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Discussions: *Research and Practice Interface*

The Editors are pleased to introduce a new section titled **"Discussions:** *Research and Practice Interface***"** for the esteemed readers of the Journal of Rock Mechanics and Tunnelling Technology (JRMTT), commencing from the July 2026 issue. This section is intended to serve as a platform for scholarly exchange and technical deliberations on papers published in JRMTT, as well as on contemporary topics of professional interest. It is envisaged that this section will foster a collaborative environment in which industry professionals, researchers, and experts can **exchange ideas, share insights, and discuss the practical applications and implications of emerging developments** in Rock Mechanics and Tunnelling Technology.

Readers are encouraged to submit their queries, comments, and viewpoints to seek expert opinions and promote meaningful technical discussions, which will be featured in this section.

This issue particularly features discussions on one paper by Nick Barton from among the three papers published in JRMTT, Volume 32(1), January 2026. In this regard, an email was circulated on 23 January 2026 to all members of the Editorial Board and other professionals associated with the field.

To initiate and encourage meaningful technical discussions, the Editor, JRMTT, also highlighted several important issues and observations emerging from the papers published in JRMTT 32(1), January 2026. These points were circulated along with the email, with a request to practising engineers, geologists, and researchers to share their experiences, observations, and views on the applicability and use of the empirical theories/correlations discussed in these papers.

The following paper-wise points were highlighted by the Editors.

Paper 1: Strengths and Weakness of NMT and NATM and due Care with Numerical Modelling (pp. 5 -29) - Nick Barton

The paper by a renowned expert has some critical observations from him, focusing on the GSI & Hoek-Brown approximations, and the assumption that 'plastic zone' modelling might justify adjustments to empirical design routines. His observations on NATM are also given.

a. Geological Strength Index (GSI): The problems start with the rock mass characterization being so crude with GSI and its limited 'one-way' joint condition scale on one axis… (See Section 1.1 and Appendix)
b. Repetition of GSI in Hoek-Brown equations (See Appendix at page 29)
c. Hoek-Brown approximations: Tunnels in jointed rock strangely modelled as continua (See Section 1.1 and Appendix)
d. About deep 'plastic zones' and comments on using GSI, H-B, Phase 2/RS2 errors (Section 1.2 and Appendix)
e. Using UDEC-BB or 3DEC more realistic behaviour is seen (See Appendix).
f. NATM: Comments on the over break (**over break is ignored in design**), lattice girders (**The lattice girder stage of NATM is sometimes full of risk, being 'soft' unbolted),** and wire mesh reinforced shotcrete. *[In our views, one can think of merging the two approaches, NATM and*

NMT, i.e., rock bolts from NMT and LG from NAMT in place of RRS. Moreover, in place of three bars LG, four bars LG can be planned with a rock bolt ring in between the two LG rings. In four bars LG, one can use rock bolts with the LG. Swellex bolts row in between two rows of LGs have been used in a highway tunnel in the Himalaya in India]

g. For water control, high-pressure pre-injection with stable grouts is common in NMT, while drainage fleeces and membranes and final concrete are standard elements of NATM road and rail tunnels.

Paper 2: Shear Strength Assessment of Rockfill Materials through JRC-JCS Model and Critical State Concept (pp. 31-52) - B. Venkateswarlu and Mahendra Singh

This article proposes that the non-linear, stress-dependent friction angle of rockfills can be approximated by using shear strength models originally developed for rock joints and jointed rocks. Two models, namely Barton's JRC-JCS shear strength model and the Modified Mohr Coulomb (MMC) criterion for jointed rocks, are considered. Based on extensive laboratory testing of rock-soil mixtures, empirical correlations are proposed to estimate the shear strength response of rockfills through simple laboratory and field measurements.

The authors have not covered the verification/validation of the correlations, which they have already discussed in some of their other publications. It will be better if they share their views while validating these correlations. They may also highlight the limitations of these correlations, if any.

Readers may use these correlations and share their experiences for further improvements.

Paper 3: Successful Construction of Twin Railway Tunnel Using TBM in Lesser Himalayas (pp. 53-73) - Sumit Jain

In this paper, the geological investigations, analysis of squeezing potential, risk mitigation mechanisms, TBM specifications, and state-of-the-art technologies installed on the TBM are highlighted, including the **use of artificial intelligence (AI) and machine learning (ML)**, which made this venture a success and boosted confidence for taking up more TBM tunnelling in the Himalayas in the future.

