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Alternancia de calizas y margas. Jurásico inferior. Playa de Rodiles, Asturias (© 2022 Juan Antonio DíezTorres)

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Editorial

Estimados miembros de la Sociedad Española de Mecánica de Rocas,

Es para nosotros un honor anunciar que la ciudad de Alicante será la sede del próximo Simposio Europeo de Mecánica de Rocas, Eurock 2024. Este evento, organizado por la Universidad de Alicante con el apoyo de la Sociedad Española de Mecánica de Rocas (SEMR) y la Sociedad internacional de Mecánica de Rocas (ISRM), reunirá a expertos de todo el mundo para discutir los avances en el campo de la mecánica de rocas y compartir sus investigaciones y desarrollos más recientes.

Eurock 2024 tendrá lugar del 15 al 19 de julio de 2024 en el Aulario II del campus de la Universidad de Alicante. La ciudad es conocida por su clima soleado, sus playas, su rica gastronomía y su historia, lo que la convierte en un lugar ideal para el intercambio de conocimientos y experiencias en el campo de la mecánica de rocas. Con su combinación única de patrimonio cultural, historia y atractivos naturales, la ciudad ofrece una ubicación muy atractiva para los participantes de distintas nacionalidades que asistirán al evento.

El programa contará con sesiones temáticas, talleres formativos y salidas de campo, que cubrirán una amplia gama de aspectos relevantes de la mecánica de rocas, tanto del ámbito de la ingeniería de minas y la ingeniería civil, así como la geología. Asimismo, se cubrirán también otros aspectos más generales, tales como el empleo de la inteligencia artificial, los sensores remotos o la modelización numérica. Además, se dispondrá de una amplia superficie dedicada a la exposición, por parte de empresas especializadas del sector.

Sin duda alguna, este simposio es una oportunidad única para que los miembros de la SEMR se reúnan con colegas de todo el mundo, intercambien ideas y establezcan colaboraciones para abordar los desafíos actuales en este campo en constante evolución. Además, los asistentes tendrán la oportunidad de asistir a sesiones técnicas, talleres formativos, excursiones técnicas, exposiciones y eventos sociales que les permitirán ampliar su red de contactos y aprender de expertos de renombre en la materia.

Por último, deseamos expresar nuestro agradecimiento a todos los patrocinadores y colaboradores que están trabajado incansablemente para hacer posible este evento. Esperamos con entusiasmo dar la bienvenida a una gran cantidad de delegados de todo el mundo a Alicante en 2024 para compartir conocimientos, hacer nuevas conexiones y disfrutar de todo lo que esta hermosa ciudad tiene para ofrecer.

¡Os esperamos en Alicante!

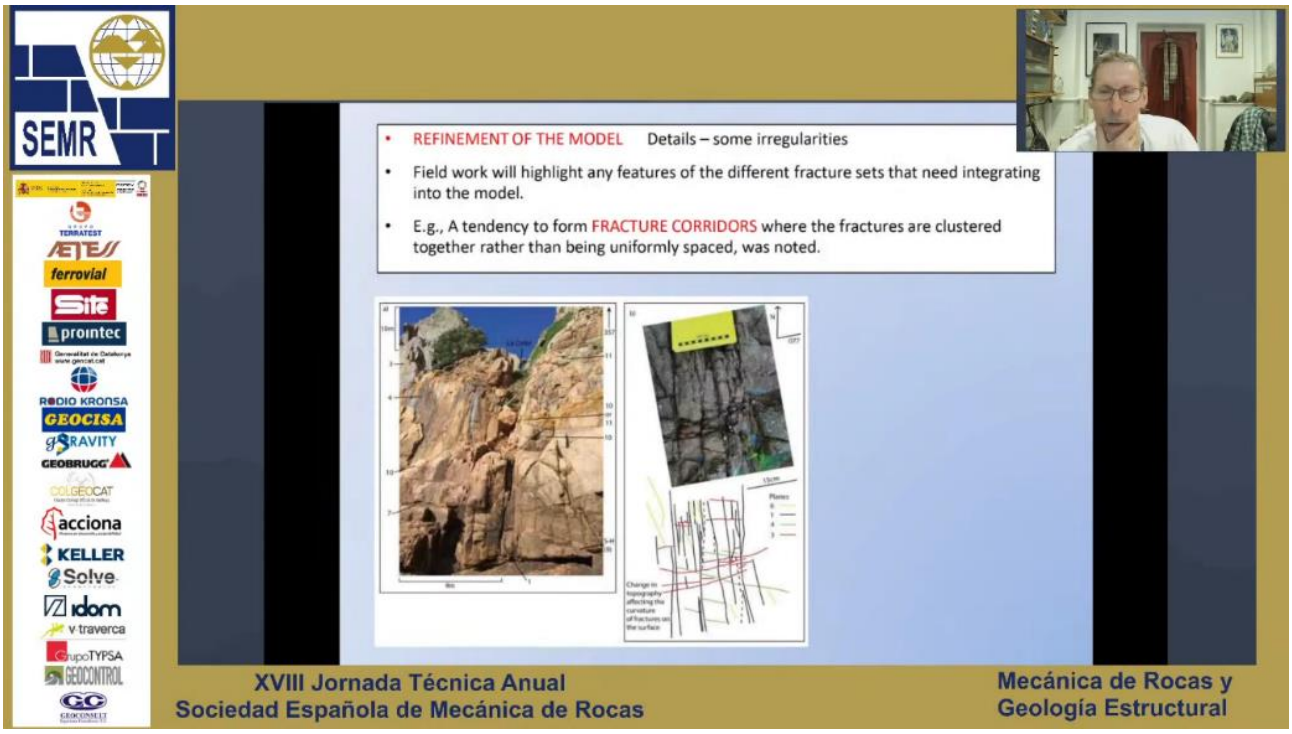
El comité organizador de Eurock 2024
Roberto Tomás, Miguel Cano, Adrián Riquelme,
José Luis Pastor, David Benavente, Salvador Ordóñez

Jornada Técnica Anual 2021

El día 13 de mayo de 2021 se celebró la XVIII Jornada Técnica Anual de la Sociedad. Debido a las restricciones de la pandemia la Jornada se celebró en modalidad telemática.
Esta jornada llevó por título "Mecánica de Rocas y Geología Estructural" y contó con la participación remota de más de 100 personas.

Durante el evento, se presentaron las siguientes ponencias:

- The geological evolution of fracture networks in rocks, impartida por el profesor del Imperial College John Cosgrove.
- The help of structural geology in tunneling activities, a cargo de Phillippe Vaskou (Francia).
- Estructura interna y propiedades mecánicas de la Falla de Alhama (Murcia) por el profesor de la UCM J. Miguel Insúa Arevalo.



Prof. John Cosgrove durante su presentación telemática en la Reunión Anual de la SEMR 2021

El evento sirvió también para entregar la distinción como Socio de Honor al Profesor de la UPC D. Eduardo Alonso Pérez de Ágreda que dirigió unas palabras al público.

La jornada concluyó con la exposición de Carmen C. García Fernandez (UNIOVI) del trabajo de investigación "Mecanismos de inicio de la rotura en materiales de comportamiento frágil, bajo condiciones traccionales" ganador de la edición 2021 del premio al mejor trabajo de investigación en Mecánica de Rocas para Jóvenes Investigadores.

El video completo de la Jornada está disponible en el canal de Youtube de la Sociedad y, hoy en día, cuenta con cerca de 900 visualizaciones. El vídeo puede verse pinchando aquí.

Jornada Técnica Anual 2022

El día 28 de abril de 2022 se celebró la XIX Jornada Técnica Anual de la Sociedad. En esta ocasión, la Jornada pudo celebrarse en modalidad presencial, al igual que otros años, en las instalaciones del CEDEX en Madrid.

Esta jornada llevó por título "Ensayos de Laboratorio en Mecánica de Rocas: Jóvenes Investigadores" y contó con la asistencia de unas 80 personas.

Durante el evento, se presentaron las siguientes ponencias:

- Leandro Alejano Monge (U. Vigo, SEMR): Métodos sugeridos de ensayo de la ISRM
- Mauro Muñiz Menéndez (CEDEX, SEMR): Ensayo de tracción directa en roca
- Álvaro Rabat Blázquez (U. Alicante): Ensayo needle penetration
- Ignacio Pérez Rey (CEDEX, SEMR): Ensayo de inclinación (tilt test)
- Andrea Muñoz Ibáñez (U. Coruña, U. Vigo): Ensayo de tenacidad a la fractura
- Jon Justo Urrutia (Cimentaciones Abando, UC): Fracturación a altas temperaturas

Fernando Pardo de Santayana (Director del Laboratorio de Geotecnia del CEDEX), Áurea Perucho (Directora del CEDEX) y Leandro Alejano (Presidente de la SEMR) durante la inauguración de la Jornada.

Durante la Jornada se hizo una presentación, por parte de Roberto Tomás Jover (profesor de la U. Alicante y vicepresidente de la SEMR) del Congreso Europeo de Mecánica de Rocas EUROCK 2024 que se celebrará en Alicante.

El video completo de la Jornada está disponible en el canal de Youtube de la Sociedad: https://www.youtube.com/@sociedadespanolademecanica7895

XI Simposio Nacional de Ingeniería Geotécnica

La SEMR participó en la organización del XI Simposio Nacional de Ingeniería Geotécnica que se celebró en Mieres (Asturias) entre el 24 y el 27 de mayo de 2022.

