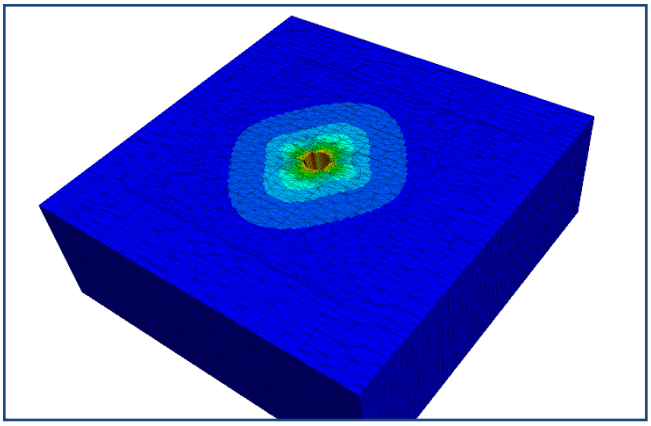
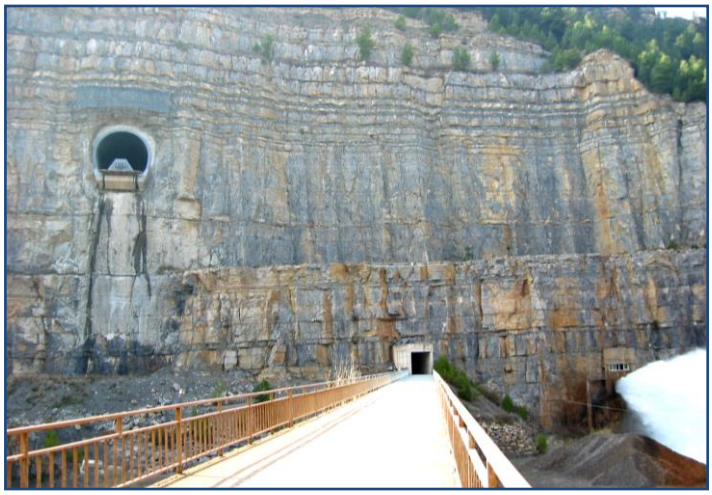
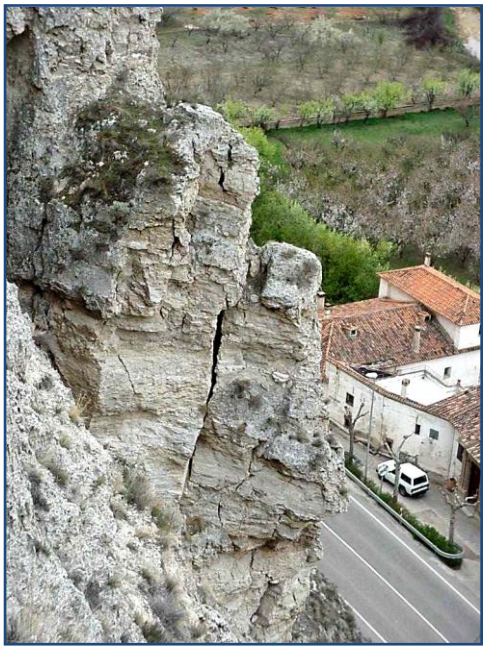
SOCIEDAD ESPAÑOLA DE MECÁNICA DE ROCAS

Año 2014 Boletín nº 7 www.semr.es







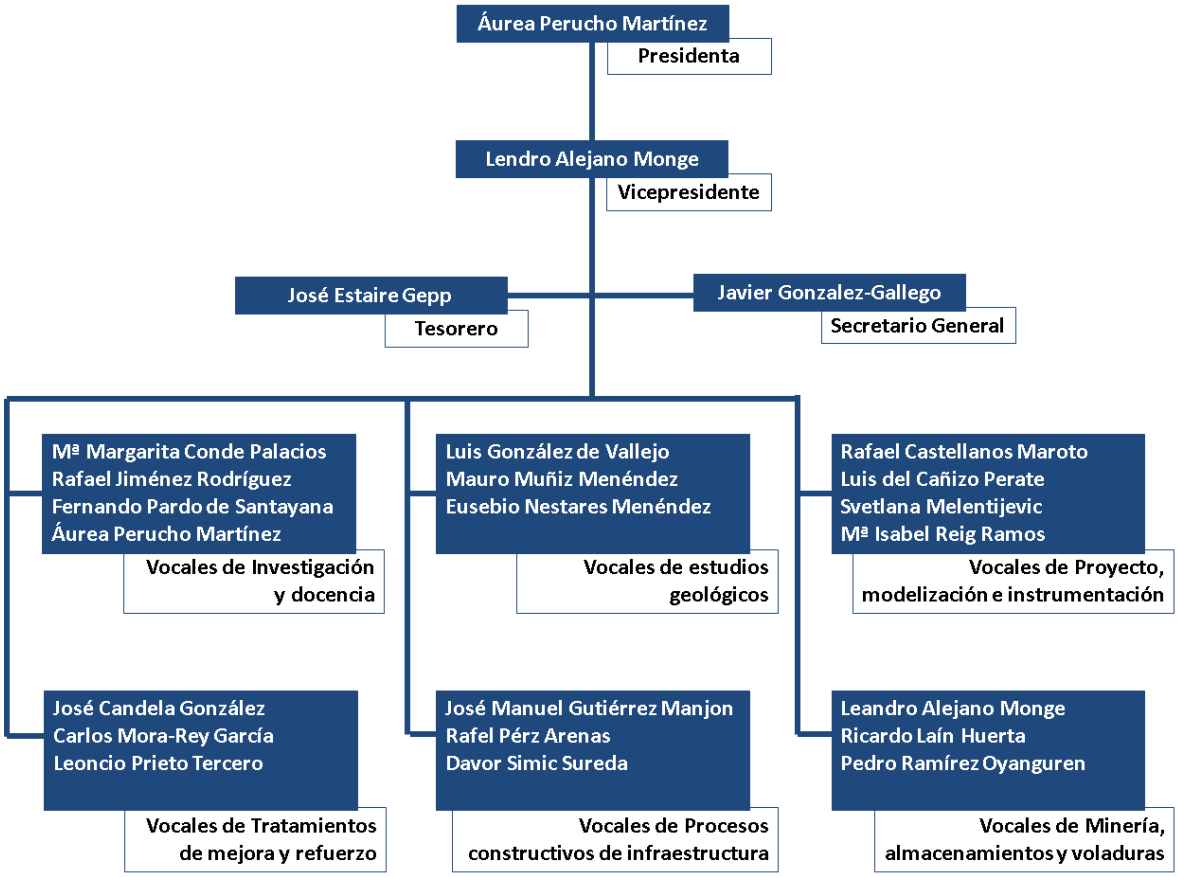
Comité de Redacción

Coordinadores:
Mauro Muñiz Menéndez
mauro.muniz@outlook.com
Javier González-Gallego (CEDEX)
javier.gonzalez@cedex.es

Comité de Redacción:
Áurea Perucho (Presidenta SEMR)
Eusebio Nestares
Leoncio Prieto (RODIO)
Juan Antonio Díez (CEDEX)
Claudio Olalla (UPM)

Sede Social
Laboratorio de Geotecnia- CEDEX
C/ Alfonso XII 3 y 5 -28014 Madrid
Teléfono: 91 335 73 33
E-mail: semr@semr.es

Junta Directiva



Representante del CEDEX: Juan Antonio Díez Torres
Representante de la SEMSIG: Enrique Dapena García

Expresidentes: Manuel Romana Ruiz
Claudio Olalla Marañon

Editorial

Queridos socios, amigos y compañeros:

En primer lugar quiero agradecer a Áurea Perucho, presidenta actual de la Sociedad, la oportunidad de dejarme participar en la misma como vicepresidente, así como la de redactar estas líneas. También quiero agradecer a la anterior junta directiva, y en especial a Claudio Olalla, toda la ayuda y el apoyo recibido en la organización del congreso EUROCK'2014 celebrado el año pasado en Vigo y que tuve el honor y el placer de organizar.

En palabras de John Hudson, reciente ganador del prestigioso premio Müller en honor a su distinguida trayectoria en el ámbito de la mecánica de rocas, la verdadera esencia de nuestra disciplina es una compleja mezcla de la mecánica pura, la idiosincrasia de la naturaleza y la determinación humana. La mecánica de rocas tiene lugar en lo alto de las montañas y en lo más profundo de la corteza terrestre; y al mismo tiempo es una disciplina con ánimo constructivo. Todo ello ha hecho que siempre me haya sentido atraído por esta rama de la ingeniería y que considere una suerte el poder desarrollar mi labor profesional en este ámbito.

Estas razones me llevaron en su día a formar parte de la Sociedad y hace unos años a proponer a la Junta Directiva la posibilidad de organizar por primera vez en España el congreso EUROCK, congreso europeo anual de la Sociedad Internacional de Mecánica de Rocas. Con la ayuda de muchos de vosotros se consiguió en el congreso internacional de Beijing en 2011 que la candidatura de Vigo fuera seleccionada para organizar el EUROCK 2014.

Desde la aprobación de la candidatura hasta la celebración del congreso muchas han sido las personas y las instituciones que nos ayudaron a lograr que EUROCK 2014 fuera un éxito de asistencia con casi 400 delegados y que los asistentes quedaran en general contentos y agradecieran el esfuerzo organizativo.

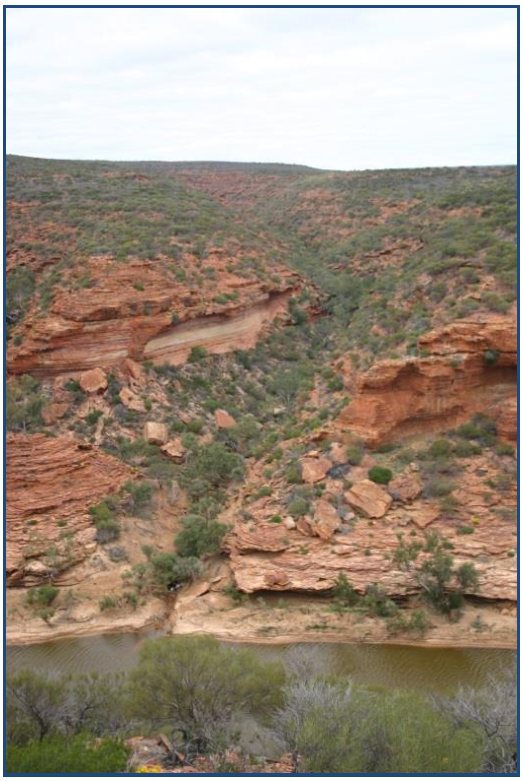
Cabe destacar la elevada presencia de estudiantes, casi un tercio de los participantes, en una época en la que nuestras titulaciones no resultan demasiado atractivas por causa de la crisis. Indudablemente fue el EUROCK con mayor presencia de jóvenes, lo cual contribuyó a hacer la reunión más dinámica y jovial.

Creo también que este congreso ha servido para poner de manifiesto el relevante papel de los profesionales y académicos españoles de la mecánica de rocas en el panorama europeo e internacional. Un número importante de artículos del congreso de alto nivel científico-técnico iban firmados por miembros de la SEMR. Nuestra Sociedad está entre las cinco mayores de Europa en número de socios y nuestros desarrollos de las últimas décadas en las ramas de la ingeniería geológica, civil y minera, aparecen representados en las revistas más relevantes del sector y están recibiendo premios de prestigio internacional como los recibidos por Svetlana Melentijevic o Eduardo Alonso, Nuria Pinyol y Antonio Gens que veréis reflejados en este boletín.

Para terminar, quiero animaros a seguir trabajando y pediros vuestra ayuda para dar visibilidad a vuestro trabajo, para lo cual esta sociedad tiene y tendrá siempre sus puertas abiertas.

Fdo. Leandro Alejano Monge

Macizo del Mont-Blanc



Kalbarri Gorges. Western Australia

Torca de Urrez. Burgos.

'Rock mechanics occurs deep in the earth, high in the mountains and often in the Word's wildest places… It is the romance and the passion associated with rock engineering that has led us to communicate some of this excitement'.

J. Hudson & J. Harrison, 1995

Actividades de la SEMR en 2014

JORNADA TÉCNICA 2014

El 29 de abril se celebró, con gran éxito de participación, la **Jornada técnica anual** de **2014**, cuyo tema fue **"La Mecánica de Rocas en el ámbito de la Ingeniería Minera"** y que contó con conferenciantes de gran prestigio como **José Miguel Galera** (Universidad Politécnica de Madrid), **Pedro Ramírez Oyanguren** (Universidad Politécnica de Madrid), **Diego Mas Ivans** (Itasca) y **Stephen Cooper y María D. Rodríguez** (Cobre Las Cruces, S.L.).

La Jornada fue coordinada por José Estaire Gepp y José Miguel Galera

CLAUDIO OLALLA SOCIO DE HONOR

En dicha Jornada anual se entregó una placa de **Socio de Honor** al profesor **Claudio Olalla Marañon**, nombrado por acuerdo de la Junta Directiva de la SEMR.

