ONDRAF/NIRAS

RD&D priorities on cement within the Belgian national programme

Xavier Sillen
Erik Coppens
Maarten Van Geet

21st Exchange Meeting ESV EURIDICE GIE

29/05/2017

Belgian Agency for Radioactive Waste and Enriched Fissile Materials

RD&D priorities on cement within the Belgian national programme

- Cementitious materials in the long term management of radioactive waste
- Research, Development and Demonstration (RD&D) on cementitious materials in that context
- Priorities in the Belgian national programme
- Conclusions

ONDRAF/NIRAS 2

RD&D priorities on cement within the Belgian national programme

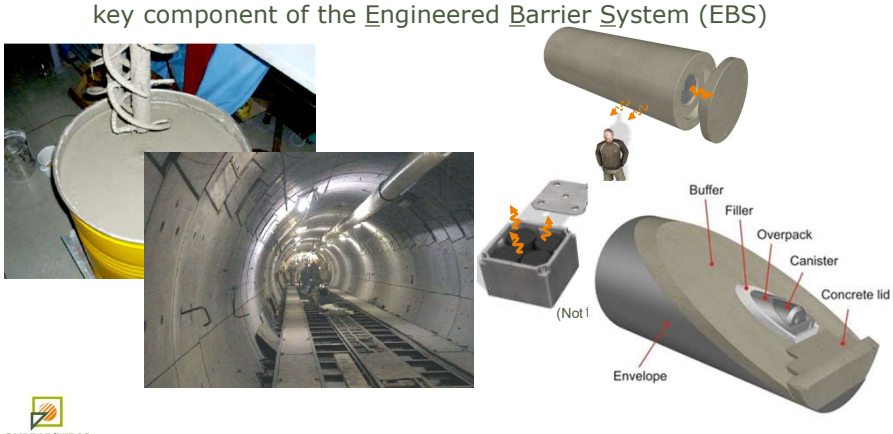
- **Cementitious materials in the long term management of radioactive waste**
- **Research, Development and Demonstration (RD&D) on cementitious materials in that context**
- **Priorities in the Belgian national programme**
- **Conclusions**

ONDRAF/NIRAS

3

Cementitious materials in long term management of radioactive waste

- **Cementitious materials are ubiquitous in long term management of radioactive waste**
  - **Many uses**: waste conditioning, structural elements, shielding, key component of the Engineered Barrier System (EBS)



ONDRAF/NIRAS

4

Cementitious materials in long term management of radioactive waste

- **Cementitious materials are ubiquitous in long term management of radioactive waste**
  - **Many uses**: waste conditioning, structural elements, shielding, key component of the Engineered Barrier System (EBS)
- **Engineered materials**
  - One can freely **select** and to some extent **design** the material to meet certain **requirements** (see 2nd presentation – Erik Coppens)
- **Evolving materials**
  - in the short term (see 1st presentation – Erik Coppens)
  - and the long term (see 3rd presentation – Quoc Tri Phung)

ONDRAF/NIRAS 5

RD&D priorities on cement within the Belgian national programme

- Cementitious materials in the long term management of radioactive waste
- **Research, Development and Demonstration (RD&D) on cementitious materials in that context**
- Priorities in the Belgian national programme
- Conclusions

ONDRAF/NIRAS 6

RD&D on cementitious materials for the long term management of radwaste

- **Many uses**
  + many choices
  + evolution
  } ➔ **plenty of possible RD&D topics!**

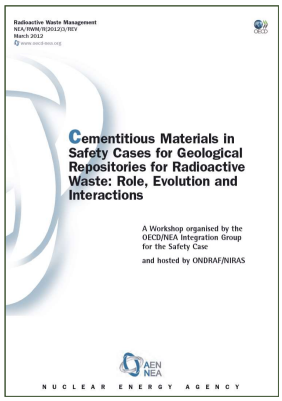
- **RD&D activities generally organised along the lines of**
  1. **Material selection/design** (w.r.t. requirements)
  ⬇
  2. **Characterisation** of key properties that will affect the evolution of the **component** and the **system** of which it is a part
  ⬇
  3. **Assessment** of the expected **evolution**
     - will the requirements be met over the necessary time frames?
     - compatibility with other components of the system?

