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Monolith2 - An On-line Database for Cement/Waste Products

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Abstract: Monolith 2 is an on-line database written as part of a project that aims to develop process envelopes for generic treatment of problematic industrial wastes by stabilisation/solidification with cementitious binders. The front-end of Monolith 2 is web-based and is made up of a core application written in HTML with Java servlets and Java server pages using NetBeans. This front-end of the system connects to a back-end MySQL database, which implements a complex data model described in the paper.

Keywords: stabilisation; solidification; cement; industrial waste; ProCeSS project; web application.

1 INTRODUCTION

This paper describes the Monolith2 on-line database system, which aims to collect a wide variety of highly technical information about waste treatment with cementitious binders from multiple laboratories.

Monolith2 is a web-based application, whose front-end consists of a core application written in HTML with Java servlets and Java server pages using NetBeans. This front-end connects to a back-end database implemented in the open-source database management software MySQL. As well as possessing the characteristics of a conventional database application, Monolith2 has specifically written facilities for searching and querying data and uses third-party tools to plot data and to provide analyses of server log activity.

2 THE PROCESS PROJECT

Stegemann and Côté [1996] defines stabilisation/solidification (S/S) with cementitious or pozzolanic binders as an option for reducing leachability of contaminants from residual, predominantly inorganic, industrial wastes before disposal or reuse. Treatment by S/S is complicated by the fact that the presence of impurities such as the components of industrial wastes can have deleterious effects on cements. Therefore careful laboratory development and testing of S/S formulations are required prior to full-scale application, to avoid technology failures.

The ProCeSS (Process Envelopes for Cement-based S/S) project, Stegemann [2006], aims to support good practice in S/S by developing 'process envelopes' [1] for generic S/S of common residual

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[1]The process envelope for a process is described in Stegemann [2006] as 'the range of operating conditions that result in an acceptable product. To determine the process envelope for any process, it is necessary to establish and quantify the key practical, technical and economic characteristics of both process and product'.

waste types. Data, gathered from a series of laboratory research projects, is being used to find relationships between engineering and leaching properties and S/S product composition in order to define process envelopes that describe the limits of applicability of S/S technology to the chosen waste types. Furthermore, such data will prove vital in developing scientific understanding of the mechanisms underlying successful S/S, and is required to predict the longevity of these materials and evaluate the long-term risk associated with their disposal.

Part of the ProCeSS project is a statistically-based experimental programme conducted by laboratories at four universities: University College London, Imperial College London, University of Surrey and University of Cambridge. The results from the experimental programme are being collected in the on-line Monolith Database and Interface for Cement Based Products, i.e. Monolith2, which has been written for data entry/search/retrieval/exchange.

3 MONOLITH2

Monolith2 is an enhancement of a Microsoft Access-based database, Monolith2001, created in a previous project, Stegemann et al. [2001], which collected data for nearly 8000 cement/waste products composed of materials such as incinerator ash and other baghouse dusts, solidified with Portland cement, fly ash, blast furnace slag and other binders, from more than 300 literature references. The on-line Monolith2 system has been developed to consolidate this wealth of information from the literature, with that generated in the ProCeSS project, in a quantitative, accessible format, which will be available to other scientists, internationally, at the completion of the project.

4 STRUCTURE

4.1 Architecture

Architecturally, Monolith2 forms a typical web-based application, where the client browser makes requests to the web server which, in turn, retrieves relevant data from the database and returns it to the client within a web page. The server comprises a core application written in HTML with Java servlets and Java server pages using integrated development environment NetBeans [2007]. Apache Tomcat [2007] is used as a 'container' to implement the run-time environment for the servlets and JSPs according to Sun Microsystems' ($http://www.sun.com$) specifications.

All aspects of Monolith2's functionality are implemented using servlets and JSPs including the basic data entry and maintenance pages, the search and query facilities and the connections to third-party products for plotting and reporting (Section 5). Its database is implemented with the open-source DBMS MySQL [2007]. The architecture of Monolith2 is shown in Figure 1.

4.2 Data model

Information regarding the handling, strength, durability and leaching characteristics of products in Monolith2 (Section 3) are defined in database tables, which, in turn, are used to define the cement/waste product composition. Other tables contain the results of various physical and leaching tests performed on the S/S products.

Monolith2's data model, described in Stegemann [2001], consists of the following components:

- **A: References** stores information about the scientific publications that data has been taken from.