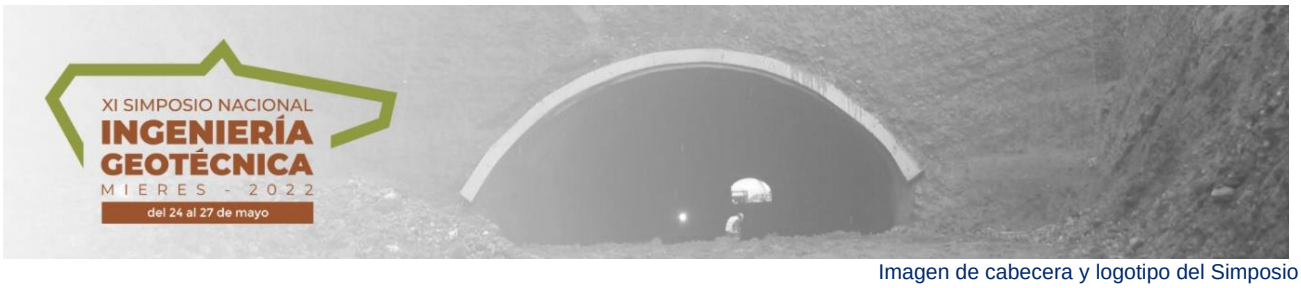


Imagen de cabecera y logotipo del Simposio

La Sociedad organizó una sesión técnica específica sobre mecánica de rocas que se tituló "La Mecánica de Rocas y la Seguridad de las Obras". En esta sesión se impartieron dos ponencias invitadas: la primera por Adrián Riquelme Guill (Universidad de Alicante) con el título "Aplicaciones de las técnicas de adquisición remota al estudio de familias de discontinuidades planas en taludes rocosos" y la segunda por Celestino González Nicieza (Universidad de Oviedo) con el título "Inyecciones en el terreno. ¿Dónde está el límite?".

Además de estas ponencias invitadas, se presentaron otras 15 comunicaciones.

Todas estas ponencias, junto al resto de las presentaciones del congreso se recogen en el libro de actas: "XI Simposio Nacional de Ingeniería Geotécnica. La Geotecnia en apoyo de la seguridad y el desarrollo sostenible. ISBN: 978-84-09-40096-6".

Sesión sobre mecánica de rocas celebrada durante el XI SNIG celebrado en Mieres (Asturias)

Premio Bienal de la SEMR 2022

Durante la Jornada Técnica se entregó el 9º Premio SEMR al mejor trabajo de investigación en Mecánica de Rocas para Jóvenes Investigadores. El galardonado fue **Jon Justo Urrutia** por el trabajo "Análisis de la fractura de rocas entalladas bajo diferentes condiciones de carga y de temperatura mediante criterios locales".

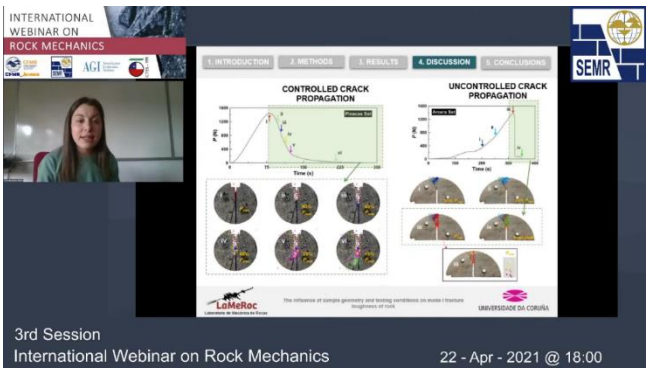
El tribunal también concedió una **Mención de Honor a Miguel Ángel Mánica Malcom** por el trabajo "Análisis de excavaciones subterráneas en suelos duros – rocas blandas arcillosas".

Jon Justo recibe el diploma de manos del Presidente de la SEMR Leandro Alejano

International Webinar on Rock Mechanics

Un grupo de miembros jóvenes de la SEMR colaboraron en la organización de una serie de conferencias telemáticas sobre mecánica de rocas. Esta serie denominada International Webinar on Rock Mechanics fue fruto de la colaboración entre la Jóvenes miembros de la SEMR, la AGI (Italia), CFMR_Jeunes (Francia), CTES-YM (Chile), SPEG (Perú) e Ingeokring (Países Bajos).

La tercera charla de la serie corrió a cargo de SEMR y fue impartida por la investigadora de la Universidad de A Coruña, Andrea Muñoz Ibáñez con el título "The influence of sample geometry and testing conditions on mode I fracture toughness of rock". El vídeo de esta charla también está disponible en el canal de Youtube de la SEMR (puede acceder pinchando aquí).



Dra. A. Muñoz durante la tercera session del International Webinar on Rock Mechanics

Esta iniciativa fue vista con muy buenos ojos por la ISRM incorporándola dentro de su organización con la denominación de ISRM Young Members' Monthly Webinar Series y en cuya organización participan miembros de la SEMR.

Antonio Gens, Socio de Honor de la SEMR

Por decisión unánime de la Junta Directiva, la SEMR nombró Socio de Honor al profesor de la UPC, D. Antonio Gens Solé. La decisión se basó en su impresionante trayectoria, tanto en el mundo académico como en la Geotecnia aplicada, así como su actividad en pro de la Ingeniería Geotécnica con la participación en todo tipo de comités, grupos de trabajo y eventos.

Durante la sesión de Mecánica de Rocas, que coordinó la Sociedad, en el XI Simposio Nacional de Ingeniería Geotécnica de Mieres, se le hizo entrega de una placa conmemorativa.

El profesor Antonio Gens recibe la placa conmemorativa de su nombramiento como Socio de Honor de la SEMR de manos del presidente Leandro Alejano durante el XI SNIG celebrado en Mieres (Asturias).

La carrera del Profesor Gens empezó en los años 70 del pasado siglo. Obtuvo el título de Ingeniero de Caminos, Canales y Puertos en la Universidad Politécnica de Madrid y posteriormente cursó un postgrado en el Imperial College de Londres. Tras pasar por la empresa Rodio, volvió como investigador al Imperial College donde se doctoraría en 1982. En 1983 comienza su andadura en la Universidad Politécnica de Cataluña donde es catedrático desde 1988.

A lo largo de esta carrera ha sido galardonado con los más prestigiosos premios del mundo geotécnico entre los que se pueden mencionar la Terzaghi Oration (2022), Geotechnical Research Medal (2014), Doctor Honoris Causa. Université de Grenoble - Joseph Fourier (2014), Coulomb Lecture (2013), George Stephenson Medal (2012), Fellow of the UK Royal Academy of Engineering (2011), varias Telford Medal (2007) o la 47th Rankine Lecture (2007).

Resumen de los artículos presentados por españoles al EUROCK 2021

Todos los artículos del congreso fueron publicados por la editorial IOP en formato abierto en el volumen 833 de la revista IOP Conference Series: Earth and Envirnmental Science: https://iopscience.iop.org/volume/1755-1315/833

KEYNOTE LECURE: Considerations on failure mechanisms of rock slopes involving toppling

L R Alejano

Probably, the most relevant issue in stability analysis of rock slopes is the correct identification of the potentially occurring failure mechanism, which should be mechanically analyzed to assess stability, later on. Traditional rock slope stability approaches consider planar, wedge, rotational and toppling failure as potential instability mechanisms. Whereas the three first types involve sliding associated to different geometries of the unstable element or mass, toppling often involves also sliding and very complex geometries of multiple elements. In this sense, toppling should be contemplated more like a group of mechanisms than like a simple mechanism such as planar or wedge failure. Toppling could involve moreover one or many blocks. Initial studies classified toppling failure mechanisms in three groups: block, flexural and block-flexural toppling. The stability analysis of rock slopes prone to toppling involves the mechanical analysis of individual slab like blocks, which are considered to present perfect rectangular cross-section. However, the actual shape of these rock elements may not be so regular, so the influence of more realistic irregular shapes is usually not accounted for. In this article, the author will address how some geometry variations may be included in this analysis based on analytical considerations and physical models. Additionally, failure mechanisms observed in rock cuts and open pits often combine toppling with other sliding phenomena in different more or less complex manners. These combined mechanisms involving toppling will be reviewed and some case studies worked out by the author will be presented. Moreover, all along this document, considerations will be put forward regarding the nature of toppling related phenomena where small equilibrium variations may produce a release of a large mechanical energy, which can ultimately produce the destabilization of large slopes or groups of blocks. This suggests that it is wise in these cases to analyze not only the factor of safety, but also the evolution of the potential failure mechanism to understand what is happening and eventually provide sensible and reliable designs or appropriate remedial measures.

