SAND2018-1748C

QUALIFICATION OF NUMERICAL & SEMI-ANALYTICAL MODELING CODES FOR THERMAL DESIGN OF HLW REPOSITORY - 184550

Waste Management Conference

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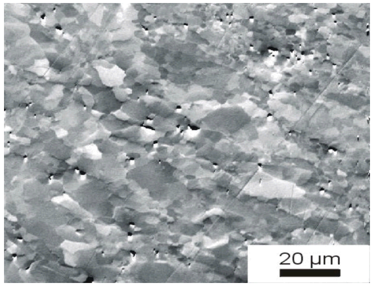

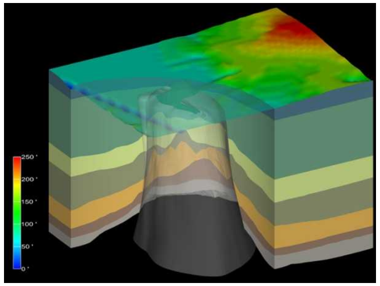

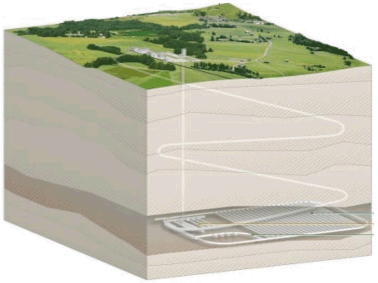

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BETREUT VOM

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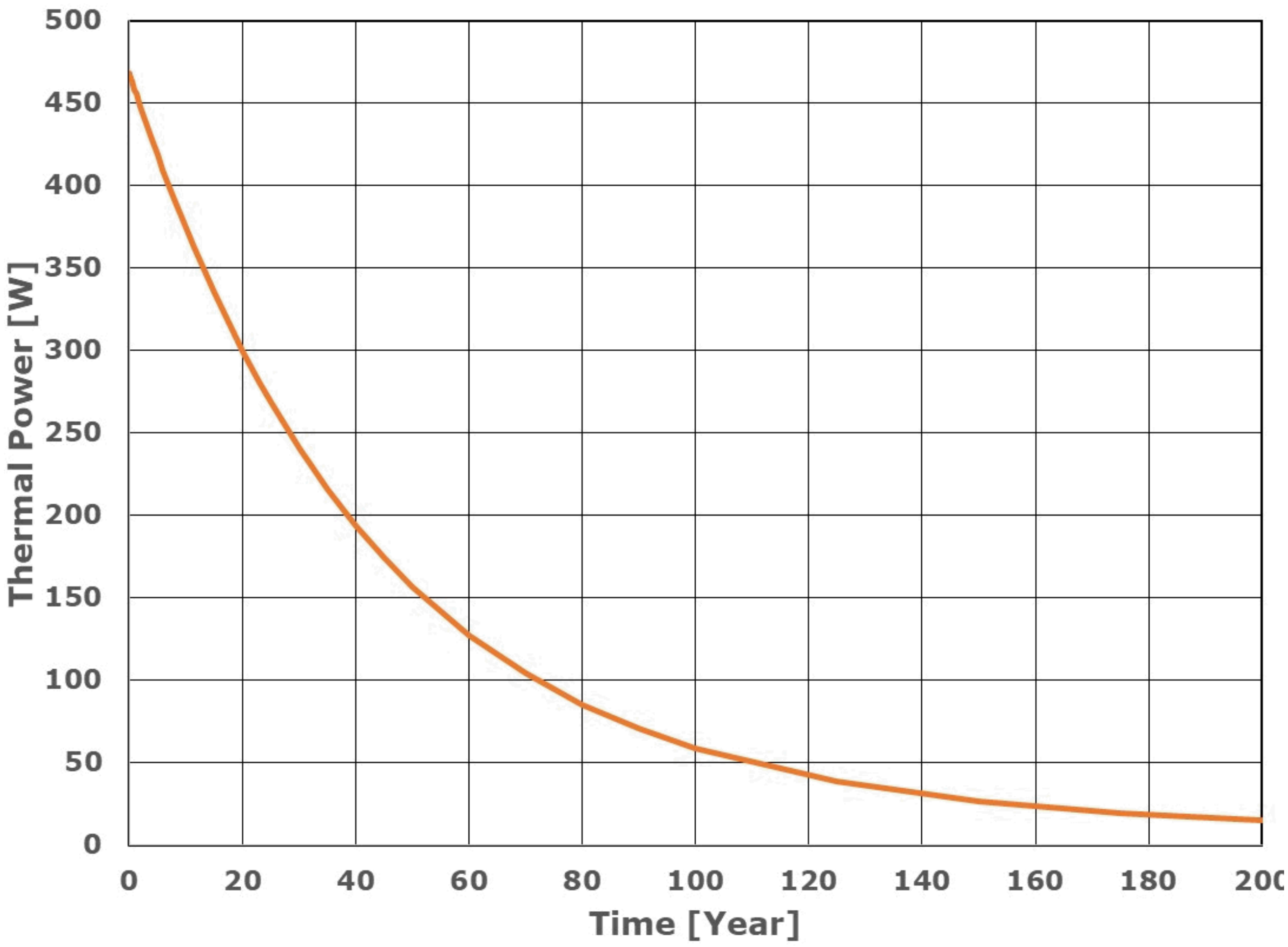
COMPARATIVE THERMAL DESIGN ANALYSIS