LA SEMR EN LA REUNIÓN DEL *INTERNATIONAL BOARD* DE LA ISRM

La presidenta de la Sociedad, Áurea Perucho, en representación de la SEMR, asistió a la reunión del *International Board* de la ISRM celebrado en Saporo (Japón).
En esta reunión se decidieron, entre otros temas:

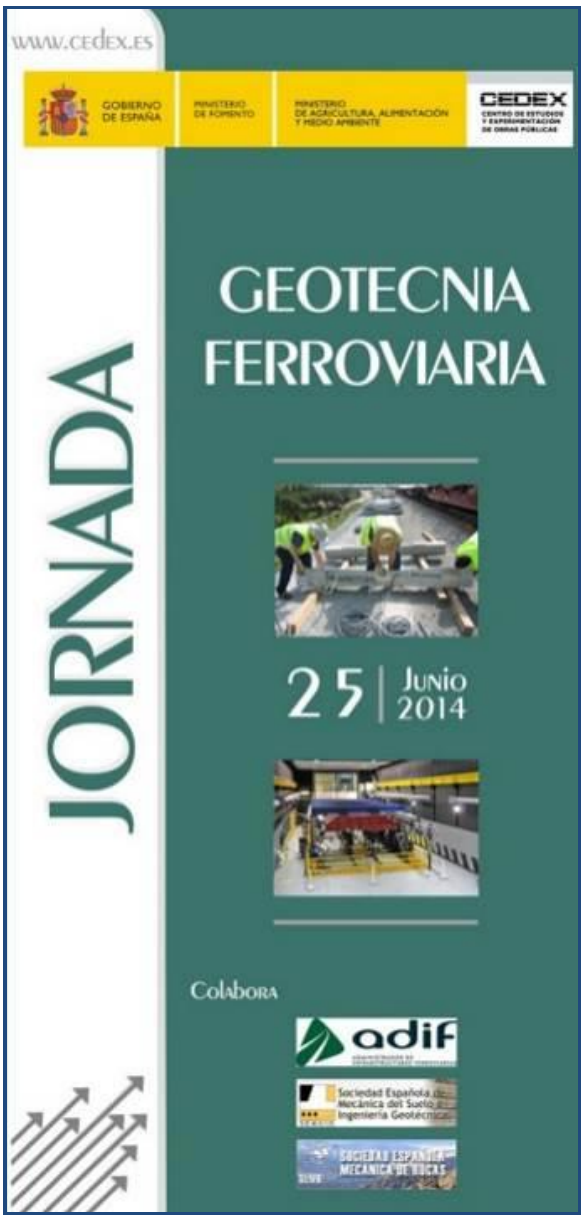
- El congreso internacional de la ISRM se celebrará en Cappadocia (Turquía) coincidiendo con el EUROCK2016.
- El galardonado con la 7ª medalla Müller en el año 2015 será el profesor John Hudson.
- El 14º Congreso de la ISRM se celebrará en 2019 en Foz de Iguaçu (Brasil).

LA SEMR ORGANIZADORA DEL EUROCK 2014 DE VIGO

El congreso europeo de mecánica de rocas se celebró en Vigo entre los días 27-29 de Mayo de 2014 con la organización de la SEMR y la Universidad de Vigo.
Esta noticia se desarrolla en siguientes apartados de este boletín.

LA SEMR PARTICIPA EN LA ORGANIZACIÓN DE LA JORNADA SOBRE GEOTECNIA FERROVIARIA

La SEMR colaboró, junto con la Sociedad Española de Mecánica del Suelo e Ingeniería Geotécnica, el CEDEX y ADIF, en la organización de la Jornada sobre **GEOTECNIA FERROVIARIA** que se celebró el día 25 de Junio de 2014 en las instalaciones del CEDEX. En esta jornada se presentaron los avances más relevantes en el ámbito geotécnico que se han alcanzado gracias a la colaboración que ADIF y el CEDEX han mantenido en los últimos años.




Cilindro de Marboré - Huesca

Nueva junta directiva de la SEMR

En las elecciones a la junta directiva celebradas durante la asamblea extraordinaria de socios de la SEMR desarrollada en Madrid el día 16 de enero de 2014, se eligió una nueva junta directiva para la Sociedad, resultando los siguientes cargos electos.

PRESIDENTA: Áurea Perucho Martínez (CEDEX)

VICEPRESIDENTE: Leandro Alejano Monge (Universidad de Vigo)

SECRETARIO: Javier González-Gallego (CEDEX)

TESORERO: José Estaire Gepp (CEDEX)

VOCALES DE LOS DIFERENTES GRUPOS DE TRABAJO:

Grupo A – Investigación y docencia:	María Margarita Conde Palacios Rafael Jiménez Rodríguez Fernando Pardo de Santayana Áurea Perucho Martínez
Grupo B – Estudios Geológicos	Luis González de Vallejo Mauro Muñiz Menéndez Eusebio Nestares Menéndez
Grupo C – Proyecto, modelización e instrumentación	Rafael Castellanos Maroto Luis del Cañizo Perate Svetlana Melentijevic Mª Isabel Reig Ramos
Grupo D – Tratamientos de mejora y refuerzo	José Candela González Carlos Mora-Rey García Leoncio Prieto Tercero
Grupo E – Procesos constructivos de infraestructura	José Manuel Gutiérrez Manjón Rafael Pérez Arenas Davor Simic Sureda
Grupo F – Minería, almacenamientos y voladuras	Leandro Alejano Monge Ricardo Laín Huerta Pedro Ramírez Oyanguren

EXPRESIDENTES: Claudio Olalla Marañón
Manuel Romana Ruiz

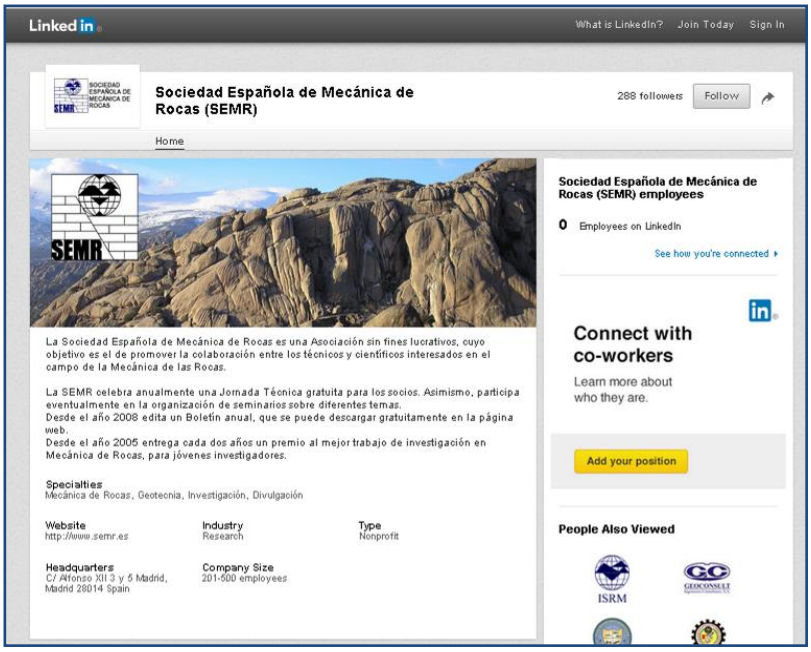
REPRESENTANTE DEL CEDEX: Juan Antonio Díez Torres

En la reunión de la junta directiva del 11 de febrero de 2014 se eligió, entre los miembros, la siguiente **comisión ejecutiva**:

Áurea Perucho (Presidenta – Grupo A)
Leandro Alejano (Vicepresidente – Grupo F)
Javier González-Gallego (Secretario)
Jose Estaire (Tesorero)
Mauro Muñiz (Grupo de trabajo B)
Svetlana Melentijevic (Grupo de trabajo C)
Leoncio Prieto (Grupo de trabajo D)
Davor Simic (Grupo de trabajo E)

La SEMR en las redes sociales

Desde el mes de junio de 2014 la SEMR está presente en las redes sociales **Linkedin** y **Facebook** consiguiendo más de 400 seguidores, entre ambas, en menos de 6 meses.
Con esta iniciativa, seguida posteriormente por la ISRM, se pretende acercar al público las actividades de la Sociedad y mantener informado, a todo el interesado, de aquellas noticias que tengan relación con la mecánica de rocas.



En estas redes se publican todas aquellas noticias destacables sobre la Mecánica de Rocas que nos llegan.

También se publicitan eventos relevantes como **congresos**, **cursos** o **conferencias** relacionadas con nuestra ciencia.

Desde la SEMR **animamos a todos los socios a colaborar** con nosotros remitiéndonos todas aquellas noticias que se puedan considerar de interés para nuestra comunidad e informándonos de aquellos hechos relevantes que deseen difundir como la publicación de artículos o la concesión de premios y menciones.

En nuestra página de **Facebook** tenemos (a día de hoy) **167 seguidores** y hemos publicado más de 50 noticias.

En **Linkedin** tenemos cerca de **300 seguidores** a los que hemos publicado 58 noticias. El promedio de visualizaciones de estas noticias de de 1.350, superando en algún caso las **4.900 visualizaciones**.

En unos meses contaremos con una **nueva página web** (www.semr.es) más moderna y dinámica, que nos servirá, al igual que nuestros sitios de Linkedin y Facebook, para **difundir nuestras actividades** y ofrecer un mejor servicio a todos los socios y colegas.

Esperamos contar con **vuestro apoyo** para continuar creciendo en las redes sociales y os ofrecemos estas plataformas para que **difundáis** todas aquellas **noticias que consideréis de interés** y relevancia en el ámbito de la mecánica de rocas y la geotecnia en general.

SVETLANA MELENTIJEVIC RECIBE EL PREMIO AL MEJOR TRABAJO EN *GROUNT IMPROVEMENT*

Svetlana Melentijevic (miembro de la junta directiva de la ISRM) recibió el premio al mejor trabajo publicado en Grount Improvement con la coautoría en el trabajo "**Grount Improvement Efficiency and Back-analasys of Settlements**"

Abstract: The ground improvement works carried out for the construction of five oil tanks at the Chiriqui Grande Phase II Oil Terminal, Chiriqui Grande, Panama, and their results are presented herein. The site is underlain by some 28 m of loose/soft, poorly graded, silty sands to clayey sands and silts. Ground improvement was used to provide the required bearing capacity and reduce the expected total and differential settlements. To fulfil the technical specifications, two ground improvement techniques were used in association with preloading: wick drains to full depth of the soft layers and stone columns in the upper 18 m. Stone columns are commonly installed as partial replacement to improve a soft ground, increasing its bearing capacity and accelerating its primary consolidation. Wick drains are used to accelerate the consolidation of soft clayey soils. Particular emphasis was given to the behaviour of the treated ground under the preloading fill: a back-analysis was carried out on measured settlements and pore pressures; the improvement of the ground and the degrees of consolidation achieved at the end of the preloading are highlighted; some correlations were derived and they provide an interpretation of the overall behaviour of the improved ground; estimates of the settlements for the short and long term are presented, the short term being that of the hydrotest and the long term being the design life of the oil terminal. They are based on results of preloading for their primary consolidation part, and on reasonable assumptions for their long-term creep (secondary consolidation) part. The estimates are compared to the actual hydrotest survey results.

http://www.icevirtuallibrary.com/content/article/10.1680/grim.11.00029

EDUARDO ALONSO, NURIA PINYOL Y ANTONIO GENS RECIBEN EL GEOTECHNICAL RESEARCH AWARD

Eduardo Alonso, Nuria Pinyol y **Antonio Gens** recibiran el Geotechnical Research Award al mejor artículo publicado en Géotechnique por su trabajo "**Compacted soil behaviour: initial state, structure and constitutive modelling**".

Abstract: The paper explores the behaviour of compacted soils throughout the (dry density–water content) compaction plane by means of a conceptual framework that incorporates microstructural information. The engineering properties of compacted soils are described by an initial state in terms of a yielding stress, soil suction and a microstructural state variable. Microstructure is defined by the ratio of microvoid volume to total void volume. The pattern of variation of the microstructural parameter within the compaction plane has been determined, for some compacted soils, by analysing mercury intrusion porosimetry data. The microstructure of wet and dry compaction conditions can then be quantified. To ensure consistency, the framework is cast in the form of a constitutive model defined in terms of an effective suction and a constitutive stress that incorporate the microstructural variable. The model is shown to be consistent with a number of experimental observations and, in particular, it explains the intrinsic collapse potential of compacted soils. It predicts, for a common initial suction, a higher collapse potential for dry of optimum conditions than for wet compaction. It also predicts in a natural manner the observed evolution of soil compressibility during drained or undrained loading. Model capabilities are illustrated by application to a testing programme on statically compacted samples of low-plasticity silty clay. The compression behaviour of samples compacted wet and dry of optimum and the variation of collapse strains with confining stress have been successfully reproduced by the model.

http://www.icevirtuallibrary.com/content/article/10.1680/geot.11.P.134

ANTONIO GENS PRONUNCIA LA *BLIGHT LECTURE*

El profesor **Antonio Gens Solé** (UPC), socio de la SEMR y vicepresidente para Europa de la ISSMGE, ha pronunciado la primera "**Geoffrey Blight Distinguished Lecture for Outstanding Achievement in the Field of Unsaturated Soil Mechanics**" con el título: "Unsaturated Soil Mechanics in Deep Geological Repositories".

"La Geoffrey Blight Distinguished Lecture for Outstanding Achievement in the Field of Unsaturated Soil Mechanics se otorga a un investigador o ingeniero cada cuatro años para reconocer contribuciones sobresalientes y sostenidas durante un período sustancial de una carrera profesional. Se concede en honor de Geoffrey Blight, ingeniero, académico y pionero en el campo de los suelos no saturados"

La Blight Lecture fue instituida por el Comité Técnico de Suelos No Saturados de la Sociedad Internacional de Mecánica del Suelo e Ingeniería Geotécnica y se ha presentado en el Congreso Internacional de Suelos No Saturados celebrado en Sydney (Australia) en el mes de julio.