While data analyses using the AI and ML, few assumptions were made, (i) Rock mass strength and behaviour is isotropic, (ii) Displacements are equally distributed around the tunnel periphery and (iii) Both parallel tunnels are treated as single tube tunnels without influencing each other (iv) Squeezing is influenced by four variables (see section 7 of the paper).

- This is an encouraging, successful case of using TBM in the fragile Lesser Himalaya. Are there any suggestions from readers on the investigation, risk mitigation, squeezing potential, etc., for further improvements?
- The views on the use of AI and ML with the assumptions are expected from readers for better and more realistic applications/approximations in future TBM tunnels.

In response to our request, we have received the following response from Rocscience on the issues in Paper 1 by Dr. Nick Barton.

Summary of Dr. Nick Barton's Criticisms of GSI and Continuum Methods and Some Responses - by Dr. Reginald Hammah, Chief Scientific Officer, Rocscience
(with inputs from Dr Brent Corkum, Chief Technology Officer, Rocscience, and from Dr Alison McQuillan, Director, Rocscience, Australia)

1. Introduction

Dr. Nick Barton, in some recent publications or discussions, including his article published in the Journal of Rock Mechanics and Tunnelling Technology (JRMTT) and a January 2026 Hong Kong RMRE course lecture titled "Continuum or Discontinuum Modelling, UDEC-BB with Q-system also applied," critiques the Geological Strength Index (GSI), the Hoek-Brown (H-B) failure criterion for rock masses, and the widespread use of continuum numerical modelling in rock engineering. He argues that the rock mechanics profession is over-relying on GSI-based continuum approaches at the expense of more physically realistic discontinuum methods (UDEC-BB, 3DEC) that explicitly model joints and faults. His specific criticisms, summarized below (to the best of my ability), are as follows:
1. GSI is "not geological" and is poorly quantified
2. GSI appears an excessive number of times in the Hoek-Brown equations
3. The rock mass Hoek-Brown equations lack an empirical basis
4. Simultaneous mobilization of cohesion and friction is fundamentally wrong
5. Continuum models produce unrealistic failure mechanisms
6. Continuum models cannot represent key physical processes, and
7. The profession has made a wrong "career choice."

In the sections below, I will provide overviews of Dr. Barton's critiques and outline some responses. To help orient the reader, my responses are grouped; I will address the historical and technical context of continuum and discontinuum methods, highlight recent advances in modelling software, discuss practical considerations for choosing between approaches, and comment on the importance of engineering judgment in method selection.

2. Dr. Barton's Specific Criticisms

2.1 GSI Is "Not Geological" and Poorly Quantified

Dr. Barton argues that GSI, despite its name, is not truly geological. He describes the following aspects of GSI:
- The GSI chart uses Bieniawski's joint condition factor along the x-axis, which forces joint surface quality to move in one direction. This means rough joints with clay filling in weathered rock are not permitted, and clean slickensided joints without clay filling or weathering are also excluded - combinations that exist in nature. Barton considers this illogical.
- GSI captures only two parameters (structure and surface condition), whereas the Q-system uses six parameters (RQD, J_n, J_r, J_a, J_w, SRF) that more comprehensively describe rock mass character, including water, stress, and distinct separation of roughness from alteration.
- The need for at least seven published equations attempting to improve GSI quantification (using Q-parameters, block volume, joint condition, etc.) is, in Barton's view, evidence that the original method is fundamentally inadequate: "Why a published and widely used method should require so much improvement, or indeed be used by so many with such apparent confidence, is not clear."

2.2 GSI Appears an Excessive Number of Times in the Hoek-Brown Equations

Dr. Barton points out that GSI appears 78 times in the full Hoek-Brown shear strength equations when all substitutions are expanded:
- GSI appears 46 times in the equation for cohesion (c) and 32 times in the equation for friction angle (φ).
- This is because GSI enters the expressions for mb, s, and a, which then propagate through the rock mass strength (σ'cm) and the equivalent Mohr-Coulomb parameters via σ'3n.

- Barton considers this level of repetition to undermine whatever utility the two-parameter GSI might have, calling the resulting equations "opaque" and the overall framework "black-box rock engineering."
- He further labels the disturbance factor D as a "joker" that can produce any desired result.

