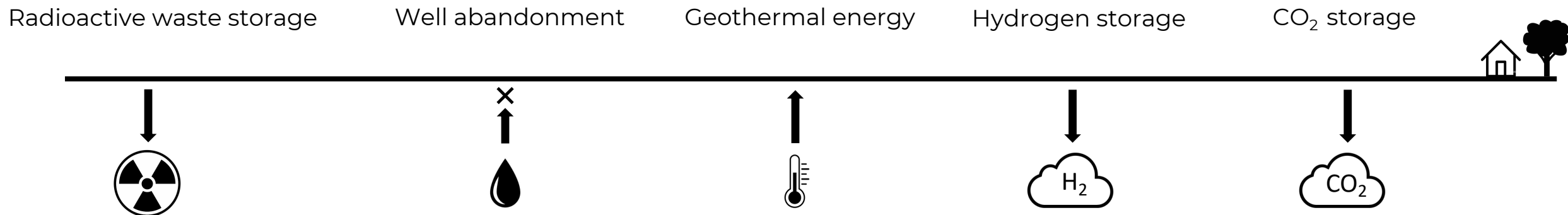


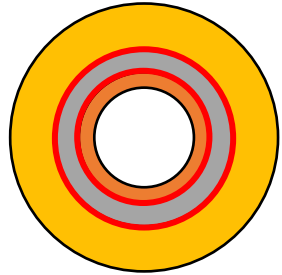
Probabilistic Well Integrity Assessment

Clément Joulin
Net-Zero Geosystems
October 2024

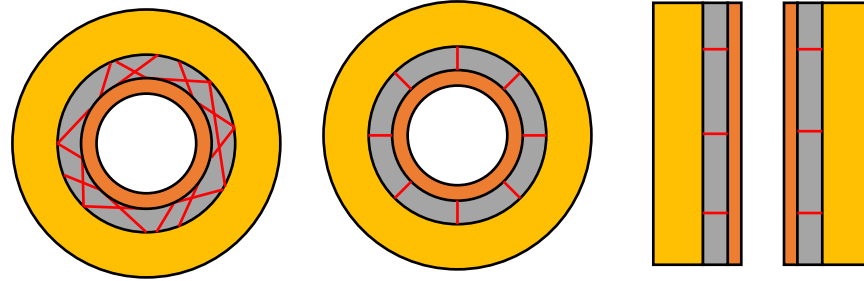
Net-Zero Geosystems is a company focused on the development of geoscientific simulation tools and services for CO₂ storage, geothermal energy, radioactive waste disposal, hydrogen storage (H₂, CH₄) and P&A.



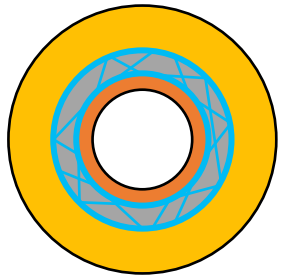
What do we predict?



