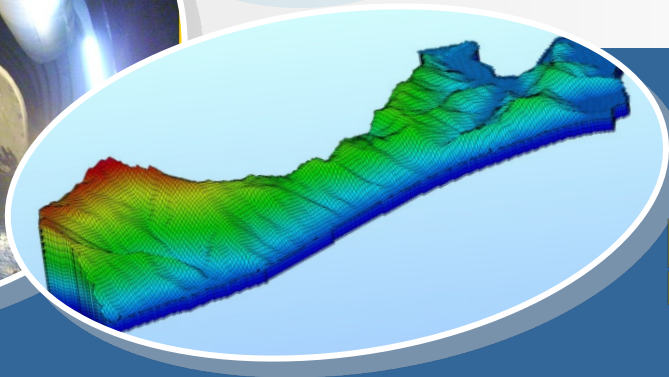
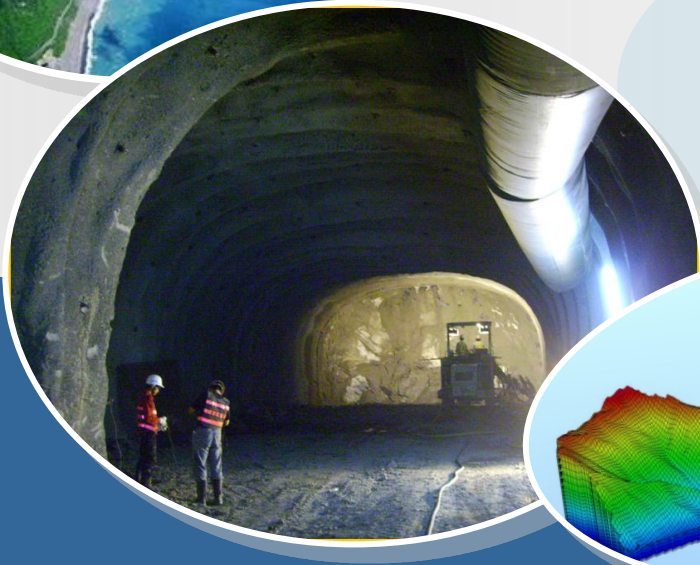


5th International Itasca Symposium

Modelling the water injection induced fault slip in an argillaceous rock

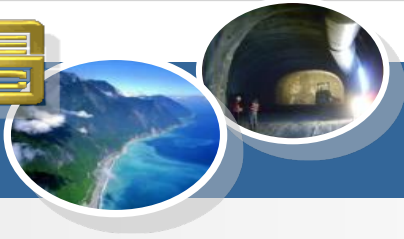
Wenjie SHIU, Weiche Chang & Fuyuan Hsiao



財團法人中興工程顧問社
SINOTECH CONSULTANTS, INC

2020 February 20, university of Vienna





Outline

- **Introduction**
- **Model description and 3DEC modelling**
- **Results and discussions**
- **Conclusions**





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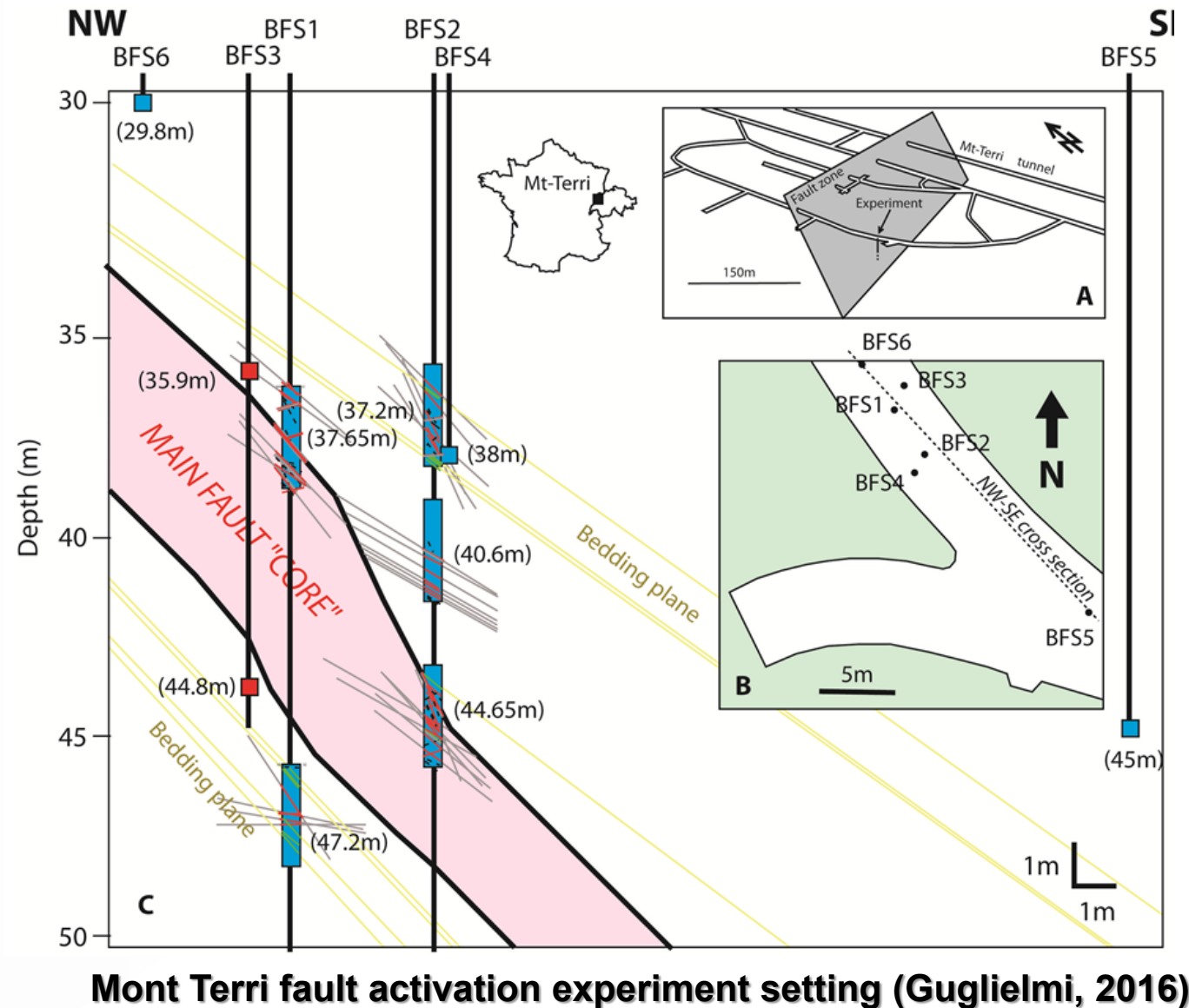
DECOVELEX 2019 - Task B

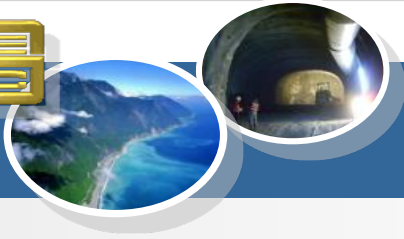


DEveloppement of COupled models and their VALidation against Experiments

An international research and model comparison collaoration

For advancing the understanding and modeling of coupled THMC processes in geological systems





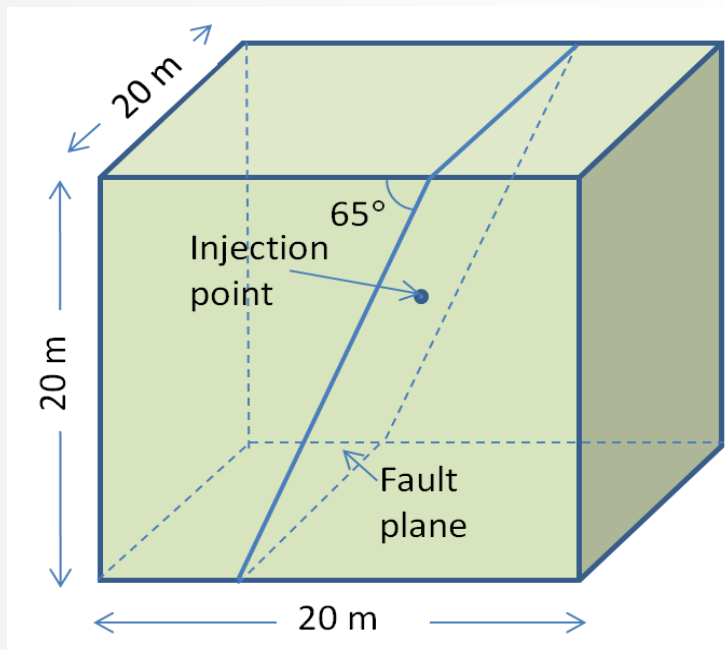
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Model description

3D Model



σ_{xx}	-3.3 Mpa
σ_{yy}	-6.0 Mpa
σ_{zz}	-7 MPa

Insitu stress

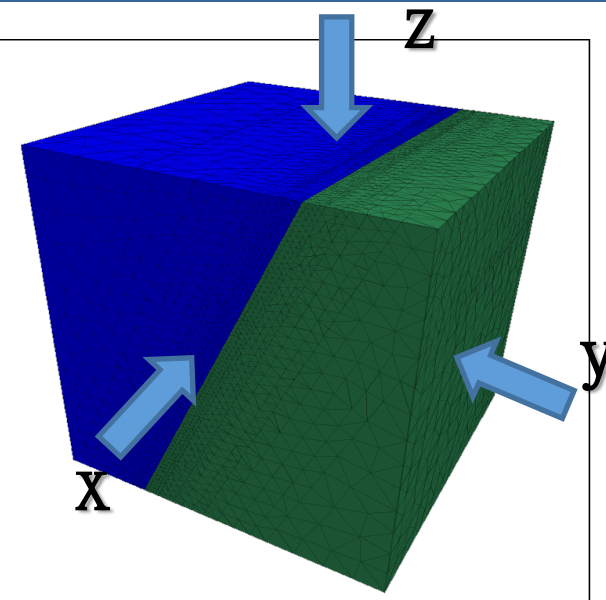
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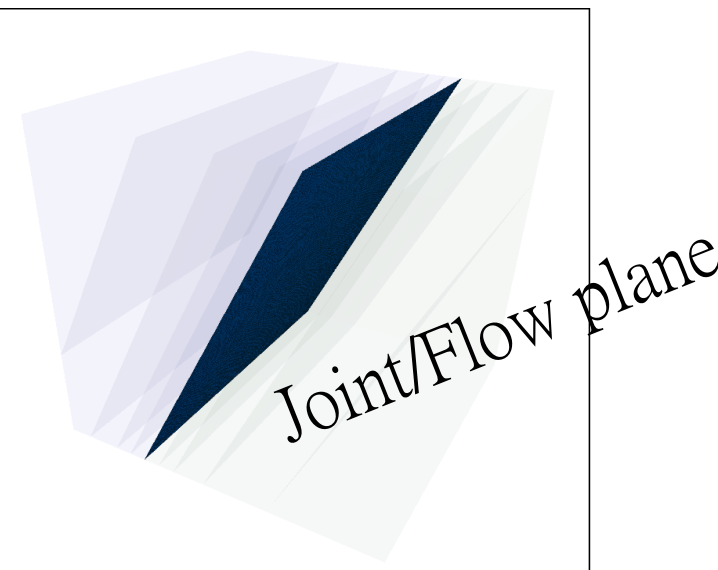
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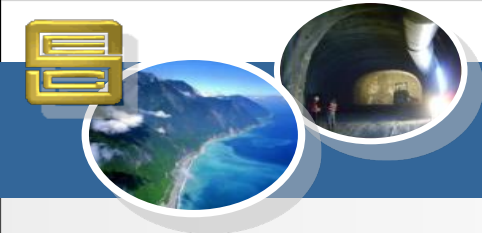
Joints