Determination of uniaxial tensile strength of brittle materials using tubular samples

D J Guerrero-Miguel, M I Alvarez-Fernández, M B Prendes-Gero and C González-Nicieza

Tensile strength of brittle materials is usually obtained through Brazilian tests. It is accepted that failure is initiated at the centre of the sample and that it propagates through the material, creating a tensile failure plane along the vertical diameter or at the majority of it. Then, the tensile stress developed at the centre of the disc is considered as the tensile strength of the material tested. However, the stress state along the vertical diameter is always biaxial, even in the centre of the sample. This implies that the strength measured using such technique is not the uniaxial tensile strength. In this article, the expressions of the stress state supported by a tubular sample subjected to a novel device to determine the tensile strength of brittle materials are described. Besides, it is noticed that the failure plane contains points with the maximum uniaxial tensile strengths so the testing method is adequate to determine the uniaxial tensile strength of brittle materials.

The importance of accounting for matedness when predicting the peak shear strength of rock joints

F Ríos-Bayona, E Andersson, F Johansson1 and D Mas Ivars

The contribution from both surface roughness and matedness in the peak shear strength of rock joints is not yet well understood. To be able to account for the influence of matedness on the peak shear strength of rock joints, both surface roughness and aperture need to be considered. Technical developments over the past few decades have shown that both surface roughness and aperture can be accurately measured using optical scanning. This technique has been utilized to account for surface roughness parameters in various shear strength criteria that assume a perfect match between joint surfaces. This paper investigates and compares the capabilities of two shear strength criteria to predict the peak shear strength of rock joints with different matedness. The analysis performed shows that both approaches have their strengths and limitations. For instance, accounting for the matedness of unmated rock joints based on their surface aperture gives better predictions of the peak shear strength. On the other hand, accounting for shearing failure mode becomes relevant at high normal loads. A possible way forward to reduce the limitations of these criteria could be to combine their strengths.

Analysis of size effects on the Hoek-Brown failure criterion of intact granite samples

M A González-Fernández, X Estévez-Ventosa, E Alonso and L R Alejano

Scale or size effects of the uniaxial strength response in rock samples have been studied in detail in the past, so a good number of studies on different rocks are available. However, analyses on triaxial strength scale effects in rocks are scarce and they seldom address failure criteria (i.e. Hoek-Brown) evolution with specimen size. This obvious lack of data can be attributed to the difficulties of having available Hoek's cell of different sizes. With the aim of filling this void, the authors have carried out sets of around 25 stress-strain triaxial tests on intact 30, 38, 54 and 84 mm diameter granite specimens, with various confinements (0.2 to 15 MPa), so reliable estimates of Hoek-Brown strength were obtained for every scale. We compare results with previous studies on UCS scale effects, showing a good correlation. Results suggest the studied granite undergoes a reverse size effect in terms of strength at low confinements. Indeed, the UCS increases as sample diameter increases up to around 50 mm, but decreases thereafter. However, results obtained put forward that this strength variation with scale tends to be mitigated for higher confinements where the scale effect may not be clearly recognised. So increased confinement can be associated with a decreased scale dependency component of strength.

Determination of thermal conductivity variation through Modified Transient Plane Source (MTPS), and its relationship with porosity variation on thermally treated Prada limestone

V Martínez-Ibáñez, M E Garrido, C Hidalgo Signes and R Tomás

In this research, the variation of thermal conductivity with temperature of a limestone and its relationship with porosity is studied. Samples from Prada formation, a lower Cretaceous limestone from the Catalan Pyrenees (Spain), obtained from the Tres Ponts road tunnel were subjected to temperatures of 105, 300, and 600 °C and then cooled at a slow rate by air-cooling to laboratory temperature. Open porosity tests were determined before and after heating to evaluate the porosity increase and the micro-cracks growth. Complementarity, thermal conductivity was measured in the rock samples before and after the application of a thermal treatment by means of C-Therm TCi device, a Modified Transient Plane Source (MTPS). This is a non-invasive, quick, and precise method, when compared with other steady-state laboratory alternatives, widely used to directly determine thermal properties of rock samples. A clear decrease in the thermal conductivity of above 10% was observed for samples heated at 600 °C, probably due to a dramatic increase in porosity. The obtained results could be of great interest for the incorporation of the effect of temperature on rock in numerical models, to evaluate the potential impacts induced by eventual fires developed inside the Tres Ponts tunnel.

Using non-destructive testing to assess static elastic modulus of a limestone exposed to high temperatures

M E Garrido, V M-Ibáñez, C H Signes and R Tomás

The determination of static elastic modulus in the laboratory requires rock core extraction and the subsequent testing of the samples by means of standardised uniaxial compressive strength tests. However, this destructive procedure is not always suitable – as in the case of protected historic buildings. In these cases, the static elastic modulus can be obtained from the dynamic elastic modulus, in turn derived from the velocity of ultrasonic waves (a non-invasive and non-destructive test). The relationship between both the dynamic and static moduli of rocks has been extensively addressed in the scientific literature. Furthermore, several researchers have separately studied the evolution of static or dynamic elastic moduli of rocks exposed to high temperatures – although few studies have compared both values. It is well known that the dynamic modulus is generally higher than the static modulus, and the values diverge especially in rocks with a low modulus of elasticity. These differences can be mainly explained by the effect of porosity and the size of cracks in the determination of both parameters. In this research, the relationship between static and dynamic moduli for 'Borriol' limestone is studied for samples previously subjected to 200, 400, 600 and 800 °C and then cooled slowly (in air) or quickly (immersed in water). The results show that the static modulus of samples heated up to 600 °C decreased 80.9 and 79.1 % and dynamic modulus decreased 62.5 and 64.8 % for slow and quick cooling samples, respectively. For samples heated to 600 and 800 °C, the static and dynamic moduli are similar. In general, no significant differences between both cooling methods are observed, even though static modulus shows more loss than dynamic modulus. Finally, linear models were used to correlate static and dynamic moduli, providing coefficients of determination of 0.99 and 0.97, for slow and quick cooling, respectively. It is also remarkable that the Edyn/Est rate was smaller than 1 for elastic moduli over 30 GPa (i.e., 105, 200 and 400 °C) and greater than 1 for lower moduli (i.e., 600 and 800 °C). The results obtained can be used to calculate the static elastic modulus of 'Borriol' limestone from dynamic modulus determined by non-destructive techniques.

Lithology, physical and mechanical characterization of Chinese Porphyry

J A Valido, M M Laz and J M Cáceres

A thorough characterisation of porphyry from China (Province of Fujian) was made, regarding three chromatic variants: red, brown and grey. The properties object of study are: petrographic, chemical and mineralogical analysis, real and apparent density as well as open and total porosity, water absorption at atmospheric pressure, resistance to salt crystallization, rupture energy, compressive strength, flexural strength, abrasion resistance and slip resistance. The achieved results remain into the expected ones for this kind of stone. Nevertheless, small differences were found according to the colour of the sample. Finally, those properties which are covered in the

CE marking were compared with the representative values of commercial samples from countries as Italy, Argentina and Mexico.

Photoelastic stress analysis of mode I fracture toughness tests using PMMA samples

A Muñoz-Ibáñez, M Herbón-Penabad and J Delgado-Martín

Rocks are usually inhomogeneous and anisotropic materials. The presence of foliation planes, grain boundaries or even microcracks may alter the stress distribution. In order to identify whether unusual behaviours in rocks are due to these imperfections or result from other factors (e.g. experimental configuration), the analyses of homogenous and isotropic materials is an useful approach. We have performed a series of mode I fracture toughness (KIC) tests using polymethyl methacrylate (PMMA) samples, which has the advantage of allowing photoelastic stress analysis based on its birefringent nature. Three different testing configurations were considered in the study: S\ emi-circular bend (SCB) test, the pseudo-compact tension (pCT) test, and a new alternative configuration based on the previous two that we have called pseudo-SCB (pSCB) test. To perform the photoelastic analysis, all the experiments were complemented with a specially-designed experimental setup consisting in two orthogonally arranged circular polarizers placed on both sides of the tested specimens. Using a source of white (polychromatic) light on one end it is possible to record the stress distribution using a digital camera aligned with the samples on the other end. As the load increases, a distinct evolving pattern of colour fringes can be visualized in the samples illustrating the spatially distributed stress levels. Based on this analysis we observe in some of the tests performed non-symmetrical stress fields. Although this behaviour could be related with the testing configuration, results suggest that other features, such as the shape of the notch tip, imperfections in sample preparation, or the misalignment of the samples in the testing device may also have an influence in stress distribution.

Experimental analysis of the pseudo-compact tension (pCT) testing configuration using two alternative sample geometries

M Herbón-Penabad, A Muñoz-Ibáñez and J Delgado-Martín

The pseudo-compact tension (pCT) method recently proposed by Muñoz-Ibáñez et al. (2020) is a satisfactory approach to measure mode I fracture toughness (KIC) in rocks and other materials using disc-shaped samples loaded under pure tensile conditions. In contrast to other methods, such as the semi-circular bend (SCB) suggested by the ISRM (2014), the pCT test provides with good control after peak load, making it possible to further characterize the processes involved in fracture propagation. In this work we assess the influence of the testing configuration at the onset of unstable crack propagation. In order to extend the pCT concept to complementary geometries with potential interest we studied an alternative to the SCB specimen, which we call pseudo-SCB (pSCB). To compute KIC in this configuration we have derived the corresponding dimensionless stress intensity factor function (Y') based on the finite element method. The results show that the pSCB test provides with consistent values of KIC and it also allows to control the propagation of the crack beyond peak load, which reinforces the idea that the loading conditions may be a more determinant factor than the sample geometry in controlling post-peak behaviour. In addition, an expression of Y' is presented for cubic samples tested using the pCT approach. This configuration may be useful for testing other materials amenable of moulding such as mortar, concrete, ceramics, etc.