- Design of repository layout requires thermal analysis to evaluate thermal distribution and meet thermal limit requirements.
- Comparative benchmark study conducted at DBE TECHNOLOGY in Germany and at Sandia National Laboratories
- Goal: evaluate the performance of semi-analytical thermal codes
- Software used in the thermal analysis:
  - LinSour Software (analytical code)
  - MathCad Based Thermal Analysis Software (analytical code)
  - FLAC3D (numerical code)

THERMAL OUTPUT USED IN THERMAL ANALYSIS



INPUT FOR THERMAL ANALYSIS REPOSITORY IN BEDDED SALT HOST ROCK

- Drift diameter – 6.1 m, Drift spacing – 20 m
- Waste package size – diameter 0.61 m, length 3.05 m
- Waste package spacing – 10 m
- Surface storage time assumed – 10 years
- Ambient temperature - 15 deg. C
- Geothermal gradient – 25 deg. C/km
- Repository depth – 500 m

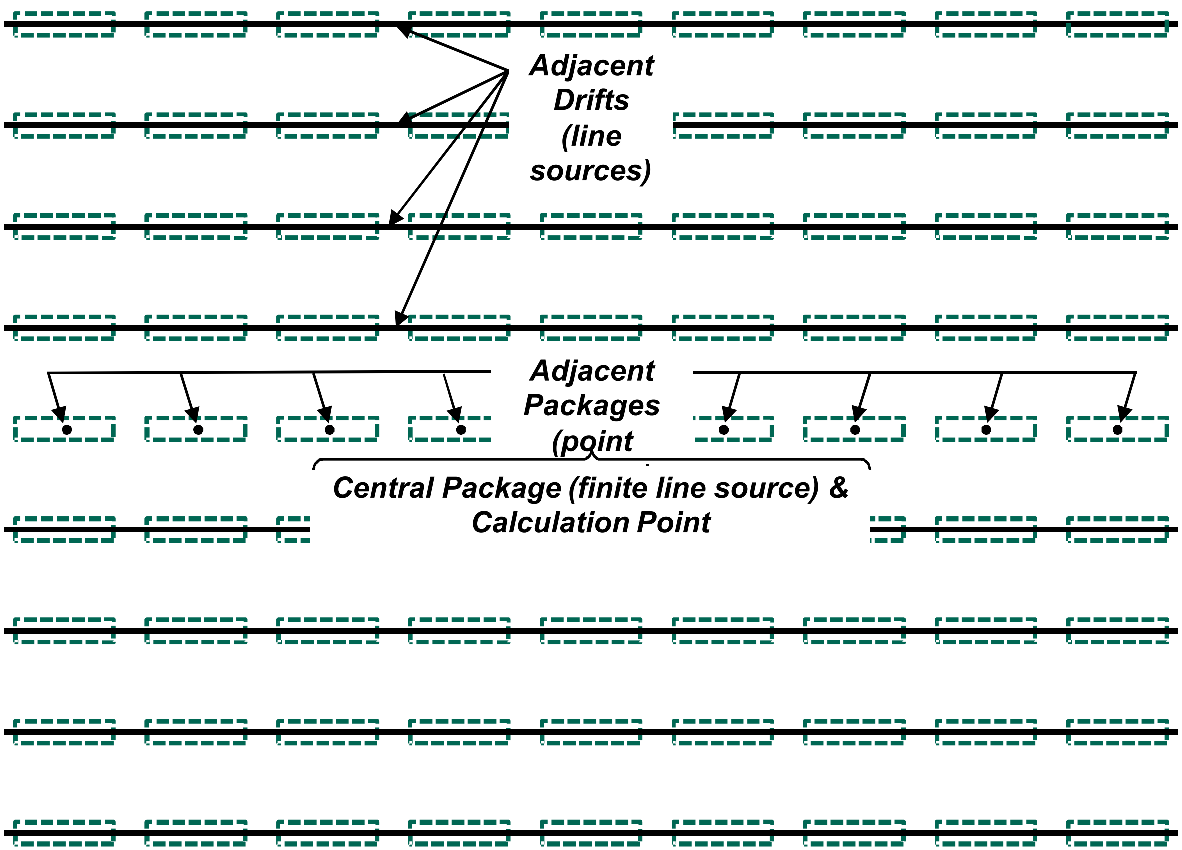
MATERIAL PROPERTIES ASSUMED

- Case #1 - Base Case – same material properties assumed for host rock, backfill and waste package
- Thermal Conductivity – 0.57 W/m/K
- Density – 2200 kg/m3
- Heat Capacity – 931 J/kg/K
- Case #2 – Representative material properties used for each material (for numerical method only)

Material	Thermal Conductivity (W/m/K)	Density (kg/m^3)	Heat Capacity (J/kg/K)	Thermal Diffusivity (m^2/s)
Intact Salt	3.20	2200	931	1.562×10^{-6}
Crushed Salt	0.57	2200	561.6	4.613×10^{-7}
Waste Package	1.0	2700	800	4.630×10^{-7}

REPRESENTATION OF SEMI-ANALYTICAL ANALYSIS METHOD

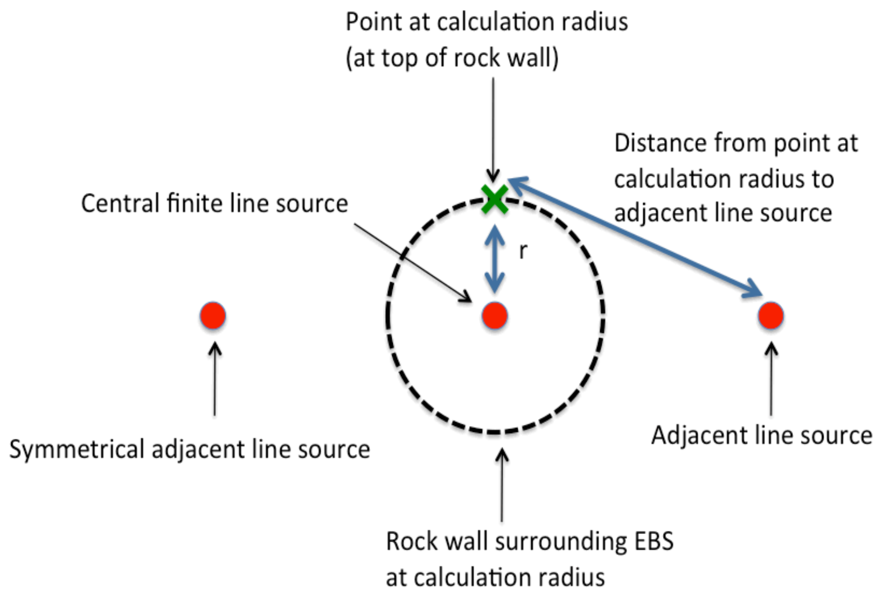
- Thermal-only analysis based on semi-analytical solution
- Based on method of superposition