ONDRAF/NIRAS

7

RD&D on cementitious materials for the long term management of radwaste

www.oecd-nea.org/rwm/docs/2012/rwm-r2012-3.pdf



http://goo.gl/hVMWJw

A good reference: NEA WS proceedings

- Workshop held in Brussels in 2012
- Discusses roles, evolution and interactions of cementitious materials in the context of geological disposal and on the related RD&D

Notable evolution (~ early 2000's)

- cementitious materials considered as "**necessary evil**" w.r.t long term performance of geological repositories; focus on detrimental effects, perturbations

⬇

- **taking advantage** of key properties of cementitious materials to **enhance** the long term performance of the EBS

ONDRAF/NIRAS

8

RD&D priorities on cement within the Belgian national programme

- Cementitious materials in the long term management of radioactive waste
- Research, Development and Demonstration (RD&D) on cementitious materials in that context
- **Priorities in the Belgian national programme**
- Conclusions

ONDRAF/NIRAS 9

Priorities in the Belgian national programme: elements of context

- **In Belgium O/N is responsible, by law, of the management of the radioactive waste (& associated RD&D programme)**
  - ➔ RD&D on cementitious materials follows the chain of this management from treatment/conditioning to long-term storage & disposal, with the aim to develop **applicable solutions** for each step: strong focus on **applied science**
- **RD&D commensurate with programme stage**
  - **Cemented wastes**: existing / future
    - RD&D can be pro-active but sometimes must be reactive (e.g. "gelvaten")
  - **cAt**: towards licensing for construction
    - RD&D should address legitimate concerns of licensing authority & stakeholders
  - **B&C**: assuming geological disposal but **no decision-in-principle yet!**
    - More generic RD&D as some boundary conditions remain uncertain
    - SFC-1: from exploratory to increasingly targeted RD&D

ONDRAF/NIRAS 10

Priorities in the Belgian national programme: setting RD&D priorities

- **For each RD&D topic (question) under consideration, check**
  - **Urgency** (e.g. is answer required for current programme stage?)
  - **Impact** (e.g. could result strongly affect the programme, or can we accommodate any outcome by minor adaptations?)
  - **Effort** involved (e.g. can we do it ourselves, did others face the same issue, can we "design around" the issue?)
- **Make the best use of available programme resources**
  - We live in a small country, but the challenges we face in long term management of radioactive waste are not smaller
  - For R&D topics/issues that are less application-specific (e.g. structural performance, concrete pathologies,...), leverage expertise from others domains (e.g. civil engineering use of cementitious materials)
  - Seek return of experience from sister programmes (F, E, GB, CH...), European projects (currently CEBAMA, upcoming EJP)
- **Remain open-minded (look for the unexpected)**

ONDRAF/NIRAS 11

Priorities in the Belgian national programme: RD&D on cemented wastes

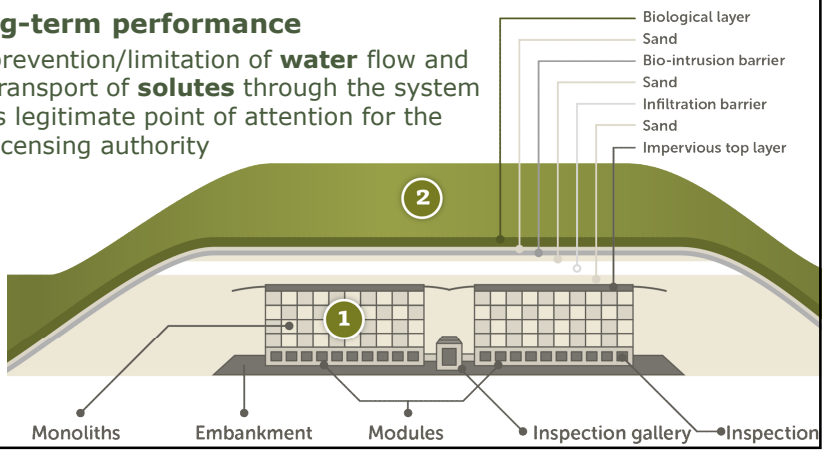
- **compatibility of cemented waste forms with disposal**
  - For **existing** cemented wastes
    - for **known problematic wastes**, characterisation efforts to understand involved processes → assess consequences → propose remediation measures (e.g. "gelvaten")
    - In gene sk studies + develop
  - For **future** e conditioning matrices (
    - E.g. co
    - Return

