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Practical and safe implementation of disposal with prefabricated EBS modules

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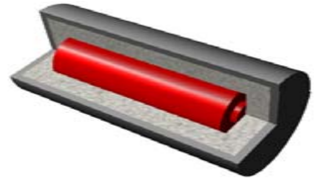
Problem definition

- Disposal concepts for HLW & SF commonly employ a backfill / buffer of highly compacted bentonite
- Compacted bentonite is a key component of the EBS, with many barrier roles contributing to the safety case
- In order to assure that such bentonite will perform as required, it must be emplaced to very strict quality standards
- Experiments in URLs have shown that, although emplacement of bentonite as blocks, monoliths or pellets is possible, it is not practical on an industrial scale under expected repository conditions in a “wet” rock
- Operational constraints will be even more limiting if operations have to be carried out using tele-handling technology or if ease of retrieval in case of operational perturbations has to be shown

Advantages of prefabricated EBS modules (PEMs)

- Many practical problems with handling bentonite can be minimised by use of prefabricated modules
- Extensive conceptual work on such options has been ongoing for more than a decade
- Apart from bentonite handling, such modules have many practical advantages from the point of view of operational safety and logistics and are well suited to remote handling
- Considerations of optimisation have, however, focused on post-closure safety: open is how designs can be optimised with regard to operations

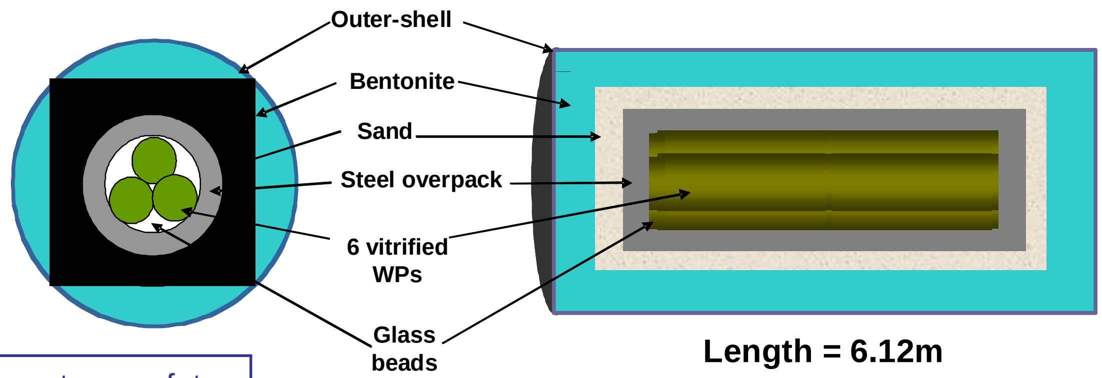
IWP
(Integrated Waste Package)



MCM
(Multi-Component Module)

Key characteristics of reference PEM design

- Large PEM containing vitrified waste, a thick steel overpack and a bentonite-based backfill (SF designs also possible)
- Steel handling shell which maintains its integrity during emplacement and has a probable containment lifetime in the order of decades to centuries
- Multiple waste package overpack; in the reference case, 6 vitrified waste canisters are assumed to be contained within each overpack



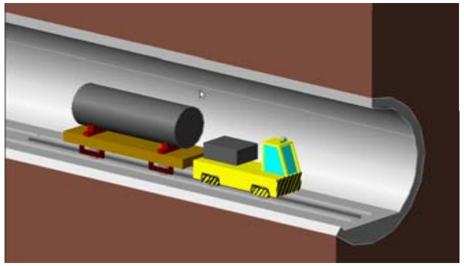
Length = 6.12m
Diameter = 2.38m
Weight = 34.0t

PEM design optimisation for long-term safety discussed in J. Geochem. Explor., **90**, 1-8,

