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International Conference: Grouting and Ground Treatment, 10 – 12 February 2003, New Orleans, USA
8th International FZK/TNO Conference on Contaminated Soil ‘ConSoil 2003’, 12 – 16 May 2003, ICC Gent, Belgium

Workshop on Stabilisation/Solidification Binders and Technologies:
Current Practice and Research Needs

The EPSRC funded Network STARNET (Stabilisation/solidification Treatment And Remediation NETwork) held its first one-day workshop on 3 July 2002 at Cambridge University Engineering Department. This workshop, the first of three which will take place over the next 18 months, concentrated on current practice and research needs for stabilisation/solidification (S/S) binders and technologies.

The purpose of these Workshops is to act as a forum where S/S researchers, problem holders, land developers, consultants, contractors and regulators meet to discuss current experience and information and to identify knowledge and research gaps. The aim of this workshop is to prioritise research needs for S/S binders and technologies.

Three state-of-practice reports have been produced, currently in draft form, which cover various aspects of S/S binders and technologies concentrating primarily on the UK experience: Part 1: Basic Principles, Part 2: Research and Part 3: Applications. Copies of the draft reports were sent to the delegates ahead of the workshop. The workshop was attended by 70 delegates with a good mix of academics, consultants, contractors and regulators.

The format of the workshop was in two parts. The morning session consisted of a number of presentations that reflected the views of the various sectors involved in S/S work. The presentations concentrated on S/S experience in that sector, lessons learnt, barriers and incentives, knowledge gaps and research needs. Presentations were given by Dr Abir Al-Tabbaa (Cambridge University) and Dr Chris Cheeseman (Imperial College) summarising the content of the state-of-practice reports, Dr Brian Bone (Environment Agency) on a regulator’s viewpoint, Dr David Tonks (Edge Consultants) on a consultant’s viewpoint, Dr Gordon Lethbridge (Shell Global Solutions) on a site owner’s viewpoint, Mr Steve Smith (Welsh Development Agency) on an end user’s viewpoint, Ms Leslie Heasman (MJ Carter Associates) on the waste management industry viewpoint and finally Dr Chris Evans (May Gurney Technical Services) on the remediation industry viewpoint.

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Manufactured Aggregates for Reclamation Sites (MARS)

Stabilisation/solidification (s/s) has been used for many years as a way of treating industrial wastes, often with the purpose of disposing of them to landfill. However, the process can also be used to create materials that can be used in construction, thus generating added value and reducing the use of primary aggregates. A current project in the north of England is demonstrating the use of innovative s/s techniques to produce granular materials for use in construction.

The project is called MARS (Manufactured Aggregates for Reclamation Sites). The process is designed and operated by Geodur CIS AG, who have an extensive database on the properties of s/s materials based on many years of experience. Materials are selected to provide the required grading and other properties when mixed with cement, water and additives. Locally available industrial waste materials are being used including foundry sand, water treatment sludge, metal refining residues, incinerator bottom ash and steel slag. Materials produced to date are for use as landfill drainage, Type 1 sub-base, Class 6F1 capping and aggregates for use in the manufacture of lightweight masonry blocks. The input materials are mixed in a computer-controlled high-speed mixer that can produce up to 30 tonnes per hour.

The Geodur immobilisation process works by developing a customised solution for each case based on full knowledge of the chemical and physical properties of the input materials and the requirements for the product. The Basic Geodur compound is a mixture of organic and non-organic chemicals. Some of the components have hydrophobic properties; others reduce surface tension and support reaction between the materials and the binders. Other additives can be included to act as reducing agents or complexing agents as required. The bespoke solution allows a reduction in the proportions of binders and water in the mix compared to treatment with conventional binders such as cement.

Both the landfill drainage material, and the masonry block aggregate are produced by using a pelletiser once the material has been mixed, as shown in the figure. The Type 1 sub-base and capping materials are obtained by mixing the components in the correct proportions to produce the required grading. The material is then further mixed in an excavator bucket with internal blades (known as an ALLU bucket) several hours after mixing to prevent the particles from sticking together until the cement has gone off.