Hardin et al., 2012

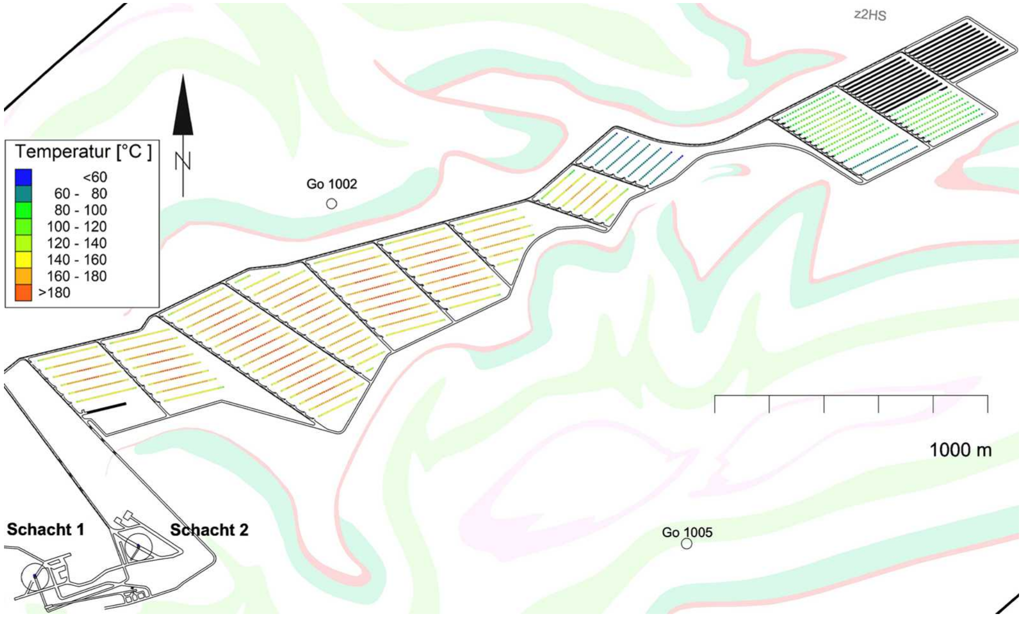
MATHCAD-BASED THERMAL ANALYSIS CODE

- MathCad-based semi-analytical transient thermal model
- Based on analytical solution of heat transport (i.e., Carlslaw and Jaeger, 1959)
- Model includes other processes such as radiation heat transfer and ventilation
- Thermal conduction solution: linear superposition of components



DBE LinSour CODE

- Semi-analytical code for simulation of thermal conduction using line sources (H. Schmidt, 1971), (K. Hahne, 1988)
  - uses superposition to model the temperature field of more than one line source
  - used for thermal analysis of entire repositories with large dimensions (up to several km2) and over a time scale of millions of years



FLAC3D

- Numerical modeling software for THM analysis in Geomechanics
- Based on Finite Difference Method
- Utilizes an explicit finite volume formulation for explicit continuum modeling of non-linear material behavior in 3D
- Well established and tested
- Used here for validation of semi-analytical codes

