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Ground Characterisation for Design using I-System Software

Case Studies

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Abstract

This article aims to provide case studies of recent use of I-System in underground, semi-surface, and surface projects in both rocks and soils. I-System is used for classification and characterisation of ground in the projects in India including USBRL and Teesta in design and/or for execution of the work. Recommendations obtained form (I)-Class including primary and final support system, required excavation technique/s for encountered condition, proper instrumentation technique/s for monitoring, appropriate prevention technique/s against possible failures, verified forecast technique/s to predict the ground condition ahead, and practical design recommendations for understanding of ground behaviour, failure mechanism, and load configuration ascertained to be practical and well optimised. Characterisation of ground's mechanical properties by (I)-GC including modulus of deformation, Poisson's ratio, unconfined compressive strength, uniaxial tensile strength, cohesion, and internal friction angle are found to be suitable to be used in design.

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

Nomenclature

(I)	I-System's value	MSK	Medvedev-Sponheuer-Karnik Scale
(I)-Class	I-System's Ground Classification	NATM	New Austrian Tunnelling Method
(I)-GC	I-System's Ground Characterisation	NHPC	National Hydroelectric Power Corporation
Ai	Armature Index	NR	Northern Railway of Indian Railway
C_g	Cohesion of ground	PGA_{SD}	Scaled Design Peak Ground Acceleration (g)
Ci	Configuration Index	Pi	Properties Index
D	Diameter/width/height of opening (the greater value)	PPV	Peak Particle Velocity
DFi	Dynamic Forces Impact	PT	Prevention Technique/s
E_g	Deformation Modulus of ground	Si	Strength Index
ET	Excavation Technique/s	SS	Support System
ETi	Excavation Technique Impact	UCS	Uniaxial Compressive Strength
ERZ	Earthquake Risk Zone	USBRL	Udhampur-Srinagar-Baramula Rail Link
FT	Forecast Technique/s	ν_g	Poisson's Ratio of ground
Hi	Hydro Index	σ_{cg}	Unconfined Compressive Strength of ground
IT	Instrumentation Technique/s	σ_{tg}	Uniaxial Tensile Strength of ground
KRCL	Konkan Railway Corporation Limited	φ_g	Internal Friction Angle of ground
LTHPL	Lanco Teesta Hydro Power Limited		

1. Introduction

I-System (Bineshian, 2019a, 2019b, 2020) has been verified in railway, metro, road, canal, hydropower, and mining projects during 22 years course of development. After it was first published in 2019, it is further applied in design of several projects in India including Tunnels T03, T05, T06, T35, T37, T44, T50, and T51 of Central Railway, Tunnels T05 wider section, T09 cut and cover, T40 wider section, T41-T47, and T14 twin tunnels of Northern Railway, Tunnels Pernem and Old Goa of Konkan Railway, and Teesta hydropower project. The results were quite satisfactory. Following sections provide a brief study on application of I-System in some of mentioned projects of recent cases. Calculation procedure is explained in details in I-System paper published in 2019 (Bineshian, 2019b); therefore, it is avoided here to repeat the calculation procedure.

2. Underground Rock Works – USBRL Project – Tunnel T05

NR is the client of the project. Work is being executed by KRCL. T05 is one of the most challenging NATM tunnels in USBRL in North India (Bineshian, 2017a, Bineshian et al, 2019). It is a 6 km twin tube tunnel in young Himalaya's terrain in dolomite rock formation, which passes through several hazardous zones. Following case is related to an incident (2019/05/11) at main tunnel (D = 8000 mm) at CH46598. I-System is utilised to assess the condition and to provide a solution to overcome the challenge. I-System's recommendations are applied and successful results obtained.

Figure 1 represents the input and output data of analysis obtained from I-System Software.

