2014

Activity Report

ESV EURIDICE EIG

2014
Activity Report

ESV EURIDICE EIG

Activity Report 2014

Doc. 15-004

Approved by:

Frank Hardeman, Board of Governors

Marc Demarche, Chairman of the Board

Responsible editor

Peter De Preter, Director of the EIG EURIDICE

Sneppenstraat 66, 3010 Kessel-Lo

EIG EURIDICE

Boeretang 200

BE-2400 MOL

Tel. +32 14 33 27 84

www.euridice.be

Contents

General foreword

Marc Demarche, Chairman of the Board of EIG EURIDICE

Dear reader,

The Activity Report 2014 provides a comprehensive overview of the main developments and achievements with respect to EIG EURIDICE's statutory tasks. EURIDICE is the Economic Interest Grouping (EIG) comprising SCK•CEN and ONDRAF/NIRAS, and is responsible for managing and operating the HADES underground research laboratory, conducting research, demonstration and development activities relating to the disposal of radioactive waste and communicating about its activities.

In 2014 an important milestone was reached in the history of EIG EURIDICE. After many years of preparatory work, the large-scale PRACLAY Heater experiment actually got underway, with the switch-on of the heating system on 3 November 2014.

The PRACLAY Heater experiment constitutes the last stage of the PRACLAY project, which began back in 1997 with the expansion of the HADES underground laboratory. The goal of this project and experiment, in which the heating phase itself will last 10 years (2015-2025), is to demonstrate that mechanical and thermal disturbances, resulting from the construction of a disposal infrastructure and the emplacement of heat-producing high-level radioactive waste, do not affect the capacity of the clay host rock to safely contain and isolate the radioactive waste. The effect of temperature on the components of the disposal infrastructure itself, such as the concrete gallery lining, will also be studied.

The Heater experiment is being run in the PRACLAY gallery, which was excavated in 2007. Since then EIG EURIDICE has been installing all the test components in this 40 m long gallery:

- 2007-2014: emplacement of all the measuring instruments in and around the PRACLAY gallery to accurately monitor all major phenomena and processes in the clay and in the gallery itself;
- 2010: installation of the steel seal structure with a ring of bentonite blocks in contact with the Boom Clay, which has to create the required hydraulic boundary conditions for the Heater experiment;
- 2010: installation of the primary heating system;
- 2011: emplacement of the central tube for the secondary heating system;
- 2011: backfilling of the PRACLAY gallery with sand;
- 2012-2013: saturation with water of the sand-backfilled PRACLAY gallery;
- 2014: installation of the secondary – replaceable – heating system ensuring redundancy of the heating system.

Since 2010 the swelling of the bentonite ring in the seal has been closely monitored, and a series of tests have been carried out to investigate the seal's hydraulic and mechanical properties. By the end of 2013 the bentonite ring had swelled enough to meet the hydraulic boundary conditions required to be able to successfully start the Heater experiment.

2014 became the year of final preparations prior to switching on the PRACLAY heating system. EIG EURIDICE, in close cooperation with ONDRAF/NIRAS, carried out a systematic analysis and verification of all the elements needed for the actual start-up of the Heater experiment. The final preparatory work was done in the period January-October 2014:

- installation of the secondary heater and its control system;
- final testing of the primary heating system and its control system;
- installation and testing of the data management tools, including the Data Acquisition System and "real-time" user interface system;
- scientific modelling to predict and assess the expected and potential disturbed experimental evolutions;
- preparation of the procedures for the management and control of the experiment, including an alarmsystem, and monitoring of the key parameters of the experiment in order to organise the scientific follow-up of the experiment.

With all the components of the experiment in place and all the follow-up tools and equipment ready, it was decided to proceed to a full test phase by switching on the primary heater for several weeks, with a heating power representative of a high-level waste repository. At the end of 2014 this test phase was evaluated and deemed fully successful, and it was decided to continue the heating phase of the experiment without interruption. So, in late 2014, the PRACLAY Heater experiment was in the start-up phase, and will remain so until the target temperature of 80°C is reached at the interface between the gallery lining and the Boom Clay in the spring of 2015. The 10-year heating phase will commence from then on.

With this important research milestone reached by the end of 2014, a great deal of energy also went into preparations for a number of communication activities that will be organised around the start of the 10-year Heater experiment. Together with its constituent members, SCK•CEN and ONDRAF/NIRAS, EURIDICE will hold several events for all political, economic, societal and scientific stakeholders involved.

As the management of acquired knowledge and expertise is a key objective and challenge for EIG EURIDICE, it will use the start-up of the Heater experiment in 2014 as a key opportunity to put the spotlight on its own unique technical and scientific RD&D in and around the HADES underground laboratory and to attract the attention of universities and other scientific institutions or engineering organisations, with a view to strengthening its network of scientific collaborative partnerships.

EIG EURIDICE: history, tasks and fields of expertise

EIG EURIDICE (European Underground Research Infrastructure for Disposal of nuclear waste In Clay Environment) is an Economic Interest Grouping (EIG) involving the Belgian Nuclear Research Centre (SCK•CEN) and the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS). It manages the HADES underground research laboratory and carries out RD&D, including feasibility studies for the disposal of high-level and long-lived radioactive waste in a clay host rock. In this way, EIG EURIDICE contributes to the national disposal programme for high-level and long-lived waste managed by ONDRAF/NIRAS, organised in a stepwise manner with major milestones at key decision points. EIG EURIDICE also contributes, to a more limited extent, to the surface disposal programme of ONDRAF/NIRAS for low-level waste.

In 1974 SCK•CEN started research into the geological disposal of high-level and long-lived radioactive waste in a clay host rock. The Boom Clay, a poorly indurated clay (or plastic clay), was and still is regarded as a potentially suitable host formation. This clay layer is found at a depth of 190 to 290 metres below the SCK•CEN research site in Mol. In 1980 SCK•CEN began construction of the HADES (High-Activity Disposal Experimental Site) underground research laboratory (HADES URL Figure 1), situated at a depth of about 225 metres. This was the first purpose-built underground research facility in plastic clay in Europe and worldwide. The laboratory was gradually extended, with the excavation of a second shaft (1997-1999) and a Connecting gallery (2001-2002) linking the second shaft to the then existing underground laboratory. At each stage of excavation and construction, new techniques were used and new technological and engineering expertise was gained. The HADES URL has been managed and operated by EIG EURIDICE since 2000.

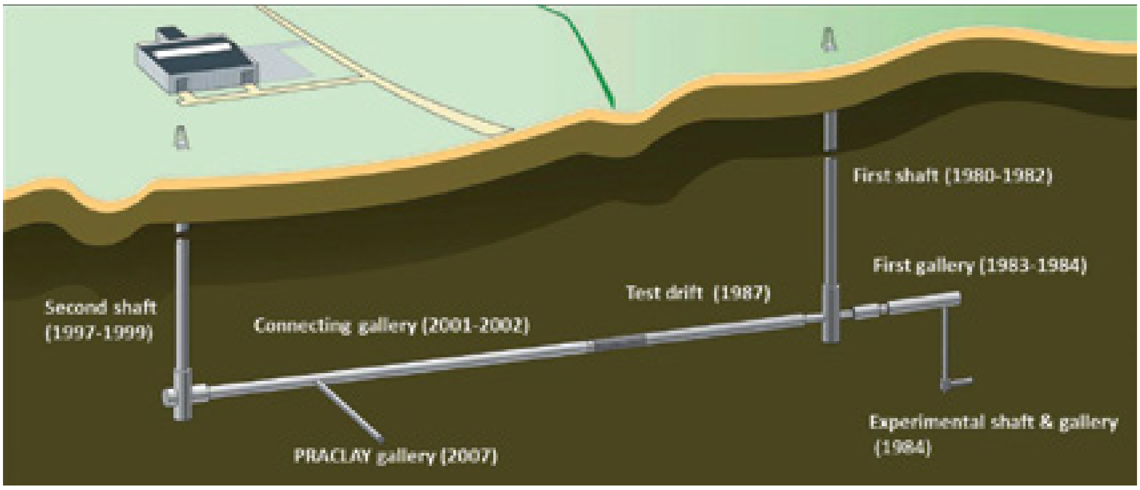


Figure 1 - The underground research laboratory HADES (High-Activity Disposal Experimental Site)

The main statutory tasks of EIG EURIDICE entail a range of activities with a view to developing and facilitating the activities of EIG EURIDICE's constituent members:

- The management and exploitation of the HADES URL and all the installations situated on the land for which EIG EURIDICE has a building lease.
- The development of the PRACLAY project, which aims to contribute to demonstrating the feasibility of disposal of radioactive waste in a clay host rock.
- The possible development, implementation and valorisation of other research projects and experiments with regard to the disposal of radioactive waste.
- The possible realisation, exploitation and valorisation of other research projects concerning the long-term management of radioactive waste in order to support the scientific programmes of its members using their resources.
- Communication about its own activities, in dialogue with its members, including the organisation of visits to the HADES URL.

After 30 years of research in and around the HADES URL, a lot of expertise and know-how have been acquired in different scientific and technological fields, of key importance for developing an underground radioactive waste disposal facility in poorly indurated clay formations such as the Boom Clay. The scientific and technological expertise of EIG EURIDICE focuses on three areas:

1. Excavation and construction techniques for an underground repository in a clay host rock.
2. The thermo-hydro-mechanical (THM) behaviour of the clay host rock.
3. Instrumentation & monitoring.

EIG EURIDICE's first area of expertise has changed significantly over the past 35 years, with excavation and construction of the HADES URL evolving from semi-manual and slow to industrial, using tailor-made tunnelling machines. The tunnelling techniques used for excavating in poorly indurated clay at great depth, including the crossing between galleries, have greatly reduced excavation-induced disturbance of the clay layer and have demonstrated that it is feasible to construct a disposal infrastructure, at a reasonable speed and cost. Since the natural clay layer will be the main barrier for radionuclide migration in a geological disposal system, reducing the excavation-damaged zone (EDZ) is a key objective and relates directly to the safety of a disposal system.

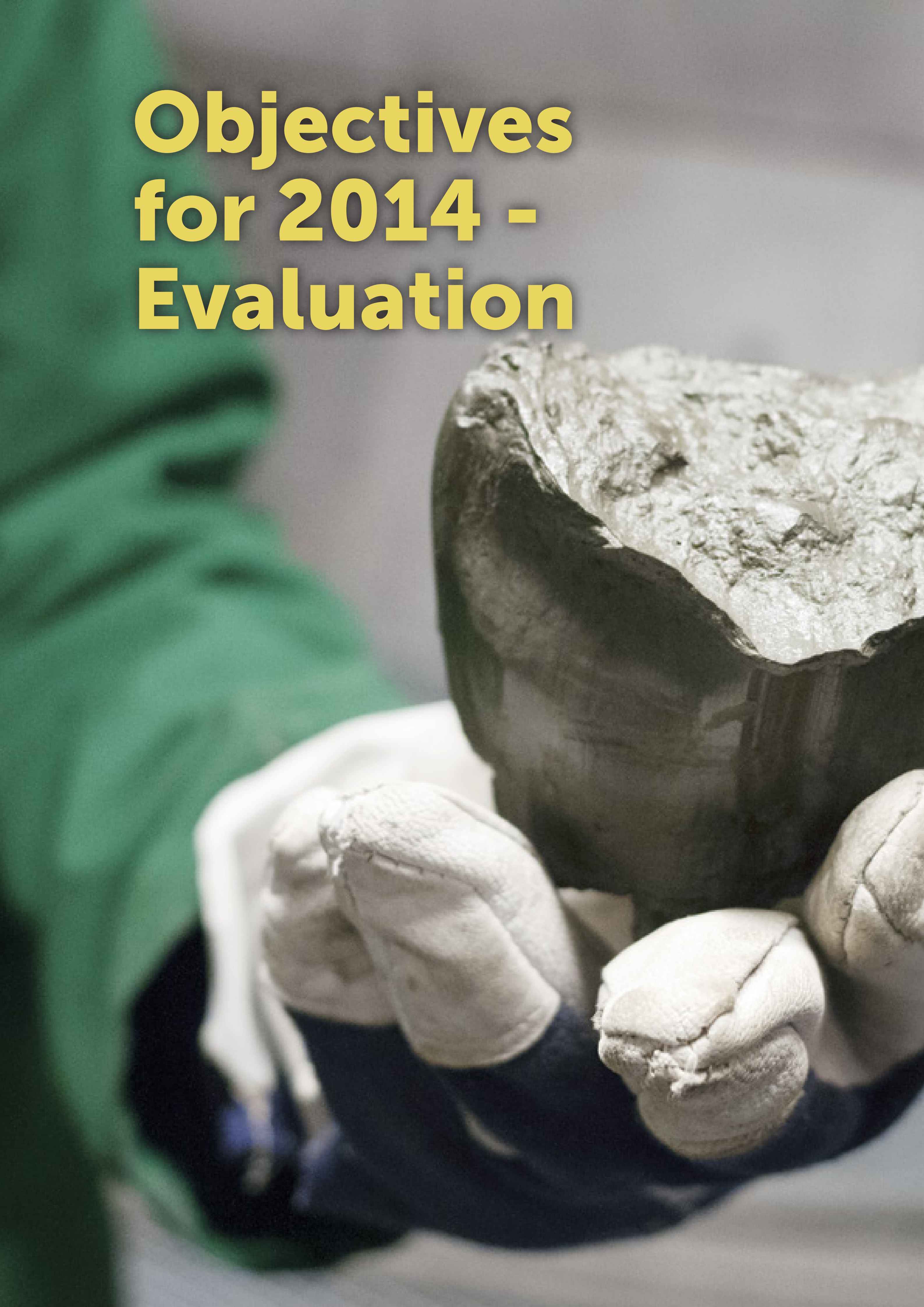
The second field of expertise of EIG EURIDICE involves understanding the THM behaviour and characterisation of a clay host rock, including all disturbance processes induced by the construction of the galleries and by the emplacement of heat-emitting radioactive waste. In low-permeability clays such as the Boom Clay, THM processes are strongly coupled. EIG EURIDICE's knowledge base is mainly built on the research activities in and around the HADES URL in the Boom Clay. The extensive scientific instrumentation systems installed in the clay before, during and after the construction of galleries made it possible to create a valuable geotechnical knowledge base and database to characterise and understand the hydro-mechanical response of Boom Clay in the short and long term, including the generation and evolution of the EDZ. Proper understanding of the coupled THM processes in a clay host rock around the repository is essential to determine to what extent these processes could affect the capacity of the clay to contain the radioactive substances and to isolate the radioactive waste. The most important project in this area is the large-scale PRACLAY experiment. Here, the combination of the hydro-mechanical disturbances due to excavation of galleries and the further coupled thermo-hydro-mechanical disturbance due to heat production, as in the case of the disposal of high-level vitrified waste or spent fuel, are studied on a large scale.

The RD&D programme in and around the HADES URL relies heavily on the use of various instrumentation devices and techniques to measure and monitor the main THM characteristics of the clay; some of these have been developed in-house. This is the third main area of expertise of EIG EURIDICE. Experience has been gained in several aspects specific to this type of instrumentation and monitoring, such as the long-term operation (decades) of sensors and their measurement data, reliability (e.g. how to implement field calibration and what the alternatives are when this is not possible) and robustness under adverse conditions, such as corrosion and mechanical strains. This extensive instrumentation experience will be an essential element in designing a monitoring programme for an underground repository for high-level and long-lived waste in a clay host rock.

With its RD&D activities and fields of expertise, EIG EURIDICE contributes to the national programme for high-level and long-lived waste disposal managed by ONDRAF/NIRAS. In 2011 ONDRAF/NIRAS published its final waste plan for the long-term management of high-level and/or long-lived waste (NIROND 2011-02, September 2011), with a view to obtaining a policy decision on the long-term management of this waste. In 2013 ONDRAF/NIRAS finalised its RD&D plan on geological disposal (NIROND-TR 2013-12 E), describing the main achievements and future challenges. The next milestones of this programme will largely depend on the timing and nature of the policy decision.

During 2014, EIG EURIDICE put a lot of effort into preparing for the start-up of the PRACLAY Heater experiment. This was done in close collaboration with ONDRAF/NIRAS, through the creation of a EURIDICE – ONDRAF/NIRAS PRACLAY project team. At the beginning of November all elements of the experimental set-up were in place and had been tested, including the heating system. On 3 November a full test phase was launched by switching on the primary heating system. As this test phase was fully successful, it was decided to continue heating in the start-up phase of the experiment up to the target temperature of 80°C at the interface between the concrete lining and the clay. This will take about six months. During the first few years of heating, it is expected that it will already be possible to make important observations, which will provide valuable input for the safety and feasibility assessments of ONDRAF/NIRAS in the context of its next programme milestone, i.e. Safety and Feasibility Case 1.

Objectives for 2014 - Evaluation



The main objectives for 2014 formulated in the Activity Report 2013 were as follows:

1. Switch-on of the PRACLAY heating system

EIG EURIDICE plans to switch on the PRACLAY heater in autumn 2014. In order to be fully prepared for the PRACLAY Heater experiment follow-up, the following objectives have to be met before the switch-on:

- Complete installation and testing of the experimental set-up. This concerns mainly the additional technical elements identified during 2013:
  - modification of the thermal control protocol in the control system for the primary heater;
  - installation of the secondary heater and its control system with the modified design;
  - installation of the thermal insulation door in front of the seal structure;
  - construction of the plugs to be used in the event of leakage through the seal feed-throughs.
- Install and test the data management tools for the test measurements. This includes the Data Acquisition System and "real-time" user interface system, as well as all associated back-ups (hardware and software) and UPS (Uninterruptible Power Supply).
- Update the analysis of the experimental evolution (bentonite ring swelling, pressure build-up in the PRACLAY gallery, etc.) taking into account the actual planning of the heater switch-on in autumn 2014. This update also includes sensitivity analysis and analysis of various altered evolution scenarios.
- Prepare and complete the procedures necessary for the management and control of the experiment. These procedures also include the implementation of the alarm system.
- Report on the modelling results (expected evolutions, minor and major deviations) that will be used to support decision-making during the experimental follow-up.

2. Technical and scientific follow-up of the PRACLAY Seal and Heater experiment

- Continue to monitor the hydration and swelling of the bentonite ring seal before and after the heater switch-on.
- Conduct baseline measurements before starting the Heater experiment and report on the "initial conditions" of the PRACLAY Heater experiment.
- Report on the seismic measurements obtained around the PRACLAY seal focusing on the response to the excavation and subsequent self-sealing of the Boom Clay. Quantitative interpretation of the mechanical properties of the Boom Clay will also be included in this report.
- Report on the numerical simulations made to prepare for the Heater experiment start-up (bentonite seal behaviour, experimental evolution, risk analyses, etc.).

3. Scientific tasks related to the thermo-hydro-mechanical behaviour of a disposal system in a clay host rock

- Carry out analysis, interpretation and numerical investigation of the fourth phase of the ATLAS test and, at the end of the cooling phase, make permeability measurements before performing a "heating pulse" test to investigate the ultimate temperature limit of the Boom Clay and possible thermally induced irreversible damage to the clay. After the heating pulse test, samples will be taken in the thermally affected zone to investigate the thermal effects on the key properties of the clay.
- PhD and post-doctoral research
  - Continue the laboratory creep tests at high temperature, the laboratory investigation of the anisotropic thermo-hydro-mechanical behaviour of Boom Clay and the thermo-hydro-mechanical-chemical behaviour of Boom Clay and Ypresian clays;
  - Continue the laboratory investigation of gas transport in the Boom Clay;
  - Continue the numerical investigation of the excavation-damaged zone (EDZ) in the Boom Clay.
- Start the detailed investigation and follow-up of the stability of the liner in HADES in cooperation with Tractebel and embark on PhD research on this subject.
- Continue the development of short-term and long-term thermo-hydro-mechanically coupled constitutive models and validate these models with the in-situ measurements.
- Define and conduct a new series of in-situ tests (hydro-fracturing and Self-Boring Pressure meter tests) in HADES to refine knowledge on the in-situ stress state of the Boom Clay at the HADES level.

