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«Sustainable Management of Waste and Recycled Materials in Construction»

ABSTRACTS



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Topic 1 Leaching: lab vs field data

Measurement of the release of contaminants from roofing felt

Ole Hjelmar
DHI Water Environment Health, Denmark

The ongoing implementation of the so-called Essential Requirement no. 3, which aims to ensure that construction products do not cause a threat to the hygiene and health of occupants or neighbours or the environment during the service life, into the Construction Products Directive (CPD), includes the development of harmonized, horizontal test procedures for determination of the release of (potentially) dangerous substances from construction products. This work, which comprises procedures addressing release to both indoor air and soil, groundwater and surface water, is carried out by the European technical standardization committee CEN/TC 351 in response to Mandate M/366 from the European Commission.
One of the harmonized test methods under development, which addresses release to soil, groundwater and surface water, is the "Generic horizontal dynamic surface leaching test (DSLT) for determination of surface dependent release of substances from construction products". The method, which addresses situations where the leaching from materials occurs as a flux through the surface(s) of the material, generally under non-equilibrium conditions, e.g. as diffusion, is based partly on an adjusted version of the Dutch tank leaching test, NEN 7375:2004. One of the adjustments has been to broaden the scope to cover not only 3-dimensional test bodies such as cubes and cylinders, but also to cover the release from sheet- and plate-like construction products.
This paper describes how the DSLT is adjusted to apply to sheet- and plate-like construction materials, and presents results of the test performed on two different brands of roofing felt. The paper also presents the test methodology (the roofing felt is placed on the inner surface of a cylinder which contains the eluent (distilled water), see figure 1). Leaching results are presented for inorganic constituents, DOC and PAHs. The results are subsequently used in scenario calculations to illustrate the potential environmental impacts under various conditions. Figure 1: A cross-section showing the set-up of the DSLT for testing of roofing felt.

Ageing under field conditions – Some results from a long-term lysimeter study

Pascal Suer, David Bendz, Ola Wik and Cecilia Toomväli
Swedish Geotechnical Institute, Sweden

Eight lysimeters have been active at the Swedish Geotechnical Institute since 1993, **Erreur ! Source du renvoi introuvable.**. They contain crushed rock, till, MSWI-bottom ash, wood ash, steel slag, electric arc furnace slag, crushed concrete, and shooting range soil. Leachates from all lysimeters have been analysed over time. The lysimeter containing 14 tons of MSWI bottom ash was carefully excavated after 12 years and 100 samples were taken at four depths.
The results confirm the rapid leaching of readily available elements, and also shows influence of solubility controlled leaching. Calcium reached a steady state after ca 1 year. Part of the mobilised calcium leached from the lysimeter, part precipitated as secondary minerals that increased buffering capacity. Both Ca and ANC showed an increase with depth.

Assessment of redox-sensitive element mobility-Discrepancy between laboratory and field data

Christian Maurice and Sofia Lidelöw
Dep. of Civil, Mining and Environmental Engineering, Luleå University of Technology, Sweden

Leaching tests have become popular tools to assess the environmental effect of materials containing pollutants e.g. wastes, construction materials, soils. Batch (EN 12457-3) and column (prEN 14405) leaching tests are both standardised. The standardisation regulates how the test should be performed i.e. the procedure, the amount of material to be used and how to handle the leachate. However, standardisation is often misinterpreted as quality insurance that the results of the test are relevant for any type of material and application. The EN 12457-3 test has thanks to the standardisation and its relatively low price become the most popular tests used to assess if waste material could be used in constructions. Basically waste materials fulfilling acceptance criteria for landfill for inert waste are often regarded as acceptable to reuse in the society.
The aim of the presentation is to discuss the risk of using tests without a critical assessment of their relevance and limitations. Materials containing sulphides, iron and arsenic are specially challenging to assess as the standard batch leaching test underestimates the risk for leaching.
The leaching of arsenic was underestimated by the EN 12457-3 test and the effect of open filtration, sample preparation and test conditions are discussed. The results showed that a material fulfilling criteria for landfill for inert waste leached more arsenic than was acceptable at a landfill for hazardous waste. In the second example, the documented generation of acidic leachate from blast furnace slag in field conditions has never been observed in the laboratory. The main hypothesis is that the development of unsaturated conditions caused the oxidation of sulphidic minerals in the blast furnace slag heap and generation of acid leachate.
The selection of appropriate leaching tests should be done with regard to the real conditions that are to be assessed. Standardisation does not mean that the test is automatically adapted to the need. A relevant assessment requires therefore understanding of the geochemical process controlling the pollutant mobilisation and immobilisation in the actual material and its application. Such comprehension is a prerequisite to the selection of appropriate leaching procedures.

Environmental assessment of a BOF steel slag used in road construction: The ECLAIR research program

Legret M.[a], Chaurand P.[b], Bénard A.[c], Capowiez Y.[d], Deneele D.[a], Reynard J.[e], Lassabatere L.[a], Yilmaz D.[a], Rose J.[b], Domas J[e], Béchet B.[a], Richard D.[f], Bottero J.-Y.[b]

[a] *Laboratoire Central des Ponts et Chaussées, BP 4129, 44340 Bouguenais, France*
[b] *CEREGE, Europôle de l'ARBOIS, BP 80, 13545 Aix-en-Provence Cedex 04*
[c] *INERIS Méditerranée, Domaine du Petit Arbois, BP 33, 13545 Aix-en-Provence Cedex 04*
[d] *UMR Ecologie des Invertébrés (LTE), Site Agroparc, 84914 Avignon Cedex 09*
[e] *CTPL, Immeuble Aristote, 25, Bd Victor Hugo, 31770 Colomiers*
[f] *ARCELOR-MITTAL, rue du Comte Jean, BP 2508, 59381 Dunkerque Cedex 01*

Steel production generates great amounts of by-products as steel slag. Unlike blast furnace slag, the use of Basic Oxygen Furnace slag (BOF slag) has been restrained due to insufficient volume stability and to the lack of environmental regulations. This study aimed at investigating the potential release and impact of pollutants, especially Cr and V that are present in rather high concentrations in slag, from a BOF slag used in a civil engineering structure (an industrial platform), using a multi-scale approach. The one-year follow up of the experimental platform showed that concentrations of Cr and V were generally low in seepage waters, and in leachates from leaching test. Micro-analyses carried out on slag allowed us to confirm the location of these metals in rather stable ferrous mineral phases, but V was also bound to more reactive silicates. No real toxicity effect of seepage waters has been revealed from eco-toxicological tests carried out with earthworms.
Keywords: Steel slag, civil engineering, chemical analysis, hydrodynamics, environmental assessment.

Evaluation of field-scale emissions from utilization of MSWI air-pollution-control residues stabilized with FeSO4

Jiri Hyks**,** Thomas Astrup, Thomas H. Christensen
Department of Environmental Engineering; Technical University of Denmark

Leaching of salts and metals (Pb, Cd, Cu, Zn, Cr, Mo, Sb, and others) from two Danish air-pollution-control
(APC) residues stabilized with FeSO4 in so-called Ferrox-process (Lundtorp et al., 2002) was monitored during
nearly 8 years long lysimeter study. The main objectives were (i) to evaluate the stabilization method in a "reallife"
utilization/disposal scenario and (ii) describe the leaching processes by means of geochemical modeling.

APC residues

APC residues were collected at two Danish MSWI plants with different APC systems: semi-dry system and wet system. The semi-dry residue, herein referred to as SD, was sampled from the ash silo; it was a mixture of fly ash, unreacted lime and acid-gas neutralization products. The other residue, herein referred to as FA, was collected in an electrostatic precipitator; it contained "pure" fly ash without added lime and the acid-gas neutralization products.

Ferrox-products

The residues were treated in a Ferrox-process pilot plant. The Ferrox-products generated from SD and FA residues will henceforth be referred to as SD-F and FA-F. Moisture content, lost on ignition (LOI), and elemental composition of SD, FA, SD-F and FA-F were determined at accredited laboratory using ICP-AES after total digestion in HCl/HF/HNO3.

Lysimeters

Four polypropylene lysimeters were used in this study (Figure 1). Two lysimeters were filled with SD and FA while the other two lysimeters were filled with SD-F and FA-F.

Leachate collection and treatment

Typically, pH, conductivity, and temperature were measured on-site. Leachates were transported to the laboratory, filtrated though 0.45 um polypropylene filters, and acidified with HNO3. Solution concentrations of Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Sn, Sr, Ti, V, and Zn were determined using ICP-OES. Chloride (Cl-) content in the acidified samples was determined by automated potentiometric titration with AgNO3.

Geochemical modeling

A percolation scenario accounting for solution/precipitation of minerals, advective transport of eluent, dispersivity, sorption on ferrous (hydr)oxides, and diffusive exchange between stagnant and mobile zones was set-up in PHREEQC-2 model (Parkhurst and Appelo, 1999). Complexation with dissolved organic carbon (DOC) was omitted in our model as the amounts of reactive DOC fractions (i.e. humic and fulvic acids) in the APC residues were negligible (Hyks et al., 2008; Quina et al., 2008).

Results – example

pH

Initial pH decreased as follows: pH SD > pH FA > pH FA-F > pH SD-F. The highest values were measured in SD where pH increased from initial pH 10.4 to pH 13.1 above L/S 1 L/kg. High pH in SD could be explained by dissolution of excess lime and Ca(OH)2 (portlandite) (Hyks et al., 2008). For FA, the pH values increased from initial pH 10.3 to pH 12.2 at L/S > 1 L/kg. Lower amount of lime in FA and consequently different pHcontrolling minerals such as Ca6Al2(SO4)3(OH)12·26H2O (ettringite), Ca4Al2O6(SO4)·6H2O (monosulphate) and CaSO4·2H2O (gypsum) have caused the difference. Addition of acidic FeSO4 suspension (pH < 2) during the Ferrox-process naturally affects

the pH development in both SD-F and FA-F. Excess of sulphate caused a significant precipitation of gypsum in the Ferrox-products (Sorensen et al., 2000). The "natural" pH of the Ferrox-products, controlled predominantly by dissolution of gypsum, is then expected to be significantly lower compared with the untreated APC residues. PHREEQC-2 simulation showed that addition of FeSO4·7H2O (log k -2.47) to the initial leachates from the untreated APC-residues (pH 10.8 ± 0.4) whilst precipitation of gypsum was allowed caused a pH decrease to pH 8.16 and pH 8.28, respectively. This was fairly comparable with pH measured in early SD-F and FA-F leachates; i.e. pH 7.62 and pH 8.35 at L/S ~ 0.1 L/kg.

Technical and environmental long-term properties of by-products – field study and laboratory simulation

Maria Arm[1], Pascal Suèr[1], Håkan Arvidsson[2], Jan-Erik Lindqvist[3]
[1]Swedish Geotechnical Institute (SGI), [2]Swedish National Road and Transport Research Institute (VTI), [3]SP Technical Research Institute of Sweden

In Sweden, use of industrial by-products is still hindered by concern for their long-term properties. A three-year research project was therefore initiated aiming to:

- Identify the crucial processes of ageing related to the usefulness of by-products in roads;
- investigate the consequences of these processes for technical and environmental properties of the by-products, and
- propose a method for accelerated ageing to predict the long-term properties.

The working hypothesis was that crucial ageing processes lead to changes in pH, effective particle size and mineralogy, which in turn determine leaching, stiffness and stability of the material.

The project, running through 2006–2008, compared naturally aged samples of two by-products used as sub-bases in existing asphalt paved roads with samples of fresh by-products from producers' piles. Steel slag of electric arc furnace type and municipal solid waste incinerator (MSWI) bottom ash was chosen. The samples were thoroughly characterized in order to identify which ageing processes had been crucial.

The following properties were studied: grain size distribution, water content, compaction properties, deformation properties according to cyclic load triaxial tests, mineralogy and micro structure according to SEM and XRD, chemical composition, pH and leaching properties. For the bottom ash also organic content and electric conductivity was studied.

The results showed that:

- Bottom ash from the pavement edge was more aged than bottom ash from the road centre. However, no difference in pH was found, instead the differences were said to be caused by differences in water exposure.
- Steel slag from the pavement edge showed traces of carbonation and leaching processes, whereas slag from the road centre was identical to fresh slag.
- Water exposure to the subbase materials after ten years in an asphalt paved road was calculated to less than 0,1–0,5 litres per kg.
- Ageing reactions in steel slag and MSWI bottom ash, ready for use, were too small to be verified by laboratory measurement of deformation properties under loaded conditions.
- An accelerated ageing test for steel slag was set up to achieve the carbonation (decrease in pH) and leaching that was observed in the pavement edge material.
- An accelerated ageing test for bottom ash was set up to achieve the pozzolan reactions that were observed in SEM analyses of in-situ specimens.
- When properties of aged material are studied, particles should not be crushed before tests or examination.

Leaching of inorganic species from APC residues: a comparison of column and batch tests

Margarida M. J. Quina [1], João C.M. Bordado[2], Rosa M. Quinta-Ferreira [1]
[1] *GERSE- Group on Environment, Reaction and Separation Engineering. Department of Chemical Engineering, Polo II University of Coimbra, R. Sílvio Lima, 3030-790 Coimbra, Portugal*
[2] *Department Chemical and Biological Engineering, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa Portugal*

In this study, the comparison of column and batch leaching tests is addressed in order to characterize the behaviour of air pollution control (APC) residues produced in municipal solid waste incineration (MSWI). This waste is hazardous, and taking into account their physical and chemical properties, leaching of contaminants into the environment is the main concern. In our work the leaching behaviour of toxic heavy metals (Pb, Zn, Cr, Ni, Cu) and inorganics associated with soluble salts (Na, K, Ca, Cl) is considered. In fact, leaching tests provide better means to assess environmental impact than the analysis of total composition. Although the pH of the leaching solution is the most important variable in leaching processes, the influence of liquid to solid ratio (L/S) may be also important for assessing the leaching behaviour under specific scenarios. In our study, column tests (NEN 7343) and batch tests (based on DIN 38414-S4) were compared, having each of those tests specific advantages. The APC residues revealed to be hazardous when analyzed according to both tests, being Pb the most problematic heavy metal, since the regulatory thresholds are highly exceeded. The material exhibits high solubility, and the batch experiments showed that when the liquid to solid ratio is high, more than 50% can be solubilized. The pattern of release for the different inorganic species may be availability or solubility controlled. In practice the availability controlled pattern is easier to identify, being mainly associated to soluble salt species. When the results from column and batch experiments were compared by representing the cumulative released amounts (in mg/kg) as a function of L/S, both curves match for Zn, Ni, Cu, K, Na, Cl and Ca, but for Cr and Pb a significant difference was observed. In fact, the column experiments revealed that under percolation conditions it should be expected slow releasing of Pb along time. From this study, it can be concluded that the released amounts obtained in batch experiments should be considered as the worst case for medium term.

Metal leaching from apc residues solidified using portland cement and ground granulated blast furnace slag

[a]Lampris C., [b]Stegemann J.A., [a]Cheeseman C.R.
[a]*Department of Civil and Environmental Engineering, Skempton Building, Imperial College London, UK*
[b]*Department of Civil and Environmental Engineering, Chadwick Building, University College London, UK*

Air pollution control (APC) residues from municipal solid waste incineration are a problematic hazardous waste due to their high concentrations of soluble salts and volatile heavy metals. These are the major barriers for reuse and disposal to landfill in the UK. APC residues are classified as a hazardous waste in the EC Waste Catalogue (19 01 07*) and they have been the focus of many studies, investigating different treatment methods to reduce mobility and leaching of contaminants present. Solidification/stabilization is a well-established method for treating metal containing hazardous wastes and a recommended technology for the treatment of APC residues. In the present study, APC residues from an energy-from-waste (EfW) plant burning municipal solid waste were solidified/stabilised using Portland cement (CEM I) and ground granulated blast furnace slag (ggbs). Mixes were prepared with binder additions ranging from 10 to 50 weight (wt) % of total dry mass and water/solids ratios between 0.35 and 0.80. The heavy metal leaching characteristics of the solidified/stabilised products as well as the dominant leaching mechanisms were determined according to the monolithic leaching test NEN 7375:2004. Zn leaching from 50 wt% binder samples was below the monolithic Waste Acceptance Criteria (monWAC) for stable non-reactive hazardous waste landfills. Pb leached from 10 and 20 wt % CEM I samples was greater than the monWAC for hazardous waste landfills. Pb release was diffusion controlled while for the release of Zn surface dissolution and wash-off was also observed during the test. Ca leaching was not fully diffusion-controlled but surface wash-off and potentially depletion of soluble Ca sources present may have also

occurred. Leaching of soluble salts and decalcification can alter the physical properties of the matrix and should be taken into account when estimating long-term emissions. It is recommended that APC residues are pre-treated prior to solidification/stabilisation.

Decrease of CU leaching from MSWI bottom ash (sand fraction) by heating and repeated washing, in view of recycling. Relation to doc fractionation in the leachate

C. Vandecasteele, S. Arickx, T. Van Gerven, A. Van Brecht[a], G. Wauters[a]
Department of chemical engineering, K.U.Leuven, de Croylaan 46, B-3001 Heverlee
a. INDAVER, Dijle, Mechelen, Belgium

In previous papers we described the problem of Cu leaching from the sand fraction (diameter 0.1-2 mm) obtained after wet treatment of MSWI bottom ash in view of recycling, mainly in building materials and for road construction. Over a period of about 6 years, we studied several methods for reducing Cu leaching: heating; extraction with ammoniumcitrate solution; particle size-based separation; accelerated carbonation; washing with water.
The present paper focuses on heating and washing with water, which appear of most practical and scientific interest.
It was already described earlier by several authors that dissolved organic carbon (DOC) from the ash plays a decisive role in Cu leaching. In this study the leachates obtained by leaching of the treated material were subjected to IHSS fractionation to identify and quantify humic acid (HA), fulvic acid (FA), and hydrophilic organic carbon (Hy), and the results were related to Cu leaching.
Heating to 400°C decreases Cu leaching to below the 0.5 mg/kg Flemish leaching limit value. Total DOC in the leachate decreases simultaneously, but Hy decreases more than FA and HA.
Repeated washing with distilled water also results in decreased Cu leaching. After 3-4 repeats, Cu leaching is below the limit. DOC in the leachate shows a comparable decrease as the Cu concentration.
All these observations are in agreement with our earlier finding (4) that high Cu leaching is mainly caused by complexation with the Hy (main contribution) and FA fractions of the DOC.
Several experimental parameters were optimised and indicate that the methods are suitable for large-scale application.

Evaluation of the distribution of Cr and Mo species in leachates from recycled concretes applied in road construction

Mesay Mulugeta[1], Christian J. Engelsen[2], Grethe Wibetoe[1], Walter Lund[1]
[1] *Department of Chemistry, University of Oslo, Norway;* [2] *SINTEF Building and Infrastructure, Norway*

A charge-based fractionation analysis has been performed for Cr and Mo species in leachates of recycled concrete materials applied in road construction. Leachate samples were collected from a part of the road not covered by asphalt. The leachates were passed through strong anion and cation exchangers to extract the negatively and positively charged species of the elements, respectively. The concentration of the charged species was determined as the difference in element concentration between the original leachate and the sorbent effluent. The elements were determined by inductively coupled plasma optical emission spectrometry. It was found that both Cr and Mo predominantly exist in anionic forms in all the leachates analyzed. The distribution of the species in the field leachates was similar to that observed in leachates prepared in a laboratory.

Accelerated carbonation and washing of MSWI bottom ash: pilot experiments and full scale applications

Jaap Steketee, *Tauw bv, PO box 133, 7400 AC Deventer, the Netherlands*
Michiel Timmerije & Jan van Aalten, *AVR Afvalverwerking bv, PO box 147, 6920 AC Duiven, the Netherlands*

Carbonation is a promising technology for treatment of alkaline materials. It combines capture of CO_2 with improvement of the leaching behaviour, for most elements. Furthermore, the process is relatively simple and cheap, if the treatment is carried out at atmospheric conditions. In that case, rather simple equipment is sufficient.

Tauw developed a process in which MSWI bottom ash is treated batch wise with a gas mixture enriched with CO_2. The primary goal of the process was to meet the requirements of the Dutch Soil Quality Decree. This decree sets limits to the leaching of raw materials which are used in contact with soil, aiming prevention of soil and groundwater pollution.
Although carbonation is the technology which is applied, other reactions occur simultaneously, e.g. degradation of organic matter and neoformation of iron oxides and aluminium silicates. Therefore, the process as a whole is specified as accelerated aging.
Carbonation results in a drastic quality improvement of MSWI bottom ash. The pH decreases from about 11.5 till 8.5, the leaching of copper, lead and dissolved organic matter (measured as DOC or COD) decreases with about 90% and elements like chromium, nickel and molybdenum with 50-60%. However, the leaching of chloride remains unaffected, the leaching of sulphate increases and antimony shows a temporary increase. Therefore, for a thorough quality improvement, carbonation alone is not sufficient but needs to be combined with the removal of soluble salts and better fixation of antimony.
Accelerated aging and combinations with washing were investigated on laboratory and pilot scale, carbonation also on a practical scale. AVR and Heros build the first practical scale carbonation plant with a capacity of 100,000 tons per year in Sluiskil, the Netherlands in 2003. Practical scale experiments were carried out in different reactors, e.g. in a former coal silo with a maximum bed height of 11 m and 1,500 till 3,000 tons of bottom ash in it. The CO_2 concentration in the gas mixture was controlled at a concentration level of 4 % (v/v). The flow varied between 1-2 Nm^3/ton bottom ash per hour. At these conditions the carbonation was completed in 4-5 days.
The Dutch incinerator Twence in Hengelo, adjusted existing composting tunnels to treat its bottom ash. Twence as well as AVR/Heros performed many experiments and measurements, and the process proved to be a robust technology for quality improvement of bottom ash.
A combination of carbonation and washing was investigated on a pilot scale of 50 tons by AVR, A&G Milieutechniek and Tauw. Sufficient lowering of the leaching of sulphate proved to be difficult, because of the low solubility or slow release of the sulphate. Therefore, a relatively high amount of water is needed to fulfil the criteria for freely applicable building materials in the Netherlands.

Potential for acid leachate formation from air-cooled blast-furnace slag used in road construction

Sofia Lidelöw[a], Mathilde Grandjean[b]
[a] *Luleå University of Technology, Division of Waste Science & Technology, Sweden;* [b] *Luleå University of Technology, Division of Geosciences, Sweden*

Air-cooled blast-furnace slag (ACBFS) has suitable physical properties for use as an unbound aggregate in road bases. Results of laboratory leaching tests have also indicated that ACBFS can be used without posing any risk of negative environmental impacts. However, monitoring of drainages from a full-scale road test section with ACBFS has indicated that acid leachates (pH<6) with associated increased releases of constituents can occur under field conditions. In this paper, the potential and responsible mechanisms for acid leachate formation from ACBFS used in road construction are discussed. Analysis of a 10-year time series of drainage samples and 12 year old ACBFS from the road section indicates that acidity might develop from the oxidation of reduced sulphides released from the ACBFS. Currently, the impact of intermittent wetting and drying

conditions on the weathering of minerals and leaching over time from ACBFS is investigated under controlled laboratory conditions to verify the field observations. A combination of chemical and mineralogical analyses is used to analyse the results.

Long term leaching of chloride salts from cement kiln dust bricks

[a]BESHARA A., [a]CHEESEMAN C.R.
[a]Centre for Environmental Control and Waste Management, Department of Civil and Environmental Engineering, Skempton Building, Imperial College, London, UK

Cement kiln dust (CKD) is a by-product from the manufacture of Portland cement, with worldwide generation estimated to be ~30 million tonnes/year. Complete recycling of CKD in the cement manufacturing process is not possible due to the high alkali content consisting of mainly chloride and sulphate salts. The non-recycled CKD, although not hazardous, must be properly managed to avoid pollution to groundwater. In the UK 200,000 tonnes of CKD are landfilled each year. The increase in landfill tax and the need to use wastes as resources are drivers to reuse CKD as a binder in waste and soil stabilisation/solidification and as a partial substitute for cement in construction products. Reusing CKD requires a leaching assessment to protect groundwater from pollution during the life-cycle of the product. This paper reports on the long-term leaching of chlorides from compacted CKD and CKD/sand bricks. Leaching from bricks was assessed using laboratory-scale tests which were then integrated with numerical models to accurately predict long-term release during potential field or management scenarios.
CKD was obtained with a total chloride content available for leaching of 60,300 mg/Kg (6.03 weight %). Samples were prepared by mixing CKD with water followed by compaction in 5cm cubic moulds using uniaxial pressures ranging from zero to 7MPa. Replacement of CKD with up to 80% sand of total dry weight was also investigated. Solid samples cured for 28 days were subjected to the monolithic tank leaching test (NEN 7375:2004). A modified tank test where leaching is interrupted and samples are dried at specific intervals was also performed. The intermittent tank leaching test allows for the effect of wetting/drying and carbonation to be taken into account when estimating the rate and potential of leaching from monolithic materials, and more accurately represents real leaching conditions.
The results show that the lowest cumulative leaching recorded after 64 days was for samples compacted at 0 MPa. Replacing CKD with up to 60% sand reduced the 64 days cumulative leaching of chlorides by around 50% compared to the cumulative leaching of 100% CKD, with less than 10% decrease in the 28 day unconfined compressive strength. The main mechanisms involved in the leaching of chloride were surface wash off (up to 2.25 days) followed by diffusion controlled leaching. The effective diffusion coefficients calculated from the continuous and intermittent tank test were used with a Fickian diffusion model to estimate the leaching of chlorides from CKD and CKD-sand bricks over a period of fifty years when used as a structural component of an external wall subjected to rainfall. The leaching at the end of life stage of the bricks was also assessed by considering a scenario where the demolished bricks are used as a roadbed fill.

Effects of humic acids on the retention of heavy metals in cementbased stabilized soil

a)Apichat Imyima, b)Aniwat Pussakob and a)Vithaya Ruangpornvisutia
a)Department of Chemistry, Faculty of Science, Chulalongkorn University, Pathumwan, Bangkok, Thailand
b)Naval Science Department, Royal Thai Navy, Budhamonthol 3 Rd., Taweewathana, Bangkok, Thailand

The properties of extracted humic acids from heavy metals (Cd, Cu, Cr, Pb, Ni, and Zn) contaminated soil had been studied to understand of their influence on metal sorption onto soil. The results demonstrated that humic acids decreased metal sorption onto soils. The retention of six metals in cement based -stabilized soil containing humic acids had been studied. The compressive strength of

concrete mortar decreased when the amount of metals and humic acids in soil increased. The TCLP test was performed on the stabilized soils, the results elucidated that humic acids in soils decreased significantly the leached amounts of cadmium and nickel. The leaching behaviors under the factors affecting metal releasing were investigated. These factors were pH, type of leaching medium (deionized water, potassium nitrate, acetic and humic acid solutions), liquid to solid ratio and contact time of leaching. The metals could be highly released at low and high pH, while their releases were moderate at neutral pH. The amounts of released metal depend on the type of leaching media. The leaching by deionized water and potassium nitrate solutions were not different. The metals were well released when high concentration of acetic acid was used. The metal solubilizations from stabilized soil with and without humic acids were distinguished different especially in the case of nickel and lead species. The increase of contact time of leaching enhanced the cumulative amount of leached metals; however, the leaching flux reduced. The ion species in the stabilized soil could be categorized into three groups by their different leaching behaviors. (1) Ions whose leachability only depend on the concentration of mobile ions in pore water (Na, and chloride ions); (2) Ions whose leachabilities significantly depend on the concentration of both acetic acid and humic acids in leachants (Cu and Cd); (3) Ions whose solubilities were not affected by humic acids, but influenced by acetic acid in leachants (Cr, Ni, Pb, and Zn).

Keywords—Heavy metal; Humic acid; Stabilisation; Leaching; Contaminated soil

Environmental Impact Assessment of the Use of Industrial Construction Materials in Hydro-engineering on German Federal Waterways

Albrecht Mueller
German Federal Institute of Hydrology (BfG)
Germany

The aim of this paper is the assessment of the environmental impacts of different industrial slags as construction materials in waterways-engineering projects.

1 The use of slags as construction material in German waterways

Various slag materials have been used in German Federal waterways as construction material for approximately 40 years. Steel and copper slags have been preferentially applied for the fortification of riverbanks and coastal shores as well as groynes.

Nowadays, in the process of waterways reconstruction and upgrading, these materials have to be removed. First experiences are now available. The materials that have to be removed now have to be classified as "waste material" because of the concentrations of heavy metals that they contain, with the consequence that safe disposal is required. The costs of disposal range between €50 and 100 per tonne.

2 The behaviour of the slag-containing construction materials in water

In order to characterise the behaviour of the material in the environment, the water/solid reaction was investigated in dependence on pH, the water-solid ratio, and the natural water conditions. Different elution methods were tested, and the results were compared and discussed.

Of special interest is the prediction of the mobilisation of elements over a range of approximately 100 years.

A simulation of liquid/solid interactions of slag materials using different leaching methods:

- DIN 38414-4;
- DIN 1744-3,
- DIN EN 12457-1;
- DIN EN 14997;
- PR DIN EN 19528

gives information about the short- and medium-term behaviour of slag-containing construction materials…

Wednesday June 3, 2009

Topic 2: Thermal process residues in construction

Characterization of IGCC Slag for recycles use

Takao TANOSAKI[1) 2)], Akihiro KOYANAKA[1)], and Yoshifumi WATANABE[2)]
1) Taiheiyo cement corporation, 2-4-2 Osaku, Sakura 285-0802, Japan,
2) Japan coal energy centre, Mita 3-14-10, Minatoku, Tokyo 108-0073, Japan

Integrated Coal Gasfication Combined Cycle (IGCC) systems improved the power generation efficiency and has lower environmental burden, owing to the increase in power generation efficiency. The emissions of SOx, NOx, and CO_2 are reduced to the level of heavy-oil-fired power generation process. Since IGCC discharges coal ash component in the form of glassy molten slag, the ash is expected to be effectively used as component for civil engineering etc. Chemical and mineralogical investigations were carried out on several IGCC slags. The glass phase which was formed by quenching is difficult to characterize by XRD analysis. So in this study, we promote the new method by optical analysis and acid extraction tests. In our study, three phases, such as glass I, glass II, and crystal are distinguished. Glass I has low flux compositions, glass II has high flux compositions which makes the basic character of the slag. Using for civil engineering work, Pozzolanic reactions are important character with hydration materials (ex: cement & concrete), but to measure Pozzolanic reaction by mortar test is necessary to wait very long term, but our method will need several hours. It will be useful to decide the additive amount and species of flux components.
Key Words: Coal, IGCC, slag, cement, concrete, crack, aggregate, pozzolanic reaction

Influence of the cooling conditions on the nature and the size of the mineral phase in a Basic Oxygen Furnace (BOF) slag

Mathieu GAUTIER[1,2], Jacques POIRIER[1,2], Gilles FRANCESCHINI[3]
1 Université d'Orléans
2 CEMHTI CNRS UPR3079
Site Haute Température, 1D avenue de la Recherche Scientifique, 45071 Orléans Cedex 2, France
3 ArcelorMittal Maizières
Research and Development, BP 30320, 57283 Maizières-lès-Metz Cedex, France

Europe has today a double challenge. First the pressure on natural resources must be reduced. Second, the emissions of greenhouse gases have to remain in the objectives set by the Kyoto protocol (down 8% over 4 years).
The slags are produced by the industrial processes of iron and steel. About 2/3 of the slag are reused after different cycles prior preparation. Blast furnace slag for example, after granulation and grinding, are for the most part reused in the cement manufacture and contribute to saving CO_2 emissions (representing 2 million of tons in France).
But depending on the type of slags, wide disparities in the recycled quantities exist. While the blast furnace slag has a recycling rate close to 100%, this rate is lower for BOF (basic oxygen furnace) slag. The quantities are extremely important because about 100 kg of BOF slags are produced per ton of steel. In France, this represents 1.2 million tons of slag produced each year.
The current valorization markets are primarily in aggregates for roads, embankments or harbour works. However, for road applications, the swelling problem due to hydration and carbonation of the free lime and free magnesia contained in the slag is highly problematic. The third of slag production is not recycled in France, representing 330 000 tonnes per year which are stored on site, or landfilled.
To a lesser extent the BOF slag are used in very small quantities for fertilizer and agricultural amendments or in the cement manufacture. Murphy *et al*. (1997) and Tsakiridis *et al*. (2008) notably characterised clinkers prepared with the using of a small fraction of BOF slag. To maximize the

current recycling (especially limit the quantities of free lime and free magnesia) and consider other valorizations, it is important to investigate BOF slag and in particular studying the influence of treatments performed on liquid slag and its cooling.
The aim of this study was to investigate the effect of different cooling conditions on the properties the BOF slags. The work particularly focused on studying the thermochemical processing, the phase combinations and microstructural changes that occur in the slag since the end of the conversion process (around 1600°C) until the cooling at room temperature…

Accelerated carbonation of converter steel slag for environmental quality improvement in construction applications

A. van Zomeren[1], S.R. van der Laan[2], J.B.A. Kobesen[3], W.J.J. Huijgen[1], R.N.J. Comans[1,4]
[1] ECN, Dept. of Environmental Risk Assessment, The Netherlands
[2] Corus RD&T, Ceramics Research Centre, The Netherlands
[3] Corus Strip Products, IJmuiden, The Netherlands
[4] Wageningen University, Department of Soil Quality, The Netherlands

Modern integrated LD/converter steelplants produce about 90-100 kg of steel slag per tonne of steel and these aggregates can be used in many applications as substitute for quarry materials. Steel slag imposes a high pH (12.5) and low redox potential (Eh) and there are currently no specific environmental criteria for (re)use of (secondary) construction materials with regard to pH and Eh or the associated buffering capacities. While the materials comply with the regulations, it is possible that the high pH and/or reducing properties may lead to environmental problems in specific application scenarios. The aim of this study is to improve the environmental pH and the leaching properties of steel slag, with specific focus on the leaching of vanadium. Accelerated carbonation of steel slag at ambient pressure and water-saturated and under-saturated conditions was chosen as a potentially interesting technology for improvement of the environmental properties of steel slag. We have observed that carbonation only takes place on the surface of the slag grains. In general the reaction proceeds fastest at higher temperature (50-90°C) in the presence of water. The free lime containing slag (K3-slag) is more prone to carbonation (about 15 g CO_2/kg) than the slag with lower free lime content (K1-slag) (about 6 g CO_2/kg). The pH reduction after carbonation was observed to lead to an increased V-leaching. Particularly the K1 slag showed a decreased pH and an increased V-leaching (10-100 mg/kgDS) while the K3 slag remained within acceptable limits (<1 mg/kgDS) at the relatively high pH. As a result, the carbonated K1 slag was found to exceed the limit values of the Dutch Soil Quality Decree. The leaching of vanadium from the K3 slag remained below these limit values, although it was found to increase substantially after carbonation. Current research focuses on improving the V-binding to the steel slag matrix during carbonation.