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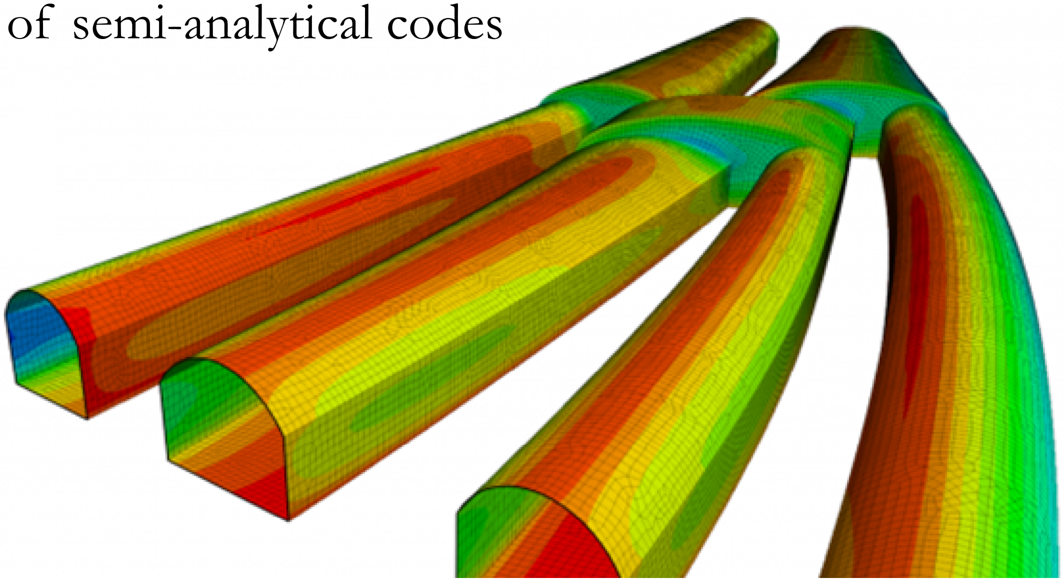
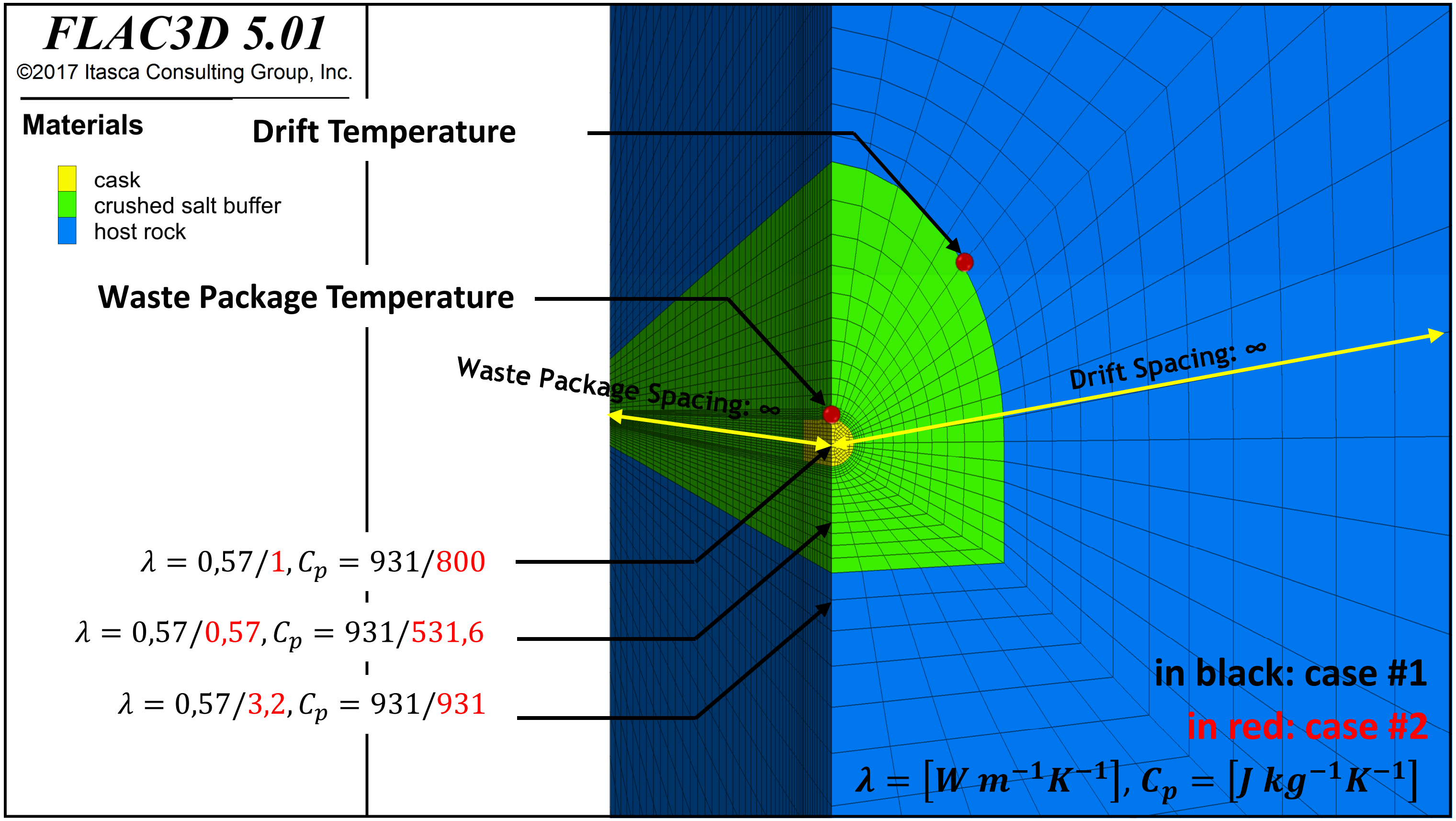