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Material properties

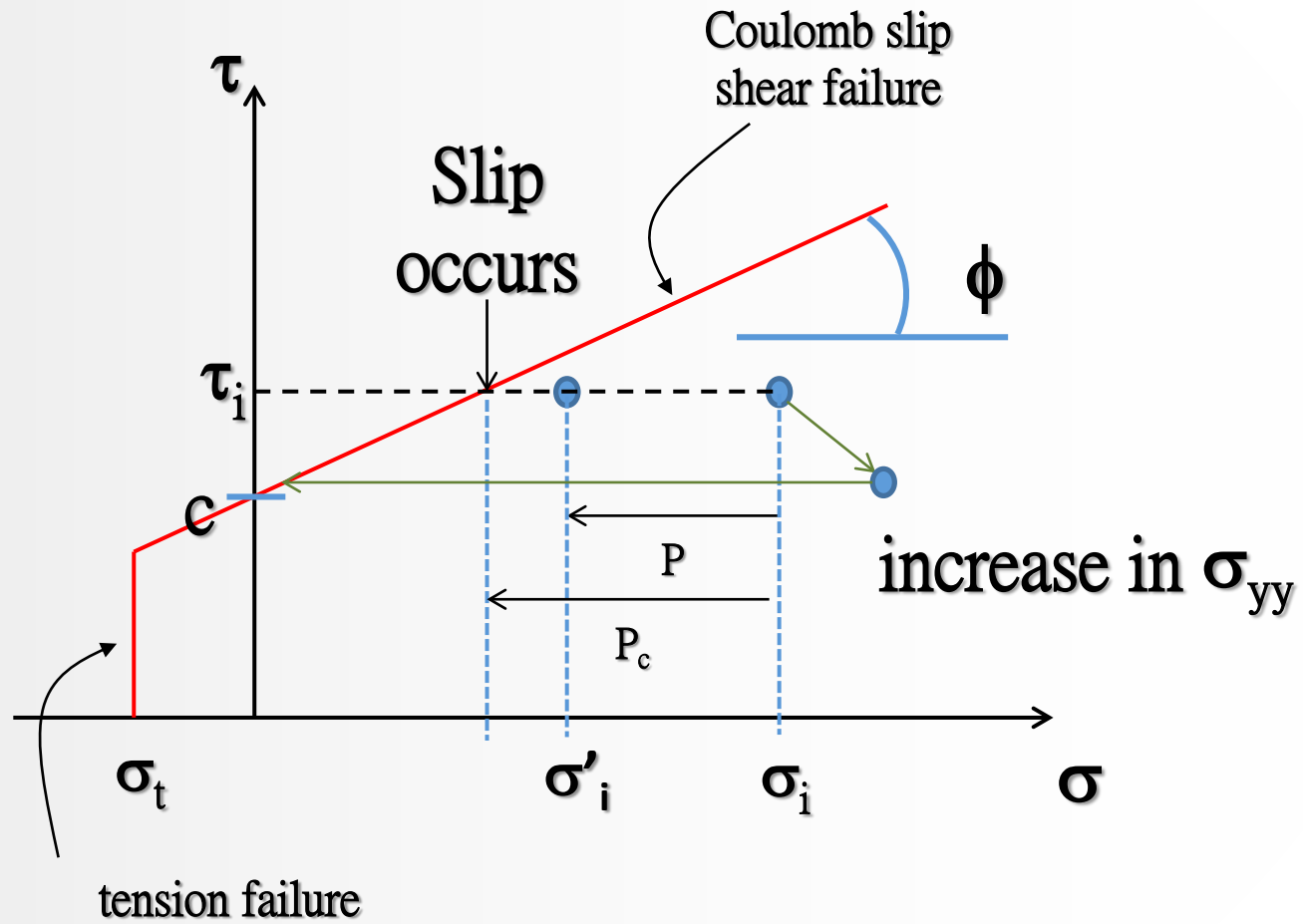
- Host rock : **Elastic** and **impermeable**
- Joint: **Coulomb slip** failure criterion

Material	Parameter	Value	
		FM 1	FM 2
Fault (Elasto-plastic)	Normal stiffness, kn (GPa/m)	20	20
	Shear stiffness, ks (GPa/m)	20	20
	Cohesion (MPa)	0	0
	Static Friction Angle (°)	22	22
	Dilation angle (°)	0	10
	Tensile strength	0	0
	Initial aperture (μm)	0	10
Host Rock Matrix (Elastic)	Initial creation aperture (μm)	28	0
	Bulk Modulus, K (GPa)	5.9	5.9
	Shear Modulus, G (GPa)	2.3	2.3
	Bulk density, ρ_R (kg/m ³)	2450	2450
Fluid	Permeability	0	0
	Density (kg/m ³)	1000	1000
	Compressibility (Pa ⁻¹)	4.4e-10	4.4e-10
	Dynamic Viscosity (Pa s)	1.0e-3	1.0e-3





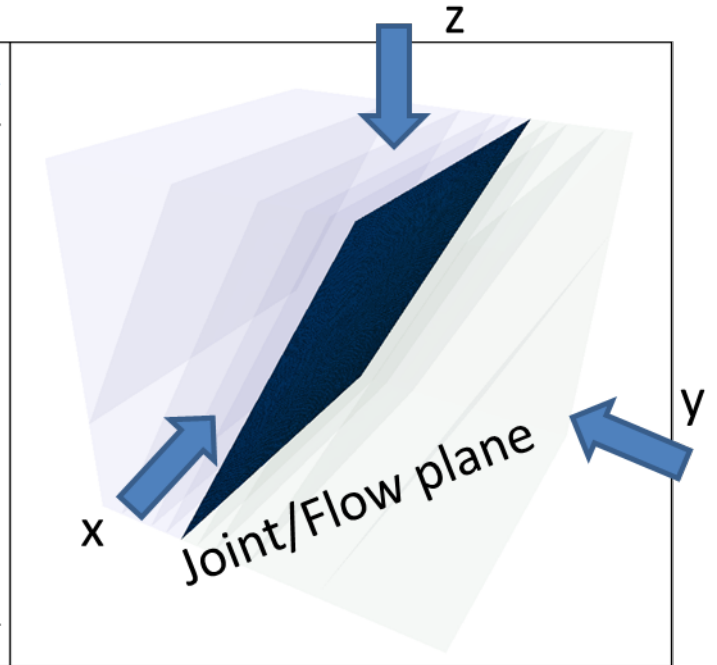
Fault slip condition



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Joints
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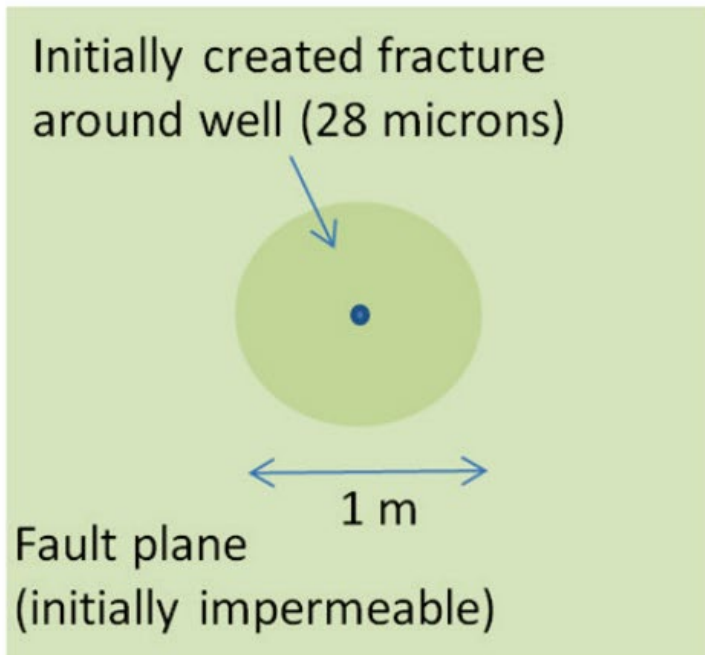
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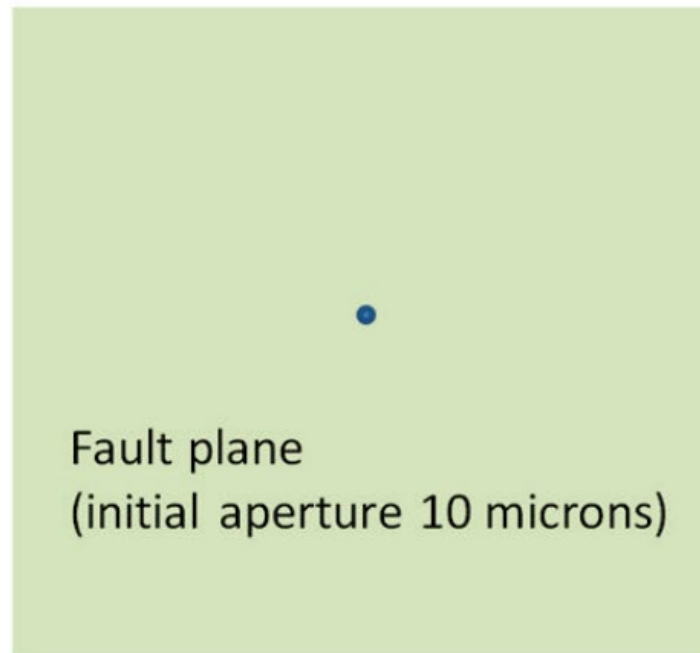
Fluid flow behavior