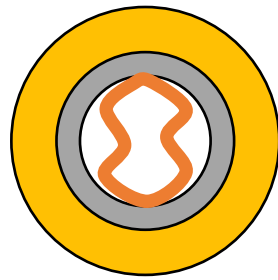
Debonding



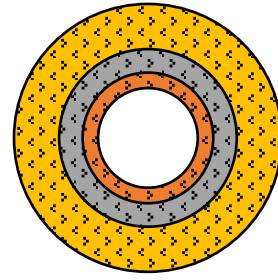
Fracturing



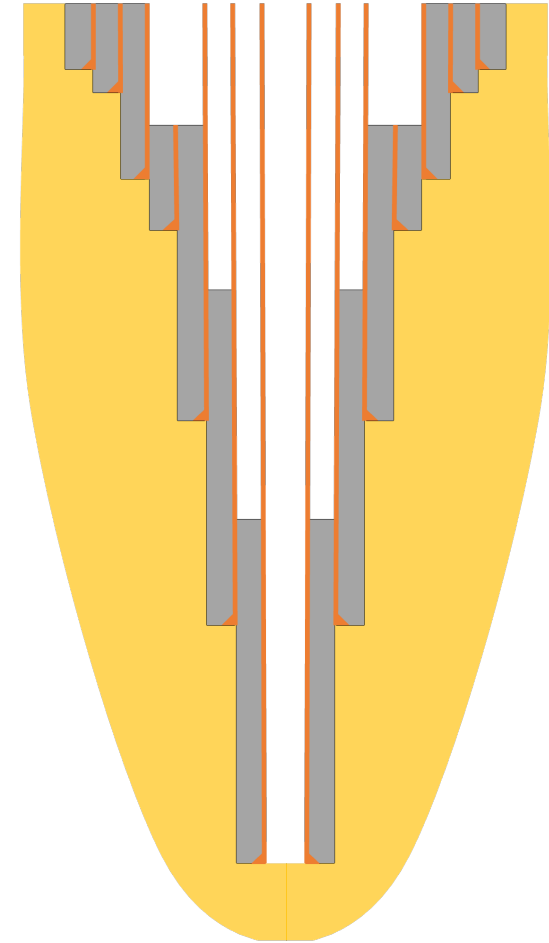
Leakages

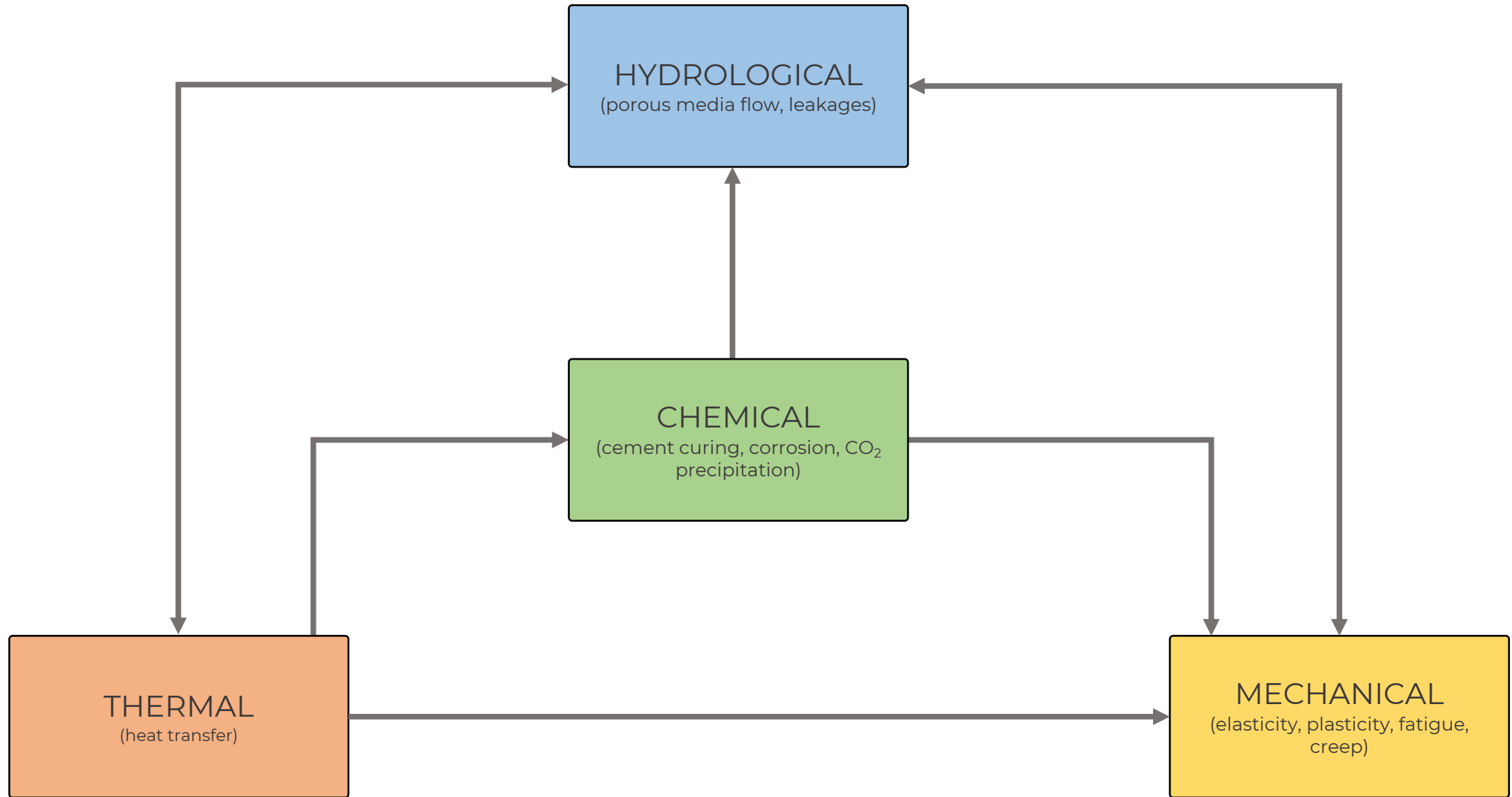


Casing collapse

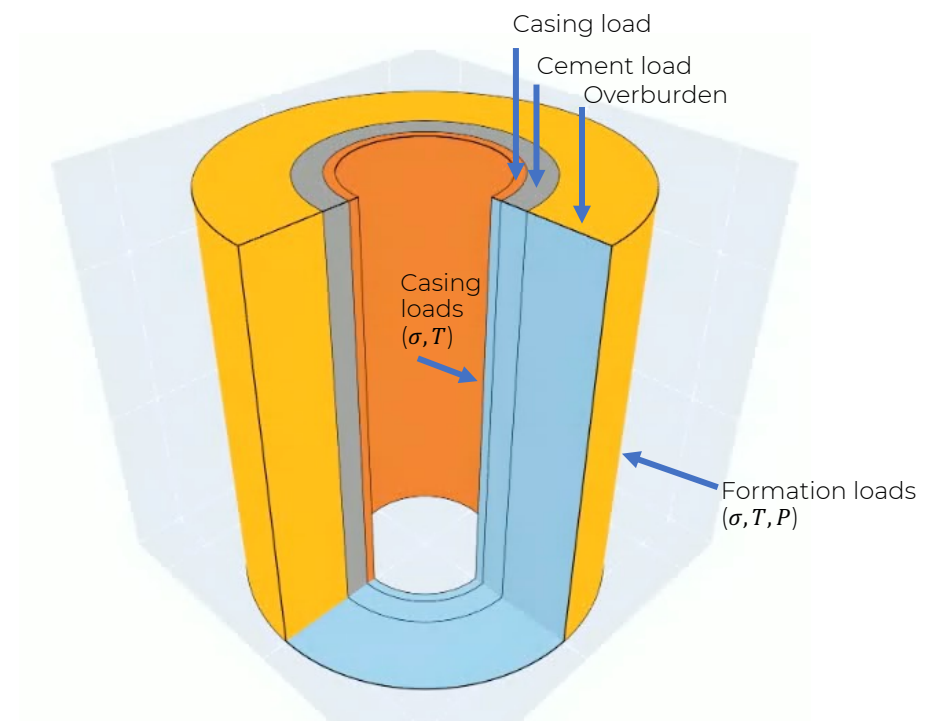


Chemical alterations

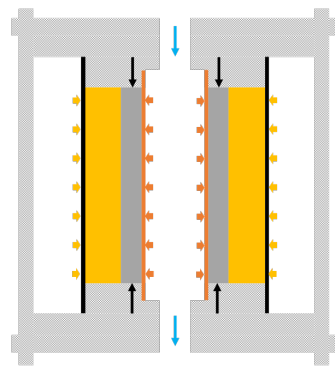




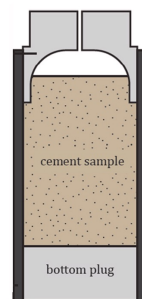
- Developed in collaboration with TotalEnergies, Shell and Equinor
- Captures the behavior of a well section including:
 - Thermo-hydro-mechanical and chemical physics
 - Fracturing, debonding & micro-annuli, cement curing, plasticity, fatigue
- Takes <1s for simulating the life of the well



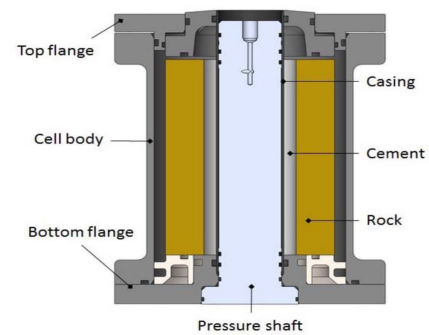
Models are being validated vs. experiments available in the literature and experiments of our partners TotalEnergies, Shell, Equinor and SINTEF.