(I) = (Ai + Ci + Hi + Pi + Si) × DFi × ETi Bineshian (2019)

Calculation Sheet: CH46598	Location: JK
Project: USBRL-T05	Type of Structure: Underground
Country: IN	Date: 2021/03/11

Ai - ARMATURE INDEX: 2.77

dn Discontinuity Number/s - per m	≥ 25
ds Discontinuity Set/s	3
di Discontinuity Inclination - °	31 - 60
da Discontinuity Aperture	Open
dd Discontinuity Disintegration	Semi-Integrated
df Discontinuity Friction	Low Friction - Smooth/Even
dp Discontinuity Persistency	≥ 0.90 x D

Ci - CONFIGURATION INDEX: 5.25

pc Problematical Configuration	Sheared - High Shear Stresses - e.g. Mylonite
sc Structural Configuration	Layered (100 - 10 cm)

Hi - HYDRO INDEX: 6.50

gc Ground Conductivity (GCD) || [Wetness]	(7 - 9.99) || [Wet]
gs Ground Softness - Mohs	5

Pi - PROPERTIES INDEX: 6.60

cc Cohesiveness Consistency	Picked Easily
dc Denseness Consistency	Never Indented by Thumbnail
ps Particle Size	Sand
pm Particle Morphology	Sub-angular
bw Body Wave Velocity - m/sec (Vp) || [Vs]	(3499 - 3000) || [1999 - 1500]

Si - STRENGTH INDEX: 8.10

cs UCS	19 - 10 MPa
se Scale Effect	D/H = 1.20 - 0.80 & σv ≥ σh

DFi - DYNAMIC FORCES IMPACT: 0.85

(PGASD) || [ERZ] || {MSK}	(0.36g - 0.50g) || [VH] || {IX-X}

ETi - EXCAVATION TECHNIQUE IMPACT: 0.99

(ET) || [PPV mm/sec]	(ME/NonExBreak) || [< 2]

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Figure 1a. I-System Software output – USBRL – T05 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

25%

(I)-Class

(I)-08

Recommended Measure/s

SS - Support System

FP32.200.L.X1/FP76.250.L.X1/PR100.300.L.X1, SysLB32.L.S, LG32.25.180.1000-/RigidR150UC23.1000-, FRS225/FRC225, FaceButt.L, FRFS200, RDH54.L+CF

ET - Excavation Technique/s

PSE-ME/NonExBreak, PL1000-

IT - Instrumentation Technique/s

3DMS@50m, StrainM@200m, PressC/LoadC@250m, SingleRodE@400m

PT - Prevention Technique/s

Apply FP/PR, Maintain Buttress, Avoid: FF & DnB

FT - Forecast Technique/s

TSP/PH54.EC.L

Design Remark/s

Passive load configuration, sensitive to scale, unsupported span, & stand-up time

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Figure 1b. I-System Software output – USBRL – T05 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

(I)-GC; I-System's Ground Characterization

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(I) = 25

Selected UCS range is 19 - 10 MPa.

Specified σ_c Value = 10 MPa

Modulus of Deformation

E_g = 2.490 GPa

Poisson's Ratio

ν_g = 0.400

Unconfined Compressive Strength

σ_{cg} = 0.244 MPa

Uniaxial Tensile Strength

σ_{tg} = -0.012 MPa

Cohesion

C_g = 1.706 KPa

Internal Friction Angle

φ_g = 28.750°

(I)-GC characterizes the ground based on (I); however, it is recommended to scrutinise it by deriving the mechanical properties of ground by standardised in-situ testing methods.