FM1

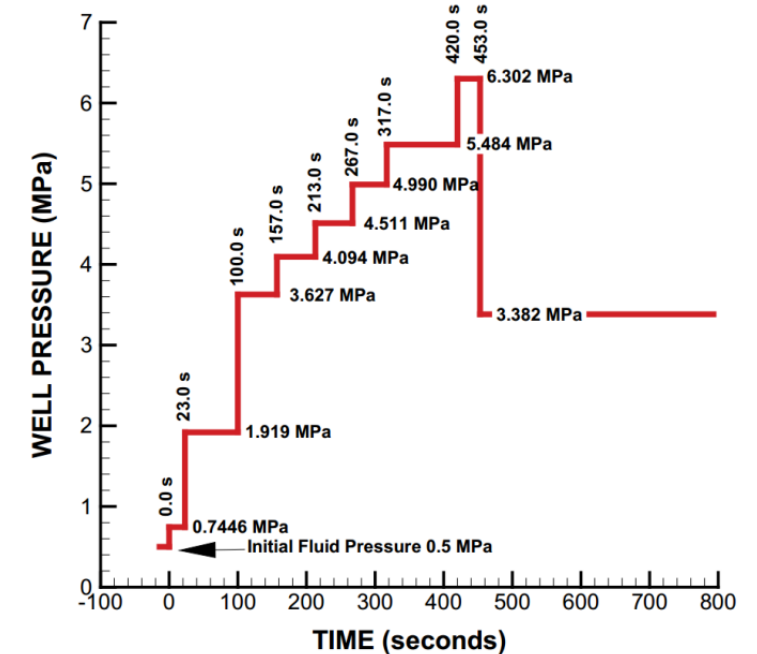


Dilation angle = 0°

FM2



Dilation angle = 10°



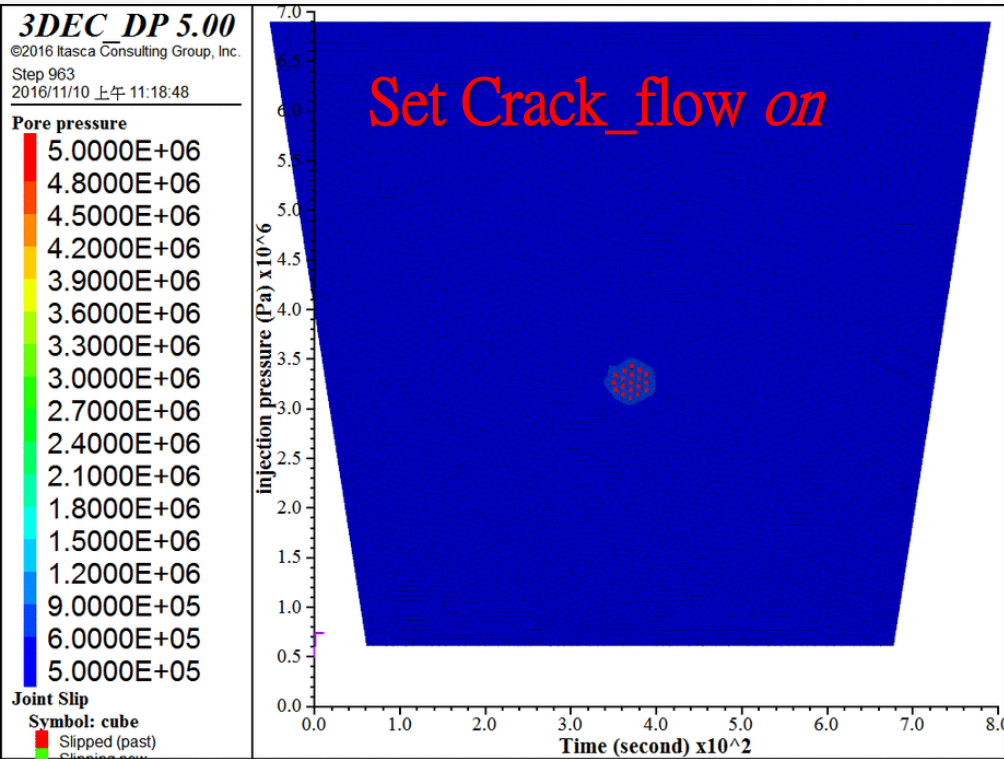
Injection time history



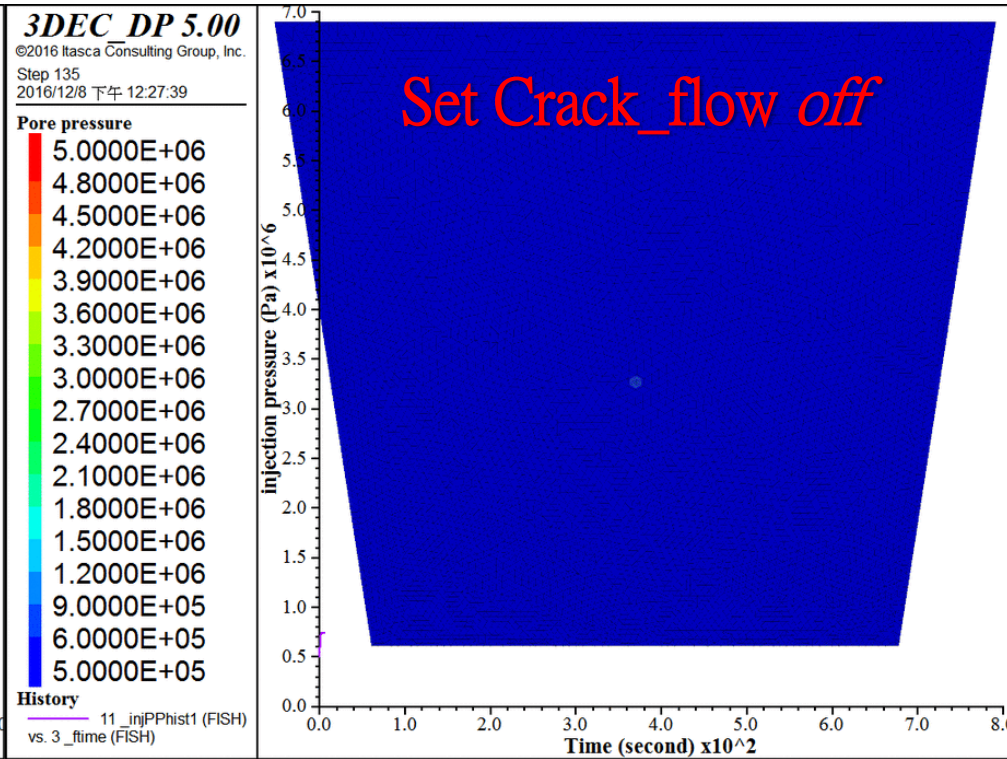


Fluid flow behavior

FM1



FM2



Unit : Pa

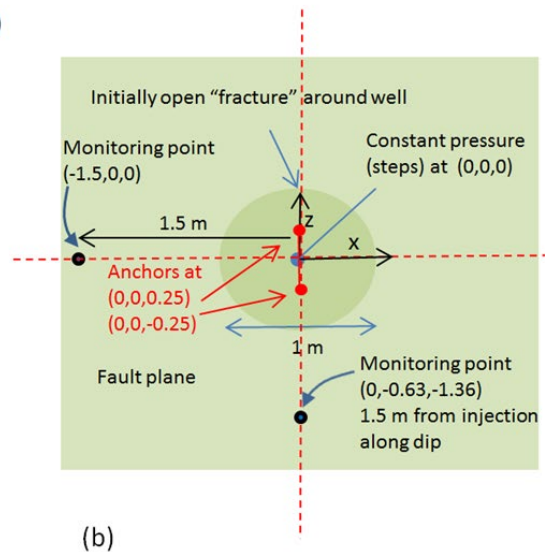
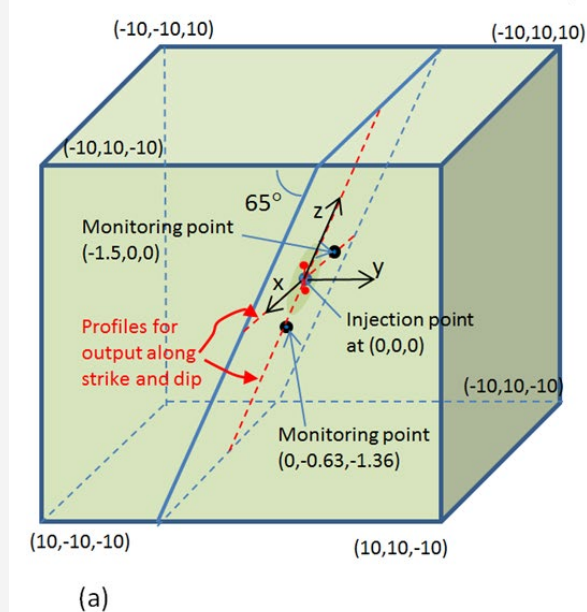
Pressure evolution on the fault during injection



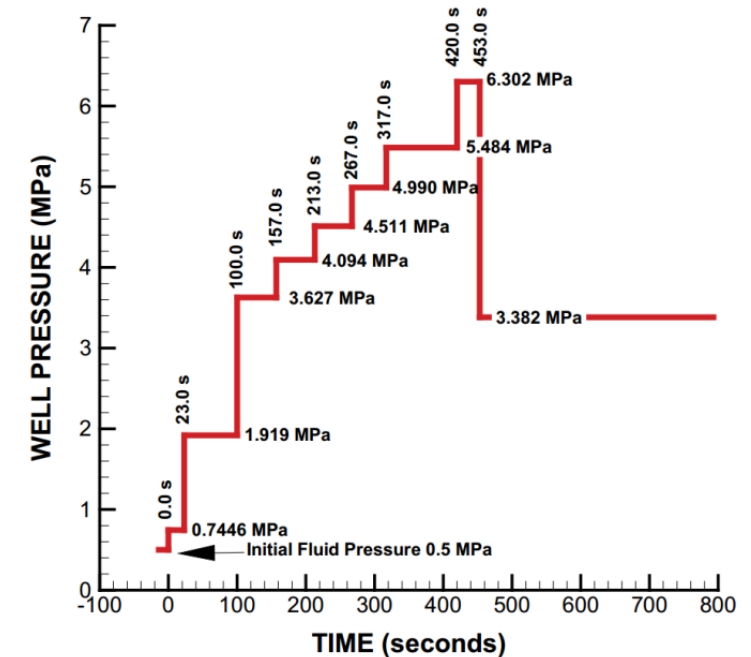


Modelling sequence

- Initial setup: properties, stress, pressure and boundary conditions
- Input: pore pressure history over 800 seconds at (0,0,0)
- Output:
 - Flow rate (in L/min) at (0,0,0)