Accelerated carbonation to improve quality of recycling materials: a study of the real-time kinetics

Mieke Quaghebeur, Peter Nielsen, Ben Laenen
1VITO - Flemish Institute for Technological Research. Separation and Convertion Technology (SCT), Waste and Secondary Raw Materials Group, Boeretang 200, 2400 Mol, Belgium

The reaction of CO2 with alkaline earth hydroxide system has been used for more than thousands of years to form carbonate cements and mortars. Accelerated carbonation of minerals has regained interest in the context of CCS. Within this context the reaction is studied with the aim to capture CO2 and hence reduce the level of greenhouse gasses in the atmosphere. CO2 generally is considered “a waste” which has to be safely disposed of. The perception between waste and product can however change quickly. CO2 can be used beneficially for carbonation of mineral wastes to improve the technical and environmental quality of waste materials. Process patents have even been issued for making high value products from CO2 and waste.
The carbonation reaction is often described as a multi-step process involving diffusion of

CO2 into the solid, hydration of CO2 to HCO3
-, dissolution of calcium containing phases
and precipitation of solid phases. Many process and material characteristics can hence influence the overall carbonation reaction. Understanding the rate limiting factors with regard to carbonation of a specific type of waste material is essential to develop industrial applications.
Different methods have been used to study the carbonation kinetics. In many studies, the CO2-uptake is determined by analyzing the CO2-content of the carbonated material at the end of the experiment. Continuous quantitative examination of the CO2-kinetics is done by measuring the decrease in CO2-pressure, decrease in CO2-concentration or increase in weight during the reaction. In most of these set-ups, however, it is difficult to control all process parameters (pressure, temperature, CO2-concentration,…) during the carbonation reaction making it difficult to develop a proper understanding.
The present investigation was undertaken to study the kinetics of the carbonation reaction with the aim to optimize the CO2-uptake as well as the environmental and technical properties of different types of waste materials. In the first step of the project a fully automated carbonation unit was instrumented in which process parameters such as pressure (0-150 bar), temperature (5-250°C) and steering rate can be controlled, monitored and changed instantaneously during the carbonation reaction. The consumption of CO2 during the reaction was monitored by measuring the flow of CO2 that was supplied to the carbonation unit. Coreolus meters, set-up in parallel, enable accurate measuring of a pressurized CO2-flow over a large range (< 0.02 g/min up to 300 g/min) for both liquid and gaseous CO2.
Experiments revealed that the ideal gas law (PV= nRT) is not accurate to calculate CO2-uptake based on observed changes in temperature and pressure. This can be explained by the fact that CO2 is not an ideal gas. The van der Waals' equation of state could in this study, successfully be used to calculate the CO2-uptake based on the observed changes in pressure, temperature and consumption of CO2 during the carbonation reaction.
Results will be presented of the effect of pressure, temperature and CO2-concentration on the real-time kinetics of the carbonation reaction of steel slags.

An Ecoefficient Method for the Valorisation of Municipal Solid Waste Incineration Fly Ash: Effect of cation alkaline

A. Guerrero[a] and M.P. Lorenzo[b], S. Goñi[a]
a. Instituto de Ciencias de la Construcción "Eduardo Torroja" (CSIC). Unidad Asociada NANOC C/ Serrano Galvache, 4, 28033 Madrid, España.
b. Facultad de Farmacia. Universidad de San Pablo (CEU). Campus de Montepríncipe. Urbanización Montepríncipe. 28668 Boadilla del Monte, Madrid, España.

The generation of bottom and fly ash from municipal solid waste incineration (MSWI) play an important role on the social and environmental problem. The great amount of these wastes must be disposed of in landfills. This paper describes a new ecoefficient methodology that allows the valorisation of fly ash from MSWI. The methodology includes a hydrothermal route that minimizes the gas emission to the atmosphere, and allows the used of different dissolutions: water, alkalis, etc together pressure and temperature in order to optimizing the valorisation of this waste in alternative materials. This methodology leads to conversion of fly ash in aluminosilicate phase, with potential value in waste treatment applications, and their use in stabilizing a variety of both toxic and radioactive wastes, opening new opportunities for stabilization and applications of this type of waste, such as new cement-based materials. This paper described the effect of two alkaline ions: sodium and potassium, and their concentration. Besides, the method, used a short range of temperature (ambient to 200ºC), the time is also an useful parameters. The fly ash was characterized by X ray diffraction (XRD), FT infrared (FTIR) spectroscopy and surface area (BET-N_2) analyses. As a result of the cation alkaline and their concentration, phases as: $Ca_3AlFe(SiO_4)(OH)_8$, of the structural family of hydrogarnets, begin to appear (the surface area of the fly ash increases); $(Ca_3Fe_2(SiO_4)_{3-x}(OH)_{4-x})$, of

the structural family of garnet, is formed and the amount of $Na_6[AlSiO_4]_6$. $4H_2O$ is formed together with aluminum tobermorite ($Ca_5Si_5Al(OH)O_{17}.5H_2O$); $Ca_3AlFe(SiO_4)(OH)_8$ decreased.

Development of geopolymers from plasma treated air pollution control residues from energy from waste plants

Ioanna Kourti[a], D.Amutha Rani [a,b], D.Deegan[c], A.R. Boccaccini[b], C.R. Cheeseman[a]
[a]*Department of Civil and Environmental Engineering, Imperial College London, UK*
[b]*Department of Materials, Imperial College London, UK*
[c]*Tetronics Ltd., South Marston Business Park, Swindon, UK*

Energy from Waste (EfW) plants treating municipal solid waste control the release of atmospheric pollutants to below regulatory emissions thresholds by removing flue gas pollutants using air pollution control systems that generate Air Pollution Control (APC) residues. This waste is classified as hazardous waste primarily because of its high alkalinity (> pH 12), although it also contains volatile heavy metals, significant levels of soluble chloride and sulphate salts, and organic contaminants including dioxins and furans. Research is developing an integrated solution using DC plasma technology to treat APC residues. This reduces the volume of the waste and produces a stable and inert glass that has potential to be beneficially reused as a product, ending its regulatory classification as a waste.

The glass derived from plasma treatment of APC residues has been characterised in terms of composition and used as the main component in the formation of geopolymers. The effect of NaOH concentration and curing time on compressive strength is reported and the optimum geopolymer has been characterised using X-ray diffraction and SEM/EDX. In order to evaluate the potential for using these materials in a range of applications the density, water absorption and porosity have been assessed. Geopolymers have been formed with mechanical properties suitable for construction materials with compressive strength ~ 100 MPa, density ~ 2000 kg/m^3, water absorption ~ 7% and porosity ~12%. The research presents a novel, simple process that transforms a hazardous waste into a marketable sustainable material.

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Topic 2: Pozzolanic materials

Valorisation des roches pouzzolaniques du gisement de Beni-Saf (Algérie) par transformation en granulats pour bétons spéciaux

A. Ferhat[a], M.S Goual[a], I. Goual[a], A. Khelafi[b]
[a] *Division : développement des matériaux, Laboratoire de Génie Civil, Université de Laghouat, Algérie.*
[b] *Laboratoire de Génie Civil, Université des Sciences et Technologies d'Oran, Algérie*

Les activités volcaniques projettent dans certaines régions des quantités importantes de roches de minéralogie différentes. Parmi ces roches volcaniques, on trouve la pouzzolane. Ce terme provenant de Pozzuoli (port italien proche de Naples) désignant des cendres trachytiques ponceuses. Par extension, ce terme désigne aujourd'hui les scories volcaniques basaltiques. Cette ressource naturelle se trouve en abondance dans la région de Béni-Saf à l'ouest de l'Algérie, actuellement peu exploitée et constitue à la fois un gène environnemental et une perte de matière première. L'importance de gisement de pouzzolane dans cette région d'Algérie a conduit vers une valorisation de cette matière première susceptible de répondre aux besoins en matériaux de construction et de satisfaire les objectifs d'économie d'énergie et de la protection de l'environnement. La proposition a été faite de

transformer ces roches en granulats pour l'élaboration de bétons de granulats légers. Celle-ci permettra d'un point de vu mécanique de minimiser les charges transmises à la structure et à la fondation et de bâtir sur des sols de faible portance. D'un point de vu thermique elle permet de procurer à la construction des performances thermiques intéressantes en minimisant le coefficient de conductivité thermique.
Deux classes granulaires de pouzzolane ont été fabriquées et exploitées pour l'élaboration du béton léger objet de cette étude. Il s'agit des classes 3/8mm et 8/16mm. La matrice liante est composée d'un mélange de sable alluvionnaire 0/2mm et de ciment CPJ. En effet, deux types de ciment composés, le CPA325 et le CPJ45 ont été utilisés afin d'apprécier l'influence de la classe de ciment sur les performances mécaniques des bétons élaborés.
L'objectif de ce travail consiste en la formulation et la caractérisation physicomécaniques des bétons de granulats pouzzolaniques. Cette étude met en évidence l'influence du dosage en granulats, le type de ciment et le mode de cure sur les performances mécaniques à court terme des bétons élaborés. Les résultats obtenus montrent que la masse volumique des bétons élaborés diminue de plus de 25% par rapport à un béton ordinaire sans que la résistance mécanique à la compression descende au-delà des valeurs recommandées pour un béton léger de construction et d'isolation thermique malgré les faibles dosages en ciment utilisés. De plus, la classe de ciment influe sur les caractéristiques mécaniques et sur la masse volumique. La cure dans l'eau permet d'augmenter la résistance à la compression à 28jours de plus de 40% par rapport à la cure dans l'air. Toutefois, l'augmentation du dosage en ciment et en granulat permet d'augmenter la résistance à la compression tout en diminuant la masse volumique du béton de granulat de pouzzolane.

The glass waste as fine aggregate and pozzolana addition in concrete

Maria GHEORGHE, Nastasia SACA, Lidia RADU
Technical University of Civil Engineering of Bucharest, Chemistry and Building Materials Department, Romania

The paper presents experimental data referring to the influence of glass waste (E type) as aggregate substitute on the concrete properties. An industrial E glass waste was ground up to a content of 64 % particles smaller than 0.5 mm.

The diminution/elimination of the aggregate alkali reaction (ASR), potential expansion in the glass waste containing concrete is based on the knowledge and control of the influence factors concerning the particle dimensions, the composition and quantity of the waste glass particles. As consequently it was studied the ASR expansion evolution due to of the reference mortar and of those with E glass or with packing glass waste, particles under 0,5mm, up to 12 month, using the mortar bars method. The mortar bar expansion was of 0.24 mm/m, for E waste addition, 0.56 mm/m for packing glass addition and 0.42 mm/m for the control bars. The alkali content ($Na_2O + K_2O$) of E glass was 0.6% and 14.5% of packing glass, was a favorable premise of alkali–silica reaction decreasing.

The compressive strength of samples with 33% E glass was 21, 26 and 30 % higher than that of the control sample at the age of 28, 90 and 360 days. The bending strengths also were higher than those of the control sample with 3, 8 and 10% at the same ages. The concrete shrinkage was 1.54 mm/m at 360 days age. The mechanical strength increase can be justified by the pozzolanic character of the fine glass particles.

The concrete workability decreases at the increase of the amount of glass due to fibrous shape and to the great quantity of fine particles, therefore the use of high-range water reducers admixture was necessary.

Based on the obtained results one may affirms that 0.5mm particle size fine aggregate substituting by E glass is beneficial to concrete compressive and bending strengths.

Use of waste glass in cement-based materials

Rachida IDIR[1,2], Martin CYR[1], Arezki TAGNIT-HAMOU[2]
[1] *Laboratoire Matériaux et Durabilité des Constructions (LMDC); Université de Toulouse; INSA-UPS, Génie civil*
[2] *Département de génie civil, Université de Sherbrooke, Sherbrooke (Québec), Canada*

Demand for recycled glass has considerably decreased in recent years, particularly for mixed-glass. Glass is cheaper to store than to recycle, as conditioners require expenses for the recycling process. There are several alternatives for the reuse of composite-glass. According to previous studies, all these applications, which require pre-conditioning and crushing, are more or less limited and unable to absorb all the quantities of waste glass available. In order to provide a sustainable solution to glass storage, a potential and incentive way would be to reuse this type of glass in concretes.
Depending on the size of the glass particles used in concrete, two antagonistic behaviours can be observed: alkali-silica reaction, which involves negative effects, and pozzolanic reaction, improving the properties of concrete.
The work undertaken here dealt with the use of fine particles of glass and glass aggregates in mortars, either separately or combined. Two parameters based on standardised tests were studied: pozzolanic assessment by mechanical tests on mortar samples and alkali-reactive aggregate characteristics and fines inhibitor evaluations by monitoring of dimensional changes. It is shown that there is no need to use glass in the form of fines since no swelling due to alkali-silica reaction is recorded when the diameter of the glass grains is less than 1mm. Besides, fine glass powders having specific surface areas ranging from 180 to 540m² / kg reduce the expansions of mortars subjected to alkali-silica reaction (especially when glass aggregates of diameters larger than 1 mm are used).
Keywords: Waste-glass, recycling, glass aggregate, glass powder, alkali-silica reaction, pozzolanic reaction, mortar.

Design and performance of masonry mortars manufactured with recycled concrete aggregates

I. Vegas1, I. Azkarate2, M.Errasti1**,** A.Lisbona1
1 LABEIN-Tecnalia, Derio, España
2 MORTEROS Y REVOCOS BIKAIN, S.A., Mañaria-Bizkaia, España

The present paper presents and discusses the technical feasibility in the utilisation of the fine fraction of recycled concrete aggregates in the manufacture of masonry mortars containing cement as binder.
Chemical and physical-mechanical characterisations of the fine recycled concrete aggregates were studied. Results show limitations in the use of this aggregate in manufacture of masonry mortars because its high absorption capacity and high sulphate content in comparison with natural sand. Similarly to the recommendations for structural concrete, this study focuses on the utilisation of mixtures of natural and recycled concrete aggregates in the manufacture of masonry mortars.
After characterisation, a dosage study and testing of mortars elaborated with recycled concrete aggregates were carried out. According to tests results, it can be established that cement-based masonry mortars can incorporate up to 25% of recycled concrete aggregate without significant losses on its performance. The design of cement-based mortar with 25% recycled sand replacing natural sand needs neither new additives nor additional cement.
Keywords: recycled concrete aggregate, masonry mortars, mechanical performance

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Topic 2: Binders

Synthesis of binders using waste materials

Martin Cyr[1], Pierre Clastres[1], Marie Coutand[1], Jean-Marc Balandier[2], Yann Rousseau[1], Pierre Silvestre[3]
[1] *Université de Toulouse; UPS, INSA; LMDC (Laboratoire Matériaux et Durabilité des Constructions), France*
[2] *A.R.F, 22 rue Jean Messager, BP 40137, 59330 Saint-Rémy-Du-Nord, France*
[3] *Consultant Environnement Tiers Expert, 48 avenue des frères Lumière,F-69008 Lyon, France*

Industries produce large quantities of wastes that contain high fractions of silica and lime: sewage sludge, paper sludge, lime sludge, foundry sands, etc. Most of these wastes are currently disposed of in landfills, spread for agricultural purposes or incinerated. Two principal reasons lead to the proposition of environment-friendly alternatives to these present uses: the European directive 1999/CE of 26 April 1999 to limit the harmful effects of landfill disposal of waste, and the progressive decrease of spreading due to regulations.
The project presented here aims to recycle wastes containing large quantities of mineral resources in order to synthesise hydraulic binders at temperatures not exceeding 1000°C. The ultimate goal is to manufacture hydraulic binders from 100% recycled waste, to be used mainly in road-building (backfill, sub-grade, etc.). The energy required for curing is obtained from substitute fuels produced from recycled waste.
The project is divided into 4 phases:

- Construction of a database of waste resources;
- Selection in the laboratory of combinations of wastes for the synthesis of binders;
- Industrial scale tests carried out in a rotary furnace;
- Validation of the results in an industrial application (road test).

This paper reports the results obtained so far.

Sound Recycling System for Fly Ash from Municipal Solid Waste Incinerator to Be Raw Material in Cement Industry

—The Study of Calcinating Process of Washed Fly Ash—

Fenfen ZHU, Masaki TAKAOKA[1], Kenji SHIOTA[1], Kazuyuki Oshita[1], Yoshinori KITAJIMA[2], Shinsuke MORISAWA[1]
1. Department of Urban & Environment Engineering, Kyoto University, Kyoto, Japan
2. High energy Accelerator Research Organization (KEK), Ibaraki, Japan

We proposed a new sound recycling system for fly ash, WCCB system —— Washing, Calcinating and Changing the treated fly ash into the raw material in cement industry. However, high concentration of chlorine in fly ash is a big problem for reutilizing fly ash as raw material in cement industry. So not only to decrease residue amount but also to reduce chlorine amount are important purposes in our research. In this system, we tried three kinds of fly ashes: raw fly ash from the boiler or cooling tower (RFA), fly ash collected by bag filter with the injection of calcium hydroxide for acid gas removal (CaFA), and fly ash collected by bag filter with the injection of sodium bicarbonate for acid gas removal (NaFA). Based on the washing experiments results, we have chosen a relatively acceptable washing condition (the 1st step: Liquid (ml) / solid (g) ratio = 3, Mixing time = 5 min, Mixing speed = 150 rpm; the 2nd step: L/S = 3, Mixing time = 10min, Mixing speed =150 rpm) and calcinating condition (Heating temperature = 1000℃, Dwelling time = 2hr, Atmosphere = 10% O_2

(90% N_2 for balance), Flux = 50ml/min) for the first and second step of WCCB system. With those conditions, 21.3% RFA, 34.9% CaFA and 72.1% NaFA can be reduced in weight, and 98.9% chlorine in RFA, 94.0% chlorine in CaFA and 99.8% chlorine in NaFA can be removed. We also try to explain the mechanism happened in calcinating process by using X-ray diffraction (XRD) and X-ray absorption near edge structure (XANES). It was found with the rising of the heating temperature, there are more complicated compounds produced such as gehlenite, akermanite and gehlenite-akermanite, which is accordant with the variation of chlorine K-edge XANES spectra of samples.

Influence of alkaline activator type and its amount on the properties of fly ash binders

Jan Deja
Łukasz Kołodziej

AGH University of Science and Technology
Department of Building Materials Technology
Faculty of Materials Science and Ceramics

Restrictions in CO_2 emission and investigation in the field of utilization of Polish ashes from hard coal combustion in pulverized-fuel boiler, fluidized bed furnace and ash from co-combustion was the reason to make research on alkali activation of this ashes.
The main goal of this investigation is to find an optimal activator amount resulting in best pastes properties, such as: setting time, normal consistency, proper amount of water which give best 28 days mechanical properties. Three types of binders containing 100% ash from different power plant installations were activated by three different type of activator containing NaOH solution, sodium or/and potassium silicate (water glass).
The significant differences in the mechanical strength, setting time and microstructure depending on the type and amount of activator were observed. To obtain information about mechanical properties, phase composition and microstructure of hardened pastes, mechanical tests, XRD analysis, SEM observation and EDS microanalysis were used.

Keywords: alkaline activation, fly ash, microstructure, paste

Investigation on composition effect of using tire-rubber powder and silica fume to reduce amount of cement

P.Hosseini[1], A.Boushehrian[1], S.Vahidi[1], S.Farshchi Tabrizi[1]
1- Department of Civil Engineering, Sharif University of Technology, Tehran, Iran.

One of the most crucial environmental issues all around the world is the disposal of the waste materials. Accumulations of discarded waste tires have been a major concern because the waste rubber is not easily biodegradable even after a long-period landfill treatment. On the other hand, deficient amount of cement in the world is a serious big problem that concrete industries are faced. So replacement of cement with tire-rubber powder in concrete matrix, first helps us with reducing environmental concerns about tire-rubber waste and second, it decreases the amount of cement usage in concrete. But due to weak binder properties of tire rubber powders in cement based materials matrix, we should use pozzolanic materials with high pozzolanic activity incorporating tire-rubber powders.
According to high pozzolanic activity of silica fume in cement based materials matrix, this pozzolanic material should be used to neutralize weak binder properties of tire-rubber powders. In this study, composition effect of using tire-rubber powder and silica fume to reduce amount of cement is investigated. To achieve this purpose, specimens with constant water to binder ratio (which equal to 0.35) and amount of binders (cement, silicafume and tire-rubber) were made and tested. Compressive strength and flexural strength tests are done. Results show the same strength of basic mixture (without

silica fume and tire-rubber powder) with specimens made by replacing cement with tire-rubber powder and addition of silica fume into cement mortars matrix.

Key words: reducing amount of cement, tire-rubber powder, silica fume, compressive strength, flexural strength.

The use of alternative materials in cement-based solidification/stabilization of electric arc furnace dust (EAFD)

Beste CUBUKCUOGLU*, Sabèha K. OUKI*
Centre for Environmental Health Engineering, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, GU2 4LE, United Kingdom

Electric Arc Furnace Dust (EAFD) is an industrial waste obtained as a by-product of the stainless steel manufacturing industry. It contains heavy metals, mainly lead (Pb), zinc (Zn), cadmium (Cd), chromium (Cr) and nickel (Ni) and hence, has been listed as a hazardous waste under the code of 10 02 07* in the European Waste Catalogue.
In the UK, the Waste Acceptance Criteria (WAC) has been introduced under the Landfill (England and Wales) Regulations in July 2005. The recent amendment in the UK Landfill Regulations meant that all hazardous wastes have to be pre-treated prior to landfill disposal. Therefore, according to the WAC, EAFD waste has to be pre-treated prior to disposal due to mainly the leaching potential of heavy metals it contains.

Various technologies have been used to pre-treat hazardous wastes prior to landfill disposal. Solidification/Stabilization (S/S) is one technique that has been demonstrated to have potential for the treatment and possible reuse of a wide range of hazardous wastes. It mainly aims to reduce the mobility of the waste and hence reduce the leachability of pollutants of concern. S/S products can either be disposed of in landfill after pre-treatment or might be reused in the construction industry depending on the structure and chemical characteristics of the final products.
Consequently, the aim of this study is two-folds; (1) to evaluate and determine the optimum process conditions for a final product that not only complies with the WAC but has also potential for reuse; (2) evaluate the potential of using cost-effective alternative materials for cement replacement…

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Topic 3: Sediments

In-situ stabilisation of contaminated sediments in Finland Case Aurajoki

Lahtinen, Pentti O., D.Sc. (Tech.), Ramboll Finland Oy, FIN-36760 Luopioinen
Niutanen, Ville, PhD, Biomaa Oy, FIN-01900 Nurmijärvi

Contaminated sediments have become a remarkable problem in harbours everywhere in the world. Stabilisation is one of the best technologies to solve this problem. Mass stabilisation technology has been already used in few harbours and the experiences have been very good. Process stabilisation technology is an environmentally safe and an economical way to stabilise the contaminated sediments. This is a relatively new technology which has been tested for the first time in the full scale pilot of EU LIFESTABLE in Turku harbour in 2008. Contaminated sediments can be stabilised with process stabilisation. The stabilised masses can be utilised in different types of soil

construction applications, for example for harbour fillings. Different types of binder admixtures can be fed into the mixer unit of the process stabilisation system. The determination of the binder recipe is a very critical factor for a successful stabilisation process. The environmentally, technically and economically best binder admixture has to be specified individually for each application and prevailing circumstances. Significant cost savings as well as other benefits can be obtained when using industrial by-products as components of the binder recipes.

The GeDSeT project: constitution of a decision support tool (DST) for the management and material recovery of waterways sediments in Belgium and Northern France.

Bruno Lemière [a], Pascale Michel [a], Nor-Edine Abriak [b], Laurence Haouche [c], Agnès Laboudigue [b], Claire Alary [b], Rabia Badreddine [e], Benoît Hazebrouck [e], Jérôme Meerseman [d].

[a]: BRGM, Service Environnement et Procédés, Orléans, France
[b]: Ecole des Mines de Douai, Douai, France
[c]: Institut scientifique de service public, Colfontaine, Belgique
[d]: Centre technologique international de la Terre et de la Pierre (CTP), Tournai, Belgique
[e]: INERIS, Comportement des Contaminants dans les Sols et Matériaux, DRC Pôle Risques, Verneuil en Halatte, France

The European InterReg IV GeDSeT project (2008-2011) is a contribution to a sustainable management of waterways sediments, in order to develop good practice in a perspective of water resource protection and of the development of regional fluvial transport.

Waterways sediments are a major environmental issue in the Walloon region of Belgium - Northern France trans-boundary region for several reasons, all of them resulting from the dense habitat, industrial pattern and waterways network, and of a long industrial history. Sediments affect water resources quality, through pollution, and availability, through flooding. Sediment dredging allows the development of environmentally-friendly regional fluvial transport, but also generates important waste deposits. Therefore material recovery for reuse in buildings or infrastructure is a key issue, as it allows a reduction of waste and limits the need for natural resources for the same use.

In order to address waterways sediments management in a global way, the GeDSeT project intends to capitalise know-how regarding the criteria to take into account for a sustainable management, and to include them in a decision support methodology applicable to the transboundary context. Such decision support aims at developing good practice in a perspective of water resource management and development of regional fluvial transport. Relevant criteria include:
- criteria evaluating the physical and chemical characteristics of the sediments to be dredged, and their level of contamination,
- costs of dredging operations and benefits with respect to improved waterways,
- potential material value and costs of sediment treatment for material recovery versus costs of sediment deposit management.

The decision support methodology will rely in part on previous BRGM and European experience in the development of an environmentally extended, physical, quasi-dynamic input-output model for waste management. Experience from other specific DSTs on sediments will be valorised with the project partners.

Potential recovery of secondary resources from dredged sediment will be addressed through a review and economic evaluation of available technologies, technical and economical constraints, side effects on the uses of recovered products, and a global balance of the environmental costs and benefits. Social

and employment impacts, as well as land use issues in this densely populated area will be fully acknowledged as primary decision-support criteria. The expected benefit of the project comprises also the transboundary comparison of specific situations and methods, issued from a different history.

Assessment of the potential mobilization of inorganic contaminants in a french harbor sediment

Vincent Chatain[1], Cécile Delolme[2], Daniel Borschneck[3], Nicolas Giroud[1,4], Laurent Thévenin[2], Marie Loustau-Cazalet[1], Denise Blanc[1]

[1] Laboratoire de Génie Civil et d'Ingénierie Environnementale. Institut National des Sciences Appliquées de Lyon. Bât. S. Carnot, 9 rue de la Physique, 69621 Villeurbanne Cédex, France.

[2] Laboratoire des Sciences de l'Environnement. Ecole Nationale des travaux Publics de l'Etat. Rue Maurice Audin, 69518 Vaulx-en-Velin, France.

[3] Centre Européen de Recherche et d'Enseignement des Géosciences de l'Environnement. Aix-Marseille Université. Europôle Méditerranéen de l'Arbois. BP 80- 13545 Aix-en-Provence Cédex 4

[4] Present address: Laboratoire de Gestion des risques et Environnement. Université de Haute Alsace. 20, rue de Chemnitz, 68200 Mulhouse, France

As part of a French national research program called "SEDiGEST" concerning the management and the environmental risk assessment of contaminated marine harbor sediments, the research presented in this paper focuses on the determination of the leachability of inorganic contaminants.

In this objective, a methodology was developed and applied to investigate the mobility of inorganic contaminants as a function of physicochemical conditions. This methodology is based on the use of leaching tests in conjunction with mineralogical and textural analysis. Muddy sediment with important Organic Matter (OM) content (*ca*. 12 wt %) has been selected and collected from a French harbor. This sediment contained also *ca*. 109 000 $mg.kg^{-1}$ calcium (Ca), *ca*. 32 170 $mg.kg^{-1}$ iron (Fe), *ca*. 19 660 $mg.kg^{-1}$ sulfur (S), *ca*. 2 120 $mg.kg^{-1}$ zinc (Zn), *ca*. 1 730 $mg.kg^{-1}$ copper (Cu), *ca*. 860 $mg.kg^{-1}$ lead (Pb) and *ca*. 150 $mg.kg^{-1}$ arsenic (As). In addition, this sediment had a natural pH and ORP (Oxidation Reduction Potential) of *ca*. 8.2 and *ca*. + 350 mV vs. Normal Hydrogen Electrode (NHE).

Main results shown in this study indicate that the release of target contaminants (As, Cu, Pb and Zn) during a contact with deionized water is very limited (*ca.* <-0.1 wt %) by the very low solubility of solids, like sulfides or carbonated phases, and by the stability of their bearing solid phases (*i.e.*, OM and/or sulfides) at natural slightly basic conditions. However, the natural pH of this matrix can vary with the loose of the buffering capacity and an increased mobilization is observed over the long term under specific leaching conditions (*i.e.*, pH < 6 or > 10, or chelation effect, etc.) which can arise in a given scenario for the management of marine sediments.

Valorization of contaminated marine sediments in clay bricks: influence of processing techniques on technological and environmental properties

R. Alonso-Santurde, N. Quijorna, A. Coz, J. Viguri, A. Andrés

Department of Chemical Engineering and Inorganic Chemistry, ETSIIT, University of Cantabria, Avda Los Castros, s/n. 39005, Santander, Spain.

Coastal sediments can contain significant concentrations of heavy metals and organic pollutants, and are considered a waste according the European Directive. Using wastes in brick manufacturing is a very useful practice in industry. It has been demostrated that marine sediments can be used as a substitute of clay in ceramic processes. Previous works developed have concluded that it is possible to obtain dense sintered compacts from sediments dredged from Cantabrian estuaries. The technological properties of a ceramic product are not only related to the characteristics of the raw materials but also to the different variables in the production process. But due to the fact that the porosity and microstructure of the ceramic body depends on the shaping technique is important evaluate the influence of this parameter on the environmental properties. In this work the influence of both extrusion and pressing process on technological and environmental properties of sediment-based ceramics is evaluated. If the results are analyzed the moulding by pressing generates a lower firing

shrinkage and a lower water absorption, derived from the densification process. The environmental analysis by means of leaching tests UNE-EN 12457-1 and 2 shows that the amount of As leached increases with the percentage of sediment introduced, while the amount of anions leached decreases, both in pressed and extruded pieces. If the shaping techniques are compared, the trends are similar, but the values of concentration are higher in extruded samples. If leached concentrations are compared with the regulatory limits collected in the Directive 2003/33/CE it can be concluded that the sediment-based bricks can not be accepted in a inert waste landfill due to the high concentrations of As and sulphates present in the leachates of pressed and extruded pieces, higher in the last case. If the concentration of metals leached are compared with those corresponding to a commercial brick it can be said that As concentration is higher in all specimens analyzed, both in pressed and extruded pieces, which present similar trends.

Wednesday June 3, 2009

Topic 3:Used tyres

Valorization of pneumatic waste uses and environmental protection "The pneusol material innovating – the research and structures carried out in Algeria"

F. Belabdelouahab [(1)] & N.T. Long [(2)]

(1) Doctor of the INSA-Lyon, Maïtre de Conférence to the E.N.T.P; National school of Public works, Algiers

(2) Doctor of the INSA-Lyon, Inventor and Expert in Pneusol (Pensioner of the LCPC of Paris)

The importance of protecting and conserving the environment has led the research community to think seriously about the use of used tyres in the field of civil Engineering, as a mean to absorb the huge quantities spread all over the world.
The research has found that used tyre could resolve some problems related to stability or bearing and also to protect certain structures.

The problem of used tyre is a problem related to all countries; in fact millions of tones of waste are thrown away prompting a serious threat to the ozone layer.

The principal objective of this article is to give starting from the various researches undertaken in the ENTP, of the results and the achievements of structures. Indeed, the purpose of this presentation is:

- to give statistics and the layer of the used tyres in Algeria and to if required present the dies of valorisation and the various applicability of this waste as materials to solve some problems in civil engineering.

- to also present research to ENTP, on "reducing Pneusol of push", "antiseismic Pneusol".

- to present the structures carried out by the technique pneusol in Algeria, such as the 12 structures in Ain Timouchent [in 1986], the project of Bousmail which is the first one conducted in full scale in Algeria, will have the benefit to improve slope stability for the adjacent road [in 2005], Protection against the slips [Béjaia in 2006], the greatest structure of Africa in Mostaganem, stability of slope and reinforcement of slope (RN11) [in 2007], dyke protection pneusol [Blida 2008]

This technique offers multiple advantages so much from the economic, ecological point of view and even on the behaviour of the ground. This communication also sticks to present all the use potential of a waste "the used tyres" in the field of the Civil Engineering, and at the same time to draw all the attention of the Engineers and the Researchers to the whole of the use potential of this material.

Key words:used tyres, environment, pneusol, supporting, reducing, protection of the slopes, stability, layers

The way of valuation and reuse of the worn used tires turned out and concretized in the road domain: case of the stability of a road embankment (the National Road No. 11) in Mostaganem-Algeria

Zahir Djidjeli
Director of Research Minsitry of public works
Masters in transport infrastructure

The world of the construction of the big projects of Public works, such as the renewal of their investment is continuously increasing in particular these last years. The realization of public works projects often generates inert waste; these projects conceived with studies of impact on the environment, of which the consideration as well of the initial state of the site, the solutions and the treatment of inconvenience and nuisances caused by the project, as those generated by the site during the work. The fact of pollution, noise generated by a project works is known to all!

However the rubble generated by the works of construction are often products or materials (surpluses of construction site) which nobody wants it, they constitute heaps which die in the nature while they can be valued for their reuse .
Other possibilities for use of industrial wastes were tested in the world such as plastics, used tires, significant achievements have been created in the maritime area for shoreline protection in slope stability or landslide, in the presence of swelling soils, etc.

In The present communication , it will be presented: the inventory of waste met in the Public works with as aimed objective "the zero waste in public works" it will be question particularly of the experiment led by the implementation of recovery and reuse used tires in the construction of civil engineering.
03 practical cases of stability landslide, including the first test site of Bou-Ismail (wilaya of Tipaza) with its 5000 Truck tires used will be presented, in the case of the RN11 in Mostaganem (stability of an embankment of the Route Nationale No. 11 in Mostaganem-Algeria), we finally show that the path of recovery of used tires is a reality in public works, thanks to coordination between different actors: client, offices study, researchers, business achievement, tire suppliers, responsible for the environment.
Key words:Environnement, publics works, nuisance, inert waste, landslide, used tires, zero waste.

