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Guest Editorial – Need for Safe and Sustainable Rock Engineering Structures in Challenging Geological Formations

It's a great privilege to receive an invitation from Dr. Subhash Mitra to write an editorial for this issue of the Journal of Rock Mechanics and Tunnelling Technology (JRMTT). From the time I published my first paper in this journal about 25 years ago, I keenly followed its progress. It's heartening to see that the Editorial Board is putting a lot of effort into improving the standard of the journal. A good mix of research and practice-based papers is being maintained on all the issues.

It is in this spirit of sincere reflection that I take this opportunity to both pay tribute to a distinguished teacher who helped shape Indian rock mechanics and to consider the challenges and opportunities that lie ahead for our community.

The year 2026 marked the end of an era in Indian rock engineering research. The passing away of Prof. Ramamurthy, whom we regard as the father of rock mechanics in India, has left us all in deep sorrow. His concept of "joint factor" and the demonstration of its capabilities to predict the strength and modulus of slightly to heavily jointed rock mass reasonably well with minimal input parameters captured the world three decades ago. The joint factor model has remained as one of the popular rock mass models till now and is used by researchers across the world. His efforts in developing rock mechanics education in our country and his contributions to this domain through numerous research articles and a valuable textbook on rock engineering principles will be remembered forever. I pay my heartfelt tributes to Prof. T. Ramamurthy and wish that all his successors uphold his passion and values.

Prof. Ramamurthy's lasting legacy makes it all the more important that we ask ourselves: how well are we, as a community, carrying forward that commitment to relevance and rigour, particularly as Indian infrastructure places demands on rock engineering practice?

The opportunities in the field of rock mechanics are rapidly expanding in our country, with many new infrastructural initiatives in hilly regions. With the successful completion of Chenab and Anjikhad bridges and several tunnels in the Himalayan region, Indian rock engineering is seeing its best phase now. But most rock mass characterization still relies on empirical methods. On the other hand, we are witnessing a paradigm shift in the way research is conducted in this field. A clear shift towards reliability-based design methods, image-based microstructural analyses and intensive computational modelling are dominating the current research. Applications of AI in rock mechanics are seeing a sudden surge. Though these are highly positive developments, the gap between research and practice is widening slowly. Unless there is a conscious effort by both researchers and practitioners to bridge this gap by aligning the research towards practical problems and using contemporary research into design and construction wherever possible, this gap will

remain. We have a long way to go before we can completely use AI for precise characterizations, create robust digital twins for large rock mass systems and confidently simulate their response using our probabilistic models. On a positive note, I see many potential applications of these trending technologies in rock engineering. With constructive integration of high-precision drone imaging, AI-ML based big data analysis, extensive non-destructive testing with minimal invasive sampling and adaptive and intelligent modelling, geological and geotechnical analyses of complex rock systems become sustainable and simplified. However, the shift is slow, mainly because we are dealing with naturally formed heterogeneous and anisotropic systems that are extremely complex and exhibit huge variations in properties with a change in geographical setting and geological conditions. But I am confident that the emerging technologies will have a positive impact on this field, and our pursuit towards realistic and precise design methods in rock engineering will soon be successful. With many young researchers working on these topics, the future is looking very bright.

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