4. Supercontainer feasibility demonstration test (on surface)

- Write the final report on the second half-scale test, including an overall analysis of all results and observations.
- Management and technical follow-up of the DEF test (Delayed Ettringite Formation).

5. Specific support to ONDRAF/NIRAS on disposal technology and Safety and Feasibility Case 1

- Support ONDRAF/NIRAS in developing an approach to the operational safety of a geological disposal facility, using EIG EURIDICE's expertise and experience in the operation of the HADES URL.
- Continue to contribute to the investigation of disturbances in the clay host rock and the thermo-hydro-mechanical behaviour of repository components, and to reporting within the context of ONDRAF/NIRAS's Safety and Feasibility Case 1.
- Consolidate the large body of knowledge (and data) available on the hydro-mechanical and thermo-hydro-mechanical behaviour of Boom Clay (and to a lesser extent Ypresian clays). In particular, this needs to be done by finalising a geotechnical synthesis report for Boom Clay (update of the 2004 "state-of-the-art" report, EIG EURIDICE 04-251)
- Introduce the key Boom Clay parameters (and Ypresian clay parameters when available) and their values into the data clearance system managed by ONDRAF/NIRAS to ensure consistency within the national RD&D programme.
- Support ONDRAF/NIRAS (provide samples, data, technical and scientific expertise) for the supervision of PhDs, post-doctoral studies and research carried out by third parties on the (thermo-) hydro-mechanical(-chemical) behaviour of Boom Clay and Ypresian clays and on gas transport.

6. Management and exploitation of EIG EURIDICE and its installations

- Management and exploitation of EIG EURIDICE and its installations according to the Statutory Rules of the EIG and in line with the ISO 9001-2008 standard.
- Prepare for the replacement of the shaft 1 hoisting system. A preliminary design study and cost estimate will be finalised in the first half of 2014, on the basis of which discussions with the authorities and inspection bodies will be held in order to decide on the applicable regulations.
- Prepare the EIG EURIDICE site for a new visitor entrance that will be built in 2014, including some modifications to technical infrastructure and roads on the site.
- Changes to the electrical infrastructure will be made, mainly in our workshop.
- Re-evaluation of some safety-related aspects, such as the fire-detection systems.

7. Monitoring

As has already been outlined in the new monitoring task, EIG EURIDICE will establish, in the first instance, an updated instrumentation review to summarise experience with the different monitoring techniques. This review will cover:

- The experimental set-up in HADES and at the surface.
- Experience with similar set-ups outside of EIG EURIDICE. The contacts that EIG EURIDICE maintains with other organisations (e.g. NAGRA) or consortia (e.g. Mont Terri) will allow us to obtain the information required for this type of study.

The second part of this task, in which the role of monitoring in the safety case will be developed, will probably not be started before 2015.

8. SAC (Scientific Advisory Committee of EIG EURIDICE)

- Continue to work with the SAC on the scientific aspects of the PRACLAY project.
- Expand the working scope of the scientific and technical remit of the SAC, in line with the scope of the main knowledge domains of EIG EURIDICE.
- Discuss and establish a set of research topics for future PhDs.
- Improve collaborative networking with the academic world.

9. POP (Programme Committee for Underground Experiments)

- Draw up an inventory of all experimental set-ups (past and current) in HADES.
- Discuss and define, at a conceptual level, possible new tests for the period 2015-2020 in line with the RD&D plan of ONDRAF/NIRAS.

10. Communication

- Develop a document on the communication strategy for the period 2014-2020 in dialogue with the constituent members.
- Establish an access procedure for visitors in preparation for the new separate entrance.
- Develop a new manual for visitor guides.
- Go online with the new website.
- Prepare an event, planned for early 2015, to mark the start-up of the PRACLAY Heater experiment.

11. Knowledge domains of EIG EURIDICE

A knowledge management team will be created to develop an integrated knowledge management system. The following steps need to be taken:

- Continue to draw up a complete and structured inventory of all information produced by EIG EURIDICE and input all experiments and instrumentation into the GSIS system.
- Start a project on excavation and construction technologies.
- Integrate the information management of EIG EURIDICE with the knowledge management systems used by SCK•CEN (Alexandria) and ONDRAF/NIRAS (Vignette).

12. Surface disposal project for category A waste

EIG EURIDICE will support ONDRAF/NIRAS in the presentation and defence of the Safety Case for the near-surface disposal site for category A waste. This support concerns the tasks entrusted to EIG EURIDICE and will be provided as stated in the agreed planning schedule.

EIG EURIDICE will provide the final report on the instrumentation of the demonstration test. Depending on how far advanced the test cover set-up is, EIG EURIDICE may also assist in the instrumentation work for this project.

13. Establish an agreement with ONDRAF/NIRAS for 2015-2020

Conclude a contractual agreement with ONDRAF/NIRAS for the programme on geological disposal of high-level waste for the period after 2014.

On 31 December 2014 the status of these objectives was as follows:

1. Switch-on of the PRACLAY heating system

- All additional technical elements identified during 2013 had been put in place by the end of October, except the thermal insulation door in front of the seal structure, which will be installed at the beginning of 2015 due to practical operational reasons. This meant that the entire experimental set-up was nearly complete. The data management tools for the follow-up of the test measurements and management of the experiment were developed, installed and tested. These include the Data Acquisition System and the "real-time" user interface system, as well as all associated back-ups (hardware and software) and UPS (Uninterruptible Power Supply). In late June/early July a "dress rehearsal test" was conducted by switching on the primary heater for three days in order to test the main components of the set-up. On 3 November a full test phase was launched and lasted several weeks. As this test phase ran successfully, it was decided to continue heating in the start-up phase of the experiment, which will take the temperature up to the target 80°C at the lining-clay interface in about six months.
- The analysis of the experimental evolution (bentonite ring swelling, pressure build-up in the PRACLAY gallery, etc.) was continuously updated, taking into account the adjusted scheduling of the experiment. This update also includes sensitivity analysis and analysis of various altered evolution scenarios.
- A "management guide"(procedures) was established for the management and control of the experiment. These procedures also include the implementation of the alarm system.
- A set of reports on the modelling results (expected evolutions, minor and major deviations) was written to support decision-making during the experimental follow-up.

2. Technical and scientific follow-up of the PRACLAY Seal and Heater experiment

- During 2014, the hydration and swelling of the PRACLAY seal were continuously monitored, reported and analysed.
- A "T0 report" was written, describing the baseline measurements of the Heater experiment (experimental set-up, thermo-hydro-mechanical conditions in the Boom Clay, etc.) before the primary heater was switched on at the beginning of November 2014. These baseline measurements serve as the "initial conditions" of the PRACLAY Heater test.
- Work began on analysing and reporting on the seismic measurements obtained around the PRACLAY seal. Preliminary quantitative interpretation of the mechanical properties of the Boom Clay (Young's modulus, shear modulus) based on the micro-seismic transmission measurements at different time periods on the paths between several selected transmitter/receiver combinations was performed.
- Finally, a series of reports were written on the modelling results (expected normal evolutions of the PRACLAY experiment, altered scenario analysis, etc.) that will be used to support decision-making during the experimental follow-up.

3. Scientific tasks related to the thermo-hydro-mechanical behaviour of a disposal system in a clay host rock

- With regard to the fourth phase of the ATLAS test, by the end of 2014 all measurements indicated that the pore water pressure, temperature and stresses had almost recovered to their initial values before heating began. The cooling phase, which started in late 2012, is expected to be completed by the beginning of 2015. A permeability test was also performed in the course of 2014 (i.e. during the cooling phase). Analysis and numerical investigation were then initiated. In the course of 2015, together with ONDRAF/NIRAS, the relevance of performing a "heating pulse" test to investigate the ultimate temperature limit of the Boom Clay and possible thermally induced irreversible damage to the clay will be re-evaluated on the basis of the recent R&D plan of ONDRAF/NIRAS. In the meantime, the necessity of taking Boom Clay samples within the heated zone of the ATLAS test will also be re-examined.
- PhD and post-doctoral research:
  - the laboratory creep tests at high temperature continued as planned and will have to be pursued in 2015, given the long-term nature of these tests;

- the laboratory investigation of the anisotropic thermo-hydro-mechanical behaviour of the Boom Clay as part of a PhD project was completed at the end of 2014. The thesis is due to be defended at the end of January 2015. A specific research project on the characterisation of the thermal conductivity on Ypresian clays was initiated during 2014;
- the laboratory investigation of gas transport in the Boom Clay continued;
- the numerical investigation of the excavation-damaged zone (EDZ) in the Boom Clay is progressing as planned.

• The detailed investigation and follow-up of the stability of the liner in HADES in cooperation with Tractebel got underway in the course of 2014. The first results will be discussed in early 2015. The PhD research on this subject will only be initiated on the basis of these initial results.
• Work on developing short-term and long-term thermo-hydro-mechanically coupled constitutive models and validating these models with the in-situ measurements is still ongoing.
• Due to the priority given to the preparations for the PRACLAY heater switch-on, the new series of in-situ tests planned in HADES (hydro-fracturing and Self-Boring Pressure meter tests) were postponed until 2015.

4. Supercontainer feasibility demonstration test (on surface)

• An initial analysis/interpretation in the form of a draft report was submitted to ONDRAF/NIRAS in July 2014.
• ONDRAF/NIRAS will complete the final analysis for the test.

5. Specific support to ONDRAF/NIRAS on disposal technology and Safety and Feasibility Case 1

EIG EURIDICE continued to provide input and feedback to ONDRAF/NIRAS for the development of an approach to the operational safety of a geological disposal facility, using its expertise and experience in the operation of the HADES URL, especially its constant re-evaluation of the regulations (safety rules) to be followed for the operation and maintenance of the HADES URL.

EIG EURIDICE also continued to support ONDRAF/NIRAS's first Safety and Feasibility Case (SFC-1) by offering its expertise in the geomechanics of clayey materials. This support involved:

- initiating and following up on a series of PhD projects on the thermo-hydro-mechanical (and to a lesser extent chemical) behaviour of Boom Clay and Ypresian clays in cooperation with different laboratories and academic institutes;
- updating the "state-of-the-art" report on the geomechanical behaviour and properties of Boom Clay;
- gradually refining the key THM parameters in Boom Clay and Ypresian clays (based on recent research results) to be input into ONDRAF/NIRAS's data clearance system.

6. Management and exploitation of EIG EURIDICE and its installations

• Management and exploitation of EIG EURIDICE and its installations proceeded according to the Statutory Rules of the EIG and in line with the ISO 9001-2008 standard.
• A preliminary design study and cost estimate for refurbishing the hoisting system of shaft 1 were finalised in the first half of 2014; the cost estimate was used to determine the budget required to refurbish shaft 1. Discussions with the authorities and inspection bodies were held to clarify the regulatory requirements.
• The new roads for the visitor entrance were constructed, both on-site and outside the fence of EIG EURIDICE, in collaboration with the technical services of SCK•CEN. The gates were fitted and cables for lighting were installed.
• Work on introducing changes to the electrical infrastructure in EURIDICE's workshop began: materials were ordered and delivered; the installation itself will start in 2015.
• With regard to the re-evaluation of some safety-related aspects: it was decided to carry out a general re-evaluation of all aspects related to safety, and health and environmental protection. An additional budget has been set aside for 2015; the re-evaluation itself was launched at the end of 2014.

7. Monitoring

The systematic review of the HADES experimental set-ups did not commence until late 2014, when the first set-up to be assessed (CLIPEX) was identified. In addition, this monitoring task now includes a review of the micro-seismic set-up around PRACLAY to assess its long-term performance and prospects for the next few years.

The monitoring task also covered preparations for a new proposal to the European Commission on monitoring (Modern2020), submitted by the coordinator (ANDRA) in mid-September.

8. SAC (Scientific Advisory Committee of EIG EURIDICE)

Even though there were no SAC meetings organised during 2014 due to the priority given to the preparations for the PRACLAY heater switch-on, a discussion was initiated on how to expand the working scope of SAC's remit and improve collaborative networking with the academic world in line with the scope of EIG EURIDICE's main knowledge domains. EIG EURIDICE also actively contributed to establishing the new agreement between ONDRAF/NIRAS and SCK•CEN on the PhD cooperation programme and may be involved in this itself.

9. POP (Programme Committee for Underground Experiments)

- Work on drawing up an inventory of all experimental set-ups started and will continue in 2015.
- Because of the priority given to the final preparations for the PRACLAY heater switch-on, no POP meetings were held during 2014; no new tests were discussed or subsequently defined. This is planned for 2015 (see also point 13).

10. Communication

- The new website came online on 20 December 2014.
- With regard to developing a communication strategy for the period 2014-2020 in dialogue with the constituent members, an agreement was made with PROSPEX to support this process. The preparatory discussions are scheduled for April and May 2015, after the PRACLAY Heater events.
- An access procedure for visitors was developed in consultation with the SCK•CEN head of security.
- A new manual for visitor guides was prepared in consultation with Bailleul Ontwerpbureau and was reviewed by EURIDICE and its members at the end of 2014.
- Two events to mark the PRACLAY Heater switch-on are planned on 20 and 23 March 2015. Preparations started in the autumn of 2014.

11. Knowledge domains of EIG EURIDICE

Due to the priority of the team for the start-up of the Heater test, the creation of a knowledge management team has been postponed until 2015.

Nevertheless, significant efforts were made throughout 2014 to update the inventory of the experimental set-up and the status of the instruments in different experiments.

12. Surface disposal project for category A waste

As part of the presentation and defence of the Safety Case for the near-surface disposal site for category A waste, additional calculations were performed and input was delivered to answer questions from the Belgian nuclear regulator, FANC.

Final reporting on the demonstration test was postponed until 2015.

13. Establish an agreement with ONDRAF/NIRAS for 2015-2020

ONDRAF/NIRAS has deferred until 2015 the conclusion of a contractual agreement for the programme on geological disposal of high-level waste for the period 2015-2020. The approval of the EURIDICE annual budget for 2015 ensures the continuity of all EURIDICE activities, pending the financing agreement 2015-2020.

Objectives for 2015

1. Technical and scientific follow-up of the PRACLAY Seal and Heater experiment

One of the main tasks and objectives of EIG EURIDICE in 2015 will be to ensure that the PRACLAY experiment proceeds smoothly by carrying out a whole range of scientific and operational activities related to this experiment. These include:

- Inspection and maintenance of the test set-up;
- Management of all data generated by the experiment. Sensor performance will be continually evaluated (lessons learned);
- Follow-up of the evolution of the experiment and scientific analysis of the test measurements (including the seal evolution, THM responses of Boom Clay, stability of the PRACLAY lining and a seismic survey around the PRACLAY gallery);
- Reporting and communication of the experimental results, including the numerical analysis.

2. Scientific tasks related to the thermo-hydro-mechanical behaviour of a disposal system in a clay host rock

- Fine-tune the numerical analysis of the fourth phase of the ATLAS test, re-evaluate the relevance of performing a "heating pulse" test after the cooling phase and re-examine the necessity of taking Boom Clay samples within the heated zone of the ATLAS test.
- PhD and post-doctoral research
  - Continue the laboratory creep tests at high temperature;
  - Continue the laboratory characterisation of the thermal conductivity of Ypresian clays;
  - Continue the laboratory investigation of gas transport in the Boom Clay;
  - Continue the numerical investigation of the excavation-damaged zone (EDZ) in the Boom Clay;
  - Continue the 3D numerical investigation of the PRACLAY Heater test by considering the creep behaviour of Boom Clay in order to study its long-term THM behaviour;
  - Identify the remaining issues regarding the coupled thermo-hydro-mechanical-chemical behaviour of Boom Clay and Ypresian clays, in line with the R&D plan of ONDRAF/NIRAS, more specifically the laboratory investigation of the anisotropic thermo-hydro-mechanical behaviour of Boom Clay, and make proposals for new PhD research topics to ONDRAF/NIRAS.
- Continue the detailed investigation and follow-up of the stability of the liner in HADES in cooperation with Tractebel.
- Continue the development of short-term and long-term thermo-hydro-mechanically coupled constitutive models and validate these models with the in-situ measurements.
- Define and conduct a new series of in-situ tests (hydro-fracturing and Self-Boring Pressure meter tests) in HADES to refine knowledge on the in-situ stress state of the Boom Clay at HADES level.

3. Supercontainer feasibility demonstration test (on surface)

EURIDICE will support ONDRAF/NIRAS in instrumenting mock-up tests performed to demonstrate the feasibility of constructing components for the Supercontainer and to assess their performance.

4. Specific support to ONDRAF/NIRAS on disposal technology and Safety and Feasibility Case 1

EURIDICE will continue to support ONDRAF/NIRAS in its preparation and development of a first Safety and Feasibility Case (SFC-1), which is planned for 2019. EURIDICE can contribute to:

- ONDRAF/NIRAS's development of an approach guaranteeing operational safety of a geological disposal facility by offering its expertise and experience in the operation of the HADES URL;
- the characterisation of the Boom Clay and Ypresian clays and their thermo-hydro-mechanical behaviour, and to the evaluation of thermo-hydro-mechanical disturbances to these clay host rocks, by offering its expertise in the geomechanics of clayey materials.
  The latter support will be provided, in particular, by:
- consolidating the large body of knowledge (and data) available on the hydro-mechanical and thermo-hydro-mechanical behaviour of Boom Clay and Ypresian clays, mainly by finalising a geotechnical synthesis report for Boom Clay (update of the 2004 "state-of-the-art" report, EIG EURIDICE 04-251);
- inputting the key Boom Clay parameters (and Ypresian clay parameters when available) and their values into ONDRAF/NIRAS's data clearance system;

- supporting (providing samples, data, technical and scientific expertise) and supervising PhDs, post-doctoral studies and research carried out by third parties on the (thermo-)hydro-mechanical (-chemical) behaviour of Boom Clay and Ypresian clays and on gas transport.

5. Management and exploitation of EIG EURIDICE and its installations

- Management and exploitation of EIG EURIDICE and its installations according to the Statutory Rules of the EIG and in line with the ISO 9001-2008 standard.
- Preparations for the replacement of the shaft 1 hoisting system: preparation of the public tendering procedure
- Finalisation of the new visitor entrance, mainly automation of the gates and installation of lights on-site, in collaboration with SCK•CEN (security and technical services)
- Changes to the electrical infrastructure in EIG EURIDICE's workshop.
- Re-evaluation of the safety-related aspects.
- Specific checks and risk analyses for the electrical installations (KB2012, old electrical installations, etc.).
- Implementation of a new electrical drawing/calculation software and creation of drawings of the general overview of the electrical power supply.

6. Monitoring

In the context of the Scientific Project "Monitoring", the following objectives can be defined:

- update of the instrumentation review, which commenced at the end of 2014, with experience gained from:
  - relevant experimental set-ups in HADES
  - similar set-ups outside EIG EURIDICE
- The review will summarise the experience acquired using different monitoring techniques and will list recommendations for applications in a repository environment;
- Application of these recommendations to the development of a monitoring plan in line with the Safety and Feasibility Case developed by ONDRAF/NIRAS;
- General approach for instrument calibration (non-accessible instruments).

7. SAC (Scientific Advisory Committee of EIG EURIDICE)

- Continue to work with the SAC on the scientific aspects of the PRACLAY project.
- Expand the working scope of the scientific and technical remit of the SAC, in line with the scope of the main knowledge domains of EIG EURIDICE.
- Discuss and establish a set of research topics for future PhDs.
- Improve collaborative networking with the academic world.

8. POP (Programme Committee for Underground Experiments)

- Finalise the inventory of all experimental set-ups (past and current) in HADES.
- Discuss and define, at a conceptual level, possible new tests for the period 2015-2020 in line with the RD&D plan of ONDRAF/NIRAS.

9. Communication

- After a successful switch-on of the PRACLAY Heater experiment at the end of 2014, the major goals for 2015 will be to organise several events to highlight this next phase in the research programme on geological disposal and to keep all scientific, political, local and international stakeholders informed.
- In 2015 a EURIDICE communication strategy will be developed for the period 2015-2020 in close consultation with its two constituent members. Based on this strategy, EURIDICE will be able to define its specific communication initiatives for the next few years.