LA ISRM CREA UNA LISTA INTERNACIONAL DE GRUPOS DE INVESTIGACIÓN EN MECÁNICA DE ROCAS

El grupo de jóvenes miembros de la ISRM (YMPG) está creando una lista de centros de investigación sobre mecánica de rocas Esta lista pretende ayudar a los jóvenes investigadores en mecánica de rocas a encontrar laboratorios, oportunidades de investigación (becas pre o postdoctorales) y colegas que trabajen en sus mismas áreas. La lista se crea de manera colaborativa a través de la siguiente página.

http://www.isrm.net/gca/index.php?id=1153

Rock Mechanics and Rock Engineering: Structures on and in rock masses
The 2014 ISRM European Rock Mechanics Symposium (EUROCK 2014)
Vigo, Spain, 27-29th May 2014

EUROCK VIGO 2014

SE CELEBRÓ EN VIGO EL CONGRESO INTERNACIONAL DE MECÁNICA DE ROCAS EUROCK 2014

El 'ISRM European Rock Mechanics Symposium (EUROCK 2014)' tuvo lugar en Vigo en fechas 27-29 de Mayo de 2014, organizado por la Universidad de Vigo y la Sociedad Española de Mecánica de Rocas. Un total de 390 delegados de 40 países asistieron al congreso que contó con 6 lecciones magistrales y la presentación de más de 200 trabajos de forma oral o en póster. Aproximadamente un tercio de los delgados fueron estudiantes.

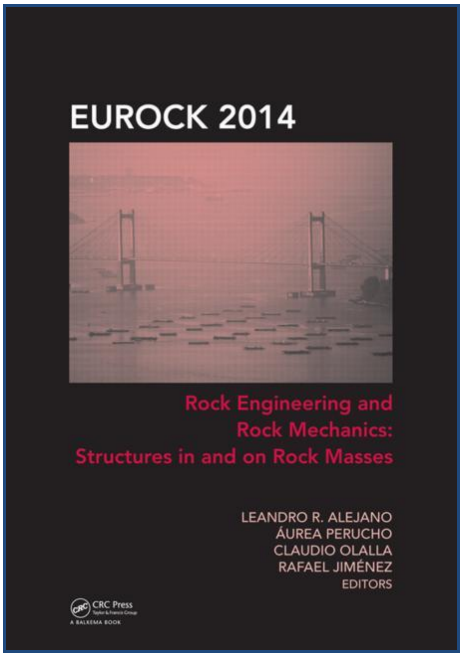
Las charlas magistrales fueron presentadas por expertos de categoría internacional incluyendo Nick Barton Barton (resistencia de macizos rocosos), Anna Maria Ferrero (caracterización con técnicas topográficas avanzadas), Derek Martin (rotura frágil de rocas), Xia-Ting Feng (grandes proyectos en China), Claudio Olalla (Cimentaciones en roca) y José Lemos (simulación de presas); que cubrieron un amplio espectro de problemas geomecánicos todavía no resueltos y casos prácticos de gran relevancia.

Adicionalmente se celebraron dos cursos titulados 'Simulación numérica en mecánica de rocas' y 'Soluciones de la mecánica de rocas en el ámbito de la protección de la roca ornamental y conservación de yacimientos arqueológicos'. También se celebró un taller sobre la 'Aplicabilidad y aplicación del Eurocódigo 7 al diseño en ingeniería de rocas'. Estos cursos y taller acogieron en total en torno a 80 asistentes.

Tres vistas técnicas fueron llevadas a cabo el día siguiente del congreso. La primera de ellas visitó la explotación subterránea de pizarra ornamental de Pizarras Gallegas y Las Médulas. La segunda la caverna subterránea para el refuerzo de potencia de la presa de Venda-Nova cerca de Braga en Portugal y la última un túnel de alta velocidad en el entorno de Xinzo de Limia. Un total de 50 personas acudieron a estas visitas.

Las actas del congreso fueron publicadas por la prestigiosa editorial Taylord & Francis, en un libro que contiene los artículos correspondientes a las charlas magistrales y los resúmenes del resto de artículos, junto con la versión electrónica completa de todos los artículos recibidos. Seis artículos magistrales y 250 artículos de 39 países fueron aceptados, que incluyeron contribuciones

de Asia (43), Australia (11), Europa (171), América (22) y África (2). Las actas, atendiendo a la calidad del proceso selectivo, están reflejadas en la base de datos científica SCOPUS. Los artículos publicados por autores españoles se recogen más adelante.



En lo que respecta a las actividades sociales, el ayuntamiento de Vigo tuvo a bien realizar una recepción para los delegados que incluyó a la sazón un coctel y estuvo amenizada por música y baile tradicional. La cena de gala se celebró en el hotel Bahía, incluyendo una sesión de cata de vinos gallegos y finalizó con una queimada. Varios tours fueron ofrecidos a los acompañantes para visitar Santiago y el Bajo Miño.

El congreso contó con el patrocinio de la Universidad de Vigo, Repsol, Gas Natural-Unión Fenosa, Geobrugg, la Diputación de Pontevedra y el Concello de Vigo, Subterra, Sibelco y la delegación Noroeste el Colegio de Minas. La Escuela de Minas de Vigo se implicó en gran manera en la organización y apoyo al congreso, concediendo 15 becas a sus estudiantes para asistir al evento. A todos ellos enviamos nuestro más sincero agradecimiento desde estas líneas.

Tres días de interesantes lecciones magistrales y presentaciones, discusiones y relaciones en el incomparable marco del Centro Social A Banca. Tres días para ver a viejos amigos y hacer nuevos, para ver los proyectos más avanzados a lo largo y ancho del mundo y familiarizarse con nuevas técnicas, discutir sobre ideas y plantear nuevos retos y proyectos. El desarrollo del congreso tuvo lugar en ambiente amigable y gran parte de los delgados agradecieron a la organización los esfuerzos realizados. Personalmente, creo que esto es lo que un congreso debe ser.

En nombre del comité organizador, no quisiera finalizar estas líneas sin agradecer a los participantes y autores que contribuyeron de forma definitiva a hacer de este congreso un evento ameno, entretenido e interesante.

Leandro Alejano
Presidente del Comité Organizador.

Visita a las Médulas - León

EUROCK 2014 – Artículos de autores españoles

A continuación se recogen los resúmenes de los 69 artículos presentados por autores españoles al **Eurock2014**:

Stability analysis of a room & pillar hematite mine and techniques to manage local instability problems

J. Arzúa & L.R. Alejano. Department of Natural Resources & Environmental Engineering, University of Vigo, Vigo, Spain
I. Clérigo, B. Pons, F. Méndez & F. Prada: PROMINDSA, Zaragoza, Spain

ABSTRACT: In this paper we briefly review the rock mechanics works carried out to analyse the stability of an old room and pillar hematite mine. Field work was initially carried out to recover a good number of discontinuity data, also a number of rock samples for lab testing were collected. UCS and triaxial tests were performed and rock masses were characterized in order to estimate rock, pillar and rock mass properties. Room stability and pillar strength and stability studies were carried out in all the relevant areas of the mine to find out a general good level of stability. Only in a location of the mine incipient instability problems were detected. Simplified stabilization methods were proposed, analysed and implemented, including the construction of a timber crib and the perimeter cabling of not-so-stable pillars in order to avoid rock-fall and progressive failure and to slightly increase pillar strength, as demonstrated by means of numerical approaches.

A lab–testing based geomechanical characterization of metamorphic rocks focusing on post–failure behavior

I. Pérez–Rey, J. Arzúa, J. Barbiero & L.R. Alejano: Department of Natural Resources and Environmental Engineering, University of Vigo, Spain
G. Walton: Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Canada

ABSTRACT: The stress–strain response of some intact metamorphic rocks (amphibolite, gneiss and marble) has been studied based on around 60 compressive uniaxial and triaxial strength tests. The results have been interpreted to obtain peak and residual strength, and post–peak parameters. Particular attention has been given to the study of dilation. The dilation angle of these intact rocks has been fitted to recently developed models for plastic shear strain and confinement–stress–dependent dilation. Even if the dilative response of these rocks has shown to follow similar trends to those observed in other hard rocks, in the case of foliated ones the peak dilation angle attain is not as high as that of more homogeneous (granite, marble). This is attributed to the fact that the final fracturing of the samples partially follows already existing weakness planes, which show less dilation than newly developed shear bands.

Abrasivity measures on geotechnical materials of the Barcelona area

C. González: PhD student, Department of Geotechnical Engineering, Universidad Politécnica de Cataluña, Barcelona, Spain
M. Arroyo: Associate Professor, Department of Geotechnical Engineering, Universidad Politécnica de Cataluña, Barcelona, Spain
A. Gens: Professor, Department of Geotechnical Engineering, Universidad Politécnica de Cataluña, Barcelona, Spain

ABSTRACT: Cutting tool replacement and maintenance operations might take up to a quarter of the total active time on mechanized tunnel excavation. Tool wear estimation is therefore necessary for accurate planning and costing of such operations. One of the main factors affecting tool replacement rates is abrasivity. Abrasivity is a property of geomaterials that quantifies their ability to cause wear on the tools interacting with them. There are several index tests (e.g. CAI) that are in use to quantify abrasivity. However, most of them are inappropriate when the tunnel operation passes through soils and rocks. In this communication we present a methodology applied to obtain a uniform measure of abrasivity for all the geotechnical units encountered on 23 km of tunnels recently perforated in the Barcelona area with different EPBs machines. The geotechnical conditions encountered were very heterogeneous, ranging from soft soils to hard and medium rocks, and frequently resulting in mixed soil-rock conditions. LCPC-type abrasivity measurements were obtained in all the materials. A descriptive summary of the main trends revealed by the data is presented. The ability of this test to evaluate abrasivity in all circumstances is highlighted by comparison with the more limited results achieved when applying other measurement methods.

A lab–testing based geomechanical characterization of metamorphic rocks focusing on post–failure behavior

I. Pérez–Rey, J. Arzúa, J. Barbiero & L.R. Alejano: Department of Natural Resources and Environmental Engineering, University of Vigo, Spain
G. Walton: Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Canada

ABSTRACT: The stress–strain response of some intact metamorphic rocks (amphibolite, gneiss and marble) has been studied based on around 60 compressive uniaxial and triaxial strength tests. The results have been interpreted to obtain peak and residual strength, and post–peak parameters. Particular attention has been given to the study of dilation. The dilation angle of these intact rocks has been fitted to recently developed models for plastic shear strain and confinement–stress–dependent dilation. Even if the dilative response of these rocks has shown to follow similar trends to those observed in other hard rocks, in the case of foliated ones the peak dilation angle attain is not as high as that of more homogeneous (granite, marble). This is attributed to the fact that the final fracturing of the samples partially follows already existing weakness planes, which show less dilation than newly developed shear bands.

Proposal of a new rock creep model

V. Brotóns, S. Ivorra, R. Tomás: Departamento de Ingeniería Civil, Escuela Politécnica Superior, Universidad de Alicante, Spain
J. Martínez-Martínez, D. Benavente: Dpto. Ciencias de la Tierra y del Medio Ambiente, Facultad de Ciencias, Universidad de Alicante, Spain

ABSTRACT: Rock materials can suffer high long-term deformations when subjected to constant compressive load (creep). This phenomenon has been studied and modelled by several authors, although the volume of existing literature on rocks is much lower than for concrete creep phenomena. The aim of this paper is to take advance of the well-known creep models established for concrete and to adapt them to the studied weak rock in order to estimate the long-term creep of rocks. One of the most common problems in the above listed studies is the brief duration of the laboratory tests and the assumed extrapolation of the obtained results. In this work 10 cylindrical samples of 54 mm diameter and 100 mm height were obtained for petrophysical and mechanical characterizations tests (ultrasounds, porosity and density, strength and creep under constant stress). Creep tests have been performed in order to study the long-term behaviour of a soft rock. A pattern concrete whose primary creep behaviour computed according to CEB-FIP code has shown to exhibit similar creep behaviour than the tested rock has been defined. A Kelvin-cells based rheological model, and a specific model based on CEB-FIP code adapted to the studied weak rock have been proposed, providing an accurate approximation to the real creep behaviour of the tested rock in the studied time period. Note that the type of concrete whose creep curve closely follows the behaviour of the tested rock, has a uniaxial compressive strength at the time of loading virtually equal to that obtained in the tests for the dry rock. This aspect suggests the possibility of adapting the CEB-FIP model to reproduce the creep behaviour of rocks beyond the tested time period.

Correlations between static and dynamic elastic modulus of a calcarenite heated at different temperatures

V. Brotóns, S. Ivorra, R. Tomás: Departamento de Ingeniería Civil, Escuela Politécnica Superior, Universidad de Alicante, Spain

ABSTRACT: This paper describes the analysis performed in order to obtain the relationship between the static and the dynamic modulus of one sedimentary rock (the San Julián´s stone) heated at different temperatures. The rocks have been subjected to heating processes at different temperatures (reaching up to 600º C in steps of 100º C), and two cooling methods for each temperature, to produce different levels of weathering on 24 cylindrical samples. The static and dynamic modulus has been measured for every specimen. Two analytic formulae are proposed for the relationship between the static and the dynamic modulus for this stone. The results have been compared with some relationships proposed by different researchers for various types of rocks. Generally low elastic modules imply highly fissured or damaged rocks. The mechanical properties, including static modulus, are highly dependent of the cracks size, orientation, and spatial distribution of these cracks. The ability to adequately detect the physical changes that affect rock mechanical capabilities by studying the propagation of ultrasonic waves has been widely discussed in many scientific papers. In this work, a high correlation between static and dynamic modules has been observed. It is concluded that in the studied range (i.e. Edyn values lower than 50 GPa) and for the soft rocks, static modulus can be obtained from dynamic tests, being the dynamic modulus (i.e. ultrasonic waves propagation velocities) a good indicator of the material degree of deterioration. The obtained relationships will allow the computation of the static modulus of elements of cultural heritage of Alicante city made of San Julián's stone, from non-destructive field tests, for the analysis of the integrity level of historical constructions affected by high temperatures.

