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The Belgian supercontainer concept

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Outline

- **The SAFIR 2 concept**
  - Description
  - Outcomes of the formal safety assessment
- **Re-evaluation of the concept through multi-criteria analysis**
- **The current reference design: the supercontainer**
- **The impact of the supercontainer design on LT safety**
- **Thermal impact issues**
- **Conclusions**

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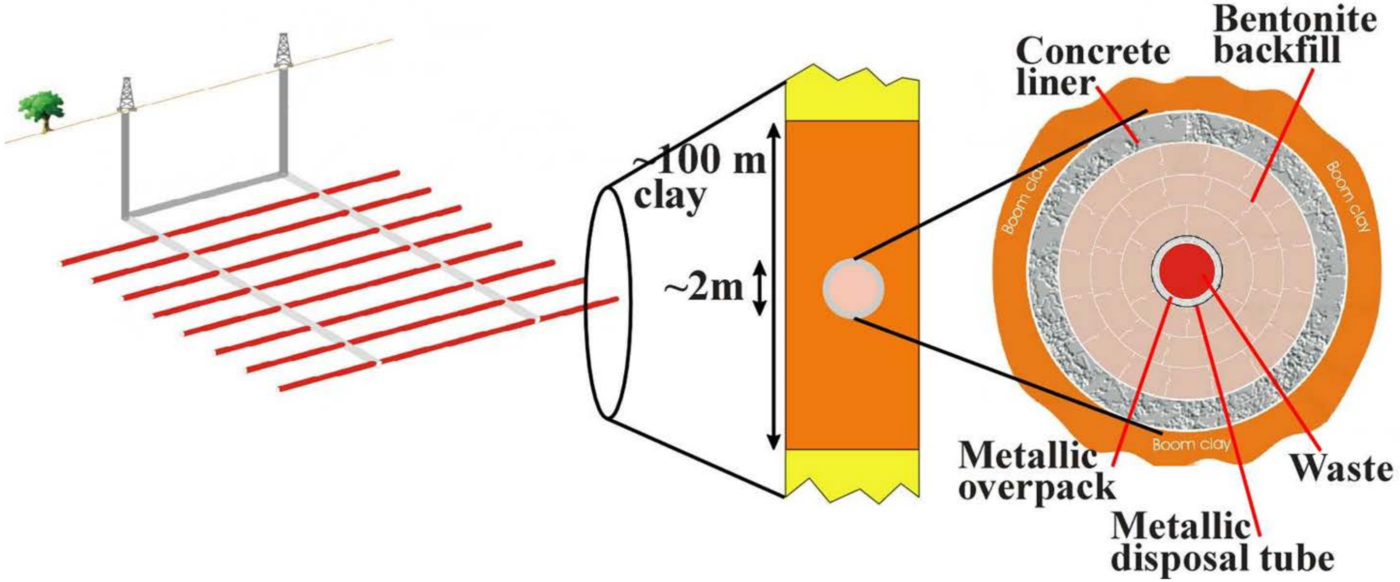
The SAFIR 2 (2001) reference concept

- Galleries in the mid-plane of the Boom Clay at about 240 m depth
- Over pack of 3 cm stainless steel
- Placed into a disposal tube of 1cm stainless steel
- Centred with bentonite blocks in the disposal gallery
- Due to limited strength of Boom Clay, gallery is lined with concrete blocks and swelling pressure of bentonite should be rather limited



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Outcomes of SAFIR 2

Based on the assessment and its international peer review

- **Geological disposal in the Boom Clay is promising**
- In the reference evolution scenario and most altered evolution scenarios, **the Boom Clay is the major contributor to overall safety**

- **The feasibility and especially operational safety were not very clear**, if not questionable
- The **EBS behaviour was rather complex** and with the **remaining uncertainties on near field evolution** it would be **difficult to guarantee full containment during the thermal phase**

Re-evaluation of the reference concept

- **In line with the safety strategy, re-evaluate the concept, based on the outcomes of the previous formal assessment**

- **Approach**
  - Structured step-by-step approach, with justification of the key decisions taken, based on awareness of the consequences
  - Multi-disciplinary task force, spanning different organisations from research and industry
  - Consultation of internationally recognised experts (e.g. corrosion panel)