Determination of frictional resistance pair Jr/Ja using a friendly – graphical approach in the Q-slope empirical method

C P Borja-Bernal and y L Jordá-Bordehore

The Q-slope index is a new geomechanical classification for slope [1] that has become popular and is spreading throughout the world. It is currently being applied in various lithologies, in different countries, mining and civil projects. The Q-slope allows engineers to adjust and optimize slope based on field observations of some geomechanical and geometric parameters that are easy to obtain. The selection of the value of each of the different parameters is made based on tables [2] some of whose parameters are the same as in the tunnel Q index, e.g. roughness (Jr), alteration (Ja), RQD etc. However, if the rock engineering has to analyse many slope with different properties, it is not so intuitive to work with very detailed tables and descriptions. We have therefore based ourselves on the concept of the graphic Geological Strengh Index [3] that uses short descriptions and designs. In this investigation we have selected the two parameters that form the pair of frictional resistance Jr / Ja (joint roughness number and joint alteration number. This Jr / Ja coefficient is very important since it is the multiplied by a correction factor for favorable or unfavorable orientation called O-factor. This O-factor is one of the novelties of the Q-slope compared to the "classic" Q of tunnels. Throughout the investigation we have simplified the descriptions of Jr and Ja (referring the reader to the previous works to know these parameters in grater detail) and created some graphic images that are easy and friendly to implement on site with a multiple choice table.

Determination of the basic friction angle of joints using the field tilt test: results of various "fast" tests on outcrops

L Jordá-Bordehore, L Alejano, R Tomás, S C Loaiza, M T García, R *et al.*

The basic friction angle of rock joints is usually obtained from tilt tests, being the most common the laboratory tilt tests. This test has been standardized according to the ISRM. However, most of the times when calculating the shear strength of discontinuities, reference tables are used to obtain the basic friction value for the lithology under study. These tables omit some lithologies complicating the

search of adequate references. An alternative, straightforward and economical way to obtain ϕb is through the field tilt test, which is carried out by sliding two blocks aside a joint. It is a well-known test, but there are few references to its implementation. In this test, unlike the laboratory tilt test, the samples are not "polished" and it is necessary to evaluate the roughness of the joint and the normal component to the weight of the upper blocks. The idea is to calculate the term of ϕb from the Barton-Bandis' equation and include the tilt angle α. Various tilt-test measurements were carried out with field blocks on both sides of the same joint, considering different lithologies (granite, limestone, andesite, dacite, coal and slate) and block sizes, evaluating the ideal ranges of applicability of the test.

Variation of Drilling Rate Index (DRI) with temperature and its relationship with thermal damage on 'Prada' limestone

V Martínez-Ibáñez, A Basco, M E Garrido, C Hidalgo Signes, R Tomás and T Miranda

This research evaluates the variation in the Drilling Rate Index (DRI) and its relationship with thermal damage on thermally treated rocks. Samples from 'Prada' limestone, a lower cretaceous formation in the southern Pyrenees (Lleida, Spain), were subjected to temperatures of 105, 300, 400 and 500 °C and then cooled at a slow rate. Ultrasound P-wave velocity tests were performed before and after heating the samples to evaluate the thermal damage experienced by the rock. Sievers' J miniature drill and brittleness tests were conducted on intact and thermally treated samples, and then resulting SJ and S20 values were combined to determine DRI. The obtained results show that thermal treatment allowed an increase of 34% in the DRI of 'Prada' limestone at 500 °C. DRI exhibited the same variation trend than S20, so we can conclude that thermal variation in DRI is more influenced by S20 than by SJ in 'Prada' limestone. We also report a strong relationship between DRI and P-wave velocity, confirming a tight dependence between the drilling performance and the thermally induced damage on the limestone. The observed substantial improvement in the drillability of the rock when heated, measured in terms of DRI value increase, could help in the advance on the development of thermally assisted mechanical excavation methods.

Extraction of discontinuity sets of rocky slopes using iPhone-12 derived 3DPC and comparison to TLS and SfM datasets

A Riquelme, R Tomás, M Cano, J L Pastor and L Jordá-Bordehore

Characterisation of a rock mass requires data from the intact rock along with the discontinuities. Assuming that the discontinuities are planar, its characterisation requires its number and orientation. This leads to the analysis of the normal spacing, the persistence and the roughness, among others. The geometrical analysis of the surface enables the calculation of the parameters to characterise the discontinuities, and the use of digital datasets enhance them. Remote sensing techniques, such as the Terrestrial Laser Scanning (TLS) instruments of Structure from Motion (SfM) technique, provide 3D point clouds that enable the geometrical analysis. The scientific community has been testing both techniques since the 2000s, and companies are introducing their use in their workflows. However, the cost of the TLS instrument could still be a barrier to its use to most scholars. Because of this, the community shows a growing interest in Remotely Piloted Aircraft Systems (RPAS) equipped with digital cameras or in smartphones equipped with high-quality cameras to capture digital datasets of rocky slopes. The SfM workflow processes the captured images, reconstructing the rocky slope through a 3D point cloud and textured meshes. Although previous studies show that the SfM-derived point clouds present less quality than TLS-derived datasets in terms of accuracy, the use of SfM is still of interest because of its cost. In 2020 Apple launched the Iphone-12 device, which is equipped with a LiDAR sensor that is not used to capture the surface coordinates but to enhance the photo's quality. Since then, the community has developed several applications to reconstruct 3D surfaces using this device. This leads to consider this device as an intermediate option between the TLS and SfM to characterise rocky slopes and their discontinuities. In this communication we explore the digitalisation of a rocky slope via TLS instruments, SfM technique and using the Iphone-12 device. It comprises a 26 meter high mechanically excavated rocky slope in Cretaceous marlstones and limestones. To capture the surface, we used three configurations, and we found that to scan ground surface the distance device-surface had to be less than 3 meters. The discontinuities are characterised using the three sources of information using the DSE software. The results show a promising match compared to the TLS or SfM. This evidences that these devices will soon be widely employed for evaluating rocky slopes.

Geomechanical behavior evolution of the rock mass involved in the Arteara rock avalanche, Gran Canaria, Canary Islands, Spain

L M Antón-Bayona, M J Rodríguez-Peces and J Yepes

In Arteara (Canary Island), a Holocene rock avalanche comprises accumulation of large reddish blocks which cover the Fataga ravine. This course, is entrenched into the Phonolitic Formation, an alternating sequence of lava flows and ignimbrites. The avalanche defines an elongated deposit of variable thickness. A low friction angle was deduced, which is related to an easily weathered bedrock favorable to the rolling of the blocks. The movement would have been a dry granular flow with a component of saltation at the head and of turbulent flow at the intermediate and distal areas. The deposit varies widely in size and is structured in bands of blocks with a polymodal distribution and low selection. The geomechanical properties of the rocks involved vary substantially in each block and along a longitudinal profile of the deposit. Schmidt Hammer rebound measured in 233 blocks show a polymodal dispersion. Some facies have been differentiated in the blocks, not only by their appearance, but also by their rebound index (R). The different hardness reflects the differences in density and porosity. The hardness zoning shows the differential weathering of the blocks, which depends on the rock anisotropy and the flow

turbulence, which determines the influence of abrasion and punching of the blocks. The rebound shows a direct correlation with the bulk density and an inverse correlation with the distance to the source area.

Characterization of joint roughness using close-range UAV-SfM photogrammetry

R García-Luna, S Senent and R Jimenez

The Structure from Motion (SfM) photogrammetric technique has emerge as an efficient alternative for remote 3D rock mass characterization, compared to laser scanner (LiDAR) or stereoscopic photogrammetry, due to its economy and ease of use. In a similar way, the recent development of the drone-based technology has turn UAVs ("Unmanned Aerial Vehicles") in a more accessible device for field applications in geotechnical engineering; allowing the acquisition of high quality images from a safe distance and without the need to stablish direct contact with the rock mass. However, the close distance applicability of UAV-SfM photogrammetry has not yet been investigated in detail to characterize joint roughness at close range (<10 m). In this work we employ the SfM technique for the generation of 3D models of the joint surfaces from aerial images taken at a relatively short distance from the slope (10, 7.5, 5, and 2.5 m). Roughness profiles are extracted from the 3D data, and their Z2 statistical parameter is used to estimate the Joint roughness coefficient (JRC). Finally, the JRC value of those profiles-obtained with the UAV-SfM approach-have been compared with those obtained with traditional measurements based on manual methods. The proposed methodology is applied to a real case in an ancient open-cast mine in Northern Spain. The results obtained at different distances are compared to analyze the potential of UAV-SfM photogrammetry to develop accurate close-distance models. Results show that it is not necessary to get too close to the slope in order to get the best results, as this may cause overestimation of the JRC value.