10. Knowledge management

- During the second half of 2015, after the start-up phase of the PRACLAY Heater experiment, a knowledge management committee will be created to define different actions for future knowledge management in an integrated way. These actions concern an inventory of all existing information, the storage and exchange of documents with the constituent members and the start of a project on excavation technology.

11. Surface disposal project for category A waste

EIG EURIDICE will provide the final report on the instrumentation of the demonstration test. Depending on how far advanced the test cover set-up is, EIG EURIDICE may also assist in the instrumentation work for this project.

12. Establish an agreement with ONDRAF/NIRAS for 2015-2020

Conclude a contractual agreement with ONDRAF/NIRAS for 2015-2020 for the programme on geological disposal of high-level and long-lived waste for the period 2015-2020.

Activities: PART I
High-level and long-lived waste disposal

1. PRACLAY "Demonstration & confirmation experiments"

1.1. Introduction: the PRACLAY project

One of the aims of EIG EURIDICE is the development of the PRACLAY project to demonstrate the feasibility of the disposal of high-level, heat-producing vitrified radioactive waste or spent fuel in deep clay strata such as the Boom Clay.

The PRACLAY project consists of several sub-projects and experiments. Together, these are referred to as the PRACLAY "Demonstration & confirmation experiments". The aims of these experiments are:

- To demonstrate the feasibility of underground construction in Boom Clay.
- To demonstrate the feasibility of the disposal concept for high-level waste in Boom Clay.
- To confirm and expand knowledge about the thermo-hydro-mechanical-chemical behaviour of Boom Clay and the gallery lining.

With the PRACLAY experiments, EIG EURIDICE is making an important contribution to the Safety and Feasibility Cases, which are part of the ONDRAF/NIRAS research programme for long-term management of category B & C radioactive waste.

In general, a distinction can be made between two groups of experiments: PRACLAY IN-SITU (meaning "in HADES") and PRACLAY ON-SURFACE experiments:

PRACLAY IN-SITU

- **DEMONSTRATION EXPERIMENTS**
  - Second shaft
  - Connecting gallery
  - Gallery & Crossing test
  - PRACLAY gallery
  - Supporting studies: European Commission's CLIPEX project

- **CONFIRMATION TESTS**
  - Heater test
  - Seal test
  - Supporting studies:
  - EDZ test (European Commission's SELFRAC & TIMODAZ projects)
  - PhD theses

PRACLAY ON-SURFACE

- **DEMONSTRATION EXPERIMENTS**
  - OPHELIE (SAFIR 2 repository design)
  - SUPERCONTAINER feasibility tests
  - Small-scale test
  - Half-scale tests
  - Annular backfill test in European Commission's ESDRED project

PRACLAY IN-SITU experiments can be divided into demonstration experiments and confirmation tests. The **demonstration experiments** focused on excavation techniques and construction. The excavation of the Connecting gallery using a tunnelling machine, for example, demonstrated the feasibility of constructing galleries on an industrial scale. With the construction of the PRACLAY gallery in 2007, it was shown that it is possible to make perpendicular connections between a disposal gallery and a main gallery, making use of a reinforcement structure. Most of the PRACLAY demonstration experiments are now finished. The **confirmation tests** are focusing on confirming and improving existing knowledge about the thermo-hydro-mechanical-chemical behaviour of the Boom Clay surrounding a disposal infrastructure. The Heater test is the main experiment in this regard. The main objective of this test is to confirm, on a large scale, that the thermal load generated by the heat-emitting waste will not jeopardise the safety functions of the host rock. In particular, the Heater test aims to assess the consequences of the coupled thermo-hydro-mechanical impact on the Boom Clay and the evolution of the excavation-damaged zone (EDZ) during the thermal transient in the case of disposal of heat-emitting waste.

For this purpose, part of the PRACLAY gallery (30 m) has been closed off and will be heated for a period of 10 years at a temperature of 80°C at the interface between the gallery lining and the clay. After the construction of the PRACLAY gallery in 2007 and the design and installation of the seal (2007-2010), installation of the heating system started in 2010 (primary heater) and was completed in 2014 (secondary heater).

PRACLAY ON-SURFACE experiments are studying different components of a disposal system and comprise laboratory tests to characterise these different components and their interaction. Many of the aspects that are studied on the surface are based on a specific disposal system design.

The current Belgian reference design for heat-producing high-level radioactive waste is based on the supercontainer concept. Tests are performed on different scales to demonstrate the feasibility of constructing a supercontainer.

1.2. Achievements in 2014

1.2.1. PRACLAY IN-SITU

The different parts of the PRACLAY Seal & Heater experimental set-up are shown in Figure 2.

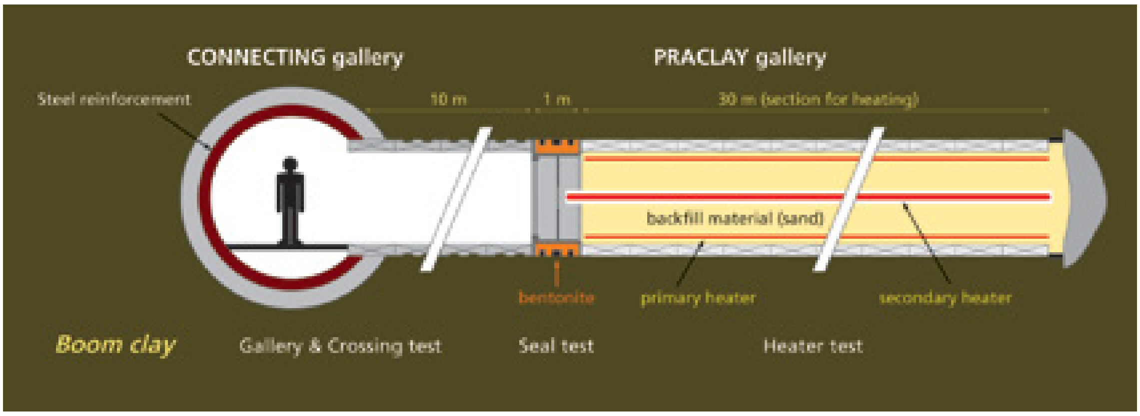


Figure 2 - Design of the PRACLAY Seal & Heater experiment

After the excavation of the PRACLAY gallery in 2007, the hydraulic seal was designed, and subsequently installed in 2010. The hydraulic seal consists of a stainless steel structure closing off the heated part of the gallery from the underground infrastructure and an annular ring of bentonite (MX80) placed against the clay (Figure 3).

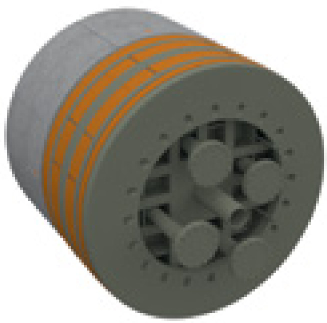


Figure 3 - 3D view of the seal with a central steel cylinder and an annular ring of bentonite (orange) against the clay

The hydraulic seal not only has to close the PRACLAY gallery; it also has to hydraulically isolate the EDZ around the gallery, which can provide a preferential pathway for water towards the main gallery during the heating phase. Bentonite has a very low hydraulic conductivity and swells when it is hydrated. The swelling pressure exerted by the hydrated bentonite on the Boom Clay will lower the hydraulic conductivity of the Boom Clay around the seal, thus creating “undrained hydraulic boundary conditions” for the Heater test and allowing pore water pressure build up. The swelling behaviour of the seal, and more specifically of the bentonite, is studied in the **Seal test**.

The placement of a heating system (primary heater in 2010 and secondary heater in 2014) and water-saturated sand in the heated section of the PRACLAY gallery (2011) completed the experimental set-up. The water-saturated backfill sand has to ensure undrained hydraulic boundary conditions at the interface between the clay and the gallery lining.

The closed part of the PRACLAY gallery (30 m) will be heated for a period of 10 years at a constant temperature of 80°C at the interface between the gallery lining and the clay. A detailed report about the design, preparation and installation of the PRACLAY Seal & Heater experiment was published in 2013, at the conclusion of the installation phase of the experiment (EUR 13-129).

To be able to switch on the heater, the status of the experimental set-up had to meet a series of requirements and EIG EURIDICE needed to be ready to monitor and control the test in an appropriate manner.

For the status of the experimental set-up, the focus was on the operation of the heating system and its control systems, the evolution of the hydraulic seal (bentonite swelling pressure), the saturation of the backfill sand and, last but not least, the implementation of the complete instrumentation & data-acquisition (DAQ) system.

Monitoring and controlling the test involves three elements that needed to be finalised before the heating system could be switched on:

- a complete set of data management tools
- simulations of the expected and altered evolution scenarios
- a management guide with procedures for the follow-up of expected and unexpected experimental evolutions. All the necessary preparations were made during 2014 to ensure that the test would be monitored appropriately.

THE HEATING SYSTEM

The heating system consists of a primary heater, attached to the gallery lining, and a secondary heater, which is placed in a central tube that rests on a support structure. Both of these are electrical heaters. Since the primary heater is inaccessible during the Heater test, twice as many primary heater cables than were necessary have been installed (100% redundancy). The secondary heater is a back-up and will remain accessible and replaceable at all times during the test.

A control system regulating the heating power as a function of measured and target temperatures is also part of the heating system. During the start-up phase, the temperature is being increased in a controlled manner to limit the thermal gradient over the gallery lining.

The **primary heater** was installed in the PRACLAY gallery in 2010. The gallery is divided into three zones (front, middle and end), each of which is subdivided into four sections (upper, lower, left, right). Each section is equipped with two heater elements, ensuring 100% redundancy of the system.

In 2013 it was decided to improve the control system of the **primary heater**. The newly defined functionalities and requirements were documented in a functional description, which formed the basis for discussions with Eurotherm/PICS[1] about possible solutions. The functional description was subsequently finalised and PICS started to write new software and implement the changes.

The primary heating control system was then modified in 2014. The main change is the way the system controls the heaters: in the previous version of the software, the intention was to heat the gallery by automatically ramping up the temperature setpoint on a continuous basis (every X hour, Y°C was to be added to the setpoint). In the new version, it will be heated up based on a set power output.

Additional changes that were incorporated include having the option of inputting different setpoints instead of one general setpoint, redefining notification and alarm levels for safety-related parameters, implementing several operational modes (manual, automatic and custom recipe[2]) and taking into account the thermocouples measuring the temperature of the heater cables. The second reason why the set-up of the primary heating control system was changed is because a more user-friendly operator interface was needed.

1 The initial primary heater control system was made by Eurotherm, but the Belgian arm of Eurotherm was sold to PICS, so the new software was written by PICS.

At the same time as adjustments were made to the control software, a modified operator interface was developed. This interface is running on a PC dedicated to the heater controller; the PC is installed in the same electrical cabinet and can be used to interact with the control system. This makes it possible to clearly see what is going on, as all alarms and measurements are displayed. Furthermore, it enables the control system settings to be adjusted without having to change the software code itself. Remote access to the dedicated PC is possible for authorised personnel.

To make it possible to get measured data out of the system, the operator interface creates data files on this PC. These files are picked up by EIG EURIDICE's data servers and stored in the databases.

Since the electrical cabinets had already been on site for several years and the adaptations mainly involved software changes, it was decided in early 2014 not to perform a new Factory Acceptance Test (FAT), and instead to carry out a thorough Site Acceptance Test (SAT). Gradually more and more aspects were tested. Any changes made were fully tested each time. In the event of problems, further adaptations were made by PICS and tested again by the EURIDICE team. This iterative approach ensures that everything in the system is tested in detail (temperature alarms, heater failures, etc.).

By October 2014 the new primary heater operator interface system was ready and tested, providing more user-friendly interaction with the control system.

The secondary heater was installed in the PRACLAY gallery in February 2012. This consists of four heater elements, which were inserted into the central tube inside the part of the PRACLAY gallery that will be heated. The central tube contains five guide tubes (four for heater cables and one for other purposes; see Figure 4) and remains accessible at all times so that the heater elements can be replaced if necessary. The secondary heater is a back-up and will only be used in the event of failure of the primary heater. Whereas the primary heater is regulated to provide a constant temperature during the steady heating phase (80°C at the interface between the gallery lining and the Boom Clay), the secondary heater will provide a constant power output, the value of which will be set at the time of the switch-over.

Detailed modelling performed in 2013 revealed several issues concerning the secondary heater design. One was that the secondary heater cables were not long enough to run the full length of the central tube and the power output was not high enough to maintain the same rate of temperature increase as previously, should there be a need to switch to the back-up system during the heat-up phase. To remedy this, longer heater elements with a higher power output were needed. If a similar configuration were to be implemented, however, this higher power output would result in unacceptably high cable temperatures, which would damage the heater cables. To solve this problem, custom-built heater assemblies were designed.

These assemblies were manufactured and installed in 2014. Each is composed of a solid stainless steel rod supporting four heater cables and protected by a stainless steel outer shell. As a result, each heater cable only has to deliver 25% of the required power compared with the previous set-up. Taking into account that the cables are also combined on a larger rod, their temperature will be acceptable.

Calculations showed that due to the higher power output of the assemblies, the welds of the supporting tubes (Figure 5) in the central tube might fail. These welds have no structural significance for the central tube, but keep the supporting tubes in place. Consequently, in the event of failure of the welds, it would no longer be possible to retrieve the heater assemblies and replace them with new ones. To address this problem, it was decided to install a new tube in the central tube. This has two objectives: first, to contain heater assemblies that could be replaced at all times and, second, to act as additional support for the existing supporting tubes.

Once the assemblies, additional support tube, heater cables, etc. had been manufactured, the secondary heater cables originally installed were taken out of the central tube. Four new assemblies were installed in the existing supporting tubes (Figure 5). The additional support tube was then inserted and four heater assemblies were placed inside this new tube.
To sum up, eight identical secondary heater assemblies were installed in total, providing a considerable degree of redundancy. For four of the assemblies, replaceability is guaranteed at all times.

---

2 In manual mode, the desired power output for each heater section is entered manually. In automatic mode, the system calculates and controls the power output of the individual sections in order to reach a predefined temperature setpoint at a certain location. In custom recipe mode, the system continuously polls an input file containing the desired power output for each heater section.

The original idea was to connect the back-up heater cables to the primary heater control system in case the primary heaters failed. In 2013 it was decided to build a separate control system for the back-up heater cables. This would result in two independent systems, so that even if the control system itself were to fail, it would be possible to switch to a second back-up heating system.

This control system was designed, installed and tested in 2014. The back-up heating system has been kept as simple as possible: it contains four controllers, each one of which can control one rod independently of the other controllers/rods. These deliver a fixed power (settings are done manually) and limit the output in case the sheath temperature exceeds its setpoint. In addition, the controllers are configured to send the measured data from the thermocouples and the power output to EURIDICE's network.

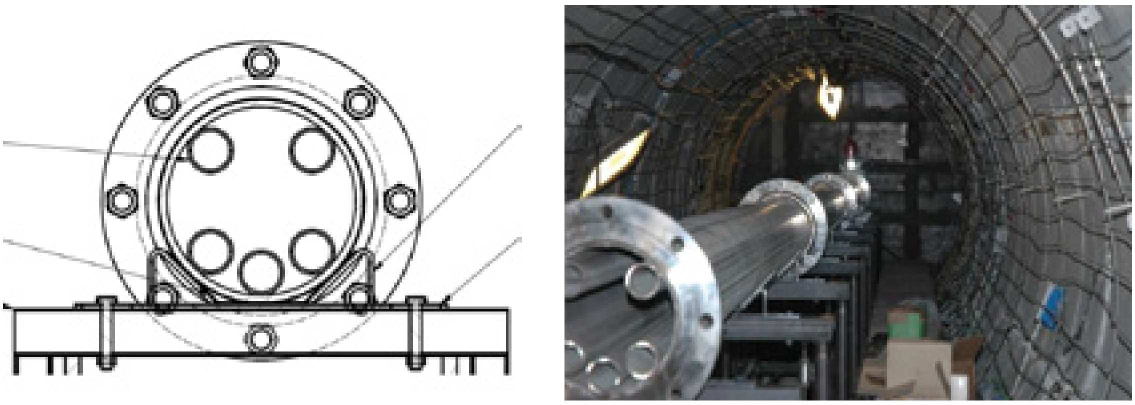


Figure 4 - Cross-section of the central tube

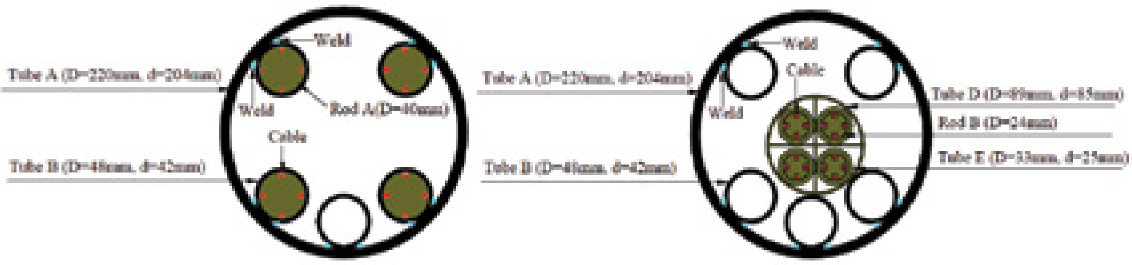


Figure 5 - Eight heater assemblies of the secondary heater to be installed in the central tube

TEST OF THE HEATING SYSTEM

Several tests were performed on the heating system, mainly in the form of Site Acceptance Tests (SATs) and Dress Rehearsal Tests (DRTs). SATs were carried out during and after the changes that were made to the control systems.

In the second half of 2014 the heating system also underwent DRTs. The goal was not only to test the heating system itself, but to generally test the whole PRACLAY set-up and the operational procedures put into place to manage the experiment on a daily basis. The heating cables were switched on, using the control system and the operator interface system for several days, in the same way as it should be done for the real experiment. The general behaviour of the heating system, sensors and instrumentation, data-loggers, alarms systems, etc. was monitored.

EVOLUTION OF THE HYDRAULIC SEAL

When designing the seal, two main criteria were defined. The maximum radial swelling pressure between the bentonite and the Boom Clay should be less than approx. 6.0 MPa (60 bar), so as not to damage the surrounding Boom Clay. The minimum swelling pressure before switch-on was set at 2.5 MPa (25 bar) to avoid creating negative effective stresses within and around the seal during the Heater test (the maximum pore water pressures in the gallery upstream of the seal and in the surrounding clay during the Heater test are estimated at 2.5 MPa by numerical prediction). The second criterion is that the hydraulic conductivity of the bentonite in saturated conditions should be lower than that of undisturbed Boom Clay (≈ 10-12 m/s).

To meet these specifications, the bentonite needs to be sufficiently hydrated. The bentonite seal has been hydrated since its installation in January 2010 by pore water coming from the Boom Clay and by water injected through filters placed on the extrados (outer surface) of the cylinder since April 2010 (Figure 6).

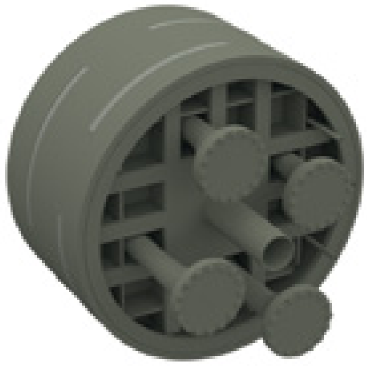


Figure 6 - Water injection filters on the outer surface of the steel cylinder (light grey areas)

Different kinds of instruments were incorporated into the bentonite rings during installation to monitor the water injection rate as well as stress (swelling pressure) and pore water pressure in the bentonite and in the Boom Clay around the seal. The instruments are grouped into sections A, B and C (Figure 7).