Figure 1c. I-System Software output – USBRL – T05 Tunnel

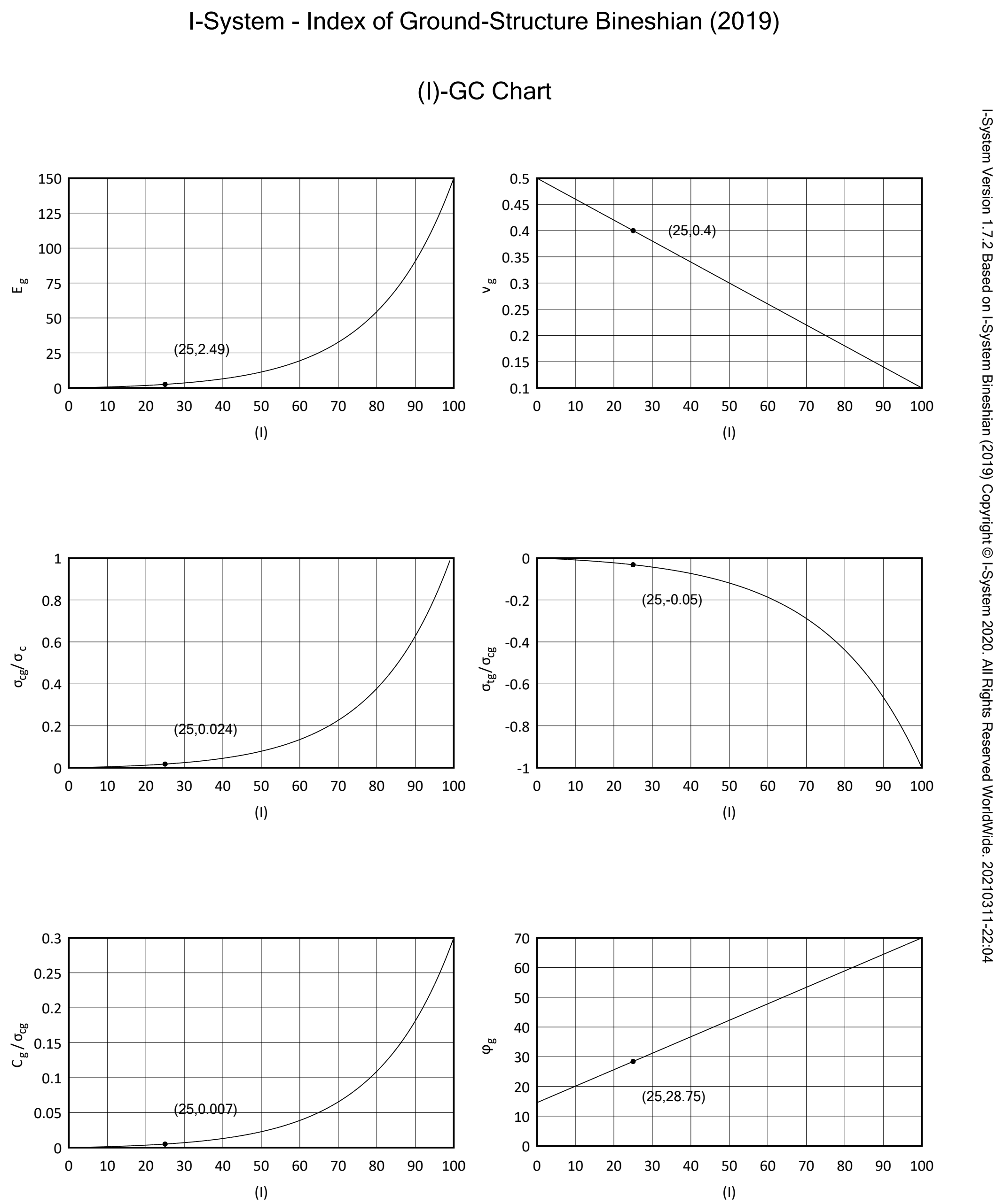

Figure 1d. I-System Software output – USBRL – T05 Tunnel

3. Underground Soil Works – USBRL Project – Tunnel T02

Tunnel T02 is another challenging NATM tunnel (D = 8000 mm) in USBRL (Client: NR, Engineer in charge: KRCL) with a length of almost 5.6 km twin tube in young Himalaya's terrain (Bineshian, 2017b). For some stretches, it passes through extremely challenging soil formation. Advancing at face of the main tunnel at CH37488 was impossible on 2018/09/23 due to gravity driven behaviour of ground. Condition is assessed by I-System. Work is resumed after application of I-System's classification recommendations and characterisation's design parameters; no instabilities occurred in the course of tunnelling in the zone.