2.3 Lack of Empirical Basis for Hoek-Brown Rock Mass Equations

Dr. Nick Barton distinguishes between the intact rock Hoek-Brown criterion (which has an excellent experimental basis from triaxial testing) and the rock mass extension of the criterion (which he argues has little direct empirical support). He questions whether it is logical to downgrade intact rock strength to rock mass behaviour using equations that poorly represent joint roughness and the number of joint sets. He suggests that it would be more physically meaningful to model joint shear strength directly and estimate the cohesive contribution of intact rock bridges between kinematically capable joint sets.

2.4 Simultaneous Mobilization of Cohesion and Friction Is Fundamentally Wrong

One of Dr. Barton's central mechanistic criticisms is that both the Mohr-Coulomb and Hoek-Brown criteria, as implemented in commercial continuum codes, incorrectly add the cohesive (c) and frictional (tan φ) components of shear strength simultaneously. Citing Brace and Müller (from over 50 years ago) and the work of Hajiabdolmajid, Martin, and Kaiser (2000), Barton argues that:

- Cohesion is mobilized and broken before friction is fully mobilized.
- The simultaneous addition leads to grossly exaggerated plastic zones around tunnels (which he states has been proven in a formal court case).
- He favours the CWFH (Cohesion Weakening Friction Hardening) approach and CcSs (crack-crunch-scrape-swoosh) progressive failure concept, which recognizes strain-dependent, sequential mobilization of strength components.

2.5 Continuum Models Produce Unrealistic Failure Mechanisms

Dr. Barton presents multiple case studies to argue that continuum analyses produce failure modes that do not match reality:

- Tunnel problems: Conventional continuum models with M-C or H-B criteria predict symmetric plastic zones that poorly represent actual brittle failure around excavations. The elastic-plastic prediction is shown to be far inferior to elastic-brittle models.
- Slope problems: Continuum models predict deep "spoon-shaped" (circular) failure surfaces in rock slopes. Barton argues that such failures are only valid for very weak materials (saprolite, hard soil, rockfill) and essentially never occur in competent jointed rock. He cites Kolapo et al. (2022), who show that major open pit failures almost universally involve structural discontinuities (faults, joint intersections, shear zones) – not circular shear through homogeneous masses.
- The Pinheiros station collapse (São Paulo, 2007): Demonstrates a case in which UDEC modelling captured the progressive, structurally controlled failure mechanism that occurred, something which a continuum model would not.
- The Bingham Canyon Mine failure (70 million m^3): Cites this failure as a wedge/fault-controlled mechanism, not a circular one.

2.6 Continuum Models Cannot Represent Key Physical Processes

Dr. Barton emphasizes that continuum models inherently cannot capture:

- Block fall-out and overbreak, which are governed by the ratio Jn/Jr (joint set number to joint roughness)

- Opening and closing of joints, sliding along joints, and block rotation
- The three deformation modes (Type A: normal loading, Type B: combined, Type C: shear loading) described by Barton (1986), which are "clearly absent from conventional continuum modelling."
- Depth- or stress-dependent deformation modulus, which the Qc-based approach can represent but the Hoek-Diederichs equation does not.

2.7 The Profession Has Made a Wrong "Career Choice"

Dr. Barton frames the continuum vs. discontinuum debate as a professional and ethical dilemma. He states the following: "Should we spend the necessary longer time performing discontinuum models with discrete joint sets and non-linear properties? And get more realistic designs for our slopes, mines and tunnels? Or can we relax with GSI and let Rocscience software solve the many Hoek-Brown equations, happy in the knowledge that the nice colour plots of plastic zones will impress our supervisors?" He sees the prevalence of continuum methods as a case of convenience triumphing over physical realism.

3. Responses to Barton's Criticisms

I would like to outline some responses to Dr. Barton's critiques.

