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Bentonite engineered barrier mechanical evolution effects on the long-term performance of the barrier
BEACON

Patrik Sellin

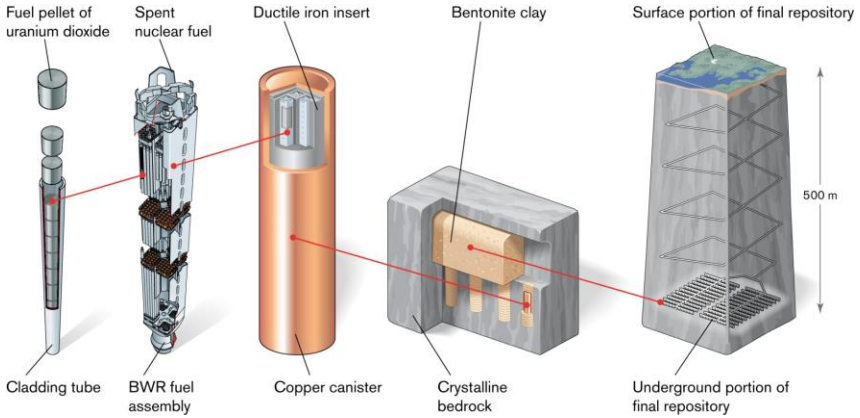
Long term disposal of high level radioactive waste

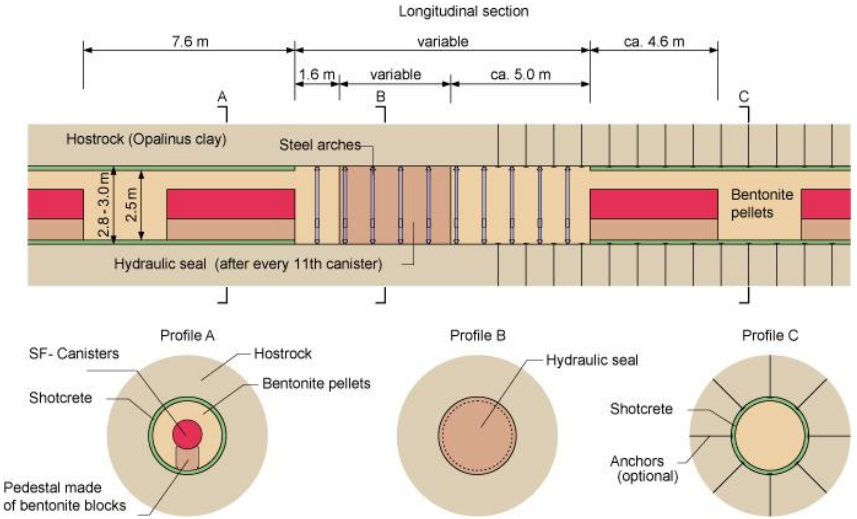
- International consensus has emerged that deep geological disposal on land is the most appropriate means for isolating such wastes permanently from man's environment
- Independent and often redundant barriers
  - to the movement of radionuclides
- These barriers generally include:
  - the leach-resistant waste form itself
  - corrosion-resistant containers into which the wastes are encapsulated,
  - special radionuclides- and groundwater-retarding material placed around the waste containers, commonly referred to as backfill,
  - the geological formation itself

Bentonite backfill, buffer and seals

- Diffusional Barrier:
  - Low Hydraulic conductivity $D_e/\Delta L > Ki$
- Maintained Thickness
- Self-sealing Ability
- Physical and Chemical Long-term Stability
- Minimize microbial activity
- Colloid filter