Stability assessment of rock slopes combining Slope Mass Rating and Qslope classification systems: A case study in Cerro San Eduardo (Guayaquil, Ecuador)

A M Macías, D K Vera, C P Borja and L Jordá-Bordehore

In the present study, the stability of the slope located in the Modesto Apolo Ramírez Avenue, is analyzed. The avenue is located prior to the access to the Cerro San Eduardo tunnel, which has had habitual problems of falling blocks to the roadway. For the study, empirical methodology was applied, including the data mapping based on geomechanical classifications such as Rock Mass Rating (RMR), Slope Mass Rating (SMR) and Q-Slope index, which assign a defined score, obtaining the quality of the rocky mass, and with this, the degree of stability of the slope. In addition, through the application of RocFall software, the empirical methodology has been compared with the analysis of rockfall trajectory, making a retrospective study of behavior and simulating the constant falling of blocks on the roadway.
As a consequence of the exploration, it was evident that the geomechanical classifications-in this particular caseare not completely effective to determine the degree of stability of the massif. This is due to the fact that, even though the slopes are globally stable, these classifications do not seem to adequately determine a level of risk against rockfalls, as can be seen from visu. Therefore, it can be seen that the slope does not have a risk of collapse, but instead presents a high danger of landslides that could cause considerable economic and human lives losses. The study recommends geometric solutions for impact mitigation to prevent future damage.

3D modelling study on landslide risk of rocky blocks, applied experience on rocky outcroppings along hillsides than can affect Generalitat Catalana roadways

I Paniagua Serrano, E Álvarez Álvarez and J A Martín-Caro Álamo

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Studying accidents caused by landslides since 2015 by DGIM (GENCAT) has brought to our attention the importance of the landslides that happen on hillsides, outside of cutting slopes of the public domain areas, that affect road safety. Other than the vulnerability of the trace caused by these events, we need to be aware of the following: the scale of the processes (rocky outcropping that occupies large areas on natural slopes), the location of the outcropping outside the railway line, the conditioning access factors due to orography, the budget and time limitations when studying these events have forced the application of 3D modelling from drone images in order to support the traditional methods of data collection through surveys and the rock mass classification through the installation of geomechanical stations in the field. The experience gained from applying these processes has allowed us to establish a study system that is being currently applied to the network. The main qualities of the method, the critical analysis of the previous facts and the future lines of work that this team is facing, are the scope of this article.

The role of joint spacing on the stability analysis of wedge failures

I Pérez-Rey, J Moreno and M Muñiz-Menéndez

Kinematic analyses of wedge failures in rock slopes are usually carried out based on stereographic techniques. Nevertheless, this methodology presents several limitations that could lead to poorly accurate conclusions. In line with this idea, the main objective of this work is to evaluate the effect of joint spacing in the estimation of the factor of safety of rock slopes affected by potential wedge failures. For this purpose, a 3D numerical distinct-element code (3DEC) was selected to carry out a good number of simulations in which the factor of safety a slope, affected by different discontinuity sets, was studied by using the Shear Strength Reduction (SSR) method. Different values of joint spacing, cohesion and friction angles were considered, combined with two angles of the slope face under study. The joint spacing has been found to relevantly affect the values of the factor of safety, which showed variations of up to 40% in comparison with those obtained from limit-equilibrium methods for rock slopes with

similar structural features. This work provides an insight into a more realistic interpretation of rock slope analyses against wedge failures, and particularly to more accurate estimations of the factor of safety.

Discrete Element Modelling of Rock Creep in Deep Tunnels using Rate Process Theory

J G Gutiérrez-Ch, S Senent, P Zeng and R Jimenez

Rock creep behaviour is a key aspect of many engineering projects, such as deep tunnels in which squeezing problems could occur. Many theories have been published in the literature to reproduce rock creep behaviour; however, most of them are not able to capture the last phase of creep (i.e., tertiary creep, or the accelerating strains that occur prior to failure). In this work, the Distinct-Element Method (DEM) approach is employed, in conjunction with Rate Process Theory (RPT), to simulate the effect of rock creep in deep tunnels. To do that, the DEM models are constructed using particles, whose interactions are simulated with a hybrid mixture of the Flat Joint Contact Model (FJCM) and the Linear Model (LM) contact models; the RPT is implemented into DEM models using a Visual C++ function. Results show that the DEM plus RPT combination can suitably reproduce the tunnel convergences due to rock creep.

Effect of thermo-hydro-mechanical coupling on the evolution of stress in the concrete liner of an underground drift in the Cigéo project

M Alonso, M N Vu, J Vaunat, G Armand, A Gens, Plua, C De Lesquen and O Ozanam

The French National Radioactive Waste Management Agency (Andra) is in charge of studying the disposal of high-level and intermediate-level long-lived waste (HLW and ILW-LL) in a deep geological repository (Cigéo project) within the host formation is the Callovo-Oxfordian claystone (COx). The heat emitted from waste packages induces a thermo-hydro-mechanical (THM) coupling within the structural elements and the host rock. This study focuses on the behavior of the concrete lining of an ILW-LL cell subjected to THM loading during its construction and operational phases. The mechanical behavior of the host rock is represented by an elasto-visco-plastic model taking into account the anisotropies in stiffness and strength. The coupled THM formulation is based on the Biot theory. Different simulations including full THM coupling and HM coupling with or without creep behavior of COx claystone have been performed to show the effect of the thermal load (generated by the waste packages), of the water seepage and of the creep strain of the host rock on the stress evolution in the concrete liner. The results show the preponderant role of the creep strain of COx claystone on the stress state of the liner during the operational phase, while the effect of the heat loading is moderate and that of the seepage is not significant.

Constructive analysis of the role that engineering geological and rock mechanics methods could play in a complex emergency. Lessons Learned from the Totalán Case

M Zango-Pascual and O Osorno Guerrero

The emergency services receive a notice on 13/01/2019 that a 2-year-old boy has fallen into a borehole in Totalán, (Málaga, Spain). After almost 13 days of unusual and overwhelming engineering and solidarity efforts his body is recovered. This was an extraordinary and unusual emergency case, due to: the superhuman effort made by the more than 300 people involved in the rescue operation; the follow-up made by the media, and all the engineering work carried out in record time. For this purpose, it was decided to build a parallel shaft and a 71-meter-deep transversal tunnel, to access the supposed hole, where he is expected to be alive. The cost was approximately 700,000 €. The contribution of geology might have been small, according to sources in the authorities and the media, due to time constraints. But was it really like that? it could have been much more useful, in terms of reducing time frames or even to making different decisions to facilitate the rescue, if other geophysical and engineering geological research methods had been taken into account in the early days. This retrospective analysis is approached with the utmost respect for the efforts made and always with the greatest possible scientific rigour.

Effect of thermal cycles on rock cliff deformation. Monitoring and interpretation

C. Villarraga, J. Vaunat, D. Virely and M. Gasc

Climatic actions are one of the factors controlling the evolution of slopes, this paper is devoted to a specific effect, relatively little studied, related to the effect of climate-driven temperature changes on rock massif deformation. The particularity of the study is to focus on permeable rocks and Temperatures varying in a range which discards freeze/thaw effects. Research has been carried out in relation with the analysis of the real case of a limestone cliff located in the Périgord region, the massif was highly instrumented, results show a slow cyclic accumulation of deformations with time, essentially synchronic with thermal cycles. An advanced constitutive model, specifically developed to capture rock degradation due to the differential expansion of the main minerals composing the rock, has been developed. It has been calibrated on experimental results obtained in the laboratory on block samples tested in a climatic chamber for a long series (several months) of daily thermal cycles. Deformation and shear wave velocity were monitored during the test. Model shows a good agreement with laboratory measurements.

Teaching rock mechanics using Virtual Reality: laboratory practices and field trips during the confinement of the COVID-19 in Ecuador, Bolivia, and Spain

M T García-Vela, C P Borja-Bernal, L Jordá-Bordehore, R Medinaceli-Torrez, S Loaiza and D A Falquez

Virtual Reality (VR) consists of creating spaces similar to reality where the viewer interacts more or less in a digital world. This digital world can be programmed so that geosciences student takes data as if it were a field trip. The VR can save money, logistical problems and avoid accessing unsafe places. Besides, students can access places that would otherwise require a veritable expedition (hydroelectric projects in the Andes, remote highways, dams, tunnels in the Himalayas, among others.). At the beginning of the project in 2019, we designed some virtual rock mechanics classes to complement the face-to-face classes: In recent years, we have seen it increasingly difficult to organize field trips. We have designed virtualscenarios where students can obtain geomechanical data from tunnels, mines and rock slopes. We have used the CoSpaces commercial platform for this purpose. Within this virtual world, we place photographs, pop-up menus, videos of field and laboratory tests and clues for the student to search the data for himself in a quasi-real scenario. With all this data from the virtual scenario (as if they were in the field trip), students interpret in the cabinet and perform complex calculations (Hoek Brown, Barton-Bandis criteria, RMR, Q index, among others). We have generated two types of virtual classes: laboratory practices and field trips. Since mid-March of this year 2020, there is no face-to-face teaching in many world faculties whererock mechanics, rock slope engineering, tunnels, and underground mining subjects need to be taught. Thanks to these Virtual Reality laboratories, we have been able to carry out our teaching successfully. Combining two means: VR and software, have allowed making classes very practical and realistic, and the students have highly valued this initiative. Besides, rock mechanics plays a very important role in the safety of underground works and excavations. The best way to learn methodologiesin risky environments is undoubtedly using simulators. In the same way that pilotsand astronauts practice stress situations in simulators, we consider it useful to use Virtual Reality and simulators to learn how to map rock mechanics and stability in mines and tunnels. It is an advance in security and quality training.