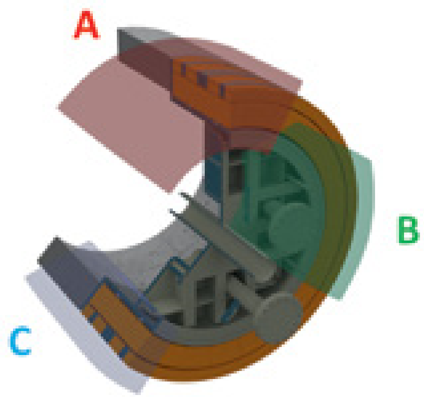


Figure 7 - Various instruments inside the bentonite, grouped into sections A, B and C

The evolution of the stresses (radial, circumferential, axial) in the bentonite ring and the stresses exerted by the bentonite on the Boom Clay indicates that the seal is behaving as expected. On 3 November 2014 the radial pressures at the interface between the bentonite and the Boom Clay were around 3.3 MPa and thus higher than the required threshold value of 2.5 MPa (Figure 8). The pore water pressure measured at corresponding points was around 0.7 MPa (Figure 9), i.e. lower than the total radial stress. The pore water pressure in the PRACLAY backfill sand at that time had reached 1 MPa (10.0 bar) and no water leakage through the seal was observed. All other filters inside the bentonite have not yet significantly deviated from atmospheric pressure, indicating the slow saturation process of the bentonite.

Hydraulic conductivity at the interface between the bentonite and the Boom Clay (at section C) was measured in September 2014 and the value obtained is similar to that of the undisturbed Boom Clay. However, compared with the measurements conducted in 2012 and 2013, this indicates that the hydraulic conductivity in the vicinity of the seal is decreasing as the bentonite swells.

Finally, the total station (electronic theodolite) did not monitor any significant seal structure movement during 2014. As of the end of 2014, the total measured displacement is about 6 mm since the PRACLAY gallery was pressurised, and the seal structure remains stable.

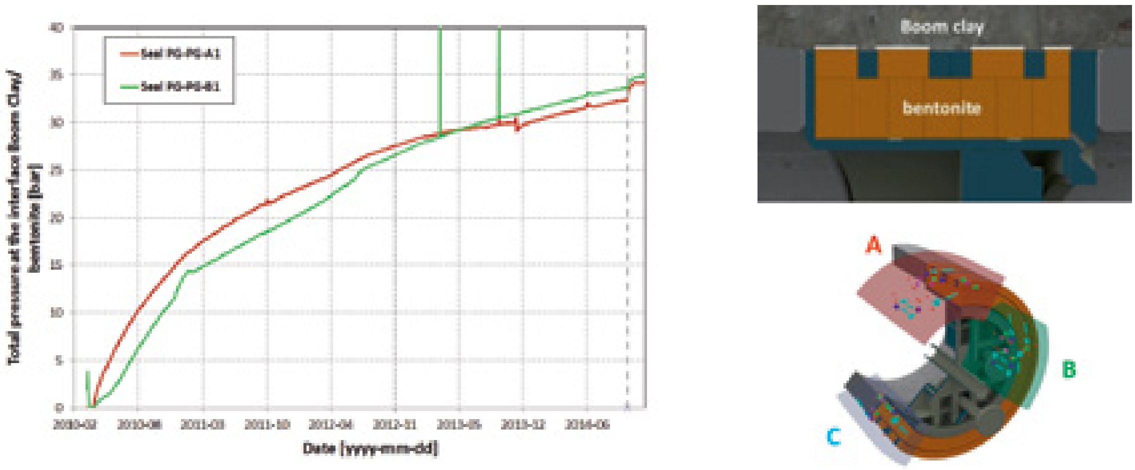


Figure 8 - Radial stresses measured at the interface between the bentonite and the Boom Clay sidewall (white line in insert), for sections A and B

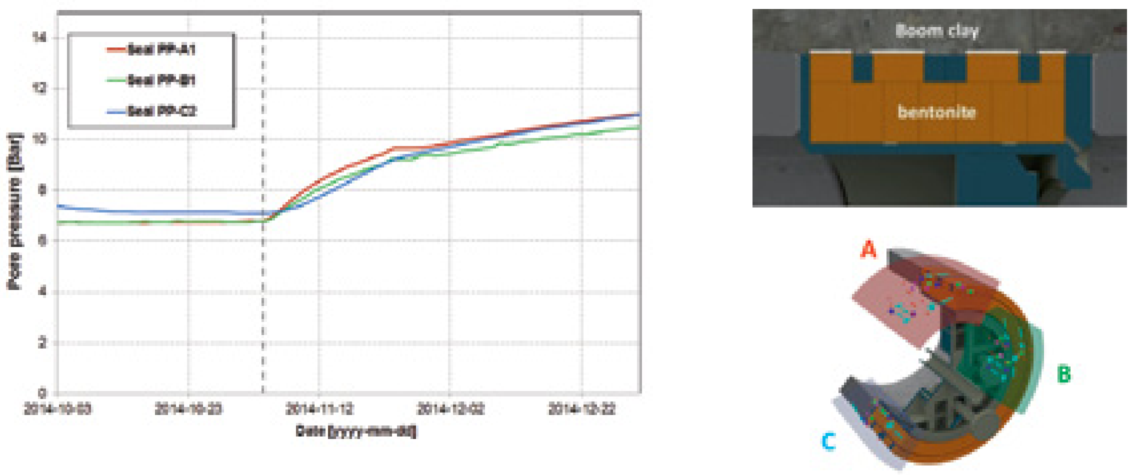


Figure 9 - Pore water pressure at the interface between the bentonite and the Boom Clay (white line in insert), for sections A, B and C

In summary, the seal is behaving as expected, with the measured swelling pressures indicating that the seal is evolving more and more towards a homogeneous state. Nearly all the sensors measured a swelling pressure higher than the target heater switch-on pressure (2.5 MPa) before 3 November 2014.

SATURATION OF THE PRACLAY GALLERY

The part of the PRACLAY gallery that will be heated is filled with water-saturated sand in order to:

- efficiently transfer heat from the heating elements to the surrounding clay;
- create "undrained" hydraulic boundary conditions at the clay-lining interface.

The sand (Mol sand M34) was put in place by blowing it in a dry state into the gallery before September 2011. Subsequently, about 43 m3 of tap water was injected into this part of gallery between January 2012 and May 2012. The backfilled gallery was then saturated gradually by the natural hydration process, with the water flowing from the host Boom Clay into the gallery. The pore water pressure in the gallery has gradually increased since then. On 3 November 2014 it reached 1 MPa, and the PRACLAY gallery was estimated to be fully saturated. Numerical simulations indicate that a water pressure of 1 MPa in the backfill sand is sufficient to achieve the expected "undrained" conditions for the PRACLAY Heater test.

INSTRUMENTATION

No important new field installations were carried out in 2014 with respect to the PRACLAY Seal & Heater experiment. Some additional sensors were installed: six pressure transmitters were connected to the saturation and vent filters in the PRACLAY gallery, the back-up heater rods were fitted with thermocouples, as was the outer surface of the seal, and relative humidity sensors were placed in the accessible part of the PRACLAY gallery. Sensors that had not yet been defined in the database were also added.

Any abnormal behaviour is detected and signalled by two alarm systems: one "hardwired" system, which is based on an autonomous circuit available to the SCK•CEN security guard to ensure 24/7 monitoring, and a system built into the database server. The hardwired system detects, for instance, water leakage, a sudden pressure drop, heater malfunction and power failure. With the database server, an alarm limit (fixed value, rate of change, etc.) can be configured for any measured variable, with notification by e-mail (smartphone). Cameras installed underground are used to inspect the accessible part of the PRACLAY gallery.

DATA MANAGEMENT

To ensure convenient access to the sensor data, a user interface has been built into the database. This interface has several functionalities: a "dashboard" to give a quick overview of some selected variables, the generation of a daily Safety Report, and an extensive graphical module to generate both time evolution and spatial profiles. Part of this work was done with the support of SCK•CEN.

Prior to the start of the Heater test, a "T0 report" was written, containing all the data that has been collected from all the available sensors around the PRACLAY gallery since excavation of the gallery began. This report was also an opportunity to have a first look at the data and to check that all sensors were functioning properly.

NUMERICAL SIMULATIONS OF THE EXPECTED AND ALTERED EVOLUTION SCENARIOS

To increase the reliability of the expected evolution of the Heater test by modelling, significant effort was devoted to understanding and then numerically reproducing past in-situ measurements. A set of reliable parameters resulting from the good agreement between the numerical results and in-situ measurements was applied for all analyses during 2014.

The design and control of the different components of the PRACLAY Heater test was supported in different ways by numerical modelling:

- The original design of the control system of the primary heater was too complex. To optimise the power control, a numerical study was performed to simplify the control system by having fewer control rules, while maintaining the objectives of the current design in terms of thermo-hydro-mechanical responses of the Boom Clay.
- Numerical modelling and calculations were performed to improve the design of the secondary heating system.
- Based on a numerical analysis, it was decided to install an insulation door in front of the seal structure to minimise heat loss.

Numerical work was performed in 2013 and 2014 to obtain a possible range of experimental evolutions, and the sensitivity analysis continued in 2014 by considering more parametric studies. The experimental evolutions were also analysed by considering more altered scenarios. Part of this work was done with the support of SCK•CEN.

Numerical modelling was required to complete the procedures for the follow-up and/or management of the Heater test:

- Should the primary heating system fail, clear instructions are needed depending on the different scenarios (time, duration, different failure combinations of 12 independent heating sections, etc.).
- If the pore water pressure in the PRACLAY gallery needs to be reduced or increased during the heating phase (due to various reasons, e.g. seal instability, lining instability), clear instructions (such as how much liquid should be discharged or injected, or how much power should be supplied) should be provided.

If seal and/or lining instability is detected during the Heater test, only two parameters can be changed to remedy the problem: the pore water pressure (PWP) inside the PRACLAY gallery and the heater power. Different scenarios were studied using numerical modelling to check the efficiency of changing the PWP in the PRACLAY gallery or regulating the heater power in response to seal and/or lining instability. The procedures to treat seal instability and lining instability in the "PRACLAY Heater test management guide" resulted from these numerical investigations.

To check the influence of potential recurring electrical power "blackouts" on the PRACLAY Heater test, one scenario (three successive six-hour blackouts) during a critical phase of the experiment (the initial six-month period) was defined. The modelling results indicate that three successive six-hour blackout events over a few weeks would not significantly affect the experimental evolution, even if these were to occur during the more critical initial phase (the first six months) of the experiment. Moreover, no specific measures would be necessary to compensate for such a sequence of events.

MANAGEMENT GUIDE

A management guide with a set of nineteen organisational procedures for the management of the Heater test was established in close cooperation with ONDRAF/NIRAS in 2014.

The purpose of these procedures is to:

- describe the follow-up of the test
- define the action plan in case of unexpected events so as to be well prepared for any such events
- clearly outline and assign the different responsibilities

Two sets of procedures were prepared.

"**Normal procedures**" address all aspects of the test follow-up where the test evolves as expected. The expected evolution is described by the "expected evolution scenario analysis". This analysis consists of numerical simulations of a "best estimate" of the test evolution and a sensitivity analysis taking into account an acceptable or realistic spread of the input parameters. More specifically, the following aspects are addressed in the normal procedures:

- inspection and maintenance of the test set-up
- test follow-up
- communication, including reporting
- management of HADES with respect to the PRACLAY Heater test

"**Abnormal evolution procedures**" address the actions required if the experiment does not evolve as expected. An evolution is considered unexpected or abnormal when there is an alarm or incident or when measurements of key parameters deviate from the expected evolution. The procedures for abnormal evolution will be largely based on the expected and altered evolution scenario analyses.

SWITCH-ON OF THE HEATING SYSTEM

As a final test, it was decided to switch on the primary heating system for longer to check whether it performs as expected over a longer period of time. This test phase started on 3 November and the test will run until early 2015. If all elements function as required or expected during this test, heating will continue in 2015 without interruption.

Initially, the power was increased to a value of 250 W/m in the three sections of the primary heating system. As a consequence of the heat input, the temperature started to increase inside and around the gallery, in the gallery lining and in the surrounding Boom Clay. Figure 10 shows the evolution of the power with time since heating began. It can be seen that the power delivered by the system is stable.

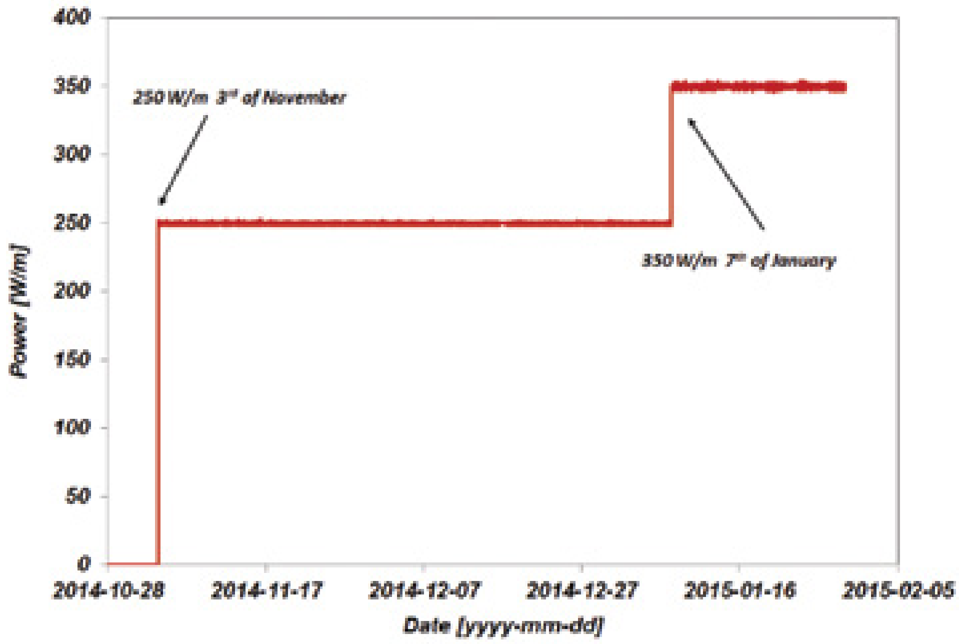


Figure 10 – Imposed power in the three zones of the primary heating system

Due to the power ramp-up, the temperature increases in the media (backfill sand and water) and in the concrete due to the dissipation of heat. Figure 11 presents the profile of the temperature along the concrete lining of the PRACLAY gallery during the first months of the experiment. A homogeneous increase in temperature is observed along the gallery. The time evolution of the temperature in ring 50 of the lining (in the middle of the heated section) can be observed in segments 8 and 4 for the inner and outer surfaces (intrados/extrados) of the concrete segment (Figure 12). The rise in temperature is almost instantaneous.

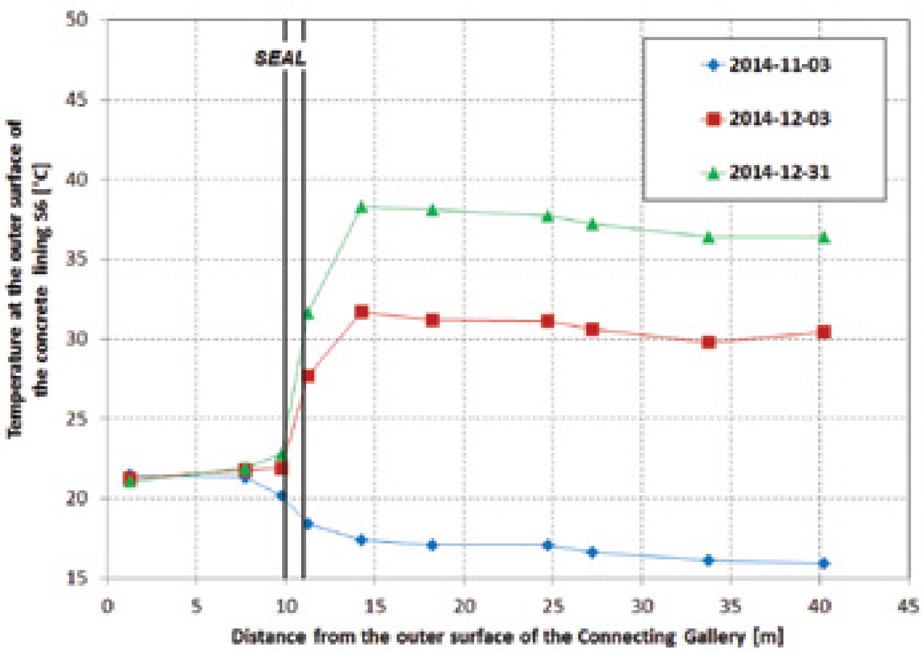


Figure 11 – Longitudinal temperature profiles along the PRACLAY gallery

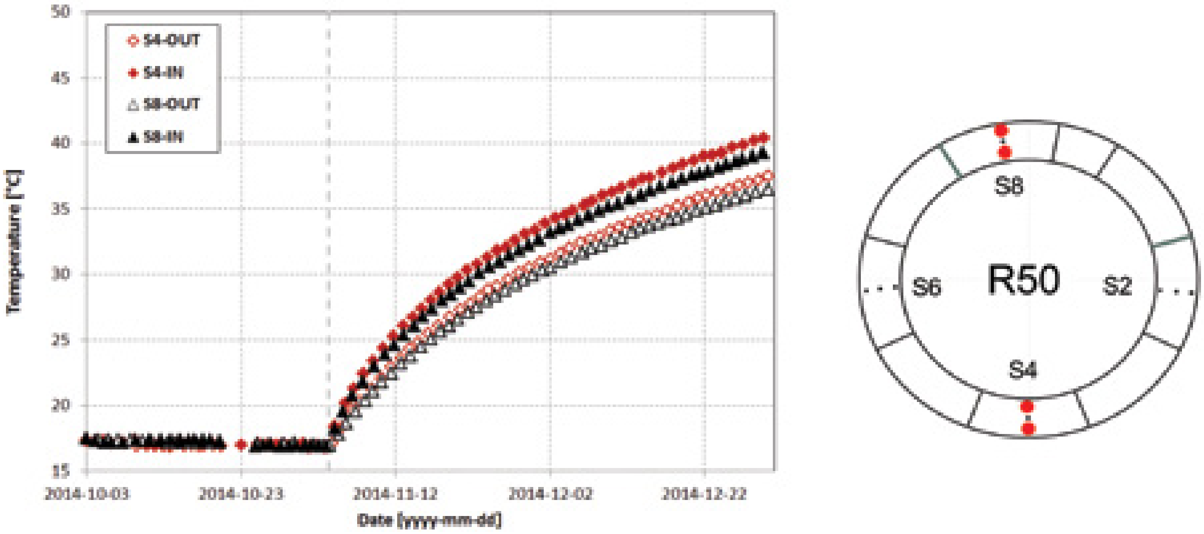


Figure 12 - Temperature evolution in the concrete lining segments of ring 50

The increase in temperature causes the pore water pressure (PWP) to rise, which is common in geomechanics when a water-saturated porous material is heated. The evolution of the thermally induced PWP is, however, largely dependent on the nature of the material, the stress state, the range of the temperature change, the heating rate, the hydro-mechanical boundary conditions, etc.

Figure 13 shows the evolution of the PWP inside the gallery. A drop of about 5 bar in this pressure occurred on 22 November, probably due to the rearrangement of the general experimental set-up (instrumented gallery with lining and surrounding excavation-damaged zone), which had never been pressurised to that level before. This pressure drop triggered the alarm system and was a good opportunity for the EURIDICE team to test the procedures.