ions
ions

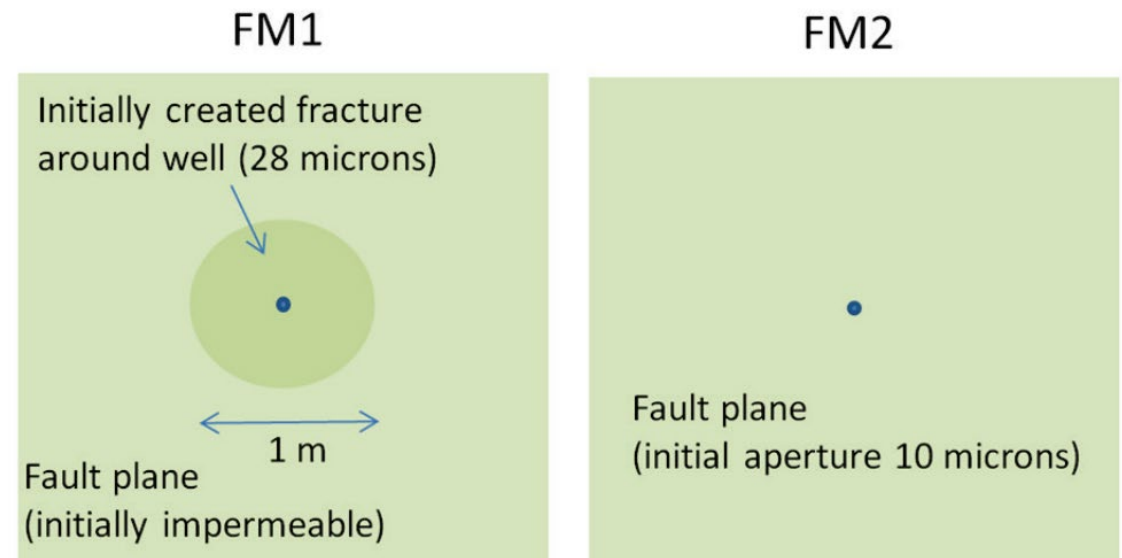




Outline

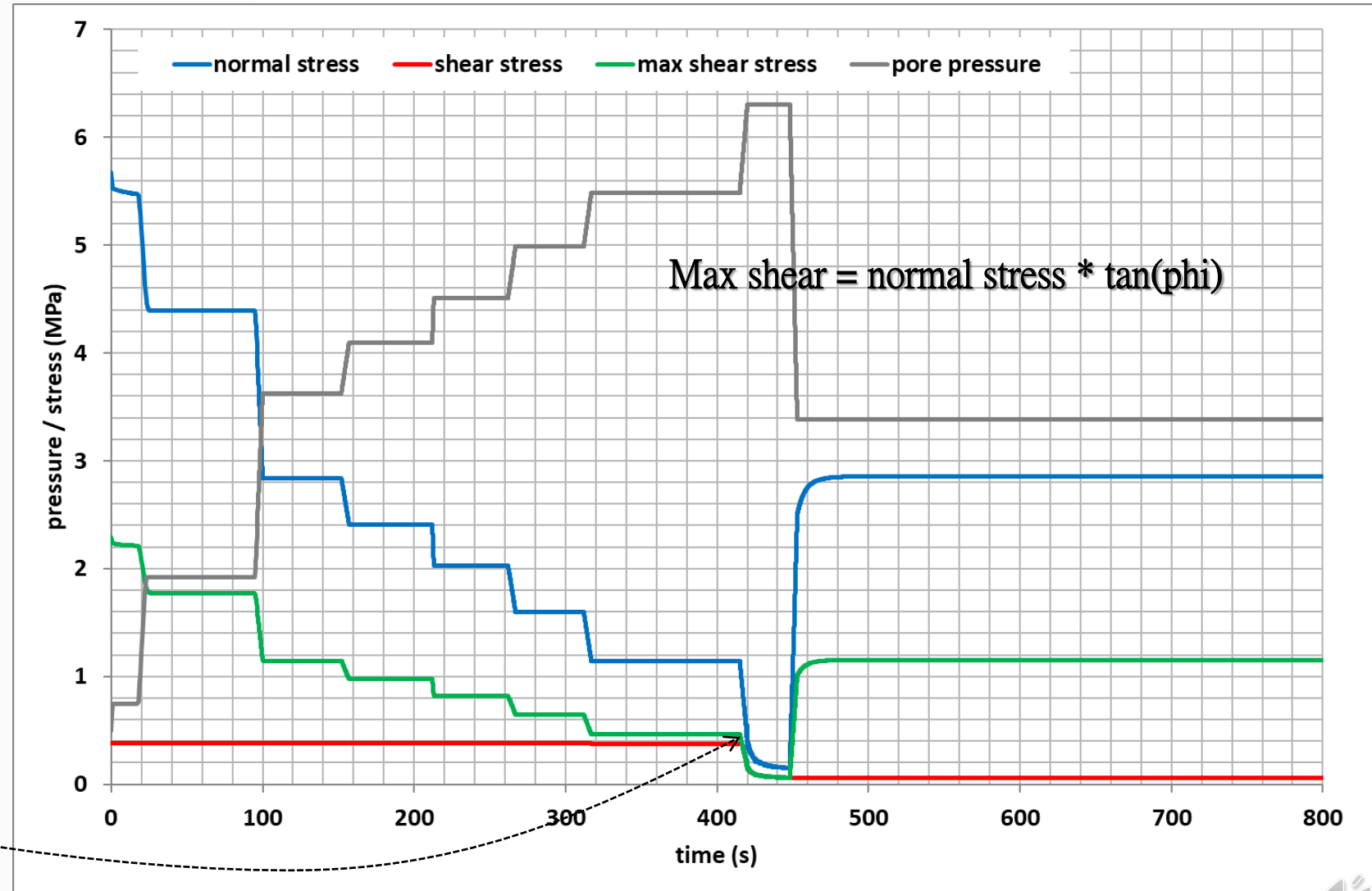
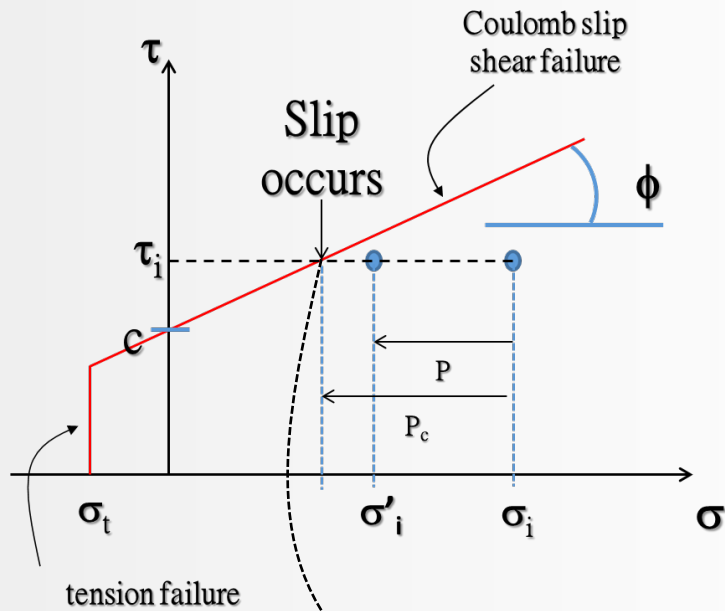


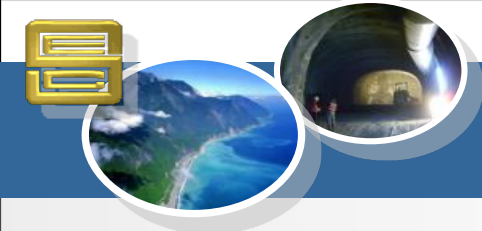
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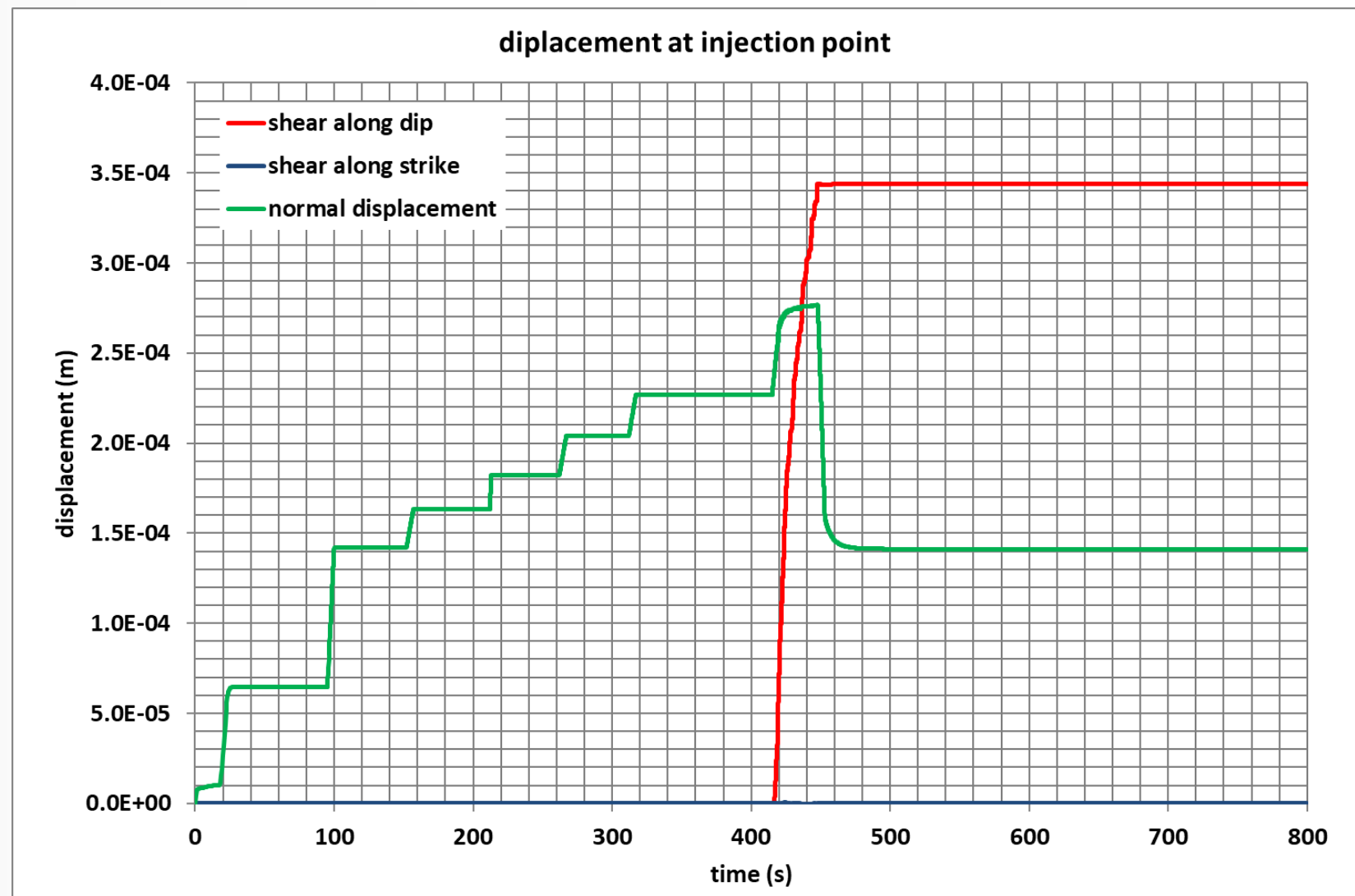
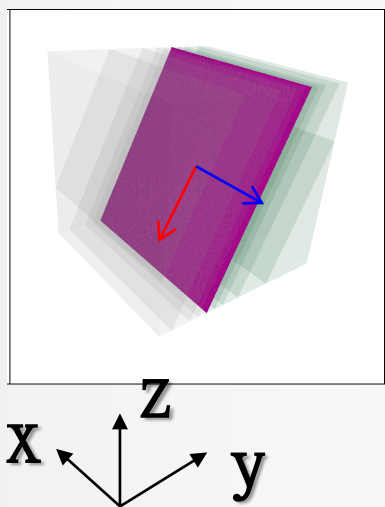