Disposal concepts



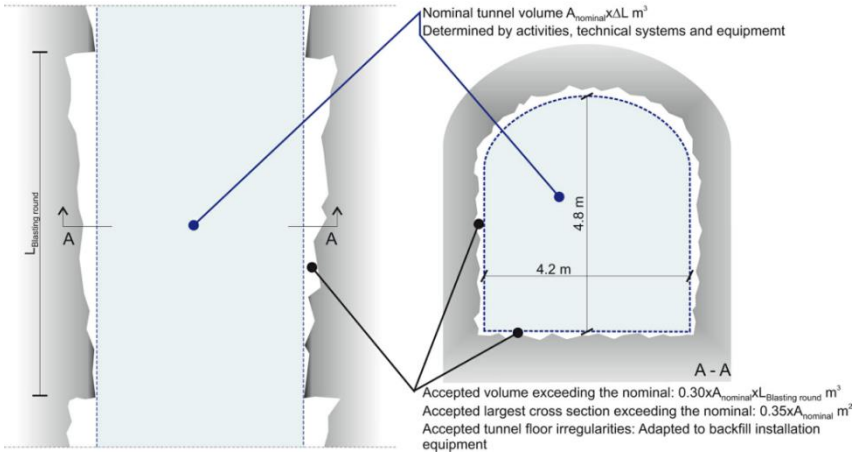


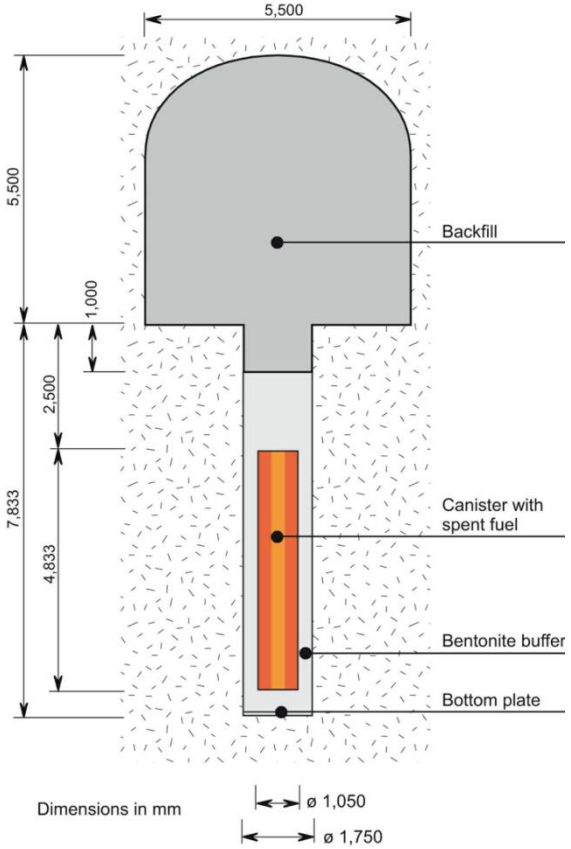
Why Mechanics?

Background

- Gaps, holes or inhomogeneous density distributions may prevail in the buffer or backfill material by several causes:
  - Very heterogeneous initial conditions caused by installation technique
    - Blocks with gaps between them
    - Gaps filled with pellets
    - Mechanical interaction
      - buffer/backfill
      - Backfill/plug
      - etc
  - Bentonite in a deposition hole or a backfilled tunnel may be lost
    - by piping and erosion during the installation and saturation phases
    - by colloid erosion during glacial groundwater conditions
- How well can the bentonite self-seal and homogenise these anomalies?
- Development, calibration and verification of material models and modelling techniques!

Optimistic approach!



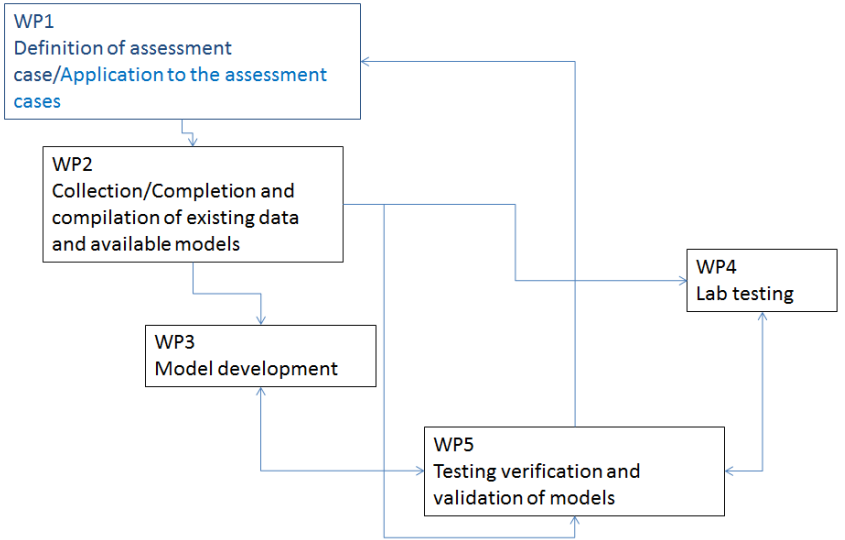


Key issues

- Can we justify the ”average dry density” approach?
  - Pellets, voids and blocks
  - Complex geometry
- Expansion of bentonite out of the deposition hole
- Mass loss
  - Erosion
  - Installation failures