Textural anisotropies characterization of granitic rocks using P-wave velocities

L. Calleja, A. Rodríguez-Rey, V.G. Ruiz de Argandoña and C. Camino: Departamento de Geología, Universidad de Oviedo, Oviedo, Asturias, España
N. Sánchez Delgado: Fundación Centro Tecnolóxico do Granito do Galicia. O Porriño, Pontevedra, España

ABSTRACT: Three granitic rocks from Galicia, Spain, namely Gris Alba, Albero Granite and Traspieles were petrographically (textural, mineralogy and fractography) characterized. Later, longitudinal waves velocity (Vp) in 3 orthogonal directions was determined; measurements were carried out on cubes 7 cm edge, wet and water saturated, previously oriented according to regional directions. Wet samples shows an anisotropic behaviour of Vp, however, on water saturated samples one of them behaves isotropically. From the obtained data and calculated IQ (quality index) and IF (microfissuration index), models of microcrack network distribution and possible mineral grains orientation were developed; the proposed models were compared with the petrographic studies, showing a perfect agreement between both of them.

Estimation of rock mass deformation modulus using a Bayesian approach

X.D. Feng & R. Jimenez:
E.S.T.I. Caminos, Canales y Puertos, Technical University of Madrid, Madrid, Spain

ABSTRACT: The deformation modulus (Erm) is one of the most important rock mass parameters; however, measuring it directly by in situ tests could be costly, time-consuming and sometimes impossible. For that reason, many models have been proposed to estimate the deformation modulus of rock masses based on aspects such as RMR (or GSI). In this study, we present a Bayesian approach to estimate the deformation modulus based on RMR (or GSI) for rock masses. Unlike traditional methods, our approach can account for model uncertainty. We work with Serafim-Pereira's model, i.e., Erm = 10((RMR-10)/40) and develop a "general" model for rock masses. Such general model is then updated using published and reliable data from in situ tests, hence allowing us to obtain updated models that are more accurate and with less uncertainty. We also show an example of how the predictive distributions of deformation modulus for rock masses based on the general model and the updated model can be employed to estimate the probability of failure of a tunnel

project, and how reducing the model uncertainty affects the reliability results.

Considerations on the laboratory estimate of the basic friction angle of rock joints

J. González, N. González-Pastoriza, U. Castro & L.R. Alejano: Natural Resources & Environmental Engineering department, University of Vigo, Spain
J. Muralha: Laboratório Nacional de Engenharia Civil, Lisbon, Portugal

ABSTRACT: The basic friction angle of planar rock joints is a parameter apparently easy to estimate from the results of laboratory tilt or pull tests on adequately cut and prepared rock specimens. However, when performing a good number of these tests, results may be surprising in terms of their wide variability and varying trends according to the particular environmental conditions of the carried out tests. By means of various series of laboratory tilt and pull tests on several specimens of different rock types some features have been deduced. First, a reassessment of the technique of tilt testing of rock cores suggests that even if the original formula was not correct, an appropriate interpretation of results could provide realistic basic friction angle values. Then, it has been observed that, in standard conditions and for the same specimens, tilt and pull tests produce comparable results. Additionally, it was noticed that large numbers of test repetitions on the same surfaces tend to produce diminishing values for the sliding angle if the surfaces are cleaned after every repetition. However, if the surfaces are not cleaned and the rock dust remains over the surfaces, a growing trend of basic friction angle values is registered. Finally, tilt tests on igneous rock specimens performed at a particular moment and months to years later, produce decreasing values for the sliding angle, which can be attributed to previous shearing movements or to surface degradation.

Petrophysical interpretation of mechanical behaviour of ornamental stones from Galicia (Spain).

N. Sánchez Delgado: Granite Technology Centre Foundation of Galicia. O Porriño, Pontevedra, Spain.
A. Rodríguez-Rey, L. Calleja, V.G. Ruiz de Argandoña and C. Camino: Department of Geology, University of Oviedo, Oviedo, Asturias, Spain.

ABSTRACT Six granitic rocks from Galicia (NW of Spain) widely used as ornamental stones have been studied. Physical properties such as bulk density and total porosity, abrasion resistance, uniaxial compressive strength and dynamic modulus of elasticity, as well as petrographic characteristics including volumetric mineral percentages and mean crystal section area have been measured. The results permit the classification of the rocks into categories and the assessment of the direct influence of some petrographic parameters in physical properties.

Measurement of the basic friction angle of rock by three different tilt test methods

J. Ruiz & C. Li: Department of Geology and Mineral Resources Engineering, Norwegian University of Science and Technology, Trondheim, Norway.

ABSTRACT: The apparent friction angle of a rock joint, φ, is the sum of two parts: the basic friction angle, φ_b, and the roughness angle, i. φ_b is decided by the mineralogy of the rock; It is usually measured through tilt test using two pieces of rock samples the contact surfaces of which are supposed perfectly smooth (i.e. i = 0). A series of tilt tests were carried out, to compare three different tilt test methods: two-piece saw sample method, two-core method and three-core method. The results showed that both the two-core and three-core methods tend to overestimate the basic friction angle of rocks comparing to the result obtained from the two-piece saw sample method. It is believed that the overestimation is due to the relative rough surfaces of the cores, but not due to any difference between sliding along generatrix and planar surfaces as it was claimed in some papers.

X-ray fluorescence methods for the recognition of minerals and rocks. Application to granite.

N. Barral-Ramón & R. Pérez-Álvarez: Area of Exploitation of Mines. Polytechnic School of Mines and Energy Engineering. University of Cantabria, Torrelavega, Cantabria, Spain.
R. Laín Huerta: Department of Exploitation of Mineral Resources and Underground Works. Superior Technical School of Mines and Energy Engineering. Polytechnic University of Madrid, Madrid, Spain.

ABSTRACT: Geological Knowledge is basic for the study of our Planet and its contents, being related to the analysis of minerals and rocks, the processes and mechanisms that act on the components of the Lithosphere and, therefore, with all the aspects that reflect the History of the Earth over time. In order to study the rocks, it is necessary to start with a petrographic analysis of the minerals, since it allows identifying them and also determining their main characteristics. The X-ray analysis allows distinguishing the structures and crystalline phases through the use of X-ray diffraction and the elemental analysis by X-ray fluorescence. This work presents some modern applications instead of the traditional analytic routines, treating portable equipment, which allows developing a multi-elemental analysis in a fast and easy way. Finally, some conclusions related to the application of the method on granite have been extracted.

Geotechnical characterization of low strength anisotropic rocks in the Strait of Gibraltar area

A. Perucho, M. Muñiz & J. A. Díez: Geotechnical Laboratory (CEDEX), Madrid, Spain

ABSTRACT: The Algeciras Unit is formed, in part, of the following geological formations: calcareous flysch (Eocene), red pellitic succession (lower Oligocene), and micaceous sandstones and marls flysch (oligocene-aquitanian). In these anisotropic formations, 14 boreholes between 15 and 20 m of depth were drilled and undisturbed and also paraffinic core samples were recovered and brought to laboratory for obtaining specimens and test the materials to characterize them from the geotechnical point of view. From the undisturbed samples 87 specimens were cored in different directions: vertical (parallel to the borehole), horizontal (with axis parallel to the direction of the bedding plane), and horizontal (with axis perpendicular to the direction of the bedding plane) and were tested: In this paper some interesting results are presented.

Shapes of failure in collapsible materials

A. Serrano
Polytechnic University of Madrid (UPM), Madrid, Spain
M. Conde & A. Perucho: Geotechnical Laboratory (CEDEX), Madrid, Spain

ABSTRACT: A deep study of geotechnical characterization has been carried out with low density volcanic pyroclasts. More than 250 samples have been tested and the strength and deformability of these materials has been studied. Many interesting results have outcome from this study, one of them being the different shapes of failure of the samples obtained both theoretically and empirically. These shapes are mainly the following ones: In uniaxial compression nearly vertical failure planes; In triaxial compression, failure planes forming angles of 45+□/2 with the major principal stress, being □ the dilatancy angle of the material; For high values of the confining stress the plasticity theory does no longer verify and the sample loses completely its structure; In the frontier zone of high confining pressures when the plasticity theory is about to stop verifying horizontal or nearly horizontal failure planes are formed. It is considered that these results may also be of interest and extended to other types of rocks.

Mathematical development of stress-strain law for rock block contacts

R. Galindo, A. Serrano & C. Olalla: PhD Civil Engineers, Geotechnical Department, Technical University of Madrid, Spain

ABSTRACT: The fracture behavior of rock block contacts has been studied for many years. Unfortunately, up to now, there is not a rigorous formulation or a solid theoretical foundation to support it. A mathematical development to represent the failure mechanism which occurs in the contacts between rock blocks is presented to evaluate the performance of breaking mechanism of such blocks relating it to the morphology of the contact and mechanical parameters of the material.
The examined framework includes the evaluation of the surface roughness of first order in the failure mechanism of the granular particles of large size and the development of a theoretical model describing the morphology of the contact between rock blocks.

Mechanical characterization of the rocks involved in the Albuñuelas landslide (South Spain)

J. Martínez-Martínez, J. Delgado Marchal, D. Benavente & S. Ordoñez: Dept. de Ciencias de la Tierra y del Medio Ambiente. Universidad de Alicante. Spain
J. Garrido. Dept. de Ingeniería Civil. Universidad de Granada. Granada, Spain
S. Martino. Dept. Scienze della Terra and Centro di Ricerca per i Rischi Geologici (CERI), Università di Roma "Sapienza". Italy
M.A. García-del-Cura. Instituto de Geociencias IGEO, CSIC, UCM. Madrid. Spain.

ABSTRACT: Mechanical characterization of four different rock varieties is presented in this work. This study is included in the research developed for modelling the stability of the Albuñuelas landslide (Granada province, Spain). Selected rocks correspond to two sandstones, a calcirudite and a brecciated marble. The mechanical behaviour was characterized by means of both static (uniaxial compression test) and dynamic (ultrasounds) methods. Porosity, rock fabric (grain-supported or matrix-supported) and fracture density result the most significant petrographic parameters for mechanical behaviour. Several correlation equations between static and dynamic parameters are presented. In general, ultrasonic measurements provide a good estimation of strength and static Young's modulus. This important conclusion guarantees the use of ultrasounds as an effective in-situ and non-destructive test for mechanical characterization.

Geotechnical characterization of rocky materials from Arteara rock avalanche (Gran Canaria)

M. Santana & J. Estaire: Laboratorio de Geotecnia, CEDEX, Spain
J. Yepes Universidad de Las Palmas de Gran Canaria, Spain

ABSTRACT: This work discusses the laboratory geotechnical characterization made with rocky materials coming from the Arteara rock avalanche, situated in Gran Canaria island. The study is based on laboratory test obtained for seven different lithotypes. The aim of them is to define strength and deformational parameters enabling subsequent modelling of the avalanche. The laboratory tests carried out included: the determination of porosity and absorption of the rock, the measurement of wave propagation speed, the evaluation of the strength in triaxial compression tests made in a Hoek cell and the shear strength in direct shear tests.

Relationship between RMRb and GSI based on in situ data

F. Ceballos Civil Engineer, Técnicas y Proyectos S.A. (TYPSA), Madrid, Spain.
C. Olalla, R. Jiménez Professors, Technical University of Madrid, Spain.

ABSTRACT: Due to the large experience accumulated in the use of the RMRb (Rock Mass Rating), as well as to the simplicity of the estimation of the GSI (Geological Strength Index) and to the importance of GSI as input data in the Hoek&Brown failure criteria, both the RMRb and GSI are widely used in geotechnical engineering practice. This article analyzes the relationship between both classifications using in situ data corresponding to different types of rocks collected from different outcrops in Spain. Currently available correlations between RMRb and GSI have been compiled and analyzed in order to compare them with the results of the analysis conducted in this study. Finally, the best (most suitable) statistical relations between RMRb and GSI, depending on the type and quality of rock media, are shown and they are used to establish general correlations. To conclude recommendations are presented, suggesting the use of a particular expression and its limits of applicability.

Geotechnical characterization and correlations obtained in Flysch units.

A. Alkorta Lertxundi Interbiak. Diputación Foral de Bizkaia, Basque Country. Spain
R. Moreno Bernal, G. Martínez Ruiz & S. Sánchez Rodríguez Ayesa, Madrid, Spain

ABSTRACT: The geotechnical characterization of rock masses in Flysch's deposits generates some difficulties due to the alternation of layers of different geomechanical behaviour. This lithological alternation is presented at

different scales, from metric to millimetric, being very difficult, sometimes impossible, to differentiate them in field-scale. Therefore, it is necessary to realize a detailed analysis at the smaller scales, which is at borehole log scale, to correctly obtain intact rock parameters. Once the intact rock parameters have been obtained for every lithotype, geotechnical parameters of the different rock masses are defined using geomechanical classifications obtained from borehole logging and geomechanical stations in field surface. Finally, the article draws the main conclusions on the correlations found from the most common classification systems: RMR from Beniawski, Q from Barton, and GSI from Hoek.

Characterization of rock joints by fractal analysis

R. Galindo, A. Serrano & C. Olalla. PhD Civil Engineers, Geotechnical Department, Technical University of Madrid, Spain

ABSTRACT: From a physical perspective, a joint experiences fracturing processes that affect the rock at both microscopic and macroscopic levels. The result is a behaviour that follows a fractal structure.

In the first place, for saw-tooth roughness profiles, the use of the triadic Koch curve appears to be adequate and by means of known correlations the JRC parameter is obtained from the angle measured on the basis of the height and length of the roughnesses. Therefore, JRC remains related to the geometric pattern that defines roughness by fractal analysis.