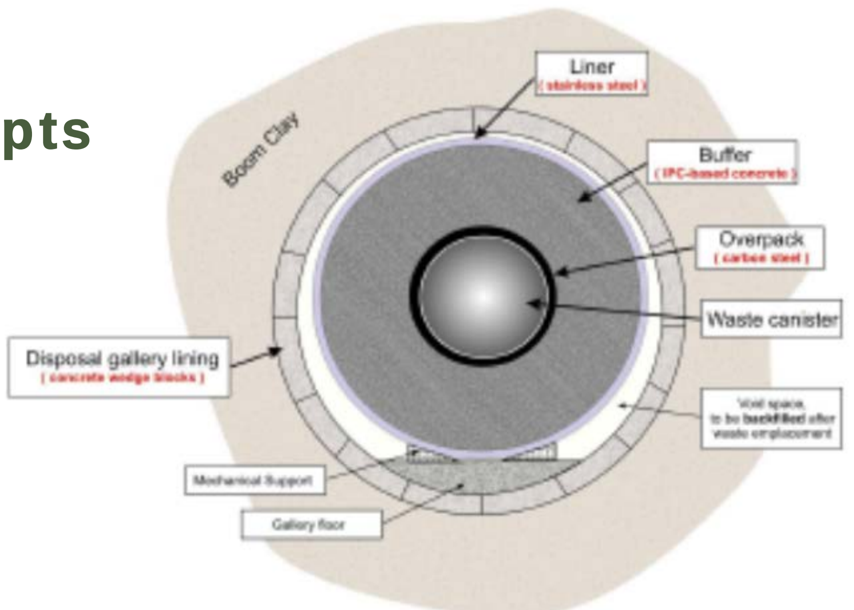
Alternative concepts and variants

- **Common aspects to all concepts**
  - Metallic over pack → emphasis on water tightness during the thermal phase
  - Overall repository configuration with (minimum) 2 shafts (redundant escape), main galleries connecting the shafts, a number of disposal galleries (perpendicular to the main galleries)

- **Three basic disposal concepts**

  1. Supercontainer

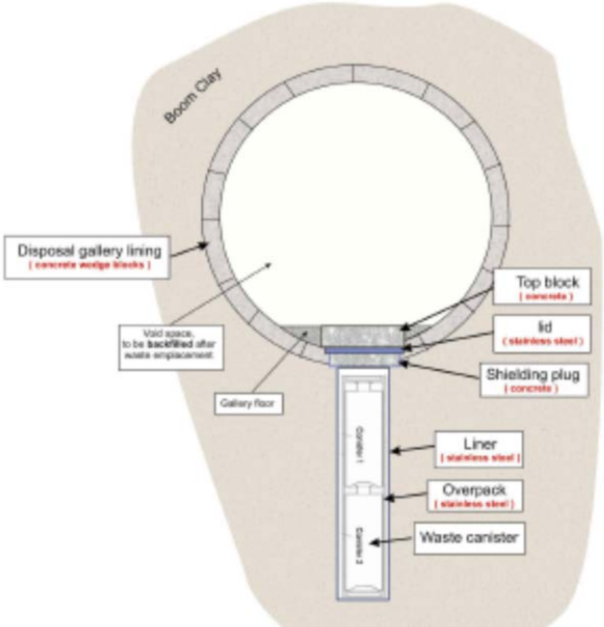
  Overpack is emplaced in the disposal gallery together with its enveloping radio-shielding buffer



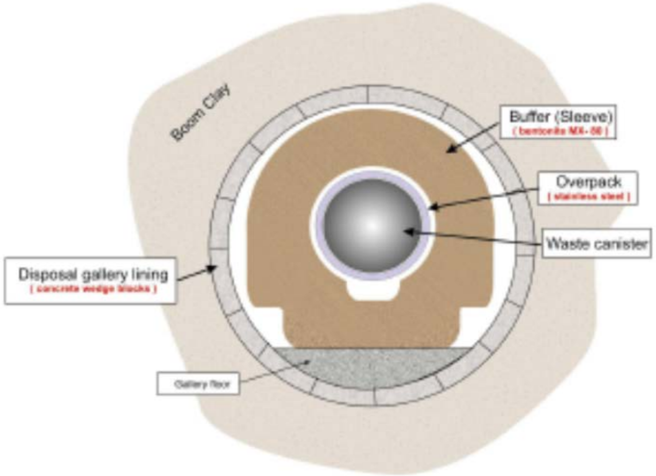
Alternative concepts and variants

- **Three basic disposal concepts**

2. **Borehole:** overpack is emplaced in a borehole perpendicular to the disposal gallery (transportation/ handling needs to be shielded)



