ITC
School of underground Waste Storage and Disposal

CEMENT AND CEMENTITIOUS MATERIALS IN GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Switzerland, 15-19 December, 2008

Monday 15th December		
	Introduction and registration	
0945 - 1020	Opening of the course and organisational aspects	R Alexander
0945 - 0955	Introduction to the ITC	R Alexander
0955 - 1010	Introduction to the IAEA	S Hossain
1010 - 1020	Introduction of participants	All
1020 - 1030	Course orientation (pre-assignment)	R Alexander
	Module I: Basics of Cement Chemistry	**C Cau-dit-Coumes**
1030 - 1130	Introduction to the basics of cement chemistry: part I	C Cau-dit-Coumes
1130 – 1145	*Coffee/tea*	
1145 - 1245	Introduction to the basics of cement chemistry: part II	C Cau-dit-Coumes
1245 – 1300	Module I wrap-up	C Cau-dit-Coumes
1300 - 1400	Lunch	
	Module II: Application of cementitious materials in geological disposal – conceptual view of the use of cementious materials	**R Alexander**
1400 - 1500	L/ILW disposal designs – shallow and deep repositories	R Alexander
1500-1600	HLW/SF/MOX disposal designs	I McKinley
1600 - 1630	*Coffee/tea*	
1630 – 1715	Long-lived ILW and special features of co-location with HLW/SF/MOX	R Alexander
1715 – 1730	Module II wrap-up	R Alexander
Tuesday 16th December		
	Module III: Long-term safety evaluation of cementitious materials in geological disposal	**I McKinley**
0830 - 0930	SA aspects of cementitious systems	I McKinley
0930 - 1030	Cement related FEPs	I McKinley
1030 – 1100	*Coffee/tea*	
1100 - 1200	Natural and archaeological analogues of OPC	R Alexander

1200 – 1215	Module III wrap-up	I McKinley
1215 - 1315	Lunch	
	Module IV: Understanding of interactions – cement, the EBS, the geosphere etc	**U Mäder**
1315 - 1415	Cement degradation reactions and modelling	F Neall
1415-1530	Cement leachate interactions with the EBS: laboratory and modelling	U Mäder & F Neall
1530 - 1600	*Coffee/tea*	
1600 – 1700	Cement leachate interactions with the geosphere: laboratory and modelling	U Mäder
1700 – 1715	Module IV wrap-up	U Mäder
Wednesday 17th December		
	Module V: Field visit I	**F Neall**
0900 - 1000	Operational safety – can we really live without concrete in a HLW/SF repository?	F Neall
1000	Departure for the Hagerbach Test Gallery (Flums)	All
1005 – 1015	Introduction to the course exercise (on the bus)	R Alexander
1030	Arrival, coffee, introduction to site	V Wetzig
1100 – 1200	Structural support (focussed on concrete or sprayed concrete) and sealing of tunnels: based on experience from the Gotthard Base and Uetliberg Tunnels	M Glättli & L Knöpfli
1200 – 1300	Lunch in Hagerbach's own underground restaurant (the Bergmannsstube)	
1300 - 1330	Aspects of the application of sprayed concrete	V Wetzig
1330 - 1500	Site visit with demonstrations of: • Production of concrete (different mixes, with/without steel fibres • Quality control of fresh concrete (does the concrete attain the design requirements?) • Working with sprayed concrete (application, use and dosage of accelerator, rebound) • Quality control of sprayed concrete (early age strength, methods of measuring quality) • Testing and investigation of concrete in the laboratory (strength, water-tightness, durability)	V Wetzig
1500 - 1700	Group exercise I: preparation for group presentations on operational safety – *with coffee/tea.* 6 groups, two topics	Participants and R Alexander, F Neall & V Wetzig
1700 - 1830	Group presentations	Participants
1830	End of day, return to the hotel by bus	
1840 – 1845	Modules V & VI wrap-up (on the bus)	F Neall

Thursday 18th December		
	Module VII: Design of permanent and removable cement/concrete structures and applications	**R Alexander**
0900 - 1000	Design and construction techniques	R Alexander
1000 - 1030	*Coffee/tea*	
1030 - 1130	Types of structures and materials	F Neall
1130 - 1200	Example of tunnel liner design	P Steiner
1200 - 1300	Lunch	
1300 - 1310	Group exercise II (requirements for structures and materials): short introduction	F Neall
1310 - 1600	Working in groups (*coffee/tea break during group work*)	Participants and F Neall, P Steiner & R Alexander
1600 – ca 1800	Group presentations: 6 groups, two topics	Participants
1900	Course dinner	All
Friday 19th December		
	Module VI (cont.): practical aspects of underground construction: Field visit II	
0730	Departure for Mont Terri URL (St Ursanne)	All
ca. 1030	Arrival, coffee	
1100 – 1130 1130 - 1200	Introduction to the site Details of the low pH shotcrete experiment (SB)	P Bossart Th Fries
1200 – 1245	Lunch	All
1245 – 1500	Site visit: rock support, tunnelling, concrete silos, grouting, etc • SB niche: presentation of the SB in-situ work • CI niche: presentation of the CI in-situ work	Ch Nussbaum Th Fries P. Bossart
	Module VII: Development of new cement materials and products- low alkali/low pH materials	**R Alexander**
1500 – 1530	Historical overview and recent progress	F Neall
1530 - 1545	*Coffee/tea*	
1545 - 1645	Applications and long-term safety and performance aspects	R Alexander
1645 – 1700	Modules V & VI wrap-up	R Alexander
1700	End of course. Catch train from St Ursanne Railway Station (direct link with Basel Main Station and from there to Basel and Zürich airports) at 1716 or return to hotel on the bus	All