BEACON

- Part of HORIZON2020
- Running 2017-2021
- Objectives:
  - To develop and test the tools necessary for the assessment of the mechanical evolution of an installed bentonite barrier
    - and the resulting performance of the barrier
  - To verify the performance of current designs for buffers, backfills, seals and plugs.
  - Beacon is focused on the direct application to real assessment cases in actual repository systems
    - cases from relevant repository systems have been selected as test examples



25 partners – 10 countries

SURAO	Czech Republic
Posiva	Finland
Andra	France
Nagra	Switzerland
ENRESA	Spain
RWM	United Kingdom
MKG	Sweden
UPC	Spain
GRS	Germany
CTU	Czech Republic
CUNI	Czech Republic
CEA	France
VTT	Finland
ULg	Belgium
BGR	Germany
KIT INE	Germany
LEI	Lithuania
CIEMAT	Spain
Clay	Sweden
EPFL	Switzerland
ICL	United Kingdom
Quintessa	United Kingdom
NERC/BGS	United Kingdom
JYU	Finland
SKB (Coordinator)	Sweden

Aim of Work Package 1

- In the framework of WP1, the needs of safety assessment regarding the evaluation of nonhomogeneous backfill properties are addressed, in particular to what extent non-homogeneous material property distributions comply with safety requirements.
- The WP1 report was compiled with the answers to a questionnaire that was distributed to the different WMOs or their representatives.
- The questionnaire aimed at reflecting the state-of-the-art regarding the treatment of heterogeneous bentonite density distribution and properties in the safety case.
- Based on the outcome of the assessment cases and the evaluation method and uncertainties, the end-user may formulate design-specific requirements that can be used for the safety case in a final workshop

WP1 Report:

- The questionnaire consisted of three different parts:
  1. Application of bentonite in the specific design
  2. The required performance of bentonite
  3. Detailed characterization of the required properties of the bentonite

Work Package 2:

- Three tasks:
  - **Task 2.1 Workshop** to present and discuss relevant national and international extant information relating to bentonite mechanical evolution. (M1)
  - **Task 2.2 Identification of relevant data/models**, improvement of understanding of main processes associated to bentonite component evolution taking into account possible heterogeneities. This acts as a source of information on which to base subsequent project WP3 and WP5 activities. The task generated a report, D2.1. (M1-M6)
  - **Task 2.3 Identification of captured knowledge** (M6-M46)

WP2 Database

- Designed a data form to collect appropriate information;
- Requested that Beacon partners fill out the data form for any studies they feel could be relevant to Beacon;
- Collated the completed data forms into a preliminary database;
- Discussed the database at a workshop and defined additional fields that would aid future selection of experiments for study within Beacon;
- Requested additional information to complete additional fields in database;
- Finalised the database.

- Information was received in different formats:
  - Almost 70 completed data forms;
  - abstracts to the Beacon kick-off meeting in Lithuania, June 2017;
  - a list of experiments on bentonite previously compiled by Andra;
  - a brief literature review covering a number of experimental studies.
- Where sufficient information was available, new data forms were created from this additional information.
- For some experiments, however, little information other than the name of the experiment was found to be readily available.