Hydrofracturing tests on granite samples using a true triaxial device equipped with acoustic emission sensors

M Herbón-Penabad, A Muñoz-Ibáñez, J Delgado-Martín, N González-Molano, J Alvarellos-Iglesias and J Canal-Vila

We present a series of tests performed on granite samples using a true triaxial device designed and built at the Rock Mechanics Laboratory (University of A Coruña). The experiments were performed using cubic rock samples of 150 mm-edge, which were loaded to different stress conditions (σh < σh < σy < 45 MPa) on each loading axis. The device is based on a stiff steel frame that can be coupled to a servo-hydraulic testing machine that provides de vertical stress (av), while two high-pressure pumps are used to deliver the lateral stress (σh and ah). An additional high-pressure pump is used to inject the fluid (mineral oil) into the rock sample at a low constant-flow rate. The aluminium loading platens, which are bevelled at the edges to avoid interaction among adjacent faces, have holes and grooves to introduce acoustic emission sensors that allow the location of fracture propagation. The specimens were drilled using a 6 mm drill bit until reaching the geometrical centre. Then, a 1/8" (~3.18 mm) stainless steel tube is glued to the samples with epoxy. Strain measurements during the experiments were conducted using four strain gages attached to the orthogonal faces of the specimens. The system was further equipped with three LVDTs to account for the bulk displacement on each axis. Our results suggest a linear relationship between the breakdown pressure and the confining stress under hydrostatic conditions but no clear correlation in non-hydrostatic stress regime.

Additional insights to EC7 from the application of reliability-based design methods: the case of debris flow protection structures

F Vagnon, AM Ferrero and L Alejano

Debris flows are dangerous natural processes that cause extensive damages to infrastructures and urbanized areas and can lead to loss of human lives. Their unpredictability, their extremely high motion and their magnitude are the main causes of these harms. Mitigation measures are fundamental for reducing the associated risk and protecting infrastructures in mountainous areas. Their design is still an open issue: there are many formulations to evaluating impact pressure. Moreover, the uncertainties in the determination of flow characteristics (velocity and thickness) are significantly high and difficult to quantify. In the European Union, the design of any type of structures involved in rock mechanics field must comply with EN-1997 Geotechnical Design (CEN 2004) (EC7). For debris flow countermeasures, EC7 requirements are very difficult to apply in practice since partial safety factors are not provided for these phenomena. However, the basic philosophy of reliability-based design (RBD), as defined in EN1990 (CEN 2002) may be a suitable and complementary approach to provide geotechnical structures with a uniform probability of failure. Reliability Based Design (RBD) can provide additional insights to EC7 design and can be applied when partial factors have still to be proposed (by EC7) to cover uncertainties of less common parameters, as in case of debris flow countermeasures. This paper presents an analysis of the advantages and limitations on the applicability of RBD approach to debris flow countermeasures, by using the first-order reliability method (FORM). In particular, data availability, the possibilities for analysing data in a statistical framework and the choice of performance function are the main limitation of the method, which force to make assumptions regarding statistical distribution of the considered parameters. A sensitivity analyses, comparing different equations, commonly used for debris flow impact pressure estimation, were performed for quantifying the effect of the selected performance function on the RBD results.

Resumen de los artículos presentados por españoles al EUROCK 2022

Todos los artículos del congreso fueron publicados por la editorial IOP en formato abierto en el volumen 1124 de la revista IOP Conference Series: Earth and Envirnmental Science:
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A brief review of the effect of wildfires on rockfall occurrence

I Pérez-Rey, R Sarro, R Tomás, LR Alejano, LE Hernández Gutiérrez, RM Mateos and A Riquelme

Wildfires and rockfalls are among the major hazards in forested mountainous regions across Europe. Understanding processes and conditions that lead to rockfalls during and after a wildfire in different geological contexts is, therefore, of great relevance. The increase of rockfalls associated with the occurrence of wildfires is connected to several factors, not only in the detached area but also in the propagation and affected area. Wildfires cause changes in the mechanical properties of rocks and discontinuities as well as the loss of protective capacity from vegetation, complemented by the effect induced by firefighting activities and by extreme temperatures that may deteriorate the installed protective measures. After the occurrence of a wildfire, there is an increase in the frequency and intensity of rockfalls in the burned area, causing a major impact of rockfalls on road networks and inhabited areas. Additionally, the rockfall risk perception is usually increased due to the removal of vegetation by wildfires, exposing both rock blocks and the rock mass. In this review, the main factors that influence the occurrence of rockfalls after a wildfire are briefly reviewed.

A Bayesian regression analysis of in situ stress using overcoring data

M A Javaid, J P Harrison, D Mas Ivars and H A Kasani

Characterising the state of in situ stress at a target depth is crucial for all underground engineering projects. Consequently, on critical projects such as nuclear waste repositories extensive campaigns are implemented with the goal of estimating the in situ stress state. These campaigns often comprise both direct measurement and indirect estimation methods, but the data obtained across a project volume may exhibit significant variability. This poses significant challenges in both quantifying the variability and uncertainty of in situ stress, and determining the stress state to be used for design purposes.
It is often assumed that the state of in situ stress increases linearly with depth, and thus linear regression of principal stress magnitude against depth are often found in the literature. As such methods not honouring the tensorial nature of stress are, strictly, incorrect. To show how this limitation may be overcome, here we present a Bayesian regression analysis of in situ stress with depth that uses the Cartesian stress tensor. The analysis is performed using over 100 overcoring data obtained at the SKB Forsmark site in Sweden.
A comparison between the customary and Bayesian approaches is presented, which shows the superiority of the tensorial technique.

Effects of the initial stress and spalling strength on spalling around deposition holes and tunnels

B Figueiredo, J Vatcher, J Sjöberg and D Mas Ivars

Spalling in the deposition holes and tunnel stability are of concern for the design of deep geological repositories for spent nuclear fuel. A 3D numerical stress model, including a single deposition tunnel and multiple deposition holes to analyse the potential for spalling resulting from the excavation phase, was developed for the proposed repository location at the Forsmark site. Several potential initial stress field cases and spalling strengths of the intact rock were considered. The magnitudes of the factor of safety, the spalling depth, the minor principal stress, and the differential stress were evaluated. The results showed that no spalling in the central deposition hole is indicated for the most likely stress field, and the occurrence of spalling and the spalling depth are minimised for a maximum horizontal stress aligned approximately parallel to the tunnel axis. For spalling occurrence and depth of spalling, the magnitude of the maximum horizontal stress is more critical than its orientation, and the spalling strength is more critical than the magnitude of the maximum horizontal stress. No instability problems were indicated in the vicinity of the roof for all analysed stress cases.

Geometrical aspects in the consideration of actual opposed surface along shearing direction in rock joints

Diego-José Guerrero-Miguel, María-Belén Prendes-Gero, Martina-Inmaculada Álvarez-Fernández, Celestino González-Nicieza and Lucía Conde-Fenández

Shear behaviour of rock joints is strongly influenced by the roughness of its surface as the different failure mechanisms will be conditioned by the shape and distribution of the asperities and undulations in it. Currently, this surface can be digitalized using scanning methods directly in the field

or in representative laboratory samples. After that, the surface is digitally reproduced using triangulation methods. This allows to analyse it using stablished parameters that do not depend on the arbitrariness of the technician. Despite the fact that 2D roughness parameters are still of great importance, these techniques are nowadays provoking a tendency to implement 3D measuring methods that allow to treat all the surface simultaneously and thus gathering valuable information of the rock joint as a whole. The vast majority of the 3D most powerful methods consider the area of the surface that is opposed against the shearing direction in order to determine the roughness, anisotropy and peak shear strength of the rock joint. However, not always the whole surface of each triangle that faces against shearing direction should be considered. In this work, a new methodology to consider the actual area of each triangular element that is involved in the shearing process is mathematically derived. Therefore, improving the accuracy of current methods, as well as the truthfulness of the mechanical characterization of rock joints.

Toppling of a rock block resting on a rough Surface

L R Alejano, J Y Gui, M A González-Fernández, I Pérez-Rey and M Muñiz-Menéndez

The main aim of this study is trying to contribute to a better understanding of the role of surface roughness basal planes on toppling-related instability phenomena. In this way, the authors focus on the stability against toppling of a single block resting on a regular rough surface. To do that they have first artificially created sample rock blocks with a regular rough base and tested them against toppling in a tilt-test machine. The authors have also developed analytical formulations to theoretically estimate toppling instability under these circumstances and have carried out simple numerical DEM models to reproduce the corresponding tests. The comparison between obtained analytical and numerical results and the physical model response indicated good representativeness of both numerical and analytical approaches. Geometry characteristics of the saw cut artificially created blocks did affect results, so the numerical and analytical models were adapted by including an equivalent curvature radius in the corner of the cut block around which the overturning phenomenon takes place to account for this geometrical effect. Further research will extend these results to the case of blocks with natural irregular rough surfaces.