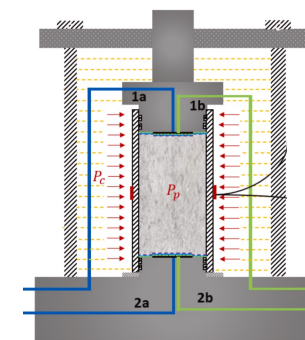
TotalEnergies' well integrity experiment
(Joulin et. al 2022)



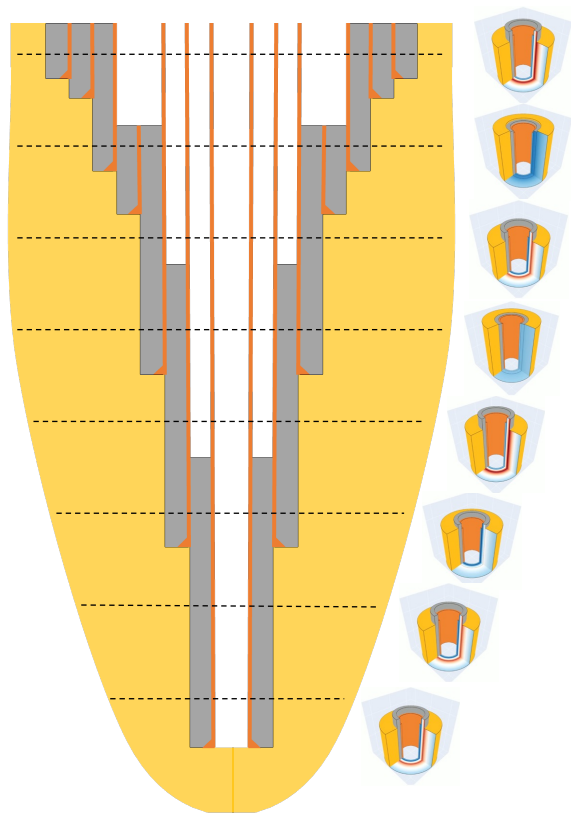
Shell's LabCat
(Wolterbeek et. al 2021)



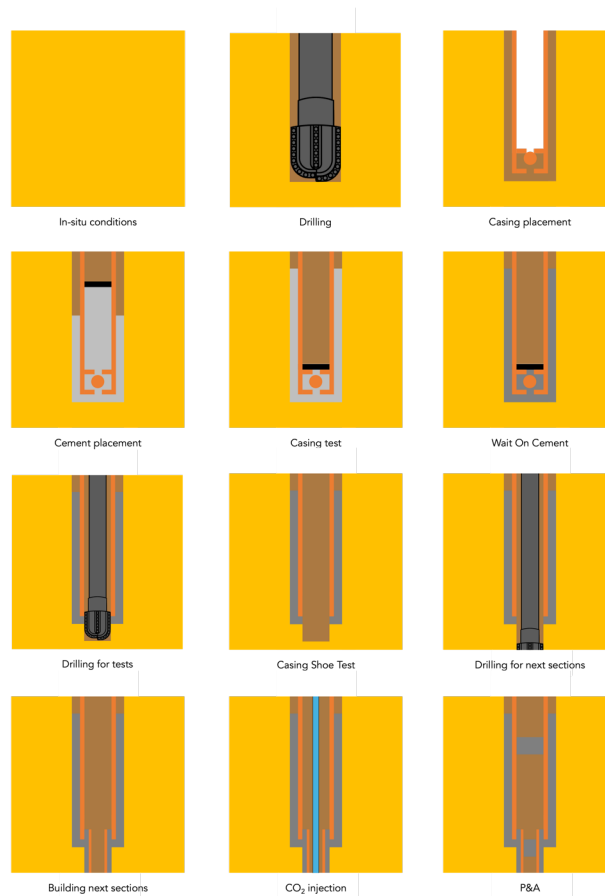
SINTEF P&T cycling cell
(Vrålstad et. al 2019)



Los Alamos triaxial curing cell
(Meng et. al 2021)



30-50 depths of interest



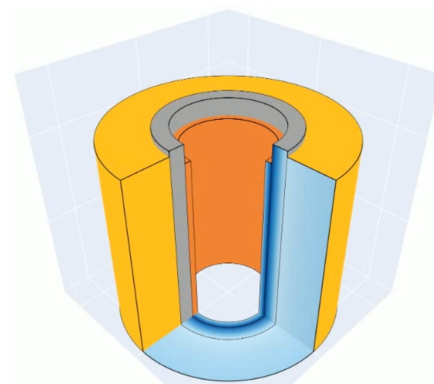
12+ Well life stages per section

Cement-casing debonding	Cement-formation debonding
Cement-casing micro-annulus	Cement-formation micro-annulus
Cement-casing leakage rate	Cement-formation leakage rate
Casing collapse	Borehole brakeouts
Cement plastic yield	Formation plastic yield