- **B: Mix Components** stores information about the materials that are mixed together to create a cement-based product, i.e. binders, industrial byproducts, water and additions.
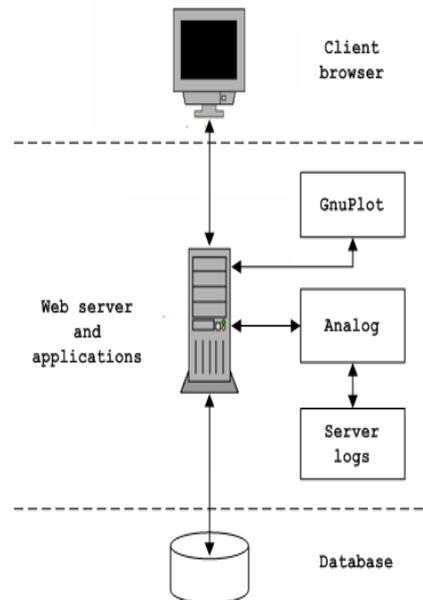
Figure 1: An abstract representation of Monolith2's architecture.

- **C: Phase and Oxide Composition** stores the phase or oxide composition of mix components.

- **D: Conventional Parameters** consists of four tables that store measurements such as pH and loss on ignition for components, products, leachants and leaching tests.

- **E: Chemical Composition** is made up of four tables storing the chemical analyses for mix components, products, leachants and leaching tests.

- **F: Product Formulation** specifies the quantity of each mix component in each cement-based product.

- **G: Product Mixing** stores information regarding the preparation of the cement-based products and their mixing, i.e. paste properties.

- **H: Physical Properties** consists of two tables storing physical properties of products (including hydration) and the physical properties of mix components.

- **I: Leaching Details** stores information regarding the leaching tests applied to the mix components and products.

- **J: Single Batch Leach** forms two tables storing data about leaching tests on mix components and products.

- **K: Other Information** stores any other information that was in the reference, but could not be accommodated elsewhere in the database, e.g. concerning matrix microstructure or transport characteristics.

The schema for the data model illustrating how the various components interact is shown in Figure 2. A number of metadata tables concerning users and privileges also exist.

5   FACILITIES

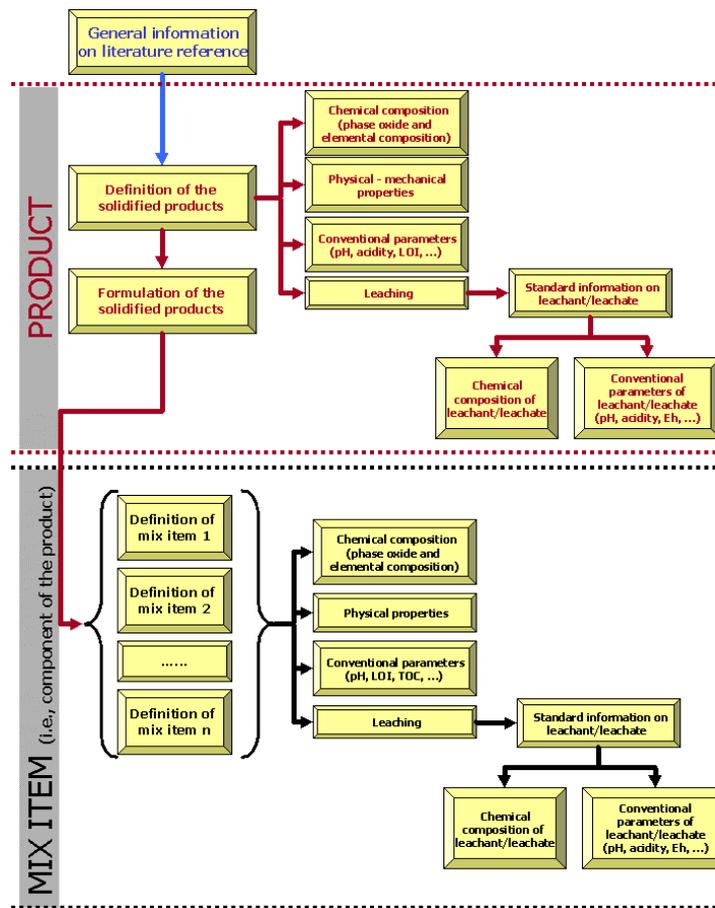The following sections describe Monolith2's key features.

Figure 2: Schematic diagram of Monolith2's database structure, illustrated in Stegemann [2001].

5.1 Interface and Access

Upon logging in, the user is presented with the application's homepage. This forms a common point of entry and, as shown in Figure 3, the data model is displayed to allow simple navigation of the tables forming the database, each of which is independently maintained. From the horizontal banner strip at the top of the homepage, all users have access to the system components described below.