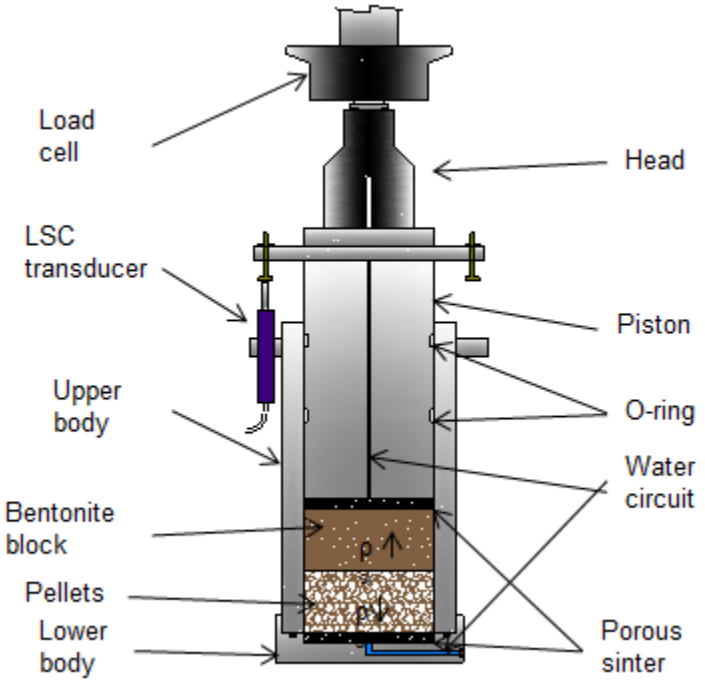
Features of WP3

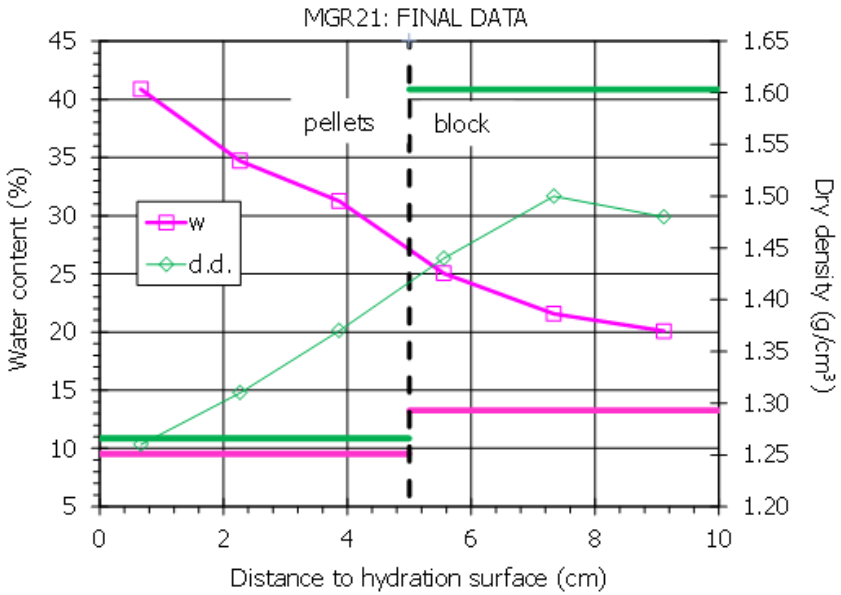
- Focus on the mechanical constitutive model because the state of the barrier at the end of the transient period is dependent on the mechanical evolution of the bentonite
  - Issues of irreversibility stress path dependency and long term deformation are critical
  - This focus on mechanical behavior is in contrast with previous projects where thermal and hydraulic behavior were the primary focus
- The following cases should in principle be considered:
  - Saturated and unsaturated material (wide range of densities)
  - Compacted (blocks) bentonite and pellet-based materials
  - Isothermal and non-isothermal conditions
- Implementation into computer codes capable of performing coupled HM and THM analyses.
  - Additional developments (gaps, large displacements) may be required

Objectives of WP4 – Laboratory Testing

- Provide input data and parameters for development and validation of models
- Reduce uncertainties about conditions and phenomena influencing bentonite homogenisation

WP4 Examples





Strategy for verification and validation of models/Structure of WP5

- Tests cases with different objectives and degrees of complexity
  - Verification/validations cases
    - Tests with simple physic
    - Tests with coupled processes

  Task 5.1 - Very well instrumented lab tests

  - Large scale experiments
    - complex geometry
    - coupled processes
    - Uncertainties on boundary and initial conditions

  Task 5.2 - Experiments well described, dismantled and showing heterogeneities effects