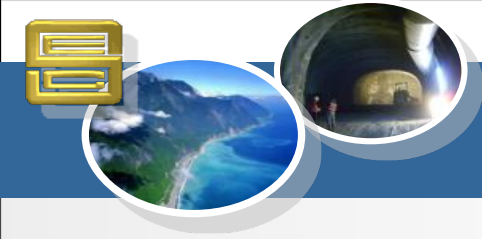
FM1 results: Stress at injection point



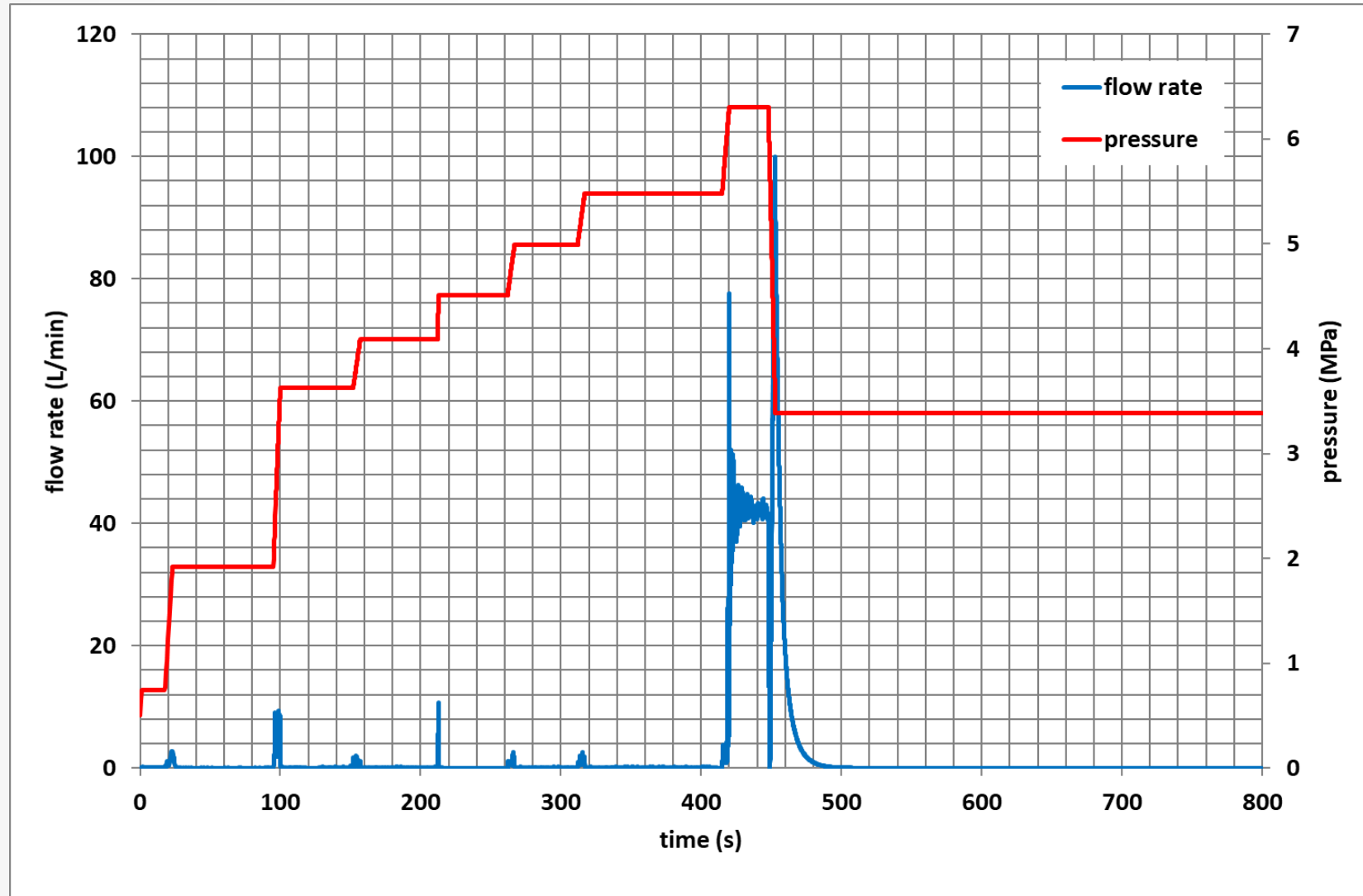


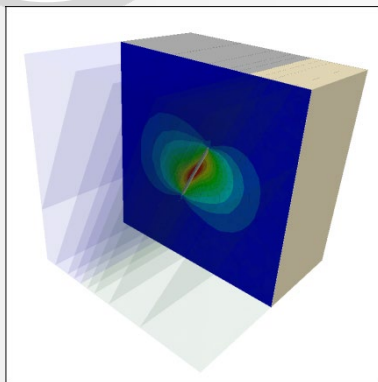
FM1 results: displacement at injection point





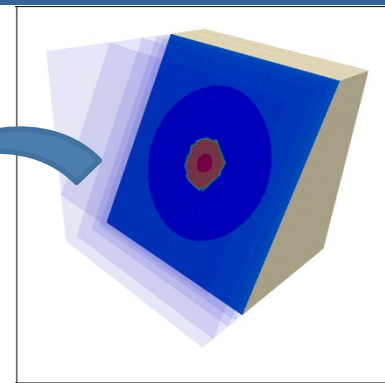
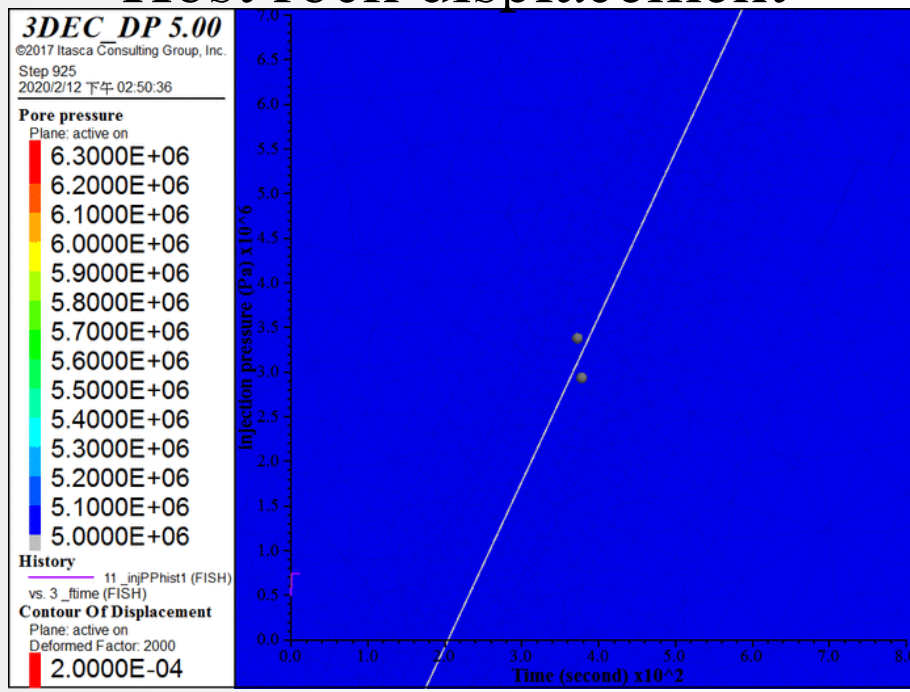
FM1 results: flow rate at injection point