In the second place, to characterise the geometry of irregularities with softened profiles, consequently, is proposed a characterisation of the fractal dimension of the joints with a circumference arc generator that is dependent on an average contact angle with regard to the mid-plane. The correlation between the JRC and the fractal dimension of the model is established with a defined statistical ratio.

Gravitational instability of a micaschist formation and its effects on road infrastructure

D. Simic, J. López: Ferrovial-Agromán, Madrid,Spain

ABSTRACT: This paper analyses the geomorphological and rock-mechanical factors that have a negative influence on the slope stability of a highway in a heavily fractured and deeply weathered rock mass consisting mainly of michaschists. The paper describes the geomechanical investigations carried out, the rock-mechanics models prepared to simulate the complex behavior in cuts and the results of the monitoring during the construction of the highway. For this purpose, an insight to the failure mechanism experienced insofar has proven necessary, as the rock mass parameters can't be obtained through conventional GI, so the backanalyzed behavior has been the main tool for the design.

Application of the Hoek & Brown (1980) failure criterion to the design of the foundation of an arch dam

C.M. Baena: Jesús Granell, Ingenieros Consultores, S.L. (JGIC) Madrid, Spain; cmb@jgicsa.com

C. Granell:Jesús Granell, Ingenieros Consultores, S.L. (JGIC) Madrid, Spain.

C. Olalla: UPM, Madrid, Spain.

ABSTRACT: Arch dams transmit to the foundation important loads; particularly, they have a high magnitude with one determinant horizontal component. To define the optimum foundation level of these type of structures on a rock mass, it is necessary to know the orders of magnitude of the safety factors incorporating the main factors that determine the ground response: type of rock, quality of the rock media, uniaxial compression strength of the rock matrix, load inclination, depth of the foundation, inclination of the surface of contact, etc. A real case is presented showing the influence of the variations of the different parameters involved in the obtained safety factors, for the bearing capacity of the rock mass. The original Hoek & Brown (1980) failure criterion has been used together with the Serrano & Olalla (1994) methodology to calculate the ultimate bearing capacity.

In-situ stress amplification in tunnels from Spain, Iran and Chile estimated by TSI and SAF indices

L. González de Vallejo: Geological Engineering, Department of Geodynamics, Universidad Complutense de Madrid, Spain

T. Hijazo: Prospección y Geotecnia, Spain

J.M. Galera: Subterra Ingenieria, Spain

Z.A. Entezari: Dpt.de Gènie de Mines, Universitè Laval, Quebec, Canada

ABSTRACT: TSI and SAF methodologies have been applied to 6 tunnels located in Spain, Iran and Chile to estimate the regional tectonic in-situ stress (K) and the increment of the principal horizontal stress over the regional horizontal stress in a particular tunnel section (SAF). For high values of SAF, deformations in the tunnel sections were much higher than those expected in the design. The increment of the principal horizontal stress over the mean regional horizontal stress, due to local geological and geomechanical anisotropies have ranged from 1.1 to 2.9. In-situ stress tunnel zoning in terms of the variation of SAF values is presented potential zones of tunnel instability. These methodologies can be particularly important in regions with complex geological conditions and with high or moderate in situ stress.

Sliding stability analysis of a gravity dam founded on a rock mass with an impersistent joint set

M. Cabrera, S. Senent, C. Olalla, R. Jiménez: Technical University of Madrid, Madrid, Spain

ABSTRACT: Sliding through the foundation is one of the most common mechanisms under which a gravity dam can fail and is one of the most difficult modes of failure to determine the safety due to uncertainties that the rock mass properties provides. This paper evaluates the sliding stability of existing gravity dams with a failure mechanism characterized by a sub-horizontal joint set acting as a sliding plane and with a potential failure path through the rock mass. For the study, a simplistic static analysis is considered, using the criteria of Barton-Choubey (1977) and Hoek-Brown (1980; 1992) to determine the shear strength for discontinuity and for rock mass respectively. The finite difference program FLAC 6.0 has been used to validate the model. Results show in a sensitivity analysis executed, that it is possible to define with acceptable accuracy a sliding safety factor for the mechanism proposed in a preliminary study, with a simple spreadsheet.

Slope stabilization methods. Alternatives for the containment of land slopes.

N. Barral-Ramón & R. Pérez-Álvarez: Area of Exploitation of Mines. Polytechnic School of Mines and Energy Engineering. University of Cantabria, Torrelavega, Cantabria, Spain.
R. Laín Huerta: Department of Exploitation of Mineral Resources and Underground Works. Superior Technical School of Mines and Energy Engineering. Polytechnic University of Madrid, Madrid, Spain.

ABSTRACT: Considering construction works, especially in the case of roads, it is often necessary to build structures of different heights, or to modify the natural slope of hillsides for the containment of land masses, understanding slope as the accumulation of lands, rocks, or weathering products. The aim of this paper is establishing the basic concepts needed to develop a comparison between the different calculation methods for slope stabilization, evaluating the parameters to be taken into account in order to select the optimal one.

Application of the electrical tomography technique in the design of a soil-nailing reinforcement for a slope in karstic limestone and sandy colluvial

I. Pérez-Santisteban & J. Dorronsoro Pérez: Dept. of Geophysics, Orbis Terrarum, Madrid, Spain
F. Puell Marín : Technical Department, Orbis Terrarum, Madrid, Spain

ABSTRACT: This case studies the implementation of a large slope in the newly built A8 motorway, located close to Buelna (Asturias), where a mesh of electrical tomography profiles has been used to detect the presence of karstified limestone ridges under sandy colluvium. The results collected were used to design a steeper slope and to undertake the necessary improvements of the colluvial area by using soil-nailing techniques. This reinforcement proves to be a more suitable solution, when necessary, than other more expensive options.

Main difficulties and lessons learnt during the TBM excavation in shales in the North portal of Pajares tunnels

M.B. Díaz Aguado: Department of Mining Exploitation, GEMMA Group of Research, University of Oviedo, Asturias, Spain
J. García de Muro: INECO, Oviedo, Asturias, Spain
R. Rodríguez: Department of Mining Exploitation, GEMMA Group of Research, University of Oviedo, Asturias, Spain

ABSTRACT: This paper analyses a tunnel length of 850 m of S. Emiliano formation, in Pajares tunnels. The main objectives are the recapitulation of problems occurred during tunneling works and the proposal of technical solutions, based on the experience gained during the works. Moreover, the RME index has been applied to the analyzed stretch. This index predicts TBM average rates of advance, ARA. The results show that the actual advance rates obtained during the excavation differ from theoretical values, mainly due to TBM problems and to the weak rock mass. The selection of a specific TBM determines the works' future development, thus requiring exhaustive geological studies. It also confirms that for tunnels currently being excavated, longer than the existing ones, ground treatments will be systematically needed. These ground treatments imply significant difficulties, especially when performed from the TBM. Thus, TBMs must be improved and adapted to deal with future challenges.

Analysis of the conditions of stability and stabilization of two slopes, in AP-68 with K.P. 59+743 to 60+038 and in AP-7 with K.P. 581+250 to 581+315, and incorprating the terrestrial photorestitution

S. Rodón: Abertis Autopistas España, Barcelona, Spain
F. J. Castanedo: Dpt. Geodynamics, UCM University & Dpt. Civil Engineering Alfonso X University, Madrid, Spain. EPSA, Equipo de Prospecciones, S. A., Madrid, Spain
M. Sopena: EPSA, Equipo de Prospecciones, S. A., Madrid, Spain

ABSTRACT: This work presents both, the analysis of stability conditions as necessary treatment for his stabilization in two slopes. One of these slopes is in the motorway AP-68 from Bilbao to Zaragoza, with K.P. of 59+743 to K.P. 60+038 in the left margin, and the other, on the AP-7 motorway from Tarragona to Valencia and Alicante, with K.P. of 581+250 to K.P. 581+315 in the left margin, too. A method of terrestrial photogrammetric restitution was incorporated for the measurement and location of stabilizing's treatments. Among others, the program used for terrestrial photorestitution was the Photomodeler Scanner v. 2.011. One of the main problems, presenting stabilitzation of rock slope projects, is the difficult geographic location, making it complicate to access, and the measurements of the area where is put treatments as well as its exact location. With terrestrial photogrammetry get detailed topography and the slope face 3D modeling.

Advanced 3D geotechnical modeling of Las Cruces Open pit

S.Cooper & M.D. Rodríguez: Cobre Las Cruces, S.A., Gerena, Sevilla, Spain
V.Pozo & J.M. Galera: Subterra Ingeniería, S.L. Madrid, Spain

ABSTRACT: Cobre Las Cruces is an open pit mine that extracts copper sulphides from the same volcano-sedimentary Paleozoic deposit as the mines of Rio Tinto, in the SW of Spain. The pit measures 1600 m long x 900 m wide x 250 m deep. The ore is overlain by 150 metres of the tertiary marly formation which behaves as overconsolidated clay, locally known as "Guadalquivir Blue Marls". These marls are structured with bedding at approximately 5m vertical intervals with an average dip of 3º to the South. A detritical aquifer between the ore and the marls exists. The water table is located 30 m below the surface and pore pressure has been shown to play a dominant role on the slope stability, particularly in the marls benches. Mineralization is embedded in volcanic and other metamorphic rocks, including some soft tuffs and clayey slates. To provide accurate data for these calculations, a comprehensive geological and geomechanical characterization has been undertaken. The geological work includes the elaboration of structural maps every 10 m (eg, every bench) based on the geological mapping of the existing pit as well as in the analysis of the borehole data that includes over 500 boreholes and 100,000m of cores. The geomechanical works consist in the construction of RMR quality maps for each bench while the

characterization is based on lab and in situ tests (dilatometer and borehole televiewer). With all these characterization an advanced 3D model solved with FLAC has been undertaken. This work forms a decisive component of the pit optimization after the first seven years of exploitation of the ore body.

An approximation to the prediction of the extent of the area crushed around a blasting drill

F. Bastante, E. Alonso & M.A. González: Department of Natural Resources and Environmental Engineering. University of Vigo. Spain

ABSTRACT: In this paper a simple methodology for estimating the extent of the crushed zone around a hole completely loaded with ANFO for different diameters of drilling is presented. Granite is chosen given the availability in the bibliography of their dynamic properties. In order to model ANFO's behavior the simplest law- γ law- has been used. For granite's behavior the shock equation of state has been used. The model is implemented by using KB hydrodynamic code. In order to determine the extent of the crushed zone, Hoek & Brown failure criterion is used considering the stress state arising from the elasto-dynamic solution to the application of a pulse of pressure in a cylindrical hole. Even being so hard the inherent assumptions of the model (step of a hydrodynamic regime to elasto-plastic without intermediate elasto-plastic behavior) results are of the same order (relative to the radius of the hole) than those commonly referred in the literature. The main contribution of this work is the introduction of a dynamic approach to deal with the resolution of the problem.

Preliminary Design of Underground Crushing Chamber

E. Trigueros & M. Martínez: Dpt. of Mining Engineering, Technical University of Cartagena, Cartagena, Spain
I. Alhama: Dpt. of Civil Engineering, Technical University of Cartagena, Cartagena, Spain

ABSTRACT: This paper explains how a large Underground Crushing Chamber of 140 m2 of section and 35 m length has been preliminary designed and optimized by applying a combination of two geotechnical well-kwon software: a 3-dimensional boundary element stress analysis as EXAMINE 3D and finite element modeling program as PHASES 2D. The first one allows us to know the correlation among the main void and the auxiliary ones, the vertical shaft and the haulage tunnel. Secondly the Finite Element Program will show the extension of the plasticizing zone around excavation. Thanks to the easy preparation of the models, this methodology enables us of making decision related to the preliminary design, knowing as well the previewed deformations.

Slope Stability Control of a Coal Mine during the filling of the artificial lake

J.I. Piñeiro Di Blasi & J. Taboada: Department of Engineering of Natural Resources and environment, University of Vigo, Spain
J. Martínez Torres: Centro Universitario de la Defensa, Academia Militar, Zaragoza, Spain

ABSTRACT: The influence of water on slope instability can generate forces that may produce a total or partial terrain collapse. An exhaustive geotechnical, geological and hydrogeological analysis was carried out during the life of the mine and served a foundation for consecutive estimating groundwater levels to achieve different sequences to fill the void of exploitation. A methodology created by robust mathematical tools combined with other techniques for calculating the instantaneous state piezometric water on the slope of the mine is presented. This application achieves make the data analysis and decision-making more dynamic in an effective and efficient way. Finally, the correspondence of actual to estimated groundwater levels was observed, and the stability of all slopes of the mine was confirmed.

Back analysis of a general rock failure in a marble quarry

M. Martínez Segura, E. Trigueros Tornero: Departamento de Ingeniería Minera, Geológica y Cartográfica, Universidad Politécnica de Cartagena, Cartagena (Murcia), Spain
J. Mulas Pérez: Departamento de Ingeniería Térmica y de Fluidos, Universidad Politécnica de Cartagena, Cartagena (Murcia), Spain

ABSTRACT: Active rock bolts have been widely used to stabilize soil and slopes in civil structures. Mining is another activity field where could be seen the application of these active bolts. However, the use of bolts in mining is restricted to marble quarries due to their specific rock characteristics. In a marble quarry, as a corrective measure, were employed active rock bolts in order to stabilize a defined area belonging to that quarry. However, a rupture of the base of a bench took place. As a result of that, there was a general failure of the whole bench which affected an area of 25 m high and 100 m long. This proceeding focuses on the study case of this failure through the use of back analysis techniques to estimate the causes of the collapse. A FLAC3D finite difference model was implemented to investigate this quarry failure in which the complex geometry of the quarry was considered. Besides, the key role of using active rock bolts in the quarry has been evaluated to find out their actual influence on the occurrence of failure. Previously these types of studies have been covered by using numerous experimental results which were compared by matching with those data provided by numerical analysis. Nevertheless, the relevance of this work relies on the fact that the present study is based on the information gathered from the real failure event, the knowledge of the geomechanical rock properties and the rock bolt characteristics.