  - Predictive simulations
    - Lab tests
    - Ongoing field scale experiments

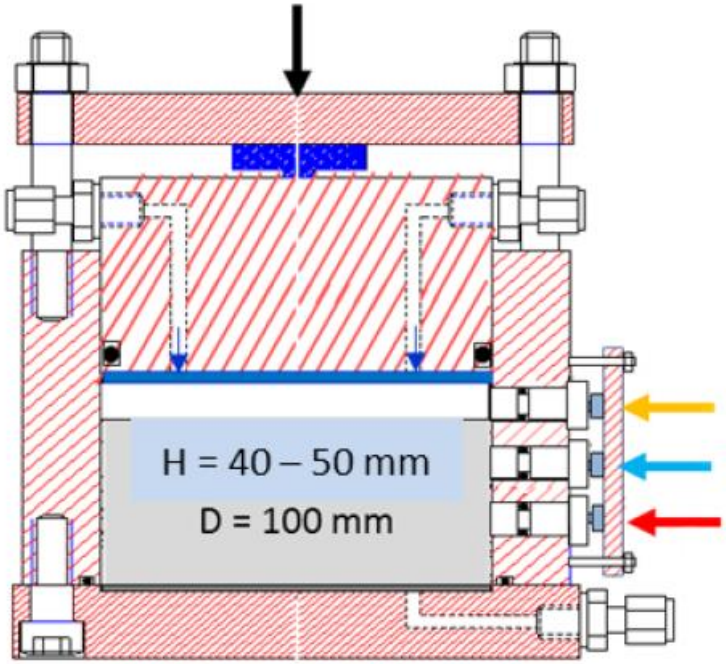
  Task 5.3 – Ongoing Experiments

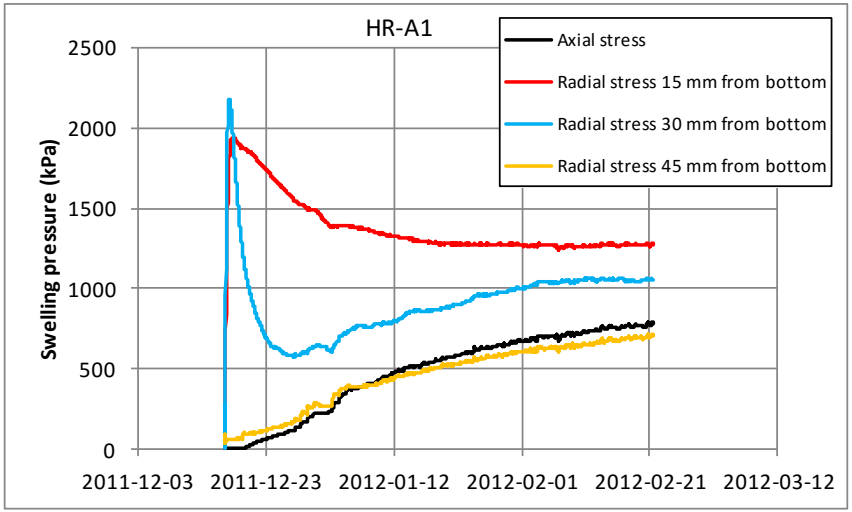
  - Assessment cases
    - Andra tunnel plug,
    - Nagra disposal cell
    - KBS-3 deposition tunnel backfill

  Task 5.4 – cases based on real bentonite component design

Task 5.1 - Very well instrumented lab tests

Constant volume swelling test with an initial gap on the top of the bentonite plug