was

ONDRAF/NIRAS 12

Priorities in the Belgian national programme: cAt RD&D

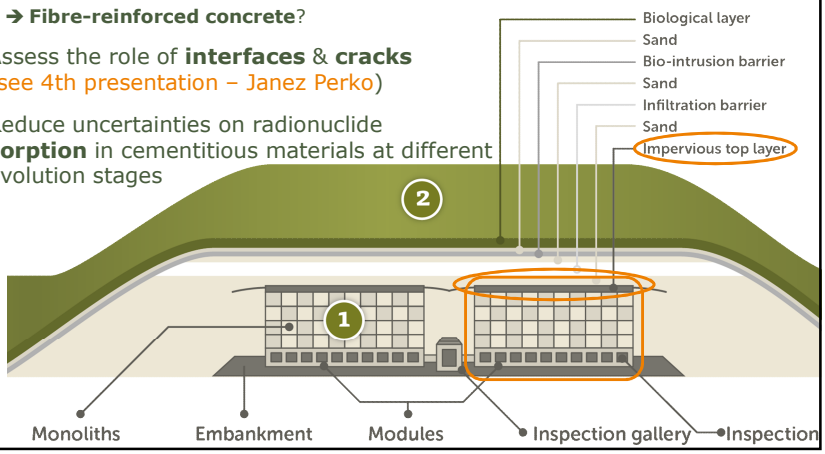
- **Nearing implementation → Engineering aspects**
  - Detailed engineering aspects
  - QA measures (towards: as built = as designed)
- **Long-term performance**
  - prevention/limitation of **water** flow and transport of **solutes** through the system is legitimate point of attention for the licensing authority



13 ONDRAF/NIRAS

Priorities in the Belgian national programme: cAt RD&D

- **Long-term performance, w.r.t. water and solute transport**
  - Finalize the development of the **Impervious Top Slab**
    - Mechanical resistance should be robust w.r.t. chemical degradation
    - Post-failure behaviour favouring diffuse rather than localized damage
    - → **Fibre-reinforced concrete**?
  - Assess the role of **interfaces** & **cracks** (see 4th presentation – Janez Perko)
  - Reduce uncertainties on radionuclide **sorption** in cementitious materials at different evolution stages



14 ONDRAF/NIRAS

Priorities in the Belgian national programme: RD&D on geological disposal (B&C wastes)

- **Preliminary repository design & costing exercise → Engineering aspects**
  - Structural elements (gallery lining): high performance concrete?
  - Choice of non-metallic fibres as reinforcement in concrete elements (e.g. in cat. B monoliths) to limit generation of gas from metal corrosion?
  - Backfilling mortars: flowability, strength to be limited for retrievability, QA aspects (e.g. homogeneous backfilling)
- **Thermo-hydro-mechanical and chemical (THMC) behaviour of the supercontainer for category C wastes**
  - "Short" term **structural** & **shielding** function
  - Long term **buffer** function

  } See next slides

ONDRAF/NIRAS 15

Priorities in the Belgian national programme: "short" term evolution of the supercontainer

- **Supercontainer for C-wastes (vitrified high level waste and spent fuel)**
  - Made on surface and to be **transported** into the repository
  - Provides **shielding** during the operational and retrievability phase

  - Can **structural integrity** be relied upon at least during operational and retrievability phase?