The toppling of large blocks on the northeast slope of the Meirama mine

C. Manera Bassa: M.M. Instrumentos
P. Ramírez Oyanguren: Universidad Politécnica de Madrid, Spain
R. González Philippon, María Fernández-Pello Lois: Gas Natural Fenosa, Spain

ABSTRACT: In this article the complex case of the toppling of large granite blocks in an opencast lignite mine, which has produced displacements of the slope greater than 50m with speeds that reached 1m/week, will be discussed. Not all the slope was composed of granite; the lower part consisted of Tertiary deposits which suffered deformations owing to the pressure exerted upon them by the inferior block of the granitic part of the slope in its tendency to tilt. The mine reached the anticipated final depth of 310m

owing to the movements of the slope being monitored with topographic prisms, time-domain-reflectometry (TDR) installations and inclinometers, and to the appropriate solutions to reduce the slope movements to admissible limits being applied: setbacks to reduce the angle of the slope and drainage wells, up to 400 m in depth, to lower the piezometric level. Once the open pit was finalised, it was partly filled with waste and is currently filling up with water.

Efficient Numerical Integration of Perzyna Viscoplasticity, with Application to Rock Slope Stability using Zero-Thickness Interface Elements

I. Aliguer & I. Carol: Geotechnical Engineering and Geosciences Department, ETSECCPB. Universitat Politécnica de Catalunya, Barcelona, Spain

ABSTRACT: In this paper, Perzyna-type viscoplastic rate equations are integrated for a time step by considering the step as stress-driven. Depending on how the increment is imposed (constant, linear etc.), different strategies arise. The secant compliance is obtained by truncated expansion of the yield function. The viscoplastic model can be applied to materials exhibiting rate-dependent behavior, but it can also be used to recover an inviscid elastoplasticity solution when stationary conditions are reached. Within this framework, a viscoplastic relaxation iterative strategy is developed, relating the iterations with the fictitious time steps. Some examples of application are presented in the context of the Finite Element Method with zero-thickness interface elements for slope and stability problems with discontinuities.

System Reliability Analysis of a Circular Rock Tunnel Using a First Order Approximation

P. Zeng & R. Jimenez: Department of Ground Engineering, Technical University of Madrid, ETSI Caminos, C. y P.

ABSTRACT: An approximated linearization approach based on the first order reliability method (FORM) is applied to analyse the system reliability of a circular tunnel in a jointed rock mass characterized by the Hoek-Brown non-linear failure criterion. Three failure modes are considered in this paper: exceedance of support deformation capacity, unacceptable tunnel convergence and insufficient rockbolt length. We employ the convergence-confinement method (CCM) to compute the stresses and displacements around the tunnel. Eight parameters---related to rock mass properties, in situ stress and shotcrete properties---are regarded as independent random variables with lognormal distributions. The series system reliability is computed, through the complementary of the intersection of safe domains, based on the results of FORM. An illustrative example is demonstrated with a circular tunnel. We compare the solution of the proposed method with Monte Carlo simulation (MCS) and bimodal bounds. The results show that the proposed approach can be applied to deal, efficiently and accurately, with the system reliability problem of circular rock tunnels.

Different FEM Models for Simulation of the Osterberg Load Test in Rock Shafts

S. Melentijevic: Grupo Rodio-Kronsa, Madrid, Spain
C. Olalla: Professor, Geotechnical Department, ETSICCP, Polytechnic University of Madrid, Spain

ABSTRACT: Osterberg load tests are widely used around the world, especially with increasing structural loads and consequently larger diameters and lengths of deep foundations. This paper describes different finite element models developed for numerical back analysis of the performed field O-cell load test. The axi-symmetric model is adopted in the numerical analysis using a commercial finite element program. The contact surface of the pile shaft drilled in rock is introduced in numerical model in agreement with the proposal by Pells et al (1980). The shaft roughness classes, varying from smooth to very rough, are in function of geometry of the shaft based on the excavation method and the rock strength. The influence of different roughness classes on results is shown. Diverse results are obtained by numerical modeling: (1) load-settlement relationship, (2) load transfer mechanism, i.e. yield zones development, (3) end bearing and skin friction resistance, etc. The importance of suitable consideration of end bearing by adequate modeling of pile toe is emphasized.

Experiences implementing high energy rockfall barriers as a tool for creating a shadow zone against rockfall in linear infrastructures

R. Luis Fonseca & C. Raimat: Geobrugg Ibérica S.A.U. Madrid, Spain
A. Sanz: University of Oviedo, Asturias, Spain

ABSTRACT: Rockfall barriers are widely known as proven efficiency element of protection of infrastructure through the interception of rock blocks in the path of the fall and the absorption of the energy generated by them. It's common in the project design phase and during installation, fix rockfall barriers for catch a high percentage of the falling blocks and in many cases consider as valid the solution when the barrier can capture all of them. However, in many cases it's possible to consider the use of these protections, simply to guarantee a secure shed the traffic and intercept simply the blocks that theoretically hit into the road surface. The results are showed in the project of the high-energy rockfall protection barriers type GBE in the GC-200 road in Las Palmas de Gran Canaria in the area of Anden Verde and see form compared with the results that could be generated, with the routine application of this interception method.

Risk Associated with Swelling Rocks in Volcanic Formations in the Design of Hydro-Tunnels

J.M. Galera, M. Paredes, C. Menchero & V. Pozo: Subterra Ingeniería, Madrid, Spain

ABSTRACT: The paper analyses how to detect the swelling potential, quantifying and interpreting the long-term impact on the final lining of underground works, from the design and the construction experience achieved in various hydro-tunnels affected by this phenomena. In all of the cases analyzed the risk of swelling is associated to volcano-sedimentary rocks as Abanico Formation, Coya-Machalí Formation and in a lesser extent in Farallones Formation, among others, located in the Andes. These swelling phenomena occur due to the presence of swelling (expansive) clay minerals contained in the rocks associated to rock mass degradation and water presence.

A strain-dependent strength and dilation model of rock to study pre-peak behaviour in confined tests

J. González-Cao: Departamento de Recursos Naturales y Medio Ambiente, Universidad de Vigo, Spain.

ABSTRACT: Some of the main features of the behaviour of strain softening rocks are associated precisely to the strain softening phase of the constitutive law, which can be modelled using data extracted from a (confined) compression test. Nevertheless, some other important aspects are connected to the pre-peak behaviour. For instance, localization phenomena are associated to the pre-peak hardening phase for many rocks. In this paper, using data from a series of confined compression tests, the derivation of a strain-hardening model for the pre-peak stage of a (otherwise) strain-softening rock is considered and the ability of this model to predict localization phenomena is examined.

Rockfall protection structures in the Tramuntana mountain range of Mallorca (Spain)

Joan M. Rius Gibert and Raül Aguiló González: Consell Insular de Mallorca, Balearic Islands, Spain

ABSTRACT: This work focuses on the determination of protective measures for rockfall in a unique area of a mountain road in the Tramuntana range of Mallorca with a daily traffic estimated at 7.200 vehicles. The wildfire that affected the area in the summer of 2013 has increased the risk of the road further accelerating the need to protect this area already sensitive. The local authorities have decreed some emergency measures and studies to protect the road from this kind of events. The first studies performed have shown a more risky scenario after the fire because of the lack of vegetation cover and this situation has involved the construction of some new protection structures on the rock slopes to decrease the rockfall risk. The performance of the studies has been undertaken by means of analysis of trajectories on simulated rockfalls to design protective measures. These new protection projects are now under development.

Comparison between continuous and discontinuous approachesto tunnel models: FLAC vs. UDEC

M. Veiga, J. Barbiero, S. Alonso & L. Alejano: Department of Natural Resources & Environmental Engineering, University of Vigo, Spain
A.M. Ferrero: Department of Earth Sciences, Universitá degli Studi di Torino, Italy

ABSTRACT: One of the most relevant problems when modeling rock masses derives from the fact that rock masses are natural materials, so their physical and mechanical features have to be assessed with the help of non-straight-forward experimental procedures and cannot be a priori accurately defined as it can be the case for other construction materials. Rock masses are discontinuous, heterogeneous, anisotropic, non-elastic, scale-affected, complex materials.In the 80s Hoek & Brown proposed and later refined a procedure to homogenize rock mass behaviorand derive equivalent continua properties of rock masses, but this approach is not suitablein all cases. The choice to model a rock mass as continuous or discontinuous is usually madein the light of the jointing of the rock mass, for instance comparing the average joint spacing or blocksize in the rock mass to the span of the underground excavation. To further study the appropriatenessof the approach in this work we have carried out a comparison of continuous and discontinuousmodels of tunnels in 6 types of rock masses of growing geotechnical quality by meansof standard codes FLAC and UDEC, following the development by Ferrero et al. (2004). In these models stresses and displacement distribution have been compared to analyses the representativeness of the derived stress-strain behavior around excavations by means of continuous and discontinuous approaches.

Back analysis and Radar Interferometry Monitoring in a Large Open Pit Slope

C. González-Nicieza & M.I. Álvarez-Fernández: Department of Mining Exploitation and Prospection, University of Oviedo, Spain
O. Mora: Altamira Information, Spain
E. Amor-Herrera: SAHVL, Spain

ABSTRACT: Between 2008 and 2012, images from the X-band high-resolution images of TerraSAR-X satellite have been acquired to monitor ground displacement evolution that affect an open pit in the north of Spain. The results of the control were consistent with those obtained with conventional measurements (as topographic monitoring). With this paper, they are demonstrated the capabilities of satellite radar technology to generate complete ground deformation maps of an open pit mine, to follow and detect movement intensities ranging from millimetric to metric scales. Several vulnerable parts of the mine have been studied and monitoring of these very small to very large instabilities has provided valuable information for risk and exploitation management at the mine. A forensic analysis, through numerical model, has been also performed and validated with these interferometric radar measurements showing itself as a key to predict future behaviour and redesign.

Procedure for obtaining and analyzing the diametric deformation of a tunnel by means of tape extensometer convergence measures

A. Bernardo Sánchez & M. Arlandi Rodríguez
Túneles y Geomecánica S.L., Madrid, Spain

ABSTRACT: The diametric deformation of a tunnel (the ratio of tunnel wall displacement vs. tunnel radius) is a very useful parameter to analyze its tenso-deformational behavior. In this paper we present a new methodology for use it as monitoring variable to assess tunnel stability. It has obtained an analytical expression useful to obtain the diametric deformation from tape extensometer convergence measures. A procedure to analyze the diametric deformation is proposed. A practical example is carried out.

Towards rockfall prediction: linking pre-failure deformation with precursory rockfall events

M.J. Royán & J.M. Vilaplana: RISKNAT research group and GEOMODELS Institute, Department of Geodynamics and Geophysics, University of Barcelona, Spain.
A. Abellán: Centre de Recherches en Environnement Terrestre (CRET). Faculté des Géosciences et de l'Environnement, Université de Lausanne. Switzerland.

ABSTRACT: In this study we compared the evolution of two types of precursory indicators over time: precursory rockfalls and pre-failure deformation. Our study was based on a multi-temporal comparison of LiDAR data using a Terrestrial Laser Scanner (TLS) Ilris 3D (Optech). The analysis was performed in a pilot study area located at Puigcercos scarp (Catalonia, Spain) using 19 different fieldwork campaigns carried out during more than five years (2143 days). Our results shows that: (a) the temporal evolution of the deformation show an exponential pattern with an acceleration before the final rupture; and (b) analogous acceleration shortly before the final failure was observed analyzing the evolution of accumulated precursory rockfalls events over time.

Some key issues regarding application of Eurocode 7 to rock engineering design

L. Lamas: National Laboratory for Civil Engineering – LNEC, Lisboa, Portugal

A. Perucho: Geotechnical Laboratory - CEDEX, Madrid, Spain

L. Alejano: Department of Natural Resources and Environmental Engineering, University of Vigo, Spain

ABSTRACT: Eurocode 7 is the harmonised European standard dealing with geotechnical engineering design. Although design involving rock masses is included in the code, rock engineering principles do not seem to be fully contemplated. This document summarizes some of the most relevant issues the authors consider that need to be improved in what concerns the application of Eurocode 7 to rock engineering design. This includes topics such as the implications of the discontinuous nature of rock masses, limit states and failure modes, strength criteria, characteristic values and partial factors for rock mass parameters, rock mass characterization, use of classification systems in design, among the most significant issues.

The approach to rock engineering in Spanish normative documents

Á. Perucho & J. Estaire: Geotechnical Laboratory, CEDEX. Madrid, Spain

ABSTRACT: In Spain there are currently three geotechnical standards: Building Technical Code (2006), for application in the field of building construction; Guide of Foundations in Road Works (2003), for application in the field of road construction; and Geotechnical Recommendation for Design of Maritime & Harbour Works (2005), for application in the field of port construction. The approach to rock mechanics in these Spanish standards is reviewed in this paper, considering different geotechnical areas: site investigation, shallow and deep foundations and slopes. It will be shown that in some cases these standards have different ways of approaching these geotechnical problems that may give out to remarkable differences in the results obtained. This reflects the fact that there are many different empirical formulae and procedures, collected in standards all around the world. Evolution in EC-7 considering more relevant aspects of rock engineering will help to unify methods and criteria used, but the variety of possible existing approaches, some of them showed in this paper, stresses the actual difficulties for that unification.

Spread foundations and slope stability calculations on rocks according to Eurocode EC-7

J. Estaire & G. Olivenza: Laboratorio de Geotecnia (CEDEX). Madrid. España.

ABSTRACT: This paper proposed a method to implement the EC-7 framework in the calculation of shallow foundations on rock and rock slope stability problems. Previously a revision of the usual methods currently used is made.