PEM emplacement outline

- Rail transportation and emplacement system in which the PEM is moved and emplaced within a supporting steel cradle
- Horizontal emplacement in relatively short (100 – 200m), large diameter (ca 3.5m) tunnels; large clearance simplifies handling and makes recovery from any perturbations relatively easy
- Tele-operated emplacement occurs in intensive work blocks; because of the simplicity of operations, a tunnel can be filled within a short time and can then be immediately backfilled after temporary seals are set in place. If required, the decision to emplace permanent seals can be postponed
- Sequence of filling tunnels within a panel can be selected to minimise peak thermal loading
- The choice of backfilling material depends on the host rock and setting; the key differences being for cases with self-supporting rock and for those where tunnel lining is required

Original simple operational concept

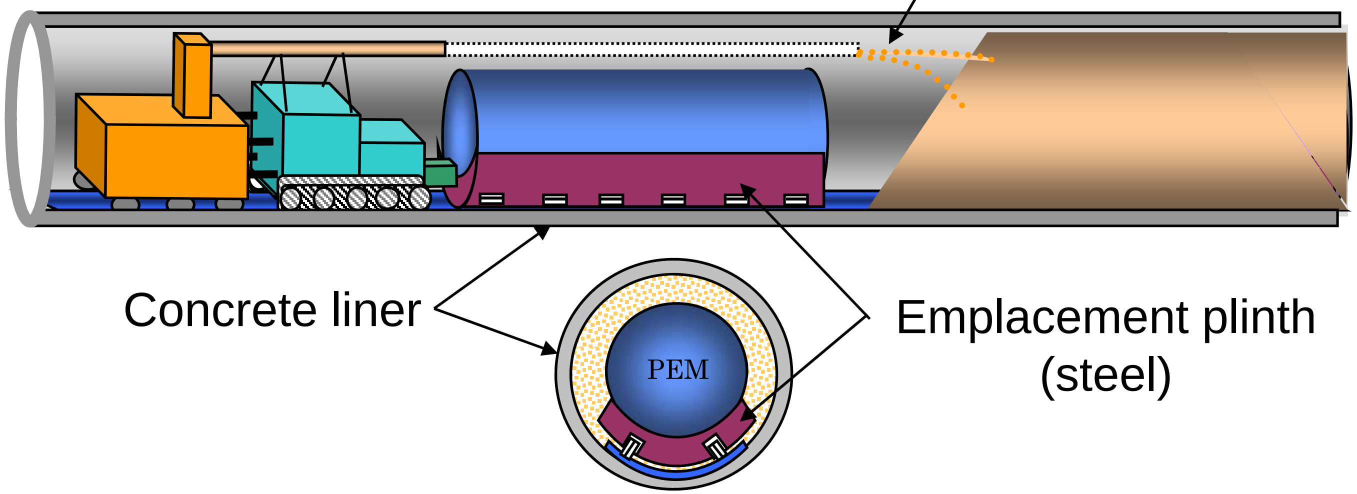


Transport in access tunnel

Integrated disposal tunnel emplacement (pushing) and backfilling module

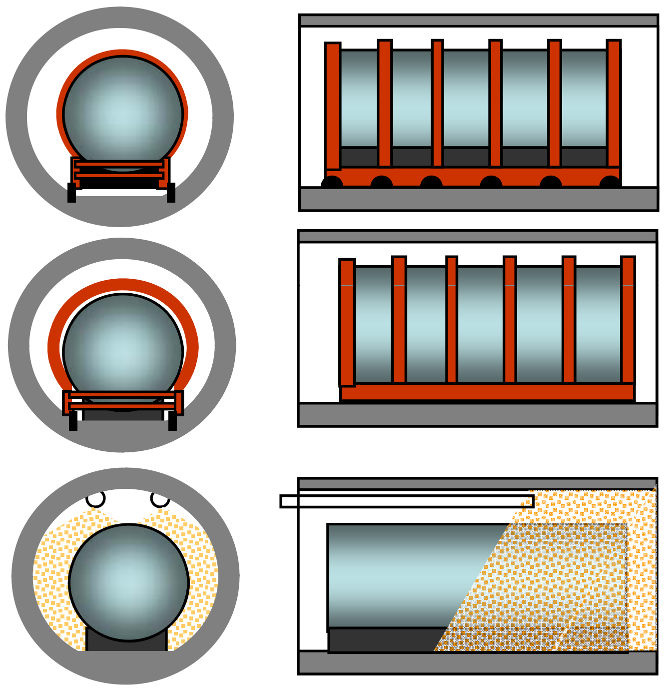
Rail based system eases tele-operation

3 Backfill options:
- crushed rock
- bentonite pellets
- crushed tuff (volcanic glass)



Optimising operational procedures (1)