3.1 Dr. Evert Hoek Was Always Aware of Discontinuous Behaviour

Evert Hoek's lifelong awareness of the structurally controlled, discontinuous behaviour of rock masses under certain conditions is well documented. In his textbook, Rock Slope Engineering (with Bray, 1974 - cited by Dr. Barton himself), he explicitly categorizes slope failure into planar, wedge, toppling, and circular modes, with circular failure reserved for heavily fractured or weak rock only. His Practical Rock Engineering (freely available on the Rocscience website) includes Chapter 5 (in some editions Chapter 8) on structurally controlled instability in tunnels. The software Unwedge, one of the earliest commercial rock mechanics programs, arose directly from Hoek's research on kinematically controlled underground wedge failures. Hoek and Brown (and later Hoek, Marinos, and others) explicitly caution in their GSI publications that "the table does not apply to structurally controlled failures" and that "where weak planar structural planes are present in an unfavourable orientation with respect to the excavation face, these will dominate the rock mass behaviour." This caveat appears on the GSI chart itself.
Therefore, although it is true that some industry practitioners, using GSI, the H-B criterion, and continuum software, ignore these caveats, Evert Hoek and many others were aware of the limitations and warned against abuse.

3.2 Rock Masses Can Behave as Pseudo-Continua Under Certain Conditions

A vast body of research supports the idea that under certain conditions - particularly when the ratio of excavation dimension to joint spacing is large, or when rock is subjected to high confining stresses - rock masses behave as equivalent continua. A classic example involves brittle failure around excavations in high-stress environments (e.g., deep mining), where the failure process involves the initiation and propagation of new fractures in intact or quasi-intact rock. The work of Martin, Kaiser, and colleagues at AECL's Underground Research Laboratory (URL) in Manitoba demonstrated that continuum-based approaches (especially those incorporating cohesion-weakening/friction-hardening, or CWFH) are essential for modelling stress-driven brittle failure. Dr. Barton himself cites Hajiabdolmajid, Martin, and Kaiser (2000) approvingly for their CWFH approach (a continuum method implemented in FLAC).

Dr. Barton actually points out in his own slides that continuum modelling is appropriate at both ends of the rock mass quality spectrum: heavily jointed, weak rock (pseudo-continuum) and massive, intact rock that may fracture. He, however, states that "90% of typical cases have 0.1 < Q < 100," implying that most real cases fall within the discontinuum range. The disagreement may therefore be about the proportion of problems suited to each approach, and not an absolute rejection of continuum methods.

3.3 Some Modern FEM Programs (e.g., RS2, RS3) Are No Longer Purely Continuum

Some modern software codes, including Rocscience's RS2 and RS3 finite element programs, explicitly represent joints, joint networks, and discrete fracture networks (DFNs). RS2 also supports joint networks modelled with XFEM (Extended Finite Element Method), and RS3 includes DFN capabilities for surface and underground excavation stability analyses. Their main limitation is that, as small-strain formulations, they cannot represent large block detachments and rearrangements. However, for problems involving the onset of instability, they are effective; non-convergence of the solution can indicate failure initiation, which may be sufficient for engineering design.
Furthermore, software such as ELFEN, which offers combined finite element/discrete element (FE/DE) modelling within an explicit framework, enables simulation of fracture initiation, propagation, blocky behaviour and full block detachment. Rocscience is also considering developing explicit numerical modelling engines within RS2 and RS3.

Hybrid FEM–DFN approaches, such as those in RS2/RS3, are indeed not equivalent to full DEM codes for simulating large post-failure block displacements and rearrangements. However, that does not mean they are inferior for designing for stability. For many engineering design problems, once large block displacements and rearrangements occur, the structure is already beyond the acceptable serviceability or ultimate limit state that design decisions are supposed to prevent in the first place. In that context, what matters most is accurate prediction of the onset of instability and the governing mechanism, not detailed post-failure kinematics.

Verification work and comparative studies (including FEM vs DEM comparisons for jointed slopes and tunnels) consistently show that, up to the onset of instability, FEM models with explicitly represented joints or DFNs reproduce factors of safety, failure initiation locations, and overall failure mechanisms that are very close to those obtained with DEM/UDEC/3DEC. As the Rocscience DFN examples show, introducing DFNs in RS3 can change the critical mechanism from pure continuum shear to sliding along joint planes and significantly lower the safety factor, which is exactly the kind of mechanism shift DEM users seek.

Consequently, for many design objectives, jointed FEM/DFN approaches in RS2/RS3 are just as suitable as discontinuum DEM, provided joints are realistically represented, and appropriate constitutive models are used. Where DEM retains a clear edge is in studies that explicitly require the simulation of large deformations, runout, fragmentation, or the dynamic interaction of detached blocks (as seen in rock avalanches and large progressive pit failures), but that is a subset of design questions rather than the norm.