Use of end-of-life tyres in quarry redevelopment

R. Moretto*, C. Clauzade**, M. Pognant***, G. Bonnefoy****

** EEDEMS, 66 boulevard Niels Bohr, BP 2132, 69603 Villeurbanne Cedex, France*
*** ALIAPUR SA, 71 cours Albert Thomas, 69003 Lyon, France*
**** EUROVIA, 18 Place de l'Europe, 92500 Rueil Malmaison, France*
***** ANTEA, 3 rue Etienne Dolet, 93400 Saint-Ouen, France*

From 2005 to 2007, ALIAPUR (company responsible for the collection, the disposal and the recycling of used tyres) and EUROVIA (a subsidiary of Vinci Group, making roads and public spaces) have initiated a study of environmental assessment of used tyres in quarry redevelopment. They entrusted the experimental implementation in situ to ANTEA (engineering department) for an experimentation in the quarry of the SMC [Feuguerolles (Calvados-France)] and to EEDEMS Group (technological platform) at INSA of Lyon (France) for an experimentation in a laboratory.

EUROVIA has proposed the implementation of whole used tyres by a technique derived from the "PNEUSOL ®" technique which could make possible: 1) the redevelopment of old quarries, 2) the security of the sites still exploited.

This practice is considered a recovery operation of used tyres under the Decree N°. 2002-1653, 24/12/2002.

The technique "PNEUSOL ®" is a combination of natural soil (all varieties of natural or artificial soils and various wastes) and used tyres (all used tyres that may endure considerable tractive effort). It is economical and easy to implement, combining low density, lightning and resistance.

The objectives of the study lie in the assessment of the consequences in terms of impact on the environment. They consist in: 1) quantifying environmental impact and identifying it with analysis of percolation water taking into account the nature of different materials that can be associated with used whole tyres; 2) using the results to contribute to the development of use recommendations and to participate in a process of standardization.

The study of available bibliography has made possible the identification of the parameters which influence the results: pH of the water, contact time (permeability of embankment and groundwater), surface contact (whole, crushed, aggregates tyres ...) salinity, soil acidity (silica, limestone), and immersion (groundwater). This study has also permitted the formalization of the experimental choices.

To reproduce the best conditions for the natural environment, two complementary approaches were taken.

The first was conducted in situ during thirty months (quarry of SMC Feuguerolles) with 2 cells 12 x 12 m [1 cell with Feuguerolles embankment only (control sample) and 1 cell with tyres and Feuguerolles embankment] taking into account the natural pluviometry and systematic irrigation with simulation of the effects of natural pluviometry for more than 20 years. A layer of tyres is in permanent contact with water percolation to simulate the presence of a groundwater.

The second was conducted in laboratory during twelve months with 5 lysimeters 2.5 x 2.5 m [1 lysimeter with Feuguerolles embankment only (control sample), 1 lysimeter with tyres and Feuguerolles embankment, 1 lysimeter with tyres and siliceous gravels, 1 lysimeter with PUNR and limestone gravels, 1 lysimeter with tyres and silty clay soil], with recirculating water to simulate the percolation of a height equivalent to that of a quarry. In the laboratory, the control data for materials other than Feuguerolles embankment have been determined by using percolation columns.

Repeated and comprehensive physicochemical analysis of percolates were conducted. 35 water samples, 46 parameters were analyzed: pH, conductivity, ammonia, cyanide, 13 heavy metals, fluorides, chlorides, sulphates, nitrates, 16 polycyclic aromatic hydrocarbons, total hydrocarbons, phenol index, total hydrocarbon. A systematic comparison of results obtained on the one hand in lysimeters and in cells in situ and on the other hand between materials alone (control values) and materials associated with tyres was conducted.

Essential supplements to physical and chemical analysis to take account of possible synergies between substances and understand the influence of any substances not sought, ecotoxicological tests staged were conducted on five samples of water that have been in contact with tyres (research for acute toxicity of *Daphnia Magnia*, research for chronic toxicity of *Ceriodaphnia dubia* and the unicellular green algae *Pseudokirchneriella subcapitata*).

The comparison between the experimentations conducted in situ and in laboratory showed similar results. No significant enrichment, no modification of the physico-chemical characteristics due to tyres have been identified whatever the conditions of use (comparison embankment/embankment with tyres; comparison siliceous gravels / siliceous gravels with tyres; comparison limestone gravels / limestone gravels with tyres; comparison silty clay material / silty clay material with tyres; comparison tests in situ/laboratory tests).

The results of ecotoxicological tests conducted on the percolates show no significant toxicity towards tested organisms and confirm the environmental safety of using end-of-life tyres in applications such as "PNEUSOL ® ".

These results were presented to the French Ministry of Environment and they will provide basis for the drafting of guidelines (dissemination of recommendations and standards of good practice).

Use of shredded end-of-life tyres in retention/infiltration/drainage of storm water

R. Moretto*, C. Clauzade**

**EEDEMS, 66 boulevard Niels Bohr, BP 2132, 69603 Villeurbanne Cedex, France*
***ALIAPUR SA, 71 cours Albert Thomas, 69003 Lyon, France*

The regulation of storm water refers to two main pieces of the French legislation: 1) the Civil Code, which regulates, among other things, the flow of runoff; 2) the Water Law, integrated in the Environmental Code, which introduces the concept of "global management of water" and reinforces the concept of "respect for the natural environment". Under the Water Law (December 2006) storm water status change: storm water is not a waste of which we must get rid as soon as possible but a resource that we must recover. This regulation emphasizes the need for alternative techniques to ensure better management of the storm water drainage rehabilitating local storage and infiltration as a means of management.

The basic principles of alternative techniques, i.e. retention, regulatory and infiltration, are quite justified and particularly suited to meet the regulation of storm water runoff set by the Civil Code. The use of alternative techniques provides answers to some obligations required by the declaration or the authorization procedure. Articles 31 and 35 of the Water Law lead to the conclusion that the introduction of alternative techniques by local authorities permit to meet the requirements of the Water Law in terms of public safety and environmental protection.

The alternative techniques are numerous and tally with storm water drainage structures, which can take various aspects. Their operation is based on two principles: 1) retention of rainwater and runoff, regulating the flow and spread the inputs to downstream; 2) infiltration into the soil when it is possible to reduce the volumes flowing downstream.

Therefore, there are different structures according to their function: 1) retention structures which temporarily store storm water before returning it to an outlet flow limited by a regulatory system; 2) infiltration structures whose outlet is the ground. They contain rainwater collected while they seep into the soil; 3) structures combining retention and infiltration. The evacuation of storm water is part of a restricted flow outlet through a regulatory body, and by infiltration into the soil; 4) drainage structures such as roads that function as structures above.

These structures are characterized by: 1) the void ratio, which defines the capacity of water storage; 2) the permeability, which defines the drainage capacity of waters; 3) the resistance of materials in compression.

The used materials are generally represented by granular natural materials (or prefabricated materials), but European and American studies concerning the physical and mechanical behaviour of shredded tyres show that these materials have a high hydraulic conductivity (equivalent to natural aggregates (gravels type)) even under strong loading condition. Also, in the context of sustainable development, this property makes possible to consider a substitution of natural aggregates by shredded tyres for the constitution of a drainage layers.

The general objectives of the research program are: 1) Evaluate different types of shredded tyres and identify the migration potential of substances and ecotoxicological impact in conditions of use, initially in pilot tests; 2) Position the pilot tests in relation to an instrumented site in full scale; 3) Define laboratory tests to make durable the application and offer guaranties for users and administration; 4) Propose and circulate recommendations and standards of good practice.

A geotechnical study conducted earlier has helped to characterize the porosity, the permeability and the compressibility of shredded end-of- life tyres. The results obtained give us the opportunity to consider a possible substitution of natural aggregates by shredded tyres for use in the structures mentioned above. Different types of shredded tyres [LARGE A (mostly passenger car tyres) and LARGE B (mostly truck tyres)] have been tested to determine the environmental impact assessment and to reproduce the real conditions under which shredded tyres are in contact with storm water. Pilot

experimentation has consisted of immersion of about 500 kg of every type of shredded tyres in tanks of one cubic meter with L/S ratio = 1.5. To try to reproduce the cycles of "filling-infiltration-drying" in real situations, which are dependent on weather conditions, it was decided to conduct short cycles at the beginning of the experimentation and then longer-term cycles, mainly for phase drying, to allow any distribution of substances in the periphery of shredded tyres during this drying phase. The experimental period is seven months long and seven water samples were analyzed for each type of shredded tyres from a physicochemical and ecotoxicological point of view. Analyzed substances are numerous [n = 122, including heavy metals (19), polycyclic aromatic hydrocarbons (16), total hydrocarbons, ammonia, nitrate, chloride, cyanide, sulphate, phenol compounds (17), nitrosamines (8), phtalates (6), amines (9) and anilines (36), …]. Ecotoxicological tests consist of evaluation of: 1) the acute toxicity (inhibition of the mobility of *Daphnia magna*); 2) the chronic toxicity (inhibition of growth of the freshwater algae *Pseudokirchneriella subcapitata*); 3) the impact of watering on terrestrial organisms (earthworms); 4) the inhibition of the germination of vegetable seeds, 5) the evaluation of the impact of watering on a turf.

From a physical-chemical point of view, the results obtained during the seven months of testing showed low concentrations for all elements and substances sought. Many values of concentrations are lower than analytical detection and for expressed values, the concentrations of various eluates are below the limits of the French legislation. In the current state of knowledge, the concentrations in the various eluates have no impact on water resources. From an ecotoxicological point of view, the various tests showed no toxicity of different eluates tested from the two types of shredded tyres during the seven months.

In addition to these pilot results, a full-scale validation is scheduled for 2009.

Use of shredded end-of-life tyres for drainage of leachate on the bottom of msw landfills

R. Moretto*, G. Didier**, A. Budka***, F. Lussac***, C. Clauzade****

**EEDEMS, 66 boulevard Niels Bohr, BP 2132, 69603 Villeurbanne Cedex, France*
***INSAVALOR Géotechnique Environnementale, Bâtiment. J.C. Coulomb, 34 avenue des Arts, 69621 Villeurbanne Cedex, France*
****SITA FRANCE, 132 rue des 3 Fontanot, 92758 Nanterre Cedex, France*
*****ALIAPUR SA, 71 cours Albert Thomas, 69003 Lyon, France*

Key words: End of Life tyre, landfill, permeability, compressibility, drainage, leachate

European and American studies concerning the physical and mechanical behaviour of shredded tyres show that these materials have a high hydraulic conductivity even under strong loading condition equivalent to natural aggregates (gravels type). Also, in context of sustainable development, this property makes possible to consider a substitution of natural aggregates by shredded tyres for the constitution of a drainage layer on the bottom of MSW landfills.

Three types of shredded tyres available in France have been studied in laboratory:

- firstly to estimate their physical and mechanical performances under various loading conditions, according to tests in connection with the European legislation and adapted to product sizes;
- secondly to recommend standard applications rules of shredded tyres in industrial contexts (drainage of leachates on bottom of MSW Landfill, drainage of surface waters after covering, drainage of biogas).

The three analysed types of shredded tyres belong to the particle-size ranges resulting from passenger car tyres (category A) and truck tyres (category B) shredding process. Particle-size analysis methods for conventional civil ingineering materials are not adapted to analyze product coming from End of Life Tyres shredding process. So, two specific methods have been used to characterize each type of products (a manual one and an image processing one; VISIOPUR© method, based on the measurement of the longest dimension of the chips). The analysis was carried out by ALIAPUR according to french experimental standard XP T47-751-July 2006 (AFNOR). Based on the reality of

the products shredded by the majority of the French operators, ALIAPUR defined, in 2006, its own shredded products.

These types of products called: "LARGE A" (mostly passenger car tyres) and "LARGE B" (mostly truck tyres) and the smaller "MEDIUM A" (mostly passenger car tyres) have been tested. The French operators commonly produce these types. The three graded categories of shredded tyres have been examined in a mechanical and hydraulic behaviours point of view. The study consists in undertaking to adapted geotechnical tests to determine grain density of the solids, compressibility and permeability of the different types of shredded tyres. Compression and compression-permeability tests have been realized at different stages of uniaxial stress between 10 and 500kPa or 10 and 300kPa. A test cell especially designed to measure the compressibility and to determine the permeability (to water) of shredded tyres "LARGE A", "LARGE B" and "MEDIUM A" was used. Preliminary compression tests were carried out on shredded tyres "LARGE A and B" and "MEDIUM A" in order to check if important variations exist between measured and determined parameters.

The main results coming from the compression-permeability ("LARGE A", "LARGE B" and "MEDIUM A") are presented in table hereafter.

σ (kPa)	Density (kg/m^3)			Total porosity (%)			Permeability (m/s)		
	LARGE A	**LARGE B**	**MEDIUM A**	**LARGE A**	**LARGE B**	**MEDIUM A**	**LARGE A**	**LARGE B**	**MEDIUM A**
10	485	570	510	67	64	57	$4.9\ 10^{-4}$	$5.0\ 10^{-4}$	$5.2\ 10^{-4}$
100	602	876	897	61	43	32	$3.4\ 10^{-4}$	$2.4\ 10^{-4}$	$2.3\ 10^{-4}$
200	732	969	1014	53	37.5	23	$2.7\ 10^{-4}$	$1.7\ 10^{-4}$	$1.4\ 10^{-4}$
300	862	1023	1083	44	34	17	$2.3\ 10^{-4}$	$1.3\ 10^{-4}$	$8.4\ 10^{-5}$
400	n.d.	1062	1132	n.d.	31.5	14	n.d.	$1.0\ 10^{-4}$	$4.5\ 10^{-5}$
500	n.d.	1092	1170	n.d.	29.5	10.5	n.d.	$7.9\ 10^{-5}$	$1.4\ 10^{-5}$

The tests results show the high compressibility of shredded tyres under weak and medium normal stress. Indeed, considering the majority of compression tests, samples lost around half their initial height. A factor of 10 is measurable between the permeability value under low loading condition (10kPa) and medium loading condition (300 to 500kPa). Results bring to light permeability roughly equal to $5\ 10^{-4}$ m/s under a 10kPa load while it reaches about 10^{-5}m/s under 300kPa to 500kPa loads.

From a geotechnical point of view, the graded categories "LARGE A", "LARGE B" and "MEDIUM A" could be bound to be used in drainage layer in bottom MSW landfill. Nevertheless, a normal stress higher than 300kPa limits this use to stay in line with the French legislation.

After this study, experimentation in full scale will be conducted in 2009 on a site from SITA Company located in the southwest of France. The type "LARGE A" has been selected for this experimentation. Nine hundred tons (900) of shredded tyres will be used to form a layer with a thickness of 50 cm for leachate drain on the bottom of a storage cell. The site will be instrumented to allow monitoring of the settlement layer of shredded tyres and monitoring of the physico-chemical evolution of the leachate composition, over several years.

Use of Scrap Tyres in Asphalt Concrete

Hafiz Muhammad Akhtar
Managing Partner
Progressive International (Engineers & Contractors)
Lahore, Pakistan.

The objective of this study has to check the suitability of the use of crushed rubber in the shape of shredded tyres in the asphalt concrete to determine its effectiveness in enhancing the properties of the mix. The shredded tyres may be used as granular material or as an additive in the bitumen; modifying

its properties at 195°C to 210°C temperature. Marshall Properties such as stability, density, flow and derived properties such as mix-density and Marshall Quotient were considered as improvement criteria. Improvement in stability, flow and Marshall Quotient compared with the standard values has been considered as improvement in the mix properties. For preparing specimen for Marshall Tests the filler (passing sieve # 200) was removed from the aggregate and substituted by rubber (passing sieve # 8) obtained from shredded tyres. The bitumen content was varied from 3.4% to 4.4% as obtained from trial. In order to determine the optimum content of rubber, rubber granular (passing sieve # 8) was varied from 0.5% to 3.5% by weight of aggregate, keeping bitumen content 4% (Optimum value) by weight of aggregate. Optimum value of rubber was obtained as 15% by weight of bitumen. Afterwards optimum content of bitumen corresponding to optimum rubber content was obtained through trials by varying the quantity of bitumen from 3 to 7% by weight of aggregate. No appreciable improvement in stability, flow and unit weight has been observed from the trials performed using rubber as a granular material in the mix.

Optimum value of shredded tyres' rubber was added in a powder form in optimum value of bitumen, Grade 60/70 at 200°C for 4 hours. The resulting gel possessed the following improved properties. Penetration changed from 63 to 39, Flash point increased from 232°C to more than 300°C while softening point increased from 44°C to 57°C. The modified bitumen was used to prepare Marshall Molds for laboratory tests. The significant modification in the characteristics of the rubber-bitumen gel is a major achievement attained through this research. In addition an increase in the stability in the mix design has also been observed during lab tests. However, performance of the rubber asphalt mix after lying in the field is yet to be observed.

Leaching of zinc from recycled rubber taking in account the degradation of the rubber

Ulbert Hofstra, the Netherlands

Leaching tests normally assume that the material from which the leaching is occurs is stable. For most investigated materials, which are stony materials, this is true. For rubber which is used as rubber infill on artificial turf football pitches the assumption appears not to be true. The leaching increases over the lifetime of the rubber infill. Therefore the degradation of the rubber has to be taken into account in the laboratory testing of the leaching of zinc from this material.
Artificial turf football pitches need a layer of ca. 1,5 cm of fine rubber granulate on the artificial grass. The rubber gives good shock absorption to the footplayer and makes it possible to conduct slidings on the field, which are not possible on a hockey field, which has only sand infill on the artificial grass. Rubber infill from recycled shreddered car tyres is very suitable for this application. Particles of 0,5 – 1 mm diameter are used as a 1 – 1,5 cm thick layer on the football field.
Rubber from car tyres is a mix of natural rubber and styrene-butadiene rubber. The rubber is vulcanized with sulphur. Zinc oxide ZnO is used as a vulcanisation accelerator by the car tyre producers. Car tyres contain up to 1,6 % m/m ZnO. Car tyres for utility vehicles, such as trucks and lorries, show higher amounts of ZnO than car tyres for normal cars. Rubber infill from shreddered car tyres contains therefore from 5000 to 17000 mg/kg zinc. The leaching of zinc from rubber infill on artificial turf football pitches might therefore be an environmental problem.
Leaching of zinc from rubber infill was investigated with an up-stream percolation test (column test, NEN 7383). The leaching of zinc varied from 4 to 12 mg/kg for freshly produced material.
The leaching of zinc varied up to 57 mg/kg/kg for three year old material, taken from a football pitch. It is assumed, that the increase of the leaching is due to the degradation of the rubber under climatological conditions. Due to microcracks in the rubber, the zinc oxide particles in the rubber matrix become more accessible to percolation water and zinc is dissolved in the water and is leached out.
Therefore a laboratory test was devised, which takes into account the degradation of the rubber. A mini-lysimeter set-up was used. An artificial grass pitch of 0,5 x 0,5 was put on a fine sieve. The grass contained the regular sand layer (1,5 cm) and rubber infill layer (1,5 cm).

The weathering conditions were varied with: rain, temperature, UV-light and ozone. The temperature cycle conditions and the UV-light conditions were taken from the existing FIFA-test on artificial grass for football pitches. The temperature was varied from -5 to +40 °C in a 3-day cycle.
The lysimeter was subject to 100 mm/m^2 per day deionised water from fine nozzles during a few hours per day. The ozone concentration was set to 300 ppb.
The concentration of zinc in the eluate water from the mini-lysimeter was analyzed every 3-day cycle. Some test results are shown in figure 1. In figure 1 the ozone concentration was raised from 0 to 300 pppm after 33 days. It is seen that the increase in leaching conincides with the start of the increasse of the ozon concentration. The main weathering mechanism for rubber infill is degradation due to ozone. The relation with the situation in the fields was demonstrated by the percolation tests before and after the lysimeter test under weathering conditions. The result of the percolation test was equal to that on samples taken from 3-year old fields.

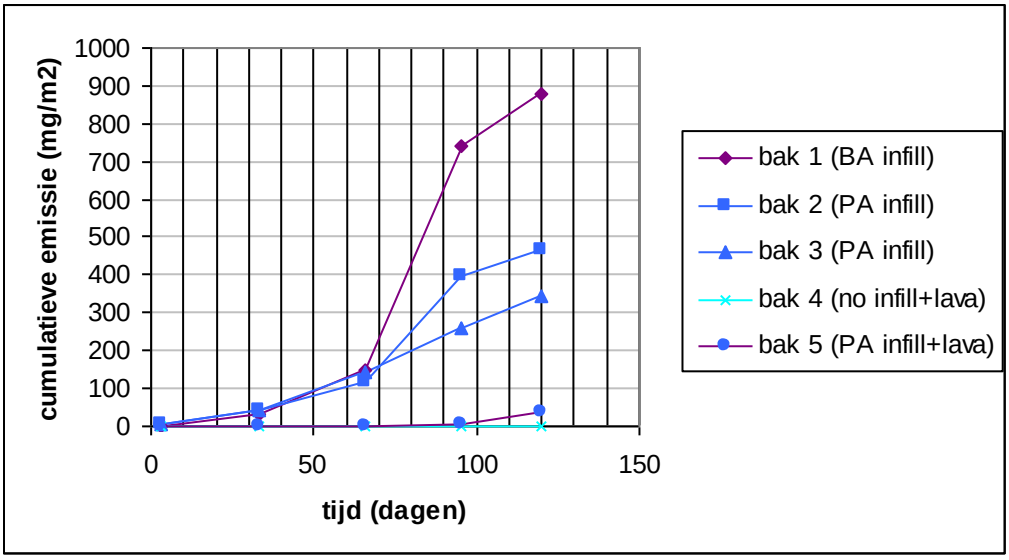

Figure 1. Cumulative leaching of zinc from rubber infill on artificial turf pitch in a lysimeter. PA infill (test 2 and 3) is rubber infill from shreddered car tyres for regular cars, BA infill (test 1) is rubber infill from shreddered truck car tyres. Test 4 is a reference test with no rubber infill and test 5 is a test with a regular 10 cm lava underlayer under the turf pitch.

From the increase of the leaching of rubber in time the time dependent leaching was calculated. Figure 2 shows the increase of the cumulative leaching of zinc from rubber infill from normar car tyres (PA infill) and from rubber infill from truck tyres (BA infill).

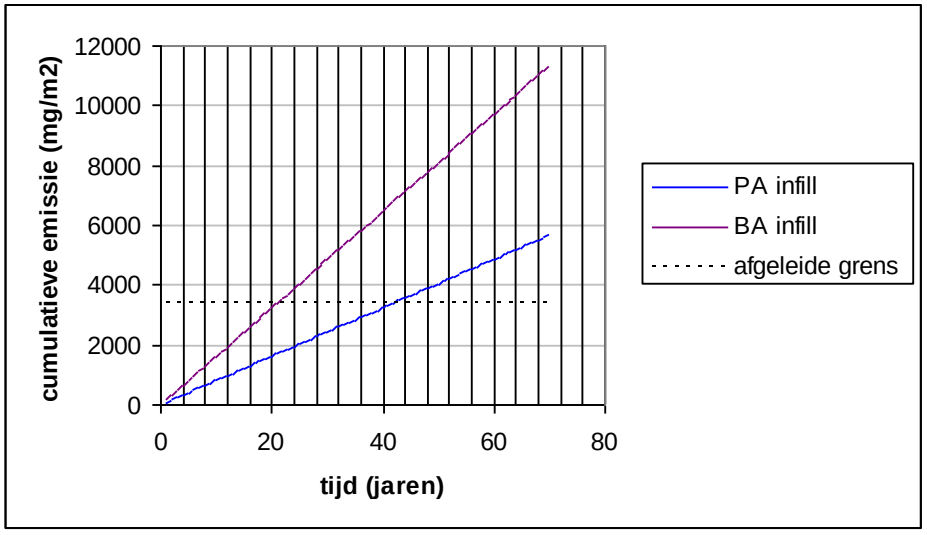

Figure 2. Calculated cumulative leaching of zinc over 80 years from the results of the laboratory lysimeter tests.

It appears from this fugure that that the cumulative leaching of zinc exceeds the indicative leaching limits derived from the Dutch Soil Quality Decree. However in an artificial turf football pitch with normal underlayers (lava and sand) the leaching to soil, groundwater and surface water does not cause an environmental risk. The zinc elauting from the rubber is adsorpbed to the lava and sand underlayers. This was confirmed by analyses of draining water from 5 to 6 year old football pitches.
Conclusion:
It is necessary to take into account the time dependent increase of leaching when assessing the leaching from rubber from recycled car tyres. It is possible to do so by using a laboratory lysimeter test under weathering conditions. it appears that the main weathering mechanism is weathering due to ozone attacks resulting in a 10-fold increase of the leaching of zinc from the rubber infill.
Additional research needed
The lysimeter tests have to be optimized on the intensity of the rain flow. Comparing the results of these tests and also percolation tests and short leaching tests (EN 12457), it is concluded that the leaching depends on the contact time with water. The lysimeter tests have therefore to be optimized on the rain flow.

Laboratory trials to develop specifications for recycled rubber in user friendly rights of way

James Brown, Joanne Edwards and Rebecca Hooper
Scott Wilson, UK

This project has provided tangible and readily achievable engineering and cost effective solutions that successfully balance durability with user demands of rights of way. This is the first time that rubber has been used in mixed use rights of way construction.
Mixed use rights of way (e.g. bridleways) need to be durable to minimise maintenance costs, while striving to meet the needs of diverse users (including walkers, cyclists and horse-riders). Asphalt provides a durable, smooth surface but has minimal shock-absorbency for runners and horse-riders; grass and sand are shock-absorbing but lack durability and are deprecated by commuting walkers and cyclists. This project has resulted in an entirely new way to address the problems of mixed use rights of way construction. It not only demonstrates a highly innovative use of a waste material but also provides a solution to a commonly occurring problem for rights of way managers.
Laboratory testing of possible materials to a variety of formulations was undertaken. On the basis of this work some candidate materials were short-listed and their applications defined in draft specifications. This work was completed in January 2006, and included:

- Testing of the stability of bitumen spray and chipping surfacing in which increasing amounts of 10 mm rubber granules were added to the structural matrix of the surface.
- Testing the surface stiffness and permanent deformation of subbase aggregate with increasing levels of 20 mm rubber granules.

Wheel track testing was undertaken to assess fatigue and permanent deformation of each formulation comprising a surface dressing (surface dressing containing rubber and surface dressing over subbase containing rubber).
The results from the testing of these mixtures were compared with test results of conventional bridleway construction materials. On the basis of this work three alternative applications for post consumer tyre rubber were short listed:

- Section A – Replacing 2% by mass of the chippings in a bitumen spray and chipping surfacing with 10 mm rubber granules.
- Section B – Replacing 5% by mass of the subbase aggregate with 20 mm rubber granules.
- Section C – Using a 20 mm thick layer of 6 mm rubber granules covered by a geotextile and 20 mm of quarry fines.
- Section D – Control section without recycled rubber

The specifications also offer cost savings as a result of reducing the maintenance requirements while increasing the life cycle of rights of way surfaces. To prove the shock-absorbing benefits of recycled rubber, a bridleway at Clipstone Forest, Nottinghamshire, UK, was reconstructed including recycled rubber in its subbase and surface dressing. Monitoring work carried out over a 12 month period

following construction included surface stiffness testing, visual assessment, user surveys and traffic counts.
The three sections containing recycled rubber had lower stiffness and higher shock-absorbencies than either the control section or the route before construction. The control section showed a significant increase in stiffness (reduction in shock-absorbency) compared to its pre-construction state. An informal visual inspection after 17 months (September 2007) confirmed that the sections containing recycled rubber were durable and performed as well as the conventional construction. This performance indicates that the increased durability of a shock-absorbing surfaced dressed route would reduce whole life costs (by reducing the maintenance required) compared to conventional construction, as well as offering a more balanced user experience.
The specifications developed during this project offer rights of way maintainers several new options to maximise value whilst meeting user needs and increase materials resource efficiency. Where full depth reconstruction is required, rubber can be mixed into the subbase. Where an asphalt path already exists, this can be surface dressed with rubber to increase shock-absorbency, and where there is a good existing granular base requiring a new surface, the discrete rubber layer could be specified. This paper sets out the experimental basis for the specifications used in the construction of the demonstration route and overviews the construction and monitoring process reported elsewhere.

Wednesday June 3, 2009

Topic 4:Environmental and sanitary impact

Relevant leaching and testing procedures for ecotoxicological hazard and risk characterization of ash

Kristian Hemström[1)], Sara Stiernström[2)], Magnus Breitholtz[2)], Ola Wik[1)]
[1)] Swedish Geotechnical Institute, SE-581 93 Linköping, Sweden,
[2)] ITM, Stockholm University, SE-106 91 Stockholm, Sweden,

In the past, waste ecotoxicological hazard or risk has predominately been assessed based on total contents of potentially toxic components in the solid material or in an eluat. This strategy may vastly overestimate environmental risks since only a fraction of the constituents may be bioavailable. Additionally, there is often a poor relationship between analyzed substances and their contribution to the total toxicity and since mixture toxicity is not considered, the same procedure may at the same time underestimate risks. To fully understand the hazard potential of ash materials, a combination of biological and chemical tests is needed as well as an integrated analysis of experimental data. However, several challenges remain to be addressed before the hazard potential of ash can be correctly assessed and toxic effects fully understood. The overall aim of this project is to provide a scientifically sound basis for characterization, both hazard identification and risk assessment, of ash with respect to ecotoxic effects. Since the start of the project (2008) we have identified several critical experimental challenges which may have a vast impact on the aquatic toxicity results, e.g.

i) preparing an eluate representative of all toxic constituents in waste
ii) managing pH-controlled effects
iii) selecting a biotest battery suitable for the often extreme properties of ash
iv) interpretation of experimental data

This paper summarise these identified experimental challenges.

A crucial task, which remains unsolved, in order to reach the overall aim, is to increase the understanding of the governing mechanisms for the observed toxic effects of a complex mixture, such as eluate from ash. If observed toxic effects can be linked to specific substances or interactions between specific substances and/or physiochemical conditions, this will be of

great benefit for the subsequent exposure assessment, as well as for identifying cost effective risk management actions. This requires a combination of methodologies; ecotoxicological tests, conventional chemical analysis, measurements of truly dissolved and direct bioavailable fraction, and geochemical modeling, describing chemical speciation.

Risk-based soil quality standards in The Netherlands – a new approach towards the sustainable reuse of soil

Ton Honders
SenterNovem – Taskgroup Soil,The Netherlands
Arjen Wintersen, Johannes Lijzen, Piet Otte
National Institute for Public Health and the Environment, The Netherlands
Joke Wezenbeek
Grontmij, The Netherlands
Marc Pruijn, Herman Walthaus
Ministry of Housing, Spatial Planning and the Environment

Keywords: soil quality standards, soil reuse, soil legislation, soil ecological risks, human-toxicological risks, agricultural risks

Introduction

Since 1999, the reuse of lightly contaminated soil in The Netherlands has been regulated by the Building Materials Decree. Reuse of soil is relevant to minimise the use of primary material (e.g. sand, clay) and to limit the number of landfills. Within the framework of the Building Materials Decree, the environmental quality of soil and other secondary materials – and hence their reuse options – were determined by a set of contaminant concentration and leaching standards. Upon evaluation of the Building Materials Decree in 2002-2003, it became apparent that specifically for soil and aquatic sediments, the regulations were limiting their reuse options. Important factors identified were: relatively high costs of application, poor enforceability, unpractical handling (and sampling) procedures, limitations for local tailor-made solutions, legislative inconsistencies and the absence of a clear relation between environmental risks and the standstill principle. It was hence decided to alleviate these problems. After an intensive consultation process with all stakeholders involved; and environmental and economic impact analyses, the new Soil Quality Decree [1] was developed. This Decree became (fully) effective in mid 2008. This paper specifically discusses the new set of soil quality standards which are at the basis of this Decree.

Policy principles

The new Soil Quality Decree relies firmly on two basic principles:

- "Standstill". Applied soil should be of equal or better quality than the receiving soil. This ensures the protection of soil quality.
- "Fit for use". The on-site soil quality should correspond with its actual (and/or future) use. This ensures the protection of the ecological environment and human beings.

A detailed discussion on the derivation process for soil / land use functions and soil quality standards is given in references [2-5].

Soil / land use functions and soil quality standards

The defined soil functions are based on dominant land use. In The Netherlands these are:
agriculture / nature, residence and industry as is depicted in Figure 1. These functions are subdivided as follows:

- Agriculture / nature / vegetable garden.
- Residence:

    - Children's playgrounds.
    - Residential areas.
    - Green areas with nature values (e.g. city parks).
- Industry:
    - Infrastructural works (e.g. road-side shoulders).
    - Industry.
    - Other green areas and buildings…

Health impacts of the use of secondary and recycled aggregates in building materials

Broos K., De Brouwere K., Quaghebeur M., Nielsen P., Bleux N., Buekers J., Torfs R.
VITO – Flemish Institute for Technological Research, Boeretang 200, 2400 Mol, Belgium

The Flanders region of Belgium strongly depends on ever scarcer stream of primary resources. Therefore, a more sustainable use of primary and secondary raw materials is one of the top priorities of the Flemish government. The current Flemish waste legislation (VLAREA) offers a legal framework for the valorization of several waste streams as secondary raw materials, thereby decreasing the need for primary raw materials whilst at the same time protecting the environment (soil/groundwater). Although specific legislation for public health and guidelines for health and safety at the work place do exist, the impacts of the use of these secondary raw materials on human health are rarely assessed.

In this study, we aim to develop a methodology for the evaluation of health impacts linked to the use of secondary aggregates in building materials. The risks associated with this use will be assessed during 3 different life stages, namely a) the production of the building materials, b) the construction of buildings and infrastructure using these building materials and c) the use of the buildings after construction.

To develop this methodology, a step-wise approach is used. In the initial step, an overview of the different secondary raw materials as well as the applications in which they are currently used in Flanders is made. The second step is the development of a methodology that can be used in practice for the risk analysis for each of the possible combinations of secondary or recycled aggregate and application. Detailed exposure pathways and exposure scenarios (duration of exposure, dose, etc…) will be developed for the most relevant applications in which the aggregates are used. Particulate matter (PM, i.e. dust) and heavy metals therein are considered the major risks to human health. Human exposure to heavy metals in secondary aggregates is possible via direct inhalation or resuspension of the particles, but also oral ingestion of dust can not be excluded. Skin contact is considered less relevant as a potential exposure pathway. The third step is the completion of an extended measurement campaign which will be used to validate and improve the general methodology. The campaign comprises a characterization of the various streams of secondary and recycled aggregates (total heavy metal content) and PM measurements (both levels of dust and their heavy metal content are measured) during real life situations (production and construction of building materials using secondary aggregates) and lab-controlled conditions (in order to mimic potential use and exposure conditions).