Cements of improved sealing capacity in CO2 geological storage

E. Estévez *1, L. Valle 2, D. del Barrio 1, G. Blázquez 1, T. Kovács3, V. Blázquez 2

1 Laboratorio Oficial para Ensayo de Materiales de Construcción, Getafe, Madrid, Spain

2 Fundación Instituto Petrofísico, Getafe, Madrid, Spain

3 Fundación Ciudad de la Energía, Ponferrada, León, Spain

ABSTRACT: Wellbore integrity is a key performance criterion in the safe long-term storage of CO2 in underground geological reservoirs. In this study, resistance to acidic attack of two cements is assessed by dynamic laboratory experiments under real reservoir conditions (50 ºC; 150 bar confining pressure) in order to evaluate their adequacy for use in injection and monitoring wells of CO2 geological reservoirs.

Effect of supercritical CO2 injection in the Corvio Sandstone during a flow-thru triaxial experiment

J. Canal, J. Delgado, V. Barrientos, R. Juncosa & B. Rodríguez-Cedrún: Civil Engineering School, University of A Coruña, A Coruña, Spain

I. Falcón: National Oceanography Centre, Southampton, United Kingdom

ABSTRACT: The effect of the injection of CO2-saturated deionized water (DIW) at supercritical state was investigated in the siliceous Corvio Sandstone while recording stress, strain, wave propagation and fluid chemical composition during a flow-through experiment. Our investigation correlated simultaneously chemical and rock physics parameters in a unique flow through experiment. The experiment illustrates interlinked hydro-mechanical processes with a minor contribution of reactive phenomena. This is a relevant approach when considering the extent of the relative contribution of isolated hydro-chemo-mechanical processes.

Behavior of a Fractured Reservoir over Time based on geomechanical Modeling

H. W. Stockhausen N.: New Ventures Asia-Pacific, Exploration-Repsol, Madrid, Spain

M.R. Lakshmikantha: E&P & Gas Technology Repsol Technology Center, Houston, USA

V. Sifontes G: G&G Reservoir development, Venezuela Business Unit, Pto. La Cruz, Venezuela

M.E. Barboza G: G&G Reservoir development, Venezuela Business Unit, Pto. La Cruz, Venezuela.

ABSTRACT: The main objective was to investigate if the fractures in the Cretaceous, containing the gas reserves, were capable of deliver their resources to the upper layer (Oligocene), where the wells are producing. For this project, was develop a new workflow to measure in the lab, fracture permeability at different reservoir conditions,

a new discrete fracture model, and core fractures where characterized and associated to rock facies. This simulator is capable of estimate production behavior more accurately and anticipates problems in surface and in the reservoir.

Hydro-mechanical coupling in zero-thickness interface elements, formulation and applications in geomechanics

D. Garolera, I. Aliguer & I.Carol: Dept. of Geotechnical Engineering and Geo-Sciences. Universitat Politècnica de Catalunya. BarcelonaTech (UPC). Barcelona, Spain.
J.M. Segura, M.R. Lakshmikantha & J. Alvarellos: Repsol. Repsol Technology Centre. Móstoles, Spain.

ABSTRACT: Zero-thickness joint/interface elements of the Goodman type, have been advantageously used to solve many problems in solid mechanics involving material interfaces or discontinuities. Some years ago, the authors have also proposed a version of such element for flow/diffusion and hydro-mechanical (H-M) coupled problems, either geomechanical or multiphysics. Some advantages are for instance that fluid pressure discontinuities and localized flow lines may be represented on the same FE mesh used for the mechanical problem, as well as the influence of fluid pressure on mechanical stresses or, conversely, of crack openings on the flow redistribution ("cubic law"). In the paper, previous developments are briefly described, together with some new Geomechanical applications under development, particularly the application to the hydraulic fracture problems, which in the past have been studied mainly via analytical or semi-analytical formulations, or using mixed FE-FD approaches.

Geomechanical study with outcrop samples to improve drilling performance for an exploration well in Northwest Africa

H.W. Stockhausen: New Ventures Asia-Pacific, Exploration-Repsol, Madrid, Spain
J.M. Hernán-Gómez, H. Gallego: Exploration Mauritania, Exploration-Repsol, Madrid, Spain
A. Alonso: Exploration Mauritania, Exploration-Repsol, Madrid, Spain
J. Barbiero: Department of Natural Resources and Environmental Engineering, University of Vigo, Vigo, Spain
J. Delgado: Civil Engineering School, University of A Coruña, A Coruña, Spain

ABSTRACT: A geomechanical survey of selected rock samples from outcrops and shallow stratigraphic wells taken from the vicinity of the prospect area has been conducted in order to obtain data and parameters useful for the selection of optimum drill bits prior to the drilling of a wildcat well in a frontier basin located in NW Africa. The available geological and drilling information suggests that the basin rocks are hard to very hard and abrasive, what will significantly increase the costs of the planned wildcat. Thus, this work is aimed at reducing drilling costs and to improve ROPs at the time of drilling by assessing realistic working properties from the drill bit selection point of view. The geomechanical survey included UCS, CCS, Schmidt hammer rebound and point load indexes, VP & VS wave propagation data (including high pressure hydrostatic determinations) and slake durability tests. A summary of the main results is presented here.

Determination of an "empirical" ground reaction curve useful for designing coal mine roadways support

R. Rodríguez & M.B. Díaz-Aguado: Department of Mining Exploitation and Prospecting, University of Oviedo. School of Mines, Oviedo, Spain. Researching group GEMMA (Group for Energy, Mining and Environment). Cluster of Energy, Environment and Climate Change, University of Oviedo, Spain

ABSTRACT: The initial objective has been to establish a methodology to use the convergence-confinement method in order to design the roadways support based on yielding steel arches, obtaining the same results than those from an empirical method widely used in coal mines. The mining method is based on an empirical relationship between the used support, the rockmass properties and the expected convergence in the gallery. The especial behaviour of the yielding steel sets, which slide under a constant external pressure (which depends on its characteristics), allows establish the relationship between a specific support design with a unique yielding pressure. Consequently, an empirical relationship between pressure against the support and convergence can established, which is equivalent to an "empirical" ground reaction curve. This equivalence between experimental recommendations (from mining field) and the convergence-confinement method (mainly from civil works) represents a nexus between empirical methods and a rational one which is a novelty.

Dimensioning of a flexible system for the stabilization of a landslide on the access road to Cotobello (Aller, Asturias).

J. Prieto Fernández, R. Luis Fonseca & R. Fernández Llata: Geobrugg Ibérica,SAU, Madrid, Spain
M. Fernández Martínez: New Construction, SL, Asturias, Spain

ABSTRACT: This paper presents the stabilization of a high slope on the road to Cotobello (Aller, Asturias), using wire mesh steel DELTAX ® high strength bolts anchored assets. Flexible systems for slope stabilization are used with great success in Spain since the 90s of last century, promoting the continuous development of this technique and manufacture of systems to ensure sustainability pressures up to 140kN/m2. The great benefits of these systems are their high landscape integration and not having any influence on the natural drainage of the slope and also its lightness in relation to the high support offered.

Protective actions against rockslides on roads of Sierra de Tramuntana. The case of Blau Gorg detachment on 2008, December 31st

R. Luis Fonseca, C. Raïmat & J. Prieto: Geobrugg Ibérica, SAU. Madrid, España
J.M. Rius Gibert & Cristòfol Massanet : Dirección Insular de Carreteras, Departamento de Urbanismo y Territorio, Consell de Mallorca. Islas Baleares, España

ABSTRACT: The roads of the Sierra de Tramuntana in Mallorca have been subjected to frequent rockfalls of varying magnitude in the last few years, which have required significant interventions from both slopes and hillsides protection as well as pavement. Among them worth mentioning the landslide of Gorg Blau, on December 31th in 2008, in the surroundings of Puig Major, the highest point of the Sierra, with a serious consequence for the road MA-10, which was cut closed to traffic for months. The magnitude of the detached soil caused the analysis in

detail of several solutions for stabilizing the hillside. Finally, a combination of active and passive protection elements throughout the hillside was chosen.

Face stability in tunnels excavated by the drill and blast method

S. Senent & R. Jimenez: Department of Ground Engineering, Technical University of Madrid, Madrid, Spain

ABSTRACT: We study the face stability of rock tunnels excavated by the drill and blast method, using an advanced failure mechanism in the framework of limit analysis. First, we study the influence of the geometry of the section and of the excavation process on the stability of the face, comparing a horseshoe section carried out in several stages with its equivalent circular section. Second, we investigate the influence on the collapse pressure of the damage induced in the rock mass during blasting, characterized by the Blast Damage Factor D. Results show that, as expected, multi-stage excavation sequences increase the stability of the face and that decreasing the height of the top-heading reduces the collapse pressure. Moreover, there is evident influence of the disturbance factor "D" on the collapse pressure, so that poor quality blasting can facilitate the collapse of the face.

In situ stresses in rock masses: methodology for its study in tunnel projects in Spain

G. Madirolas & A. Perucho: Geotechnical laboratory (CEDEX), Madrid, Spain

ABSTRACT: In situ stress is one of the main factors to be taken into account in the design of tunnels, as they can cause inadmissible stresses and strains leading to high deviations in the budgets. For that reason, the stress state is directly introduced into the numerical models used for the design of tunnels. In Spain, although several tunnels have been carried out with important overburden in tectonic relevant zones, a quantitative determination of the stresses has not been usually included in civil work projects. Therefore, it is considered necessary to implement a routine procedure of study of civil work projects involving tunnels excavated in rock, and a new detailed methodology is proposed. The purpose of this study is that project managers who face works in which stresses may play a determinant role, may have a practical reference enabling them to optimize available resources and to include the real stress information in the design of underground works.

Abacus for the analysis of technical and economical consequences of over-excavation in tunnels

C. Iglesias, M. Veiga: Department of Natural Resources and Environmental Engineering, University of Vigo, 36310, Spain

H. Larrocha: UTE Ave Porto-Miamán, Vilar de Barrio, Ourense, 37205, Spain

ABSTRACT: During the execution of a tunnel in a civil construction work such as a railway or a motorway, the excavation has to be controlled in order to ensure the technical specifications are met with the minimum cost. Bearing this in mind, over-excavation is an undesirable situation, since it implies the need of a higher amount of shotcrete to regularize the surface of the opening as well as a longer nozzling task. These facts are analyzed and presented in the form of abacus that enable the estimation of the consequences of a certain over-excavation, being a useful tool for a quick, visual evaluation.

Influence of groundwater and joints orientation in the Tunnel Prado support

D. Salorio & J. P. Villanueva: ADIF, Madrid, Madrid, Spain

F.J. Castanedo: EPSA, Madrid, Madrid, Spain

L. Jordá & C. Oteo: Counsellor ADIF, Madrid, Madrid, Spain

ABSTRACT: In this paper, a rigorous analysis by a 2D finite element code of the influence of rock mass fracturing and the influence of the water seepage in the design of a tunnel support, excavated by N.A.T.M. are introduced. Also, the existence of longitudinal joints in the rock mass is their influence in the variation of the safety factor of the primary support is taken into account. The rock mass formation is constituted by schists and shales. The field case of reference is the Prado Tunnel in the High Speed Line between Lubián and Ourense (North of the Spain). The rock characterization has been done by the Bieniawski's rock index RMR and Barton's index Q. Also the definition of the Hoek and Marinos GSI index is employed. The range of corrections of the RMR and Q index, originated by the influence of the analyzed factors, is determinated by the numerical simulation.

Problem and risk analysis in the implementation of the project of a tunnel in weak rock with high coverage, Z-Morh, middle Himalayan Tunnel.

H. Bhavsar: Vice President of IL&FS Transportation Networks Ltd, Ahmedabad, Gujarayat , India.

P. Dombriz & S. Murgia: GRUSAMAR Engineering & Consulting (Group ELSAMEX), Madrid, Spain.

F.J. Castanedo: Tunneling Professor, UCM and Alfonso X Universities, Madrid, Spain

ABSTRACT: This paper presents the design features of the Z-Mohr tunnel and poses the problems and risks that it entails. This work is located in the Himalayas, specifically in the tectonic unit of the Medium Himalayas, in the region of Jammu & Kashmir. The length of the tunnel is 6500 m in a single tube two-lane bidirectional and with maximum overburden of 1000 m. The tunnel passes through two formations: Zojila Fm., (Precambrian- lower Paleozoic) with slates, calco-schists, phyllites and banded quartzite; and the Panjal Trap Fm., with andesites and metabasites (Upper Carboniferous-Triasic). The hazards that are expected are, mainly, Rock-Bursting and Squeezing, which have been studied on the criteria established by different authors with experience in the construction of deep tunnels in the Lower Himalayas for hydroelectric development (Singh, Goel, Methwa, etc.). These criteria are based, mainly, on the Q of Barton, considering the relationship between the roughness with the weathered of the joints to establish the boundary between the Rock-Bursting hazard and the Squeezing hazard.

Update of 1989 Bieniawski's RMR guidelines for tunnel excavation and support

M. Romana: Valencia Technical University, Spain

ABSTRACT: Many tunnels are being designed and/or built according the RMR system, and with convergence control. Bieniawski (1989) proposed guidelines for excavation and support of tunnels, guidelines which have not been

modified afterwards. Most of academic and engineering books and/or webs on tunnels reproduce the 1989 guidelines. Conditions for application of those guidelines were: “shape: horseshoe; width: 10 m; vertical stress < 25 Mpa; construction: drilling and blasting”. A lot of things have changed in tunnel construction from 1989 to the present: tunnels size, construction methods, and safety rules. The paper gives adequate RMR guidelines for excavation and support of actually built tunnels, taking account of these facts.

