



CFMR

COMITE FRANCAIS DE MECANIQUE DES ROCHES

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March 18, 2022

Dr. Luis Lamas
Secretary General
International Society for Rock Mechanics and Rock Engineering
c/o LNEC, Av. do Brasil 101,
1700-066 Lisboa, Portugal

Nomination of Professor Jean Sulem for the ISRM Science Award

Dear Dr. Luis Lamas,

The ISRM National Group of France, le Comité Français de Mécanique des Roches (CFMR), would like to nominate Professor Jean Sulem, the past President of CFMR for the ISRM Science Award.

Please find attached a descriptive report addressing the Prof. Jean Sulem's achievements as required by the Guideline for the ISRM Science and Technology Awards (approved on 31 May 2019). A supplementary document indicating the publications and the patents of our distinguished colleague is also provided.

CFMR is honored and proud to nominate Professor Jean Sulem for this prestigious award. As you will read in the attached documents, his nomination is eloquent and merits the consideration of the ISRM Board.

Sincerely yours,



P. COSENZA

Philippe Cosenza, Ph.D., Professor
President of *Comité Français de Mécanique des Roches*



Nomination of Professor Jean Sulem for the ISRM Science Award

Descriptive report

I. Major scientific contributions of Jean Sulem

Jean Sulem has brought seminal contributions in the analysis of **time dependent behavior of deep tunnels** and in the understanding and modelling of **failure and instabilities of rocks as a bifurcation phenomenon**.

The convergence law proposed in his PhD thesis has permitted to distinguish between the effect of the face advance and of the delayed behavior of the rock mass on the time-dependent convergence of tunnels. The parameters of this law can be easily calibrated on convergence measurements recorded at early time after the excavation of a section. This convergence law has proven to be very efficient for the prediction of long-term response of the ground around a tunnel and is nowadays commonly used in the design of underground excavations. On the other hand, this law can also be used to evaluate the mechanical parameters of the rock mass from back analysis of convergence measurements.

Jean Sulem together with late Professor Vardoulakis has published pioneering works on the analysis of strain localization phenomena in rock mechanics. Localized deformation in the form of shear bands is one of the most common features of failure in geomaterials. Shear zones appear at all scales from tens of kilometres for large crustal faults, which accommodate tectonic deformation of the Earth's crust, to few microns for slip zones observed inside faults core. The actual width of the shear band plays a key role in the post-localization. It is well known nowadays that a major drawback of classical continuum theories for rate-independent materials is that strain localized in a zone of zero thickness, which is unphysical and which leads to major difficulties when dealing with numerical computations such as mesh dependency. This can be traced back to the absence of a material length in the constitutive equations. This can be remedied by resorting to continuum models with microstructure such as Cosserat continuum or higher grade continua which introduce a material length of the smaller scale physics that limits the localization zone thickness and permits robust post localization computations. The concepts of bifurcation analysis have been applied to various challenging topics such as borehole stability, localized compaction banding in reservoirs, seismic slip in fault zones.

Jean Sulem's contributions in the domain of fault mechanics mainly concern the effect of multi-physics couplings on seismic slip. They highlight the important role of thermal effects in pore fluid pressurization and onset of mineral decomposition as weakening mechanisms of the fault. Such phenomena enhance strain localization inside the fault core and subsequent stronger strength softening and slip acceleration.

In the domain of petroleum geomechanics, Jean Sulem and co-authors have brought significant contributions in constitutive modelling of cement paste from hydration to hardened state in order to assess the cement sheath integrity in oil and gas wells. This is a key issue for avoiding the creation of a micro-annulus leading to fluid migration up to the surface and damage of the infrastructure. Moreover, through experimental studies and modelling, Jean Sulem and co-workers have identified some dominant mechanisms related to migration and deposition of small particles associated with the formation of pseudo-cracks in the form of dilation bands in unconsolidated sand-like reservoirs.