Based on the above, I think that the claim that "the industry applies continuum approaches to everything" is a tad overstated. There is a substantial body of work - and real design practice - that uses discontinuum and block-based methods for slopes, tunnels, dam foundations, and mining excavations. Many rock mechanics research and consulting offices routinely employ distinct element and related discontinuum techniques for problems where joint-controlled block behaviour is critical. There is also active work that explicitly combines continuum and discontinuum models for slopes and tunnels, selecting the appropriate representation based on jointing intensity and failure mode.

The more defensible reading of the situation is that continuum methods are very widespread and sometimes misapplied, while discontinuum methods are heavily used in certain sub-communities and problem types. In other words, there is heterogeneity in practice: some designers rely on continuum models, others use discontinuous methods routinely, and some combine the two.

3.4 Many in the Industry Believe in Applying the Right Tool to the Right Problem

The industry fundamentally believes that different problems require different approaches. This belief is precisely what enables software companies, including Rocscience, to produce a broad suite of software packages. Rocscience provides Unwedge and RocSlope2 for structurally controlled wedge, planar and toppling failures, Dips for kinematic analysis, Slide2/Slide3 for limit equilibrium analysis, RS2/RS3 for stress-deformation analysis, and now ELFEN for explicit FE/DE modelling. The company's product philosophy is that engineers should select the appropriate tool for each problem. Of course, the existence of the right tools does not guarantee their correct application.

3.5 Dr. Barton Is Right About Misuse of Continuum Modelling; However, the Reverse Is Also True

Dr. Barton is correct that using continuum software for inherently discontinuous problems is wrong and potentially dangerous. However, the opposite also holds true: treating fundamentally continuum problems with discontinuum approaches would be inefficient and misleading if the relevant failure mechanism is stress-driven fracturing of intact rock rather than sliding along pre-existing joints.

As Whitman and Bailey warned in 1967: “The use of sophisticated methods together with a computer does not free the engineer from making a judgment concerning the reasonableness of a solution.” This statement, originally made in the context of limit equilibrium slope stability analysis, remains profoundly relevant to the current discussion. Software is a tool, not a substitute for understanding, and engineering judgment cannot be automated. Practitioners must always exercise judgment in determining which solution approach is appropriate.

3.6 The Multiple Repetitions of GSI in Hoek-Brown Equations Do Not Necessarily Indicate Incorrectness

Dr. Barton's count of GSI appearing 78 times in the expanded Hoek-Brown shear strength equations is of arithmetical interest. However, this situation does not, in itself, prove that the equations are wrong. When empirically derived parameters are substituted through a chain of dependent equations, algebraic repetition is inevitable. What matters is whether the equations produce physically logical results within their intended scope: for example, lower GSI should yield lower rock mass strength and modulus; higher GSI should approach intact rock behaviour. The Hoek-Brown system satisfies these requirements.

I understand Dr. Barton's deeper concerns about a poorly constrained input parameter (GSI, which he argues is subjective and limited to two descriptors) getting amplified 78-fold through nested equations. If indeed true, this would mean that small errors or subjectivity in the GSI estimate could propagate dramatically. However, I don’t think that is the case. Many have used the Hoek-Brown framework to adequately represent rock mass behaviour under certain conditions.

3.7 Continuum Predictions vs Field Evidence: It’s About Failure Mechanism and Method Selection

In rock and soil engineering, the accepted practice is to employ the multi-mode, “lowest factor of safety governs” philosophy - examine multiple kinematically feasible modes and treat the mode with the lowest factor of safety as the critical. When a continuum analysis predicts a circular or spoon-shaped failure that is not corroborated by field observations, the core issue is unlikely to be that the method is inherently wrong, but rather that it is being applied to the wrong failure mechanism (it is returning the factor of safety for one admissible mechanism under its assumptions - a shear band through rock mass zones). For discontinuous, joint-controlled problems, discontinuum or explicit-joint methods will typically identify a different, more realistic mechanism, often with a significantly lower factor of safety than any circular-continuum mode, and this lower safety factor should govern.

Seen in this light, there is nothing inherently alarming about a continuum model predicting a mechanism that does not occur in the field, provided engineers recognize that it is only one candidate mechanism and complement it with appropriate structural and discontinuum analyses. The real professional obligation is to use a suite of techniques to explore all plausible modes and then design against the most critical one.