Intact rock deformation bimodularity: an experimental study

Mauro Muñiz-Menéndez and Ignacio Pérez-Rey

Rock deformability under tensile stresses plays an important role in different scenarios like, e.g., in the mechanical behaviour of roofs in underground openings, hydraulic fracturing, dilatometer tests performed in massive rock masses or in tensile strength tests. Different authors have proved that the tensile deformation modulus of the intact rock can be significantly different than that obtained under compressive load, being this so-called 'bimodularity' often ignored. In this work, we present preliminary results from uniaxial compressive and tensile strength tests carried out in three rocks with a testing apparatus recently modified to be able to perform both types of tests. Experimental results show that the deformational behaviour of the rocks studied is dependent on the type of load applied. The present work aims at contributing to a better understanding of the deformational behaviour of rocks, in particular when subjected to uniaxial tensile loads as well as in dealing with future updates of existing test methodologies.

Experimental Device for the Determination of Fracture Toughness at High Pressure

A Muñoz-Ibáñez, M Herbón-Penabad and J Delgado-Martín

Mode I fracture toughness (KIC) is a relevant property in many applications involving rock mechanics. However, the conventional methods for its determination only consider ambient pressure conditions. Although the available experimentation on high pressure fracture toughness shows that KIC tends to increase with confining pressure not all the published results provide with the same evidence. Among the available methodologies for KIC testing, the pseudo-compact tension (pCT) test approach provides with a number of operational advantages over other alternatives and makes it a good candidate for its extension to high pressure research. Based on it, we have designed and constructed a simple high-pressure cell that may be easily installed in any conventional compression frame without modifications to test pCT specimens. The cell may accommodate either a gas or liquid as confining fluids and work with samples of up to 50 mm (~2") diameter. In order to verify the expected performance, we have conducted different calibration tests, including leak rate and the assessment of axial friction. For the demonstration and validation of the experimental approach presented, we have selected virtually impervious poly-methacrylate (PMMA) and Corvio sandstone samples. Results obtained at room conditions and at high pressure are compared and discussed.

Study of size effects on the peak and residual strength of intact and artificially fissured granite samples

M A González-Fernández, X Estévez-Ventosa, F García-Bastante, L R Alejano and A M Ferrero

There are not many studies on jointed rock specimens, which can be considered small scale rock mass analogs. On the other hand, the scale effects in the mechanical properties of such samples have seldom been studied. With the aim of continuing previous research on intact granite rocks, the authors have carried out sets of 25 stress-strain triaxial compressive tests on 1 sub-vertical and 2 sub-horizontal 38 mm, 54 mm and 84 mm diameter jointed granite specimens at various confinements. Peak and residual strength values were obtained and compared to those recovered form intact rock samples. Results suggest

that peak strength follows similar trends with scale to those observed on intact rock, even if lower strength values are logically recorded. Regarding residual strength, the obtained results are in line with those observed trends for standard size samples, showing a similar trend for all cases independently of scale, even if we observe larger variability for jointed samples. The authors have also compared the values fitting the generalized Hoek-Brown criterion for rock masses to better understand the behavior in relation to sample size. So scale effects clearly appear on jointed rock peak strength of jointed sample; even if residual strength seems hardly affected by scale.

Definition of Structural Domains Using Acoustic Borehole Image Televiewer Data in Minera Los Frailes Mining Site, Sevilla, Spain

M Heredia Bilbao, R Sánchez Marín, R Cano Martín, A Deu Lozano, P Martínez Diaz and M Devincenzi Fabetti

Six structural domains were defined using structural data from acoustic televiewers and oriented boreholes in Minera Los Frailes (MLF) mining site, in Sevilla, southern Spain. This paper describes the methodology used for the definition, some of the issues encountered during the investigation, the results obtained and the utility of this defined structural domains in the develop of the MLF mining site reopening.

Remotely Operated Submersible Drilling Rig for Offshore Rock Investigations

A Deu Lozano, M. Heredia Bilbao, M Pérez Casas, R del Castillo, and M Devincenzi Fabetti

A remotely operated submersible drilling rig able to obtain continuous cores up to 6m long was developed in 2012. It is suitable for relatively shallow water projects (up to 200 m water depth) when short target penetrations are required. The system is launched on the seabed and is able to drill with a diameter up to 113 mm thus allowing the recovery of relatively large-diameter samples. The operations are fully instrumented: the equipment positioning, drilling parameters and the digital camera image are displayed in real-time on the computer, allowing the operator to take decisions during positioning and drilling. The rig has been extensively used in the last years in different type of projects such as inter-array and export cables for offshore wind farms, submarine interconnection cables as well as in dredging projects in Europe, North America and Middle East. The drilling parameters of a representative test in a heterogeneous seabed and some laboratory results on samples recovered are presented.

Influence of Geological Conditions on the Design and Construction of the Carlberg Main Tunnel. A case study in large railway tunnel in Moss (Norway), with low rock overburden in an urban area near deposits of sensitivity material.

Francisco Planells Valero, I Reig and J Martín

This article presents an example of how the geomechanical conditions and the detailed analysis of their effect on the global stability of the area influenced the modification of the conceptual design of the northern entrance to a railway tunnel in Moss (Norway). This entrance to the tunnel required the drill and blast of a large volume of hard granitic gneiss rock in an area with low rock overburden over the tunnel (minimum 0.5D), near soil deposits sensitive to vibrations from blasting and with buildings at surface. Initially, 4 tracks were defined penetrating the rock mass according to 3 parallel tunnels in combination with small rock pillars and rock cuts with an unfavorable orientation. Based on the analyses carried out and in order to reduce the volume of excavation and the stability problems detected, the three initial tunnels were combined into a single larger tunnel, while optimizing the orientation and width of the rock cuts. The features of the initial tunnel entrance indicated a potential failure mode of block instability controlled by the geological structures, discontinuities and in-situ stress level. The numerical code 3DEC, suitable for block stability study, was used to model and check the stability of the tunnel entrance and the different geometrical alternatives and orientations.

Arcillas y yesos del Aragoniense, Mioceno medio, Maluenda, Zaragoza (© Juan Antonio Díez 2022)

ISRM *Online Lectures* 2021

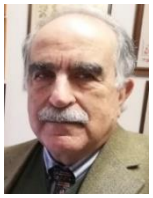
En 2021 se impartieron cuatro conferencias *on line* en la ISRM. A continuación se muestran los títulos de las mismas y pinchando en la foto de los autores se puede acceder a cada una de las conferencias.

Diciembre 2021	Methodologies of underground rock support and applications	Prof. Charlie Chunlin Li	
Septiembre 2021	Findings from Numerical Modeling at the Site of a High Dam on the Jinsha River	Dr Christine Detournay	
Junio 2021	Rock Slope Engineering: A Combined Remote Sensing-Numerical Modelling Approach	Prof. Doug Stead	
Marzo 2021	The role of rock mechanics in the safe and economic development of oil fields	Prof. Sergio Fontoura	

Rotura de un talud en un flysch en Alicante (© Miguel Cano, 2022)

ISRM *Online Lectures* 2022

En 2022 se impartieron cuatro conferencias *on line* en la ISRM. A continuación, se muestran los títulos de las mismas y pinchando en la foto de los autores se puede acceder a cada una de las conferencias.

Diciembre 2022	Stone in Cultural Heritage - From the rock mass to the stone piece	Dr. José Delgado Rodrigues	
Septiembre 2022	Non-conventional surface subsidence – a challenge for an improved fundamental understanding	Prof. Bruce Hebblewhite	
Junio 2022	The Rock Engineering Process (for Cavern Construction)	Prof. Zhou Yingxin	
Marzo 2022	Evolution of numerical methods for coupled problems in rock mechanics and engineering	Prof. Yuzo Ohnishi	

Mina “Cobre Las Cruces”, Gerena, Sevilla (© Juan Antonio Díez 2022)

Próximos eventos de interés

XX Jornada técnica Anual de la SEMR: Mecánica de rocas y geología estructural	**27-04-2023**	**27-04-2023**	**España**	**Madrid**
15th International ISRM Congress 2023	09-11-2023	14-11-2023	Austria	Salzburgo
EUROCK 2024 - New challenges in rock mechanics and rock engineering	**15-07-2024**	**19-07-2024**	**España**	**Alicante**
NROCK2023 - The IV Nordic Symposium on Rock Mechanics and Rock Engineering	24-05-2023	26-05-2023	Islandia	Reykjavik
3rd JTC1 Workshop on Impact of global changes on landslide risk	07-06-2023	10-06-2023	Noruega	Oslo
8th International Conference on Debris Flow Hazard Mitigation	26-06-2023	29-06-2023	Italia	Turín
10th Nordic Grouting Symposium - an ISRM Specialized Conference	11-09-2023	13-09-2023	Suecia	Estocolmo
The 18th World Conference of the Associated Research Centers for the Urban Underground Space (ACUUS 2023)	01-11-2023	03-11-2023	Singapore	
1st Chilean Congress in Rock Mechanics	22-11-2023	24-11-2023	Chile	Santiago
7th Peruvian Symposium on Geoingeneering	29-11-2023	01-12-2023	Perú	Lima
1st SLRMES Conference on Rock Mechanics for Infrastructure and Geo-Resources Development - an ISRM Specialized Conference	02-12-2023	07-12-2023	Sri Lanka	Colombo
2024 ISRM International Symposium: ARMS13 - 13th Asian Rock Mechanics Symposium "Advances in Rock Mechanics - Infrastructure Development"	24-09-2024	28-09-2023	India	Nueva Deli
1st international Rock Mass Classification Conference (RMCC)	30-10-2024	31-10-2024	Noruega	Oslo
Eurock 2025 - Expanding the underground space - future development of the subsurface - an ISRM Regional Symposium	01-06-2025	07-06-2025	Noruega	Throndheim

Pliegue en areniscas y lutitas de la Formación Uncastillo junto al Río Gállego. Riglos. Huesca
(© 2022 Juan Antonio Díez)

Jornadas Técnicas Anuales

Desde el año **2002** la **SEMR** lleva organizando una **Jornada Técnica Anual**, cuya celebración se viene realizando en la segunda semana después de Semana Santa. Tradicionalmente, y gracias a la colaboración del **CEDEX,** esta jornada se realiza en el Salón de Actos de este organismo.