Currently, access to Monolith2 is restricted to a small user base whose user details are maintained by the database administrator. However, there are plans to change this so that any potential user will be able to register with the system on-line.

5.2 Data entry and update

Individual pages for each database table's insert, update and delete operations are implemented in Monolith2 using servlets and JSPs which are generated at run-time using embedded SQL and HTML. During data entry and maintenance, database keys are automatically generated and displayed in drop-down menus for ready selection; all units for value columns can also be chosen in this way. Additionally, Monolith2 has a built-in safeguard allowing the data entered by a particular user to be maintained only by that user or by those of that user's organisation, rather than by anybody else.
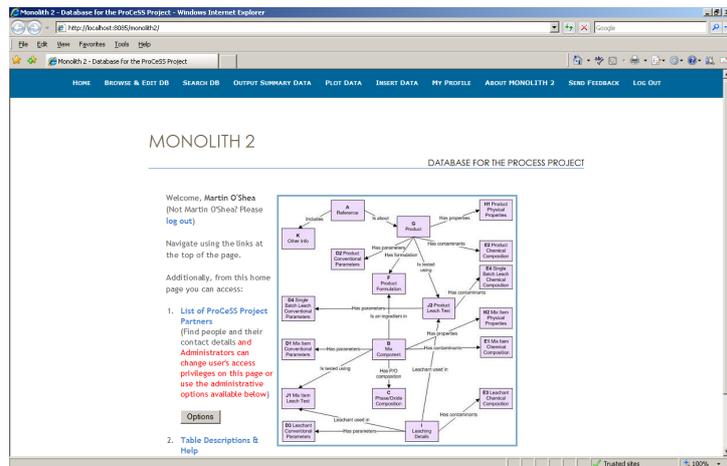
Figure 3: Navigation in Monolith2.

5.3 Searching

Two forms of searching are available. A 'table' search will display all the data in a table from a particular affiliation, and a 'value' search will retrieve data according to the value of a field in one of the tables.

5.4 Querying

Monolith2's principal method of database querying is via a pair of servlets, each of which serves the products or mix components types in the database. These types consist of several tables each (Section 4.2) and the dynamically generated HTML pages allow users to select from lists of these tables, their fields and field values for physical properties, e.g. unconfined compressive strength. Once selection is made, appropriate SQL is generated and temporary database views are created to retrieve the data and present it the user in the form of an HTML table.
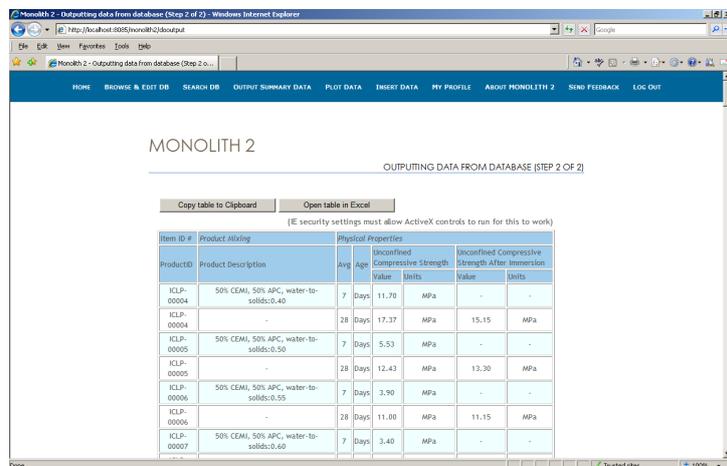

Figure 4: Querying unconfined compressive strength data in Monolith2.

Product data can also be displayed with age averages in rows or columns according to the criteria of physical properties entered. An example of query output is shown in Figure 4.

Additional data querying options allow for the generated output to be copied to the user's PC Clipboard or to be exported directly into Microsoft Excel.

5.5 Plotting

Monolith2 provides a tool for users to graphically represent types and ranges of the data entered. This facility consists of a set of web pages where users select items for the plot's *X*, *Y* and *Z* axes from drop down menus which correspond to tables, or individual columns of tables, from the database.

Users can also specify options for the plot including:

- The plot image's size and type, i.e. a fixed surface, a fixed surface with contours or a grid with contours.

- The plot's title and axes labels and font size to be used.

- Horizontal and vertical rotation.

The items and options chosen are then combined with system-generated SQL and temporary views to extract the relevant data from the database, 'plotted' as an image and returned to the user within a web page.

For each plot, all data and options are also permanently recorded in the database. Currently plotting is restricted to product data in Monolith2 but the facility has been written in a flexible manner to allow its future extension over mix item data.