Finally, on the basis of these results, the potential human health impacts related to the use of secondary aggregates as a replacement for gravel will be mapped out for the Flanders region.

Ecotoxicological risks of road runoff water sediments on aquatic ecosystems

Bernard Clément, Valérie Raevel, Wenwen Xu, Lynda Souki

Université de Lyon, Ecole Nationale des Travaux Publics de l'Etat, Laboratoire des Sciences de l'Environnement, rue Maurice Audin, 69518 Vaulx en Velin Cedex, France

The management of road runoff water sediments is an environmental, economical and social important issue. In addition to the strengthening of regulations about waste management, the valorization of these heterogeneous materials, which are produced in high quantities on a national scale, is limited due to their physico-chemical characteristics and their polluting load (heavy metals and petroleum hydrocarbons).
The Laboratoire Central des Ponts et Chaussées (LCPC) of Nantes has developed a treatment process of such materials with the aim to valorize them in road building (road embankment, ...) (Pétavy, 2007). This process consists in separating the sediments into several valorizable fractions and discarding the finest particles onto which most of the metal and organic pollution is located.
In this study, raw and treated materials were characterized on a physico-chemical level and submitted to a leaching test reflecting the transfer of pollutants from the solid phase to the aqueous phase when the re-used materials are exposed to rainfall. Ecotoxicological single-species tests and microcosm assays were then carried out on the leachates to predict the potential effects of the leachates reaching a close aquatic lentic ecosystem.
The results obtained on 13 raw materials and 2 valorizable granulometric fractions for 3 of them, suggest absence of acute ecotoxicity of the leachates at dilution factor > 2 and absence of chronic ecotoxicity (21 day exposure) at dilution factor > 10.
The analysis of metallic contents and bioassay results lead concordingly to propose a no chronic effect concentration close to 1% (v : v). On an ecotoxicological point of view, the granulometric fractioning does not seem to produce a valorizable fraction which would be systematically innocuous.

Keywords : road runoff water sediment ; heavy metal ; microcosm

Environmental impacts of construction sand mining on rivers: a case study

Dr. S. Mohan
Department of Civil Engineering
Indian Institute of Technology Madras
Chennai – 600 036
India

India's construction industry contributing over 8% to its GDP requires over 27 million cubic meters of sand annually (expanded in the short term due to additional demands of post tsunami construction) which is obtained from the country's river beds, river sides or mined from previous riverbeds and sand dunes. Though until recently manual harvesting was the norm, increasing mechanized and often illegal, river sand harvesting has caused major loss of water security and ecosystem damage due to lowering of water tables, bank erosion, land degradation and salinity intrusion; damage to infrastructure; increased health hazards and negative impacts on women, as rural women have to spend more time and energy to fetch the groundwater for drinking purpose, which is the common practice in India. The steep increase in cost of sand (over 250% over the last decade) has encouraged the growth of a politically powerful, often violent “Sand Mafia” operating uncontrolled in a country already saddled with a plethora of laws and regulations covering of natural resource use, within a poor regulatory environment which is further complicated by the prevailing security concerns. Rivers in the south India are under immense pressure due to various kinds of human activities among which indiscriminate extraction of construction grade sand is the most disastrous one. The situation is rather alarming in the Palar river which has catchments as the area hosts one of the fast developing urban-cum-industrial centre, the Chennai city. The Palar basin mostly serves the ever-increasing sand needs

of builders in and around the city and therefore is the most exploited of the river basins in the State. The background note says that mining operations, both legal and illegal, have been noticed in a number of places and the norm regarding the depth of the mine is often flouted. Irrigation and drinking water supply are the major casualties. Besides, lorries that are overloaded with sand damage village roads. In some places, houses are found to have developed cracks. Also, the people in the region are exposed to lungs-related diseases because of the dust emanating from the sand-laden lorries. And whenever the mining licensees face trouble from the local community, they use their workers, most of whom were until recently farm labour, against their own people, thus causing disharmony in the community. Sometimes the miners use the caste divisions in these villages to their advantage. On an average, 1 million ty^{-1} of sand are being extracted from the active river floodplains. The quantity of in stream mining is about 40 times the higher than the sand input estimated in the gauging stations. As a result of indiscriminate sand mining, the riverbed in the storage zone is getting lowered at a rate of 10-15 cm y^{-1} over the past two decades. This, in turn, imposes severe damages to the physical and biological environments of these river systems. The present paper deals with the environmental effects of indiscriminate sand mining from the Palar river in the south India, as an example.

Ecotoxic evaluation of mortar leachate using the amphibian larvae (*Xenopus laevis*)

M. Coutand[1], F. Mouchet[2], M. Cyr[1], L. Gauthier[2], and P. Clastres[1].
1) Université de Toulouse; UPS, INSA; LMDC (Laboratoire Matériaux et Durabilité des Constructions); 135, avenue de Rangueil; F-31 077 Toulouse Cedex 04, France
2) Université de Toulouse; UPS, Ecotoxicologie et Génotoxicologie environnementale, Laboratoire d'Ecologie Fonctionnelle Ecolab– UMR CNRS 5245, Institut National Polytechnique de Toulouse INPT, Campus INP-ENSAT, Avenue de l'Agrobiopole, 31326 Auzeville-Tolosane, France

Nowadays, many projects aim to reuse by-products (e.g. sewage sludge ash, sediments of dredging, MSWI…) in cement-based materials. However, some questions remain concerning the environmental impacts of these wastes in this kind of application. The cement-based materials in buildings or roads are subjected to leaching/draining by rainwater or subterranean water. Consequently, draining waters may constitute an important reservoir for contaminants, such as water extractible elements, in the aquatic environment. So these elements, which are potentially pollutant, could be in contact with living organisms of the ecosystems.
The regulations in the field of waste materials are mainly based on the chemical composition of the waste, or on the quantity of leached elements and use standard tests. However the quantity of elements that are potentially leachable does not necessarily reflect the ecotoxic behaviour of the waste in the environment. The impact of a leachate depends on many factors such as: the intrinsic toxicity of the elements, speciation of metals, the nature of the medium, and physical and chemical interactions leading to the modification of the bioavailability of the pollutants.
In order to assess the ecotoxic potential of by-products used in cement-based materials, measurements were made to evaluate the effects of acute toxicity and the possible effects of toxicity on the genome (genotoxicity) of larvae of amphibians exposed to various concentrations of mortar leachates. This work is related to the evaluation of the environmental impact of meat and bone meal ashes in the cement matrix using the standardized ISO 21427 amphibian micronucleus assay on *Xenopus laevis* larvae (ISO, 2006).

Wednesday June 3, 2009

Topic 4: Multicriteria analysis - decision and policy making tools

Effects of waste utilization on reduction of natural resource consumption, landfilling and greenhouse gas emission in the cement production process in Japan

Kosuke Kawai and Masahiro Osako
Research Center for Material Cycles and Waste Management, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan

Thirty two of cement plants in Japan have annually produced about 70 million metric tons of cement product which mainly consists of about 50 million metric tons of portland cement and 15 million metric tons of blast furnace cement. In the cement production processes, cement industry has utilized various wastes discharged from other industries as an alternative for natural resources. Cement industry in Japan has such a practice in order to avoid high expenditure for natural resources because of lack of them in the country, compared to the industries in other regions where natural resources can be procured at an easy rate. Utilizations of blast furnace slag, coal ash, sludge and polluted soil as alternative for natural raw materials contribute to depression of natural resources consumption and landfilling. These wastes are charged before cement pyroprocess as raw materials or charged after the process as admixtures. Utilizations of plastic scrap, woodchip and scrap tire as alternative for coal contribute to depression of greenhouse gas emission. In spite of decrease in cement production affected by the economic recession, waste utilization has increased and cement industry in Japan has achieved the high waste utilization, thus, 30 million metric tons of wastes per year or 400 kg of wastes for 1,000 kg of cement product. Because utilization of wastes brings revenue of the disposal as well as depresses cost for natural resources, an indicator of depression of natural resources consumption is quite important for cement industry.

By reference to the statistics such as the amount of waste utilization disclosed by Japan Cement Association, this study evaluated waste utilization not only with the indicator of depression of natural resources consumption which provided benefits to cement industry utilizing wastes, but also with the indicator of depression of landfilling which provided benefits to other industries discharging wastes and with the indicator of depression of greenhouse gas emission which provides benefits to both of industries. Raw materials for cement production consist of lime stone, clay, silica stone, ferric oxide and gypsum physically, or mainly consist of CaO, Al_2O_3, SiO_2 and Fe_2O_3 chemically. Any waste including main chemical components above can be raw material for cement production. Base on the main chemical components for cement production and relevant ones included in wastes, current situation was compared to the situation without any waste utilization with three indicators (depression of natural resources consumption, depression of landfilling and depression of greenhouse gas emission). In addition, changes in utilization of natural resources, in landfillng and in greenhouse emission were estimated varying the amount of utilized each waste, which was optimized through the indicators. Likewise, wastes stored thermal energy as an alternative for coal were discussed. Improvement in productivity of natural resources, which refers to the value of gross domestic product divided by input of natural resources in Japan was estimated in case of more utilization of waste in cement production.

Current situation resulted in great contribution for all three indicators and productivity of natural resources. Particularly, natural resources contributing to Al_2O_3 and Fe_2O_3 has not been utilized anymore, thus, wastes have been major sources for the components. As a future issue, cement industry waits for a waste which can be an alternative for lime stone or CaO, but few wastes including rich CaO exist.

Although the most important indicator is different from each other country, the indicator of "cost" must be taken into account in cement industry in addition to the three indicators (depression of natural resources consumption, depression of landfilling and depression of greenhouse gas emission). Since waste utilizations in cement industry have a high correlation with other industries, it is necessary to

evaluate waste utilizations not only in one industry but also in the whole industries including iron and steel industry, nonferrous industry, etc.

Environmental evaluation of mineral additions in concrete. Effects of the different allocation methods

Chen, C.[1], Habert, G.[1], Bouzidi, Y.[2], Jullien, A.[3]
[1] *Université Paris-Est, LCPC, 58 Bd Lefebvre 75732 Paris, France*
[2] *UTT, laboratoire CREIDD, 12, Rue Marie Curie - BP 2060, 10010 Troyes, France*
[3] *LCPC / DDGC, Route de Bouaye, BP 4129 44341 Bouguenais, France*

Concrete is the most widely used construction material on Earth. Current estimates of world production of cement are of the order of $2.5.10^9$ tons per year, which is enough to produce over one concrete cubic meter per person. This induces large environmental impacts, especially due to the use of Portland cement as the aggregate binder in the concrete. Actually, recent studies have confirmed that Portland cement was the primary source of CO_2 generated by typical commercially produced concrete mixes, and that CO_2 emissions from the cement industry represented 5% of the total anthropogenic CO_2 emissions. To reduce this environmental impact, cement and concrete industries have been engaged over the last ten years to increase the replacement of Portland cement with alternative cementitious materials that are principally derived from industrial by-products, such as blast-furnace slags, coal combustion fly ashes and silica fume from silicium industry. Note that limestone filler is also a replacement material that is now widely used. If environmental impacts of cement have been investigated thoroughly in recent time, those from supplementary materials have been scarce and reduced to the energy and consumption required for their processing. The objective of this study is to assure that no other pollution occur when using alternative cementitious materials, and that trying to reduce CO_2 emissions by substituting cement will not increase another pollution component.

Life Cycle Assessment (LCA) is a methodology for evaluating the environmental load of processes and products during their life cycle and its methodology is based on international standards of series ISO 14040 and consists of four distinct analytical steps: defining the goal and the scope, creating the inventory, assessing the impact and finally interpreting the results **(ISO, 2006)**. When a production system produces more than one product, it may provide more functions than the one investigated in LCA. The material and energy flows and associated environmental burdens must then be allocated to each of its co-products in order to accurately reflect their individual contribution to the environmental impact of the system under study. The choice of allocation procedure has proven to be one of the most controversial methodological issues in LCA, largely because it can significantly influence the results of a study. ISO 14040 procedure indicates that when a constituent enters into the life cycle of a building material (process 2) as a waste product of a previous industrial process (process 1); the environmental impacts related to process 1 are not taken into account in the counting of the impacts of process 2. But when a constituent enters into the life cycle of a material (process 2) as a by-product of a previous industrial process (process 1), the environmental impacts from the process 1 must be taken into account in the counting of the impacts of process 2. When allocation has to be done, the first step is to try to avoid allocation by detailing the process and looking at specific processes for every fraction. If not possible, an allocation on a mass or on an economic basis must be realised for the process. Sometimes the economic allocation is considered more appropriate than the mass allocation since the prices between product and by product differ significantly.

The objective of the study is to address an allocation method on environmental impacts of different mineral additions. Actually, while considerable research has been published on topic of co-product allocation in LCA, the specific allocation problems faced in LCA of cement substitution products in concrete have not been formally addressed. This paper provides a study of the influence of different allocation methods on environmental impacts of mineral addition in concrete. The data used about industrial processes come from the Ecoinvent database and have been compiled by SimaPro7.0 software with CML 2001 environmental indicator method. This evaluation is followed by a discussion on the specificity of the cement substitution products and the identification of the driving forces for the use of these by-products. The paper concludes with a description of a different allocation methods

where it is not the relative economic value that permits to evaluate the environmental burdens but the contrary.

Modeling the recycling processes in the LCA of buildings

S. Lasvaux [a,b], B. Peuportier [a], J. Chevalier [b]
[a] *Centre Energétique et Procédés MINES ParisTech*
60, Bd St Michel 75272 PARIS Cedex 06, France
[b] *Centre Scientifique et Technique du Bâtiment*
Départment Energie Santé Environnement
24, Rue Joseph Fourier 38400 St Martin d'Hères, France

The building sector identified as a main contributor of energy and resources consumption contributes to many environmental impacts such as resources depletion or climate change. The identification, quantification and analysis of the main flows of matter, energy and pollution through the building system by means of appropriate methods can help to provide knowledge and tools for decision making.
The Life Cycle Assessment (LCA) is, in this context, a method which can be applied to study the environmental impacts of buildings. Several LCA-based environmental analysis tools have been developed over the past few years. However, the relevance of such tools is often questioned. The methodological choices seriously influence the results of the analysis particularly in terms of data quality, recycling take-account, modelling of the end of life and more widely the chosen system boundaries.
In this article, we present a mathematical model for discussing the recycling aspects in the LCA of buildings. It allows us to review the current recycling take-account in existing building LCA tools. We emphasis the differences of existing approaches first on a single cumulative energy demand indicator, then on detailed mass flow inventory balance. We then go on to detail a proposal for a recycling model in accordance with specific databases (environmental product declaration) of construction products.

We conclude by providing recommendations for new strategies of integration of the recycling aspects in the LCA of buildings.
Keywords: recycling, LCA of buildings, construction products, model, resources indicators, sensitivity analysis, temporal aspects.

Life Cycle Assessment as a Tool for Evaluating the Valorization of APC Residues from MSW Incineration in Lightweight Aggregates

Ana S. Simões, Margarida J. Quina, Rosa M. Quinta-Ferreira
GERSE – Group on Environment, Reaction and Separation Engineering, Department of Chemical Engineering, University of Coimbra, Pólo II, Rua Silvio Lima, 3030-790 Coimbra, Portugal.

Keywords: Valorization of APC Residues, Life Cycle Assessment, Lightweight Aggregates

The Air Pollution Control (APC) residues produced during Municipal Solid Waste Incineration (MSWI) arise from gaseous cleaning systems, being mainly composed by inorganic materials. These residues are considered hazardous, mainly due to the release amounts observed in the leaching processes in what respects some toxic heavy metals and soluble salts. The hazardous characteristics of the APC residues limit very much the utilization options and a treatment is required before landfilling. Nowadays, this waste is mainly submitted to solidification/stabilization treatments and landfilled. Among the potential applications, ceramic or glass-ceramic materials may be environmental sound options. In the present work the valorization of APC residues in Lightweight Aggregates (LWA) was selected. Thus, the main objective is the analysis of the industrial production phase of LWA by using

Life Cycle Assessment (LCA) framework. This methodology is used to identify and qualify the environmental performance of a process or a product from "cradle to grave". The application of LCA was supported by using Simapro7.0 code, which is one of the most widely used LCA software. The method CML 2000 was used for transforming the characterization factors on quantified effects on environment. The data were collected in a Portuguese industrial plant in 2008, and include: input materials flows (clay, auxiliary materials and packaging materials); energy consumption (electricity and heavy oil); water consumption; airborne and waterborne emissions; and wastes. The functional unit for calculations was 1 kg of LWA. The system boundary includes raw materials extraction, grinding, mixture, burning in furnace, cooling and packing. The application of LCA methodology to the LWA productive process points out that the most significant impact categories are the marine aquatic ecotoxicity, abiotic depletion, acidification and global warming. The burning in furnace, mixture and grinding have the biggest contributions, mainly as a consequence of electricity consumption and fossil fuels combustion processes. When the valorization of 10% APC residues is considered on the mixture process, almost all the impact categories were slightly increased, but the augment was not significant. This study showed that from the environmental point of view, the valorization of APC residues in LWA may be a good solution in order to help to solve the problem of the huge amounts of this hazardous residue.

The FORWAST project: Design of future waste policies for a cleaner Europe

Jacques Villeneuve(a), Stéphane Vaxelaire(a), Bruno Lemière(a), Bo Weidema(b), Jannick Schmidt(b), Hans *Daxbeck(c), Bernd Brandt(c), Heinz Buschmann(c).*
(a) BRGM, France
(b) 2.-0 LCA Consultants, Denmark
(c) RMA, Austria

In the wider context of sustainable development and environment protection, the connections between the use of natural resources, their accumulation in the economy and waste generation and management, need to be more clearly understood. Waste management policies may affect potentially all sectors. Their influence on the use of natural resources must also account for the potential recovery of these resources from stocks, the technical and economical constraints of recycling, the side effects on the by-products associated with natural resources, and at the end, the global balance of the environmental costs and benefits.

The European FP6 FORWAST project intends to provide comprehensive and validated data on the material flows, stocks and environmental pressures coming from the different sectors of the life cycle of resources to waste. Certain stocks are particularly relevant to recycling in the construction industry.

The method implemented is based on an environmentally extended, physical, quasi-dynamic input-output model. This model combined with a robust method of Material Flow Analysis guides the mining of new data that take place as a combination of "in-depth" studies in selected countries where high-quality statistics are available, and an EU-wide effort aimed at consolidating and calibrating different statistical and technical data sources.

The model will be applied to historical time series of resource inflows into the economy, and calibrated to known quantities of waste generation, a core question being the estimation of coefficients for lifetime stocks, for the different materials (sand/gravel, wood, metals, paper, etc.) and the dynamic interpretation of the causes of stock variations (accumulation versus waste generation or dispersive losses). The policy-relevance of the project is strengthened by the definition of 25 years horizon scenarios of waste generation, combined with technological options for waste prevention and recycling. The waste with the highest stakes with respect to environmental pressure reduction will be identified through simulation.

This paper presents the first results of the project: the principles and the structure of the model and the progress/difficulties of the data mining. It highlights the necessary disaggregations of economic

activities for accounting for waste flows and the substances taken into account for calculating environmental impacts.

Life-cycle assessment of construction and demolition derived biomass/wood waste management

Kevin Gardner[1,] Alberta Carpenter[1],Jenna Jambeck[1], Keith Weitz[2]
[1]University of New Hampshire, Durham, NH 03820, [2]RTI International, 3040 Cornwallis Road, Research Triangle Park, NC 27709,

To provide assistance in quantifying trade-offs for the management of wood derived from construction and demolition (C&D) debris in New Hampshire, a life-cycle assessment of various management options using the U.S. Environmental Protection Agency's Municipal Solid Waste Decision Support Tool was conducted. Seven different management scenarios were considered based upon the annual production of C&D debris in the state of New Hampshire, and one scenario was used to compare the combustion for energy production of virgin wood from northern New Hampshire with locally produced C&D wood. The scenarios included transport distance and various management options for C&D wood (combustion, recycling, and landfilling) as well as different types of offsets for energy production (Northeast power grid and coal combustion). Impacts were obtained for energy consumption, carbon emissions, criteria air pollutants, ancillary solid waste produced, and organic and inorganic constituents in water. These impacts were normalized by person equivalents and then ranked with each impact given equal weighting. In the ranking, all scenarios with C&D debris recycling coupled with wood waste combustion and energy recovery had lower impacts than the others. The C&D debris recycling-only scenarios resulted in less overall impact than the disposal-only scenarios. For the disposal scenarios, the landfill gas (LFG) -to-energy scenario had fewer impacts than when the LFG is flared. The lowest impact scenario included C&D debris recycling along with local combustion of the C&D wood derived product with energy recovery providing a net gain in energy production of over 7 trillion BTU/yr, and up to a 130K tons/year reduction in carbon emissions.

Thursday June 4, 2009

Topic 1:Modelling

Development of an environmental behavior prediction model incorporating predominant parameters obtained from leaching tests

Hirofumi Sakanakura[1], Kazuto Endo[1], Masahiro Osako[1], Shin-ichi Sakai[2]
[1] *National Institute for Environmental Studies*
[2] *Kyoto University*
16-2 Onogawa Tsukuba Ibaraki 305-8506 Japan

The possibility that recycled materials could pollute the natural environment is of great concern. This study presents a method of predicting the environmental behavior of toxic inorganic substances by using a numerical model using predominant parameters obtained from leaching tests. The parameters are the leaching flux coefficient, the leaching flux quotient, maximum concentration in pore water and maximum leachable amount in the recycled material. As a case study, a set of leaching test data of copper slag when used in road base was applied in the model. No absorption was considered in the current model. In the set condition, contaminants plume reaches the ground water table 10 m below the ground in about 5 years and is then transferred horizontally with the ground water stream. At the end of the modeling time (30 years), release of contaminants is continuing at an almost constant concentration, due to the fact that the leacheable fractions are abundant in the material and the rate of release of the contaminants is slow.

Reactive transport modeling of leachate evolution of MSWI bottom ash used as road basement, Hérouville (France) and Dåva (Sweden) sites

L. De Windt[a], D. Dabo[a,b], S. Lidelöw[c], R. Badreddine[b], A. Lagerkvist[c]
[a] *Ecole des Mines de Paris, Hydrodynamic reaction Group, 77305 Fontainebleau Cédex, France;*
[b] *INERIS, Wastes and Contaminated Sites Unit, 60550 Verneuil-en-Halatte (France)*
[c] *Luleå University of Technology, Division of Waste Science and Technology, SE-971 87 Luleå, Sweden*

The recycling of municipal solid waste of incineration (MSWI) bottom ash as aggregates for road basement requires a better characterization of the evolution of leachate chemistry over a timescale of many decades. In this paper, a common reactive transport model is applied to the Hérouville (France) and Dåva (Sweden) pilot roads whose leachate emissions have been sampled during 10 and 6 years, respectively. The model considers simultaneously the hydrodynamic processes (rain water infiltration, advective and diffusive transport), pH-buffering and solubility-controlled processes by secondary minerals, ageing by atmospheric carbonation, and the leachate chemistry (major elements and trace metals such as Al, Cu, Pb). The evolution of pH is fairly well simulated with the following pH-buffering sequence: portlandite, calcium silicate hydrate (CSH), ettringite and, finally, calcite. The quantity of CO_2 dissolved in the percolating rain water is generally not sufficient to explain the pH evolution and carbonation processes, requiring atmospheric gaseous inputs. The relation between pH evolution and element release is discussed for both sites. Calculated Pb release is overestimated when based on solubility-controlled mechanisms only. Edge effects are shown to be important at both sites with an emphasis of carbonation and release of non reactive elements. Temperature has no significant effect on the calculated leachate chemistry in the range of 5 – 30° C, except at high pH.

Assessment of contaminant leaching from secondary materials in road constructions – numerical modelling of mass transfer and attenuation processes

Christof Beyer[1], Uli Maier[2], Wilfried Konrad[2], Bernd Susset[3], Chan Hee Park[4]
Hermann Rügner[4], Sebastian Bauer[1], Rudi Liedl[5], Peter Grathwohl[2]

[1] *Institute of Geosciences, Christian Albrechts University of Kiel, Germany*
[2] *Center for Applied Geoscience (ZAG), University of Tübingen, Germany*
[3] *Consulting Office for Groundwater Risk Assessment, Düsseldorf, Germany*
[4] *Helmholtz Centre for Environmental Research - UFZ, Leipzig / Halle, Germany*
[5] *Institut für Grundwasserwirtschaft, TU Dresden, Germany*

In this contribution we present results from recent studies, where numerical modelling was used for the evaluation of the sensitivity and effectiveness of coupled contaminant attenuation processes along the leaching pathway road construction - vadose zone - groundwater. Extensive scenario analyses were carried out to investigate the complex interaction of hydrodynamic, physichochemical and microbiological attenuation processes in detail. Reactive transport simulations were performed for three different reuse scenarios (a parking lot, a noise protection dam and a road dam), where secondary materials (blast furnace slag, municipal solid waste incineration ash or demolition waste, respectively) are used in base and frost protection layers. For the vadose zone below the various constructions, a number of different characteristic subsoils, representative for a wide spectrum of grain size distributions, soil physical and chemical properties, was considered. Results of a sensitivity analysis showed that breakthrough times (BTT) of readily soluble salts at the groundwater surface (i.e. the point of compliance) primarily depend on the subsoil unsaturated hydraulic properties, groundwater recharge rates and the depth of the groundwater surface. For weakly or strongly sorbing organic contaminants like naphthalene or phenanthrene, respectively, also K_{oc} and subsoil organic carbon content have a dominant influence on observed BTT. Significant concentration reductions from dispersion only occur when source concentrations decrease prior to contaminant breakthrough. Biodegradation may be an effective attenuation mechanism for organic contaminants, especially, if residence times in the vadose zone are sufficiently long. Attenuation factors derived from the numerical scenario analyses served as valuable input for the establishment of a new regulatory concept in the upcoming upcoming "federal decree for the use of mineral recycling materials" (ErsatzbaustoffV).

Identification of leaching-controlling process by differential acid neutralization analysis for geochemical modeling – application to metal hydroxide sludge stabilization with coal fly ash

Olivier Peyronnard[a] ; Denise Blanc[a] ; Mostafa Benzaazoua[b] ; Pierre Moszkowicz[a]
[a] *LGCIE Site Carnot, INSA-Lyon, 9, rue de la Physique, F69621, France*
[b] *UQAT, 445 Blvd de l'Université, Rouyn –Noranda, Québec, Canada J9X 5E4*

The modeling of the leaching behavior of cementitious materials containing wastes requires the identification of the minerals reacting in contact with aqueous media. The differential analysis of acid neutralization data permits to highlight the dissolutions of phases occurring during the acidification of the solid matrix. Nevertheless, the identification of these dissolving phases is fairly complex because of the influences of the geochemical context on the cementitious hydrates stability. In this work, we propose to use a numerical simulator as an aid tool for the identification of the dissolving hydrated minerals. This work is based on the results of a differential acid neutralization analysis test performed on synthetic hydroxide sludge stabilized/solidified by hydraulic binders. The proposed method permits the identification of semi-validated mineral assemblages representing the studied materials and their leaching behavior.

Modelling of leaching in an aged MSWIBA subbase layer: 1. Hydrological conditions

David Bendz1, Peter Flyhammar, David Kosson, Pascal Suer, Hans van der Sloot
1)Swedish Geotechnical Institute
581 93 Linköping, Sweden

In a previous project presented at Wascon 2006 (Bendz et al: The accumulated effects of long–term leaching of MSW bottom ash in a sub-base layer in a test road) the accumulated effects of leaching and aging in a subbase layer of bottom ash were investigated and some observations were made:

- The physical properties of the pavement structure influence the way and the extent to which the construction materials become exposed to water and air. The observed patterns of EC, pH and leachable amounts of Cl-, Ca, DOC, Cu, As and Cr in the bottom ash reflect exposure to water, atmosphere, aging and transformation processes. The data clearly show pH fronts that propagate from the road shoulders towards the center of road.
- Spatial distribution patterns of mobile elements (leaching controlled by availability), such as Cl-, in the subbase layer confirm the existence of two major transport processes in a paved road construction with permeable shoulders. The existence of diffusion and capillary transport are indicated by gradients in the subbase layer directed towards the road shoulders.
- The spatial distribution of leachable content of Cu is closely associated with the leachability of DOC, which in turn, is governed by the content of organic matter (decreases with time due to degradation) and transformation into less soluble forms with time.
- The spatial distribution of the leachability of As and Cr indicate a dependency on varying redox conditions. This manifest itself in a spatial pattern of Cr that shows low leachability in the center of the road body and increasing leachable amounts towards the road shoulders. The spatial distribution of As show the opposite pattern with high leachable amounts in the center of the road and decreasing figures towards the road shoulders.

The overall objective of this ongoing study (presented here in two accompanying conference papers) was to bring the evaluation of the field data further by taking advantage of the existing data, performing complementory laboratory experiments (pH-stat test, column test, diffusion test, Fe/Al oxide, DOC fractioning) and geochemical and hydrological modelling with LeachXS and Hydrus 2-D.

In this paper the specific objectives were to investigate how the hydrologic conditions, infiltration of water and leachate production has evolved with time. This include also the distribution of water in the bottom ash layer as a function of space and time.

The data and results from the hydrological modelling will be presented and discussed

Modelling of leaching in an aged MSWIBA subbase layer: 2. Geochemical processes

Pascal Suer[1)], Hans van der Sloot, David Bendz, Peter Flyhammar, David Kosson

[1)]Swedish Geotechnical Institute
581 93 Linköping, Sweden

In a previous project: *Vändöra Q4-241 (report 964),* funded by Värmeforsk (Swedish Thermal Engineering Research Institute) presented at Wascon 2006 (Bendz et al, 2006), the accumulated effects of leaching and aging in a subbase layer of bottom ash in a test road were investigated. The test road were constructed in 1987 in Linköping, Sweden, and was in use until the start of the *Vändöra Q4-241* study in September 2003. The overall objective of the present study (presented here in two accompanying conference contributions) was to bring the evaluation of the previous project further by taking advantage of the existing data, perform complementary laboratory experiments on four composite samples reflecting different degree of exposure to atmosphere and leaching. The specific

objectives were to investigate: (i) what processes and mineral phases that govern leaching of macro- and trace elements and DOC in the bottom ash after 16 years (1987-2003) of aging under field conditions. (ii) how the hydrologic conditions, infiltration of water and leachate production has evolved with time. The following tests were performed on the composite samples: pH-stat test, column test, Fe/Al oxide extraction and TOC fractioning. Geochemical modelling where performed with LeachXS/Orchestra.
The geochemical speciation modeling was carried out for major, minor and trace elements and integrate mineral dissolution/precipitation, iron-oxide adsorption, incorporation in ettringite solid solution, clay interaction and interaction with dissolved and particulate organic matter. The geochemical model was parameterized with data on HFO, TOC and IC. The governing mineral assembly was selected based on experience. Iron-oxide sorption was shown to be important for many trace elements (metals as well as oxyanions). The role of organic matter (both dissolved and particulate) is important for elements like Cu, Cr, Cd, Pb (although the major fraction of the available content is associated with the mineral phases). Obviously, proper mineral solubility data are limited for some elements, like Sb, B, Se. The model fit for macroelements was good and for trace elements the match was quite acceptable. The model confirms that Cu, Cr, Pb, and partially Zn, in solution is bound to DOC. The elements Zn, Cd, Mo and Ni are present in the solution mainly as free ions. It is important to emphasize that for ecotoxicity evaluations the free element is of importance and the DOC associated metal is not affecting many organisms. In the solid phase As is entirely associated with iron oxides. Other elements where iron oxides plays an important role are: Pb, Cd and Cu. The elements Cu, Zn and Ni are mainly associated with the solid phase as minerals: malachite (copper hydroxide carbonate) willemite (zinc silicate), nickel silicate and iron chromate. The result implies that release of elements could be predicted for a bottom ash under certain environmental conditions if available HFO and TOC are measured. The major environmental conditions that needs to be specified are: pH, DOC and DIC of intruding water and degree of exposure to atmosphere.

Groundwater impact simulations for establishing criteria for the recycling of alternative materials in road construction

Gaël Bellenfant[1], Dominique Guyonnet[1], Patrick Vaillant[2], Laurent Chateau[3], Jacques Méhu[4], Frédéric Leray[2]

1: BRGM, Orléans, France
2: MEEDDAT, French Ministry for Energy and Ecology, Paris, France
3: ADEME, French Environment Agency, Angers, France
4: INSA-Lyon, Lyon, France

The recent European Waste Framework Directive (OJEU, 2008) promotes a waste hierarchy which places recycling above elimination in landfills in terms of community preference. In view of increasing difficulties with respect to the access to natural granular materials (e.g. sand and gravel), there is an incentive in France to promote the use of alternative granular materials such as those derived from certain types of waste, for applications in road construction for example (MEEDDAT, 2009). The suitability and acceptability of such alternative materials derived from waste is established primarily on the basis of geotechnical and environmental criteria. From a geotechnical standpoint, the alternative materials must provide a "service" in terms of geotechnical properties, such that it may be substituted for natural materials without loss of road structure functionality and durability. From an environmental standpoint, the material must not generate unacceptable risks for the environment and/or human health.

In this context, an important issue is the potential for contamination of groundwater located below or down-gradient from a roadwork. This potential is typically assessed using models that simulate the migration of substances emitted from the alternative material once it is used in a roadwork as defined by a specific utilization scenario (CEN, 2006). Such assessments are generally performed backwards: given a certain objective of groundwater quality at a certain distance from the roadwork (called a "point of compliance" or POC), what characteristics of the source (the alternative material) guarantee that this quality objective will be respected at all times? Such an approach was adopted for the

definition of the waste admission criteria in landfill that appear in Decision 2003/33/EC (OJEC, 2003; Hjelmar et al., 2001).

As part of the drafting of the French guidance document (MEEDDAT, 2009), a similar approach was used (consistent with CEN, 2006) to establish acceptance criteria for alternative materials, including those recovered from waste, in road works. This paper presents the methodology used and the results of numerical transport simulations which led to the calculation of attenuation factors (AF) used for establishing the criteria.