8+ Failure metrics

Quantity	Casing	Cement	Formation
Δ	0.005	0.017	8.000
E	200.0	15.0	30.0
ν	0.27	0.25	0.49
ρ	7.9	2.3	2.7
β	1.3	0.9	1.0
k	45.2	6.2	4.9
$c^{(V)}$	3.4	4.0	1.6
ϕ	0.00	0.35	0.08
α	0.00	0.80	0.82
λ	0.00	0.15	30.00
C	250.0	22.6	16.0
ψ	0.0	15.0	42.0

Input set 1



Simulation 1

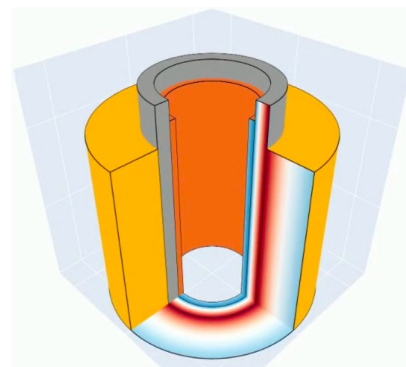


No debonding

Result 1

Quantity	Casing	Cement	Formation
Δ	0.005	0.017	8.000
E	200.0	16.0	28.0
ν	0.25	0.24	0.44
ρ	7.4	2.1	2.5
β	1.3	1.2	1.5
k	45.2	6.7	4.4
$c^{(V)}$	3.4	4.0	1.6
ϕ	0.00	0.34	0.07
α	0.00	0.80	0.82
λ	0.00	0.14	34.00
C	250.0	22.6	16.0
ψ	0.0	15.0	42.0

Input set 2

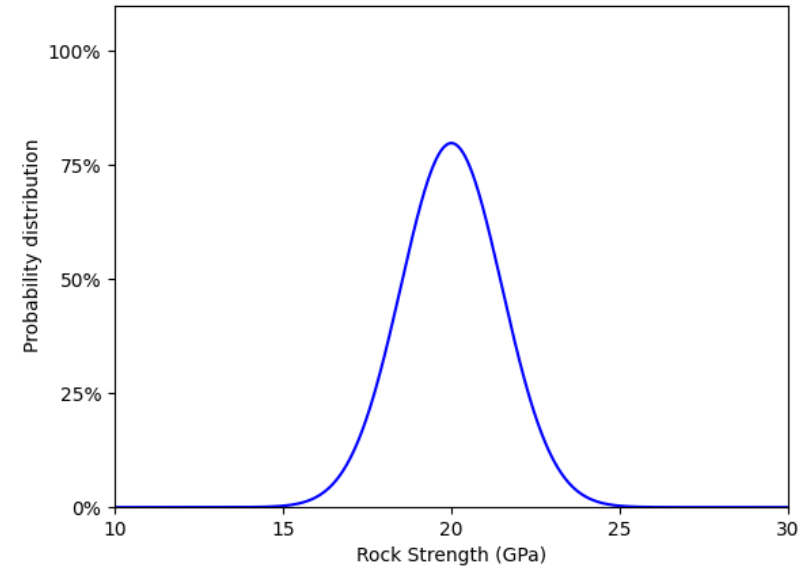
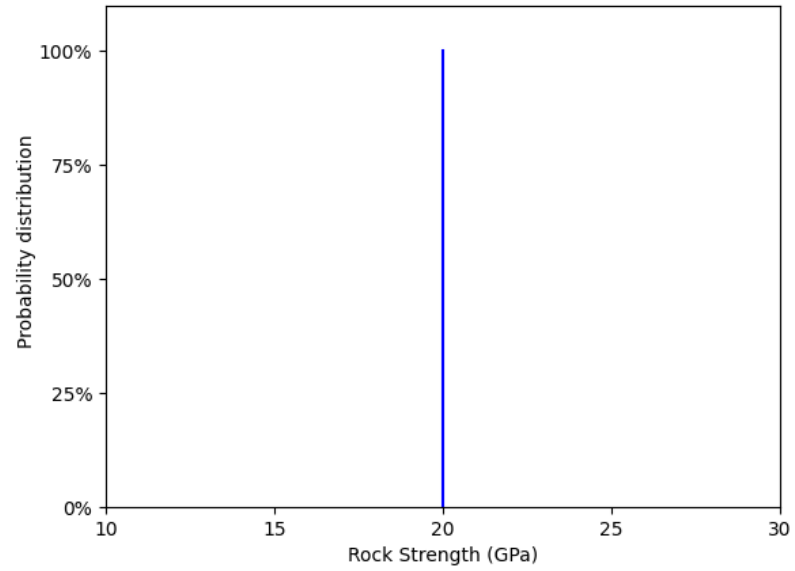