Course Outline

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This course will be a repeat of the new ITC course on the uses of cement and cementitious materials in the geological disposal of radioactive waste (June, 2008). The first presentation of this course has proved very popular and spaces for the June course were rapidly filled, well before the closing date for applications and so is repeated here only six months later. The 5 day programme for December 2008 features seven, interlinked, modules which cover all aspects of the use of cementitious materials in radwaste disposal. Sufficient time will be allocated for questions and discussions in each presentation module and afterwards, over coffee and lunch.

In addition to formal teaching (including group exercises and field visits) each course participant is required to prepare a pre- and post-assignment related to the course. The purpose of the assignment is that the participants devise a specific cement-related topic to focus on during the course (see details below).

Module I: Basics of Cement Chemistry

This module includes presentations on the fundamentals of cement chemistry and mineralogy and will provide enough information for a novice in this area to understand the following 6 modules. Areas covered will include basic cement chemistry and mineralogy, historic development of cements (including pre-industrial uses), cement production and applications (why are there such a wide range of cement formulations?). Participants will come to understand that, although cement and concrete are ubiquitous in the modern world (and were, to a degree, in the ancient world), they are complex materials and there are still many things to learn about them, especially in the context of radwaste disposal. The focus will be on 'standard OPC (Ordinary Portland Cement) types, but other formulations will be covered in module VI.

Module II: Application of cementitious materials in geological disposal – conceptual view of the use of cementious materials

The course participants will be introduced to the specific application of cement in the geological disposal of radwaste, including the historical development of cementitious repository design (who first thought of disposing radwaste in concrete and why?). What are the advantages and disadvantages of the use of cementitious materials in waste disposal? Could we build and operate our repositories without cement and concrete? What are the strengths and weaknesses of the different designs for the different waste streams? Are there any designs or waste streams, which could not be considered for cementitious materials? Considering that industrial cements were first introduced over 150 years ago, which areas require further, repository-relevant R&D? By the end of this module, the course participants should have an understanding of the current range of cementitious repository designs and the logic behind the use of cement and concrete in radwaste disposal.

Module III: Long-term safety evaluation of cementitious materials in geological disposal

Here, experienced safety assessment (SA) modellers will explain how cementitious material are viewed within a repository safety assessment - and what role it needs to fulfill to immobilise radwaste. This is a significantly different role from that of design, construction- and operational-related cement and requires the course participants to see cementitious materials in a different light. The participants will also learn something of the SA approach to evaluating the role of cement in a repository and how the SA modellers assess the strengths and weaknesses of cement in repository systems. Of course, one of the crucial questions about any man-made material such as industrial cement is 'how long will it last, how long can we depend on it to do the job we require of it?. This will also be addressed by the SA modellers and the participants will be introduced to the methodology of long-term testing – namely, natural analogues. Here, the course participants will gain an insight into how examples from nature's own laboratory can support our short-term laboratory experiments and give us confidence that cement and concrete can indeed last as long as we need to immobilise even the longest-lived wastes.

Module IV: Understanding of interactions – cement, the EBS, the geosphere etc

Although most people probably view cement and concrete as 'wonder materials' with which we can do almost anything, there are some aspects of cementitious materials which have to be considered most carefully when using them in a radwaste repository. In Module II, the clear advantages of cements were pointed out but, here, some of the potential disadvantages are examined. These stem from the basic fact that cement is out of equilibrium with its surroundings when placed in the geosphere: cement leachates have an initial pH of >13, whereas most repository host rocks' ground- and porewater has a pH somewhere between 6 and 8. This clear disequilibrium leads to reactions which attempt to re-assert equilibrium by dissolution of some mineral phases and the crystallisation of others. This module will address these changes, beginning with how the cementitious material itself slowly degrades and the impact this then has on the surrounding host rock and other parts of the engineered barrier system (EBS). Evidence from laboratory experiments will be backed up with model calculations to provide the course participants with a clear overview of the likely impact these complex cement/EBS/host rock interactions will have on the long-term performance of a repository.

