RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

NRC WORKSHOP: WHAT RESEARCH FOR BEYOND 80 YEARS FOR CIVIL STRUCTURES - IRSN CONTRIBUTION

Fabienne Ribeiro

OUTLINE

- French National Contexte
- Containment building
- RPV support structure
- Conclusion

FRENCH NATIONAL CONTEXTE

- ≈75% of the reactors built between 1980 and 1990 ==>reaching 40 years of operation

- Licence renewal decided after ten years periodic inspections:

  - **2021** : ASN decided on the conditions applicable to all **900 MWe** reactors for their continued operation beyond their **4th periodic** review.
  - **2025** : ASN will decide on the continued operation of the **1300 MWe** reactors beyond their **4th periodic** review.
  - ASN will take a position on the conditions for the continued operation of reactors **beyond 50 years** at the time of their **5th periodic** review.

- ASN has requested that EDF justifies the hypothesis of a continuation of the operation of current reactors for **up to 60 years** and beyond by **2025**.

➔ ***Current goal: 60 years and beyond***

CONCRETE COMPONENTS UNDER STUDY

- Containment building

Laurent Zylberman/Graphix-Images/Médiathèque IRSN

Grégoire Maisonneuve/Médiathèque IRSN

- RPV support structures

CONTAINMENT BUILDING : safety requirement

We want: to predict the structure's response …

- *Structural strength*
- *tightness* (1300 MWe and 1450 MWe double-walled enclosure)

… to normal and extreme load

- *External : earthquake, storm, aggression…*
- *Internal : severe accident, T, P…*

Laurent Zylberman/Graphix-Images/Médiathèque IRSN

We need: Modelling tools and material behavior laws P=f(t) …

Function of the ageing process/microstructural evolution

- *Microstructural evolution as a function of (time, initial/intermediate conditions, external conditions…)*
- *Microstructural evolution characterization (CND, advanced characterization methods…)*

…Reference experimental data

- *Representative test-solicitations*
- *Representative materials*

CONTAINMENT BUILDING : knowledge needed

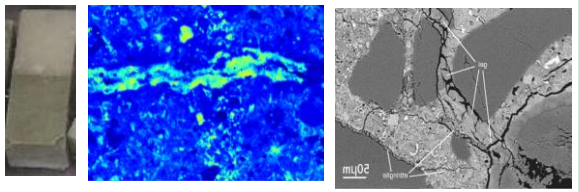
Aging Mechanisms :

- *Corrosion (reinforcement, prestressed cables, etc.)*
- *Delayed deformations (shrinkage, creep, etc.)*
- *Internal Swelling Reaction (ISR)*

Scientific challenges: from the laboratory to the enclosure

- *Scale effects :*
  - Slow phenomena ➔ need aging acceleration to be study (time)
  - From the microstructure (phenomena, conventional test specimen) to the macroscopic component (space)
- *Coupling :*
  - Pathologies-Pathologies
  - Prestresses-Pathologies
  - Corrosion-Pathologies…

ITZ/local phenomena



Specimen scale

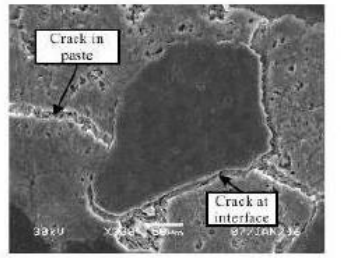
Structural scale

CONTAINMENT BUILDING : Pathologies R&D Axes

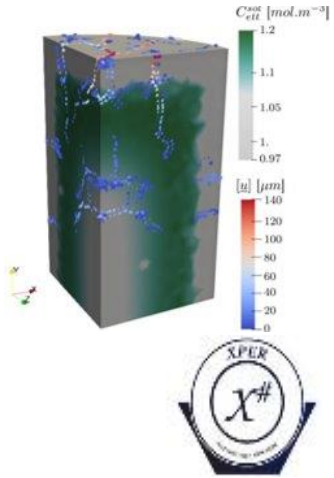
- **Identification of the elementary processes** characterizing initiation and development of pathologies
  - development of accelerated aging protocols
  - characterization of the mechanical properties of the paste-aggregate interface (Interfacial Transition Zone)

