Journal of Engineering Geology *Volume XLVI, No 1*
A bi-annual Journal of ISEG *June 2021*

Chronology of Development of I-System

A Brief History

H Bineshian, PhD
Principal, Technical Director, Amberg Engineering AG, Australia
DrBineshian@outlook.com

Received May 2021, Accepted June 2021

Abstract

This article provides chronology of development of I-System. The purpose to develop a new classification is explained and the aim to develop a comprehensive characterisation is presented. The general shortcomings of the existing classifications are briefly addressed and the reason to use I-System is clarified. Importance of comprehensiveness of an engineering classification system for both rocks and soils as well as varieties of tunnelling methods is described and necessity of consideration of most important features of ground as well as structures is briefed.

Keywords: (I)-Class, (I)-GC, I-System

1. Introduction

Empirical and observational design elements in a healthy design procedure is based on a suitable engineering classification and ground characterisation as the main part in design of structures in ground (Bineshian, 2019a, 2019b, 2020). It is necessary that the engineering classification to be comprehensive enough to be applicable for both rocks and soils and to be appropriate for application in modern tunnelling methods (e.g., NATM, NMT, SEM, SCL, etc.). Existing engineering classifications come with limitations in use, imprecision in regular application, and inaccuracy in estimation, which make engineers uncertain in determination and dimensioning of structures specially when they encounter ground complications (Bineshian, 2014, Bineshian, 2017a, Bineshian et al, 2019). RMR by Bieniawski (1973) and Q by Barton et al (1974) are widely used existing classifications; however, they lag in applications, comprehensiveness, accuracy, and precision. They are only applicable for rock medium; RMR is proposed for surface and underground works and Q for tunnels only. They take few parameters of rocks as input for the classification while very important parameters of ground are ignored, which have great impact on the ground quality. None of them considering excavation methods or properly taking the structures specifications (Bineshian, 2019b). I-System is developed to be used as a comprehensive classification and characterisation system for ground; i.e., both rocks and soils (Bineshian, 2019b). It is verified against varieties of ground conditions and scrutinised in several projects through 22 years research to address and resolve the aforesaid issues involved with existing classifications. I-System provides prediction of ground behaviour together with recommendations on required support system/s, excavation technique/s, instrumentation technique/s, prevention technique/s, and forecast technique/s followed by design remark/s as well as estimation for important mechanical properties of ground. Its output is optimised by analytical, numerical, and observational methods to compensate the demerits of existing classifications and strengthen its comprehensiveness.

2. Chronology

Table 1 represents a brief chronology of the development course of I-System. It is avoided to present all the details; however, main progress in research and the development is listed.

Table 1. Chronology and development procedure of I-System since 1999.

Year	Description
1999	- Initial form of (I) is developed as a function of uniaxial compressive strength, RQD, discontinuities' dip effect, rocks and soils' fabric, texture, and structure, and ground water condition.
2000	- Further development is attained by adding more important structural properties of rocks as armature index. - RQD is removed from the system due to its inefficiency in designating the rock quality. - Important easily derivable soils properties considering ground structural configurations is added to the system for better modelling of soils properties. - Dynamic forces' impact on the structure is added to the system for a better modelling of ground-structure reaction.
2001	- Further development is obtained by improvement of soil modelling in the system using morphology, cohesiveness consistency, and denseness consistency as some elements of properties index of the system.
2002	- Further development is achieved by adding the most important seismic properties of ground to the system to describe better the properties of rocks and soils.
2003	- Further development is applied to the system by establishing the structural as well as problematical configurations of ground including the tectonic features and structural geological aspects of ground; this part is called configuration index of the system.
2004	- I-System was further developed by considering the negative effects of water on ground including the effects in softening of the ground materials as well as the pressure effect both as main elements of hydro index of the system. - Excavation method's impact is added to the system by considering the method of excavation and peak particle velocity.
2005	- Seismic as well as dynamic effects including peak ground acceleration's effect on the structure is further developed as impact factor for proper modelling of the structure in relation to the ground.

2006	-	Scale effect and consideration of shape and depth of placement of the structure is considered in the system as elements of the strength index.
2007	-	Indices and impact factors are further assessed and the derivation of parameters are tested in practice.
2008	-	Hydraulic conductivity of ground is included in the system as part of hydro index and the system is further developed to approach its final form.
2009	-	(I)-Class's development is initiated as I-System's classification system and its initial form for underground, semi-surface, and surface structures is prepared.
2010	-	Special ground conditions including burst prone, squeezing, swelling, heaving, gravity driven, and time dependent grounds/behaviour are taken into consideration to be included in the (I)-Class.
	-	I-System is further verified in practice.
2011	-	Development of Stress Release Holes (SRH) for squeezing, swelling, and heaving (SSH) ground is initiated.
	-	I-System is further verified in various ground conditions; consequently, corrections/amendments in scoring system is applied.
2012	-	Further verification of I-System and its (I)-Class is conducted in practice.
	-	Scoring system is further assessed for the parameters of the indices and impact factors.
	-	Classification for SSH condition is initiated.
2013	-	Development of Ground Conductivity Designation (GCD) is initiated as a criterion for assessment of ground conductivity as well as solidification quality.
	-	I-System is further verified in practice.
	-	(I)-Class's recommendations were assessed in details for different structures and its recommendations were further improved.
	-	Further development on SRH is obtained.
2014	-	GCD is tested in practice and it is further assessed.
	-	I-System's scoring system is further modified.
	-	(I)-Class's recommendations are further improved.
	-	SRH research is reached to its final form to be applied in practice.
2015	-	SRH is applied in practice and the results are assessed.
	-	Further work is conducted on I-System's scoring system to form its final format.