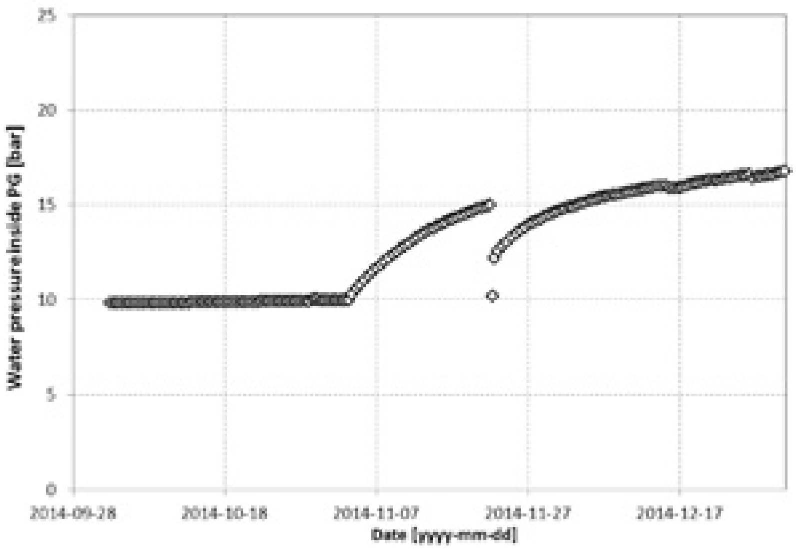
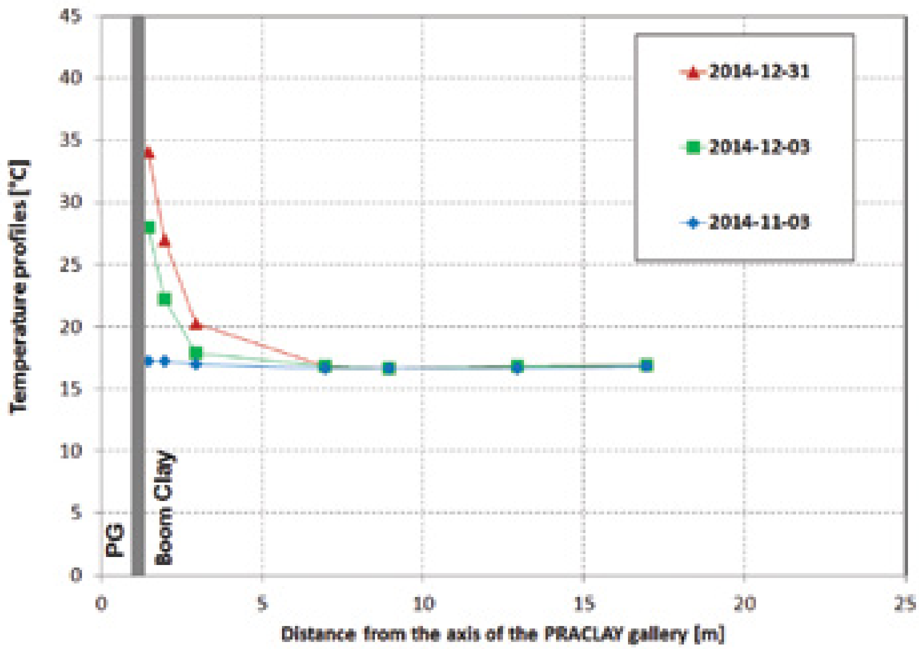


Figure 13 - Pore water pressure evolution in the PRACLAY gallery since the beginning of the heater test

The variations in PWP inside the Boom Clay, and associated temperature variation, can be observed for a vertical and a horizontal borehole leading from ring 50 of the gallery (Figure 14 and Figure 15, respectively). It can be observed that a 5 m area around the gallery is affected by the change in temperature and PWP for the vertical borehole. A larger area is observed for the horizontal borehole, which can be explained by a possible effect of the casing. This possibility will be studied in more detail over the coming year.

(a)



(b)

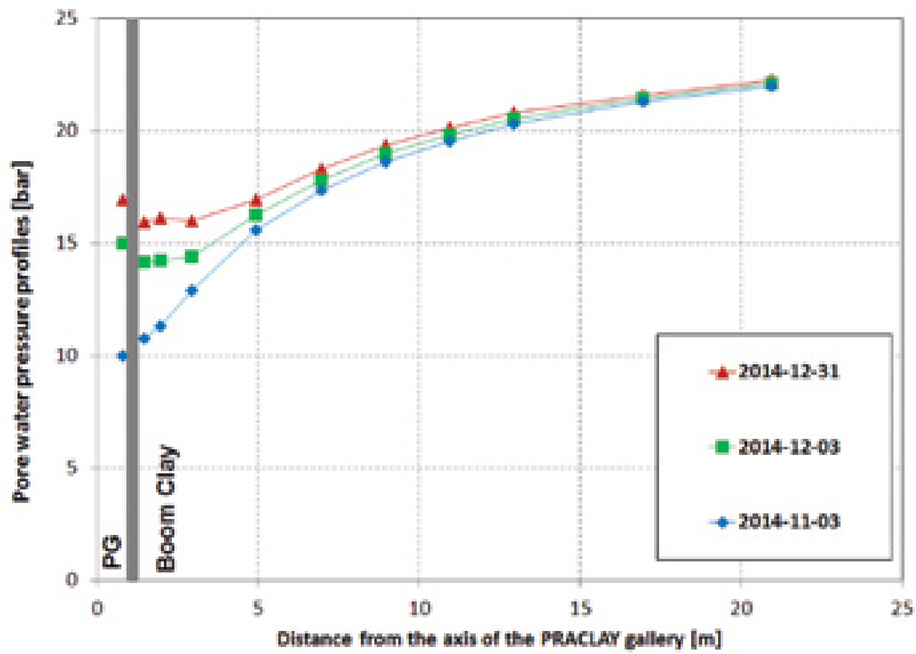
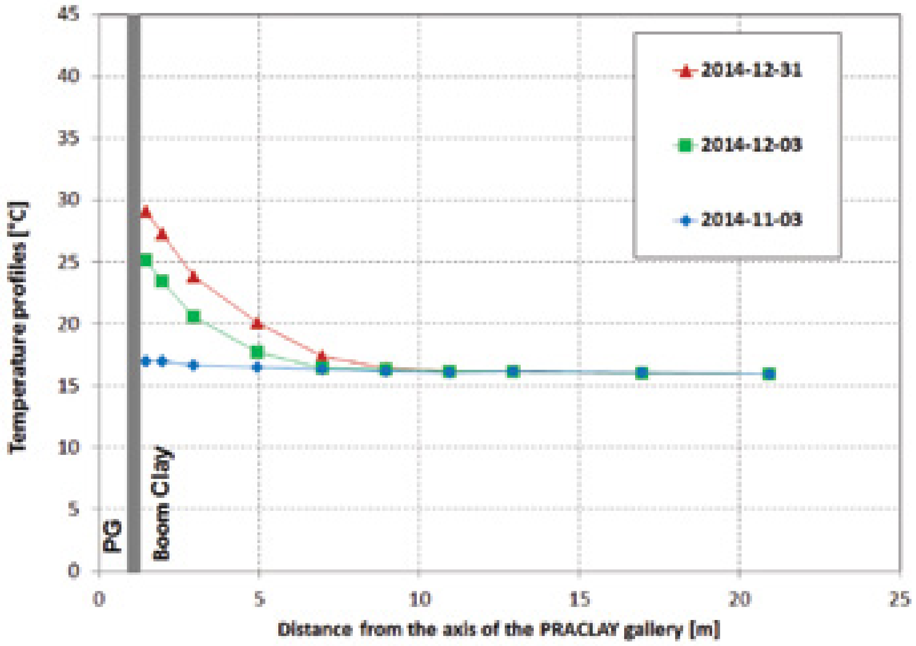


Figure 14 - Temperature profiles (a) and pore water pressure profiles (b) in vertical borehole PG50D (in the middle of the heated section)

(a)



(b)

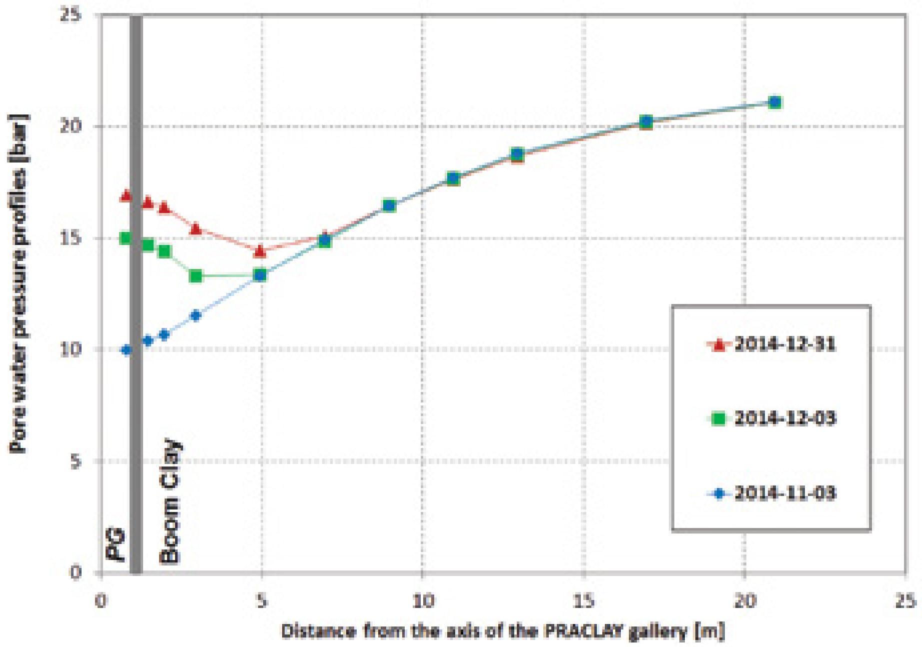


Figure 15 - Temperature profiles (a) and pore water pressure profiles (b) in horizontal borehole PG50S (in the middle of the heated section)

1.2.2. PRACLAY ON-SURFACE

HALF-SCALE TESTS: SUPERCONTAINER CONSTRUCTION FEASIBILITY TEST NO. 2

The second half scale test (HST2) was performed in 2013 to gain further insight into the construction feasibility of the Supercontainer. The test comprised two main construction phases. The first was the construction of the concrete buffer using a self compacting concrete (SCC) mixture. This construction phase created the concrete buffer with an inner hollow cavity in which the overpack, filler and lid were later installed. The second phase involved the use of a heater to simulate the heat emitted by a 'real' overpack.

The HST2 incorporated both state of the art as well as new and innovative techniques to monitor various phenomena in the concrete buffer. These included the initiation and propagation of cracks in the concrete, the evolution of stress and strain in three mutually perpendicular directions, and the corrosion potential in the carbon steel overpack.

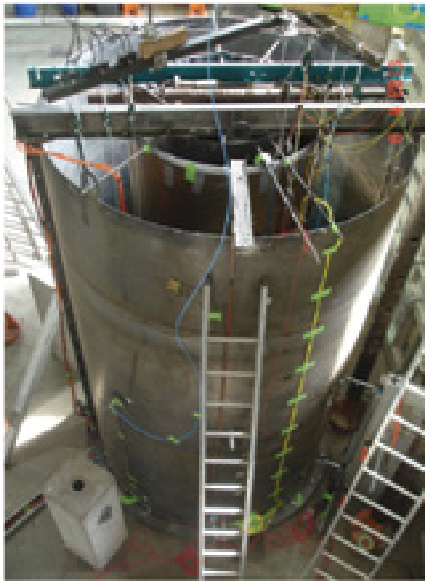


Figure 16 - Installed mould ready to cast concrete buffer

The figure below shows a typical evolution of temperature in the HST2 during the two construction phases. The measurements indicate the presence of low temperature gradients generated during the first construction phase. The second phase shows higher temperature gradients but these remain limited to ±10°C, which is well below the 15-20 °C range beneficial in reducing the potential for cracking in massive concrete structures. An important factor contributing to the observed low temperature gradients was the presence of a layer of rockwool insulation installed around the test mock-up. Another contributing factor was the presence of a protective wall around part of the test to minimise the effects of ambient temperature fluctuations.

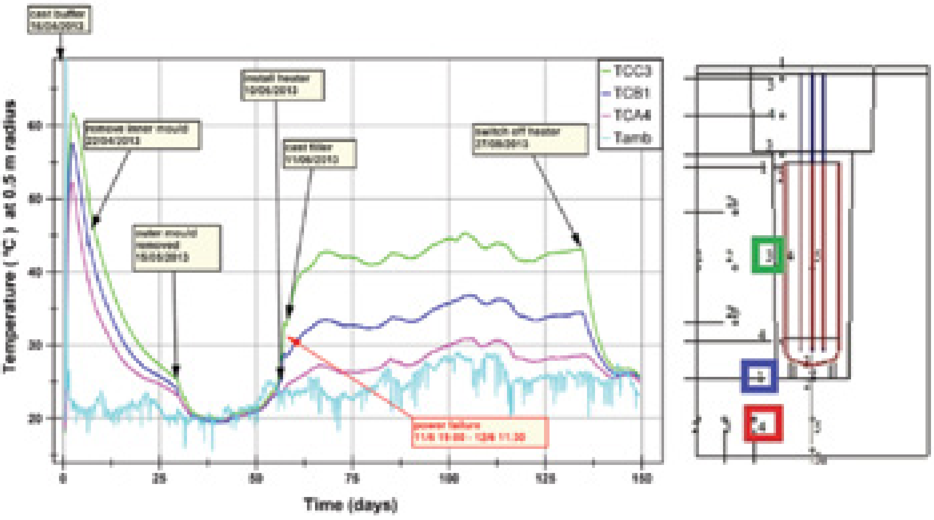


Figure 17 -Temperature evolution [left] and location of measurements [right] during the HST2

An initial analysis and preliminary interpretation of the results have been submitted to ONDRAF/NIRAS in July 2014, in the form of a preliminary draft report. ONDRAF/NIRAS will complete the final analysis of the test.

2. Supporting studies

2.1. ATLAS

The small-scale in-situ ATLAS tests are performed to assess the thermo-hydro-mechanical (THM) behaviour of the Boom Clay at the HADES URL.

To broaden the THM characterisation of the Boom Clay on a larger scale and at different temperature levels, the ATLAS test set-up installed in 1993 and 1996 (ATLAS I & II) was extended in 2006 by drilling two additional instrumented boreholes (AT97E and AT98E) (Figure 18). The heater was switched on again from April 2007 to April 2008 with a stepwise power increase, followed by instantaneous shutdown. This phase is called ATLAS III. Three-dimensional coupled THM modelling of the ATLAS III test has been performed. The good agreement between measurements and numerical modelling of temperature and pore water pressure in the horizontal plane of the heater highlights the THM anisotropy of the Boom Clay and yields a set of THM parameters. By introducing mechanical anisotropy into the THM coupling model, the numerical simulation predicts an instantaneous but temporary pore water pressure decrease after increasing power, and a temporary pore water pressure increase after cooling in the horizontal plane, but not in the vertical plane. The former phenomenon has been confirmed by in-situ measurements from ATLAS III.

To gain better insight into the anisotropic THM behaviour of the Boom Clay, a new upward, instrumented borehole AT90IU was drilled above the ATLAS heater at the end of 2010 (Figure 19).

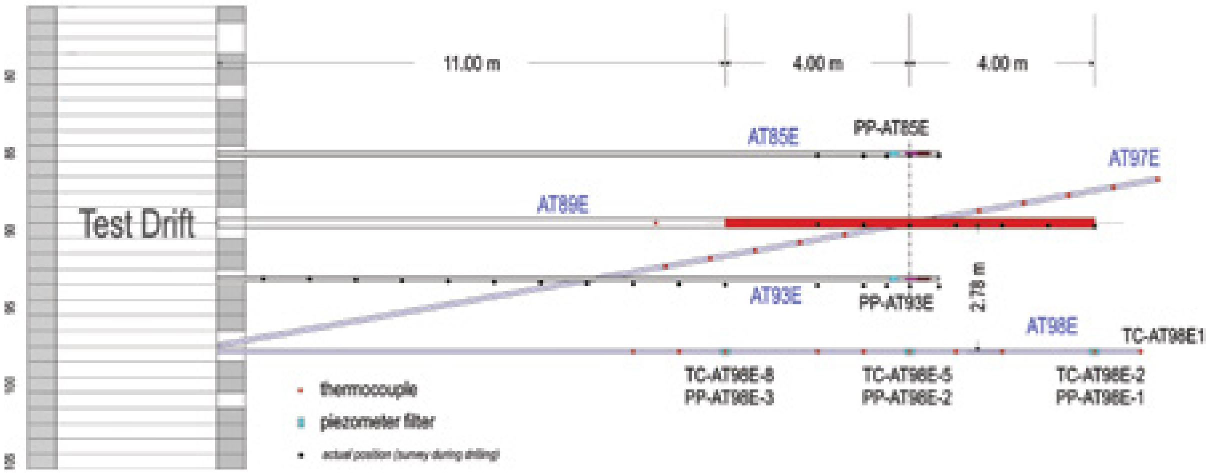


Figure 18 - Schematic view of the small-scale in-situ ATLAS test

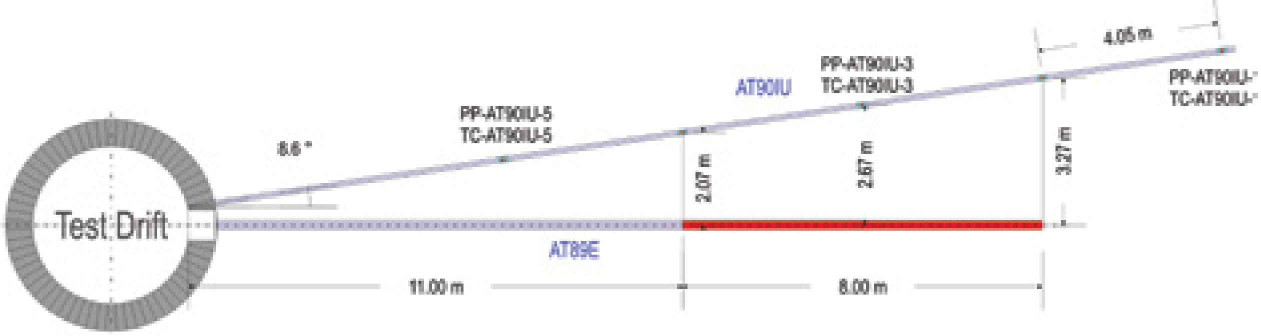


Figure 19 - Upward borehole AT90IU drilled above the heater for ATLAS IV

The new phase of the ATLAS heater test (ATLAS IV) started on 18 October 2011, using the same heating strategy as for ATLAS III to facilitate interpretation and comparison between the ATLAS III and ATLAS IV tests. The heater was shut down on 29 November 2012 and the cooling phase started. By the end of 2014, pore water pressure, temperature and stresses had almost recovered to their initial values before heating began.

As can be seen in Figure 20 and Figure 21, for the four existing boreholes in both tests, ATLAS IV gave almost the same measured data as ATLAS III, confirming recoverable THM responses (e.g. no irreversible effects) in the far field (note that the third step of the heating phase in ATLAS IV is longer than that in ATLAS III).