- Assuring safe transportation of large, heavy PEMs
  - – robust rail transport system
  - – use of supporting cradle:
    - base left in place, upper cradle removed (reference)
    - entire support cradle left in place (alternative option)



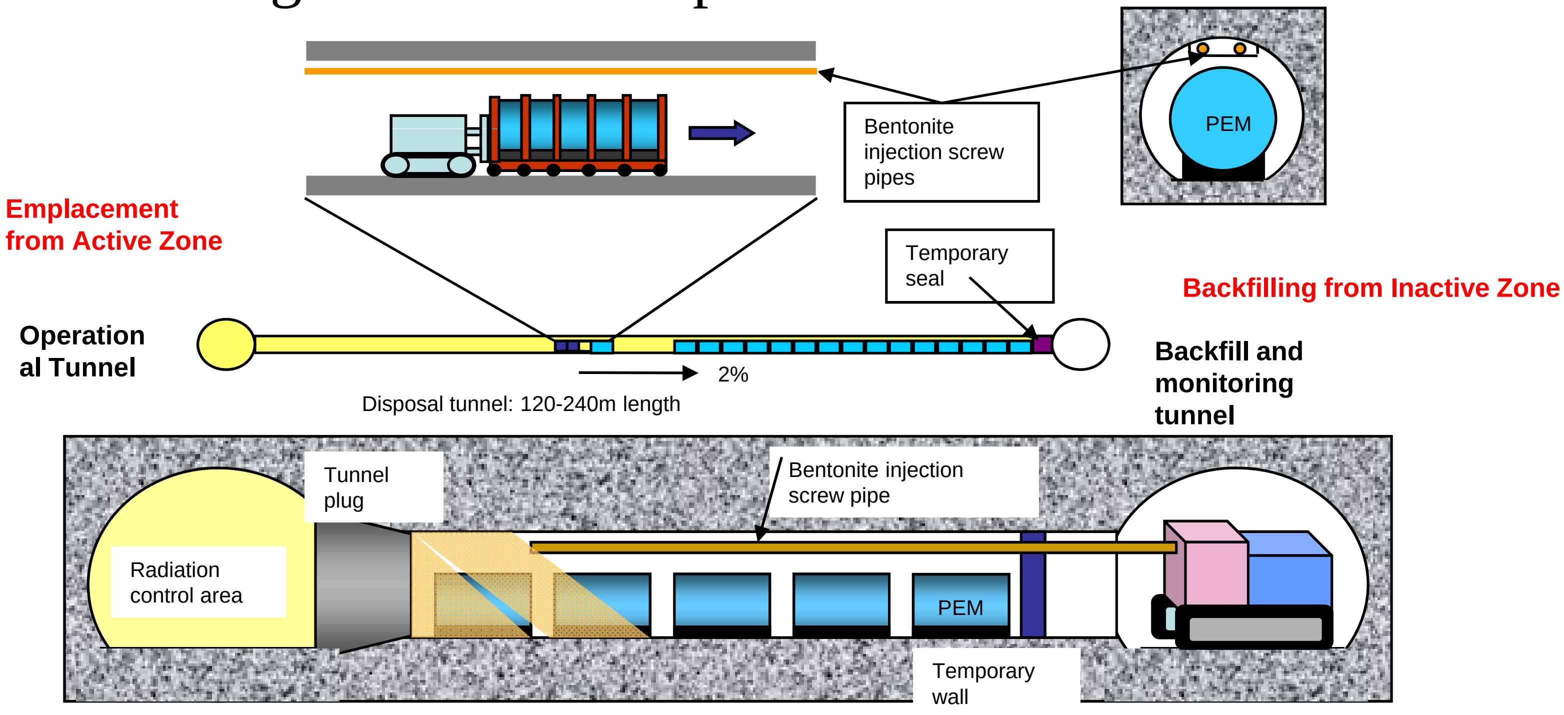
a. Transportation in disposal tunnel

b. Unloading PEM at emplacement location

c. Backfilling space in disposal tunnel

Optimising operational procedures (2)