ONDRAF/NIRAS 16

Priorities in the Belgian national programme: "short" term evolution of the supercontainer

- **"Half-Scale Tests" (HST) programme**
  - Demonstrate feasibility of construction: 2 tests have been performed (HST-1, HST-2) of the construction of an (instrumented) buffer
- **Phase 1: hardening after casting**
  - Check temperature, deformations against model predictions
  - Verify absence of early-age thermal cracking
- **Phase 2: dummy waste canister insertion**
  - Casting of filler under thermal load
  - Check temperature, deformations against model predictions
  - Assess risk of cracking under thermal load
- **Phase 3: cooling**
  - Verify absence of Delayed Ettringite Formation (see presentation 1) after high temperature excursion

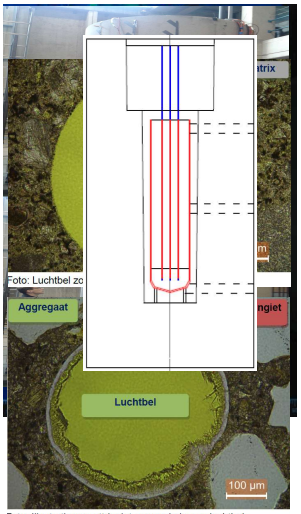
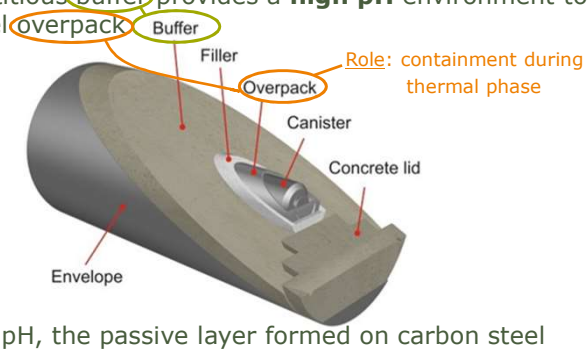


Foto: Illustratie van ettringiet aanwezig in een luchtbel.

ONDRAF/NIRAS 17

Priorities in the Belgian national programme: long term evolution of the supercontainer

- **Contained environment concept**
  - The cementitious buffer provides a **high pH** environment to the carbon steel overpack



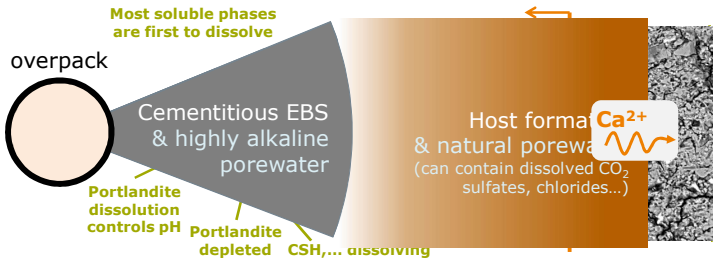
  - Under high pH, the passive layer formed on carbon steel ensures **uniform corrosion** with **very low corrosion rates**

➔ **how long** can the cementitious buffer ensure the high pH conditions at the buffer/overpack interface?

ONDRAF/NIRAS 18

Priorities in the Belgian national programme: long term evolution of the supercontainer

- **Time scales involved → stepwise approach to bound the evolution, by modelling**
  - **Ca-leaching** (as in presentation 3), but **diffusion**-controlled



ONDRAF/NIRAS

19

Priorities in the Belgian national programme: long term evolution of the supercontainer

- **Example of Ca-leaching model results (Diffu-Ca model, CEA)**
  - Model with simplified chemistry
    - Except for time, distance, all parameters are expressed as functions of the concentration of calcium in solution
  - Provides profiles of calcium in solution and solid, flux of leached calcium, pH, porosity and diffusion coefficient