To demonstrate that the materials are fit for purpose, a 200m trial road will be constructed with the capping and sub-base materials at a landfill site close to the mixing plant. VHE Limited, who operate the landfill site, will construct the road, which will be unfinished. The road will carry lorries taking waste to one of the active cells on the site, and records of the traffic will be kept. The design of the trial road, supervision of construction, laboratory testing of the materials, in-situ testing and monitoring of performance are being carried out by TRL Limited. The capping and sub-base materials have to satisfy the requirements of the Specification for Highway Works with regard to grading and mechanical properties. The drainage will be sampled at regular intervals to assess whether any leaching from the s/s materials is taking place. All the drainage is directed into one of the landfill cells on the site.

Construction of the trial road is expected to take place in June and July 2002, and monitoring will continue for several months. The final report will summarise the mechanical and environmental performance of the road and give guidance on use of the technique. The project is being managed by exSite Research Limited and is funded by the shanks first fund.

The project demonstrates the versatility of s/s and its potential to produce useful construction products out of materials that would otherwise have been disposed of as waste.

For further details contact Dr. Murray Reid

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Workshop on S/S Binders and Technologies (Cont’d)

The afternoon session started with seven breakout discussion groups, each consisting of up to 10 delegates. Five of the groups were assembled according to sector and two groups were mixed. The groups were asked to discuss and report their views on two questions related to S/S binders and technologies: ‘What are the research needs?’ and ‘How can the research needs be met?’ The morning presentations, which were extremely focused and well received lead the way to active discussions during those afternoon breakout sessions.

Following presentations from a representative from each group on the outcome of their discussions in terms of priority research needs, the chosen research topics were consolidated, collated and amalgamated into 15 separate research topics. The delegates then each selected their three priority topics. The list of 15 topics and the votes that each received (in brackets) are listed below.

1. Calibration of laboratory results to the field and modelling (32)
2. Binder/contaminant interactions (25)
3. Standards/protocols for minimum variability and standard specifications (15)
4. Binder characterisation (source variability and standard specifications) (15)
5. Organised access to information (case studies, databases, reviews & identification of gaps) (14)
6. Proof of durability (14)
7. Codes of practice for use of binders and construction (13)
8. Speciality binders (for problem soils/contaminants, organics and soluble salts) (6)
10. Robust systems and applicability guidelines/matrix (3)
11. Clarity of leaching tests (2)
12. Clear guidance from end users and priorities for research (1)
13. Guidance for non-technical specialists (1)
14. QA/QC on ex-situ and in-situ processes (1)
15. Risk assessment (1)

A discussion then followed on each of the top seven priority areas to answer the second questions of ‘How can these research needs be met?’

A detailed report on the workshop content and outcome is being produced and this will be published in addition to the three state-of-practice reports. It is intended that the highest priority research topics will be worked into research proposals over the next few months in collaboration with workshop delegates and others who would like to be involved. Anyone interested is encouraged to contact Dr Abir Al-Tabbaa.

The next workshop is proposed to be on Testing, Performance and Modelling in March/April 2003.

About STARNET

STARNET is an EPSRC funded Network on Stabilisation/Solidification Treatment and Remediation. It includes leading UK engineers, scientists, organisations and regulators involved with S/S technologies. The overall aim is to build a Network of key participants who will work together to promote the development of research, work on and implementation of UK S/S technologies. The Network is co-ordinated by Dr. Abir Al-Tabbaa of Cambridge University.

Key scientific and technical issues which are being addressed by STARNET include: a) Binder Selection,
The MONOLITH Database and Prediction of Interactions in Cement/Waste Systems

The presence of impurities can have damaging effects on the quality of products made with Portland cement, which are difficult to predict. Nevertheless, introduction of impurities into cement systems is inherent to recycling of industrial by-products by utilisation in cement-based building materials and in treatment of industrial wastes by cement-based solidification prior to disposal. The consequences of design of cement-based products without proper consideration of the potential for complex interactions between cementing components and impurities are: handling difficulties, failure to set, improper strength development, and deterioration over time. These hazards, and the difficulty in predicting their occurrence, have hindered both utilisation and/or solidification of industrial by-products, because potential benefits are outweighed by the expense of failures.