- PEM emplacement can proceed rapidly; if required several PEMs can be emplaced as a train in a single operation
- PEMs are relatively insensitive to tunnel humidity and tunnel can be completely filled before backfilling is carried out as a single continuous operation



Selecting backfill

- Roles:
  1. filling void space (essential)
  2. acting as a chemical buffer (if concrete liner)
  3. improving performance of main EBS
     a) low permeability
     b) high permeability
- Options examined
  – bentonite (granular or pellets) - 1, (2), 3a
  – crushed rock / sand - 1, (2), 3b
  – crushed tuff / volcanic glass - 1, 2, 3b

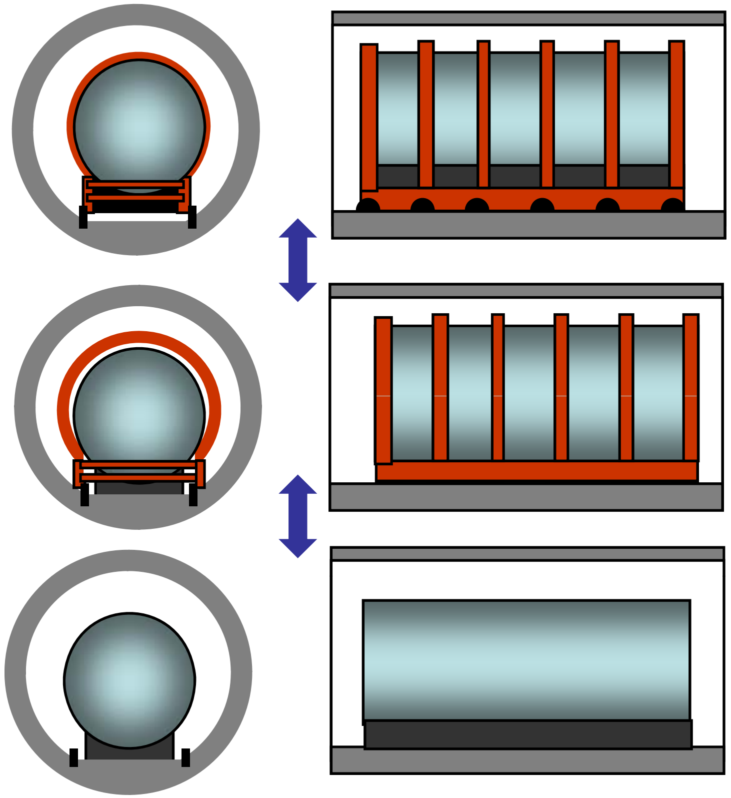
Robustness to perturbations (1)

The PEM design has three main attributes that contribute to overall robustness of operational performance:

- simplicity of the rail-based emplacement process, ideally suited to tele-operation, can be strictly monitored and can be designed to reduce risks of perturbations
- very high emplacement rate; reduces time pressure and ensures that minor divergences from operational specifications can be investigated and remediated without concern about throughput
- large clearances in emplacement tunnels and self-shielding properties of PEM – easing recovery from any unlikely perturbation (e.g. derailment, mechanical failure of trolley / emplacement cradle, etc.).

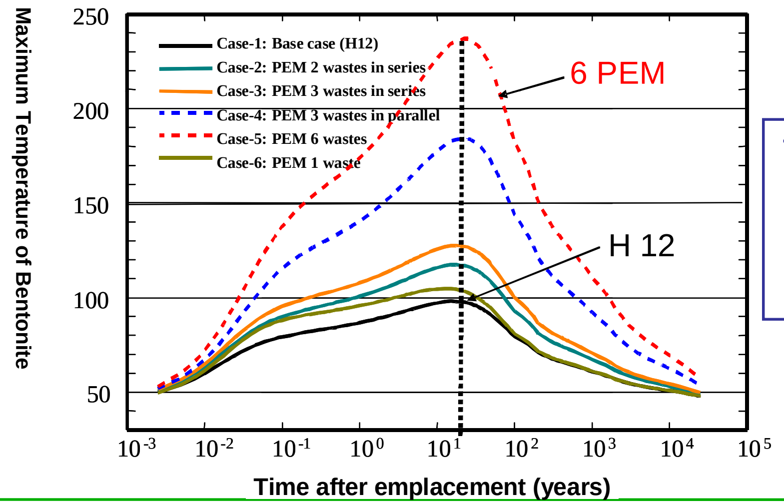
Robustness to perturbations (2)