- (I)-Class's recommendations are verified for challenging tunnelling condition.
- GCD is further tested in practice.

2016
- Development of (I)-GC as I-System's ground characterisation for estimation of mechanical properties of ground is initiated.
- I-System and (I)-Class are reached to their final form while they are further verified in practice.
- SRH is successfully applied in practice.

2017
- GCD's results cited in publications (Bineshian, 2017a, 2017b, Bineshian, et al, 2019).
- Further researches on SRH are performed.
- I-System is further verified in practice.
- (I)-GC's accuracy is further improved by derivation of best fit on empirical data.

2018
- I-System is further verified; it is formally used in design.
- GCD and SRH have obtained their final forms.
- (I)-GC is further developed while it has obtained acceptable accuracy in estimation of mechanical properties of ground.

2019
- I-System is first ever published (Bineshian, 2019a, 2019b) while it is further applied in design and its performance was verified systematically.
- GCD and SRH are further applied in practice and their suitability were verified.
- Research on ViD (vibration-induced damage) is initiated as a function of (I).
- Development of empirical equations/methods for estimation of pull length in underground works as well as rock bolting system calculation based on I-System is initiated.
- (I)-GC is included in I-System as a comprehensive characterisation system.

2020
- ViD, pull length advisor, and systematic bolting calculator are developed based on (I).
- GCD is published (Bineshian, 2020a).
- SRH System is published (Bineshian, 2020b).
- I-System is further verified.
- I-System Software is developed (Bineshian, 2020c).

2021
- ViD is published (Bineshian, 2021).
- 2021 edition of I-System is in press containing further clarifications as well as added features; application of I-System is eased.
- I-System Software is further developed to include all added features of I-System.

3. References

1. Barton, N, Lien, R, Lunde, J 1974. 'Engineering classification of rock masses for the design of tunnel support', Rock Mechanics, 6: 4: 189 - 236.
2. Bieniawski, Z.T, 1973. 'Engineering classification of jointed rock masses', Civil Engineer, South Africa, 15 (12).
3. Bineshian, H 2014. 'Stress non-uniformity in concrete and rock structures', LAP Lambert Publishing, Germany, 333p.
4. Bineshian, H 2017a. 'Tunnelling in Visco-Elasto-Plastic ground in tunnel T05 of the Katra-Dharam Section of the Udhampur Srinagar Baramulla Rail Link Project', Proceedings of Tunnelling in Himalayan Geology, Jammu, India.
5. Bineshian, H 2017b. 'Plastic ground at T02 tunnel; Method of treatment using SRH', DDC Project Register, USBRL, KRCL.
6. Bineshian, H 2019a. 'I-System; A quick introduction', Proceedings of the 8th IndoRock-2019 Conference, Delhi, India, 254 - 271.
7. Bineshian, H 2019b. 'I-System: Index of Ground-Structure; A Comprehensive Indexing System for Ground-Structure Behaviour; Classification and Characterization', Journal of Engineering Geology (JOEG), XLIV (1 & 2), 73 - 109, ISSN 0970-5317.
8. Bineshian, H, Gupta, S, Hegde, R K 2019. 'NATM in Hazardous Condition – Challenging Visco-Elasto-Plastic Ground – T5 Tunnel – USBRL Project', Proceedings of International Conference, Tunnelling Asia, Mumbai, India, 120 - 135.
9. Bineshian, H 2020a. 'GCD – Ground Conductivity Designation; A testing method to quantify ground's hydraulic conductivity and solidification quality', Journal of Engineering Geology (JOEG), XLV (1 & 2), 17 - 23, ISSN 0970-5317.
10. Bineshian, H 2020b. 'SRH System – Stress Release Hole/s; A substitution to conventional yield support system', Journal of Engineering Geology (JOEG), XLV (1 & 2), 1 - 16, ISSN 0970-5317.
11. Bineshian, H 2021. 'Vibration-induced Damage Assessment; New practical methods applicable for engineered blasting', TAI Journal, 10 (1): 5 - 14.
12. Bineshian, H 2020c. 'I-System: Index of Ground-Structure; Definition, applications, and utilisation in design/practice', TAI Journal, 9 (1): 42 - 64.
13. Bineshian, H 2021. 'Vibration-induced Damage Assessment; New practical methods applicable for engineered blasting', TAI Journal, 10 (1): 12 - 21.