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Topic 1:Solid characterization

Heavy metal and oxyanion binding in fresh and carbonated hydrated Ordinary Portland cement pastes

C. Annette Johnson, Ann-Kathrin Leuz and Amit Bhatnagar
Eawag, Swiss Federal Institute of Aquatic Science and Technology, Ueberlandstrasse 133, CH-8600 Duebendorf, Switzerland

Secondary materials, or wastes, are being increasingly used in the production of cement and concrete. They may be added as raw meal substitutes, fuels or as mineral additives. Other industrial wastes such as, e.g., fly ash and blast furnace slag are used as additives for cement blending. While organic contaminants are destroyed in the kiln, an increase in metal concentrations is possible. Also, the use of cement to immobilize hazardous and nuclear wastes and to chemically bind inorganic species in the cement matrix has increased over the last decades. Incineration residues of, for example, municipal solid waste or sewage sludge that are landfilled are generally alkaline and have geochemical properties that are similar to cementitious materials while also having elevated heavy metal concentrations. For all these materials the long-term release of heavy metals to the environment is an essential element of risk assessment.

Porewater concentrations of heavy metal(loid) species are thought to be controlled by a combination of the precipitation of mineral phases and the sorption to or the incorporation in cement minerals. Cement minerals can substantially reduce heavy metal solubility of metal(loid) species that are soluble in alkaline media. The hydrated Portland cement matrix contains calcium silicate hydrate (C-S-H, 50 wt%), portlandite ($Ca(OH)_2$, 20 wt%) and Ca aluminates (ettringite, $3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$; monosulphate, $3CaO{\cdot}Al_2O_3{\cdot}CaSO_4{\cdot}12H_2O$ and Ca carboaluminate, $3CaO{\cdot}Al_2O_3{\cdot}CaCO_3{\cdot}11H_2O$). As cementitious materials age the basic Ca minerals are carbonated, Al and Fe form hydroxides, while SO_4 transforms to $CaSO_4$.

In fresh cementitious materials published investigations show evidence for the sorption of heavy metal cations to C-S-H. Anions appear to bind to Ca aluminate phases, substituting for, usually partially for anions such as sulphate, though adsorption to the surfaces of C-S-H, ettringite ($3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$) and monosulphate ($3CaO{\cdot}Al_2O_3{\cdot}CaSO_4{\cdot}12H_2O$) is an alternative immobilisation mechanism.

Attempts have been made to translate the mechanistic insights into thermodynamic models that can explain the leaching process, but leaching processes are very difficult to model because not only is there, in many cases, insufficient thermodynamic data to allow the prediction of porewater concentrations of metal(loid) species, but physical changes, resulting from carbonation and weathering, affect diffusion processes. Here we examine the solubility of of selected cations, namely Zn(II) and Pb(II) and of the oxyanions chromate, selenate, selenite and antimonate in hydrated

Ordinary Portland cement pastes. We examine the relationship between solid and dissolved concentrations in porewater, in solution at different pH values down to pH 12.5 and after carbonation.

Heavy metal pollution risk for beneficial reuse of stainless steel slag

Hua Zhang, Pin-Jing He, Chang-Lin Wu, Li-Ming Shao

State Key Laboratory of Pollution Control & Resources Reuse, College of Environmental Science and Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, P.R. China

The annual production of stainless steel slag has reached up to about 2.3 million tons in China, most of which is stored in dump sites after recovery of valuable metals. With stricter requirement for environmental protection and greater pressure on limited landfill space, sustainable treatment or beneficial reuse of the stainless steel slag is of increasing concern. Attention should be paid not only to the technical quality of the slag and slag-derived products (such as cement, concrete block), but also to the environmental compatibility during the utilization of the products. In this study, the feasibility of beneficial reuse of two kinds of stainless steel slag (EAF slag and AOD slag) and their heavy metal contamination were studied. The results indicate that the main elements (>1%) in the EAF slag were Ca, Si, Mg, Al, Fe, O, and Cr, existing as Ca_2SiO_4 and $Ca_3Mg(SiO_4)_2$, while the AOD slag was mainly composed of Ca, Si, Mg, C, and O, and the main minerals were Ca_2SiO_4, $CaCO_3$, and $Ca(OH)_2$. The slags were suitable for beneficial reuse. The leaching concentrations of heavy metals from the slags by the identification leaching tests for hazardous waste (GB5085.6-2007 and TCLP) were far lower than the related limit values for hazardous waste. Most of the heavy metals existed as stable speciation. The availability leaching test result shows that Cr could possibly leach out at the "worst scenario", but mainly as the less hazardous Cr(III), which was confirmed by the XRD analysis result.

Key words: Stainless steel slag; heavy metals; leaching; pollution risk

Sulphate and chromate aft solid solutions; characterization and thermodynamic modelling

Sabine Leisinger1, Barbara Lothenbach[2], Ralph Kägi[1], Frank Winnefeld[2], Bernhard Wehrli[1], C. Annette Johnson[1]

[1] *Swiss Federal Institute of Aquatic Science and Technology (Eawag), Switzerland*

[2] *Swiss Federal Laboratories for Materials Testing and Research (EMPA), Section Concrete and Construction Chemistry, Switzerland*

It is generally accepted that chromate incorporates in AFt and AFm phases in hydrated cement pastes and that these phases have a substantial uptake capacity. In the absence of a comprehensive understanding of binding mechanism and thus modelling capabilities, wet-chemical experiments have been carried out to assess CrO_4^{2-} uptake and leachability. The solubility of CrO_4^{2-} in equilibrated suspensions of crushed CrO_4^{2-}-doped cement pastes appears to be strongly related to the solid-phase CrO_4^{2-}-content, indicating either a sorption or solid solution binding mechanism. Given the uptake capacity, the latter mechanism is most likely. Perkins [1] was the first make a detailed investigation of the SO_4^{2-} / CrO_4^{2-}-AFt solid solution system but he was not able to complete the work. At present we are not in a position to predict solubility of CrO_4^{2-} in cementitious systems.

The aim of the research project is to determine the processes controlling the solubility of chromate in cementitious matrices in order to be able to predict porewater concentrations from solid-phase composition. In a first step solid solutions of CrO_4^{2-} and SO_4^{2-} -AFt have been prepared, characterized and thermodynamic stability ranges determined. Results will be investigated with chromate doped cements and their leachability will be predicted.

Solid solution phases with variable CrO_4^{2-} mole fractions ($XCrO_4$) for Cr0.3, 0.01, Cr0.001 and Cr0.0002 already exist. Additional synthesis of solid solutions will be made to determine possible miscibility gaps. The geochemical modelling code GEMS is used to calculate solubility products (Ksp) of solid solutions and stability ranges. Scanning electron microscopic investigations of the synthesised solid solution series show the typical needle-like habit with crystal lengths of 1 to 5μm. Crystals with higher $XCrO_4$ tend to be thinner and less crystalline. X-ray diffraction analysis identified the minerals to be AFt phases and the solid solutions differ in peak intensity and have small 2 theta shifts with respect to the pure Cr-ettringite. Unit cell volumes increase with increasing $XCrO_4$ because of the larger ionic radius of CrO_4^{2-} (2.4 Å) compared to that of SO_4^{2-} (2.3 Å). Characterization and thermodynamic solubility of the SO_4^{2-} / CrO_4^{2-} -AFt solid solutions system together with thermodynamic stability modelling will be shown.

Influences of Fe/Al minerals on the Leachability of Pb and Zn from Weathered Municipal Solid Waste Incineration Residues

Ruina ZHANG* and Takayuki SHIMAOKA**

** Shanghai Environment Group Company Limited, No.11, 345Lane, Shilong Rd., Shanghai 200232, China*
*** Department of Urban and Environmental Engineering, Faculty of Engineering, Kyushu University, 744, Motooka, Nishi-ku, Fukuoka city, 819-0395, Japan*

Key words: municipal solid waste incineration residues, landfill, heavy metals, leaching, chemical equilibrium calculation, LeachXS

INTRODUCTION

Research on leaching behavior of Pb and Zn from municipal solid waste incineration (MSWI) residues is very important, because these two heavy metals show not only high leaching concentrations from MSWI residues, but also have a strong influence to the environment. Some researches have identified amorphous Fe/Al minerals can prevent leaching of Pb and Zn from MSWI residues to a certain extent (e.g. Giehyeon Lee et al., 2002) and this also had been proved on a 20-year landfilled MSWI residues (e.g. Meima and Comans et al., 2006). However the chemical forms of Pb and Zn minerals in MSWI residues at different landfilled ages and landfill depths, the relations of leachability of Pb and Zn with the alterations of Fe/Al minerals have not been well known.

MATERIALS AND EXPERIMENTS

In this paper, landfilled MSWI residues were taken from the different depths at two landfill sites with bore sampling at several spots. One is a MSWI residues mono-landfill located in the northern part of the Unitead States and the other is MSWI residues co-landfilled with incombustible waste, which located in the southern part of Japan. The landfilled MSWI residues were taken from 0 to 5m landfill depth. Total composition, Japanese regulated leaching test (JLT46), and pH dependency leaching test were conducted. The contents of 17 elements such as Ca, Na, K, Mg, Fe, Al, Cu, Cd, Ni, Pb and Zn etc. in the leachates from leaching test were analyzed by ICP-AES or ICP- MS. Major anions such as Cl^-, SO_4^{2-} and PO_4^{3-} in the leachates were analyzed by ion chromatography and the organic contents in the leachates were anaylzed by TOC-analyzer. The analyzed data were calculated by a chemical

equilium caculation software of LeachXS to identify the major chemical forms which control solubility of elements under concern.

RESULTS AND CONCLUSIONS

From the chemical forms analysis of Fe /Al minerals, the amorphous Fe/Al firstly increased with landfilled age, however it showed a slowly decreasing trends afterwards. The decreasing of quantity of amorphous Fe/Al might indicate the recrystallization of Fe/Al minerals.

The identified Al minerals in the different age landfilled MSWI residues were $CaO(Al_2O_3)10H_2O$ in the fresh residues, after several years landfilling, the Al minerals were identified as combination of $CaO(Al_2O_3)10H_2O$, ettringite, and Zn layered double hydroxide. for the longest landfilled residues, gibbsite and ettringite were identified. The results also indicated a close correlation between the oxidation-reduction potential and the chemical forms of Al/Fe minerals. Leaching concentrations of Pb and Zn between pH 6 and 8 had a close correlations with quantity of amorphous Fe/Al minerals. In the studied landfilled MSWI residues, major solubility controlled minerals for Pb were cerrusite, hydcerrusite, $Pb(OH)_2$, $Pb_2(OH)_3Cl$, $Pb_3(VO_4)_2$, and $Pb_4(OH)_6SO_4$. Major solubility controll minerals for Zn were CaZincate, willemite, zincite, and $ZnSiO_3$.

Emissions flow study in Waelz slag recycling into ceramic process

N. Quijorna, R. Alonso-Santurde, A. Coz, J.R. Viguri, A. Andrés
Department of Chemical Engineering and Inorganic Chemistry. University of Cantabria, Spain

The use of waste or by-products inside productive cycles with thermal treatment allows the immobilization of pollutants, it avoids the depletion of natural resources and it is a sustainable alternative in front of land disposal. Bricks firing process is considered to be promising management option due to the involvement of low cost. On the basis of Industrial Ecology, the incorporation of the Waelz slag into ceramic products has been assessed in order to solve the problem related to the management of this by-product.
The aim of this work is the assessment of gaseous emissions: nitrogen oxide, carbon dioxide, water vapour and sulphur oxides, originated from the firing of the new ceramic products with Waelz slag and Waelz slag/Moulding sand mix which are affected by European legislation. For this purpose, the physico-chemical characterization of raw materials has been developed. Moreover, the potential release of N_2O, CO_2, H_2O emissions and SO_3 were estimated with a mass balance of elemental composition before and after the firing process. The results of this work prove that the introduction of Waelz slag or Waelz slag/Moulding sand mix not affect the N_2O emission, reduce CO_2 and H_2O and produce negative values of SO_3 in flue-gases could be due to both the atmosphere of the kiln and the high concentrations of CaO. The addition of Moulding sand into ceramic matrix increases the CO_2 emissions due to the carbon content in sand is higher than in Waelz slag.

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Topic 2:New concrete and cement-based materials

The use of fluidized ashes in the technology of autoclaved aerated concrete (AAC)

Katarzyna Łaskawiec, MSc.CE, *Research&Development Center for Concrete Industry "CEBET", Marywilska 42b, 03-042Warszawa, Poland*
Jan Małolepszy, Assoc. Prof., *AGH University of Science and Technology, Faculty of Materials Science and Ceramics, al. Mickiewicza 30, A3 p.307, 30-059 Kraków , Poland*
Genowefa Zapotoczna-Sytek, DSC CE., *Research&Development Center for Concrete Industry "CEBET", Marywilska 42b, 03-042Warszawa, Poland*

Changes in the power industry based on solid fuels, resulting from introducing different methods of the desulphurization of flue gases and energy from renewable sources result in producing fly ashes of a new generation. These ashes differ in physical-chemical properties from those, known and widely applied, from burning coal by traditional methods in dust boilers. So far, the fly ash technologies used in building materials industry in Poland and other countries were developed, in principle, for ashes generated by conventional combustion of coal in pulverized-fuel boilers. One of the building materials where fly ashes can be used effectively (up to 70%) is autoclaved aerated concrete (AAC). The technologies of production of AAC characterize by low raw materials and energy consumption in relation to technology of production of other building materials. These results come of low density of AAC as well as of suitably production process, being waste-free one and friendly for environment.
The paper presents a characteristic of fly ashes generated at burning coals in fluidized boilers (analysis of chemical and physical properties, and their phase composition). Possibility of the utilization of these ashes in production of AAC has been indicated, showing also feasible to achieve properties of such AAC.

Solidification/stabilisation of treated oil drill cuttings as sandcrete construction products

Babagana Mohammed and Christopher R. Cheeseman
Centre for Environmental Control and Waste Management,
Department of Civil and Environmental Engineering, Skempton Building,
Imperial College London, SW7 2AZ, United Kingdom

The extraction of oil and gas results in large quantities of oil drill cuttings (ODC), the disposal of which can have a significant environmental impact. ODC is a fine granular blend of minerals with residual hydrocarbon contamination and the management of ODC remains an issue. In Nigeria ODC are increasingly treated by low temperature thermal desorption, and in this work treated ODC have been used in the production of sandcrete construction blocks. These have been made using a sand to cement ratio of 12, with test samples prepared with the sand replaced by treated ODC. The density, water absorption, compressive strength and thermal conductivity of the blocks produced are reported. The work demonstrates the potential to beneficially reuse oil drill cuttings treated by thermal desorption to replace for up to 50% of the sand in sandcrete construction products.

Keywords: sandcrete; blocks; oil drill cuttings; waste reuse; Nigeria

The Feasibility Study of Manufacturing Eco- blocks cement by Using Marble Sludge as Raw Materials

Fakher J. Aukour
Faculty of Natural Resources and Environment, The Hashemite University, Zarqa-Jordan

This study evaluated preliminarily the feasibility of using marble sludge and cement materials in construction blocks by drying sludge and analyzing their physical and chemical characteristics. In addition, to enhance the amounts of sludge used, this study calculated and designed the mix of all kinds of sludge under different cement percentages and sludge usage to produce the eco - blocks. After that, the kinds of physical and chemical character of produced blocks were analyzed, and the microscopic observation of cement paste was analyzed to discuss the feasibility of ecocement and the effect of sludge addition on the properties of ecocement.
According to the experimental results, all of the sludge in this study contained more than 50% of ash, and had low content of heavy metal. Therefore, the sludge did not belong to hazardous waste and had positive effect on sintering cement. Additionally, the sludge and limestone material had the similarity leading to high potential for the sludge to substitute for cement material.
Moreover, because of the content of CaO in marble sludge was less than limestone and SiO_2 was more than that, the melting point in sintering cement would decreased when marble sludge replaced limestone partially. The compressive strength at age of 28 days only reached 20% of that in controlled limestone blocks. In contrast, the partial melting of clinker could be avoided when 50% of limestone was replaced by marble sludge. However, the content of CaO in clinker was insufficient and leaded C_2S to be formed primarily in cement. The experimental results and their theoretical interpretation show that suitable incorporation of marble sludge can result in building blocks of 15 cm with superior properties, in terms of water absorption (7%). The compressive strength at age of 28 days reached (195.8 KN or 7.8 N/mm2). Sludge incorporation had negligible effect on density, shrinkage and plasticity during all stages of production process, anticipating some modifications in the industrial production line.

Technical and ecological compatibility of the secondary aluminium slags with portland cement matrix

Maria Gheorghe[1,] Nastasia Saca[1], Lidia Radu[1], Romanița Teodorescu[2] and Maria Roman[2]
[1] *Technical University of Civil Engineering of Bucharest, Romania*
122-124 Lacul Tei B-ld, Sector 2, RO-020396, Bucharest, Romania,
[2] *R&D National Institute for Nonferrous And Rare Metals 102 Biruinței B-ld, Com. Pantelimon, S.A. Ilfov, Romania*

The purpose of this work is to investigate the secondary Al slag (SAS) relating to its technical and environmental properties and, as consequence, to its compatibility with Portland cement matrix.

The DRX mineralogical analyses revealed that SAS includes transition alumina compounds, especial boehmite. The hydration process evolution and the hydration products nature in the Portland cement-SAS systems were studied by measurement of the Ca^{2+} concentrations and by DRX investigation. Also, was studied the compatibility of the Portland cement matrix with the SAS, concretized by its ability to immobilize heavy metals contained of SAS. The heavy metals immobilization was measured by MAF leaching test.

Mixes of Cement: Sand: SAS with various substitution ratios of sand by SAS are carried out. SAS accelerates setting of cement pastes and decreases compression strengths of mortars. Treated SAS by washing causes a positive evolution of the mortars compression strengths up to 360 days.

The use of SAS as SRM in the concretes with low mechanical resistance - masonry blocks, road infrastructure -, can reduce the amount of secondary Al wastes and may contribute to environmental preservation.

The researches of the SAS valorization as SRM, as partially substitute of sand and cement, in mortars or concretes are just recently and don't content relevant experimental data referring to long term prediction of mechanical strengths and durability.

The paper aim is to contribute to finding of adequate solutions, of technical and ecological point of view, for SAS valorization as - aggregate and cement substitute into low mechanical strengths concrete.

The study of the physico mechanical behaviour of a concrete with limestone sand renforced by synthetic fibers

Bendjillali Khadra[1], Goual M.Sayeh[1], Chemrouk Mohamed[2], Damene Zineb[1]

[1] *Laboratory of Civil Engineering, University Amar Telidji, Laghouat, Algeria.*
[2] *Department of Civil Engineering, USTHB, Algiers-Algeria*

Laghouat region (situated in the south Algeria) is among the parts of Algeria which have a large natural limestone deposit, which extends over the totality of the southern side of the Saharan Atlas. The exploitation of this material in the industry of coarse aggregates generates significant amounts of fine residues, currently badly or less exploited and meanwhile causes harm to the environment. In order to valorise this waste material and met the environmental requirements, the idea is to exploit these residues as limestone fine aggregate for concrete. Beside for enhancing the mechanical properties of concrete and exploit polypropylene fibres wastes resulting from the industry of brushes and sweep domestic, we decide to incorporate them in the limestone mortar.
The study of the physical and mechanical properties of the limestone mortars reinforced by polypropylene fibres are presented in this article, with fibre content percentage varies between 0.5 and 4 wt%. In view of results obtained, we advance that the workability of limestone mortars is inversely influenced by the percentage content and the ratio l/d of polypropylene fibre, while their mechanical properties are generally enhanced.

Key-words: Valorisation, Limestone Sand, Fibre, Reinforced Concrete, workability, Mechanical proprieties.

Physicomecanical and thermal properties of clayey cellular concretes to basis of clayey by products

M. S. Goual[1], I.Goual[1], Z. Damene[1], A. Bali[2], M. Quéneudec[3]
[1] *Laboratoire de Génie Civil, Université de Laghouat, B.P 37G, 03000, Algérie*
[2] *Laboratoire de Construction et Environnement, Ecole Nationale Polytechnique, Alger-Algérie*
[3] *Laboratoire des technologies innovantes, Université Jules Vernes, Amiens- France*

The natural sand is one of the main components of the concretes. In some regions, the deposits of natural sand risk to exhaust or to involve very elevated costs due to the transportation cost or the restrictions relative to the environment protection. In the west of France, for example, the deposits of fossil sailors sand of the tertiary end era have been very solicited and are about to be exhausted. It conducts to exploit the more and more clayey sands and the wastes of exploitation constitute therefore more and more important quantities. In the aim of enhancing the reuse of clayey by-products, the notion of their transformation into building materials and especially thermal insulation building materials becomes very attractive not just from economic perspective but from an environmental one as well. Such objectives have led to developing Clayey Cellular Concretes (CCC) by means of expanding a clay–cement paste through adding a small quantity of aluminium powder during mixing. These concretes are composed of clayey type kaolinites stabilised with a small quantity of cement. In general, cellular concretes are manufactured using an autoclaving process along the lines of

Autoclaved Aerated Concrete AAC, yet this process remains very costly due to the need for an autoclave and the high energy consumption involved. Clayey Cellular Concretes however are produced at room temperature and without any autoclaving.
A series of six mixes with varying porosities has been elaborated and examined herein. Mercury intrusion porosimetry analysis shows that CCC materials exhibit dual porosity: a microporosity localised essentially in the clay–cement matrix and a macroporosity dispersed within the matrix in form of gaseous cells, as produced by chemical reaction with the aluminium powder.
The objective of the present work is to present the experimental results of the mechanical and thermal properties of various compositions of CCC. A theoretical models for predicting compressive strength and thermal conductivity of clayey cellular concretes as function of porosity has also examined.
Experimental results shows the potentiality of the use of clayey by products in the development of insulating or bearing and insulating building materials with a few manufacturing cost.

Key words: Valorisation, Clayey wastes, Lightweight concrete, Cellular concrete, compressive strength, thermal conductivity, thermal diffusivity, porosity

Design and performance of masonry mortars manufactured with recycled aggregates from concrete debris

M.Errasti[1], I. Vegas[1], I. Azkarate[2], A.Lisbona[1]
[1] LABEIN-Tecnalia, Derio, España
[2] MORTEROS Y REVOCOS BIKAIN, S.A., Mañaria-Bizkaia, España

The present paper presents and discusses the technical viability in the utilisation of the fine fraction of recycled aggregates originated from concrete debris obtained from the manufacture of masonry mortars containing cement as binder.
Initially, chemical and physical-mechanical characterisations for the fine fraction of recycled aggregates were carried out. Results showed limitations in the use of this aggregate in masonry mortars because its high absorption capacity and high sulphate content in comparison with natural sand. Similarly to the recommendations for structural concrete, this study focuses on the utilisation of mixtures of natural and recycled aggregates in the manufacture of masonry mortars.
From the dosage study and testing of mortars elaborated with recycled concrete aggregates, it can be established that cement-based masonry mortars can incorporate up to 25% of recycled aggregate without significant losses on its performance. The design of cement-based mortar with 25% of recycled sand replacing natural sand needs neither new additives nor more quantity of cement.
Keywords: recycled concrete debris, masonry mortars, mechanical performance

Application of nano-technology to improve green concrete (mechanical and microstructural properties)

P.Hosseini[1], A.Boushehrain[1], M.M.Khodavirdi Zanjani[2], M.Delkash[1], S.Ghavami[1]
1- Department of Civil Engineering, Sharif University of Technology, Tehran, Iran.
2- Ati Saz Constrution Co. Tehran, Iran

The purpose of this paper is providing new type of recycled aggregate concrete (RAC) incorporating nano-SiO2. The reuse of debris from building demolition is one of increasing public interests because it decreases the volume of material to be disposed to landfill. In addition, nanotechnology has changed and will continue to change our vision, expectations and abilities to control the material world. These developments will definitely affect construction and also the field of construction materials. The objective of the research was to investigate the effects of colloidal nano-silica solution on the

properties of fresh and hardened concrete. The main variables included the dosage of nano-silica (0%, 1.5%, and 3% of cement content) and the cement content of concrete (350, 400 and 450 kg/m3). Results were compared with plain concretes. Tests were conducted to determine the physical properties, mechanical (compressive strength) and micro structural properties of concretes (SEM test). The experimental results are presented in different related graphs and tables.

Keywords: recycled aggregate concretes, nano-silica, mechanical properties, microstructure.

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Topic 2: MSWI bottom ash

Production and beneficial reuse of MSWI bottom ash in China

Hua Zhang, Pin-Jing He, Li-Ming Shao

State Key Laboratory of Pollution Control & Resources Reuse, College of Environmental Science and Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, P.R. China

With the increase of municipal solid waste incineration (MSWI) plants constructed in China in recent years, great attention has been paid to management of MSWI residues. In 2007, about 3.87 million tons of bottom ash was produced in China, posing an urgent requirement for environmentally-sound treatment and beneficial reuse. The mechanical properties of MSWI bottom ash have been reported to be similar to those of natural aggregates, and heavy metals in bottom ash are usually far less leachable than those in air pollution control residues. Therefore, it presents a good prospect for beneficial reuse as aggregate or other construction material.

The production and current status of treatment, disposal and beneficial reuse of bottom ash in China were introduced in this paper. Based on the characteristics of the bottom ash, the utilization of bottom ash and its challenges were discussed. Based on which, a typical pretreatment process was presented to produce bottom ash as aggregates, including magnetic separation of iron, size grading using screening and size reduction, eddy current separation of non-ferrous metals, and air separation of light substances. The successful application practice of the aggregate products in paving brick for sidewalk (road construction) in Shanghai was demonstrated.

Key words: Municipal solid waste incineration, bottom ash, heavy metals, paving brick, beneficial reuse

The use of MSWI-bottom ash as aggregate in concrete – limitations and possible solutions

Peter Nielsen[a], Mieke Quaghebeur[a], Ben Laenen[a], Raymond Kumps[a], Peter Van Bommel[c]
[a]*VITO - Flemish Institute for Technological Research.- Boeretang 200, 2400 Mol, Belgium.*

The reuse of bottom ash (BA) from municipal solid waste incineration (MSWI) is mainly restricted to unbound aggregate applications. BA, however, has the potential to be used in high value applications. It can for example be used as hydraulic bound aggregate in concrete to replace gravel. Its use in concrete is controlled by environmental requirements (the concentration and leaching of heavy metals must not exceed regulatory limits) and technical specifications. The main bottleneck at the moment is the presence of reactive constituents, such as glass and ferrous and non-ferrous metal particles, which can be detrimental to the quality of concrete made with BA aggregate. The most prominent reaction observed in concrete made with BA aggregate is the formation of pop-outs. Pop-outs are a common

surface defect in concrete, which appear when aggregates in or at the surface of the concrete expand, and break free from the concrete surface.
In this study, the mechanism as well as the factors controlling pop-outs caused by the reuse of BA aggregate in concrete are examined. The expansion of Al particles was identified as the main cause for pop-out formation in concrete. Thus in order to increase the value of bottom ash for the concrete industry it is necessary to remove or reduce the reactivity of the non-ferrous metals from the bottom ash prior to utilization. The removal of non-ferrous metal particles from BA aggregate of 2-6 mm was in this study accomplished by industrial Eddy Current separators from different manufacturers. The recovery rate of the metallic aluminium was highly variable, ranging from approximately 30 % to more than 85 %. In addition ageing of BA was investigated as a tool to reduce the reactivity of the metallic aluminium in the BA. The influence of temperature, moisture content and pCO_2 on the remaining metallic aluminium content during ageing of the BA aggregate was investigated in controlled lab experiments. Aged bottom ashes are generally characterised by a pH below 9. At this pH level aluminium oxides and hydroxides are relatively stable.
An evaluation was made of the maximum amount of metallic aluminium that may be present in BA aggregate for a safe reuse in concrete. This evaluation was linked to other controlling factors, such as grain size of the aluminium particles. Pilot-scale production of concrete blocks made with BA aggregate (2-6 mm) from which the non-ferrous metals had been removed was accomplished to evaluate the performance of the blocks. The concrete blocks were also exposed to accelerated ageing tests to evaluate the long term durability of the blocks.

An investigation of RDF bottom ash activation for blended cement formulation

R. Onori, A. Polettini, R. Pomi
Department of Hydraulics, Transportation and Roads - University of Rome "La Sapienza", Rome, Italy

In the present study the feasibility of chemical and mechanical activation to improve the reactivity of incinerator bottom ash in Portland cement mixtures was investigated. Three chemical activators, NaOH, KOH and $CaCl_2$, were selected for the experimental campaign on the basis of the results from previous studies. The experiments were arranged according to a full factorial design of three factors - "bottom ash content", "activator type" and "activator dosage" - set at 2, 3 and 2 levels, respectively. The evolution of mechanical strength and the leaching behavior of activated bottom ash/Portland cement mixtures was a matter of major concern in this study. The results indicated that $CaCl_2$ exhibited by far the best effects on the evolution of the hydration process of the mixtures and metal leaching from the hardened material. As for the other activators used, while an improvement in the mechanical properties was still recognizable when KOH was added to the mixtures, no positive effect could be observed in the presence of NaOH. This study provides some promising indications about the feasibility of incinerator bottom ash utilization for the formulation of blended cements, which however will need to be further assessed through a deeper insight into the mechanisms governing the development of mechanical strength in cementitious systems containing bottom ash.

Influence of Sulfate on Reusing MSWI Ash in Eco-cement Production

Pai-Haung Shih, Li-Choung Chiang, Yi-Kuo Chang
Department of Environmental Engineering and Science
Fooyin University
151, Chinhsueh Rd., Ta-liao
Kaohsiung, Taiwan

In this study, municipal solid waste incineration (MSWI) ashes were pretreated and reused as alternative cement raw materials. Ashes from MSW incineration plant in southern Taiwan were sampled, pretreated and mixed according to three compositional equations. Additives are blended into the MSWI ashes in the fashion that values of compositional factors fall in the range of modern

clinkers. Sintered clinkers were analyzed with XRD technique. The interference of sulfate in MSWI ashes were investigated according to the relative intensity to reference (RIR) technique.
Results from the X-ray diffraction of clinkers show that sulfate in raw mixes would generally form gypsum in elevated temperature. Gypsum would further hinder the formation of tricalcium silicate. Formation mechanisms of gypsum depend upon the sulfate species added. In case of sodium sulfate (soluble form of sulfate) added, sodium sulfate would react with calcium aluminate or extra calcium oxide and transform to gypsum. Decrease in the intensity of calcium oxide and aluminate phases and formation of gypsum phases could be observed. In case of calcium sulfate (insoluble form of sulfate) added, the calcium sulfate would directly transform into γ-$CaSO_4$ (gypsum) phase in elevated temperature without taking up extra calcium oxide during the firing process.
RIR results further identify the above observation that C_3S would not be affected until calcium sulfate added amount increased to 3.5%. On the other hand, with 1% of sodium sulfate addition would seriously inhibit the formation of C_3S; the amount of C_3S would drop to 60% relative to ordinary Portland cement (OPC). In comparison with C_3S, β-C_2S phases are more resistance to large amount sulfate addition in elevated temperature. Regardless of sodium sulfate addition increases to 6%, amount of C_2S remains 49%.
With MSWI ash, RIR of C_3S and β-C_2S are 57.55% and 77.11% when the sulfate amount in the fly ash (FA)/bottom ash (BA) formulated raw mix is 3.65%. When the sulfate amount exceeds 3.65%, C_3S starts to decrease. Formation of β-C_2S is not affected until the sulfate amount exceeds 5.2%. Comparing the sulfate content in FA and BA, it is found that the weight percentage of soluble sulfate in FA is much higher than BA due to formation mechanism in municipal solid waste incinerator. Soluble sulfate content consume calcium oxide which C_3S needed during the process of gypsum formation at elevated temperature. Therefore, the BA raw mixes might have higher sulfate tolerance level than the other MSWI ash.

Keywords: MSWI ash, eco-cement, sulfate, sintering, RIR.

Quality improvement of MSWI bottom ash: possibilities of input management

Jaap Steketee, *Tauw bv, PO box 133, 7400 AC Deventer, the Netherlands*
Michiel Timmerije & Jan van Aalten, *AVR Afvalverwerking bv, PO box 147, 6920 AC Duiven, the Netherlands*

MSWI bottom ash is the most important residue of waste incineration. From a civil engineering viewpoint the material is suitable as a building material, e.g. for road embankments. However, the relatively high leaching of some heavy metals and salts restrict the use of the material. Therefore quality improvement is desirable, also to minimize future risks.
Nowadays, quality improvement is almost always achieved by after treatment of the material. Input management is quit a different approach. With input management it may be possible to exclude highly contaminated waste streams, to optimize the input from the viewpoint of macro composition and to assure a good conversion of the organic matter.
The possibilities for input management were explored by full scale incineration experiments. Three different types of waste were burned in a grate furnace: (1) Waste from industries and sorting plants; (2) Household waste and (3) A mix of commercial waste (offices, shops et cetera) and household waste.
During the experiments, bottom ash and fly ash were sampled. In the laboratory, composition, leaching, availability and speciation of DOC, levels of iron and aluminium (hydr)oxides and buffer capacity were investigated.
Analysis of the bottom ash shows that commercial waste contains the highest amounts of antimony and sulphur. At pH values which simulate aged material (pH 8,5), the leaching of antimony and sulphate is also at its maximum for this bottom ash. The amount of unburned organic matter and DOC is highest in the experiment with household waste. This DOC also contains the highest amounts of fulvic and humic acids and not surprising, the copper leaching of the bottom ash from this experiment also shows the maximum value of the three experiments. Furthermore, residues from household waste show increased chloride leaching.

Regarding the concentrations of iron and aluminium oxides it is clear that the bottom ash from household waste contains the highest amounts of aluminium oxides and amorphous aluminium silicates. The amounts of iron oxides differ not much.
The main conclusions from these experiments are:

1. It is possible to identify waste streams which contain high amounts of (potential) leachable contaminants
2. From a geochemical point of view, burning a mix of waste produces a better bottom ash than burning specific waste streams like industrial or household waste. Some waste streams contain or produce more beneficial components like iron and aluminium (hydr)oxides than others and also a more stable and complete conversion of organic matter can be reached if a mix of waste is burned.