II. Curriculum vitae

Date of birth: 5 January 1959

Nationality: French

- Professor of Rock Mechanics at Ecole des Ponts ParisTech
- Research Director of Exceptional Class at Ecole des Ponts Paris Tech
- Director of Laboratoire Navier, Ecole des Ponts ParisTech, Université Gustave Eiffel, CNRS
- Editor-in-Chief of *Rock Mechanics and Rock Engineering (Springer)*
- Member of the *Steering Committee* of the M/HM Underground Laboratory (ANDRA)
- Member of the Board of Directors of *ALERT Geomaterials* network
- President of the French NG of the International Society of Rock Mechanics (2016-2020)

Degrees

- Habilitation to supervise research (HDR) in Earth Science, University Paris 7, France, 1994
- PhD in Civil Engineering, Ecole Nationale des Ponts et Chaussées, Paris, France, 1983
- Engineering degree, Ecole Nationale des Ponts et Chaussées, Paris, France, 1981

Current and previous positions

2020- : Director of Laboratoire Navier, Ecole des Ponts ParisTech, Université Gustave Eiffel, CNRS

2010-2019: Head of the Geotechnical Group CERMES, Laboratoire Navier

2012- : Professor of Rock Mechanics at Ecole des Ponts ParisTech

1998- : Research Director at Ecole Nationale des Ponts et Chaussées (ENPC)

1985-1998: Research scientist at ENPC

Teaching activities

Graduate classes in Rock Mechanics, Tunnelling, Energy related Geomechanics

Research activities

Research fields

Rock mechanics (Experimental and constitutive modelling), Strain localization and bifurcation phenomena in geomechanics, Fault mechanics, Thermo-hydro-mechanical couplings in geomaterials, Underground storage, Petroleum Geomechanics.

PhD Students

Supervision of 30 PhD students.

Publications and patents (see details in the attached list)

More than **240 publications** (Web of Science H index: 28, 2491 citations, Google Scholar H index: 39, 5540 citations) including 2 books and **3 patents**. Edition of 2 collective books, 4 special issues of international scientific journals, 120 journal papers or book chapters, 123 papers in proceedings of international conferences.

Prestigious invited conferences

- Several keynote lectures in major rock mechanics conferences (EUROCK 2010, ISRM congress 2015, Euro-rock conference 2017, Israel, Computational & geoenvironmental geomechanics for underground and subsurface structures, Nancy, France, 2019, IACMAG 2022)
- 10th International Society of Rock Mechanics online lecture (2015) (<https://isrm.net/isrm/page/show/1229>)
- 2018: Warren Seminar, Vardoulakis lecture, University of Minnesota
- 2019: SPREE Seminar, Northwestern University, Evanston, USA
- 2020: Distinguished Seminar on Rock Mechanics, Tsinghua University Seminar Series, China

Awards

2018: Vardoulakis lecture Award (University of Minnesota, USA)

Editorial activities

2020- : Editor-in-chief of *Rock Mechanics and Rock Engineering (Springer)*

2016-2019: Associate Editor of Rock Mechanics and Rock Engineering (Springer)

2000- : Editorial board member, International Journal of Geomechanics, (ASCE)

2006- : Editorial board member, Acta Geotechnica (Springer)

2013-2015: Panel Advisory member, Géotechnique (ICE)

2015- : Editorial board member, Geomechanics for Energy and Environment (Elsevier)

Project Management

Project manager of Research contracts with a dozen of companies (e.g., Total, Agence Nationale pour la gestion des déchets radioactifs France (ANDRA), Tunnel Euralpin Lyon-Turin (TELT)).



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List of publications and patents

Books

VARDOULAKIS I. and **SULEM J.**, (1995) *Bifurcation in geomechanics*, 459 pp., Taylor and Francis, CRC Press, England (more than 1000 citations in Google Scholar).

PANET M., **SULEM J.** (2021) *Le calcul des tunnels par la méthode convergence-confinement*, Presses des Ponts et Chaussées.

PANET M., **SULEM J.** (2022) *Convergence-confinement Method for Tunnel Design*, Springer.

Collective books:

HATZOR Y., **SULEM J.**, VARDOULAKIS I. (2009) *Meso-scale Shear Physics in Earthquake and Landslide Mechanics*, Taylor & Francis.

STEFANO I., **SULEM J.** (2021) *Instabilities in Geomechanics* Wiley.