Module V: Field visit to a Swiss URL

Switzerland is unusual in that it plays host to no less than 5 URLs (underground research laboratories) and the participants will visit two over the duration of the course. In this module, focus will be on repository-related operations where concrete has been utilised in a wide range of rôles, including waste silo construction, tunnel support, waste encapsulation, tunnel flooring etc. The visit will also include time in the underground research tunnel used for field testing of deep geological disposal methods and technologies.

Module VI: Development of new cement materials and products

If industrial cements are already over 150 years old, why do we need new formulations? This has already been addressed to a degree in modules I-IV, but will be examined more closely here. The drivers behind new formulations will be explored as will the historical development of 'alternative' cement types. The main focus will be on a range of low alkali cements which have the advantage of lower pH (~10.5 to 11.5) than the traditional OPC formulations, but other materials, such as silica sol and bentonite grouts will also be discussed and their role in repository construction and performance examined. By the end of this module, the course participants will have an understanding of the newer cement formulations and how they can be employed in a wide range of repository designs – one focus of this area of R&D in this area is the use of these cements in HLW/SF/MOX repositories, for example.

Module VII: Design of permanent and removable cement/concrete structures and applications

The participants will be introduced to some examples of repository-relevant concrete structures which, in addition to the information provided in the previous course modules, will act as a basis for the group exercise. Here, the groups will define design requirements for concrete structures in both L/ILW and HLW repositories, bearing in mind the different nature of the repository engineered barriers and the specific rôles which they have to play in the long-term performance of the repository. To add some additional variation to the tasks, different groups will be assigned different host rock types with different physico-chemical properties.

The current state-of-the art in concrete structure requirements for deep geological disposal is still developing, so the course participants could make a real contribution to the body of knowledge in this field.

The module will finish with a site visit to a second Swiss URL where the focus is on concrete construction methods for underground facilities, with an opportunity for the participants to get a view of how concrete designs and structures are developed and how their quality is assured in both the R&D and production environments. An overview of the tools (equipment, manpower etc) of relevance will also be provided with information on cutting-edge design developments and international best practice.

Participants' profile – is this course for you?

The course is ideal for those involved in any component of a national radwaste programme and who have a desire to learn about all aspects of working with cement and concrete in waste disposal. While some background in either cement or radwaste is useful, the modules have been so designed as to ensure that any participant who currently only has a rough idea of the use of cement in waste disposal, will profit from this course. A basic grasp of chemistry is required, but more important is a genuine interest in being involved in cement-related issues in waste disposal. If you are unsure if this course is for you, please feel

free to contact the course director, Russell Alexander (russell.alexander@itc-school.org), for an informal chat.

Course organisers

The course is organised by the **ITC-School** (www.itc-school.org) and is supported by a wide range of organisations and individuals who are actively involved in the use of cementitious materials in radwaste disposal.

Teaching

The course will be held in an informal, workshop atmosphere and participants will be encouraged to interact with and question the tutors at all times. In addition to the ITC course director, who will be present at all times, each module will have a dedicated director whose aim is to ensure that the participants fully understand the module contents and are ready to move on to the next part of the course.

Each course module will be taught by highly qualified and internationally recognised specialists from a range of organisations active in the field of radioactive waste disposal. They will provide the most up to date and comprehensive information currently available on each topic. To back up the taught information, hard copies of course material will be provided to each participant. Modules will generally be taught throughout the day, but there will also be two field trips to course-relevant sites. In addition, a focussed, group session will be held where the participants will be split into small groups and encouraged to develop their own thoughts on the requirements for cementitious materials in repository construction and operation.

And finally.....

To help you to get the most out of this course, we would like you to produce a short pre-course assignment. But don't worry, we are not asking you for much effort, just a little thought in advance of attending the course which will focus your thinking and give us an insight into your requirements. And don't worry if you cannot express yourself fluently, *this is not a test*, rather it is simply intended to help us get to know you a bit in advance. In return, you will be given the course tutors' CVs when you start the course.

Course Assignment – please email to Gabi Vonlanthen (gabi.vonlanthen@itc-school.org) by 14th November, 2008 with 'Cement course assignment' in the subject line.

- why have you chosen this course?
- what are your learning objectives for the course?
- what other objectives do you have for the course?
- tell us a little (a couple of sentences) about your educational and professional background
- tell us a little about your current job – and about any relevant projects you are currently working on or have recently completed. How do these relate to cement studies in waste disposal?
- if not covered in the previous question, what is your previous experience in cement studies in general and in the field of waste disposal in particular?
- is there any specific area of cement and cementitious materials in the geological disposal of radioactive waste where you expect to increase your knowledge by the end of the course?

  -pick at least one topic bearing in mind that this should be your 'guiding theme' during the course

  -how is this topic relevant to your disposal system?

  -what is already known about the topic?

  -what more do you need to know on the topic?

As an outcome of the course, we expect you to prepare a short plan on how you are going address your topic using the additional knowledge gained during the course – this will help both you and us assess if we have addressed your training requirements appropriately.