The plots, generated by a third-party plotting tool, GnuPlot [2007], are designed to be easily comprehensible according to the principles of 'graphical excellence' and 'graphical integrity' defined in Tufte [2001]. An example plot is shown in Figure 5.
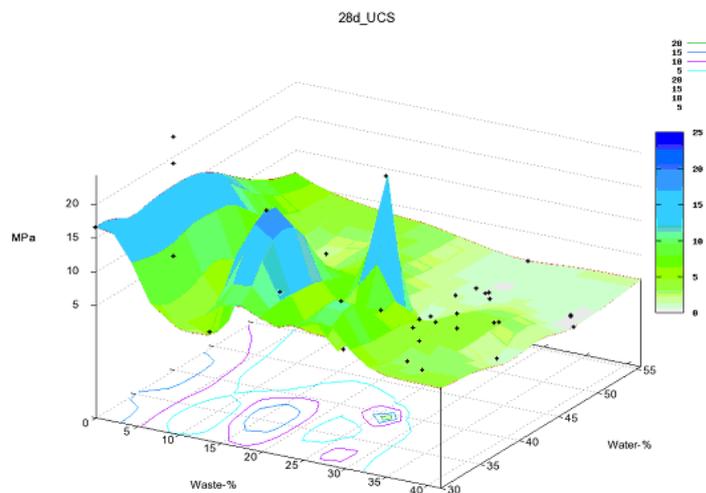

Figure 5: A plot generated by Monolith2 showing unconfined compressive strengths measured at 28 days for a variety of metal sludges treated with several different blended binder systems (the spike in strength occurs at 25% waste, 40% water and 75% binder, dry mass basis).

5.6   Reporting

A web server accepts HTTP requests from clients and serves those clients HTTP responses along with optional data contents, i.e. web pages, graphics et al. A web server also records data concerning user agents, i.e. browsers, date and times of visits, client IP addresses, quantity of data downloaded and so on. Data mining techniques are then employed to analyse this data to 'measure the "success" of the site with reference to its objectives', as described by Levene [2006].

In Monolith2, administrators can use the popular, open-source tool Analog [2007] to generate simple reports which include tables, bar- and pie-charts listing data concerning Monolith2's usage. Monolith2 also logs user requests for data from its database, updates, browsing and run-time exceptions in text files rather than the database. This data can also be used to model user activity within Monolith2 according to known techniques, e.g. Markov chains or forms of statistical analysis.

5.7   Other features

Monolith2 also includes a simple feedback facility to allow users to report comments or incidents directly to the database administrator by email. Extensive, on-line help text also describes each database table, their fields and their domain types, lengths and so on.

Finally, Monolith2 administrators have a servlet-based option to manually run a back up of Monolith2's MySQL database. This process emails the DBA so that the back up can be permanently archived.

6   APPLICATIONS

As stated in Stegemann [2001], 'Monolith2 was developed to catalogue the technical properties of cement-based products, not to make judgements about whether the properties or materials are good or bad, or where the line between "nonwastes" and "wastes" should be drawn. It is hoped that one of the uses of the database will be to make it easier for the appropriate authorities to make these distinctions in a sensible way, in order that more "waste" materials will be utilised, conserving natural resources and minimizing landfill while protecting the environment'. Stegemann [2006] further states that 'such data will be invaluable in developing a scientific understanding of the mechanisms involved in S/S, which is required to be able to predict the longevity of waste materials and evaluate the long-term risk associated with their management'.

7   FUTURE DIRECTIONS

The potential for future development of the Monolith2 database is defined in Stegemann [2001] 'by entry of information from users in both research and industry, as well as expansion of its structure to accommodate additional properties', e.g. related to contaminant transport and materials, and 'use of the data for development of additional models and knowledge-based systems'.

Interim plans for functionality include improving output overall and extending the plotting facilities. Monolith2's 'help' and feedback facilities are also likely to be enhanced with questionnaires. Longer term plans for Monolith2 include: improving the presentation of query and graphical output to match the specific requirements of the user base, providing data mining capabilities for modelling user activity within Monolith2, and personalisation to tailor pages to individual users' characteristics and preferences.

8   CONCLUSION

Stegemann [2001] states that the Monolith2 database 'can accommodate a wide variety of quan-

titative information about the characteristics of raw wastes, cement/waste product formulations, physical properties of cement/waste products, and single batch leaching test results for wastes and cement/wastes products'. The interface also 'provides flexible access to this information, allowing users to search for materials of interest, to aid in formulation design, evaluation, or process feasibility assessment'.

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