Patents

- Méthode de caractérisation du comportement mécanique de ciments, WO 2013124588 A1, Axel-Pierre BOIS, André Garnier, Jean-Benoît LAUDET, Manh-Huyen VU, Siavash GHABEZLOO, **Jean SULEM**, 2013

- A method for determining a plasticity parameter of a hydrating cement paste, QT N° IB2016/000645, Christian URBANCZYK, André GARNIER, **Jean SULEM**, Siavash GHABEZLOO, Nicolaine AGOFACK, 2016

- Method for determining a time window in which a casing pressure test can be performed without damaging a cement sheath, QT N° IB2016/000661, Christian URBANCZYK, André GARNIER, **Jean SULEM**, Siavash GHABEZLOO, Nicolaine AGOFACK., 2016

Some selected publications

Tunnels

SULEM J., PANET M. and GUENOT A., (1987). Closure analysis in deep tunnels. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*, 24(3), pp. 145-154.

VU T.M., **SULEM J.**, SUBRIN D., MONIN N., LASCOLS J. (2013) Anisotropic closure in squeezing rocks : the example of Saint-Martin-la-Porte access gallery, *Rock Mechanics and Rock Engineering*, 46, 2, 231-246.

TRAN MANH, H., **SULEM J.**, SUBRIN D. (2015) Closed-form solution for tunnels with arbitrary cross section excavated in elastic anisotropic ground, *Rock Mechanics and Rock Engineering*, 48, 1, 277-288.

TRAN MANH, H., **SULEM J.**, SUBRIN D., BILLAUX D. (2015) Anisotropic time-dependent modeling of tunnels in squeezing ground, *Rock Mechanics and Rock Engineering*, 48, 6, 2301-2317.

DE LA FUENTE, M., **SULEM, J.**, TAHERZADEH, R., SUBRIN, D. (2020) Tunneling in squeezing ground: effect of the excavation method, *Rock Mechanics and Rock Engineering*, 53, 2, 601-623.

GUAYACÁN-CARRILLO, L. M., **SULEM, J.**, GHABEZLOO, S. (2021). Main insights from 2D/3D poroelastic analysis of tunnel excavation in low permeability anisotropic ground. *Computers and Geotechnics*, 130, 103935

LIU, Y., **SULEM, J.**, SUBRIN, D., TRAN-MANH, H., HUMBERT, E. (2021). Time-dependent behavior of Saint-Martin-la-Porte exploratory galleries: Field data processing and numerical modeling of excavation in squeezing rock conditions. *International Journal of Geomechanics* (ASCE), DOI: 10.1061/(ASCE)GM.1943-5622.0002200 (in print).

Radioactive waste disposals

MONFARED, M., **SULEM, J.**, DELAGE, P., MOHAJERANI, M. (2011) A laboratory investigation on thermal properties of the Opalinus claystone, *Rock Mechanics and Rock Engineering*, 44, 6, 735-747 .

MONFARED, M., SULEM, J., DELAGE, P., MOHAJERANI, M (2012) On the THM behaviour of a sheared Boom clay sample: application to the behaviour and sealing properties of the EDZ, *J. Eng. Geol.*, 124, 47-58.

GUAYACAN-CARRILLO L.-M., SULEM, J., SEYEDI D., GHABEZLOO S., NOIRET A, ARMAND G. (2016) Analysis of long-term anisotropic convergence in drifts excavated in Callovo-Oxfordian claystone, *Rock Mechanics and Rock Engineering*, 49, 1, 97-114.

Strain localization and bifurcation analysis

VARDOULAKIS, I., SULEM, J. and GUENOT A., (1988). Borehole instabilities as bifurcation phenomena. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts* 25(3), pp. 159-170.

VARDOULAKIS I. and SULEM J., (1993). Application of bifurcation theory in rock mechanics problems. in: *Comprehensive Rock Engineering*, Ed: J. Hudson, Pergamon Press vol. 1, chap. 23, pp 575-609.

SULEM, J., I. VARDOULAKIS, E. PAPAMICHOS, A. OULAHNA and J. TRONVOLL, (1999). Elasto-plastic modelling of Red Wildmoor sandstone, *Mechanics of Cohesive-Frictional Materials*, 4, 215-245

SULEM, J., H. OUFFROUKH (2006) Shear banding in drained and undrained triaxial tests on a saturated sandstone: Porosity and permeability evolution, *International Journal of Rock Mechanics and Mining Sciences* 43, 2, 292-310.