Este acto está dirigido a todos los profesionales vinculados a la Ingeniería del Terreno. Los principales objetivos de las entidades organizadoras son, por una parte, ofrecer a los asistentes la oportunidad de disponer de los conocimientos más avanzados y de las más recientes aportaciones y tendencias en relación con la Mecánica de Rocas y, por otra, servir de foro de discusión que permita el intercambio de opiniones y experiencias entre los diferentes técnicos relacionados con los temas expuestos.

Esta **Jornada Técnica** ha venido teniendo gran acogida entre los profesionales que trabajan en Mecánica de Rocas. La asistencia media suele estar entre 100 y 200 personas, tanto de socios como no socios.

En la página web de la **SEMR** se puede consultar el programa detallado de todas las jornadas que se han celebrado hasta el momento y que han sido:

- **Excavaciones subterráneas en roca**, 23 de abril de 2002.
- **Taludes en roca**, 23 de abril de 2003.
- **Tratamiento de túneles en roca**, 21 de abril de 2004.
- **Reconocimiento y estudio de medios rocosos**, 20 de abril de 2005.
- **Túneles en rocas blandas**, 26 de abril de 2006.
- **Cimentaciones de presas en roca**, 18 de abril de 2007.
- **Túneles en condiciones difíciles**, 2 de abril de 2008.
- **Cálculo de Túneles,** 22 de abril de 2009.
- **Almacenamiento profundo de CO_2,** 14 de abril de 2010.
- **Últimos Avances en la Mecánica de Rocas,** 4 de mayo de 2011.
- **Ingeniería en Rocas Blandas,** 24 de abril de 2012
- **Cimentación de presas de fábrica en medios rocosos,** 17 de abril de 2013
- **La Mecánica de Rocas en el ámbito de la ingeniería de minas,** 29 de abril de 2014.
- **La Mecánica de Rocas en el Eurocódigo 7 y otras normativas.** 15 de abril de 2015.
- **Últimas técnicas aplicadas en la Caracterización Geomecánica de Macizos rocosos.** 06 de abril de 2016.
- **Casos históricos en Mecánica de Rocas.** 26 de abril de 2018.
- **Cavidades en Rorca,** 8 de mayo de 2019.
- **Mecánica de rocas y geología estructural,** 13 de mayo de 2021.
- **Ensayos de laboratorio en mecánica de rocas: Jóvenes investigadores,** 28 de abril de 2022.

También se han celebrado varias **Jornadas Extraordinarias**:

- **Tuneladoras en roca,** 16 de marzo de 2006.
- **Experiencias recientes en tuneladoras,** 5 de junio de 2007.
- **Jornada conmemorativa del 50 Aniversario,** 6 de abril de 2017
- **Jornada Extraordinaria en Asturias, Homenaje a P. Ramirez Oyanguren,** Oviedo, 14 de marzo de 2019.

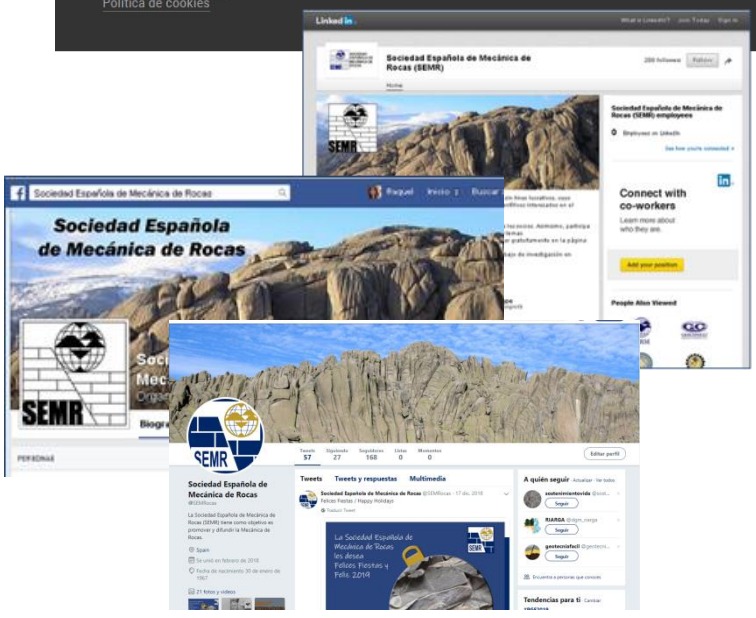
La SEMR en las redes sociales

Tras el éxito de la incorporación, en junio de 2014, de la SEMR a las redes sociales, se renovó en 2015 su web para hacerla más dinámica, accesible y útil para todos los socios.

En la web se informa de todas las cuestiones relativas a la SEMR, tanto desde el punto de vista administrativo y organizativo como desde la difusión de actividades, colaboración con otras entidades, noticias de interés, etc.

Se ha incluido la posibilidad de suscribirse al boletín de noticias para que todo el que lo desee pueda estar puntualmente informado de las últimas novedades en el mundo de la Mecánica de Rocas.

En la web se incluye una sección de publicaciones donde se pueden descargar todos los boletines anuales editados por la SEMR desde el año 2008.



Además, la web cuenta con enlaces directos a nuestras cuentas de LinkedIn, Twitter y Facebook lo que ha sido de gran ayuda para la difusión de noticias relacionadas con la Mecánica de Rocas y actividades de la SEMR.

En la actualidad la SEMR cuenta con más de **2200 seguidores en Facebook, 3600 en LinkedIn, 660 en Twitter y 125 en Youtube**

Animamos a todos nuestros socios a que colaboren en la actividad en las redes sociales de la SEMR publicando comentarios, noticias, eventos de interés, etc.

Enlaces de interés

INTERNACIONALES

International Society for Rock Mechanics and Rock Engineering (ISRM)
Federation of the International Geo-engineering Societies (FedIGS)
International Association for Engineering Geology and the Environment (IAEG)
International Commission on Large Dams (ICOLD)
International Geosynthetics Society (IGS)
International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE)
International Tunnelling Association (ITA)
International Union of Geological Sciences (IUGS)
Society of Petroleum Engineers (SPE)

NACIONALES

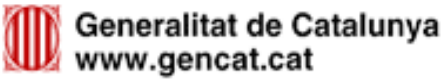
CEDEX
Sociedad Española de Mecánica de Suelos e Ingeniería Geotécnica (SEMSIG)
Colegio de Ingenieros de Caminos, Canales y Puertos
Consejo Superior de Colegios de Ingenieros de Minas
Colegio Oficial de Geólogos (ICOG)
Asociación Española de Empresas de Ingeniería del Suelo y Subsuelo (AETESS)
Asociación Española de Túneles y Obras Subterráneas (AETOS)
Asociación Española de Empresas de Ingeniería (TECNIBERIA/ASINCE)
Asociación Española de Ingeniería Sísmica (AEIS)
Comité Español de Grandes Presas (CEGP)

Ser socio de la SEMR

La cuota de inscripción a la SEMR es de 36 euros por año, que deben ser abonados mediante domiciliación bancaria. Esta cuota da derecho a:

- Asistencia gratuita a la Jornada Técnica anual de la SEMR, y obtención de la documentación que se entregue.
- Tomar parte en las Asambleas Generales y en las votaciones estatutarias.
- Poder ser elegidos por cualquier cargo de la Sociedad de acuerdo con los presentes Estatutos.
- Recibir información de la Sociedad y participar en ella.
- Elevar a la Junta Directiva, las propuestas que tiendan a un mejor logro de los fines de la Sociedad.
- Pertenecer a la ISRM como miembro de la SEMR lo que da derecho al acceso a más información en la página de la ISRM: www.isrm.net:
    - Copia digital del ISRM News Journal y de la ISRM Newsletter.
    - Acceso al área para miembros de la web (en la que se pueden descargar Informes, los “Suggested Methods”, participar en Foros de discusión, etc.)
    - Descarga gratuita de hasta 100 artículos por año de la biblioteca digital de la ISRM en el portal OnePetro: www.onepetro.org
    - Participar en Comisiones y grupos de interés de la ISRM.
    - Descuentos en Congresos de la ISRM o patrocinados por ella.
    - Descuentos en la suscripción de algunas revistas (International Journal of Rock Mechanics and Mining Sciences, Rock Mechanics and Rock Engineering).

Los **socios menores de 30 años** contarán con una **cuota reducida** de 15 euros.

La solicitud de ingreso se puede enviar a través de la página web (www.semr.es) o por correo electrónico (semr@semr.es).

Entidades y empresas colaboradoras