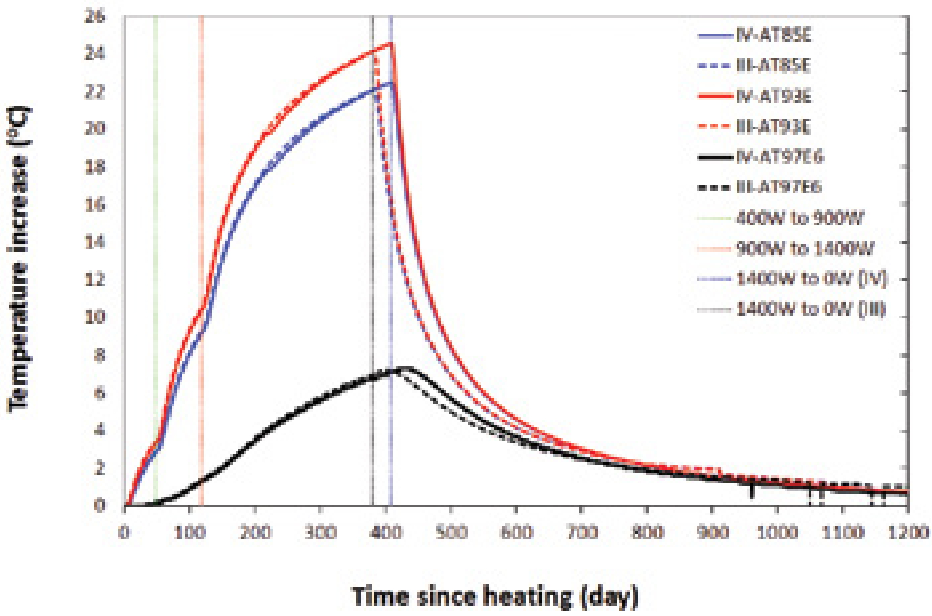


Figure 20 - Comparison between ATLAS III and ATLAS IV: temperature

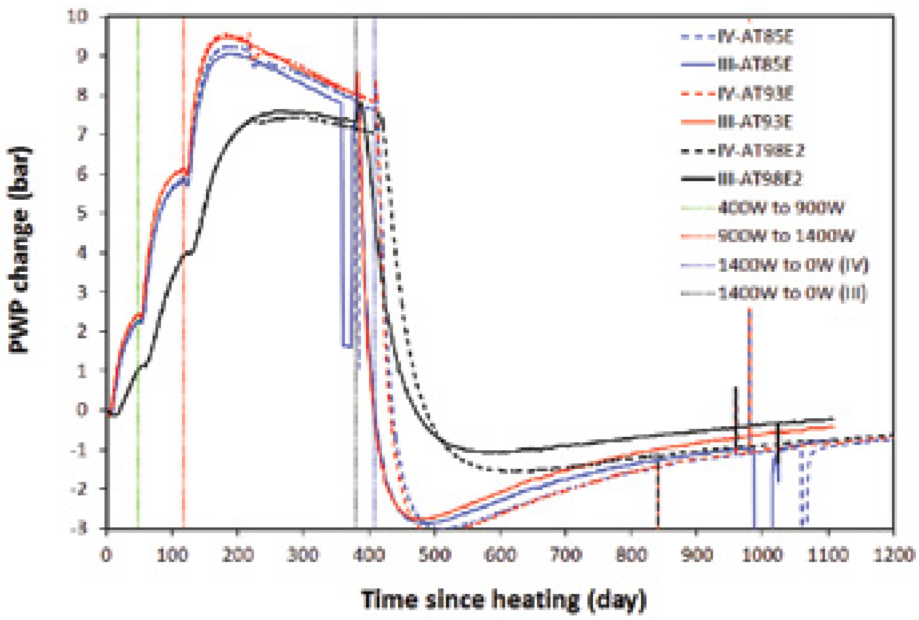


Figure 21 - Comparison between ATLAS III and ATLAS IV: pore water pressure

The extended picture of the temperature field further confirms the thermal anisotropy of the Boom Clay and, as shown in Figure 22, the anisotropic thermal conductivity deduced from ATLAS III can still accurately reproduce the measurements from the new upward borehole.

As expected, the available measured variation in the pore water pressure from the new upward borehole was different from that measured from the borehole in the horizontal plane, which confirms the mechanical anisotropy of the Boom Clay. However, the measurements from the new upward borehole deviate from the numerical simulation using the same parameters deduced from ATLAS III, as shown in Figure 23. The parametric sensitivity analysis is ongoing to improve the set of THM parameters of the Boom Clay (especially HM-related parameters).

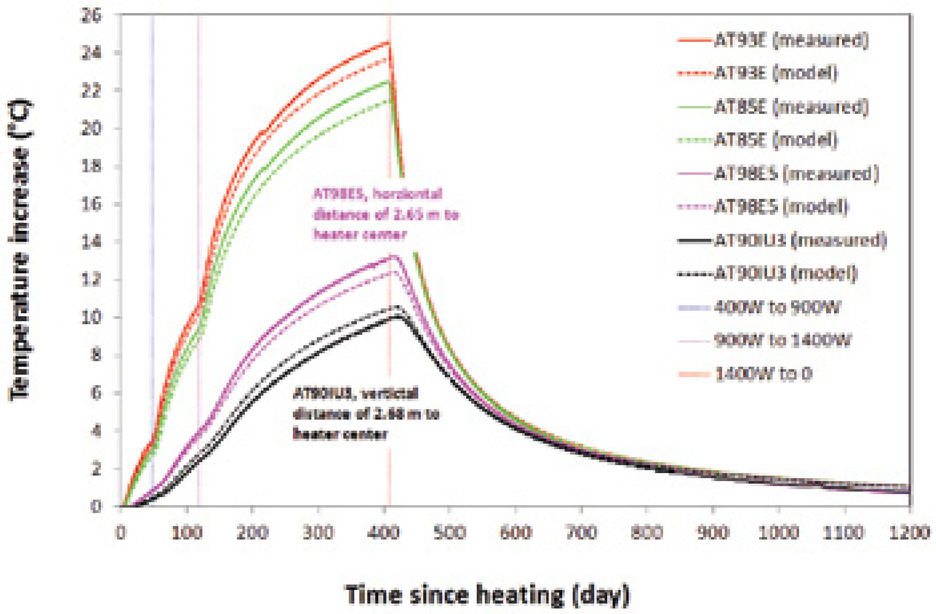


Figure 22 - Temperature measured by four sensors in the upward borehole (AT90IU) and three horizontal boreholes (AT85E, AT93E and AT98E), and comparison with numerical modelling.

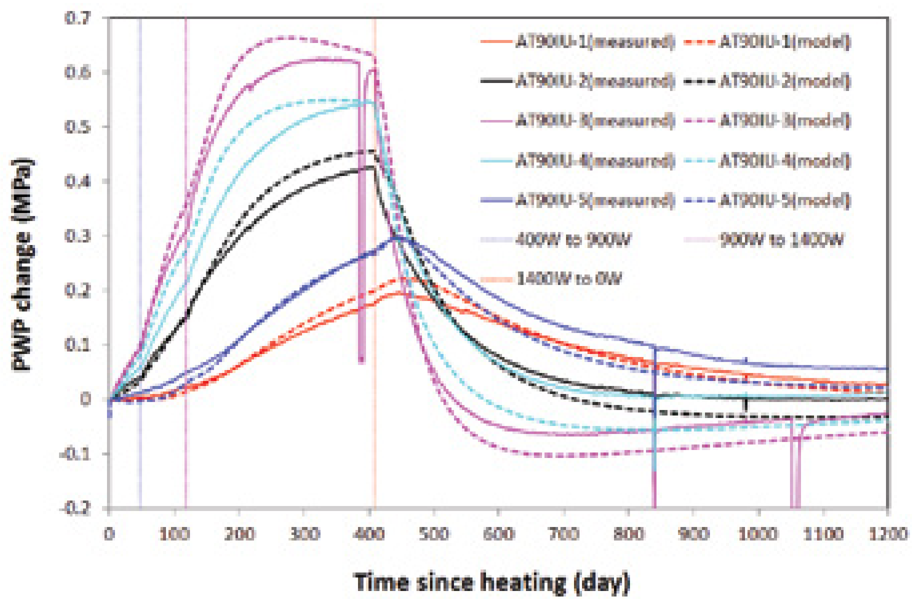


Figure 23 - Pore water pressure variation measured by the sensors installed in the upward borehole (AT90IU), and comparison with numerical modelling

2.2. Stability of the Connecting gallery

The strains in and the convergence of the lining of the Connecting gallery have been monitored since the construction of the gallery in 2002. The strains observed in the lining are used, for example, for the back-analysis of the stress inside the concrete lining. Initial analysis of the stress based on the strains observed began in 2013 and some results showed that the stress state is probably higher than expected. For this reason, a new study was organised in collaboration with TRACTEBEL engineering, SCK•CEN and EURIDICE. The goal is to accurately determine the correct stress inside the concrete segments, and the pressure exerted against the lining.

The convergence of the rings that have been surveyed since the outset has been analysed. These observations have indicated that the convergence (diagonal reduction) can reach a value of around 10 mm for different diagonals of the rings, as can be seen in Figure 24. An ovalisation of the gallery is also evident. The latter is consistent with the strain gauge measurements showing a bending moment due to the reduction in the vertical diameter (and the increase in the horizontal diameter).

An investigation of the diagnostic methodology used to determine the state of the concrete lining was initiated. All the fractures, as well as the shifts (offsets) between segments and rings (contact deficiencies), have been mapped to gain a better idea of the possible areas where problems might occur in the future.

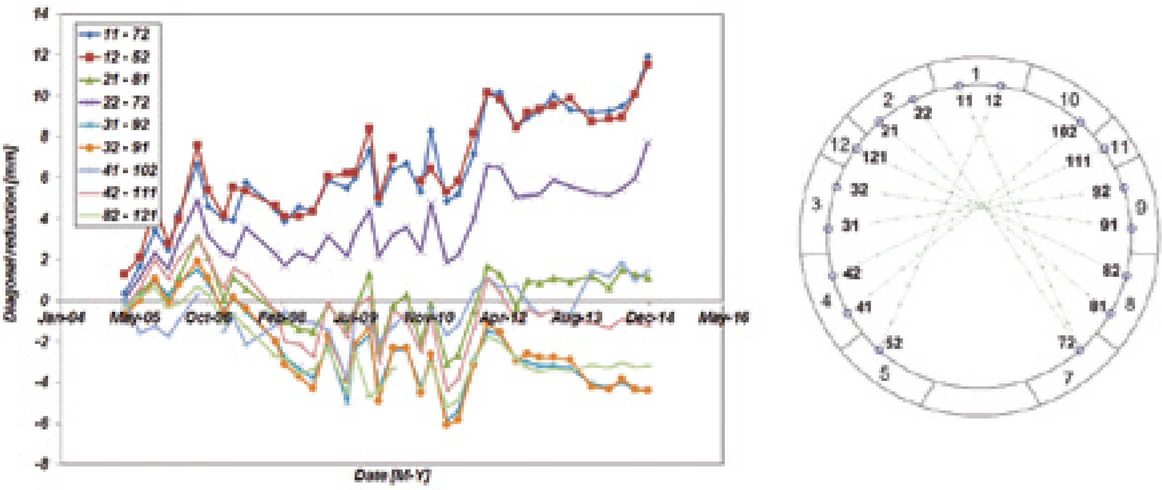


Figure 24 - Observed convergence in concrete ring 50

2.3. PhD research

A specific thermo-hydro-mechanical-chemical characterisation programme on Boom Clay has been run in parallel with the PRACLAY experiments, in collaboration with different universities and laboratories through several PhD research projects. EIG EURIDICE is involved in the definition and supervision of these projects.

In the context of the ONDRAF/NIRAS geological disposal research programme to examine other potential host formations for high-level waste disposal, and based on the outcomes of several PhD research programmes on the thermo-hydro-mechanical-chemical behaviour of Ypresian clays, a specific research project was initiated in 2014 and is being co-supervised by EIG EURIDICE to further study the anisotropy features of the thermal conductivity of Ypresian clays.

CIMNE (Universitat Politècnica de Catalunya, Barcelona (UPC), Spain)

A. "Laboratory investigation of gas transport processes in Boom Clay"

Financed directly by ONDRAF/NIRAS, a PhD research project on the "Laboratory investigation of gas transport processes in Boom Clay" started at the end of 2012. EIG EURIDICE is involved in supervising and following up the project.

This research aims to study, on a laboratory scale, the gas transport mechanisms and breakthrough processes in Boom Clay.

The specific objectives of the research relate to the following aspects of the experimental behaviour of the Boom Clay during gas injection processes:

- Examine the effects of the stress state and stress history under isotropic conditions or with a deviatoric component.
- Investigate the volume change behaviour during gas tests and its impact on gas permeability.
- Check the role played by the orientation of natural discontinuities in rock or artificial interfaces.
- Study temperature effects on breakthrough processes.
- Estimate the influence of the gas injection rate.

During 2014, air tests under oedometer conditions at different injection rates and bedding orientations were conducted. Complementary tests (pore size distribution, air diffusion, compressibility on loading/unloading) were also performed. The annual meeting between ONDRAF/NIRAS, EIG EURIDICE and CIMNE/UPC was held in Mol on 16 May 2014 for the purpose of presenting the experimental work developed and the main achievements and jointly defining new tests and protocols. A yearly progress report was delivered to ONDRAF/NIRAS and EIG EURIDICE in October 2014. The progress of the project in 2014 led to several publications in conference proceedings (see Scientific output).

B. Tests on the thermal anisotropy of Ypresian clays

A specific project agreement between ONDRAF/NIRAS, EIG EURIDICE and CIMNE/UPC was established for the period July 2014-April 2015.

The main objectives of this research project are:

- To continue previous research on "Thermo-hydro-mechanical characterisation of Ypresian clays" (2010-2011)
- To advance knowledge of the anisotropy features of thermal conductivity
- To compare different reported values of thermal conductivity of Ypresian clays, using direct and indirect determinations

This is an experimental research programme, mainly studying anisotropy features of the thermal conductivity of Ypresian clays.

In 2014 a new thermal conductivity set-up was developed. All related sensors (thermocouples and the linear variable differential transformer (LVDT)) were carefully calibrated. Basic characterisation of selected Ypresian clay cores was carried out (limits of consistency, particle size distribution, bulk density, water content, density of solid particles, mercury intrusion porosimetry).

In order to investigate in detail the effect of pre-conditioning the samples on the thermal conductivity measurements, the triaxial cell that will be used in the sample pre-conditioning tests was updated. The associated sensors (electro-optical laser systems, LVDT) and automatic pressure regulators were carefully calibrated too.

The experimental set-up and test protocols developed (pre-conditioning and thermal tests) were first tested on statically compacted Boom Clay samples. Preliminary pre-conditioning and thermal tests were subsequently performed on Ypresian clays.

A mid-term report was delivered in December 2014. The first progress meeting will be held at the beginning of 2015.

IRSM (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, China)

The project "Research on long-term coupled thermo-hydro-mechanical (THM) behaviour of the Boom Clay" aims to investigate the effect of temperature on the creep and self-sealing capacity of the Boom Clay and to gain knowledge and information for simulating the PRACLAY Heater test. This project started at the end of 2011.

The research project is in three parts:

A. Laboratory tests
B. Constitutive law development, taking into account long-term behaviour and thermo-hydro-mechanical coupling, including damage and self-sealing processes.
C. Back-analysis of long-term in-situ measurements and prediction of the PRACLAY experiment.

During 2014, the research focused on the laboratory tests.

In order to investigate in detail the mechanism of the variation in hydraulic conductivity under complex thermo-mechanical conditions so as to gain a better understanding of the thermo-hydro-mechanical coupling behaviour, a series of permeability tests were conducted under controlled and combined heating/cooling and loading/unloading conditions. A set of relations governing the hydraulic conductivity evolution under various thermo-mechanical conditions was obtained. The test results confirmed that the temperature effects on this evolution are mainly governed by the variation in fluid viscosity and density. The variation under heating/cooling cycles is reversible. However, under loading/unloading cycles, irreversible variation occurs. The microstructure properties of Boom Clay were studied by performing SEM (Scanning Electron Microscope) and NMR (Nuclear Magnetic Resonance) analyses at IRSM. The SEM results highlighted the transversely isotropic character of Boom Clay due to the presence of bedding. The results of NMR tests showed that heating under unconstrained boundary conditions produced large pore sizes and leads to micro-structural weakening.

Meanwhile, a series of THM coupled creep tests under drained conditions in triaxial cells were carried out during 2014. The creep phases were conducted under various temperature and loading conditions (confined and deviatoric stresses). The test results obtained indicated that there is no obvious thermal effect on the threshold of the deviatoric stress. As observed from the HM creep test at ambient temperature, the THM creep tests further confirmed that the value of the deviatoric stress threshold is in the vicinity of 1.0 MPa even when the temperature increases to 80°C. As soon as this threshold value is exceeded, however, the effect of the temperature on the creep becomes significant. The creep under a deviatoric stress of 1.5 MPa is more remarkable compared with that under ambient temperature. Moreover, the test results indicate that the creep becomes insignificant during the cooling phase. This phenomenon merits further experimental investigation.

In the course of 2014, the 3D simulation of the PRACLAY Heater test using the thermo-hydro-mechanically coupled constitutive laws developed was further refined.

CERMES (Centre d'Enseignement et de Recherche en Mécanique des Sols, France), ENPC

In 2014 the research activities at CERMES involved two research programmes:
- Investigation of the anisotropic behaviour of Boom Clay (PhD project 2011-2014)
- Modelling the hydro-mechanical behaviour of Boom Clay in the context of the bounding surface concept (2½-year post-doctoral project)

INVESTIGATION OF THE ANISOTROPIC BEHAVIOUR OF BOOM CLAY

A PhD research project entitled "Investigation of anisotropic behaviour of Boom Clay" started at CERMES at the end of 2011 and comprises three parts:

1. Literature review
2. Experimental study
    - anisotropic hydraulic conductivity determination
    - anisotropic thermal conductivity determination
    - K0 determination (ratio of effective stress to vertical stress)
    - mechanical anisotropy in triaxial cells equipped with bender elements and/or ultrasonic sensors
    - microstructure investigation: initial state and its evolution under different loading paths
3. Constitutive modelling

Throughout 2014, the research continued to focus on the characterisation of the mechanical anisotropic behaviour of Boom Clay.

The anisotropy of the swelling pressure (σ_s) on natural Boom Clay was examined by means of several swelling tests performed in a standard oedometer cell (without lateral pressure measurements) in accordance with three conventional methods:

(1) zero-swell under low pressure (sample saturated at 0.1 MPa)
(2) zero-swell under high pressure (sample saturated at σ_v = 2.4 MPa)
(3) pre-swell under high pressure (sample saturated at σ_v = 2.4 MPa)

The samples were tested along different orientations with respect to the axis of the oedometer cell: perpendicular (θ = 0°), inclined 45° (θ = 45°) and parallel (θ = 90°) to the bedding plane. The results established the anisotropy of σ_s: the swelling pressure in the direction perpendicular to the bedding plane is the highest.

The swelling under constant volume was also investigated using an oedometer cell with lateral pressure σ_h measurement. The values of σ_s in two directions were measured at the same time using a lateral pressure sensor (in the horizontal direction) and a force sensor (in the vertical direction). Two sample orientations were tested: θ = 0°, θ = 90°. Several tests were performed for each orientation, starting from different initial vertical stresses σ_v (before saturation). From these results, the anisotropy was identified: the swelling pressure perpendicular to the bedding plane is higher than that parallel to the bedding plane. This observation was also confirmed by considering the free swelling under constant confining pressure in the triaxial cell.

The anisotropy of the shear behaviour was studied using a triaxial cell equipped with bender elements (installed at the top and bottom pedestal). Several triaxial tests on three types of Boom Clay specimens (θ = 0°, θ= 45°, θ = 90°) were carried out. The effect of confining pressure was also examined. Under the same confined pressure, the anisotropy of a maximum deviatoric stress q was found: $q_{45} < q_{\perp} < q_{//}$. In other words, the shear strength in the direction parallel to the bedding plane is higher than that perpendicular to the bedding plane. The velocities of the compressional waves (V_p) and shear waves (V_s) were also measured during the isotropic consolidation, re-saturation and shear stages by bender elements. An inherent anisotropy was observed: both velocities are higher along the bedding plane than in the perpendicular direction. The anisotropic behaviour was also evidenced by analysing elastic modulus ($E_{\perp}$, $E_{//}$) variations. Based on these experimental results, five elastic parameters used for an anisotropic elasto-plastic model developed for Boom Clay (ACC-2A) were proposed.

NUMERICAL ANALYSES OF DEEP EXCAVATION IN BOOM CLAY

This work is being undertaken in collaboration with the University of Liège. The post-doctoral agreement was further extended to a total duration of 2½ years due to the promising numerical results obtained.