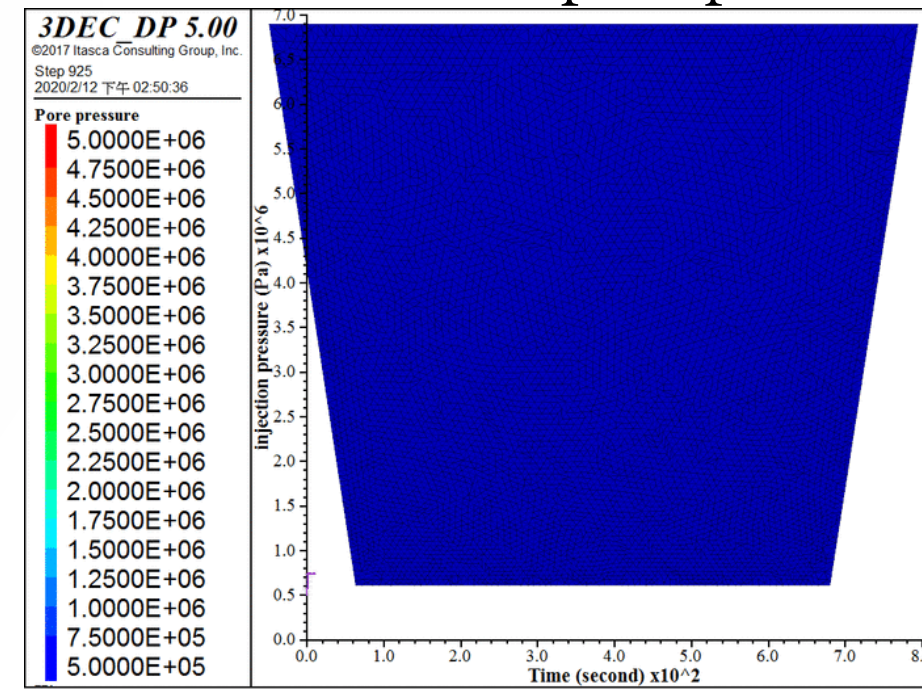
Cutting plane

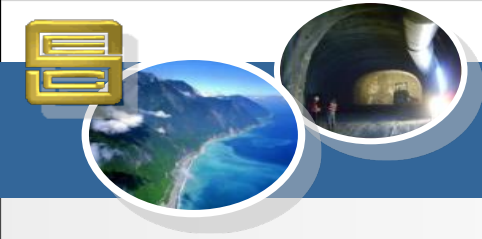
Host rock displacement



Fault plane

Fault pore pressure





Pore pressure evolution from 420 to 430 seconds

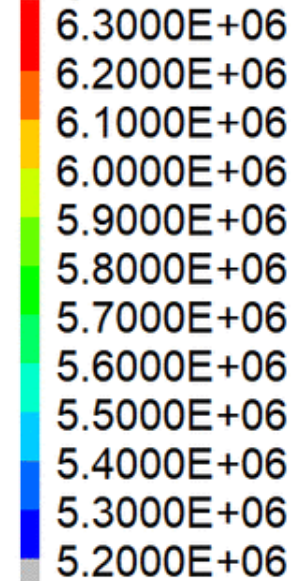
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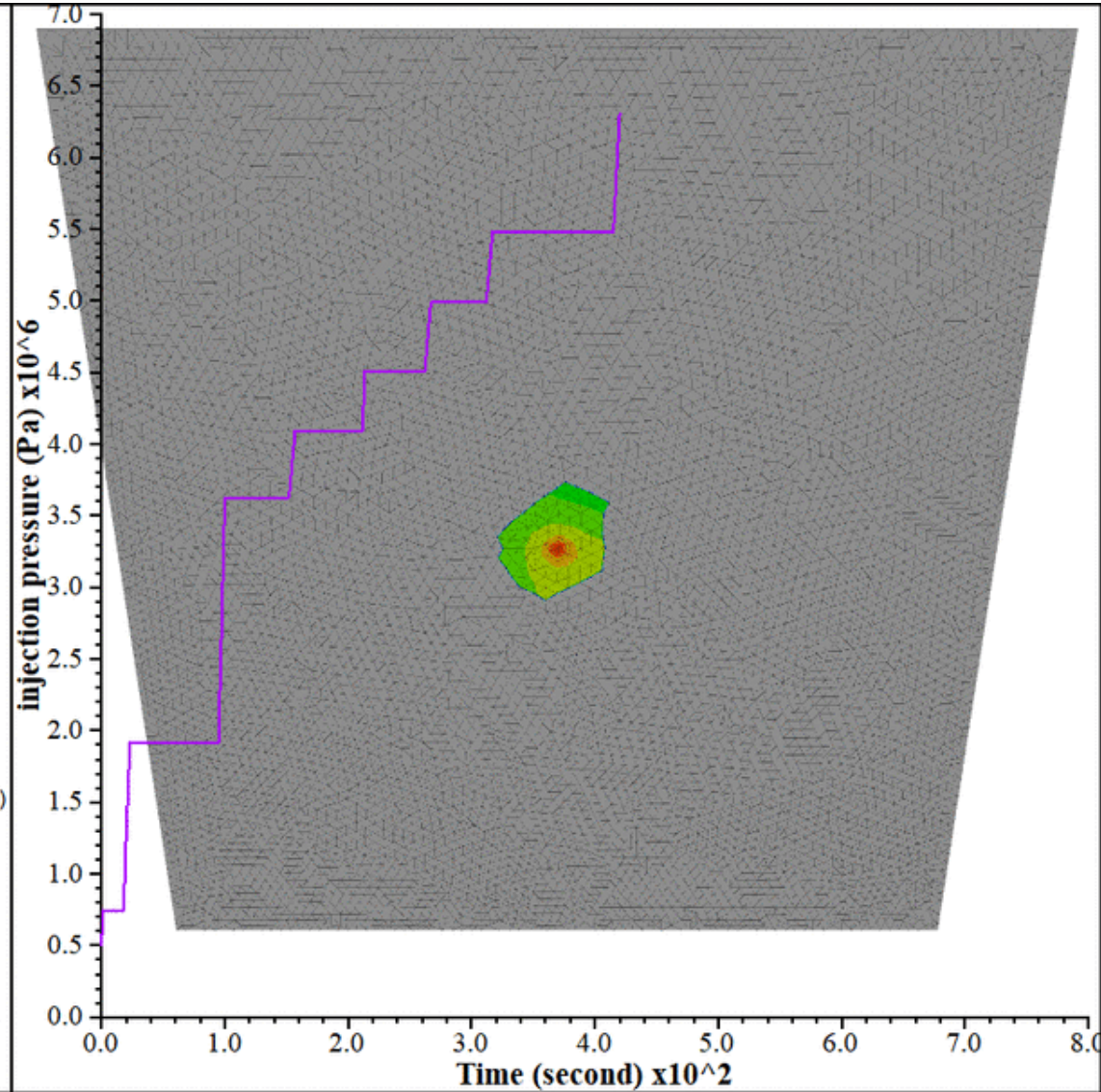
Pore pressure



History

11_injPPhist1 (FISH)
vs. 3_time (FISH)

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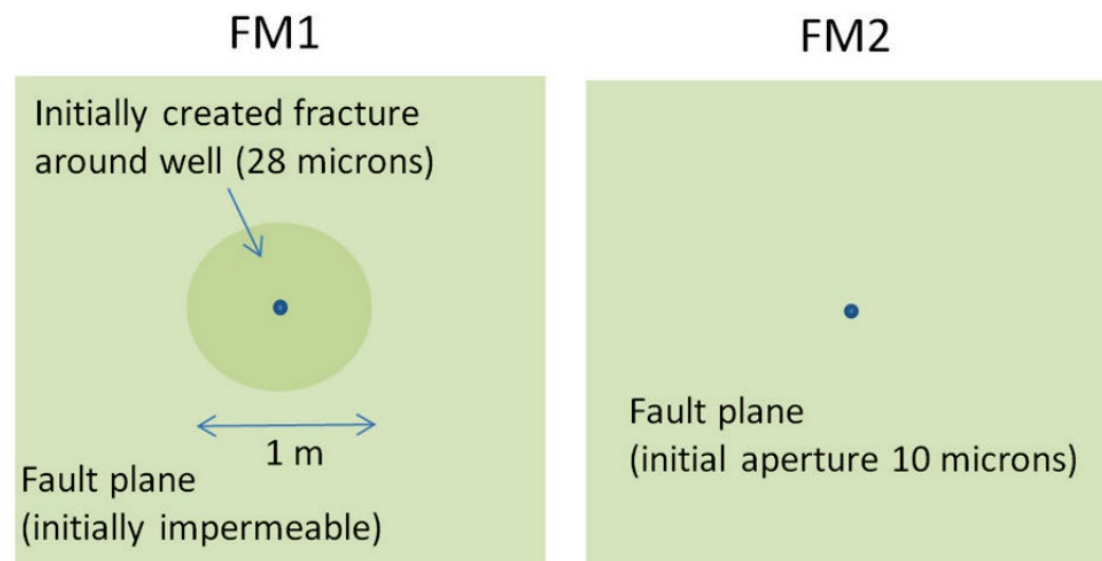


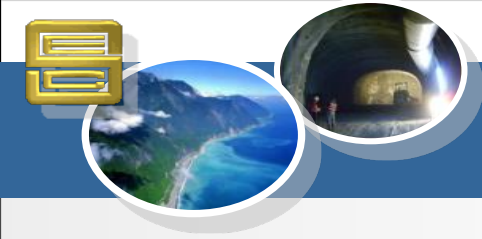


Outline

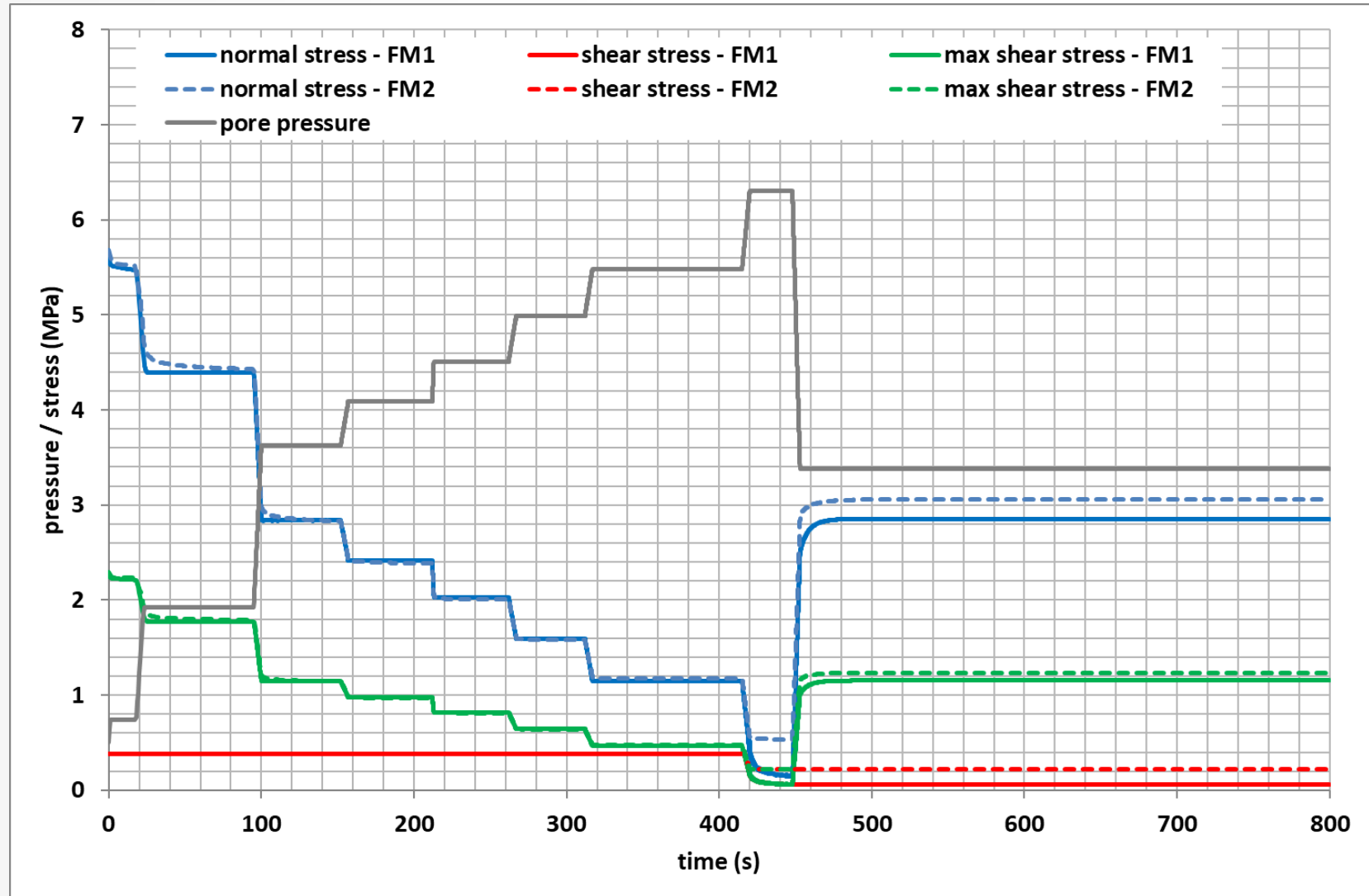


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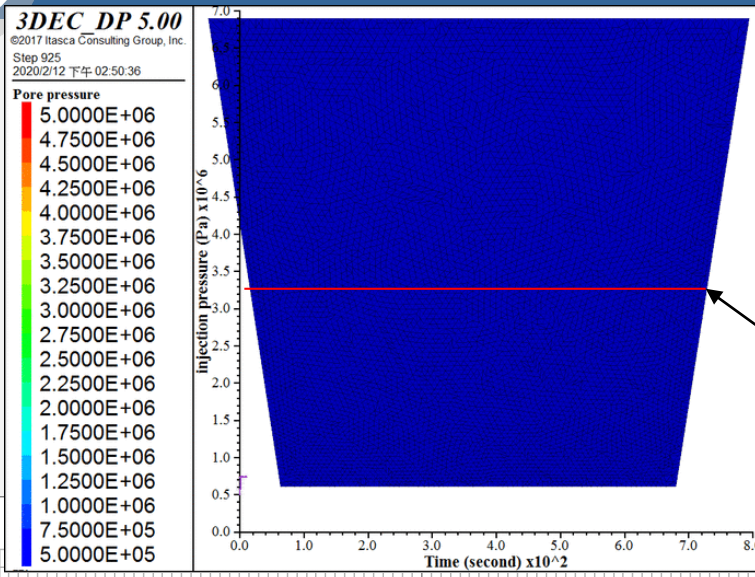