SULEM, J., I. STEFANO, E. VEVEAKIS (2011) Stability analysis of undrained adiabatic shearing of a rock layer with Cosserat microstructure. *Granular matter*, 13, 3, 261-268, doi 10.1007/s10035-010-0244-1.

SULEM, J., STEFANO I. (2016) Thermal and chemical effects in shear and compaction bands, *Geomechanics for Energy and the Environment*, 6, 4-21.

ABDALLAH, Y., SULEM, J., BORNERT, M., GHABEZLOO, S., STEFANO, I. (2021). Compaction Banding in High-Porosity Carbonate Rocks: 1. Experimental Observations. *Journal of Geophysical Research: Solid Earth*, 126(1), 1–24.

ABDALLAH, Y., SULEM, J., STEFANO, I. (2020). Compaction Banding in High-Porosity Carbonate Rocks: 2. A Gradient-Dependent Plasticity Model. *Journal of Geophysical Research: Solid Earth*, 125(12), 1–24.

Fault Mechanics

SULEM, J., VARDOULAKIS, I., OUFFROUKH, H., PERDIKATSI, V. (2005) Thermo-poro-mechanical Properties of the Aigion Fault Clayey Gouge - Application to the Analysis of Shear Heating and Fluid Pressurization, *Soils and foundations* 45,2, 97-108

SULEM, J., LAZAR, P., VARDOULAKIS, I. (2007) Thermo-poro-mechanical properties of clayey gouge and application to rapid shearing, *International Journal of Numerical and Analytical Methods in Geomechanics*, 31 523-540

SULEM, J., FAMIN, V. (2009) Thermal decomposition of carbonates in fault zones: slip-weakening and temperature limiting effects, *Journal of Geophysical Research*, 114, B03309.

BRANTUT, N., SULEM, J., SCHUBNEL, A. (2011) Effect of dehydration reactions on earthquake nucleation: Stable sliding, slow transients and unstable slip. *Journal of Geophysical Research* 116, B05304,

RATTEZ H., STEFANO, I., SULEM, J. (2018). The importance of Thermo-Hydro-Mechanical couplings and microstructure to strain localization in 3D continua with application to seismic faults. Part I: Theory and Linear Stability Analysis. *Journal of Mechanics and Physics of Solids*, 15, 54-76,

RATTEZ H., STEFANO, I., SULEM, J., VEVEAKIS M., POULET T. (2018). The importance of Thermo-Hydro-Mechanical couplings and microstructure to strain localization in 3D continua with application to seismic faults. Part II: Numerical implementation and post-bifurcation analysis. *Journal of Mechanics and Physics of Solids*, 115, 1-29.

Petroleum Geomechanics

GHABEZLOO, S., SULEM, J., GUÉDON, S., MARTINEAU, F., SAINT-MARC J. (2008) Poromechanical behaviour of hardened cement paste under isotropic loading, *Cement and Concrete Research*, Volume 38, 12, 1424-1437.

GHABEZLOO, S., SULEM, J., GUÉDON, S., MARTINEAU, F. (2009) Effective stress law for the permeability of a limestone, *International Journal of Rock Mechanics and Mining Sciences*, 46(2) 297-306.

AGOFACK, N., GHABEZLOO, S., SULEM, J., GARNIER, A., URBANCZYK, C. (2019). Experimental investigation of the early-age mechanical behaviour of oil-well cement paste. *Cement and Concrete Research*, 117, 91–102.

FEIA S., DUPLA J.C., GHABEZLOO S., **SULEM, J.**, CANOU J., ONAISI A., LESCANNE H., AUBRY E. (2015) Experimental investigation of particle suspension injection and permeability impairment in porous media, *Geomechanics for Energy and the Environment*, 3, 24-39.

NGUYEN, T.-T. , **SULEM, J.**, MUHAMMED, R., DUPLA, J.-C., CANOU, J., BOERO-ROLLO J.-G., OCHI, J. (2022). An experimental setup with radial injection cell for investigation of fracturing in unconsolidated sand reservoirs under fluid injection, *Journal of Petroleum Science and Engineering*, <https://doi.org/10.1016/j.petrol.2022.110362>.