A calcarenite exposed to true fire conditions: a methodological proposal

V. Brotóns, R. Tomás, S. Ivorra: Departamento de Ingeniería Civil, Escuela Politécnica Superior, Universidad de Alicante, Spain

ABSTRACT: San Julian’s Stone has been widely used for the construction of the main historical buildings of the city of Alicante (Spain). The main objective of this study is to propose a novel methodology for studying the effects of fire on the mechanical properties of this material. In most existing studies, stone materials are heated in an electric oven. This paper seeks a closer approximation to the true conditions to which the stone is under fire. In historic buildings, a point located in the masonry is not usually subjected to fire-conditions more than 20-40 minutes, either by fuel exhaustion or by the extinction services action. Typical maximum temperature in a fire is between 500-600 ° C. The tests proposed in this study were performed in an enclosure used to train fire crews with real fire, so that the thermal load and the duration of fire produced can be controlled. In this room, there have been trials with material samples subjected to different conditions and duration of the fire. The temperature of the samples and the fire area has been monitored with thermal imaging camera. The fire extinguishing was performed by action of firefighters with commonly used products in this type of building. After fire exposure, the samples can be subjected to laboratory tests to determine their physical and mechanical properties (particularly strength and deformability), and compare them with those of the intact material previously tested.

Temperature induced-changes on the mechanical properties of a calcarenite

V. Brotóns, R. Tomás, S. Ivorra: Departamento de Ingeniería Civil, Escuela Politécnica Superior, Universidad de Alicante, Spain

ABSTRACT: The influence of thermal damage and cooling method on some physical properties (i.e. open porosity, ultrasonic waves propagation, elasticity and uniaxial compressive strength) of the San Julian’s calcarenite stone has been studied. Samples were previously heated at different temperatures (from 105 ºC to 900 ºC). For each temperature, the samples were divided into two groups of five units: one group was air-cooled and the other group was water-cooled. The properties obtained with the group that was heated at 105 °C were taken as reference. Non-destructive tests (porosity and ultrasonic waves propagation) and destructive tests (uniaxial compressive strength and deformability) were performed over available samples. The results show that uniaxial compressive strength and elastic modulus decrease as the temperature increase for the tested range of temperatures. A reduction of the uniaxial compressive strength up to 35% and 53% is observed in air-cooled and water-cooled samples respectively when the samples are heated to 600º C. In fact, this is the more sensitive parameter to cooling method. Regarding the Young's modulus, there has been a decline of about 80% with both cooling methods at 600 ºC. Heating temperatures of 700 °C and above represents the complete degradation of the material. Other physical properties, closely related with the mechanical properties of the stone, are porosity and propagation velocity of ultrasonic waves in the material. All of them exhibit considerable changes with temperature. Excepting for porosity, the changes produced by the heat treatment are amplified when cooling is realized by immersion in water.

Analysis of a complex slope failure in a quartzite slope

Carlos León-Buendía1, Jesús Santamaría Arias1, Leandro R. Alejano2 & Raul Giráldez2
1Design and Engineering Department, Isolux-Corsan, Madrid, Spain 2Department of Natural Resources & Environmental Engineering, University of Vigo, Vigo, Spain

ABSTRACT: In this paper the authors analyse a slope failure occurred during the construction of a road cut in a fissured quartzite rock mass in 2009. Although the mechanism has been described in the technical literature (Stead & Eberhardt, 1997), a particular approach by the limit equilibrium method was carried out during the construction development, in order to solve the instability occurred. Furthermore, this approach is coherent with the physical models described two years after this first study by Alejano et al. (2011). Additionally, a numerical model by means of the DEM-based code UDEC (Itasca, 2008) is carried out to simulate the observed phenomena. This model is able to better explain the features of the failure mechanism observed in place which encompasses sliding in the upper part of the slope, and induces a toppling mechanism in the middle and lower part of the slope and block extrusion in the toe.

Slope stabilization at km 25.5 El Cobre highway – CODELCO Chile, El Teniente mine division

V.H. Recabarren Guerra: Project Manager. SIGA Mineria y Geotecnia, Santiago, Chile
F.J. Peña Díaz: Project Engineer. SIGA Minería y Geotecnia, Santiago, Chile

ABSTRACT: A solution delivered to CODELCO - CHILE El Teniente mine by SIGA Minería y Geotecnia S. A. to an instability and rock fall from an upper slope located at kilometer 25.5 at El Cobre highway is presented. This highway is the main transportation route for personnel and supplies for the underground copper El Teniente mine, thus road safety is paramount for the organization. A total of four stabilization alternatives were considered for the slope. The stabilization approach considered: 1) Spider mesh and rock bolts, 2) stabi-lization with cables, 3) stabilization with shotcrete and localized rock bolts and 4) reduce the slope angle. The options identified were evaluated using the Analytical Hierarchy Process methodology based on a decision matrix involving criterion for suitability, construction, durability, visualization and maintenance. Cost estima-tion for the selected stabilization approach is included.

Evaluation of the effectiveness of a new nanoconsolidant in granitic rocks

I. de Rosario & J. Feijoo & T. Rivas: Dpt. Ingeniería de los Recursos Naturales y Medio Ambiente, Universidad de Vigo-SPAIN
M.J. Mosquera & F. Elhaddad: Dpt. De Física-química de la Facultad de Ciencias de la Universidad de Cádiz-SPAIN

ABSTRACT: This study evaluates the efficacy of a tetraethoxysilane used as consolidant (Estel 1000) and a nanoconsolidant based on silicon oligomers modified with n-octylamina (UCAD-2o) in two types of granitic rocks. The application of these products was carried out under different moisture conditions in the rocks, evaluating the consolidant efficacy, the changes generated in the colour of the stone and in the water vapour permeability. Results show a higher effectiveness of the nanoconsolidant comparatively to the conventional tetraethoxysilane, confirming the advantage of the incorporation of the non-ionic surfactant to TEOS polimer.

Protective treatments against pyrite and pyrrhotite oxidation in roofing slates

J. Iglesias & J. Feijoo & I. Cañas & J. Taboada & T. Rivas: Dept. of Engineering of Natural Resources and Environment, University of Vigo, Spain

ABSTRACT: Slate is a valuable ornamental rock, specially used as roofing material due to its aesthetic and waterproofing properties. Among the characteristics that define the technical and aesthetic quality of slate, the presence of metallic inclusions is one of the most important because the oxidation of these inclu- sions may reduce water resistance and cause unsightly problems. This study shows the results of the effec- tiveness evaluation of five protective treatments against sulphide oxidation: Tegosivin 100-HL®, Tegos ivin HE328®, Triethylenetetramine, Oxino® and Rewopol SK -Rewopon IMOA 275. The products were applied on commercial roofing slate slabs. The effectiveness was evaluated by subjecting the samples to thermal cy- cles, also assessing colour modifications. Of the five products tested, both Tegosivin treatments showed great efficacy as protection against oxidation. Of these two products, the use of Tegosivin HL is recommended be- cause it generated a lesser colour change and left no visible residue on the treated surfaces.

Comparison of disc cutter consumptions in two tunnelling machines due to wearing in two tunnels partially built in ortogneis

P. Ramírez Oyanguren, C. Laín Huerta, R. Laín Huerta: Departamento de Explotación de Recursos Minerales y Obras Subterráneas, Universidad Politécnica de Madrid, España
C. González Nicieza: Departamento de Explotación y Prospección de Minas, Universidad de Oviedo, España

ABSTRACT: So far, several methods to estimate the advance rate of a tunneling machine (TBM) in hard rock have been developed. However, only the NTNU has developed a reliable method to estimate the lifetime of the cutters in a tunneling machine operating in hard rock. Such method is important, as the cutter lifetime is directly related to the excavation cost as well as to the advance rate of the TBM. In this paper, the relationships between the force applied to the cutter, its penetration into the rock and its wear have been examined. Also, the wear of the discs of two TBM operating in gneis, first in the Guadarrama tunnel, between Madrid and Segovia, and second in the Vigo-Das Maceiras tunnel, in Galicia, have been compared. As a conclusion, a modification of the NTNU method to predict cutter wear in very strong and abrasive rock to take into account the compressive strength of the rock is recommended.

Protecting roofing slates against oxidation: Analysis of the chemical interaction between protective treatments and pyrite

J. Iglesias & J. Feijoo & J. Taboada & T. Rivas: Dpt. Ingeniería de los recursos naturales y medio ambiente, University of Vigo-Spain
M. Modino: Áridos do Mendo S.L, Spain

ABSTRACT: In the framework of the investigation of the effectiveness and durability of different commercial products as protectors against oxidation of metal sulfides in roofing slate, we present the analysis of the interaction degree between pyrite and five protective products (Tegosivin® 100-HL-HL, Tegosivin HE328®-HE, Triethyltetramine, Oxino® and Rewopol SK 275-Rewopon IMOA) as well as the durability of such interaction during accelerated oxidation cycles. The aim of the work is to know how durable these products are over time. The degree of interaction was studied after application of products over pyrite using X-ray diffraction, Fourier transformed infrared spectrometry and X-ray photoelectron spectroscopy. The durability of the interaction has been evaluated by analyzing the samples after accelerated oxidation cycles. At least two products showed a chemical interaction with mineral enough stable and resistant to the accelerated oxidation processes.

Eventos de interés

Master en Mecánica del Suelo e Ingeniería Geotécnica 2015_CEDEX-UNED	02/02/2015	30/10/2015	España	Madrid
Engineering Geology – Rock Mechanics	04/02/2015	05/02/2015	Hungary	Budapest
12th Australia New Zealand Conference on Geomechanics (ANZ 2015)	22/02/2015	25/02/2015	New Zealand	Wellington
GeoProc2015: International Conference on Coupled THMC Processes in Geosystems	25/02/2015	27/02/2015	USA	Salt Lake City
VietRock 2015 International Workshop - an ISRM Specialised Congerence	12/03/2015	15/03/2015	Vietnam	Hanoi
24th International Mining Congress and Exhibition of Turkey	14/04/2015	17/04/2015	Turkey	Antalya
DAM WORLD 2015 - Second International Dam World Conference	21/04/2015	24/04/2015	Portugal	Lisboa
La Mecánica de Rocas en el Eurocódigo 7 y otras normativas: Jornada técnica anual de la SEMR	**15/04/2015**	**19/04/2015**	**España**	**Madrid**
ISRM 13th International Congress on Rock Mechanics	10/05/2015	13/05/2015	Canada	Montréal
Rock Reinforcement Techniques and Systems	15/05/2015	17/05/2015	India	Kolkata
Fifth International Conference on Design and Analysis of Protective Structures (DAPS2015)	19/05/2015	21/05/2015	Singapore	
I International research and Practice Conference - "Rock Mechanics in Petroleum Industry"	26/05/2015	27/05/2015	Russia	Saint-Petersburg
49th U.S. Rock/Geomechanics Symposium	28/06/2015	01/07/2015	USA	San Francisco
China Shale Gas 2015 - an ISRM Specialized Conference	06/09/2015	08/09/2015	China	Wuhan
Workshop on Volcanic Rocks and Soils - an ISRM Specialised Conference	24/09/2015	25/09/2015	Italy	Isle of Ischia
EUROCK 2015 - ISRM European Regional Symposium - the 64th Geomechanics Colloquy	07/10/2015	10/10/2015	Austria	Salzburg
6th International Conference on Earthquake Geotechnical Engineering	02/11/2015	04/11/2015	New Zealand	Christchuch
VIII South American Congress on Rock Mechanics	15/11/2015	18/11/2015	Argentina	Buenos Aires
VIII South American Congress on Rock Mechanics - an ISRM Regional Symposium	15/11/2015	18/11/2015	Argentina	Buenos Aires
1st International Conference on Tunnel Boring Machines in Difficult Grounds (TBM DiGs)	18/11/2015	20/11/2015	Singapore	Singapore

Jornada Técnica Anual

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 150 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 Mecáncia de Rocas en en ámbito de la ingeniería de minas,** 29 de abril de 2014.

Además, dado el importante avance en el campo de las tuneladoras, se han celebrado dos **Jornadas Extraordinarias** relacionadas con este tema:

- **Tuneladoras en roca,** 16 de marzo de 2006.
- **Experiencias recientes en tuneladoras**, 5 de junio de 2007.

EL TEMA DE LA **JORNADA TÉCNICA DE 2015** SERÁ:

"La Mecánica de Rocas en el Eurocódigo 7 y otras normativas"

Los conferenciantes serán:

- **Prof. John P. Harrison** (Univ. de Toronto - Pte. del "Evolution group" de Mecánica de Rocas en el Eurocódigo-7)
- **Dr. Luis Lamas** (LNEC - Secretario general de la ISRM)
- **Dr. Alber Bernal** (UPM)
- **Dr. José Estaire Gepp** (CEDEX - UPM)

EL LUGAR DE CELEBRACIÓN SERÁ EL SALÓN DE ACTOS DEL CETA (CEDEX) Y LA FECHA EL MIERCOLES 15 DE ABRIL

El Berrueco, Madrid

Enlaces de interés

INTERNACIONALES

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

NACIONALES

CEDEX
Colegio de Ingenieros de Caminos, Canales y Puertos
Consejo Superior de Colegios de Ingenieros de Minas
Colegio Oficial de Geólogos
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)
Sociedad Española de Mecánica de Suelos
Asociación Española de Ingeniería Sísmica
Comité Español de Grandes Presas

Ser Socio de la SEMR

¿Qué supone 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 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, Journal Rock Mechanics and Rock Engineering).

La solicitud de ingreso se puede enviar a través de la página web (www.semr.es), por correo electrónico (semr@semr.es) o postal (C/ Alfonso XII 3, 28014 Madrid).

Entidades y Empresas Colaboradoras