Artificial Aggregate Made by Cementitious Granulation of Waste Incinerator Bottom Fly Ash

Raffaele Cioffi[1], Francesco Colangelo[1], Fabio Montagnaro[2] and Luciano Santoro[2]
[1]*Dipartimento per le Tecnologie, Università di Napoli Parthenope, Centro Direzionale Is. C4, 80143 Naples, Italy*
[2]*Dipartimento di Chimica, Università di Napoli Federico II, Complesso Universitario Monte S. Angelo, 80126 Naples, Italy*

In the last few years the use of aggregates in the different fields of civil engineering has been steadily growing. As a consequence, the resulting environmental impact is an issue that must be faced to have sustainable development in all the fields of civil engineering. The replacement (at least partial) of natural aggregates with artificial ones can help solve the above problem and also can address waste management towards matter recovery. This possibility is of great importance in the light of the increasingly high availability of industrial solid wastes, marine and lake sediments as well as construction and demolition wastes. So, it is not surprising that many papers can be found in the literature on the replacement of natural aggregate with unprocessed wastes from several different sources. However, artificial aggregate of improved technological and leaching properties can be manufactured from re-processed wastes according to specific treatments that can be of different type depending on the nature of the waste and on the characteristics of the desired product. Specifically, the waste properties that can be of concern are the physical nature (homogenous, heterogeneous, monolithic, granular, sludge), the structure (amorphous, crystalline, compact, porous), the chemical composition and the compatibility with binding matrices. On the other hand, the characteristics of the desired product that are of concern are those linked to the specific use the aggregate is intended for. Artificial aggregates can be manufactured by means of two types of processes: cement-based granulation and high temperature sintering. Of these, the latter has been widely studied and the pertinent literature is rich of applications in which many waste materials proved to have potential for use as feedstock: bottom and fly ashes from combustors and municipal solid waste incinerators, metallurgical slags, dust from furnace, mine and quarry tailings, sediments, shredder waste, etc.. On the other hand, although cement-based granulation processes have not yet been studied equally deeply, their suitability for the manufacture of artificial aggregates is undoubtedly worthy of consideration. First of all, it is well known that the treatment of wastes (often hazardous) largely relies on cement-based stabilization/solidification processes which allow safer disposal and/or matter recovery for the manufacture of building materials. Furthermore, the application of such processes has economical and environmental advantages due to the reduced energy requirement (process carried out at ordinary temperature) and the lack of secondary pollution (no gaseous emission is involved). As previously pointed out, cement-based processes can be equally well addressed towards safer disposal of the waste or matter recovery for the manufacture of building materials inasmuch as their twofold aim is to reduce the pollutants mobility and form monolithic products. The occurrence of physical and chemical stabilization/solidification mechanisms is necessary to warrant treatment effectiveness. Under this point of view, it is useful to outline that cement-based processes have high potential and flexibility so that safer disposal may be favored in respect to matter recovery or vice versa depending on the optimization of the numerous variables that affect the same processes. In fact, the main operating conditions that can be optimized are: the binding matrix composition in respect to waste nature and

composition, the waste/binder ratio, the time and temperature of curing, the use of specific additives and so on. More specifically, in addition to ordinary Portland cement and other established binders, alternative and innovative matrices have been successfully employed in many cases. These alternative and innovative matrices can be obtained from industrial wastes such as coal fly ash, blast furnace slag, chemical gypsums. The waste employed in this work comes from an incineration plant in which municipal, hospital and industrial wastes are treated. The plant is equipped with rotary and stoker furnaces and both bottom ash samples coming from these two equipments have been individually employed. This work reports the results of an extensive investigation on stabilization/solidification of the above ash samples by addition of hydraulic binders in a granulation equipment. A rotary plate granulator was used with binders based on cement and coal fly ash. Granulation was carried out with several mixes in which the ash content was up to 70%. In some cases, the granules obtained in this way are suited for matter recovery by reusing the waste for the manufacture of building materials. The possibility to get matter recovery from incinerator ash is a crucial issue for making the granulation process environmentally and economically sound. In fact, the most direct application of granules is in the field of artificial aggregates for road construction and concrete manufacture. The granules obtained from the treatment of bottom ash samples have been tested to assess their physico-mechanical and leaching properties. Specifically, measurements have been carried out regarding the following properties: density, water adsorption capacity, compressive (crushing) strength, Los Angles coefficient and leaching behavior. Moreover, concrete mixes have been prepared with some of the artificial aggregates made by granulation. Once hardened, these mixes have been successfully tested from the technological point of view, proving to be suitable for the manufacture of classified concrete blocks.

Undisturbed sampling and material characterisation of a MSWI bottom ash sub base layer

Karl-Johan Loorents, *Swedish Road Administration*
Paul Frogner-Kockum, *Swedish Geotechnical Institute*
Jan-Erik Lindqvist, *CBI Betonginstitutet*

Although recycling technology has now been used for many years, there are still (*technical)* issues that need to be studied in further detail; one of the more important issues are the technical and environmental long-term performance of recyclates. Today, it is not possible to predict the future long-term properties of recyclates with regard to durability and leaching. Material properties for a wide range of recyclates are not constant over the full service life. In the short time they will change during manufacture, transport and laying. In the long term, they will change under the combined effects of loading conditions, ageing, climate and additives (e.g. de-icing products). Research has so far been devoted to mechanical or environmental properties, each evolving separately. It has been shown that recyclates are generally more sensitive to degradation and more prone to leaching than natural aggregates normally used.
The prime technical factors influencing use in roads are stiffness and stability, which are determined by material properties as particle/aggregate size and microstructure. Characterisation of the macro and micro structure are of prime interest as secondary alteration is a key process. Long term changes in this context is considered to correlates with a road construction's technical service life, e.g. for an unbound application up to 40 years. It is therefore understood that to quantifying changes taking place in situ in a road, a sampling technique that acknowledge undisturbed samples are of uttermost importance in order to acquiring microstructural characteristics.
In this study, the objective for sampling is a municipal road holding a 500 meter long test section. Traffic load is estimated to 400 vehicles each day with a low number of heavy traffic. A typical urban section characterise the test road; levelled by shoulders (no inslopes) with a drainage system (inlets and pipe sewers) running beneath and along the outside of the shoulders. The MSWI-bottom ash test section comprises a 60 m long segment of the test road; other segments have been constructed using structural layers of brick and crushed concrete. The pavement design of the sampled section consist of a 130 mm surface course (surface layer and a bitumen bound base), followed by a 150 mm unbound base course (crushed granite), and then a 465 mm unbound sub-base (MSWI bottom ash). The soil subgrade consists of a clayey till.

The objective of the sampling was to obtain samples of no or a very low degree of disturbance to the application's in-situ properties. A stabilizing procedure was chosen using epoxy glue, a coating of wire net and a gypsum plaster resulting in undisturbed block sample of the MSWI bottom ash sub-base layer. Access to the sub-base was achieved by removing the surface course and unbound base course, leaving the top surface of the unbound sub-base reachable. A narrow ditch was dug from the midpoint to the shoulder of road section through the unbound sub-base, to give access to the full height of the application. Due to the good cohesion of the material, two pillars of an approximate size of 500 x 300 x 460 mm were cleared by hand using smaller hand spades. The pillars were stabilized by hand brushing of epoxy glue on to the surfaces, and subsequently placing wire net on to all exposed surfaces, leaving the bottom un-coated from the start. A thick coating of gypsum plaster was put on to the wire net to stabilize the sample. After hardening of the gypsum plaster the pillars were tip over. The tip over was done in order to be able to put additional epoxy glue, wire net and gypsum plaster onto to the now free bottom surface to finalize the coating and stabilization work. Sampling provided stabilized pillars of bottom ash, mainly with no or a very low degree of disturbance.
Prior to laboratory preparation the sample body was further stabilized by freezing. The frozen sample was cut into slabs, displaying a cross section of almost the full height of the sub-base layer. Sample pieces were further prepared by cutting and grinding into sizes required for further analysis. One of the samples was put in a freezing cabinet with -25^{o}C for about one month. After that three about 5 cm thick were dry sawed with a diamond saw from the sample. The area of the slabs covers almost the full cross section of the sample. The sawed surface of the remaining sample was sealed with epoxy. The sawed slabs were put on a sand bed and vacuum dried and subsequently vacuum impregnated with epoxy with fluorescent dye. The impregnated slabs were glued to a glass slice and plane polished. This resulted in an epoxy impregnated flat polished slab with a size close to that of the depth of the bottom ash were the undisturbed ash could be studied from micro to decimetre scale. Laboratory preparation provided slabs of such a high quality (low degree of disturbance) that macroscopic textural analysis together with material analysis of the application was feasible.
The plane polished samples were analysed regarding to their composition and micro textural characteristics. The composition was determined by a point counting technique by use of a stereoscopic microscope, and constituent materials were categorised into 9 groups. Furthermore the slabs were also used for a macro/micro textural characterisation of the MSWI bottom ash sub-base layer. The characterisation was based on a mapping of high resolution micro photos of the slabs. Analysis's show a homogeneous structure with no marked differences between top, mid or bottom section of the application. Furthermore no zones of in situ alteration or weathering layers were detected, indicating an unaltered technical functionality of the sub base layer.

Gas adsorption capacity of Municipal Solid Waste Incineration Bottom Ashes based materials

Le Coq Laurence[1], Navarro Stéphanie[2] and Grellier Solenne[2]

[1] *GEPEA, Ecole des Mines de Nantes, CNRS, UMR 6144, 4 rue A. Kastler, BP 20277, 44307 Nantes Cedex 3, France*

[2] *CRPE, Environmental Services Research Center, Veolia Environnement, Zone Portuaire de Limay, 291 avenue Dreyfous Ducas, 78520 Limay, France*

In order to deepen the knowledge on MSWI BA (Municipal Solid Waste Incineration Bottom Ashes) properties, a study has been focused on gas adsorption capacities of MSWI BA. Tests have been carried out on two materials based mostly on MSWI BA: physico-chemical characterisation (based on the elemental and chemical compositions, scanning electron microscopy coupled to energy dispersive X-ray spectrometry, porosity determination and surface pH), gas adsorption isotherms and kinetics performed in a static reactor, and gas breakthrough test in fixed bed reactor.
The first stage of physico-chemical characterisation showed similar results for both materials in terms of average porosity properties, chemical composition and surface pH. The results of this first characterisation highlight the adsorption possibilities towards acid gas for the studied materials. Thus the reactor studies will focus on one acid gas: H_2S. The adsorption isotherms and kinetics in static reactors allow determining removal performances of H_2S under the influence of various parameters:

air humidity, gas composition, sample moisture. They show 1) a great influence of the global moisture (air humidity but mostly sample moisture) on H_2S adsorption for both samples; 2) adsorption capacity similar to the one of some activated carbons but with necessary contact time much longer; 3) and confirm that there is no competition between CH_4 and H_2S adsorption. The breakthrough test shows: 1) a very high purification efficiency from the beginning and all along the test; 2) but some residual H_2S concentration still existing at the outlet of the gas treatment process indicating that the fixed bed thickness must be increased.
Thus this study highlights the good performances of MSWI BA-based materials to adsorb acid gas (especially H_2S) considering long enough contact time and in presence of humidity in the material to allow chemisorptions.

Thursday June 4, 2009

Topic 2: New developments in Civil Engineering

Study of consolidation of soil by the Olive Mill Wastewater

Tyouri M.[1], Elbouardi A.[1], Manal A.[2], Kellati N.[1], Ezbakhe H.[1].

[1]Energetic Laboratory, Thermal, Solar Energy and Environment Team
Abdelmalek Essaadi University, Faculty of Sciences, Tétouan, Morocco
[2]Public Laboratory of Tries and Studies, Casablanca, Morocco

Abstract: In this paper, we try to valorize the Olive Mill Wastewater in civil engineering; these sewages of olive oil are rich in polyphénols. Olive Mill Wastewater treated by thermal way are characterized and use in the stabilization of different types of soils.
We started with the characterization and the classification of different soils in many regions in the Morocco, where the production of the Olive Mill Wastewater is enormous.
In this study of consolidation, we measure the axial distortion of test-tubes according to the time, under a constant load for the different types of soils. The determination of the values consolidation coefficients are to value by the Casagrande's and Taylor's methods.
The experimental results show that the utilization of the Olive Mill Wastewater in the consolidation of soils is an encouraging solution for the realization of tracks in farming middle.
Key words: Soil, Olive Mill Wastewater, Consolidation of soils, Agricultural track.

New Development of cement-based matrices for the safe disposal of heavy metal: Cadmium and Cesium

S. Goñi[a], A. Guerrero, M.P. Lorenzo[b] and J. Ibañez[c]

a. Instituto de Ciencias de la Construcción "Eduardo Torroja" (CSIC). Unidad Asociada NANOC
C/ Serrano Galvache, 4, 28033 Madrid, España.
b. Facultad de Farmacia. Universidad de San Pablo (CEU). Campus de Montepríncipe. Urbanización Montepríncipe. 28668 Boadilla del Monte, Madrid, España.
c. Fundación Labein-Unidad Asociada NANOC
C/ Geldo. Vizcaya

An innovative multicomponent matrix for immobilizing cadmium and caesium is presented in this work. The matrix formulation included the use of fly ash belite cement (FABC), nanoadditions and zeolite NaP gismondine type, which is synthesized from type F coal fly ash. The design of this innovative matrix allows using a high relation simulated liquid waste to solid matrix. The integrity of matrices and the effect of the high ratio waste/solid, was evaluated by X-ray diffraction analysis and

surface area by BET-N_2, pore-size distribution and nanoporosity by adsorption isotherms of nitrogen. Matrices with 100% of FABC will be used as a reference. Besides, this innovative matrix has an important impact social and environmental, since the cement employed in the formulation of the matrix is a low CO_2-content and low hydration heat. Also, the cement and zeolite were synthesized in our laboratory by a ecoefficient process and we used as raw materials industrial by-products such as coal fly ash, which means a contribution from the waste management point of view, to its elimination and elimination of the related landfills, to the preservation of natural resources and to the by-product revalorisation by incorporation in the marked.

Production of lightweight aggregate from industrial waste and carbon dioxide

P.J.Gunning*, C.D.Hills, P.J.Carey
Carbon8 Contracting Ltd, Medway Enterprise Hub, University of Greenwich, Chatham Maritime, United Kingdom

The present work discusses the use of a novel technique to produce synthetic construction materials from industrial waste and carbon dioxide gas. Accelerated carbonation is a process which allows conversion of gaseous carbon dioxide into solid calcium carbonate through reaction with reactive phases in industrial thermal residues. The carbonate can be used a cement to bind grains of waste together to form pellets or aggregates which can be used as aggregate substitutes in concrete, horticultural and filtration applications.
Increasing demand for aggregate in the UK is contrasted by rising taxation upon the use of virgin materials. Similarly, disposal of waste to landfill is subjected to rising taxation and environmental pressure. These issues must be mitigated by the use of recycled materials derived from waste. As such, treatment by accelerated carbonation facilitates the re-use of industrial wastes by reconstituting them into an artificial aggregate.
Aggregates can be manufactured from a broad range of industrial wastes. Trials were conducted with bauxite, biomass ashes, metal dusts, municipal incineration ashes, paper ashes, pulverized fuel ash, quarry fines, steel waste and sewage sludge ash. The wastes were tested for reactivity with carbon dioxide. Paper ashes, biomass ashes and municipal ashes were found to be highly reactive, and were pelletised without additional binder. The poorly reactive wastes were mixed with Portland cement and pelletised. Reactivity is attributed to the crystalline phase compositions of the wastes.
The pellets conform to the 1200kg/m^3 maximum bulk density for lightweight aggregate (LWA) specified by British Standard. Specification for lightweight aggregate is limited, and two commercial LWAs are tested alongside the manufactured pellets for comparison. Compressive strength of the pellets is highly variable, and in accordance with previous research, may be attributed to the physio-mechanical properties of the waste materials including particle size distribution and particle shape. Pellets with strengths exceeding the commercial LWAs can be manufactured from bauxite, biomass ash, clinical ash, paper ash and quarry fines. Low strength pellets with poor durability are formed from pulverised fuel ash, sewage incineration ash, steel sludge and wood ash.

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Topic 3:Demolition/construction wastes

The Disposal of Construction & Demolition Waste from a Large Project in a Small Island Developing State

Prof Timothy Michael Lewis, PhD
The University of the West Indies, St Augustine, Trinidad & Tobago

The issues facing small island developing states (SIDS) are different in both scale and quality from those faced by larger countries and by developed countries. Lack of physical space limits the possibilites for land fill disposal of wastes, and the danger of contaminating the water-table or valuable

coastal sites restricts disposal further. The construction industry internationally is responsible for a large proportion of the solid waste generated by a country and in Trinidad & Tobago the industry has recently been experiencing a period of very significant growth and as a result is faced with the need to manage its wastes more effectively. Local contractors and sub-contractors to a large extent have been very casual about waste disposal but the presence of foreign consultants and contractors has made them more conscious of their practices. An analysis of the cost of waste disposal suggests that it is of the order of 0.5% of the total project cost. It is suggested that a worthwhile proportion of this could be recovered.

Construction and demolition wastes: applications, innovations and limitations of recycled aggregates in brazil

Rembiski, Fabrícia *D. Architect. Master Student in Civil Engineering at Federal University of Espírito Santo (PPGEC-UFES), CAPES (Masters Scholarship). Montevidel St. 254, Araçás. Vila Velha (ES). 29103-025. Brazil*
Calmon, João L. *Civil Engineering. Professor Doctor Ingeniero. Pos-Graduation Program in Civil Engineering at Federal University of Espírito Santo (PPGEC-UFES). Fernando Ferrari St., Goiabeiras. Vitória (ES). 29060-970. Brazil.*
Pinto, Miriam M. *Chemical Professor Doctor in Engineering Production. Pos-Graduation Program in Economy at Federal University of Espírito Santo (PPGE – UFES). Fernando Ferrari St., CT IV, Room 11,Goiabeiras. Vitória (ES). 29060-720. Brazil.*

This research is part of an ongoing Master's thesis that aims to propose a set of guidelines to incorporate the recycled aggregates (RA) of construction and demolition wastes (CDW) such as raw material in the Civil Construction Industry (CCI). This paper presents the state of the art of RA in Brazil, reporting its mains applications as building material and raw material, as well as its limitations and its potential for upcoming use. The methodology was based on literature review of technical reports, research papers, dissertation and thesis from Brazilian researches, which structured the guidelines and recommendations that were proposed for the development of this new sustainable construction material. As part of the results, it is presented the current scenario and some characteristics of CDW that they intervene in the properties of RA.

Keywords: construction and demolition wastes, recycled aggregates, applications, limitations, guidelines.

Quantities of construction waste from residential buildings and its development rate

Amnon Katz and Hadassa Baum
National building Research Institute
Department of Civil and Environmental Engineering
Technion – Israel Institute of Technology

Construction waste accumulates in large quantities in many countries. The amount of construction waste is estimated to be about 0.5 ton per capita per year, which is about tow third of the local solid waste. These numbers are based on the amount of waste arriving at the landfilling site do not necessarily represent individual construction sites. In order to establish an enforcement policy as well as treatment measures for the waste by reusing or recycling, it is important to systematically collect data on site, so as to determine in a reliable manner the predicted amounts of construction waste generated in any project. Information concerning the waste constituents, their relative quantities and the construction activity that generates them is essential for finding appropriate solutions to their recycling. This paper presents results of a study concerning the accumulation of construction waste in landfilling sites as well as monitoring the amounts of waste produced on new residential construction

sites. Components like concrete, steel, wood, bricks, tiles, plastic and paper, in relatively large amounts, were observed in all sites. About 64% of the waste can actually be recycled into construction materials as aggregates of various qualities and only small part of the rest (plastic, aluminum, gypsum, etc.) can be recycled into useful materials.
The stage of finishing works makes about 3 times more waste than the waste generated at the construction of the structural frame. About 60% of the waste generates during the construction of the structural frame consists of waste concrete and steel. At the stage of finishing works, the relative amount of plastics, paper and cardboard increases significantly. Based on the monitoring data collected on 10 sites, about 20 m^3 of waste is generated in the construction of 100 m^2 of new residential buildings.

Investigating the Factors of Waste Generation for Building Construction and Demolition Projects in Taiwan

Huang, Rong-Yau, Huang, Ching-Chung and Lin, Jen-Hong

[1]Professor, Graduate Institute of Construction and Engineering Management, National Central Univ. No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan (designated presenter and corresponding author).
[1]Senior Specialist, Department of Waste Management, Environmental Protection Agency, Taiwan
[1]Graduate student, Graduate Institute of Construction and Engineering Management, National Central Univ

There are in excess of several million tons of building construction and demolition wastes (CD&Ws) generated each year in Taiwan. Following the global trend of sustainable construction, efforts are being taken by the Taiwan government to ensure the proper handling and recycling of construction and demolition wastes. The major components of CD&Ws are recyclable materials such as concrete rubble, brick, metal, wood, plastic, paper, etc. In order to ensure that these wastes go into the recycling plants or legal dumping sites for appropriate treatment, the contractor of a building project is required to submit a waste handling plan to the local EPA (Environmental Protection Agency) for review before they can start work on the project. In the plan, they have to estimate the expected quantity of wastes, and to state clearly where these will go, how they will be treated, and so on. Later on, the contractor has to report the actual generation and handling of the wastes online using the EPA Waste Reporting System. The estimated quantity serves as a basis for the local EPA to monitor and control the wastes produced during the remaining process of construction waste management.
The objective of this study is to investigate the major factors influencing the quantity of waste generated during building construction and building demolition. Factors considered include the building's floor area, functional type, structural type, whether with or without a basement, dollar value of the contract, whether there is recycling on site, and so on. Data regarding several thousands of building construction and demolition waste records (cases) from the local Waste Reporting System are investigated and analyzed. Statistical regression analysis is performed on each of the considered factors to identify those which have the greatest influence on the quantity of waste generated during a building project. These factors can serve as the basis for the local EPA to better audit and control the amount of wastes generated during a building project and facilitate the process of waste management.
Key words: Waste, building, construction, demolition, factor, statistical regression

Recycling plant and research center of construction and demolition waste in the metropolitan area of vitória (Espírito Santo, Brazil)

Rembiski, Fabrícia *D. Architect. Master's Student in Civil Engineering (PPGEC) at Federal University of Espírito Santo, CAPES Scholarship. Montevidel St. 254, Araçás. Vila Velha-ES. 29103-025. Brazil*

Alvarez, Cristina E. *Architect.Professor Doctor in Architecture and Urbanism. Pos-Graduation Program in Architecture at Federal University of Espírito Santo. Av. Fernando Ferrari, 514. Cemuni I. Goiabeiras. Vitória-ES. 29075-910. Brazil*

Bissoli, Márcia. *Architect.MSc in Civil Construction at Federal University of Espírito Santo. Profª Zilda Andrade St., 165. Ed. Alamanda. Ap. 303. Bairro de Lourdes. Vitória-ES. 29.042-751. Brazil*

This article presents the design essay of a Recycling and Research Center for Construction and Demolition Waste planned for the Greater Vitória Metropolitan Area (GVMA) and developed during the study that resulted in the research paper required for obtaining the Architecture and Urbanism degree at the Federal University of Espírito Santo (Vitória, Brazil). For conceptual, technical and methodological basis, semi-structured interviews and field work were carried out in the cities of São Paulo (SP), São Bernardo do Campo (SP), Guarulhos (SP) and Belo Horizonte (MG), the ones representing the national scenario of construction and demolition waste (CDW) management. The cities of Cariacica, Vila Velha, Vitória and Serra, in the state of Espírito Santo, served as samples of the local scenario. International literature review on similar cases showed recycling plants with sustainable characteristics, which also provided basis for developing this architectural design. The design essay mainly aims at reusing CDW, which is intended for meeting the demands deriving from the expansion of urban nucleus in GVMA. In order to achieve these goals, systematized guidelines were adopted and grouped according to the following themes: i) Building; ii) Conservation and protection of natural resources; iii) Sustainable surroundings; iv) Thermal, acoustic and lighting comfort; and v) Social, environmental and economical issues. It was verified that there is a national demand for recycling plants to mitigate environmental and economical problems caused by the irregular deposition of these wastes.

Keywords: construction and demolition wastes, recycling, design essay, sustainability, project guidelines.

USABILITY'S PERSPECTIVES OF RECYCLED AGGREGATE CONCRETE (RAC) FOR STRUCTURAL APPLICATIONS

Mario Bassan[1], Marco Quattrone[1], Vittorio Basilico[2]
[1] *Politecnico di Milano, Italy*
[2] *Freelance Engineer, Italy*

Techniques to recycle rubble from building dismantling are replacing landfill techniques.
From a quantitative point of view, it is now established (at least in most European countries) that debris recycling regards above all ceramics, brick and concrete rubble.
The use of these recycled materials is not particularly problematic for low-performance applications. On the other side, the use of recycled aggregate concrete (RAC) in high performance structural elements requires more attention.
In this case, first second materials, with their specific characteristics, require a deep knowledge of potentially achievable performances and of suitable procedures for their maximization.
A number of ongoing experimental tests carried out at the Building Environment Science and Technology Department of Politecnico di Milano, have allowed to identify both specific characteristics of recycled materials and procedures for their correct use to manufacture RAC.

In this paper a first series of results, concerning test on specimens and on real scale structural elements, are presented. These results, when conveniently completed, will be used to provide a set of recommendations for the structural use of RAC. The final goal is to draft a set of guidelines for designers and building contractors.

Keywords: C&D Waste, Recycled Aggregate, Mix Design, Recycled Aggregate Concrete (RAC), HP-RAC.

Behavior of the Concretes Containing Recycled Aggregates

SAADANI Sabrina
HOUARI Hacène
Laboratory of Materials and Durability of Constructions
Department of Civil engineering, Faculty of Science of the Engineer, University Mentouri Constantine, Algeria

The exhaustion of the natural aggregate layers and the difficulties to open new careers force to seek new sources of supply.
The recycling and the valorization of waste are today regarded as a solution with a future in order to answer the deficit between production and consumption and to protect the environment.
This thesis seeks to highlight the possibility of using the marble scrap like aggregates for hydraulic concrete.
One analyzed the characteristics of the aggregates recycled (marble scrap) in order to formulate the studied concretes.
The study consists in comparing the properties of a concrete of reference at the fresh and hardened state, those of the concretes incorporating of the marble aggregates in substitution of a voluminal fraction from sand, gravels and both whole with rates of substitution of (25%, 50%, 75%, 100%).
The thesis shows the main interest which could have the development and the provision of the experimental results concerning the use of the marble scrap like aggregates recycled for hydraulic concretes.
Key words:
Aggregates, Recycling, Valorization, Environment, Marble, Characterization, Concretes, Tests, Performanc

Thursday June 4, 2009

Topic 3:Other waste streams

Treatment methods for shredder waste

Ole Hjelmar
DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark

Shredder waste, which is produced by companies that crush and shred various metal-containing waste products such as discarded vehicles and hard white goods in order to recover and recycle the metals to be used in new consumer goods, constitutes a substantial waste stream in many countries. The management of the shredder waste differs from country to country and varies from extensive recovery of the remaining metals and energy content to much lower recovery and landfilling. In countries such as Denmark, where most of the shredder waste is landfilled, the potential for upgrading of the product by various treatment processes is substantial.
This paper presents the results of a Nordic project evaluating the feasibility of various processes to improve the recovery of useful materials and upgrade the remaining waste portion from shredder waste. The feasibility is evaluated in terms of:

- Description of the technology that is used for the treatment

- Description of the treated substances
- Possible achieved results of the treatment
- Limitations of the method
- The cost of treatment
- The type of waste that is generated by the treatment
- Experiences of the methods in full scale
- The stability of the treated waste (in relation to landfill requirements)
- Potential problems with generated waste
- Other economic aspects
- The environmental effects such as recycling or energy use or emissions of the treatment
- Practical advantages or disadvantages of the treatment method
- Other advantages or disadvantages of the treatment methods

The paper will provide an overview of the most promising treatment options and place them in an economic and regulatory context within the European Union.

Development of standardised methods for characterization of wastes from extractive industry – overview of current activities

Margareta Wahlström[1], Tommi Kaartinen[1] and Jutta Laine-Ylijoki
[1] *VTT Technical Research Centre of Finland, P.O. Box 1000, FI-02044 VTT, Finland*

The European Directive (2006/21/EC) on the management of waste from the extractive industries requires guidance on waste characterisation as a basis for the development of waste management plans. For the implementation of the Directive, the Commission has given a mandate M395 to CEN, the European standardisation organisation. A working group "Wastes from the extractive industries" (WG8) has been established under CEN/TC 292 "Characterization of waste" with the task to develop standards for extractive waste.

The working group is currently working on following work items:

1. Guidance on characterisation of extractive waste
   - Development of an overall guidance (technical report) for characterisation of waste from extractive industry
   - work planned to cover the whole testing field (sampling, method recommendations, methodology)
   - to point out both physical/geotechnical aspects and other significant aspects from planning to interpretation and reporting to take into account
   - to give references to existing standards/ guidelines.
2. Sampling guidance, complement to sampling package prCEN/TR 15310 developed for waste material.
   - Development of specific sampling examples for waste from the extractive industry with focus on selected sampling situations. The examples are aimed to give information on appropriate sampling techniques for selected sampling situations and would also include special key aspects relating to subsampling, packaging etc.
3. Test methods for determination of acid generation behaviour for sulphide containing waste materials
   - Development of EN on static test (screening test)
   - Development of Technical report (TR) on kinetic test (guidance document for the planning, execution and interpretation of tests)
4. Methods for WAD cyanide in tailing ponds
   - Development of a Technical Specification (TS) for sampling and analysis of WAD Cyanides in tailing ponds

The presentation will give an overview of current activities in WG8. The background for the choice of the methods to be standardized is discussed in the paper. Especially the methods for the determination

of acid generation behaviour will be described. The importance of the work for construction products (e.g. aggregates) and other wastes than extractive waste will also be discussed.

Japanese coal ash guideline for marine construction -Environmental aspect-

Kenichi SATO[1)], Suehiko YOKOTA[2)], Yoshifumi WATANABE[2)]
Masato KAWAGUCHI[2)], Akira OHNAKA[2)], and Takao TANOSAKI[2)3)]

1) Fukuoka university, 8-19-11 Nanakuma, Jonanku,Fukuoka 814-0180,Japan
2) Japan coal energy centre, Mita 3-14-10, Minatoku, Tokyo 108-0073, Japan
3) Taiheiyo cement corporation, 2-4-2 Osaku, Sakura 285-0802, Japan,

Japan faces all frontiers by sea, so there are lots of marine construction which are necessary to sustainable development. To use the waste material is done for landfill on the sea side, especially, coal ash of about 12 million tons production in each year is strongly desire to use marine constructions. However, when anyone try to make the environmental assessment with contact marine waters, there is no guideline or regulation for this case. Moreover, no consideration of the weather of Asian monsoon regions is found on this situation. So newly the coal ash guideline marine construction was asked.
JCOAL (Japan Coal Energy Centre) are the only non-profit organization in Japan, which covers consistently all fields from the coal mining to the field of coal utilization. JCOAL has been conducting a nation-wide survey in Japan on coal ash usage by enterprises in general industries, aiming to develop and expand technologies for effectively using coal ash, as its production is expected to increase in the future. Moreover, Coal Ash Working Group which consists by specialist that consists of the member of the official body, the university, and the private company, are organized and its aims are preparing the guideline within two years.
Concretely, the guideline will descript of the merit or demerit of the coal ash use to the user of marine construction stakeholders. When the coal ash that makes the best use as the sand grain with the same of lightness, the safety mortgage is asked their life time. In guideline various leaching tests and bioassay techniques are going to be compared. Chemical target elements are focused to Boron and heavy metals.
Keyword: Coal ash, Japan, Marine construction, Guideline, Stakeholder, Leaching test

Performance assessment of stabilised/solidified waste forms: an overview of results from the passify project

C.D. Hills, A.Antemir, P.J.Carey, K.H.Gardner

Centre for Contaminated Land Remediation, University of Greenwich, Chatham Maritime, Kent ME4 4TB, UK
Recycled Materials Research Centre, University of New Hampshire, Durham, NH 03824, USA

The utilisation of cement-based systems for the treatment of hazardous waste and contaminated soil has been widely applied over four or more decades. Process wastes are treated in huge volumes in a number of countries by stabilisation/solidification systems and waste forms of 1M tonnes exist in, for example, France and the USA.
In the UK, the rapid reduction in availability of landfill space coupled with progressive legislation prompted the Environment Agency (EA) to produce detailed national guidance on the use of stabilisation/solidification technology in 2004. During the preparation of the EA Guidance, it became obvious that key field-performance related data was missing from the literature. This issue was also of concern to the French Environment Agency (ADEME) and the US Environment protection Agency (US EPA).
In order to gain insight into the stability of stabilised/solidified wastes and soils a number of universities, practitioners and the three regulatory agencies given above, formed a collaborative project called PASSIFY (Performance Assessment of Stabilised/Solidified Waste Forms). The project

team obtained permission to extract samples from nine full-scale remedial operations in three countries, and one field-scale experiment, all involving the use of cement-based stabilisation/solidification technology. Included were a number of SUPERFUND sites. The age of the stabilised/solidified materials investigated ranged from 2 to 20 years and involved both organic and inorganic contaminants of concern. The results of this investigation are overviewed in this present work.
At each site, sampling relied upon local contractors to retrieve cores of sufficient quality for examination. The cores were obtained by the practitioner who undertook the remedial action at the particular site in a small number of cases. Cores were taken from sufficient depth not to penetrate the base of the waste form to provided materials for a comparison of the current performance of the treated waste/soil with the design criteria, an assessment of leaching utilising European standard methods and a microstructural and surface chemistry analysis. Selected data from a number of sites were modelled using Leach XS.
At some sites it was difficult to extract intact samples, and this was due to a variety of reasons, including the treated materials being too hard, or too soft. Nevertheless, material from each site was retrieved and examined and a data-base of results constructed for future reference.
The microstructural results, obtained using transmitted light and electron optical techniques clearly showed that the various waste forms examined were behaving as cement-bound systems, as might be expected. A number of waste-binder and binder-soil interactions were identified and these are discussed, as they are key indicators of the performance that might be expected from a complex system involving soil, waste and cement.
The PASSIFY project has enabled real-world data to be obtained on the field-performance of cement-based stabilisation/solidification systems. Both organic and inorganic contaminated waste/soil were shown to be 'compatible' with inorganic binder systems. A number of indicators showed that upon treatment, longer-term interactions involving soil, waste and binder can take place, but were seen to be non-deleterious in nature. However, due consideration needs to be given to the possibility of time-dependent disruptive effects; these are best managed by a sound understanding of the applicability of cement-based systems and the utilisation of industry best practice.