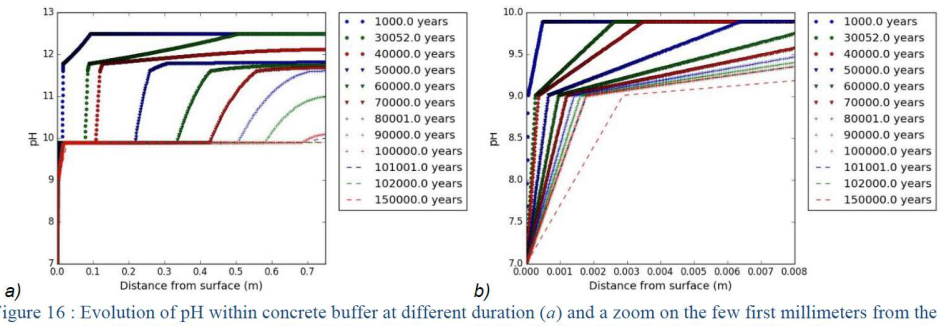
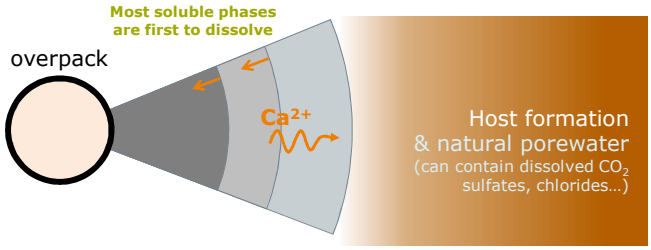


Figure 16 : Evolution of pH within concrete buffer at different duration (*a*) and a zoom on the few first millimeters from the interface between aggressive solution and concrete buffer (*b*) for a discretization with 1000 meshes.

20

Priorities in the Belgian national programme: long term evolution of the supercontainer

- **Time scales involved → stepwise approach to bound the evolution, by modelling**
  - **Ca-leaching** (as in presentation 3), but **diffusion**-controlled



- Carbonation: what happens at the interfaces? (→CEBAMA)
- Effect of sulfates,… on buffer? (→resistance to chemical attacks?)
- What if the porosity is heterogeneous (cracks)?

→ With more "realism" come more parameters & associated uncertainties!

ONDRAF/NIRAS 21

RD&D priorities on cement within the Belgian national programme

- Cementitious materials in the long term management of radioactive waste
- Research, Development and Demonstration (RD&D) on cementitious materials in that context
- Priorities in the Belgian national programme
- **Conclusions**

ONDRAF/NIRAS 22

Conclusions

- **Cementitious materials are ubiquitous in long term management of radioactive wastes**
- **As uses are multiple, possible RD&D topics abound**
- **R&D priorities strongly linked to programme stage and boundary conditions**
  - Focus first on application specific, urgent & potentially high impact topics (for the latter, compare to potential cost of non-R&D in terms of later design change)
  - Leverage generic expertise from "classical" uses of cementitious materials + benefit from return of expertise from sister programmes
  - Some level of long-term, more fundamental research is desirable in a spirit of confidence building, evaluation of performance reserves and openness for the unexpected

ONDRAF/NIRAS 23

Conclusions

- **Current priorities for ONDRAF:**
  - compatibility of **cemented waste forms** with disposal
    - Screening for problematic behaviour, characterisation efforts
    - Formulations of waste immobilization matrices
    - Strong link with waste acceptance process, criteria
  - For **cAt**,
    - Impervious top slab development
    - Role of discontinuities in flow and transport through modules
    - Reduce uncertainties on radionuclide sorption in cementitious materials at different evolution stages
  - For **deep disposal**, focus is on performance of supercontainer
    - THM evolution of the buffer: can structural integrity be relied upon at least during operational and retrievability phase?
    - Long term chemical evolution of the buffer, starting with Ca-leaching: how long could high pH conditions prevail at the overpack?
    - Other long-term processes that could affect the role of the buffer

ONDRAF/NIRAS 24

Thank you for your attention

- **Questions?**

- **Thanks to colleagues S. Ben Hadj Hassine, W. Wacquier, S. Brassinnes, D. Léonard, H. Van Baelen and R. Gens for valuable input to this presentation**

ONDRAF/NIRAS

25