3. **Sleeve:** overpack is emplaced in a « sleeve », which is emplaced in the disposal gallery prior to the overpack (transporation/handling needs to be shielded)



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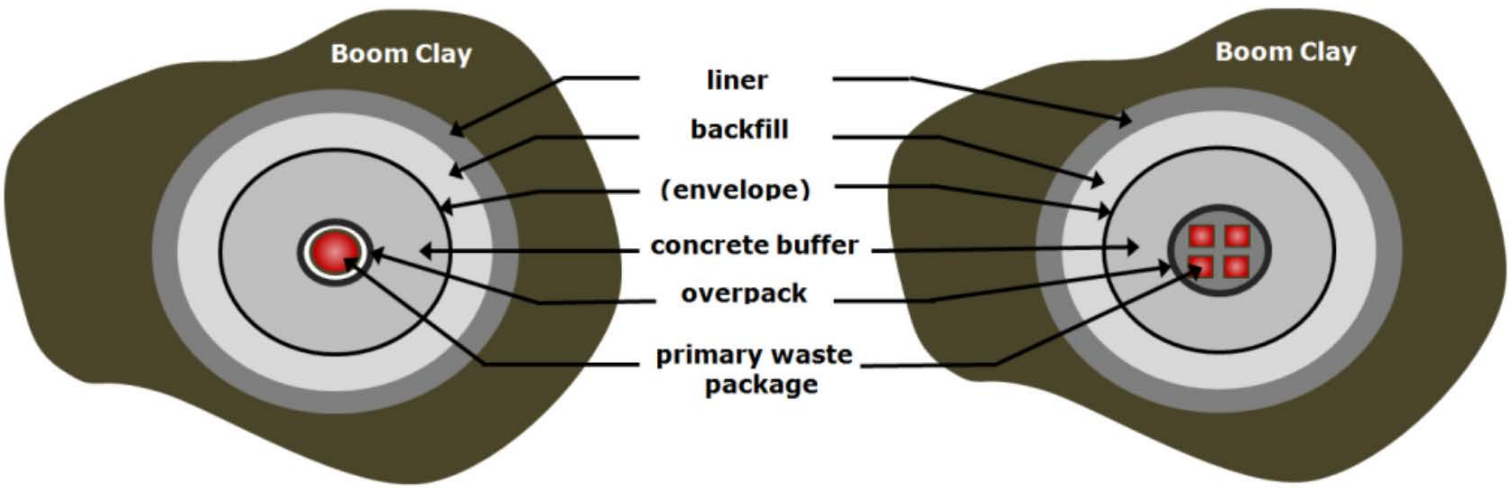
Selection of a new reference concept in 2003
Result of a multi-criteria analysis

- **Key rationale for selection of the supercontainer design**
  - The requirement for a **watertight containment** of the waste during a predefined time, which means a design focussed on the control of the corrosion of the overpack
  - The **ability to characterize and to model phenomena** (especially in the buffer); concrete is an industrial product, whereas bentonite is a natural product



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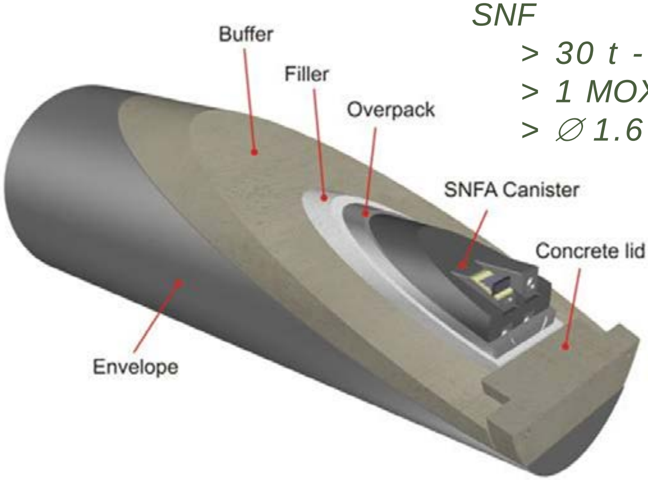
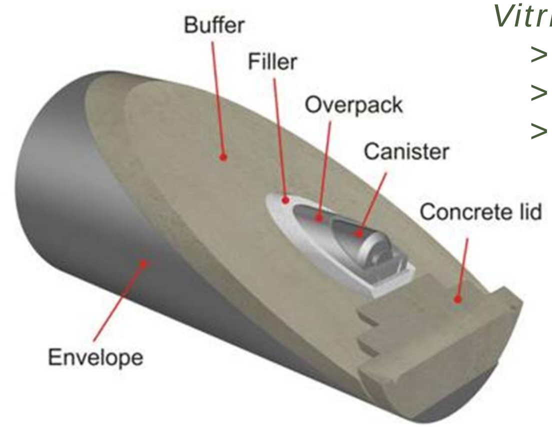
Selection of a new reference concept in 2003
Result of a multi-criteria analysis