FM1 vs FM2: Stress at injection point

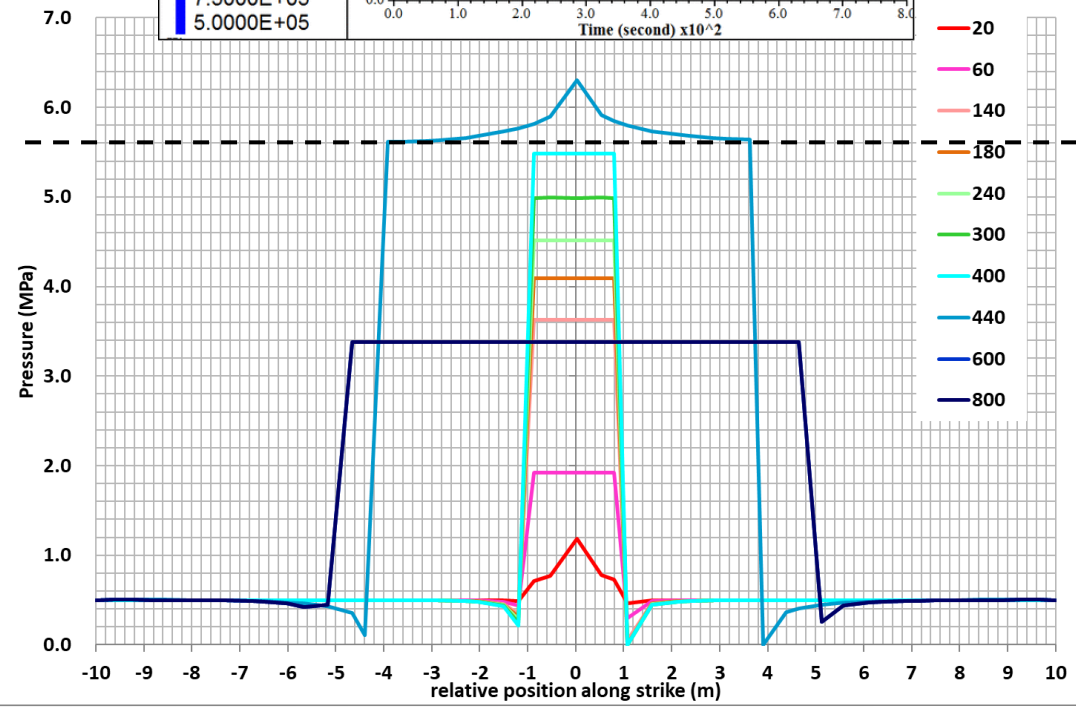
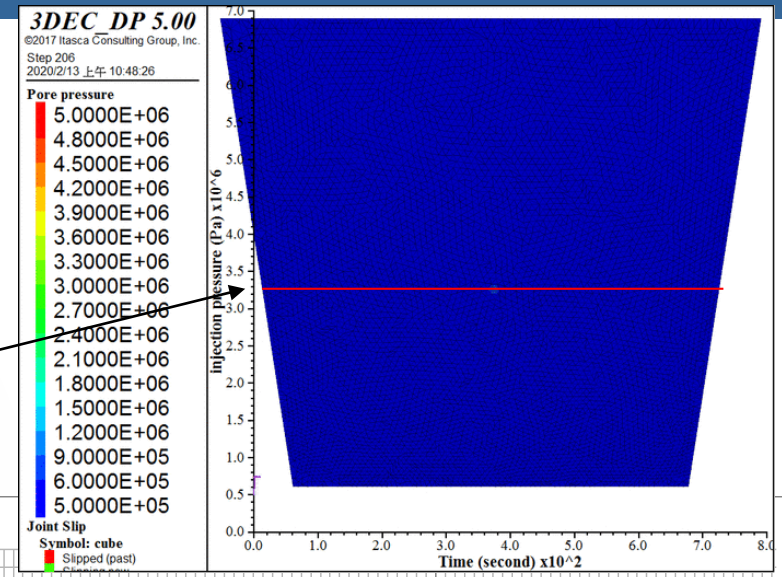