3.8 Discontinuum Modelling Presents Its Own Set of Challenges

While explicit joint and DFN-based discontinuum models are powerful, they do not solve all problems and introduce serious challenges of their own. First, the underlying geological information for such modelling is often incomplete: joint location, persistence, aperture, connectivity, and size distributions must be inferred from sparse core, mapping, and scan data. Papers on DFN calibration and joint characterization repeatedly emphasize the large epistemic uncertainty (uncertainty that comes from lack of knowledge or incomplete information, not from natural randomness) in these inputs. In practice, overcoming this limitation requires generating multiple DFN realizations to bracket possible conditions. This quickly becomes computationally expensive for large 3D models. Second, even with many realizations, there is no guarantee that all critical mechanisms are captured; unknown structures, or rare but governing configurations can still be missed. Several authors explicitly discuss the difficulty of ensuring that DFN geometries truly represent the controlling joints in a rock mass.

Third, discontinuum analyses often require much longer run times and more complex model construction and specialist expertise than equivalent continuum models, aspects that constrain the number of scenarios that can feasibly be explored during design. For these reasons, explicit joint and discontinuum methods are very important for some classes of problems, but are not easy to use and are not automatically better in all cases.

4. Concluding Remarks

I understand Dr. Barton's concerns about the logical gaps in GSI's joint condition axis; it does not allow rock engineers, for example, to represent rough joints with clay filling or clean, slickensided joints without weathering. I believe this is a genuine limitation of the GSI chart's structure. However, the framework can also be expanded to explicitly include such cases.

Dr. Barton's criticisms serve as an important corrective to the uncritical use of GSI and continuum methods. His advocacy for discontinuum modelling with explicit joint representation is well-supported for the class of problems involving blocky, jointed, and faulted rock masses. However, the legitimate domain of continuum mechanics in rock engineering (stress-strain mechanisms in rock masses behaving as a pseudo-continuum, such as heavily fractured weak rock) must also not be discounted. And it must also be remembered that the lines between continuum and discontinuum methods are blurring, with continuum methods able to represent discontinuities explicitly through joint elements.

The most productive path forward is not to abandon either approach but to ensure that engineers understand when each is appropriate, which requires exactly the kind of engineering judgment that Whitman and Bailey called for nearly 60 years ago, and which no software can replace.

The above response from Rocscience was subsequently forwarded to Dr. Nick Barton for his information and response, if any. The following is the response from Dr. Nick Barton received on 22.3.2026

First, I would like to thank Dr Hammah for his lengthy and balanced summary of many of the points I have raised in recent articles and indeed short courses, including my most recent Indian conference article published in the January 2026 edition of the JRMTT *'Strengths and weakness of NMT and NATM and due care with numerical modelling'.*

I had little to dispute in Dr Hammah's 3-page summary of my critical points of view about GSI, the Hoek-Brown equations and the exaggerations (of plastic zones) and the seldom realistic circular failure predictions for slopes in rock (i.e. Carranza-Torres, 2021) when using continuum models. I was also able to agree with a lot of what Dr Hammah wrote in his three pages of 'Responses'. However, I will comment on the more recent attempts by Rocscience to 'explicitly represent joints' later.

The profession has a rich choice of numerical models thanks to such companies as Itasca and Rocscience, but much fewer constitutive behaviour models. With obvious bias here, one could just compare the GSI-based Hoek-Brown criterion (seven equations, 78x repetition of GSI) for the continuum-based assumed shear strength of rock masses, with the Barton-Bandis criterion for rock joints (four equations, 1x repetition of JRC and 1x repetition of JCS following block-size correction to the lower values JRC_n and JCS_n). Inevitably, the GSI-H-B method is devoid of case records as evidenced by the numerous attempts to improve the quantification of GSI, while the BB model is specifically derived from (the much easier to acquire) case records of rock joint i.e., DST behaviour. As we all know, the original and empirically based Hoek-Brown equation for intact rock has a large body of triaxial test data (in fact, I recall contributing without knowing when first using the Hoek-Franklin cell in 1968 or 1969 with other PhD students at Imperial College). The fact remains that rock masses are mostly more discontinuous than intact (at least within 100m of the surface) so joint and fault-based equations make more sense. It has also been shown that the H-B intact strength criterion is insufficiently non-linear due to a relative lack of high stress data (Singh et al., 2011 and Shen et al., 2018). As a partly related comment, the Hoek-Diederichs equations for estimating deformation modulus are devoid of a depth or stress correction, unless users feel they can employ the poorly defined disturbance factor D.