The two-surface plasticity model developed as part of the PhD research conducted by Hong (2013) was first applied in the finite element simulation for the hydro-mechanical behaviour perturbations of Boom Clay in the PRACLAY gallery excavation. The two-surface model, namely ACC-2, was chosen since it can accurately describe some important mechanical features of Boom Clay evidenced experimentally, such as the limited elastic zone and the smooth transition from elastic to plastic behaviour. Figure 25 compares the results of the finite element modelling with in-situ measurements along the horizontal profile around the PRACLAY gallery. The pore water pressure obtained with ACC-2 is quantitatively closer to the in-situ measurements than the results obtained with the conventional MCC (Modified Cam Clay) and Mohr-Coulomb models, indicating the importance of considering the smooth transition between elasticity and plasticity with a limited elastic zone of the clay.

Meanwhile, the ACC-2 model has also been applied to investigate the hydro-mechanical responses of the Boom Clay in a bituminised radioactive waste disposal facility. In contact with the groundwater, the bituminised radioactive waste will swell due to the presence of a high content of $NaNO3$. The swelling rates of 0.01 mm/year, 0.1 mm/year and 1 mm/year were considered, respectively. The simulation results show that the hydro-mechanical behaviour in this process depends on the competition between the swelling pressure from the nuclear waste and the water flow in the clays. The contribution of the water flow is dominant at an early stage, and the contribution of the swelling pressure becomes dominant in subsequent stages. When a higher swelling rate is applied, the swelling pressure effect becomes dominant at an earlier point in time.

To predict the time-dependent behaviour of Boom Clay, an advanced viscoplastic model was finally developed in the context of studying two-surface plasticity and isotach viscosity. The model was well validated by simulating experimental tests involving variable stress and/or strain rate conditions. The results show the model's relevance in reproducing the general features of the time-dependent behaviour of Boom clay. This model will be further validated by long-term in-situ measurements and then applied to predict the long-term hydro-mechanical behaviour of Boom Clay in a real repository.

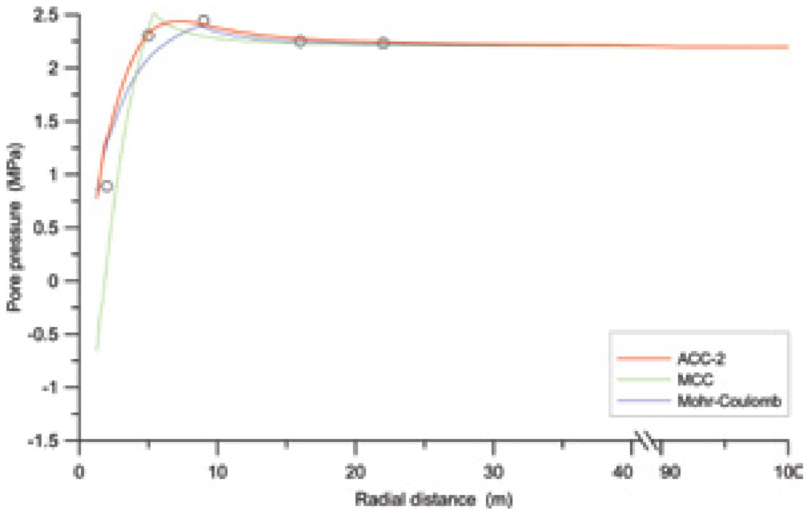


Figure 25 - Comparison of the pore pressure distribution at the end of the excavation along a horizontal profile at mid-plane of the PRACLAY gallery using ACC-2, MCC and Mohr-Coulomb models

ULg (University of Liège, Belgium)

A PhD research project on the evolution of the excavation-damaged zone (EDZ) started in 2011 at ULg. The aim of this thesis is to study the evolution of the EDZ's structure and fractures using numerical tools, in particular the second gradient concept implemented in the finite element software LAGAMINE. This thesis is financed directly by ONDRAF/ NIRAS and is supervised jointly by EIG EURIDICE and ONDRAF/ NIRAS.

The focus was on two aspects in 2014. The first concerned the hydro-mechanical coupling observed in the clay after the excavation of the Connecting gallery. The numerical and experimental results were compared using the data on the pore water pressure monitored in boreholes R55 and R13. The initial comparison showed poor agreement between the numerical and experimental data. This agreement was improved by taking the gravitational head into account in the model.

The role of the concrete lining was highlighted in the development of the damaged and fractured zone. Indeed, the decrease in the extension of the EDZ is observed where a lining supports the host rock. The agreement between numerical and experimental results (the monitored strain and the convergence of the ring) improved by taking into account the contact element between the concrete segments.

The main goal in 2015 will be to write up the thesis.

2.4. GeoScientific Information System (GSIS)

As manager of the URL HADES, EIG EURIDICE supports the GSIS (GeoScientific Information System) project being developed by SCK•CEN on behalf of ONDRAF/NIRAS. The GSIS structures all field information in a geographical way, and contains elements ranging from shafts to analysis results from specific water samples obtained at a particular piezometer filter. EIG EURIDICE's contribution consists in adding and validating the elements (constructive components like shafts and galleries, boreholes, etc.). It will also use this database as an inventory for all geographically related information on equipment and instrumentation, and for the validated data series of selected sensors to be published for external users.

Since a new database structure is being set up by SCK•CEN (to be delivered early 2015), work in 2014 was limited to the structuring of the historical information available on the constructive elements (so that it can be properly referenced in the GSIS system), consultation with the surveyor regarding the different localisation techniques and coordinate systems used in HADES, and some initial work on a validation procedure to clear measurement data for external use.

3. Monitoring approach

The issue of repository monitoring has gained a lot of international attention in recent years – mainly due to the more detailed specifications that are required by the regulatory bodies in countries with advanced programmes (e.g. Finland), and also because of growing awareness of the societal role of monitoring. EIG EURIDICE has therefore set out a programme to investigate this in more detail, comprising a technical part and a more strategic part.

For the technical part, EIG EURIDICE can draw on its long-standing experience monitoring in underground conditions (relevant to a repository environment) for the past 30 years and more. To secure this knowledge, it has embarked on a systematic review of relevant set-ups in HADES that have been run over the past few decades (essentially since the start of the HADES experimental programme in the 1980s), focusing in particular on the performance of the sensors in field conditions and in the long term.

For the strategic part, EIG EURIDICE will start by assessing which safety statements can be substantiated by specific monitoring parameters. In the reporting year, it did not do any work on this aspect, but had already carried out similar tasks as part of the European Commission's MoDeRn project (see 4.1.).

4. Participation in international research projects

4.1. European Commission (EC) projects

MoDeRn

This project, initiated under the 7th Framework Programme of Euratom, started on 1 May 2009 and ran for 54 months, officially ending on 1 November 2013. Consequently, no project-related activities were undertaken in 2014. Nevertheless, some final reports (including the Synthesis report) were published in early 2014. By May 2014, the EC had approved all reports and the project was officially closed.

In the meantime, negotiations were started with a view to preparing a new project proposal for the H2020 Euratom Work Programme NFRP6-2014 "Supporting the implementation of the first-of-the-kind geological repositories". With ANDRA as coordinator, a proposal ("Modern2020") was introduced in September 2014. It consists of four main work packages, and EURIDICE is participating in two of these: WP3 (monitoring technology) as observer and WP4 (Demonstration and Practical Implementation) as coordinator. The other two are Strategy (WP2) and Societal Concerns and Stakeholder Involvement (WP5). The project consortium consists of 28 partners from 12 countries. For EURIDICE, the project would involve nine person-months of staff time and a total budget of EUR 227,000 (total for four years). A decision by the EC is expected in the first quarter of 2015.

4.2. Other international collaborations

NAGRA (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle)

For the preparation of its experimental set-ups in Mont Terri, EURIDICE has acted as a consultant on an ad-hoc basis. In 2014 no specific activities were undertaken, as the large-scale heater experiment (FE) is currently being implemented.

LUCOEX (Large Underground Concept Experiments)

EURIDICE participates, indirectly through SCK•CEN, in the Expert Group that reviews progress in the LUCOEX project. LUCOEX (Large Underground Concept Experiments) is a four-year project under the 7th Framework Programme of Euratom. Its overall objective is to demonstrate the technical feasibility in situ for safe and reliable construction, manufacturing, disposal and sealing of repositories for long-lived high-level nuclear waste. The demonstrations take place in four different underground research laboratories (operated by POSIVA, SKB, ANDRA and NAGRA), each with their own specific concept (horizontal disposal in hard rock or in indurated clay and vertical disposal in hard rock).

The establishment of the Expert Group (consisting of four "internal" experts – i.e. one from each of the laboratories – and four external experts, EURIDICE being one of them) is one of the ways to enhance the quality and use of the technical achievements; others range from workshops and scholarships to direct dialogue with interested parties by opening up the participating URLs with the actual sites of demonstrations to domestic and foreign engineers, decision-makers and the general public.

EURIDICE's review input as a member of the Expert Group allows it to have direct access to the scientific, technical and societal aspects of these demonstrations. During 2014, visits were organised to Äspö (SKB's horizontal disposal concept in hard rock), Olkiluoto (POSIVA's vertical disposal concept in hard rock) and Mont Terri (NAGRA's horizontal disposal concept in Opalinus Clay – realised through the FE experiment).

IRMM (Institute for Reference Materials and Measurements)

Since 1999 EIG EURIDICE has also delivered services for IRMM's long-standing operation of an ultra-low level radioactivity laboratory in support of European Commission policies in such fields as international standardisation, radioactive waste management and radioprotection. Some key projects in 2014 included: characterisation of Europallet-sized reference materials for a Free Release Measurement Facility, radiotracer studies from all over the Northern Pacific to map ocean currents and study uptake in the food chain and characterisation of food reference materials following the Fukushima accident.

For this purpose, part of the HADES underground research laboratory has been leased to IRMM. The contract is a Service Agreement that can be extended on a yearly basis.

5. Scientific Advisory Committee (SAC)

In June 2013 the composition of the Scientific Advisory Committee (SAC) of EIG EURIDICE was amended due to the expiry of the term of office of all previous members.

The two constituent members of EIG EURIDICE each appoint three external experts for a period of four years.

The members appointed by SCK•CEN for the period June 2013 – June 2017 are:

- Prof. Robert Charlier, Professor of Geotechnical Engineering and Soil and Rock Mechanics at Liège University (Belgium)
- Prof. Geert De Schutter, Professor of Concrete Technology at Ghent University and Technical Director
  of the Magnel Laboratory for Concrete Research (Belgium)
- Prof. Tilmann Rothfuchs, Retired Head of GRS (Gesellschaft für Anlagen und Reaktorsicherheit) -division of Repository Safety Research (Germany)

The members appointed by ONDRAF/NIRAS for the same period are:

- Dr Gilles Armand, Head of the Fluid and Solid Mechanics Department at the French National Agency for Radioactive Waste Management - ANDRA (France)
- Prof. Jean-Marc Baele, Professor of Geology and Applied Geology, University of Mons (Belgium)
- Prof. Philippe Claeys, Head of the interdisciplinary research unit Earth System Sciences, Vrije Universiteit Brussel (Belgium)

The new SAC regulations, approved by the General Assembly of EIG EURIDICE on 23 April 2012, extend the scope of the committee's remit to all scientific and technological activities of EIG EURIDICE.

EIG EURIDICE organised the second workshop on the preparation of the PRACLAY heater switch-on on 12 and 13 December 2013 with the participation of the SAC members and other international experts. Based on the outcomes of this workshop, EURIDICE made the final preparations for the Heater test, leading up to the start of heating on 3 November 2014.

The first SAC meeting after the heater switch-on will be organised in March 2015.

6. Programme Committee for Underground Experiments (POP)

Due to the fact that almost all activities in 2014 related to the preparations for the switch-on of the PRACLAY Heater experiment, no POP meetings were held.

Nevertheless, work on drawing up a complete inventory of all past and ongoing in-situ experiments and developing a core management procedure is in progress.

7. Management & exploitation of installations

GENERAL

The Statutory Rules define the tasks of EIG EURIDICE concerning the management and exploitation of the installations on the land for which EIG EURIDICE holds a building lease. In 2014 these tasks were performed in accordance with applicable regulations.

The exploitation team continually supported RD&D activities in different projects:

- Connection of monitoring devices to the data-logging system in HADES;
- Technical adaptations to PRACLAY (e.g. installation and connection of a revised control system for the primary heaters, installation of back-up heaters and their control system, extra thermocouples for the control systems, alarm system, UPS system, etc.).

The exploitation team delivered services related to required maintenance on machinery, site and infrastructure. These were performed in accordance with the operating licence and applicable legal and regulatory requirements and in line with the ISO 9001:2008 standard. Finally, the necessary support for providing visitors with guided tours through the underground laboratory was provided throughout 2014.

UNDERGROUND INSTALLATIONS AND ASSOCIATED HOISTING SYSTEMS

The exploitation team and/or AIB Vinçotte carried out the necessary controls and checks on the shafts, cables, hoisting equipment, etc. There were some interruptions in, for instance, the hoisting systems and shafts, but these were resolved within a reasonable period of time and without any major problems.

As already explained in the Activity Report 2012, EIG EURIDICE proactively launched a study on the various options and corresponding regulations for the refurbishment of the shaft 1 hoisting system. DBE (Germany) finalised its study at the beginning of 2014 and based on this a budget estimation was made. Discussions with the competent authorities (Belgian Federal Public Service for Employment, Labour and Social Dialogue) and with external inspection body AIB Vinçotte on the applicable regulations for the shaft refurbishment were held during 2014. In 2015 EIG EURIDICE will start preparations for a public tender (detailed design study and implementation).

Other standard maintenance and repair work on the hoisting systems, shafts and galleries was performed by the exploitation team in 2014.

ABOVE-GROUND INSTALLATIONS AND BUILDINGS

The exploitation team carried out standard maintenance and necessary repairs on installations, buildings and infrastructure in 2014.

As announced in the previous Activity Report, it was decided to build a new entry road into EIG EURIDICE. The public tender took place in 2014. Construction work started at the end of August; it was completed by the end of the year and new gates were installed. What remains to be done in 2015 is mainly the electrical work: street lights and automation for the gates.

The entry procedure to the EURIDICE site and between the EURIDICE site and the SCK•CEN site has been issued.

LICENCES

The operating licence is valid until 2024. Nothing changed in this respect in 2014.

The nuclear licence of EIG EURIDICE (issued in August 2006) is valid until 2021. All inspections and checks under this licence were carried out by BEL V.

The environmental licence of EIG EURIDICE (granted in November 2013) is valid for 20 years.

8. Specific support for the repository technology study of ONDRAF/NIRAS

EIG EURIDICE supports ONDRAF/NIRAS in its RD&D technical feasibility programme of geological disposal. This programme aims to demonstrate the construction and operational feasibility of the proposed concept for geological disposal and the repository design. The next programme milestone is the first Safety and Feasibility Case (SFC-1), which is scheduled for 2019.

The repository technology studies cover the following topics:
- fabrication of the waste disposal packages
- construction of the underground repository
- operation and closure of the underground repository

EIG EURIDICE is involved in research on the fabrication of the waste disposal packages through its contributions to the experimental programme on the Supercontainer (see 1.2.2), including the instrumentation plan, participation in the research project meetings and review of the reports produced by the project partners.

9. Support for Safety and Feasibility Case 1 of ONDRAF/NIRAS

EIG EURIDICE provides scientific and technical input for the development of ONDRAF/NIRAS's first Safety and Feasibility Case (SFC-1) with its expertise in the geomechanics of clays. In particular, it is preparing a state-of-the-art report on the geomechanical behaviour and properties of Boom Clay, with emphasis on the results from the HADES URL. In the context of the research and development programme on the thermo-hydro-mechanical behaviour of Boom Clay and Ypresian clays, EIG EURIDICE also supervises and/or provides support for several PhD research projects (see 2.3).

EIG EURIDICE also contributes to the integration of this scientific knowledge into the Safety and Feasibility Case as the body responsible for drafting the "integration report" on the evolution of the disturbed zone around a deep repository for high-level and/or long-lived waste in a clay layer. This report will be part of the set of documents formally making up ONDRAF/NIRAS's SFC-1.

Activities: PART II
The surface disposal programme for category A waste - cAt Project

Introduction

On 23 June 2006 the Belgian federal government decided that the long-term management of category A waste should take the form of a surface disposal facility within the municipality of Dessel, situated in the northern, Flemish part of Belgium in the Province of Antwerp. The government commissioned ONDRAF/NIRAS to carry out this integrated project – i.e. the cAt project. To fulfil its appointed task, ONDRAF/NIRAS works in close collaboration with the STORA and MONA partnerships it has with the municipalities of Dessel and Mol, respectively.

An important step in the successful completion of this project has been the licence application that ONDRAF/NIRAS submitted on 31 January 2013 to the Belgian nuclear regulator, the Federal Agency for Nuclear Control (FANC), for the surface disposal facility.

EIG EURIDICE supports the cAt project in the following areas:

- Calculations of the long-term radiological impact of the planned repository;
- Preparation and instrumentation of the planned test cover; and
- Instrumentation of the demonstration test for construction of concrete modules.

1. Radiological long-term safety assessments and quality assurance of models and codes

Radiological long-term safety assessments, prepared and documented during the period 2010-2012, are a key part of the safety arguments presented in the licence application.
Results from the safety assessments have been documented in scientific papers:

- S.C. Seetharam, J. Perko, D. Jacques, D. Mallants, 2014. Influence of fracture networks on radionuclide transport from solidified waste forms. Nuclear Engineering and Design 270, pp. 162-175.
- D. Jacques, J. Perko, S.C. Seetharam, D. Mallants, 2014. A cement degradation model for evaluating the evolution of retardation factors in radionuclide leaching models. Applied Geochemistry 49, pp. 143-158.

The existing QA/QC records of the safety assessments in the licence application have been more systematically archived and measures have been implemented to develop the data collection forms and database for new calculations.

EIG EURIDICE has contributed to answering questions from FANC on the licence application. The answers entailed both clarification and further analysis and calculations. Uncertainties have been further analysed, resulting in a more systematic identification and description. Modelling of carbon-14 in the biosphere has been refined. A sensitivity study on the influence of the distance and the number of modules on the dilution factor in the geosphere has been carried out. New near-field models of the disposal facility have been established for several safety assessment scenarios. Sensitivity calculations on the influence of various near-field assumptions have been performed in order to argue the envelope character of the models and scenarios used.

In addition, further scoping calculations have been performed on the evolution of water flow and water saturation degree, taking into account voids in the system.

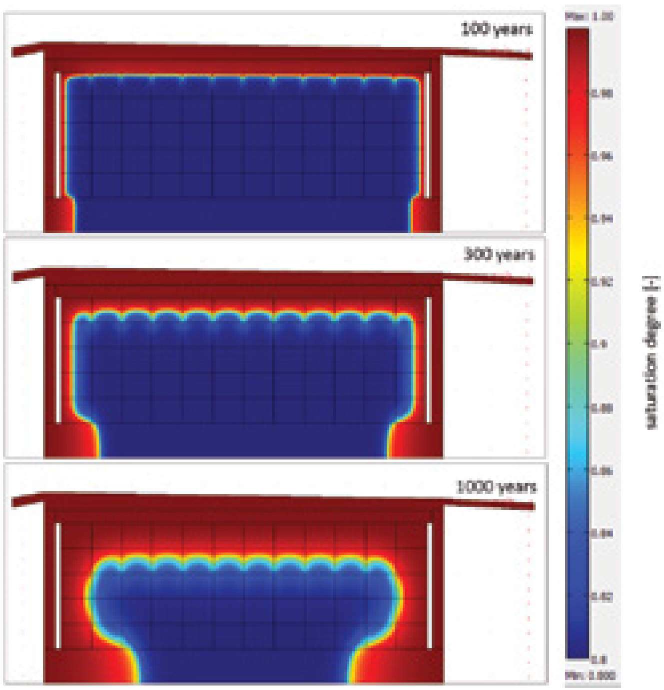


Figure 26 - Evolution of the saturation degree in the disposal facility, taking into account voids between the monolithic stacks for intact concrete

These calculations indicate that the cementitious barriers in the disposal facility would to a large extent remain unsaturated for hundreds of years (see Figure 26). In such an unsaturated state, the diffusion of radionuclides is much lower than in a saturated system. This confirms the envelope character of the safety assessment models.