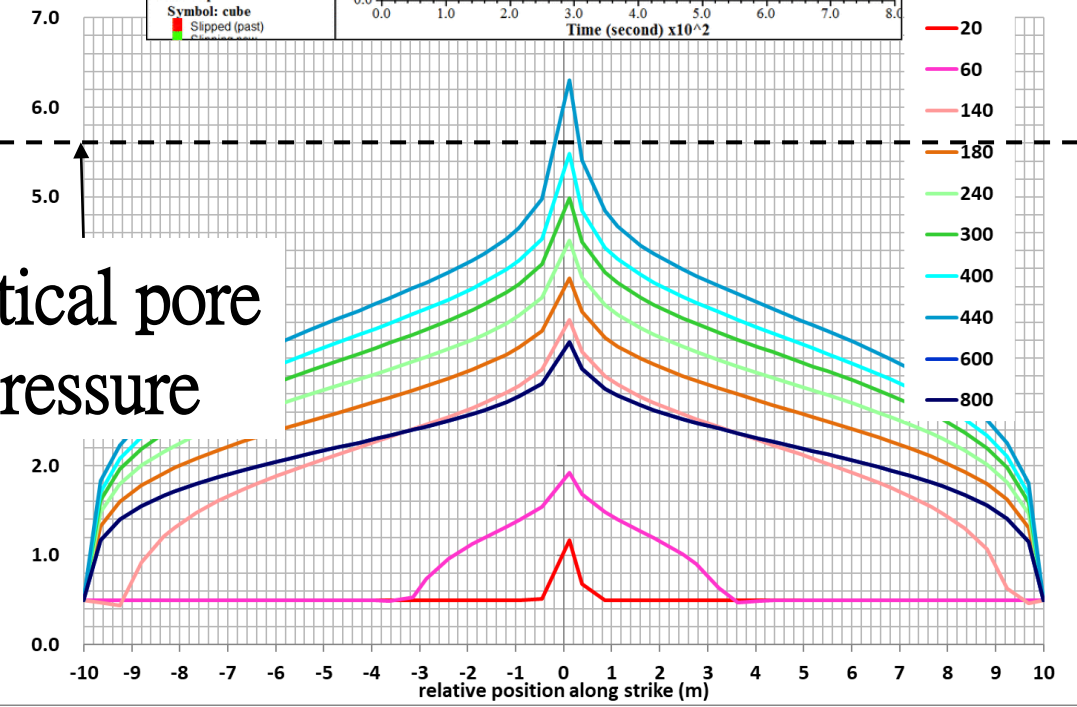
Pore pressure profile along strike

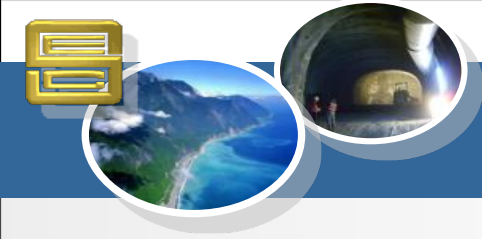


Scan line of the profile

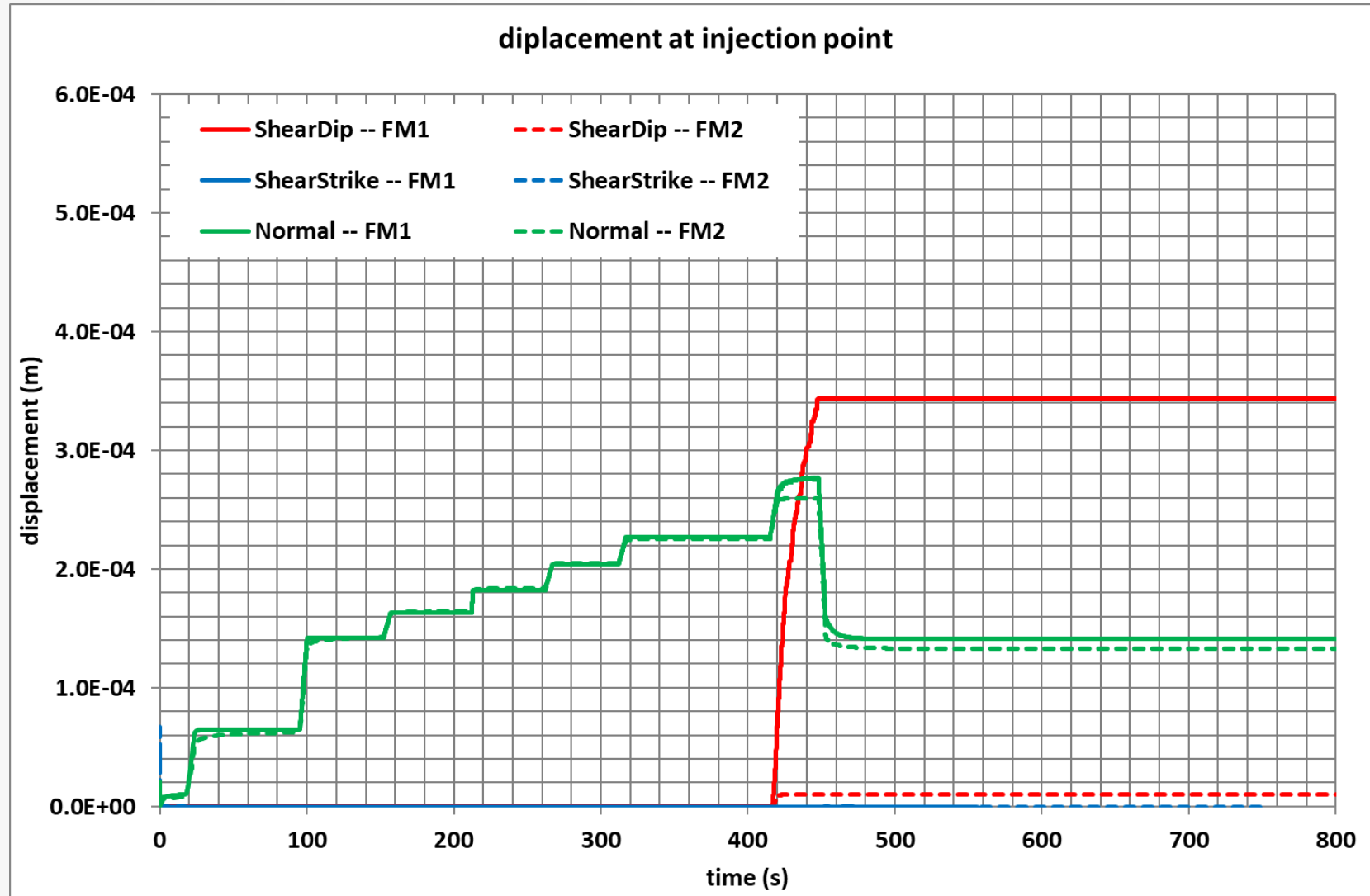


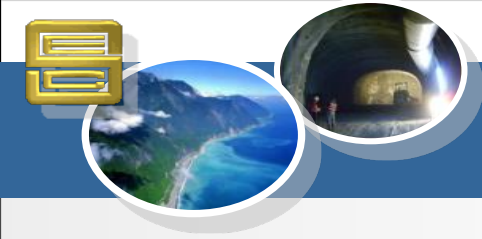
Critical pore pressure



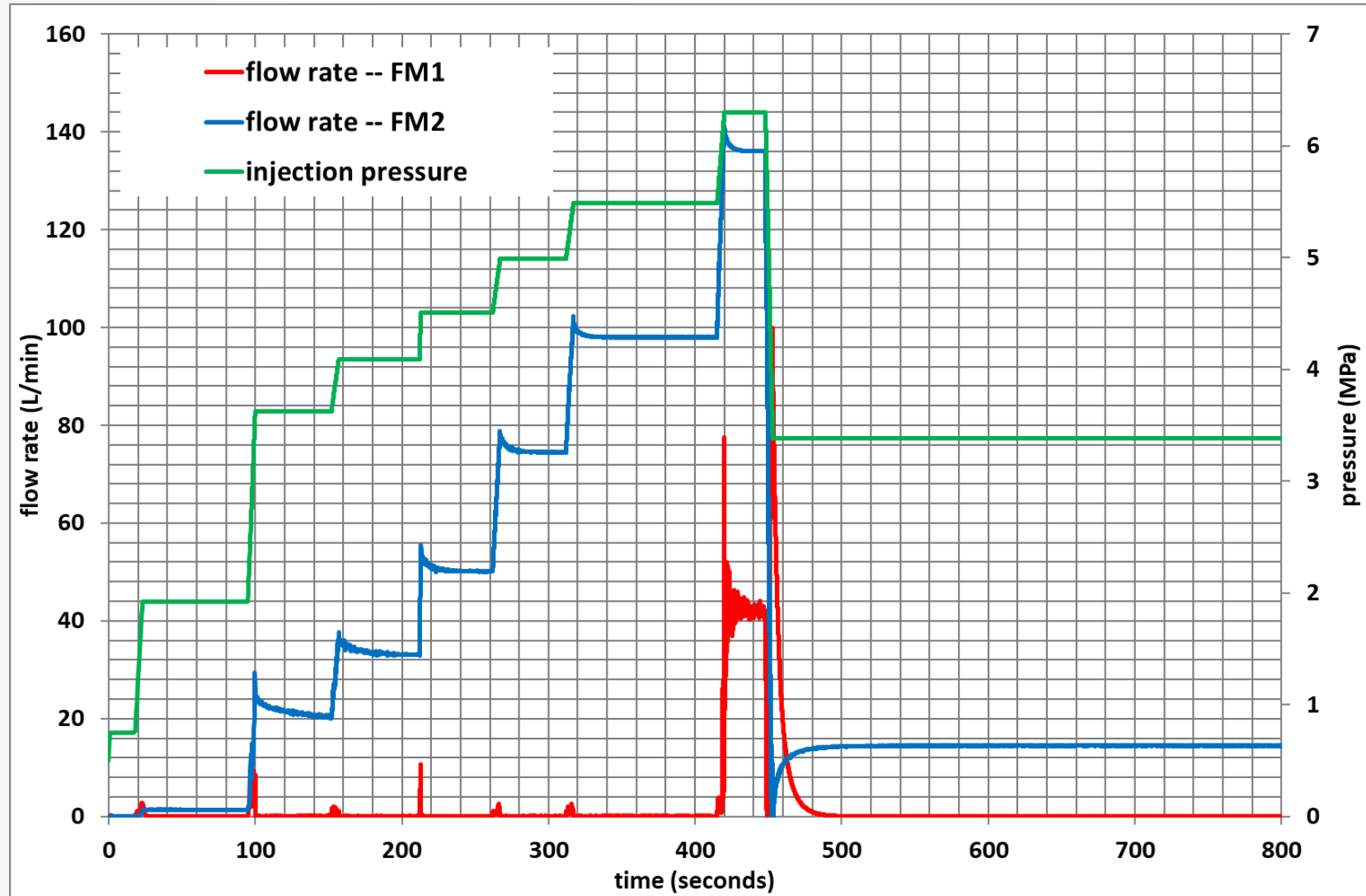


FM1 vs FM2: Displacement at injection point





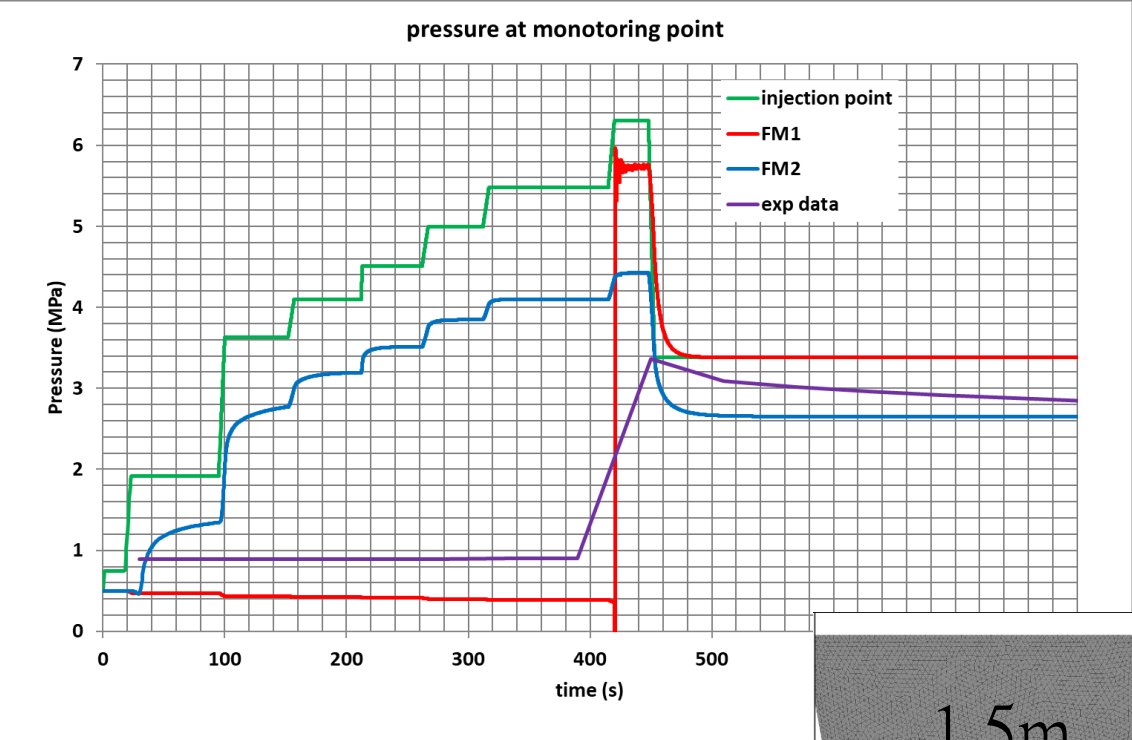
FM1 vs FM2: Flow rate at injection point



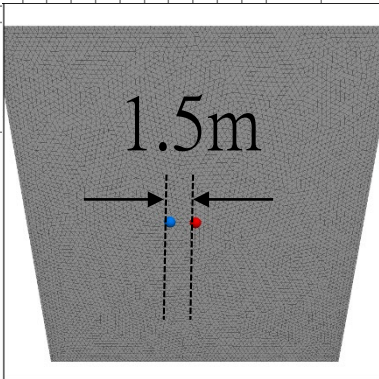


Model vs Data

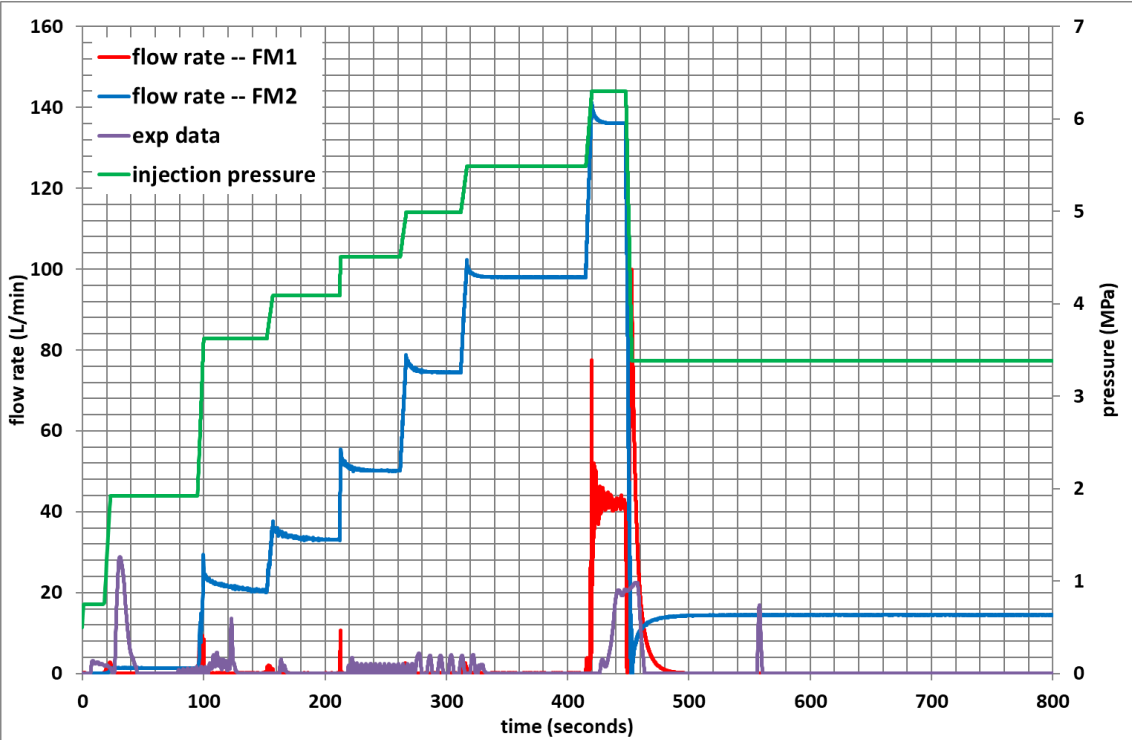
Pressure at monitoring point



injection point
monitoring point



Flow rate at injection point



FM1 is more close to the
experiment data



Conclusion

- Fault slip due to water injection is reproduced using a simple conceptual model and reasonable results are obtained
- The general HM coupling behavior is observed during stepwise water injection
 - ➔ Increase in joint normal displacement with increase in pore pressure
 - ➔ Significant increase in shear displacement if pore pressure is higher than a certain value
 - ➔ Joint closure takes place when water pressure is removed
- Two fluid flow models are studied
 - ➔ FM1: cumulated pore pressure → higher shear displacement and increase in flow rate at onset of fault slip
 - ➔ FM2: flow leakage through the entire flow plane → lower shear displacement → higher flow rate



Thank you for your attention

All questions and comments are welcome
wshiu@sinotech.org.tw