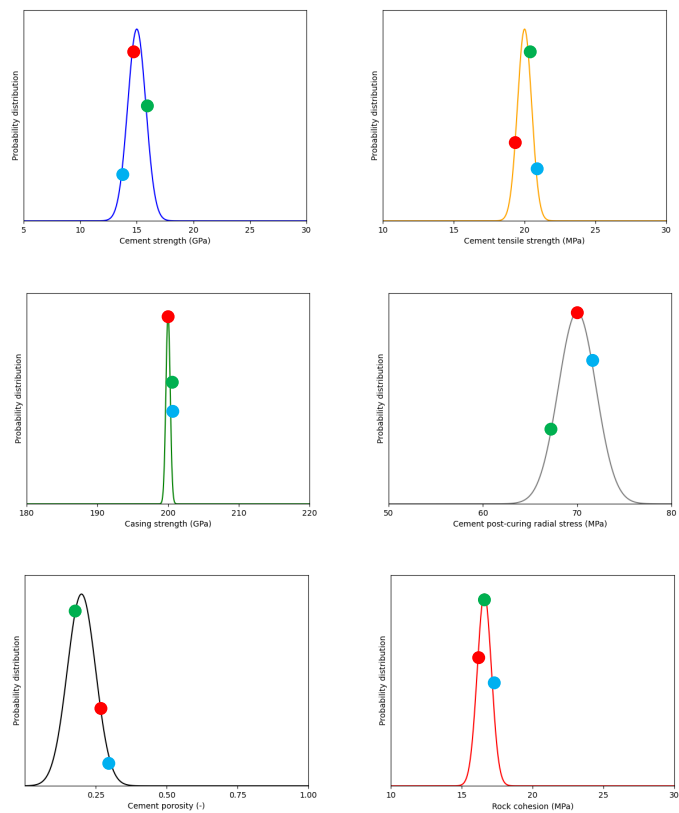
Simulation 2



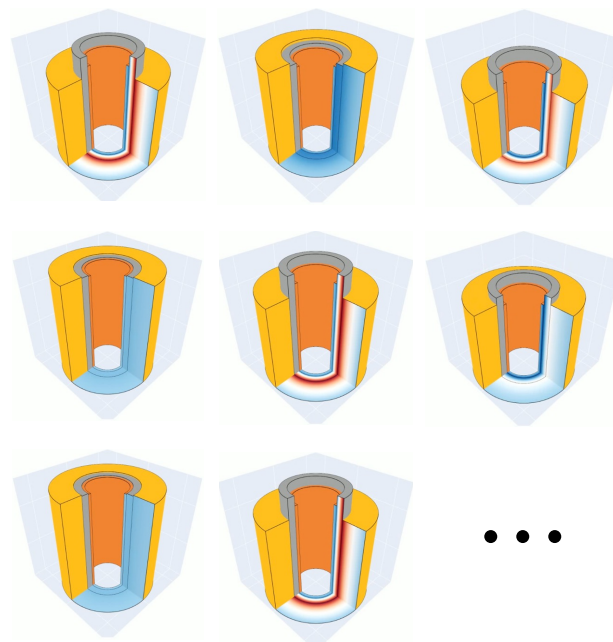
Debonding

Result 2

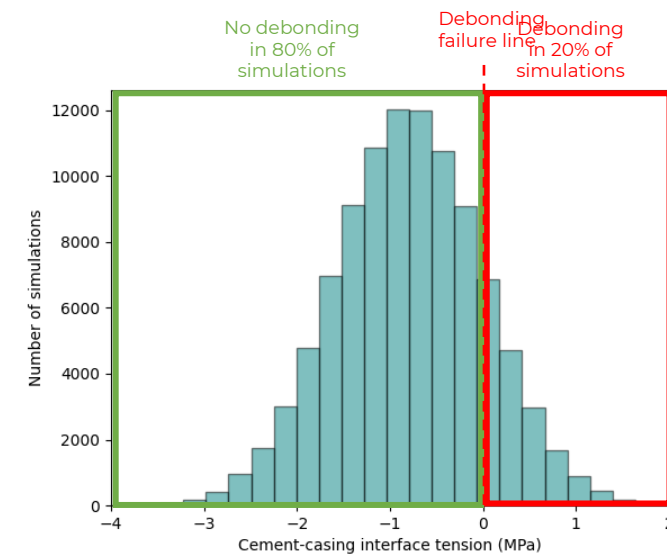




Inputs



Simulations



Results