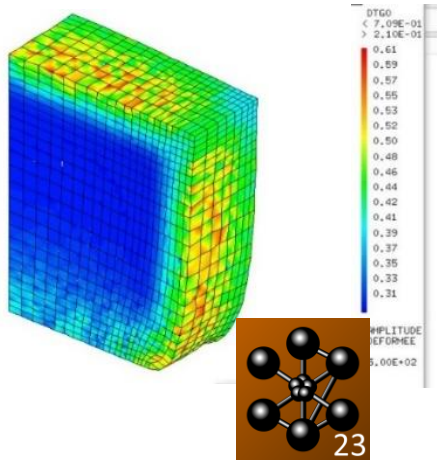
- **Development of predictive tools** to evaluate the behavior of a concrete affected by pathologies
  - durability indicators
  - Multiscale and Multiphysics simulation tools

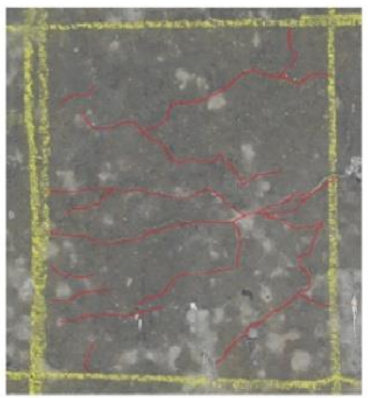
- **Acquisition of reference experimental data** on concrete affected by pathologies
  - Development of non-destructive testing techniques
  - Scale effect evaluation
  - Validation of simulation tools



Fissuration typique d'une Réaction Sulfatique Interne [Eddy et al., 2017]