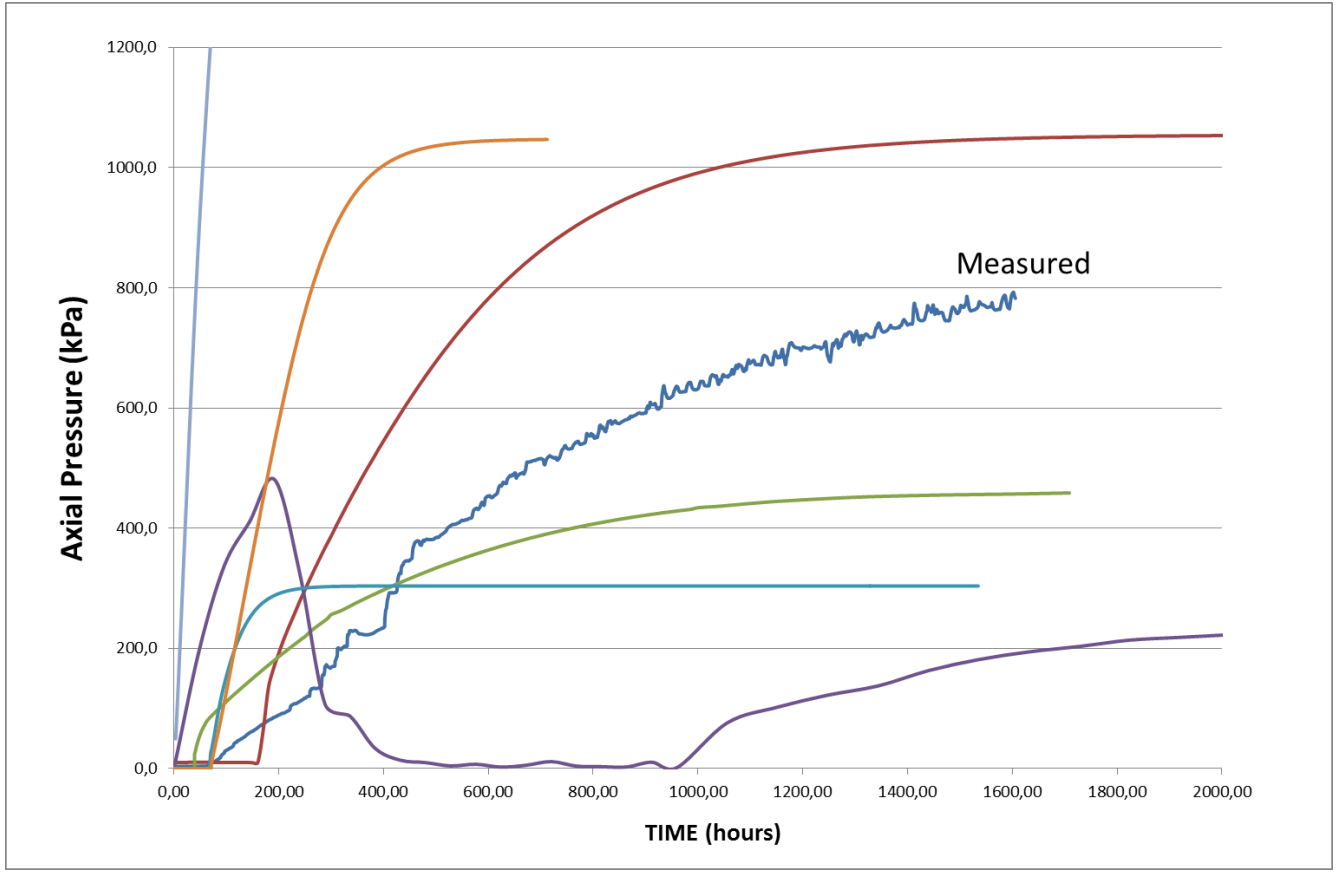


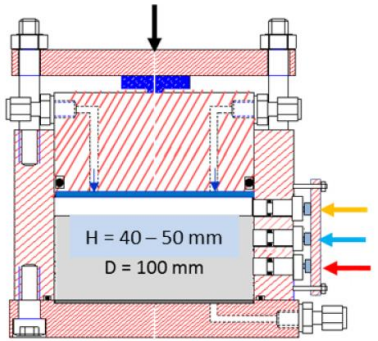


Participants for task5.1

Team	Model/code	Parameters used	Boundary conditions	Results test1a01	Results test1a02
ICL	ICFEP	yes	yes	yes	yes
BGR	OpenGeoSys 5	yes	yes	yes	no
Claytech	Comsol/HBM	Yes	yes	yes	yes
EPFL	Lagamine/ACMEG	yes	yes	yes	yes
LEI	Comsol	yes	yes	yes	no
Quintessa	QPAC/ILM	yes	yes	yes	yes
SKB	DACSAR	yes	yes	no	yes
ULG	Lagamine	yes	yes	yes	yes
CU-CTU	Sifel	yes	yes	yes	no
VTT					
UPC					

Analysis of Test 1a02 Axial pressure





Main comments for test1a

- General trend for water ratio and dry density is well reproduced in most cases
- Voids introduces new difficulties →difficult in these zone to obtain simultaneously pressure evolution, void ratio and water content
- Transient phase are difficult to catch
- Collapse during saturation over or under estimated in most cases
- Hysteresis needs to be taken into account?
- Selection of main parameters → comparison needs to be done
- Role of friction in small tests?
- Uncertainties on measurements are sometimes difficult to identify and should be considered
  - Initial gaps
  - Sensor surfaces
  - …

→Needs some exchanges between modelers and experimentalists

WP6

- To give civil society the opportunity to follow, discuss and give feedback on the research conducted in the project by the development of a relevant interaction framework.
- To facilitate the translation of scientific results and other output from WP1-5 to the public and creating the conditions for civil society local and national representatives to interpret, discuss and give feedback on the research result and other information made available by the project.
- To enhance the possibilities of civil society participation in future situations where there are consultation processes as a part of safety case review.

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