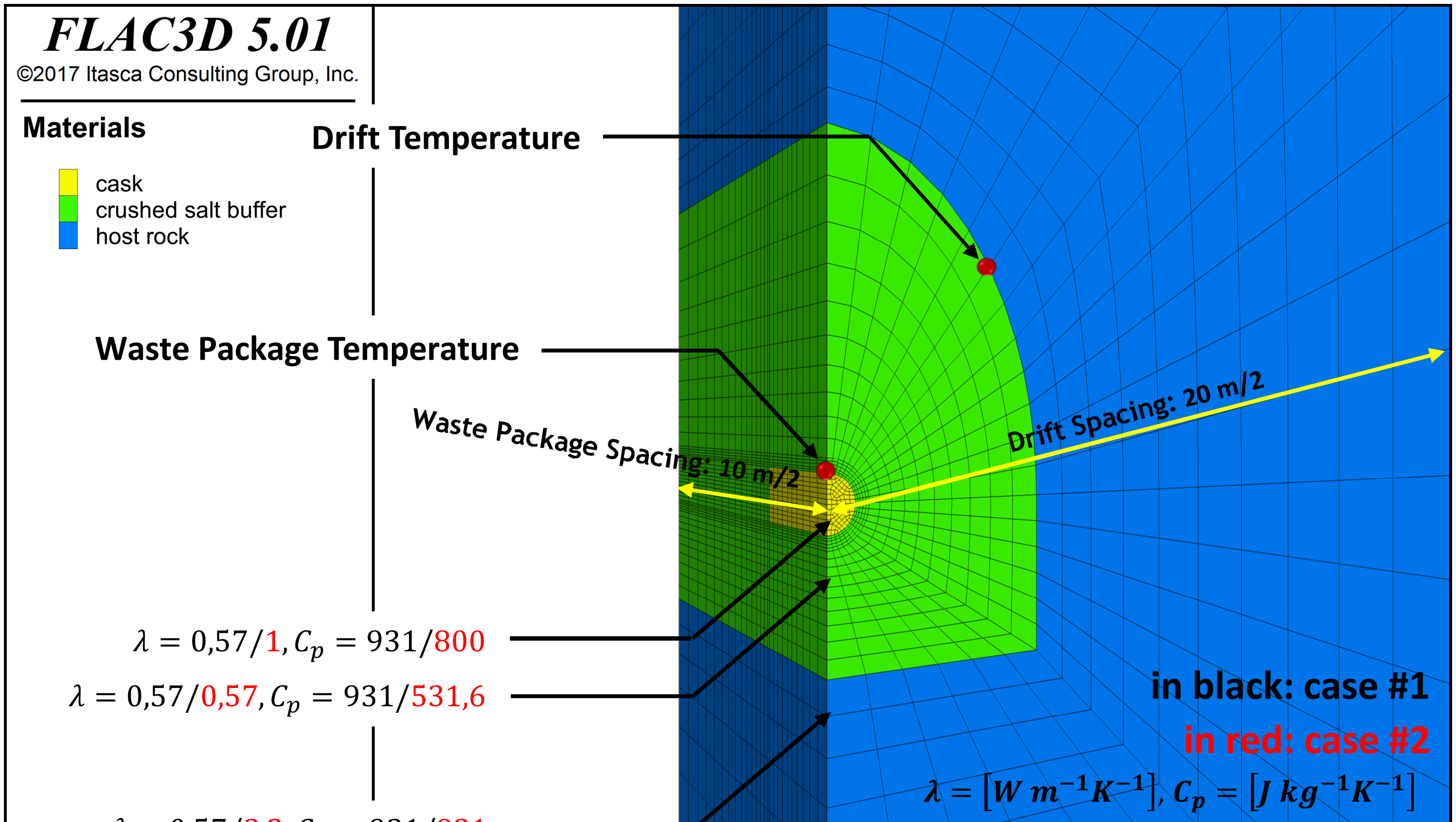
BENCHMARK MODELING CASES, 1/2

- Configuration 1: A single waste package emplaced in an infinite medium



BENCHMARK MODELING CASES, 2/2

- Configuration 2: representative repository layout with given waste package spacing and drift spacing