It is my belief, apparently shared by others in the profession, both consultants and academics, that the Rocscience and Hoek assisted spread of GSI to so many countries (Erharter et al., 2024) for rock slope analyses, as continua, has gradually adversely affected the teaching of engineering geology and rock mechanics in universities. I have heard this from those in a position to know. For many years, it has been distressing to see analyses showing (unclamped, dilation-free) wedges 'threatening' empirical thinking of tunnel and cavern support needs, and of course, the impossible circular failures predicted for competent jointed rock. Such indeed suggests reduced educational standards in many countries. It would be interesting indeed to know more about how the shear strength of rock masses is being taught. It is actually a difficult subject and is unfortunately not solved by GSI and H-B. Maybe *the addition* of the 'c' and 'ϕ' components is the problem: linear M-C or non-linear H-B.

I have been shown attempts to model jointed rock mass behaviour using the more recent 'explicit representation of joints' by Rocscience, as described by Dr Hammah. Of course, such models are designed to be small-strain in character, but cutting corners so much that the 'joints' cannot open causes bolt loading to be incorrect, and causes apparent disturbed zones to stretch many tens of meters in each direction in the case of large caverns, not then being consistent with MPBX-based deformation measurements. The idea of the BB model is that it can give consistent results also for coupled M-H analysis, so joint apertures, both hydraulic and physical (i.e., groutable) are modelled. So, the jointed FEM/DFN approaches in RS2/RS3 are definitely not as suitable as in discontinuum DEM, simply because the joints are not realistically represented.

I am sure that I at least have never claimed that 'the industry applies continuum approaches to everything'. That would indeed be grossly overstated. But since 90% of rock masses *may have* Q-values in the range 0.1 to 100 (an opinion shared also by others), the need to take more time and model joints will contribute to understanding in a better way than is possible with continuum modelling with its truncation of reality. A court case was indeed needed to demonstrate the gross exaggeration of so-called plastic zones using Phase 2 and GSI and H-B for a small tunnel driven 7km without needing shotcrete, which was actually partly invert damaged due to too fast emptying. The modellers lost their case against the contractor.

1. Erharter GH, Bar N, Hansen TF, Jain S, Marcher T (2024). International distribution and development of rock mass classification: a review. Rock Mechanics and Rock Engineering, 58:11169-11180. https://doi.org/10.1007/s00603-024-04215-8
2. Carranza-Torres C (2021). Computational tools for the analysis of circular failure of rock slopes. Keynote Lecture. In: Proc. of EUROCK 2021, Torino, Italy.
3. Singh M, Raj A, Singh B (2011). Modified Mohr–Coulomb criterion for non-linear triaxial and polyaxial strength of intact rocks. Int J Rock Mech & Min Sci 48:546–555.
4. Shen B, Shi J, Barton N (2018). An Approximate Non-linear modified Mohr-Coulomb shear strength criterion with critical state for intact rocks. J Rock Mech Geotech Eng, 10:645-652.
5. Barton N (2025). Twenty strange years in the world of rock mechanics and engineering geology. Current Trends in Civil & Structural Engineering, 1(4): 13p.

Also, we have received the following response from Prof. Robert Galler on the issues of NATM in Paper 1 by Dr. Nick Barton.

We discussed this issue within the Austrian Society for Geomechanics and came to the conclusion that we will NOT send clarifications to the paper of Barton, as these discussions have been ongoing for years, especially with my former Austrian colleagues and Professors. The decision was very clear that we are not in a position that we have to defend ourselves, as NATM is used with great success around the globe, in case all aspects that we teach in detail are followed by the client, the designer, as well as the construction company.

With the response of the author and professionals involved in Rock Engineering, further discussions on the paper by Dr. Nick Barton are hereby closed.

The Editors would like to extend their gratitude to Rocscience, Prof. Robert Galler, and Dr. Nick Barton for taking the time to clarify the relevant issues and highlight the benefits of the approaches discussed. We trust that the insights shared will assist professionals in resolving their queries and effectively applying the approach and software with a solid understanding.

The Editors welcome feedback and discussions on the other two papers, as well as any research/paper published in the past two years in JRMTT. You can freely access all papers published in JRMTT by visiting www.isrmtt.com