- **Strengths & opportunities of the supercontainer design**
  - Construction of EBS on surface guarantees better Quality Assurance
  - Permanent shielding of workers (no absolute need for underground remote controlled transfers of waste packages)
    - Allows separation of conventional mining and nuclear operations
  - Use of well known, cost effective and available materials
  - Broad acceptance basis: the concept is the result of discussions within an integrated and multidisciplinary working group, assisted by experts



SNF
> 30 t - 70 t
> 1 MOX - 4 UOX
> ∅ 1.6 - 2.1 m x 4.3 - 6.2 m



Vitrified waste
> 32 t
> 2 CSD-V
> ∅ 2m x 4m

Current reference design: supercontainer with OPC

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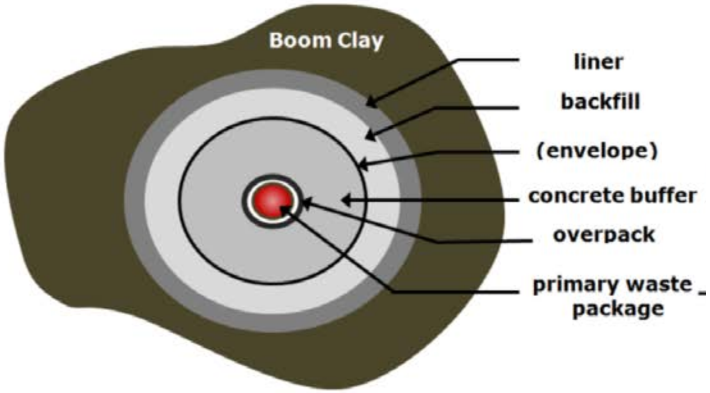

	Overpack
Functions	**Long-Term Safety** Prevent water in contact with waste during at least thermal phase
Main Requirements	▪ Good predictability of corrosion rate ▪ Resistance to local corrosion
Considered Material	30 mm thick Carbon Steel

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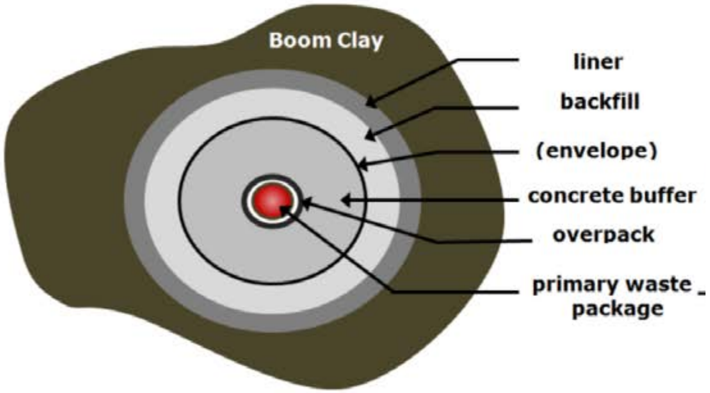
Current reference design: supercontainer with OPC

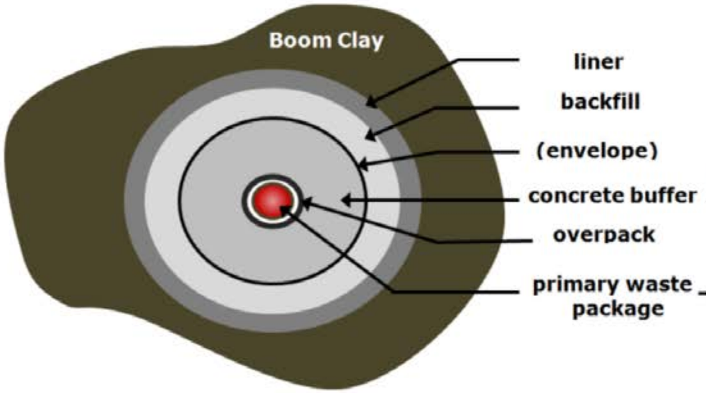


	Concrete Buffer
Functions	**Long-Term Safety** Provide favorable chemical environment to delay overpack degradation (High pH) **Operational Safety** Provide shielding for workers (25µSv/h at 1 m)