2. Test cover

After placing waste in a surface-type disposal facility for several decades, a multi-layer cover will be placed on top of the disposal modules, with the aim of reducing water infiltration into these modules so as to limit degradation through leaching of the underlying components and to limit leaching of radionuclides from the facility. In the meantime, a long-term test cover programme has been developed to gather information on the technical aspects and the dynamics of a multi-layer cover; the experience gained will form a solid basis for building confidence and experience with multi-layer cover systems to be used in the design, construction and monitoring of the final tumulus.

Due to a change in the planning schedule and other more urgent priorities, the construction of the test cover has been postponed until 2016. Work and studies concerning the further implementation of the test cover were limited to the further testing of some instrumentation (pCO2 and pO2 devices), the design of a prototype of a water tank, and the further development of the complete 3D model (see Figure 27). The main objective of the latter task is to optimise the design of the concrete structure, instrumentation, connecting cables, drainage system, cellars, and control panels and demultiplexers. An electricity plan was worked out, including the lighting plan.

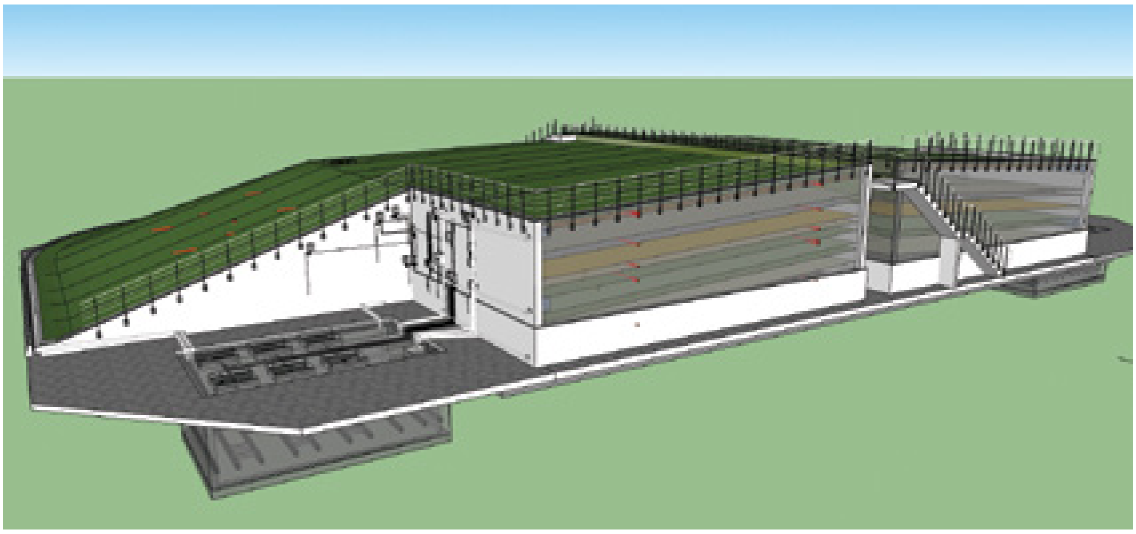


Figure 27 - 3D overview of planned instrumentation

As a consequence of the development of a visual quality plan for the whole cAt site, the initial location of the test cover was re-evaluated. Due to the position of the information and communication centre, there was not enough room left to build the test cover near the demonstration test. As a result, the new test cover location is now situated near the SME zone (small and medium-sized enterprises).

3. Demonstration test

In order to assess the technical feasibility of the module construction techniques and the industrial feasibility of the concrete that has been optimised for long-term safety and has been tested on a laboratory scale, a demonstration module construction test for the cAt project has been underway since 2011 (Figure 28).

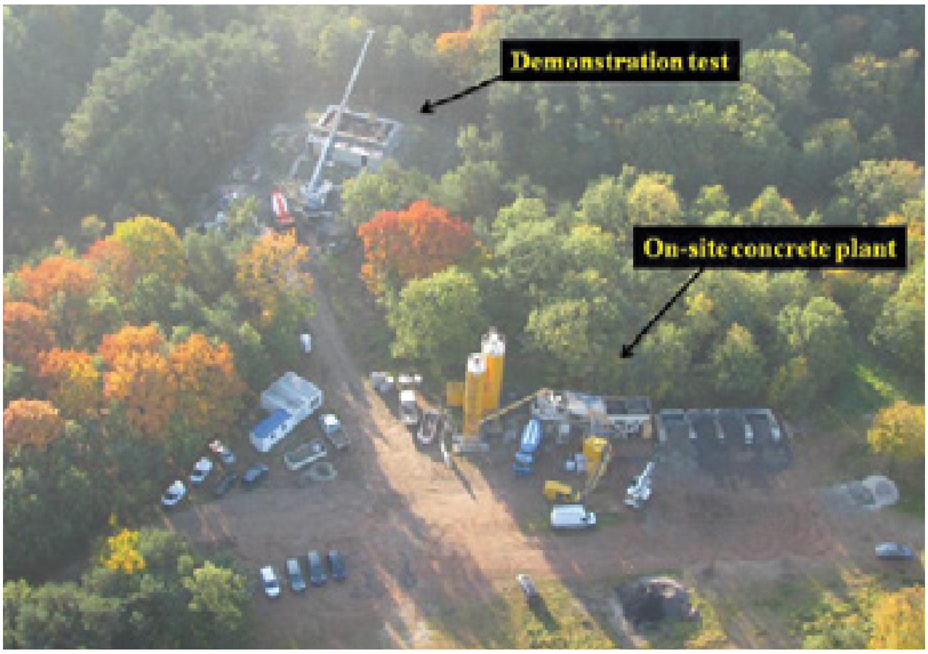


Figure 28 - Overview of the demonstration test

EIG EURIDICE, together with ONDRAF/NIRAS and Tractebel Engineering, devised an instrumentation plan for assessing the temperature and stress conditions within the concrete used in the demonstration test.

In 2011 the test module and two test panels were built by ONDRAF/NIRAS and instrumented by EIG EURIDICE. A third panel was built in 2013 and was also instrumented by EIG EURIDICE. Vibrating wire strain gauges and formwork pressure sensors were installed. A fourth test panel was built in 2014, again instrumented by EIG EURIDICE. This time only thermocouples were installed.

Scientific output

PUBLICATIONS

Areias L., Pyl L., Iliopoulos S., Gu J., Aggelis D., Craeye B., De Schutter G., Gens R., Van Marcke P., Coppens E. and Van Cotthem, A.- *Detection and Monitoring of Cracks in a Concrete Buffer from DIC and AE Measurements – 14439.* Proc. of the WM2014 Conference, March 2-6 2014, Phoenix.

Chen G., Maes T., Vandervoort F., Sillen X., Van Marcke P., Honty M., e.a.- *Thermal Impact on Damaged Boom Clay and Opalinus Clay: Permeameter and Isostatic Tests with µCT Scanning.*- In: Rock Mechanics and Rock Engineering. Special Issue: Thermo-Hydro-Mechanical Effects in Clay Host Rocks for Radioactive Waste Repositories, 47:1(2014), p. 87-99.- ISSN 0723-2632.

Dao D., Cui Y., Tang A., Pereira J., Li X., Sillen X.- *Investigating the anisotropy of the shear modulus of natural Boom Clay.*- In: Géotechnique Letters, 4:2(2014), p. 98-101.- ISSN 2045-2543.

Dao L., Delage P., Tang A., Cui Y., Pereira J., Li X., e.a.- *Anisotropic thermal conductivity of natural Boom Clay.*- In: Applied Clay Science, 101:11(2014), p. 282-287.- ISSN 0169-1317.

Delay J., Bossart P., Li X., Blechschmidt I., Ohlsson M., Vinsot A., e.a.- *Three decades of underground research laboratories: what have we learned?:* Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, Montpellier, France, 22-25 October 2012.- In: Geological Society Special Publications, 400(2014), p. 7-32.

Dieudonné A.-C., Salehnia F., Li X., Charlier, R.- *Hydromechanical behaviour of interfaces in the framework of nuclear waste disposal.* Alert workshop 2014. 29th September – 1st October 2014, Aussois, France.- [Presentation]

François B., Labiouse V., Dizier A., Marinelli F., Charlier R., Collin F.- *Hollow Cylinder Tests on Boom Clay: Modelling of Strain Localization in the Anisotropic Excavation Damaged Zone.*- In: Rock Mechanics and Rock Engineering. Special Issue: Thermo-Hydro-Mechanical Effects in Clay Host Rocks for Radioactive Waste Repositories, 47:1(2014), p. 71-86.- ISSN 0723-2632.

Geernaert T., Sulejmani S., Sonnenfeld C., Luyckx G., Chah K., Areias L., Mergo P., Urbanczyk W., Van Marcke Ph., Coppens C., Thienpont H. and Berghmans F.- *Microstructured optical fiber Bragg grating-based strain and temperature sensing in the concrete buffer of the Belgian supercontainer concept.* Proc. of the 23rd International Conference on Optical Fiber Sensors OFS23, 2nd – to 6th June 2014, Santander (Cantabria) Spain.

González-Blanco et al.- *Importance of sample volume changes and material degradation on gas transport properties in Boom Clay.* Proc. 7th International Congress on Environmental Geotechnics 2014, Melbourne, Australia, 10-14 November. In: Bouazza, S. Yuen and B. Brown (eds). Engineers Australia ISBN 978-1-922107-23-7: 850-857.

González-Blanco et al. (2014).- *Importance of stress state and material degradation on gas transport processes in Boom Clay.* IGDTP Geodisposal 2014, Manchester, UK, 24-26 June 2014.- [Poster]

Hong P., Pereira J., Cui Y., Tang A., Collin F., Li X.- *An elastoplastic model with combined isotropic–kinematic hardening to predict the cyclic behavior of stiff clays.*- In: Computers and Geotechnics, 62:10(2014), p. 193-202.- ISSN 0266-352X.

Kursten B., Druyts F., Areias L., van Ingelgem Y., De Wilde D., Nieubourg G., Duffo G. S. and Bataillon C. *Preliminary results of corrosion monitoring studies of carbon steel overpack exposed to supercontainer concrete buffer.* Journal of Corrosion Engineering, Science and Technology 49:6 (2014), p. 485-491.

Nguyen X., Cui Y., Tang A., Li X., Wouters L.- *Physical and microstructural impacts on the hydro-mechanical behaviour of Ypresian clays.*- In: Applied Clay Science, 102:12(2014), p. 172-185.- ISSN 0169-1317.

Philippe V., Li X., Chen G., Verstricht J., Bastiaens W., Sillen X.- Installation of the PRACLAY Seal and Heater: Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, Montpellier, France, 22-25 October 2012.- In: Geological Society Special Publications, 400(2014), p. 107-115.- ISSN 0305-8719.

Salehnia F., Charlier R., Sillen X., Dizier A. *Modeling of Excavation Damaged Zone through the strain* *localization approach in Boom clay.* Proc. of the 14th Int. Conference of International Association for Computer Methods and Recent Advances in Geomechanics, IACMAG 2014. 22-25, Kyoto, Japan.

Sulem J. [edit.], Li X. [edit.].- Rock Mechanics and Rock Engineering. *Special Issue: Thermo-Hydro-Mechanical Effects in Clay Host Rocks for Radioactive Waste Repositories.*- In: Rock Mechanics and Rock Engineering, 47:1(2014).- 328 p.- ISSN 0723-2632.

Wouters L., Li X.- *Belgian Country Report 2013-2014.*- 24th NEA Clay Club Meeting.- Bure, France, 30-30 September 2014.- [Presentation]

Yu H., Chen W., Li X., Sillen X.- *A Transversely Isotropic Damage Model for Boom Clay.*- In: Rock Mechanics and Rock Engineering. Special Issue: Thermo-Hydro-Mechanical Effects in Clay Host Rocks for Radioactive Waste Repositories, 47:1(2014), p. 207-219.- ISSN 0723-2632.

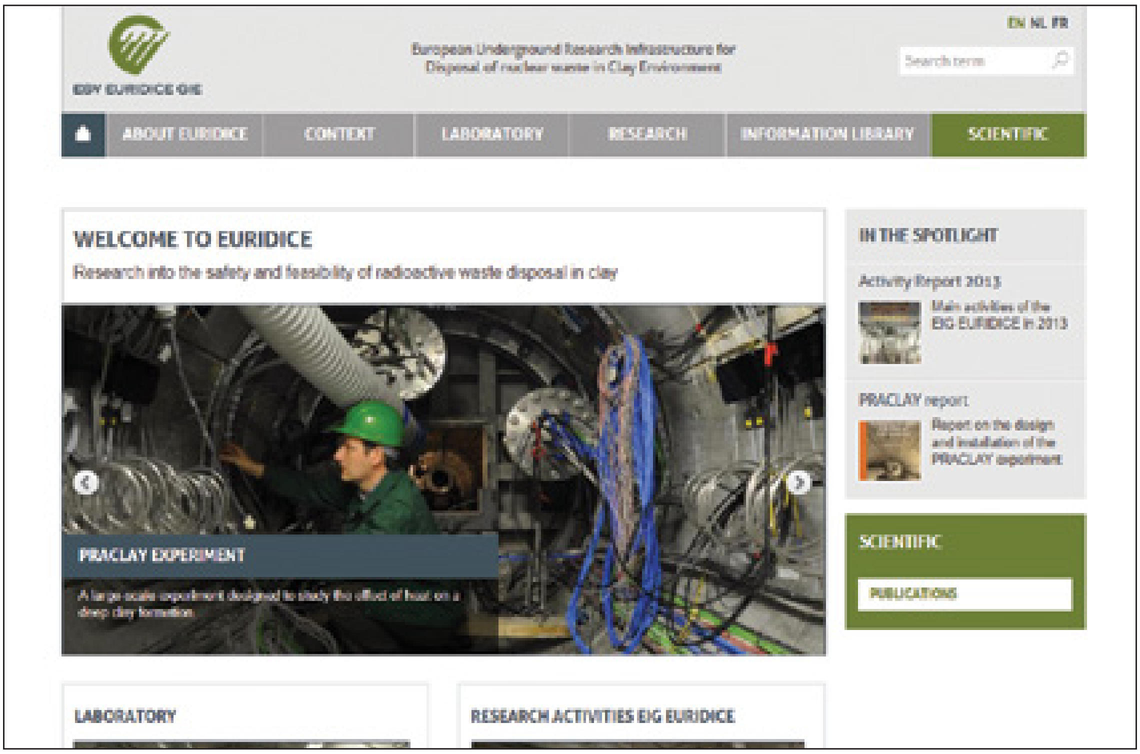
Communication & general management

1. Communication

Communicating about its activities is one of EIG EURIDICE's main tasks. The HADES underground research laboratory (URL) is a powerful tool for explaining the concept of geological disposal and is a perfect starting point to present and explain the research that has been going on for the past 35 years.

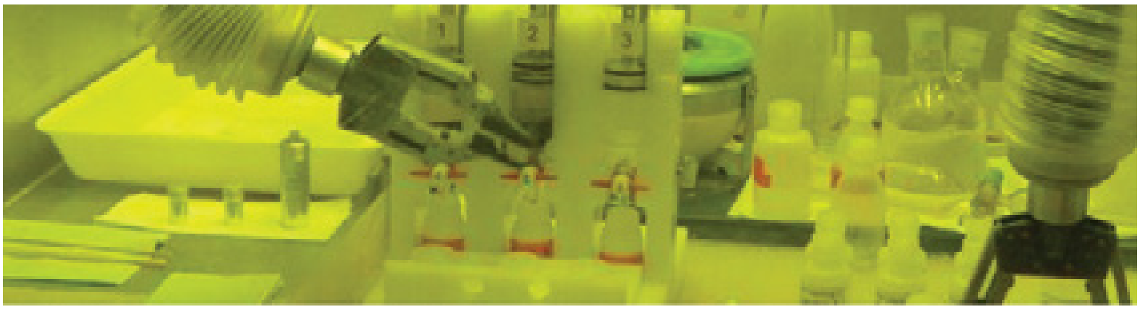
WEBSITE

The new website of EURIDICE went online at the end of 2014. It gives an overview of the activities and fields of expertise of EIG EURIDICE and of the construction and importance of the HADES URL. By means of a virtual visit and several videos, visitors get a good idea of EIG EURIDICE's work environment. The website also contains a searchable list of scientific publications and downloadable brochures and leaflets for a wide audience.



EVENTS

On 6 May EIG EURIDICE organised the 19th Exchange Meeting on the theme of "The long-term evolution of high-level waste forms".



Researchers from the SCK•CEN's Waste & Disposal expert group gave an overview of the status of research on the long-term evolution of vitrified waste and spent fuel. ONDRAF/NIRAS placed these presentations in the context of the Belgian research programme on geological disposal of high-level and/or long-lived waste. The presentations are available on the new EURIDICE website.

VISITS

Anyone over the age of 18 can visit EIG EURIDICE and the underground research laboratory in small groups. Sociocultural organisations are looked after by trained guides, who also lead visits at ISOTOPOLIS, the information centre of ONDRAF/NIRAS on radioactive waste. Geological disposal experts, journalists, university students with a scientific background and key political and economic figures are given a guided tour by scientific personnel, the Communication Manager and/or the Director of EIG EURIDICE, sometimes accompanied by ONDRAF/NIRAS or SCK•CEN management.

In 2014 EIG EURIDICE welcomed 1,433 visitors during 102 visits to the HADES URL and the above-ground exhibition on geological disposal; 45 of the 102 visits were led by trained tour guides. Of the 102 visits, 39 were for training and educational purposes and only 11 involved sociocultural organisations. The remaining 52 concerned direct stakeholders of EIG EURIDICE or were arranged at the request of SCK•CEN or ONDRAF/NIRAS. Forty-eight were Dutch-speaking, 34 English-speaking and 20 French-speaking. Overall, people are very positive about their visit to EIG EURIDICE, the quality of the guides and the high standard of the research. They are especially impressed by the tour of the HADES URL. After going underground, they have a more realistic view of the scope and effort of the RD&D work and of what an actual repository might look like.

2. Personnel

Under its Statutory Rules, EIG EURIDICE has no employees of its own. Personnel working for EIG EURIDICE are under contract to either SCK•CEN or ONDRAF/NIRAS and have operated as the EIG EURIDICE team since 2000, based at the EIG EURIDICE site.

In 2014 there were no new recruitments for EIG EURIDICE and the team still consists of 16 members.

Director:
Peter De Preter

Scientific team:
Xiangling Li - scientific manager
Lou Areias - scientific collaborator
Wim Bastiaens - scientific collaborator
Arnaud Dizier - scientific collaborator
Guangjing Chen - scientific collaborator
Ioannis Troullinos - scientific collaborator
Jan Verstricht - scientific collaborator

Technical team:
Jef Leysen - operations & safety manager
Hendrik Huysmans - exploitation technician
Christian Lefèvre - exploitation technician
Johan Peters - exploitation technician
Bert Vreys - exploitation technician

Office manager:
Caroline Poortmans

Team support:
Els Van Musscher

Communication manager:
Jan Rypens

3. Quality Management

Since 2007, EIG EURIDICE has been ISO-certified according to the ISO 9001:2008 standard for Quality Management. The current certificate is granted for the period from 22 April 2013 to 21 April 2016. An external audit took place on 17 February 2014. There were no major or minor non-conformities.

On 11 December 2014 Pascale Palinckx from ONDRAF/NIRAS performed an internal audit. No non-conformities were found.

ESV EURIDICE EIG

EIG EURIDICE is an Economic Interest Grouping involving the Belgian Nuclear Research Centre SCK•CEN and the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS). It manages the HADES underground research facility and carries out safety and feasibility studies for the disposal of high-level and/or long-lived radioactive waste in a clay host rock.

Boeretang 200
2400 Mol
tel. 014 33 27 84
fax 014 32 37 09
www.euridice.be