Mineralization of carbon dioxide by accelerated carbonation of thermal residues

Lourdes Yurramendi, Susana Caballero and Emma Gil
INASMET-Tecnalia, Environment Unit, Paseo Mikeletegi 2, Parque Tecnológico, E-20009 San Sebastián, Spain

Greenhouse gases are emitted to the atmosphere through natural processes and human activities. The increase in emissions has forced the international community towards the adoption of actions focused on their reduction. Carbon dioxide sequestration by carbonation is one of the alternatives under development in order to achieve that objective.
In carbonation processes diverse reagents can be used, as mineral deposits and industrial wastes. During the present research it was proved that Air Pollution Control (APC) wastes, one of the thermal residues generated in Municipal Solid Waste Incineration (MSWI) plants, due to their chemical properties and composition, are a source of alkaline material required for the potential sequestration of the CO_2 emitted by the industrial activities.
An accelerated carbonation process was investigated for APC ashes. Samples from different MSWI plants in Spain were treated by gas/solid carbonation at different temperatures and carbon dioxide concentrations. The residues were characterized before and after the treatment with the purpose of knowing their chemical composition, their acid neutralization capacity, mineralogical phases, thermal decomposition and leaching behaviour. The treated samples were analyzed by different methodologies to obtain information about the carbonation degree during the treatment.
In conclusion, CO_2 absorption using APC wastes should be considered as an effective alternative in terms of safety carbon dioxide storage and a technology that can contribute to the mitigation of carbon dioxide emissions.

Leaching Assessment for the Proposed Beneficial Use of Red Mud and Phosphogypsum as Alternative Construction Materials

A.C. Garrabrants[1], R.A. Kirkland[1], H.A. van der Sloot[2], L.M. Price[3], and D.S. Kosson[1]

[1] *Department of Civil & Environmental Engineering, Vanderbilt University, Nashville, Tennessee, USA*
[2] *Energy Research Center of the Netherlands, Petten, the Netherlands*
[3] *United States Environmental Protection Agency Region 6, Houston, Texas, USA*

Over the last century, a significant amount of land has been lost along the Mississippi River in southern Louisiana. As part of land reclamation and levee building efforts, the US Army Corps of Engineers is looking for millions of cubic meters of fill. In response, the US Environmental Protection Agency is evaluating the beneficial use of red mud and phosphogypsum as alternative construction material. These process wastes currently are managed in high-volume monofills or surface impoundments along the Mississippi River, where material costs and transport to construction sites make their use appealing. However, the risks associated with adverse environmental impact and remediation of thousands of square kilometers of coastal wetlands may outweigh the cost savings of beneficial reuse. As one step in a comprehensive assessment project, the leaching characteristics of geotechnically acceptable mixtures of red mud and phosphogypsum have been determined through draft USEPA leaching tests. This paper presents an example set of leaching test data for two potential levee materials. Ongoing data interpretation, geochemical speciation modeling, and release scenario simulations will provide the USEPA with the information required to support beneficial use decisions for these secondary materials.

Material analysis of drinking water sludge in terms of environmental impact and decomposition

[1]Yasutaka Watanabe, [1]Hideo Komine, [1]Kazuya Yasuhara, [1]Satoshi Murakami and [2]Kazuhiro Toyoda

[1]*Department of Urban and Civil Engineering, Ibaraki University, Ibaraki, Japan*
[2]*Bureau of Water, Hitachi Municipal Office, Ibaraki, Japan*

Drinking water sludge is discharged during water purification, and is classified as industrial waste. It is important for reusing drinking water sludge as road subgrade to evaluate the decomposition for a long-term. This study focused on the leaching of flocculating agent contained in drinking water sludge, and investigated the leaching behavior of aluminum, which related to environmental impact. The environmental impact and the decomposition of drinking water sludge were discussed in this paper, and it was quantitatively represented that lower groundwater level with asphalt surface enables the mitigation of the decomposition and the environmental impact at same time.

Thursday June 4, 2009

Workshop 2:Percolation

Abstract for the topic: "Application of percolation tests for the assessment of emissions from construction products"
Comparison of percolation to batch and sequential leaching tests:
Theory and data

Peter Grathwohl, Bernd Susset
Center for Applied Geoscience
University of Tübingen
Sigwartstr. 10
72076 Tübingen, Germany

Aqueous leaching tests become increasingly important for assessing the risk of release of potential pollutants from a wide variety of solids (contaminated soils and sediments, mineral and demolition waste, construction products, etc.) into seepage water, groundwater or surface waters. In the past batch - often called shaking - tests originally developed for sewage sludge (DIN 38414-S4, 1984; DIN EN 12457-4, 2002) were frequently used for this purpose. Nowadays percolation tests are preferred because they are able to simulate the flow of water through solid material closer to natural conditions and they allow to follow the leaching behaviour over extended periods of time (DIN E 19528, 2008). Sometimes, relatively rarely, sequential leaching tests (also called cascade tests, NEN 7349, 1995) are employed as well. Generally, all leaching tests are aimed to determine contaminant concentrations, which can be expected in water which is in contact with the solid material under consideration. The aqueous concentration may crucially depend on the contact time of the water with the material, and then the dynamics of the mass transfer process is relevant. After sufficient contact time, however, equilibrium is reached between the concentration in the solids and in the water (the net mass transfer rate between solids and water becomes zero). The equilibrium concentration may be influenced by other, secondary water constituents. Commonly, in the different leaching tests (percolation, tank, shaking) different volumes of water are brought into contact with the solids for different time intervals. The results of the different tests can be compared, provided that the relevant boundary conditions are considered. Under equilibrium conditions aqueous concentrations are the same in all tests if dilution is negligible. In the case of shaking tests, equilibrium conditions are usually assumed *a priori* (generally without proving it), while tank tests are intentionally conducted under non-equilibrium conditions (e.g. by exchanging the water often). In column experiments, both conditions occur sequentially. Initially equilibrium concentrations are commonly observed at the column effluent - later the concentrations will decrease indicating non-equilibrium (this means, that boundary conditions in a column experiment will be similar to those in a tank test) or just depletion of high soluble substances (e.g. Chloride).The shift between equilibrium and non-equilibrium conditions depends on the flow-velocity, grain sizes (and diffusion distances respectively), sorption capacity and generally the contaminant release kinetics as described below.
The objective of this contribution is to show i) how the different tests are related based on theoretical considerations, ii) to compare the leaching behaviour in batch and column test as well as in field lysimeters, and iii) to show extensive data of leaching of waste materials. Data are compared with analytical solutions of the advection-dispersion-equation for percolation and for dilution in batch- and sequential leaching tests. The theory is applied to comprehensive data sets from various field and laboratory test for leaching of different solutes from mineral waste materials and soils collected in long term joint research projects of the German Federal Ministry for Education and Research and the Federal Environment Agency. The comparison of theory and different test data is based on plotting concentrations and cumulative release vs. the liquid solid ratios (*LS*) which proves to be very practical. Theory and data indicate that leaching behaviour is more or less independent on duration and dimension of percolation leaching tests even if natural field lysimeters are compared to laboratory

columns of different size, at different flow velocities and contact times. On the long run, batch tests overpredict effluent concentrations of percolation tests and vice versa (if $LS < Kd$). Leaching of solutes from solid samples of a certain material class (e.g. chloride from incineration ashes or sulphate from demolition waste samples) in column and lysimeter tests compares very well and fits with theory. In general reproducibilities and agreement with theory of column tests are better than of batch tests presumably because the latter are prone to artefacts e.g. in liquid solid separation steps (DIN E 19528, 2007).

State-of-the-art of the column leaching test: Performance and critical test conditions

Ole Hjelmar
DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark

The column leaching test is becoming more and more accepted as a useful tool in the assessment of the environmental impact of contaminants released from granular materials (e.g. waste products, soil, sediments, aggregates). Column leaching tests have been or are being incorporated into EU legislation on landfilling of waste and CE marking of construction products and national legislation on management and utilization of waste materials and contaminated soil. CEN has produced a technical specification describing a column leaching procedure, CEN/TS 14405. This technical specification must undergo a validation exercise before it can become a full CEN standard. A validation comprising the use of the CEN column test on several different materials is being planned and will most likely be carried out in 2009 or 2010. The initial part of the validation process consists of a determination of the ruggedness or robustness of the test, i.e. the sensitivity of the test results to moderate variations in the test conditions.
This paper will discuss existing information on the robustness of the column test when applied to several materials, based on available literature and scientific reports and on tests performed by DHI. The discussion will focus on critical test conditions and in particular on conditions that may influence the fulfillment of the local equilibrium assumption. Comparisons between column leaching test results and batch leaching test results will be made for some waste materials and soils, as well as comparisons between results of laboratory column leaching tests and results of large scale lysimeter tests. Recommendations will be given concerning critical test conditions/conditions to be checked, and the implementation of column tests into legislation and the applicability of column leaching test results to assessments of longer term leaching effects will be briefly addressed.

Ruggedness Testing to develop a practicable percolation upflow test - test results, interpretation and application in regulation

Bernd Susset, *Consulting Office for Groundwater Risk Assessment, Jahnstraße 10, 40215 Düsseldorf, Germany*

Wolfgang Leuchs, *State Office for Nature, Environment and Consumer Protection, North Rhine-Westphalia, Düsseldorf, Germany*

Peter Grathwohl, *Center for Applied Geosciences, University of Tübingen, Germany*

Parallel to the legislative procedure of the German Federal Ministry of Environment ("federal decree for the use of mineral recycling materials" and "1st amendment of the german federal soil protection decree") a strong demand exists for the improvement of existing column percolation methods. The German soil protection ordinance (BBodschV, 1999) requires column experiments for the leaching of organic contaminants (‘Sickerwasserprognose’) and with the amendment of this degree column tests

both for inorganic and organic contaminants will be required. With the first draft of the "federal decree for the use of mineral recycling materials" the Federal Ministry of Environment is planning to establish a quality control system based on column tests for basic characterisation and compliance testing for self monitoring and external quality control. To reach consensus for decrees which establish column tests it is important to raise the practicability of the tests with respect to practicable column setups (dimensions), total testing time and costs. Finally these tests have to be validated and standardized to get them implemented in decrees. Developing column tests which are required to be practicable on the one hand and to deliver scientific robust and justiciable results is a tightrope walk.

In a long-term joint research effort funded by the German Federal Ministry for Education and Research (BMBF) extensive data on contaminant leaching were collected for various soils and sediments, demolition and mineral wastes and different types of industrial wastes. Leaching tests comprised batch and column tests as well as field lysimeters and the release of organic and inorganic contaminants was monitored. In two additional research projects funded by the Federal Environmental Agency (UBA) many samples from different mineral waste recycling facilities all over Germany, different types of industrial waste and incineration ashes, as well as natural and contaminated soils were investigated also in batch and column tests.
In this contribution special focus is given to the results of ruggedness testing to identify the critical test conditions of column tests. For robustness testing the samples were investigated in different column setups and field lysimeters to study scale effects. Special column tests with different contact times and saturation times aimed for identifying the critical contact time which allows for sufficient equilibration. Reduced contact and saturation times will lead to reduced total testing times and costs. The ruggedness testing was done with different materials and grain sizes and for a wide spectrum of inorganic and organic contaminants with different physicochemical characteristics.
In a second part of the contribution we give an overview about interpretation and application of column test results in regulation. Particularly with respect to the legislative procedure of the German Federal Ministry of Environment the cumulative concentrations are relevant. The German "groundwater protection philosophy" is concentration based, e.g. for risk assessment material-specific values are derived in short-term column leaching tests where the aqueous effluent is collected up to a liquid-/solid ratio (LS) of 2. The cumulative concentration at LS 2 thus represents an averaged concentration which for field applications (e.g. road construction, noise protection dams etc.) corresponds to medium time scales. These material specific values obtained at LS 2 (cumulative) are compared with application and media related values, which are derived depending on the retardation or attenuation of contaminants in soils (distinction of suitable und non-suitable properties of the unsaturated zone) and on the hydraulic properties of road construction and landscaping .
The findings are reflected in a standardization project of the German Institute for Standardization (DIN E 19528, 2007) where a short column test up to LS 2 is developed to measure the cumulative concentration. Din 19528 was validated by an extensive ring test in 2008 and is published by DIN in 01/2009.

Modelling of Non-equilibrium Leaching in Column Tests

Rudolf Liedl *Technische Universität Dresden, Insitute for Groundwater Management, 01062 Dresden, Germany*

Point sources of organic contaminants in the unsaturated zone are a potential threat to groundwater quality. Groundwater risk assessment therefore strongly requires valid information about contaminant concentrations to be expected due to pollutant leaching from contaminant sources. The prediction of time-dependent concentrations at the downstream edge of the source may be supported by process-based modelling, which has to account for relevant processes like desorption. These concentration-time series may also serve as upper boundary conditions for modelling contaminant transport towards the groundwater table.

This presentation is specifically focusing on the influence of desorption kinetics on the leaching behaviour under steady-state flow conditions, thus aiming at the quantification of long-term scenarios instead of considering short-term fluctuations. This approach appears to be justified due to the significant persistence of many organics in the subsurface. Effects of desorption kinetics are demonstrated by employing results obtained with a process-based modelling tool. The underlying modelling concept represents desorption kinetics by non-linearly retarded intra-particle diffusion.

Modelling of unsaturated flow through recycled material in dam constructions

Uli Maier[1], Bernd Susset[1], Christof Beyer[2], Peter Grathwohl[1]
(1) University of Tübingen, Center for Applied Geoscience, Sigwartstr. 10, 72070 Tübingen, Germany
http://www.uni-tuebingen.de/geo/zag/
(2) University of Kiel, Institute of Geosciences, Ludewig-Meyn-Str. 10, 24118 Kiel, Germany

About 250 million tons of construction and demolition waste are produced in Germany each year, which should be re-utilized for economic and sustainability reasons, e.g. in road and traffic construction or building of noise reduction walls. For the replacement of natural materials by construction and demolition wastes with the aim of protection of natural ressources, adverse environmental effects must be prevented, i.e. significant leaching of contaminants from the secondary materials to on sub-soils and groundwater is not acceptable, as a fundamental principle for sustainable recycling is environmental acceptability. However, it is not clear whether leaching of contaminants in such material is posing a long term risk of groundwater pollution. Therefore, reliable model based prognoses are required prior to large scale emplacement of such material in the field.
According to the principle of "preventive groundwater protection", limit values for leachate concentrations of contaminants from the secondary materials and limit values to exclude a suspected risk for groundwater quality of sites must guarantee that concentrations at the point of compliance, i.e. at the groundwater surface, remain below "insignificance threshhold values".
As such a decision, however, should be based on a thorough and careful analysis of the influences of the unsaturated flow behaviour through dams with such recycled waste materials implemented. Numerical simulations were performed in 2D vertical cross sections to predict the amount of water percolating in dam constructions composed of layers and zones of dramatically different hydraulic properties, including capillary barrier effects.

Results of German ring tests on the validation of leaching standards for source term determination

Ute Kalbe, Wolfgang Berger, Franz-Georg Simon
BAM Federal Institute for Materials Research and Testing, Unter den Eichen 87, 12205 Berlin, Germany

In order to comply with the regulations of soil and groundwater protection, the characterization of the leaching behavior of waste materials is required if they are intended for reuse in soil applications, such as road construction or landscaping.
Standardized and validated leaching procedures for contaminated soil and mineral waste materials with reuse potential are urgently needed in Germany in association with the amendment of the German Ordinance on Soil Protection and a new German Ordinance on Mineral Waste Utilization. Therefore, the standardization committee „Leaching procedures“ of the German Institute for Standardization (DIN) developed two new standards for materials with a particle size up to 32 mm. One standard comprises a column percolation test for examination of the leaching behavior of organic and inorganic substances (DIN 19528, basic characterization and compliance testing). The other standard presents a batch test at a liquid to solid ratio of 2 l/kg that examines the leaching behavior of inorganic substances (DIN 19529, only compliance testing). The standard drafts were published in October 2007 taking into account research results in recent years, especially the outcome of the German joint project “Leachate forecast”, and of two associated projects funded by the Federal Ministry of Education and

Research. Taking all this into account, the standard procedures contain special stipulations leading to an improvement of source term determination concerning comparability and level of reliability.
Since only validated standards are citable in legal regulations in Germany, the Federal Institute for Materials Research and Testing (BAM) was assigned to conduct interlaboratory comparisons based on these two standard drafts with the objective of their validation. Four materials having a high reuse potential (MSWI bottom ash, demolition waste, contaminated soil, and steelworks slag) were processed as reference materials. The parameters to be analyzed were selected in consideration of the relevance for legislation. In addition to the leaching test based on the reference materials, the 53 participating laboratories had to analyze two reference solutions. The statistical data evaluation of the validation ring tests was performed following DIN 38402-42 (equivalent to ISO 5725-2) where the general mean served as reference value.
It has been proved that satisfying reproducibility can be achieved for the determination of the released amount of inorganic and organic contaminants based on batch tests as well as column tests by application of well established stipulations. This conclusion is further supported by the wide range of grain size of the reference materials, the relatively high variation of L/S (liquid-to-solid) ratio allowed for the leachate sampling intervals of the column tests, and the relatively low level of familiarity with the new procedures of many participants. Based on the experiences of the interlaboratory comparisons, improvements have been introduced to the standardization procedure. Both standards have been published in January 2009 containing the validation results.

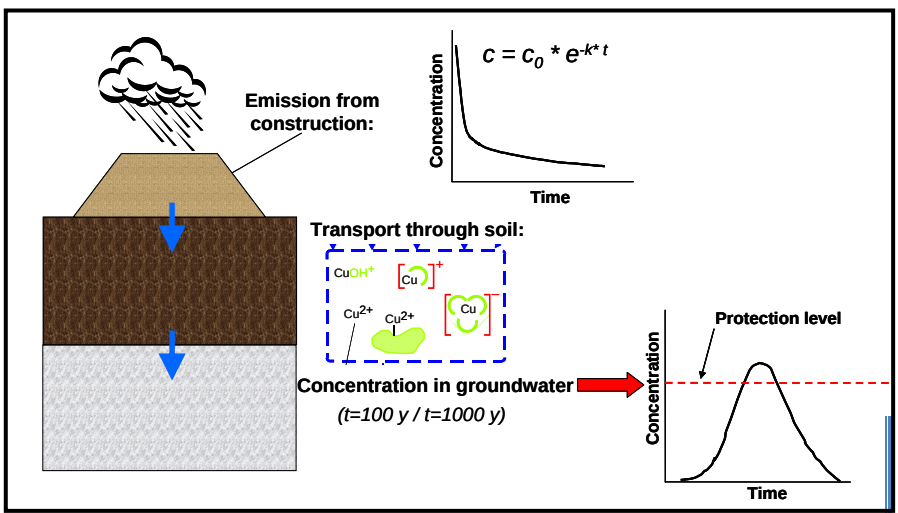
Thursday June 4, 2009

Workshop 1: Methodology and International Policies for Environmental assessment of emissions

Use of recent scientific knowledge in the development of emission limits for construction products in the new Dutch Soil Quality Decree: benefits and limitations

Rob Comans[1], Joris Dijkstra[1], Hans Meeussen[1], Anja Verschoor[2] & Job Spijker[2]
[1]*Energy research Centre of the Netherlands (ECN), P.O. Box 1, 1755 ZG Petten, The Netherlands*
[2]*National Institute for Public Health and the Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands.*

A new approach has been followed in The Netherlands in the development of emission limits for construction products in the new Dutch Soil Quality Decree, published in 2008. The approach is based on prediction of the concentrations of a large number (>20) of regulated inorganic substances that will develop in the soil and groundwater, as a result of their release from the construction product, over a period of 100 years. These predictions take into account the most recent scientific insights into the chemical speciation and interactions of these substances, and have been performed with a model set up within the ORCHESTRA geochemical modelling framework. Based on the desired protection level for the soil and groundwater after 100 years, the maximum allowable emissions from the construction products have been calculated. The figure below presents a schematic overview of the modelling approach. Based on the experiences obtained from this novel approach, this presentation will focus particularly on the following aspects: (1) outline of the modelling approach and justification of its use



for environmental policy development (e.g., why is this "fundamental" scientific modelling approach believed to be sufficiently developed for this purpose?); (2) brief discussion of its benefits and limitations; (3) illustration of the calculated emission limits and their sensitivity to the chosen environmental scenario and soil properties. Finally, preliminary results from follow-up research into the sources, quantification and presentation of uncertainties in the modelling predictions will be discussed.

Schematic overview of geochemical modelling approach used for the calculation of emission limits for construction products in the new Dutch Soil Quality Decree

Improved Leach Testing for Evaluating Fate of Mercury and Other Metals from Management of Coal Combustion Residues

SUSAN A. THORNELOE[1], DAVID KOSSON[2], GREG HELMS[3], FLORENCE SANCHEZ[2], AND BERNINE KHAN[1]

[1]U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory, Research Triangle Park, NC 27711, USA
[2]Vanderbilt University, Department of Civil & Environmental Engineering, Nashville, TN 27235, USA
[3]U.S. EPA, Office of Solid Waste and Emergency Response, Washington, D.C. 20460, USA

Coal-fired power plants, the largest domestic source of atmospheric mercury emissions in the U.S., are also a major emission source of nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter (PM). In response to the U.S. Environmental Protection Agency's (EPA's) Clean Air Interstate Rule (CAIR)[2] and concern for mercury emissions, multi-pollutant control technologies are being installed at U.S. coal-fired power plants to reduce emissions of concern. Multi-pollutant control technologies include the use of fabric filters, electrostatic precipitators (ESPs), oxidizing chemicals, sorbents, and wet scrubbers. Pollutants of concern are being transferred from the flue gas to the fly ash and other air pollution control residues. The properties of fly ash, scrubber residues, and other coal combustion residues (CCRs) may change as a result of implementation of multi-pollutant control technologies. The characteristics of these residues and how they are managed will influence whether mercury and other pollutants being controlled at the power plant will be released later through cross media transfer. In 2006, the U.S. EPA issued its Mercury Roadmap, which describes progress to date in addressing a broad range of mercury sources and identifies priority activities for addressing remaining U.S. mercury risks, among them, mercury from coal fired power plants. A key scientific question to be addressed is: What is the fate of mercury and other metals from the management of residues generated by power plants implementing new multi-pollutant control technologies? Meeting the commitment made in the Mercury Roadmap is challenging due to a lack of data that allows comparison between CCRs and the wide range management practices for these materials. This paper provides an overview of ongoing research to evaluate the fate of mercury and other metals from the management of CCRs through either beneficial use or land disposal.

Analysis of Identification for Leaching Toxicity of Hazardous Waste in China

Jianguo LIU, Zhaoji SU, Yongfeng NIE
(Department of Environmental Science and Engineering, Tsinghua University, Beijing 100084, China)

Leaching toxicity test is an important component of hazardous waste identification system, and it is commonly used to estimate the potential mobility of the contaminants of concern from the materials

[2] While the CAIR rule has been remanded to the EPA by the U.S. Court of Appeals (DC Circuit) due to legal flaws, the rule remains in effect until the EPA corrects those flaws. See: http://www.epa.gov/cair/index.html

and is widely applied to determine whether a waste is a hazardous waste. In 2007, the identification standards for leaching toxicity of hazardous waste in China and the corresponding leaching test methods were modified, based on a clear conceptual model under "acid-precipitation scenario" hypothesis. The new identification standards encompass a broader range of constituents and the new leaching test methods were defined. The new identification standard do enhance the hazardous waste management in China, meanwhile there are some significant limitations. In future, research and survey have to be done on related fields to make the concept model more rational, the identification standard more accurate, and the leaching tests more scientific.

Key words: leaching toxicity, hazardous waste, toxic organics, identification standard

A novel framework of generally applicable release tests for evaluation of the release of dangerous substances from primary and secondary construction products

J.J. Dijkstra*, H.A. van der Sloot, R.N.J. Comans
Energy Research centre of the Netherlands (ECN).

Recently, recommendations were given with respect to the development of generally applicable ("horizontal") release tests for "dangerous substances" from construction products, that will be needed to fulfill Essential requirement no. 3 under the Construction Products Directive (draft report TR2, CEN TC351). These recommendations were driven by the growing sense that a lot of efficiency can be gained when the existing large number of different release tests (for different countries, products and purposes) can be reduced to a limited set of horizontal release tests. Such tests need to be flexible with respect to answering different questions and cover as many products as technically possible. A further requirement of such test methods is that these allow correct identification of release mechanisms and provide sufficient information to allow extrapolation of results to conditions in practice.
In this paper we describe a transparent horizontal testing approach, that can be used in a wide range of situations, based on a single characterization of the relevant properties of the concerned material or product. The basis for the framework is formed by the recent scientific insight that the release of contaminants under a wide range of conditions is a function of a limited number of chemical and physical mechanisms. Depending on the properties of the material and external factors in a given release scenario which describes the intended use of the product, each of these mechanisms may have a different importance and/or intensity.
With the focus on "characterization"- level test methods (in the construction sector referred to as Initial Type Tests, ITT), we will demonstrate at the conference how the resulting limited set of test methods provides the necessary process-level information to assess the (short and long-term) release behavior of different products under the variety of conditions that can be met in practice. We will stepwise explain the test methods, and clarify a number of important issues such as: Which test should be selected for which material or product? How do the different proposed test methods relate to each other? Finally, we discuss what type of information is needed to make the translation from test result to (long-term) release under conditions in practice ("source terms"), and provide a brief overview on how well current models are capable to extrapolate release data to practice.

Reference:

1. Van der Sloot, H. A.; Dijkstra, J. J.; Hjelmar, O.; Spanka, G.; Bluyssen, P.; Giselsson, S. Evaluation of a horizontal approach to assess the possible release of dangerous substances from construction products in support of the requirements of the construction products directive; ECN-E--08-089; Energy Research Centre of the Netherlands (ECN), Petten, The Netherlands: 2008. Download at http://www.ecn.nl/en/publications/

Characterisation leaching tests as basis of reference for quality control and decisions on acceptability of alternative materials in construction

Hans A. van der Sloot[1], Joris J. Dijkstra[1], Paul F.A.B. Seignette[1], Ole Hjelmar[2], Gerd Spanka[3]
[1] Environmental Risk Assessment, Energy research Centre of the Netherlands, P.O. Box 1, 1755 ZG Petten, The Netherlands; [2] DHI – Water, Environment & Health, Hørsholm, Denmark, [3]. VDZ, Düsseldorf, Germany

In the context of the adoption of leaching tests for the assessment of release to soil, surface & groundwater as required under Mandate/366 to satisfy Essential requirement number 3 of the European Construction Products Directive, there is an urgent need to be as efficient as possible to avoid unnecessary testing for products that are non critical (WT – without testing) and adequate testing in case testing is definitely needed. The latter may be of relevance only once to determine if substances released from a product or a product entirely can be considered WFT (without further testing) or a product must be tested on a regular basis (FT – further testing) with a frequency depending on the risk of non compliance.
In Technical Report 2 prepared for CEN TC 351 the horizontal test methods considered suitable to address the release of substances from the wide range of possible construction products have been identified. These comprise a percolation test for granular construction products, a dynamic surface leach test, a pH dependence leaching test and a compacted granular leach test.
To ensure environmental compatibility during the service life of the construction product in its intended use a wider range of exposure conditions needs to be addressed, than will be needed for conformity assessment. This relates to the fact that the properties controlling release may change with time due to exposure to natural weathering (e.g. carbonation, oxidation).
An integrated system of testing, statistical data evaluation and judgment against class boundaries or regulatory criteria has been developed that allows a cost effective quality assurance satisfying Essential requirement 3 of the CPD. The role of previous knowledge in the form of historic testing results is of great importance in this context as it helps to avoid unnecessary duplication of work. Bringing such information together in a manageable form is highly relevant for the producers of various construction products as it helps to build the dossiers for declaration of WT, identify substances in a product that are WFT and optimize testing requirements in case of FT.
The role of statistics for judgment of WFT, frequency of testing related to the risk of non-compliance and ensuring environmental compatibility over the entire phase of intended use of a construction product is illustrated for a few construction products representing a fraction of the European market of construction products.

Development of environmental criteria for re-use of contaminated soil

Ole Hjelmar, Jette Bjerre Hansen, Erik Aagaard Hansen and Anke Oberender
DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark

Every year large amounts of excavated soil in Denmark and the other Nordic countries are classified as contaminated in various degrees due to spills or specific activities that have taken place at specific sites or due to contamination caused by more diffuse and non-specific sources. Those parts of the excavated soil which exceed the existing criteria for "clean" soil must be managed in an environmentally safe and economically responsible manner. The major end-placement options are utilisation under specified conditions and landfilling. Contaminated soil which has undergone treatment must also be either utilised or landfilled. Due to the costs of landfilling, the difficulties in securing landfill space and the desire to replace virgin raw materials, utilisation under specified conditions will generally be the preferred option. The specified conditions will normally apply both to the environmental properties of the contaminated soil and to the physical circumstances under which it may by utilised (e.g. restrictions on height/thickness, area, top cover, distance to water extraction wells, etc.).
Traditionally, contaminated soil has been classified and its suitability for utilisation regulated solely on the basis of the content of organic and inorganic contaminants. In many cases, this classification also

pretends to cover the risk of groundwater or surface water contamination by contaminants released from the soil by percolating water and transported by water to the point of impact. Determination of the content is, however, a poor tool for addressing the environmental impact of contaminated soil, since for many contaminants, both inorganic and organic, only a fraction of the total content is available for leaching under environmental exposure conditions and is not easily leached under the expected conditions and time frames. In general, there is no direct or simple relationship between the content of a contaminant in soil and its leachability. The use of content in contaminated soil regulation aimed at the protection of soil and groundwater or surface water may hence lead to erroneous decisions in terms of environmental protection and application of resources.
Environmental impact assessments and regulation of utilisation of contaminated soil should instead be based on determination of the leaching properties of the contaminated soil combined with modelling of the release and transport of the contaminant(s) in question in appropriate scenarios. The result of the "forward" modelling may be the impact (e.g. the resulting concentration level) of the contaminants in the water phase at the point targeted for protection (often referred to as the point of compliance – POC). Another result may be achieved by subsequent "reverse" modelling to calculate the leaching properties of the soil corresponding to a certain upper concentration level at the POC. Those leaching properties of the soil corresponding to the criteria set at the POC would then become the leaching limit values for utilisation in accordance with the scenario used in the calculations. This methodology was actually used in setting the EU leaching criteria for acceptance of waste – which may include contaminated soil – for landfilling.
Despite the growing awareness of the insufficiency of determination of contaminant content in regulations on soil management and utilisation, there has been some interest in finding the answer to the question whether or not determination of content can serve as a first screening or a surrogate test for leachability at low levels of content. In other words: If the content of a contaminant in a soil is below a certain level, will the probability that the leachable amount of that component will be lower than a certain (acceptable) level be sufficiently high? During the period 2006 to 2008, DHI has carried out a number of studies for the Danish EPA, trying to provide answer(s) to this question. The studies were based on comparisons of sets of determinations of total contents and leachability of inorganic and organic contaminants performed on the same soils and on forward and reverse scenario model calculations. This paper presents and discusses some of the results of these studies and some of the difficulties involved.

Assessment of the potential impact of wastes on the environment through the Dutch Building Materials Decree

Margarida M. J. Quina [1], João C.M. Bordado[2], Rosa M. Quinta-Ferreira [1]
[1] *GERSE- Group on Environment, Reaction and Separation Engineering. Department of Chemical Engineering, Polo II University of Coimbra, R. Sílvio Lima, 3030-790 Coimbra, Portugal*
[2] *Department Chemical and Biological Engineering, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001 Lisboa Portugal*

The modern societies are very aware of the production of wastes and to find sound solutions to environmental preservation is absolutely mandatory. In our study, the waste considered are APC residues, which are a mixture of fly ash from the combustion chamber and fine particulate residues (including the additives of lime and activated carbon) collected in the units used for cleaning the gaseous emissions (scrubbers and fabric filters). This waste has hazardous characteristics that are mainly related with leaching processes involving the heavy metals and soluble salts. These properties impose in general the need of treatment before landfilling, and although different treatments can be efficient for fixing the various potential toxic components, it would be better to find a practical application than just dump the material in a landfill site. For practical applications of materials, besides technical specifications also the environment should be protected. The Dutch Building Materials Decree (BMD) is a very valuable instrument in this ambit, being based on the soil and the surface water protection acts. The BDM is in force in the Netherlands since 1999, and it aims to create an environmental legal framework for using building materials (from any source) but protecting from pollution the soil, ground water and surface water. In this study, only the inorganic species were

considered, and the assessment of the impact was performed for several unmoulded and moulded secondary materials in order to evaluate the potential possibility of using them as building materials. The main conclusion is that the amount of soluble salts in the APC residues leads to a situation where this material is prohibited as building material in any of the conditions tested. For the case of moulding materials, the limits of heavy metals are complied, and their use in category 1 would be allowed. However, also in this case, the soluble salts lead to the classification of "building material not allowed". The treatments with phosphates or silicates are able to eliminate the problem of heavy metals, but difficulties with the soluble salts are still observed. This analysis suggests that the only way of using the APC residues as building material will be by pre-treating the waste in order to solve the major drawback of the soluble salts.

Derivation of leaching standards -a regulatory concept for the upcoming German Federal Decree for the Use of Mineral Waste Materials and By-Products

Bernd Susset[1], Wolfgang Leuchs[2], Peter Grathwohl[3]

[1] *Consulting Office for Groundwater Risk Assessment, Düsseldorf, Germany*
[2] *North Rhine Westphalian State Agency for Nature, Environment and Consumer (LANUV NRW), Recklinghausen, Germany*
[3] *Center for Applied Geoscience (ZAG), University of Tübingen, Germany*

In this contribution we present results from an evaluation of recent studies in Germany which focused on leaching from contaminated materials and reactive transport in the unsaturated soil zone to identify the key factors for risk assessment. Based on these results we developed new and improved existing methods for groundwater risk assessment and established a new regulatory concept for the upcoming "German Federal Decree for the Use of Mineral Waste Materials and By-Products and Amendment of the German Federal Soil Protection Decree" of the German Federal Ministry of Environment. A concept was developed which allows a holistic and scientifically sound assessment of the use of mineral waste materials and by-products which is based on a mechanistic understanding of leaching and transport processes as well as the construction details of landscape and road constructions. Basis for risk assessment is the derivation of material-specific values for mineral wastes, industrial products and soils in short-term column leaching tests. These column leaching tests are performed in an up-flow mode, where the aqueous effluent is collected up to a liquid-/solid ratio (LS) of 2. These material values obtained in LS 2 leachates are compared with predefined application and media related values, which are based on the retardation or attenuation of contaminants in soils (distinction of suitable und non-suitable properties of the unsaturated zone) and on the hydraulic properties of road construction and landscaping. In the upcoming federal decree this assessment concept is realized in simplified but detailed tables which classify the material qualities based on required material values and demonstrate the potential use of the classified mineral materials (mineral wastes, by-products and soils for use as construction materials). The decree promotes the use of selected mineral waste materials and by-products as construction materials fulfilling the defined requirements instead of an authorization of individual cases which have to be evaluated according to the requirements of water laws (simplification of the environmental permit system). A quality control system will be mandatory which defines material specific testing programs (number and schedule of testing) using standardized methods. A first draft of the "Federal Decree for the Use of Mineral Waste Materials and By-Products" was published by the German Federal Ministry of Environment end of 2007. After hearings have been finished a second draft is now in preparation and will be published in 2009.