- Individual emplacement steps are fully reversible with the tele-operated equipment used
- Even in case of perturbation, large clearance greatly aids recovery, e.g. in case of
  - derailment
  - mechanical failure of transport trolley components
  - toppling of PEM from plinth (e.g. as a result of earthquake)
- Concepts for recovery equipment not yet firmed up in designs



Optimising layout - thermal aspects

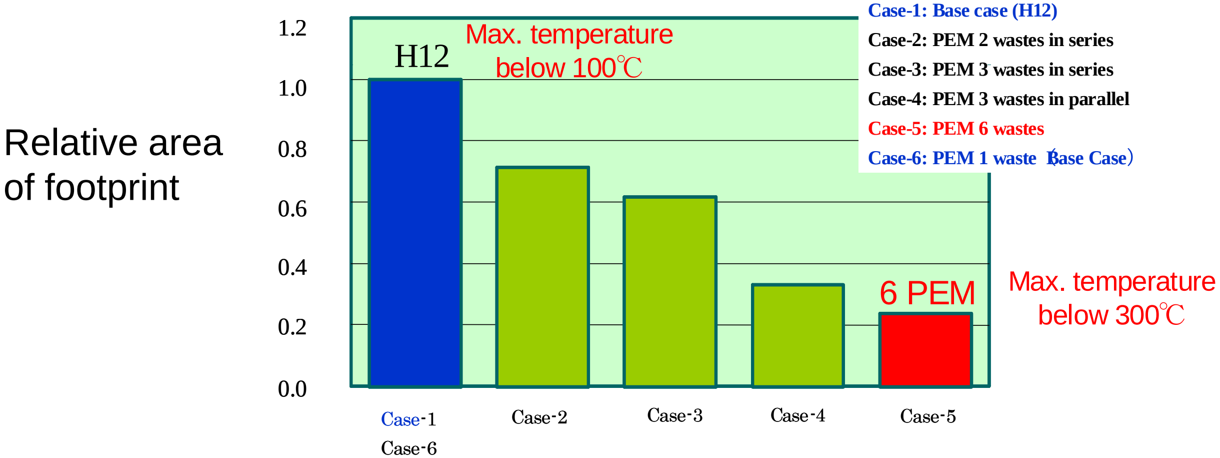
- Multiple waste package PEMs are very efficient but can result in rather high peak temperatures
- Peak temperatures influenced by emplacement density but, in all cases, relatively short-lived (decades - hundreds of years) and may lie within lifetime of handling shell
- Concerns about bentonite stability reduced by balancing layout (PEM and tunnel pitch) with operational procedures (sequence of tunnel filling) and design (shell lifetime)



Temperature profiles for various PEM loadings (number of waste packages, geometry); peak temperatures can be reduced by increasing PEM seperation

Other aspects influencing design / layout

- High emplacement density and insensitivity to moisture allows footprint to be reduced significantly (may reduce costs in some cases)
- Total volume of rock broken out and volumes of buffer / backfill significantly reduced compared to conventional designs
- Main concerns for soft rock - cost / practicality of the larger diameter tunnels considered



Conclusions and a look to the future

- As repository projects move closer to implementation, operational aspects must receive much more attention; early designs were suitable for proof of post-closure safety, but not optimised for many key operational concerns
- PEMs offer many operational advantages, particularly for concepts requiring strict QA of compacted bentonite; even more so if remote handled in a wet rock
- Operational analysis indicates that PEM emplacement operations are relatively simple and robust in case of perturbations
- Future work should concentrate on specific sites and consider open questions - especially for soft rock.