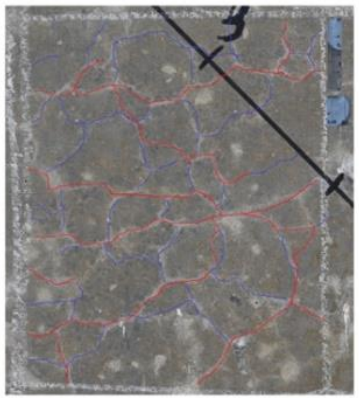






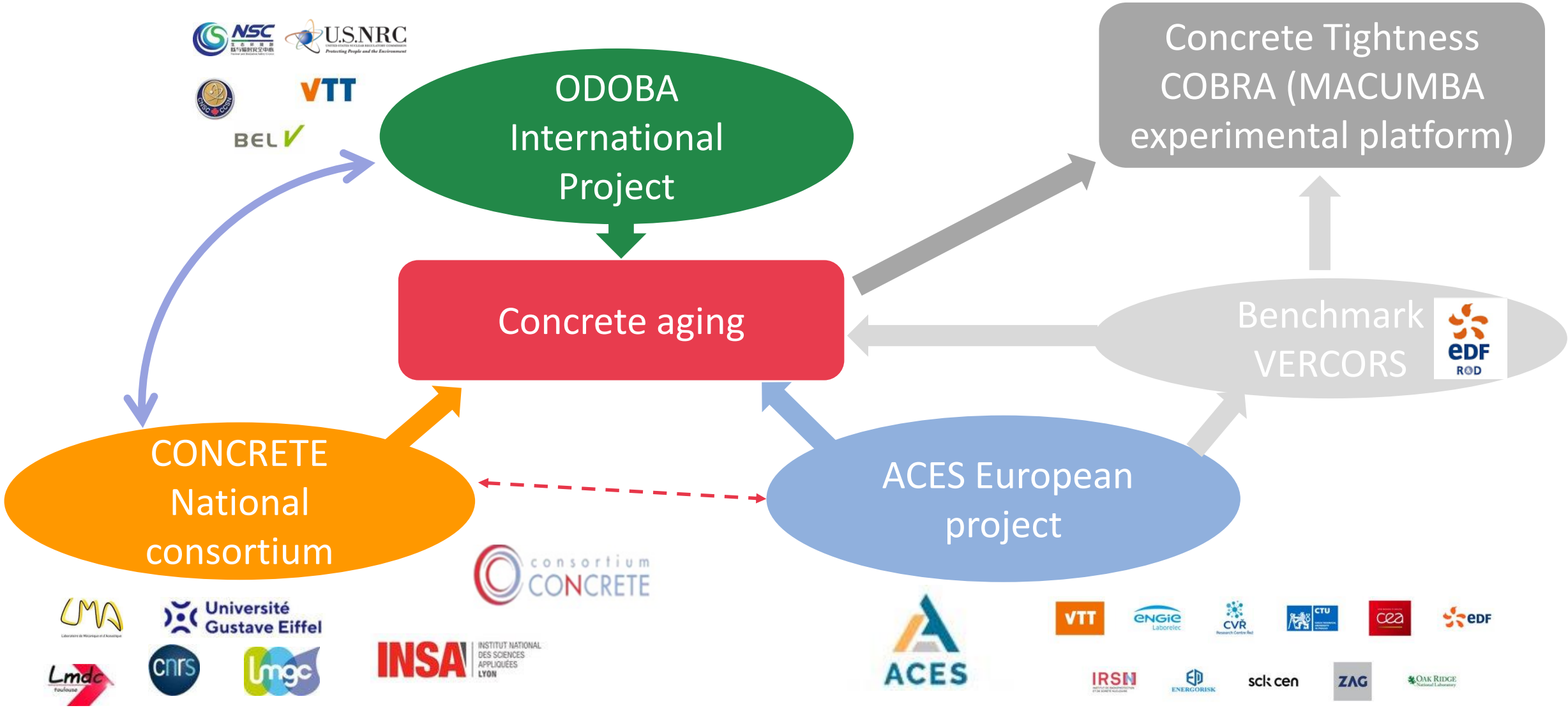
496 days, primary cracks

KB East Zone 02



944 days, secondary cracks

CONTAINMENT BUILDING: partnership network



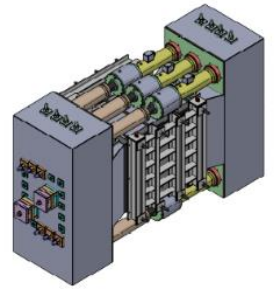
CONTAINMENT BUILDING : Experimental platform (ISR)

Observatory of Concrete Durability (ODE/ODOBA):

Focus on internal swelling reactions and their consequences at the structural level

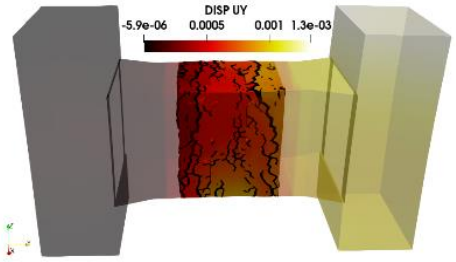
- Understand the development of pathologies at the block scale as well as their consequences on mechanical properties.
- Qualify innovative in situ NDTs for the early detection of swelling pathologies and the monitoring of their evolution
- Build an experimental database for the validation of predictive calculation tools at the scale of the structure

CONTAINMENT BUILDING : Experimental platform (SA conditions)



MACUMBA Platform (Test Facilities Applied to the Study of Containment by Reinforced Concrete Walls)/ **COBRA Project** (Sealing of the Reactor Building in Accident Conditions)

- Structural damage and leakage rate of a containment wall mock-up, under a thermo-hygro-mechanical loading state ***representative of severe accident conditions***
- Transposition coefficient between the leakage rate measured during periodic tests (dry air, 5 bars, 20°C) and the leakage rate in severe accident (air-vapour, 5 bars, 150°C)
- *Behaviour of composite skins under severe accident conditions*
- *Influence of ISR-like pathologies on cracking and permeability*



RPV support structure : safety requirement

Grégoire Maisonneuve/Médiathèque IRSN

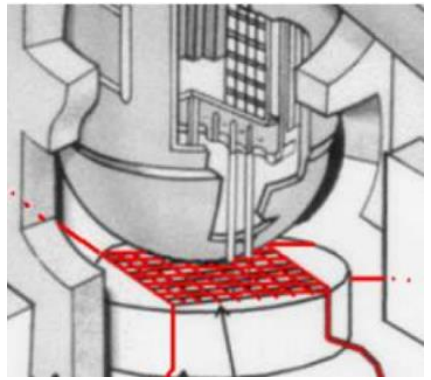
We want: to predict the structure's response …

- *Structural stability of irradiated concrete*

We need: to predict concrete damage by the effect of irradiation P=f(fluence)…

- usable elements of the European ACES program,
- International knowledge (CEA, NRA, NRC, US Oakridge …)

➔*Take stock of knowledge and examine needs and opportunities for further development*



…Evaluation of fluence in concrete

- *Neutrons*
- *Gamma*

RPV support structure : R&D Axes Fluence quantification

- Extend the VACS calculation scheme originally built for the vessel fluence to the concrete vessel support :

Specificities: *farther from the core* ➔ *More neutron attenuation*

➔Bigger challenges in terms of Monte Carlo methods

- ➢More optimized variance reduction method
- ➢**Need for dedicated validation for the concrete vessel support**

- Study the historical management of French PWRs to take into account the realistic irradiation history

CONCLUSION

- IRSN SCOPE : beyond 60 years…
- Focus on 2 components : Containment building and vessel support
- Experimental capabilities through specific platform
- Need for :
  - *Behavior understanding*
  - *Modelling and simulation tools*
  - *NDT development*
  - *Representative validation data*

➔*Materials, Mechanical and neutronic R&D required*