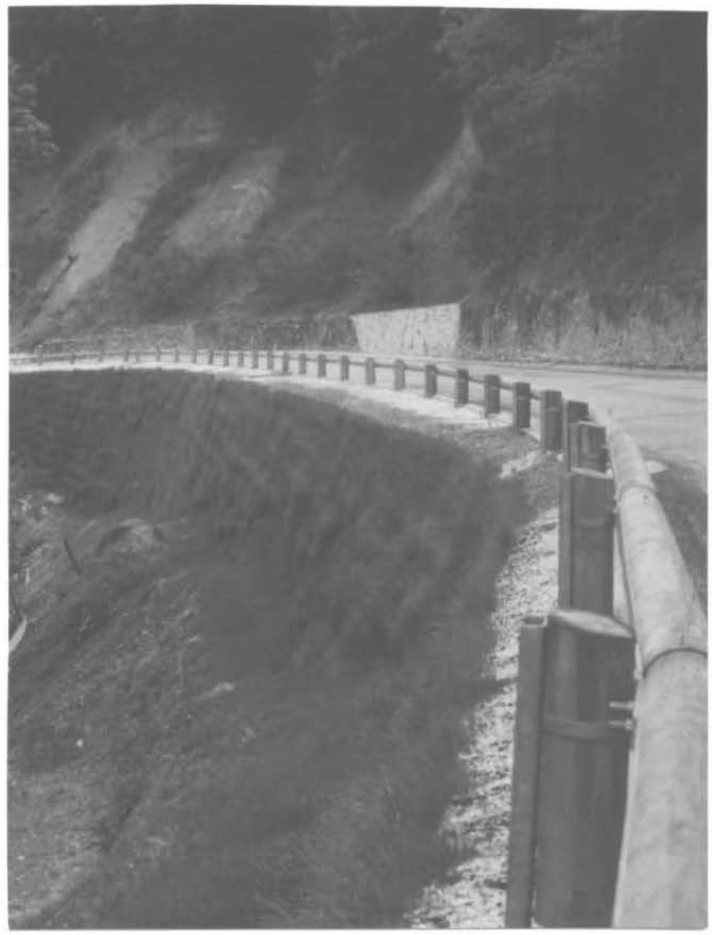

photo 6: The wall facing 8 months after (05/95)

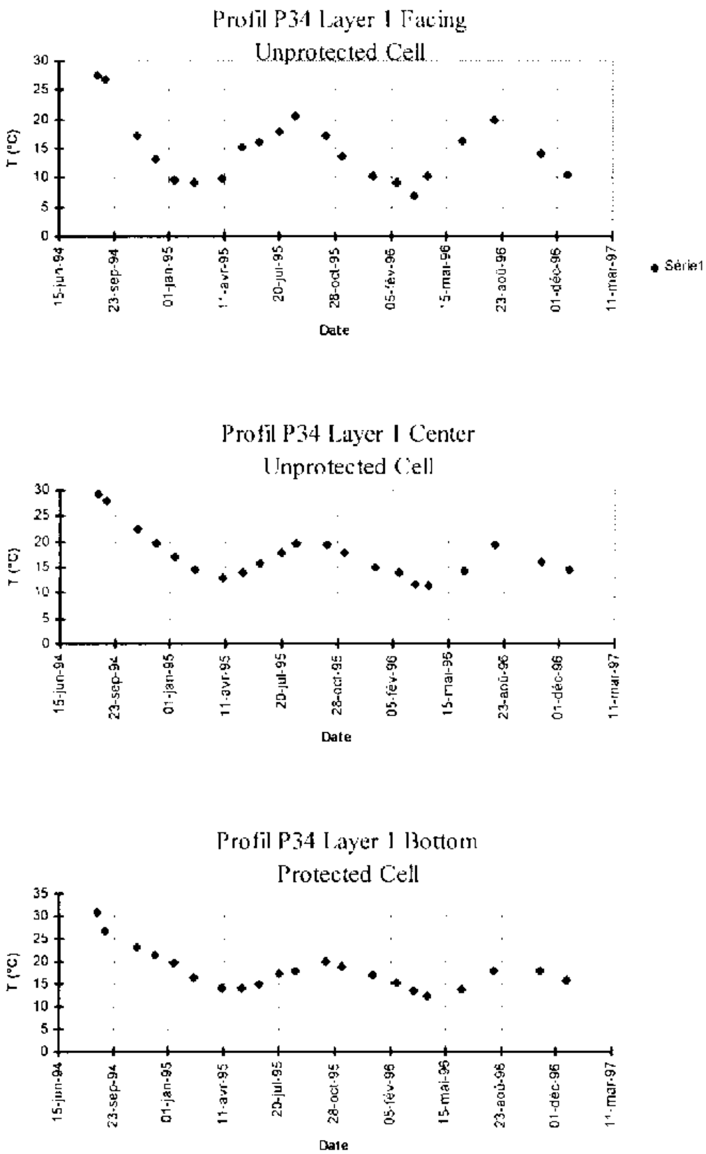

fig.2: Evolution of thermic cells
(at the base of profil P34 H−7.70m)

REFERENCES

Bossoney G., Dieny P., Gotteland Ph. [1995] An innovative ecotechnical alternative : an embankment of incinerated minicipal solid waste reinforced with geosynthetics, 2nd french Conference on Geosynthetics, Rencontres 95,Beaunes,pp79-84

Gripond JL [1993], Mass "Green" planted retaining wall formed and reinforced by geotextile, Proceeding Geotextiles and Geomembranes Rencontres 93,Tours, pp. 223-231

Gotteland Ph., Milanov V. [1993], Possibilités d'utilisation des Mâchefers d'incinération des ordures Ménagères en travaux publics , Proceeding Symposium Geotechniques et Environnement, Nancy,pp.287-297.

Ministere de l'environnement Français, 9 Mai 1994,[1994] Circulaire sur l'elimination des machefres d'incineration des residus urbains, DPPR/SEI/BPSIED/FC/FC n°94-IV-I

Ministere de l'Equipement Français, SETRA-LCPC RTR [1992], Realisation des remblais et couches de forme, Fascicule 1:principes generaux, Fascicule 2:annexes techniques, 98p, 101p

AFNOR [1992], norme NFX31-210, relatif aux essais de lixiviation des dechets solides, 13p