Friday June 5, 2009

Topic 2: Ceramic materials

Beneficial reuse of dc plasma treated air pollution control residues from an energy from waste facility

D. AMUTHA RANI[a,b], A.R. BOCCACCINI[b], D. DEEGAN[c] and C.R. CHEESEMAN[a]
[a]*Department of Civil and Environmental Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK*
[b]*Department of Materials, Imperial College London, South Kensington Campus, London SW7 2BP, UK*
[c]*Tetronics Ltd., Swindon, Wiltshire SN3 4DE, UK*

Flue gas emissions from energy from waste (EfW) plants that combust municipal solid waste are controlled by air pollution abatement systems that generate significant amounts of air pollution control (APC) residues. These are classified as hazardous waste, primarily because of their high alkalinity, although they also contain volatile heavy metals, soluble salts and trace organics, including dioxins and furans. An integrated solution for managing APC residues using DC plasma technology has been developed. This reduces the APC residue volume and produces an inert glass that has potential to be beneficially reused. In this work APC residues from a major UK EfW plant were combined with suitable fluxing agents and melted using DC plasma arc technology. The properties of glass-ceramic tiles prepared from APC residue derived glass are reported. These were manufactured by fritting APC residue derived glass as it exits the plasma furnace at ~1450°C and crushing the granular material formed to give a powder with a particle size less than 250μm. 5 wt% of bentonite was added to act as a binder and tile samples were formed by uni-axially pressing and sintering at a range of temperatures. Samples were also prepared using identical processing with 50% and 100% of the APC residue derived glass replaced by normal recycled cullet glass. The tiles prepared from 100% plasma treated APC residue glass powder had comparable physical properties to porcelain and improved properties compared to monoporosa and other floor tile ceramics. The product had high bulk density (2.4 $g.cm^{-3}$), low water absorption (< 6%), high flexural strength (~ 60 MPa) and high hardness (5.45 GPa). The APC residue glass containing tiles could be sintered at much lower temperatures than commercial tile bodies, 900ºC compared to 1100ºC, and exhibited low and constant shrinkage over a range of sintering temperatures. The crystalline phases present were gehlinite ($Ca_2Al_2SiO_2$), anorthite ($CaAl_2Si_2O_8$) and wollastonite ($CaSiO_3$), which produces elongated acicular grains in the microstructure. It is concluded that DC thermal plasma technology combined with the manufacture of glass-ceramic tiles represents a viable solution to the current issues associated with UK APC residues.

The Properties of Ceramic Masses and Ceramic Materials Made of Waste Carbon Slate

Józef STOLECKI, Jan MAŁOLEPSZY, Paweł MURZYN
AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Krakow, Poland

In production of traditional ceramics building wares, except traditional clay raw materials, the waste materials are used. In Poland such a waste material is carbon slate which occurs in ceiling and floor of hard coal layers and often makes up also vain insertions in mere carbon rock. It is mined during exploitation of hard coal-beds. Obtained amount of waste slate by one mine is about 2.6 million tons for a year, and utilization of it in ceramic industry does not exceed even 2% i.e. 40 thousand tones for a year. In significant majority this valuable raw material is accumulated on heap.
This is charakteristic to the slate to have various content of the clay minerals. The major mineral components of the slate are kaolinite in quantity up to 50% and illite in quantity not exceeding 30%. The ramaining mineral components make up: quartz, iron spar (siderite), pyrite, smectite and carbon.

The largest technological complications in production of ceramic articles result from large content of carbon and iron compounds (ironstone and pyrite) in slate
In this investigations the natural slate ground to granulation below 1.0 mm, and calcined slate in temperature 500 ºC in time 4 hours was applied
The lowering of the content of carbon which to a large extent contributes to formation of defects while firing (the melting ferruginous and discoloration on shell, the reductive black core inside ceramic body) was the aim of calcination of the slate. The temperature of calcination of natural slate (500ºC) was conditioned on the necessity of preservation of the shale plasticity after it's calcinations, well not to exceeding the temperature of dehydroxylation of kaolinite.
Natural and calcined slate with addition (10 wt %) of quartz sand, melaphyre and basalt were used to obtain ceramic masses. The benefit of use of calcined slate is the obtainment of materials without defects mentioned above that is reductive black core, reductive stains and melting ferruginous on their surface. Moreover, the investigations of materials made of calcined slate show the deterioration of the compression strength. In turn the addition of melaphyre and the basalt to ceramic masses with content of natural and calcined slate improves the proprieties of ceramic materials.

The research work is executed in frames of investigative project of Polish Ministry of Science and Higher Education no. N N508 381835.

Influence of coal fly ashes grain composition on properties of building materials.

Jan MAŁOLESZY, Jerzy LIS, Wojciech WONS, Leszek CHLUBNY
AGH - University of Science and Technology in Cracow

One of the few industrial waste materials which found wide application in the building material technology, especially as a raw material for building ceramics materials, are coal fly ashes. Their usability is determined by physical properties such as fine grain size, spherical shape of the grains and chemical composition close to the traditional clay materials used as a basic raw material in these technologies. Fly ashes found their application as a technological addition which has influence on ceramic bulk and sintering processes in the porous body ceramics. In result of that, addition of 60% of fly ashes to the ceramic bulk is possible. In the ceramics sintered with presence of liquid phase, fly ashes could be addition promoting sintering process. In. the paper modern and more intense approaches to utilization of fly ashes as a raw material for building ceramics production are presented. The key for to these approaches is selective collection of various fly ashes. Physical and chemical characteristic of the fly ashes and products is presented in the experimental part of the paper. The XRD/Rietveld, SEM/EDS, Malvern and dilatometric measurements were applied for determining these properties.

Friday June 5, 2009

Topic 2: Other new contruction materials

Development of operating windows for treatment of industrial wastes using blended binder systems

Julia A. Stegemann* and Qizhi Zhou
Department of Civil, Environmental & Geomatic Engineering
University College London

Treatment by stabilisation/solidification (S/S) with hydraulic binders is often proposed for residual wastes that can not be destroyed or recycled. Mixing such wastes with cementitious or pozzolanic binders ideally results in a durable monolithic matrix in which pollutants are physically trapped and

may have low solubility. Depending on the level of contamination and other waste characteristics that affect the final physical and chemical properties, products resulting from S/S may be suitable for utilisation or disposal. Development of formulations for waste S/S is complicated by potentially detrimental interactions between components of waste and hydraulic binders, and therefore necessitates intensive development in the laboratory.
UCL is leading a collaborative project to support good practice in S/S by developing operating windows for cement-based S/S of four common UK residual waste types. A group of screening tests has been assembled for application to a range of stabilised/ solidified (s/s) products prepared using generic binder systems. Depending on the desired management option, threshold values of the key properties measured in the screening tests can be used to define operating windows that describe the limits of applicability of S/S treatment technology to the waste types of interest.
This paper summarises the use of the screening tests to develop an operating window for S/S of metal treatment sludges using Portland cement with ground granulated blast furnace slag or pulverised fuel ash. It was found that the addition of three parts binder to one part filtercake (dry mass basis), with a water-to-binder ratio of 0.49-0.63 resulted in acceptable physical performance (for flow, setting, unconfined compressive strength and hydraulic conductivity) for all binder types; leachability was pH dependent, but acid neutralisation capacity depended on binder type and proportions; 64 d emissions in the monolithic leaching test were more dependent on the waste type than the binder.

Addition's influence (olive stones and hay) on the physico-mécanical characteristics of terracotta bricks

S.Djadouf, A.Tahakourt, N.Chelouah, D.Merabet
Laboratore de technologie des matériaux et de génie des procédés.
Béjaia University
Algiers

Agricultural production is increased and the development of agro-industry in many countries around the world has given more quantities of agricultural waste which are not properly managed and used. However, efforts are investigated for their recovery in animal feed and also as fertilizer and fuel for energy production. But little work has been realized to develop the use of these wastes in the production of building materials.
The overriding idea of this research is to provide the world of manufacturers a substitute material. The use of vegetable particles constitutes an important way for development and it offers the advantage of using a renewable raw material unlike inorganic additions whose their resources are limited and rare. More that the use of vegetal substance is interest to improve the characteristics of the brick like its insulation ability. Because one of the possibilities of strengthening the insulation in a material is increase its porosity. Organic residues are combustible materials and their intrusion into the clay, they consume during the combustion; creating several pores in the structure of the finished product.
It's in this type of materials where is situated the brick with additions of olive stones and hay, the subject of our study.
The choice of these additions is justified by the following reasons:
• The olive stones are very abundant in Algiers and they are discharged into rivers and coastal waters. This situation conduces to the pollutions which can have negative impacts on human health and the environment.
• Hay is moreover the most abundant. It is a natural product with important characteristics that make it as useful as necessary in many branches of industry.
However, it's not enough to guarantee production in preserving the environment; we must verify the physical and mechanical qualities of the finished product. That is why technical tests were made to show the qualities of the bricks those are prepared.
Seven (7) series of samples were prepared for testing for different ratio of residue's additions. The series 1 is the standard clay brick (0% additions for the pure simple). The series 2, 3, 4, 5, 6 and 7 contain respectively 1%, 2%, 3%, 4%, 5%, 10% of organic residues.
The olive stone is taken once in the rough and once after sieved (only the hull of olive stone). So we have three (3) additions to add in the clay to make bricks samples: the olive stones gross (OSG), the

hull of olive stones (OSH) and hay. The time of combustion of these residues is relatively long and this factor contributes to increase heat in the oven. Thermal gravimetric analysis (Figure 1) showed that the residues burn completely around 580 ° C.

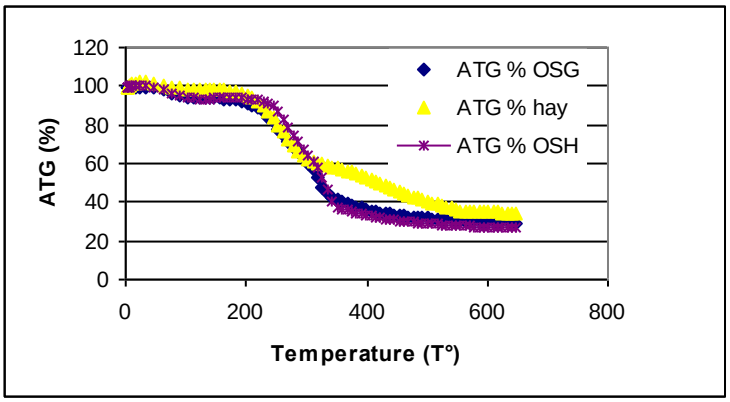


Figure 1: Analysis of thermal gravimetric of the residues

The series of samples were fired in a muffle furnace to 900 ° C. Plasticity, bulk density, coefficient of water absorption, flexural and compressive strength were studied. Additions of residues for 1% until 5% were successful to increase the pores in the structure of the samples (Figure 2) with mechanical strength adequate

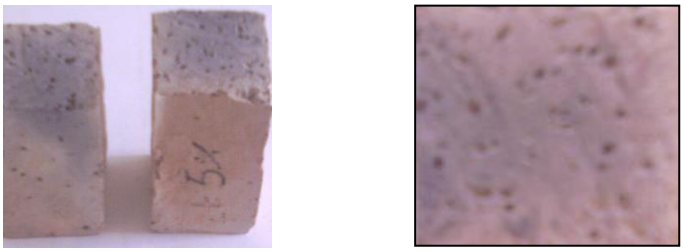


Figure 2: Cross section in a sample of brick with the addition showing pores

The fibrous residue does not create any problem during the confection of specimens, but contrary it increases the compressive strength of unfired samples as compared with pure simple but it's also increasing the water content for plasticity.
And in conclusion the use of stone olive and hay for produce building bricks constitute an interesting idea for several points of view. They can therefore be used as additions to produce porous bricks and at the same time they contribute to the protection of the environment.

Keyword:
olive stones - hay - clay - thermal analysis - characteristics.

Study of the properties and of some environmental impacts of new bio-based additives of polyvinyl chloride (pvc) for its recycling in constructions

V. Massardier-Nageotte[(1)] , M. T. Benaniba[(2)], N. Lardjane[(3)], N. Belhaneche-Bensemra[(3)]
[(1)] Université de Lyon, F-69003, Lyon, France; INSA Lyon, F-69621, Villeurbanne, France; Université Lyon 1, F-69622 Villeurbanne, France; CNRS, UMR5223, Ingénierie des Matériaux Polymères.
[(2)] Laboratoire des Matériaux Polymèriques MuliPhasiques, Faculté des Sciences de l'Ingénieur, Université de Sétif, 19000 Algérie.
[(3)] Département de Génie de l'Environnement, Ecole Nationale Polytechnique, BP 182, El-Harrach, Alger, Algérie.

PVC is one of the main plastics produced in large quantities with widespread and diverse, uses ranging from every day products to highly specialized applications as construction [1]. PVC is still one of the

polymers that contain the highest % of additives as most of the plasticizers and heat stabilizers representing together one-third of the additives production are used in PVC [2]. Plasticizers, such as phthalates, are added to the originally rigid PVC in order to make flexible products. Stabilizers are indispensable to provide the necessary stability of the PVC against heat, light and weathering. Conventional stabilizers are heavy metal and organotin compounds as well as organic co-stabilizers [3-7] that are not always environment-friendly.
With the aim of facilitating recycling of PVC, the first part of this work was to substitute conventional additives by renewable and bio-based molecules such as epoxidized sunflower oil (ESO) as heat stabilizer and di-isononyle adipate (DINA) as alternative plasticizer [8].
The second part was to study the release of additives from semi-rigid and plasticized PVC stabilized with ESO and to compare it to the traditional formulations based on conventional phthalate plasticizers.
The results showed that, although the mechanical properties remained close, the new bio-based formulations exhibited better thermal stability than the conventional ones. Furthermore, the soil burial test showed the loss of additives by migration and biodegradation which lead to the modification of the density and mechanical properties of the PVC samples and it seems that the simple structure of DINA favours its biodegradation in comparison with phthalate plasticizers. The better adequacy of these new partially bio-based materials with environment should facilitate the recycling of PVC in constructions.
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Friday June 5, 2009

Topic 4: Economy, regulation sustainability and territorial metabolism

Carbon and financial savings associated with recycling utility trench arisings

Yue Huang and Rebecca Hooper
Scott Wilson, Nottinghamshire, UK

Funded by WRAP (the Waste & Resources Action Programme) this work determined industry average factors to estimate the carbon dioxide and financial savings accrued by recycling trench arisings (and using other materials) back into trench reinstatement. Such trench arisings generally comprise road construction materials, aggregates and soild.
The project examined the life cycle of four scenarios for trench excavation and reinstatement, to identify the greenhouse gas impacts and costs associated with each. Each trench excavation scenario includes first and second time permanent reinstatement (where temporary overlying layers are replaced once any anticipated settlement has occurred). The trench excavation scenarios include excavation and disposal of arising to landfill, followed by reinstatement with only primary materials; excavation and disposal of arisings to landfill followed by reinstatement with recycled materials; excavation and transportation of arisings to a recycling hub for conversion to a hydraulically bound

material for reinstatement; and in situ recycling into hydraulically bound material. These intrusive scenarios were complemented by two 'trenchless' scenarios, including pipe bursting and slip lining.
Building on previous studies by WRAP, existing carbon dioxide data were used to populate the models for each scenario with standard conversion factors used with new data gathered from the utilities reinstatement sector where necessary. New industry data includes the levels of application of each scenario (or intermediate ones), average distances of relevant transportation loops and modes of transportations, and typical reinstatement designs. These data were also used, in combination with standard cost data (from industry price books) to prepare financial models.
These collective data sets have been collated to provide conversion factors so that utility companies can readily convert their gains in recycling trench arisings and other materials, avoiding landfill disposal, and using trenchless technologies, to carbon dioxide and financial savings. This also allows benchmarking and reporting on a sector level with a known certainty level and the scenarios provide a model approach for future studies by individual organisations.
This paper sets out the scenarios, the data collation and analysis, and the sector analysis.

Business case for using microwave technology to produce a lightweight aggregate

David Hann[+], Joanne Edwards[+], Tony Parry[§] and Rebecca Hooper[+]
[+] *Scott Wilson*
[§] *University of Nottingham*
Nottinghamshire, UK

Funded by MIST (the Mineral Industry Sustainable Technology Programme) this work determined the business case for producing lightweight aggregates from pulverized-fuel ash (fly ash) and quarry fines using innovative microwave technology, when compared to the supply of existing lightweight aggregates (LWA). The business case aimed to ascertain the economic viability of full scale manufacture of LWA using the microwave technology by comparing the potential size of the LWA market with estimates of the potential costs of setting up and operating a full scale manufacturing facility.
The business case is based on innovative laboratory work (not reported here) that demonstrated the manufacturing process could produce an acceptable LWA and allowed experimentation to refine the best mixture of fly ash and quarry fines input materials. The business case focussed on two primary and two secondary issues. The two primary issues were CO_2 emissions and energy consumption, when compared to the current production process of importing pumice (a primary LWA alternative) from Greece. The two secondary issues production location and the relative transport distances involved.
This paper sets out details of the market assessment for LWA, three production scenarios, the analysis and comparison of these scenarios to define the preferred scenario. Finally, the economic viability of the preferred scenarios is explored and recommendations made for moving to the scaled up pilot trial of the technology. These findings will be updated to account for changes to the UK housing market in recent months.

Use of Industrial By-Products in Urban Transportation Infrastructure: life cycle argument for increased industrial symbiosis

Kevin H. Gardner and Alberta C. Carpenter
Recycled Materials Resource Center, University of New Hampshire, Durham, NH 03824

The incorporation of roadways into a region's industrial ecology is an efficient method of managing some of the industrial by-products that are generated. Current management of these industrial by-products is through beneficial use (for certain types of materials), but also stockpiling or landfilling, which have economic and environmental implications. Considering the Pittsburgh, Pennsylvania (USA) urban regional aggregate demand for both vertical and horizontal infrastructure, this article compares the use of industrial by-products (e.g. coal ash, foundry sand and slag) and virgin aggregate

with virgin aggregate alone for use as base material for roadway construction in an optimization analysis to minimize the transportation impacts. The life cycle impacts associated with the choice of material (virgin or industrial by-products) are also evaluated in this article, and it is shown that industrial by-products usage results in lower life cycle impacts in almost all categories. Additionally the transportation costs are 25% less for the combined industrial by-products and virgin aggregate usage than for the use of virgin aggregates alone due to the closer proximity to the source materials. The combination of reduced economic and environmental costs provide a strong argument for state transportation departments to develop symbiotic relationships with large industrial by-products producers in their regions to minimize impacts associated with roadway construction and maintenance with the additional benefit of improved management of these materials.

Environmental sustainability evaluaton of secondary materials: case study, secondary materials from ferroalloys manufacture

Ángel Irabien[a], Rubén Aldaco[a], Álvaro Ruiz[a], María Margallo[a], Cristina Rodríguez[a,b]
[a]*Departamento de Ingeniería Química y Química Inorgánica, Universidad de Cantabria*
Avda. de Los Castros, s.n., 39005, Santander, Spain
[b]*Ferroatlántica, División de Ferroaleaciones, Fábrica de Bóo de Guarnizo, Cantabria, Spain*

Sustainability indexes or indicators may be considered objective functions for secondary materials. The Environmental Sustainability is based on two different variables: (1) Natural Resources Sustainability (NRS), and (2) Environmental Burdens Sustainability (EBS). The main components of EBS have been classified as atmospheric pollutants, water pollutants, soil pollutants and a fourth group including specific environmental burdens such as noise, etc.
In this work normalization procedures for the environmental sustainability evaluation of processes and products have been developed and applied in order to get suitable objective functions, a case study on secondary materials from ferroalloy wastes is described.
Taking into account the Integrated Pollution Prevention Control (IPPC) policy [1] and the Integrated Product Policy (IPP) of the European Union, which includes an information system based on the European Pollutants Release and Transfer-Register (EPRT-R) [2] an initial classification and technical evaluation of the pollutants of concern has been considered for normalization purposes; following these reference; as first step a general normalized multi-objective function based on atmospheric pollutants, water pollutants soil pollutants and transferred pollutants is defined for environmental sustainability evaluation of processes and products, which can be used in the Life Cycle Assessment (LCA) [3].
The normalization procedure, which has been developed according to E-PRTR allows the reduction of the complexity in the evaluation of the environmental sustainability of secondary materials. Near 250 atmospheric pollutants can be weighted in a dimensionless indicator for atmospheric impact, 55 aquatic pollutants can be reduced to one indicator of aquatic impact and the land impact can be managed by one weighted variable.

Use of Concrete with granulates in The Netherlands: observed barriers in the market and logistics and possible solutions

Daaf de Kok, Heleen Lieftink
De Kok & Partners;
P.O. Box 896
6800 AW Arnhem
The Netherlands

De Kok & partners is a small independed consultancy,.. We accomplish and accompany cooperation-processes in the field of innovation and sustainability. We will give a presentation about concrete in which concrete granulates (partly) replace gravel as a filler for concrete.

Concrete with granulates

Concrete is a product with a long history. It is made of cement, water, sand and gravel . The excavation of sand and gravel has a negative influence on the environment hence it is restricted due to government policy. Since more than a decade, a substitute is available for a part of the gravel. This can be used without compromising the technical requirements of the standard type concrete. The substitute is recycling aggregate or concrete granulates, a stony material that is the outcome of the recycling process of debris.

After the second world war a lot of buildings were build with concrete. Within two decades most of these buildings will be demolished. In The Netherlands the volume of concrete granulates will double in 2025. At that time the volume of granulates is almost the same as the volume of gravel needed. Research has shown that nowadays only 1,5 percent of the gravel in concrete is substituted by granular. This despite of government policies that stimulate the use of this secondary material.

Causes

The reasons why organisations in the concrete industry are resistant towards the use of granulates in concrete are related to institutional pressures. It appears that granulate producers are driven by a lack of economic fitness with their current market, due to declining sales. Granulate producers are relatively active to change, but the concrete market is hard to enter. The concrete market has a long history that result in strong interorganisational relationships and integration of these organisations.

The main question

The main question is: What are the factors that influence the behaviour of individual organisations in the concrete industry that make them reluctant to use this new material and what are the possibilities that may enlarge the use of granulates in concrete?

In the past years we have observed the following aspects:

- concrete companies with financial interests in gravel trade companies;
- reluctancy of concrete producers to switch from gravel to granulates
- a mismatch between the concrete, granulate and demolition markets
- regional differences;
- ……..

At the presentation at the Wascon conference these observed constraints will be illustrated and possible ways to solutions discussed.

New legislation on the sustainable reuse of lightly contaminated soil in The Netherlands

Ton Honders, Michiel Gadella, Tommy Bolleboom
SenterNovem – Taskgroup Soil+
The Netherlands
Johannes Lijzen, Piet Otte, Arjen Wintersen
National Institute for Public Health and the Environment
Bilthoven – The Netherlands
Marc Pruijn, Herman Walthaus
Ministry of Housing, Spatial Planning and the Environment
The Hague, The Netherlands

Keywords: soil protection, soil reuse, soil legislation, soil quality standards

1. INTRODUCTION

The Netherlands is a densely populated country with intensive agricultural and industrial activities, large river and lake systems and a high groundwater table. This has resulted in the accumulation of a large variety of contaminants in the soil and aquatic sediments. Hence we have a long history of policy

making, implementation and improvement regarding soil protection, reuse and remediation. Ballpark figures on soil turnover and associated costs are depicted in Figure 1.

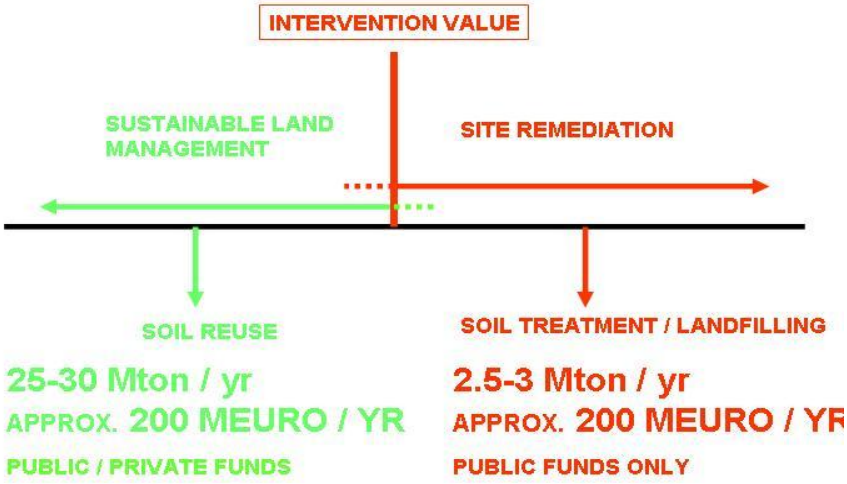

Figure 1. Yearly quantities and cost factors for sustainable landmanagement and site remediation.

On the highly contaminated side of the soil quality spectrum, The Netherlands are faced with an estimated 600.000 potentially contaminated sites. Approximately 60.000 sites require remediation or some form of management (e.g. containment, capping). Of these 60.000 sites, approximately 15.000 sites require urgent risk reduction (for human health or spreading to the groundwater) – preferably by full remediation - before 2015. Total anticipated costs are in the order of 12 billion Euro's within a time-frame of 20-25 years.
On the other side of the soil quality spectrum, nation-wide land use changes on average each 25 years. To steer and control this latter process, a revised scheme on sustainable land management and reuse of lightly contaminated soil was developed.
This paper focuses on soil reuse and sustainable land management. The policy principles and processes, the new rules for soil management and some preliminary results are highlighted.

2. POLICY PROCESS

Since 1999, the reuse of lightly contaminated soil has been regulated by the Dutch Building Materials Decree. The environmental quality of soil and other secondary materials – and hence their reuse options - were determined by a set of contaminant concentration and leaching standards. Whilst environmentally sound, the reuse of soil – and consequently sustainable land management – was severely hampered by various factors. Upon evaluation in the 2002-2003 period, a variety of impeding factors were identified: relatively high costs, poor enforceability, unpractical handling (and sampling) procedures, limitations for local tailor-made solutions, legislative inconsistencies and the absence of a clear relation between environmental risks and the standstill principle. Hence a Policy Letter was prepared for the Dutch parliament sketching the basic principles for a policy renewal process. A quote from this letter:
"A further step needs to be taken in renewing soil policies to foster the more sustainable management of soil in our society and to remove inconsistencies and inadequacies in the existing soil policies and legislation".
In the 2004-2008 period, the policy development process was conducted to alleviate the fore mentioned problems. This process involved intense consultation with all public and private stakeholders: the Ministry of Housing, Spatial Planning and the Environment, the Ministry of Transport, Public Works and Water Management, the Ministry of Agriculture, national and local environmental guard, local authorities (provinces, municipalities), Water Directorates, consultants and

contractors. At crucial points in the process, the proposed sets of regulations were tested against enforceability. In addition, economic and environmental impact assessments were conducted. The resulting new Soil Quality Decree [1] was adopted by the Dutch Parliament and has been (fully) effective since mid 2008. The Soil Quality Decree regulates:

- The use and reuse of building materials.
- The use and reuse of soil and aquatic sediments.
- Quality assurance and control mechanisms for both the environmental quality characteristics of the materials (re)used and the processes of production and application of these materials.

This paper highlights the reuse of soil only.

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Workshop 3: Industrial feedback of practical use of waste in civil engineering –critical issues

DIRECT-MAT – sharing knowledge and practices on recycling of road materials in Europe

Dr Maria Arm[1], Dr Yannick Descantes[2], Dr Chantal de La Roche[2], Mr Knud A. Pihl[3], Prof Laszlo Gaspar[4], Dr.-Ing. Konrad Mollenhauer[5], Dr Maria de Lurdes Antunes[6], Mr Luc De Bock[7], Dr Ciaran McNally[8]

[1]*Swedish Geotechnical Institute (SGI)*
[2]*Laboratoire Central des Ponts et Chaussées (LCPC), France*
[3]*Danish Road Institute (DRI)*
[4]*Institute for Transport Sciences (KTI), Hungary*
[5]*Braunschweig Institute of Technology (TUBS/ISBS), Germany*
[6]*Laboratòrio Nacional de Engenharia Civil (LNEC), Portugal*
[7]*Belgian Road Research Centre (BRRC)*
[8]*University College Dublin (UCD), Ireland*

DIRECT-MAT is a three-year European project aiming to facilitate the sharing of national experiences on dismantling and recycling or safe disposal of road and road related materials at the European level. It was initiated within the EC 7th Framework Programme Transport first call and is comprised of partners from fifteen participating countries for a budget of 1,2 million Euros. The project runs through 2009–2011 and involves building a European Web database and drafting best practice guides on DIsmantling and RECycling Techniques for road MATerials ("DIRECT-MAT"). The intention is that project results shall support the daily work of practitioners, researchers and standardisation bodies.

Several materials are addressed – unbound, hydraulically bound and asphalt road materials, but also other materials related to road use but not commonly recycled in road construction. These include tyre shreds, sediment from ditches, industrial by-products and reinforcement materials. The work programme is organised into seven work packages where four packages focus on the various construction materials, one is devoted to the database and the remaining two work packages to management & coordination and dissemination.

Dissemination activities include cooperation with a Reference Group consisting of end users in several countries; presentations in national and international papers and conferences as well as the arrangement of national seminars and a European workshop for end users. Continuous project information will be available at http://direct-mat.fehrl.org.

At present, many European countries have acquired experience in dismantling and recycling road materials back into roads. However, research results are not widely implemented and national documents are not often available to specialists from other countries. In this European project, twenty

partners cooperate to build a web database that will provide access to validated guidelines, national document references, harmonised literature reviews and practical application case studies based on jobsite data sets.
In this way DIRECT-MAT will actively contribute to generating closer cooperation between research and practice within road material recycling and also contribute to reducing the waste disposal associated with roads.

Feed-back from French industrial developments on steel slags in road-base applications

Jérémie DOMAS
CTPL – Technical and Promotional Center for Iron and Steel Slags
Site ArcelorMittal – Aile 3, Bureau 200 – 13776 Fos-sur-Mer cedex – France

French production of iron and steel slags represents more than 6 millions tons per year (CTPL, 2007), 75% of which are reused mostly in public works, other applications like industrial raw materials, internal site recycling, storage or landfilling being more marginal.
However, the lack of explicit national or European harmonised environmental framework has led the iron and steel industry, under the coordination of the Technical and Promotional Centre for iron and steel slags (CTPL), together with the French administration (ADEME and Ministry in charge of Environment), to launch an harmonised approach in 2006, based on an experimental characterization program and data-base collection for slags used in road applications, the final objective being an officially recognized environmental characterization methodology, together with acceptable leaching thresholds applicable to slag aggregates being used in road works.
Several couples of "slags/reuse scenario" were identified in order to cover most road applications (aggregates for embankment, road layers, and platform for industry) and different types of slags in order to dispose of nine experimental working sites, at a true scale. All these road applications were in compliance with accepted technical specifications and/or standards, the only interest of this programme being the study of the respective environmental behaviours of these road structures.
Geotechnical and chemical/environmental characterization studies were made in order to get basic information on specific slags properties. These elements aim to the creation of a reference laboratory data-base on tested materials.
Then, pilot road sections were built in 2007, and field experiments have been conducted ever since. Water volumes measurements, sampling and analysis were carried out at an increasing frequency for more than twenty parameters. Geotechnical evolution of the works (deformation, cracking …) was also observed during the duration of the experiments.
The final results of this program are expected for mid-2009, but the first elements in hand already allow environmental behaviour of slags used in road applications being better understood. The use of alternative aggregates fabricated from iron and steel slags, although they are heavy materials, may provide suitable local technical solutions for road applications, which ensure adapted level of performance together with harmless environmental impact.

Keywords : steel slags, environmental assessment, construction products, pilot scale experimental sites

Use of residues from thermally treated sewage sludge in concrete construction works : preliminary study

Sylvie Baig – Degrémont

E.Jayr – CSTB, E.Vernus – POLDEN, J.Méhu - EEDEMS

Introduction (1)

- The need for more and more stringent solutions for the wastewater treatment is leading to an increasing sludge production ;
- Thermal treatment of sewage sludge is a complementary solution for the sludge management ;
- Use of residues from thermally treated sludge in construction materials could be an environmentally friendly way of management :
  - Avoiding landfill saturation ;
  - Limiting natural resources extraction ;
  - Managing wastes produced on the wastewater treatment plant

Evaluation of the Impacts of Coal Type and Facility Configuration on Leaching Characteristics of Coal Combustion Residues

D. S. Kosson[1], F. Sanchez[1], P. Kariher[2], S. Thorneloe[3],
H. van der Sloot[4], A. Garrabrants[1] and G. Helms[5]

[1]*Vanderbilt University, Nashville, Tennessee, USA*
[2]*Arcadis, Inc., Research Triangle Park, North Carolina, USA*
[3]*USEPA, Office of Research and Development, Research Triangle Park, North Carolina, USA*
[4]*Energy Research Centre of The Netherlands, Petten, NL*
[5]*USEPA, Office of Solid Waste and Emergency Response, Washington, D.C., USA*

Approximately 60 samples of coal combustion residues (CCRs) have been evaluated for leaching characteristics as part of a life cycle analysis of the impacts of coal type and air pollution control processes on environmental impacts. CCRs evaluated include fly ash, gypsum, scrubber residues and combined residues (as managed for disposal) from facilities with different air pollution control configurations including particulate capture (electrostatic precipitators, fabric filters), sorbent injection for mercury control (powdered activated carbon, brominated activated carbon), nitrogen oxide controls (selective catalytic reaction, and selective non-catalytic reaction), and scrubber type (inhibited, natural and forced oxidation). Coal types include bituminous and sub-bituminous coals typically combusted in the United States. Leaching characterization included pH-dependent and liquid-solid ratio dependent batch leaching tests with approximately 40 analytes to facilitate geochemical speciation and management scenario-based evaluations. Laboratory test results are compared with field observations from disposal impoundments and landfills. The resulting information provides the basis for establishing classes of CCRs based on characteristic leaching behavior for constituents of potential concern that then can be used for comparative evaluation of CCRs from other facilities and quality control for beneficial use. This paper will emphasize observations concerning the impacts of facility configuration and coal type on CCR leaching for selected elements.