A 41-month project (12/1997-4/2001) was conducted by a consortium of 8 partners (Imperial College, BNFL, Universidad de Cantabria with Euroresiduos, Universita di Roma with GE.SE.N.U., Surrey University and Trinity College Dublin), under the European Commission's Industrial and Materials Technologies Programme, to collect and use existing data from the literature and supplementary data from a laboratory programme to examine the application of neural network analysis for predicting interactions in, and final properties of, cement-based products containing impurities (NNAPICS). The NNAPICS project results have been published in the open literature.

More information can be obtained from the website at [http://www.concrete.cv.ic.ac.uk/iscowaa/nnapics/intro.html](http://www.concrete.cv.ic.ac.uk/iscowaa/nnapics/intro.html).

The main achievements of the project were:
1) creation of the MONOLITH database of 1506 literature references and properties of 7953 cement-based products containing impurities, which represents a large proportion of the information available in the literature.
2) development of the MONOLITH interface, which allows flexible search, output and viewing of the data in the database, as well as providing example neural network models, and enabling storage of new data by future users,
3) the findings of neural network analysis of cohesive data subsets extracted from the MONOLITH database, and
4) the findings from the laboratory programme, for 230 cement/waste products.

The NNAPICS project final report, and the MONOLITH database and user-interface, can be obtained at no charge by registering with the project coordinator:
* To obtain the NNAPICS project final report, send an e-mail containing your name, affiliation, address, telephone number and e-mail address, with the words NNAPICS REPORT in the subject line, to julia.stegemann@eng.ox.ac.uk.
* To obtain the MONOLITH database and user-interface, send an e-mail containing your name, affiliation, address, telephone number and e-mail address, with the words SEND MONOLITH in the subject line, to julia.stegemann@eng.ox.ac.uk.

Collection of data focussed on composition, and measurements of setting, strength and leachate pH for cement-based products containing primarily inorganic industrial by-products and wastes. The most common wastes were synthetic wastes prepared for laboratory investigations, MSWI fly ash, other baghouse dusts and metal plating waste. Many products were prepared using the industrial by-products coal fly ash and slag. Commercial binders included ordinary Portland cement, as well as other Portland cements and calcium aluminate cement. The most common physical property measurements were unconfined compressive strength, bulk density, moisture content, specific gravity, and setting time, and the most common leaching tests were the acetic acid USEPA EP-tox/TCLP, the distilled water DIN 38414 S4, acid neutralisation capacity, as well as other distilled water and acid leaching tests. The main analytical parameters measured in the wastes and leachates were pH, As, Cd, Cr, Cu, Ni, Pb and Zn.

The properties and materials for neural network analysis were chosen based on their practical importance and availability in the database. Neural network models were constructed for prediction of:
1) setting time of calcium aluminate cements containing contaminants,
2) unconfined compressive strength (UCS) of Portland cement containing contaminants,
3) leachate pH for Portland cement containing contaminants, and
4) UCS of Portland cement containing electric arc furnace dust, foundry dust, municipal waste incinerator fly ash, other ashes and plating sludge.

The effects of each of the input variables on the model predictions was examined. It was found that construction of successful models was possible, with prediction errors approaching experimental error, and that modelling was useful for generalising about the relative effects of the input variables on the outputs using the results from different studies. The work has shown that the potential for practical implementation of models of this type in prediction of long-term durability, and/or formulation design in waste treatment facilities clearly exists, but more detailed definition of the dataspace by experimentation, with more complete harmonisation of methods and measurement and reporting of experimental variables, will be necessary before reliable, trustworthy models can be developed. In the meantime, neural network models are useful as a research tool, which can highlight important variables for design of formulations and test methods, and guide experiments to investigate interference and contaminant immobilisation mechanisms. Also, the MONOLITH database and interface provides a building block that can be helpful to both researchers and industry in advancing this field.

The NNAPICS consortium partners are interested in possible further collaborations in this area. If you have an idea to work together, please contact the project coordinator at julia.stegemann@eng.ox.ac.uk.