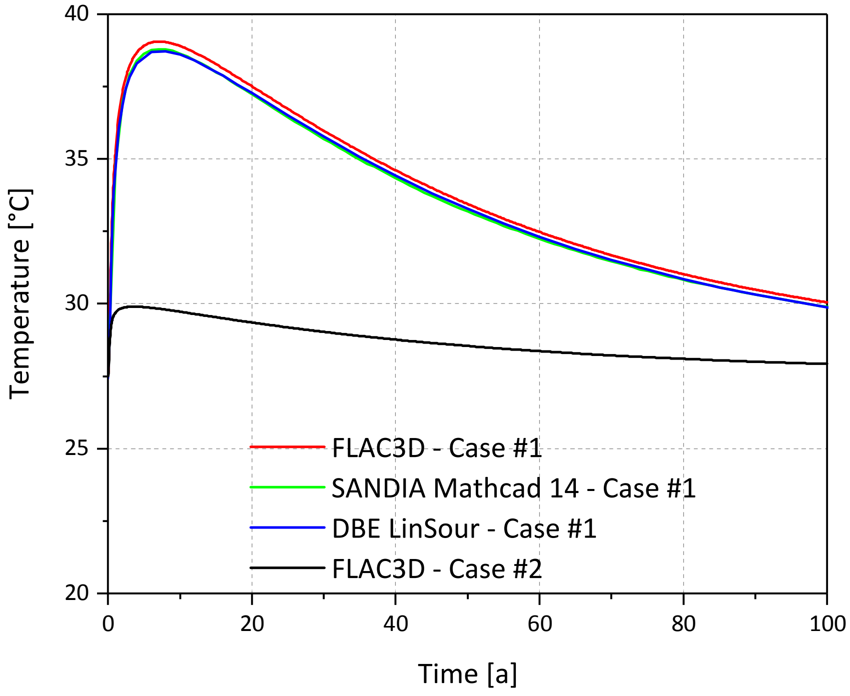
SIMULATION CASES

- FLAC3D Simulation with homogeneous parameter
  (Case #1 - Base Case)
- DBE LinSour Calculation with homogeneous material properties
  (Case #1 - Base Case)
- SANDIA MathCad 14 Calculation with homogeneous material properties
  (Case #1 - Base Case)
- FLAC3D Simulation with real material properties: more realistic case
  (Case #2)

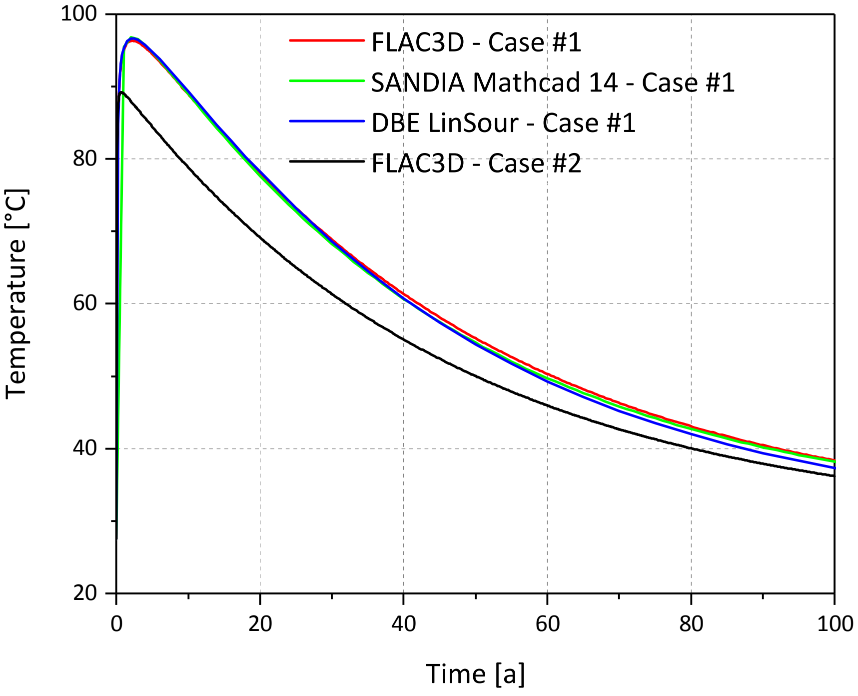
SIMULATION RESULTS, 1/2

◦ Configuration 1:

Drift Temperature



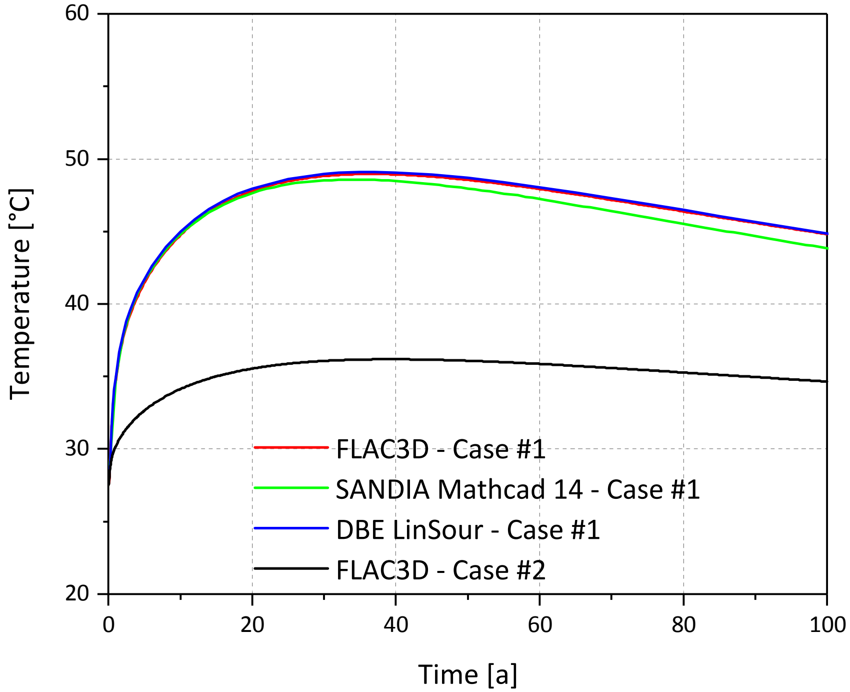
Cask Temperature



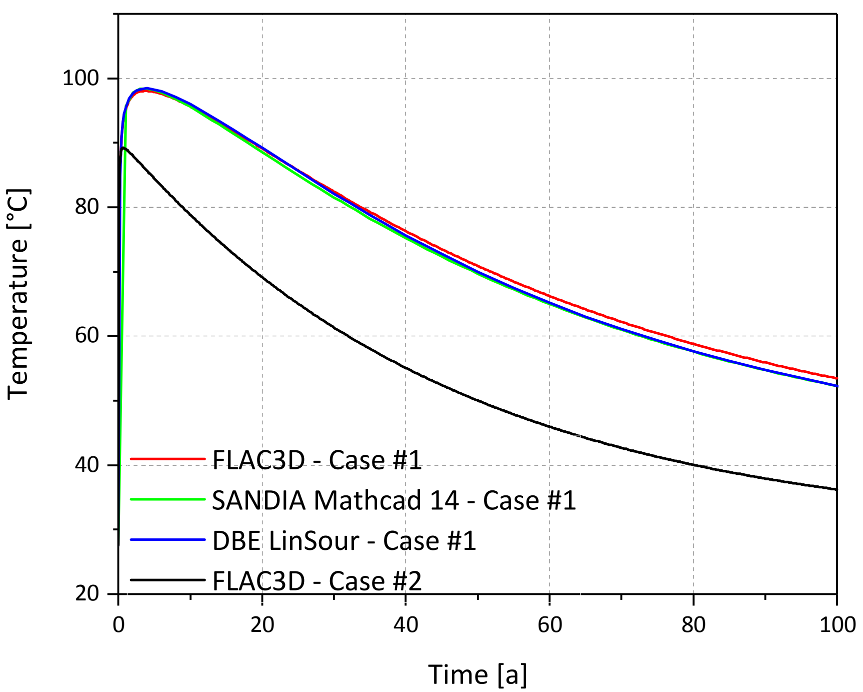
SIMULATION RESULTS, 2/2

- Configuration 2:

Drift Temperature



Cask Temperature



CONCLUSIONS

- Under identical initial and boundary conditions
  - Mathcad 14 Code and LinSour perform as well as the numerical Code FLAC3D
- Under realistic initial and boundary conditions
  - Analytical codes tend to be more conservative
  - Although, the temperature limit are always met
- The accuracy of semi-analytical codes can be improved
  - by parameter calibration using a numerical model (LinSour)
  - by considering multiple material properties (MathCad 14)
  - by using non-constant material properties (MathCad 14)
- The results show that the analytical codes studied are suitable for thermal design of a HLW repository.

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