Main Requirements	▪ Chemical restrictions:
	  ▪ OPC CEM I to limit corrosive species and maintain a high pH
	  ▪ Limestone ($CaCO_3$) aggregates and filler to prevent ASR (Alkali-Silica Reaction)
	▪ Sufficient Tensile & Compressive strengths to avoid through-going cracks during fabrication and Operation
	▪ Good workability: Fluidity (Pumpable) and Stability (prevent segregation)

Considered Material	SCC (Self-Compacting Concrete) → Highly-fluid concrete - no need for vibration

Current reference design: supercontainer with OPC



	Enveloppe
Functions	**Long-Term Safety** Delay ingress of aggressive species from the poorly indurated clay (such as Chlorides, Thiosulphates, Sulphides) **Feasibility roles** ▪ Serves as a mould to allow the pouring of the buffer concrete ▪ Provides mechanical strength and confinement during transportation and handling ▪ Facilitates retrievability
Main Requirements	
Considered Material	6 mm thick Stainless Steel

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Impact of the new design on safety assessment

- **Containment**
  - Well constrained boundary conditions for corrosion to better underpin overpack integrity during thermal phase (several hundred to thousand of years)
    - IF high pH is maintained (expected ~100,000y in Boom Clay)

    → uniform corrosion occurs in absence of aggressive species

- **Limited RN release from waste form**
  - Limited consequences of chemical near field environment on RN release from waste form compared to other concepts
    - Release from vitrified waste is faster compared to previous concept, BUT strategic choice not to rely too much on this safety function (minor impact on overall safety of the system, at least for vitrified HLW)
    - For spent fuel there is no noticeable difference expected in the rate of contaminant releases from the waste form for similar anaerobic conditions

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Impact of the new design on safety assessment

- **Delay and attenuate releases by solubility limit & sorption**
  - Near Field
    - Prevailing pH/(Eh) conditions of supercontainer design allows comparable (or an order of magnitude higher) solubility for fission products and for actinides
    - Prevailing conditions need to be considered on sorption capacity
      - Concrete often used as barrier in near surface disposal and for medium-level long-lived waste → Transferability of data?

    → *Limited quantity of RN in solution thanks to high pH of concrete*

  - Far Field
    - No changes for both solubility limit & sorption compared to other concepts
      - IF extent of disturbed zone not too large → mainly alkaline plume

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Thermal impact issues: Thermal design of the supercontainer

- **Over pack temperature limited to 100° C for corrosion issues**
- **Fabrication aspects:**
  - Temperature increase due to concrete hydration (T_{max} ~60° C)
  - Once over pack is inserted: C-waste heat production

    Half Scale Test → gradients of temperature above the admissible limit to avoid cracking = formation of cracks in the concrete buffer

Main role of supercontainer = chemical buffer

- **A priori negligible negative impact on its safety functions (chemical barrier)**
- **However, on-going dedicated research programme to limit cracks and to better specify concrete properties**

Conclusions on Belgian supercontainer concept

- **It is believed that the safety concept has been reinforced as this supercontainer design should provide**
  - Permanent shielding during operational phase
  - Facilitated quality control
  - Adequately understood engineered containment during the thermal phase
- **Moreover, this design**
  - Is based on proven technologies and widely available, affordable materials
  - Has negligible negative impact on the safety functions provided by the most important barrier, the clayey host rock
  - May provide complementary sorption with respect to the clay host rock for radionuclides that are mobile in clay.

Conclusions on Belgian supercontainer concept

- **It should be kept in mind that concrete is difficult to avoid in plastic clay (e.g. as gallery lining)**

- **Use of high pH concrete in this context is fairly new**
  - Many aspects look very promising
  - Different aspects need to be scrutinised and results need to be confirmed

- **Thermal impact**
  - Potential formation of cracks in the concrete buffer with *a priori* negligible negative impact on its safety functions (chemical barrier)
  - Still need to be investigated

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Thanks for your attention

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