Figure 2 shows the input and output of analysis using I-System Software.

(I) = (Ai + Ci + Hi + Pi + Si) × DFi × ETi Bineshian (2019)

Calculation Sheet: Failure	Location: JnK
Project: USBRL - T02	Type of Structure: Underground
Country: IN	Date: 2021/06/03

Ai - ARMATURE INDEX: 0.00

dn Discontinuity Number/s - per m	N/A || Jointless
ds Discontinuity Set/s	N/A || Jointless
di Discontinuity Inclination - °	N/A || Jointless
da Discontinuity Aperture	N/A || Jointless
dd Discontinuity Disintegration	N/A || Jointless
df Discontinuity Friction	N/A || Jointless
dp Discontinuity Persistency	N/A || Jointless

Ci - CONFIGURATION INDEX: 4.00

pc Problematical Configuration	Homogeneous || Isotropic || Jointless || Granular
sc Structural Configuration	Cohesive Matrix Skeleton

Hi - HYDRO INDEX: 2.40

gc Ground Conductivity (GCD) || [Wetness]	(25 - 49) || [Flow]
gs Ground Softness - Mohs	4

Pi - PROPERTIES INDEX: 8.12

cc Cohesiveness Consistency	Picked Easily
dc Denseness Consistency	Never Indented by Thumbnail
ps Particle Size	Gravel
pm Particle Morphology	Angular
bw Body Wave Velocity - m/sec (Vp) || [Vs]	(3999 - 3500) || [2199 - 2000]

Si - STRENGTH INDEX: 7.20

cs UCS	9 - 5 MPa
se Scale Effect	D/H = 1.20 - 0.80 & $\sigma v \geq \sigma h$

DFi - DYNAMIC FORCES IMPACT: 0.85

(PGASD) || [ERZ] || {MSK}	(0.36g - 0.50g) || [VH] || {IX-X}

ETi - EXCAVATION TECHNIQUE IMPACT: 0.90

(ET) || [PPV mm/sec]	(CtldBlast) || [120 - 449]

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Figure 2a. I-System Software output – USBRL – T02 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

17%

(I)-Class

(I)-09

Recommended Measure/s

SS - Support System

PR100.250.L.X1/FP76.200.L.X1/FP32.200.L.X2, FaceB25.L.S/FaceP300-, FaceButt.L, PreG/I, RigidR150UC23.750-+RingC, SysN32.L.S, FRS225/FRC225, FRFS200, RDH54.L+CF

ET - Excavation Technique/s

PSD-ME, PL750-

IT - Instrumentation Technique/s

3DMS@25m, StrainM@150m, PressC/LoadC@200m, MultiRodE@400m, StrainG@500m

PT - Prevention Technique/s

Apply PreG/I & PR/FP, Maintain Buttress, Avoid: FF, NonExBreak/DnB, & Ductile SS

FT - Forecast Technique/s

TSP/PH54.EC.L

Design Remark/s

Passive load configuration, sensitive to scale, unsupported span, & stand-up time

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Figure 2b. I-System Software output – USBRL – T02 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

(I)-GC; I-System's Ground Characterization

(I) = 17

Selected UCS range is 9 - 5 MPa.

Specified σ_c Value = 5 MPa

Modulus of Deformation

E_g = 1.340 GPa

Poisson's Ratio

ν_g = 0.432

Unconfined Compressive Strength

σ_{cg} = 0.082 MPa

Uniaxial Tensile Strength

σ_{tg} = -0.003 MPa

Cohesion

C_g = 0.383 KPa

Internal Friction Angle

φ_g = 24.350°

(I)-GC characterizes the ground based on (I); however, it is recommended to scrutinise it by deriving the mechanical properties of ground by standardised in-situ testing methods.

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Figure 2c. I-System Software output – USBRL – T02 Tunnel

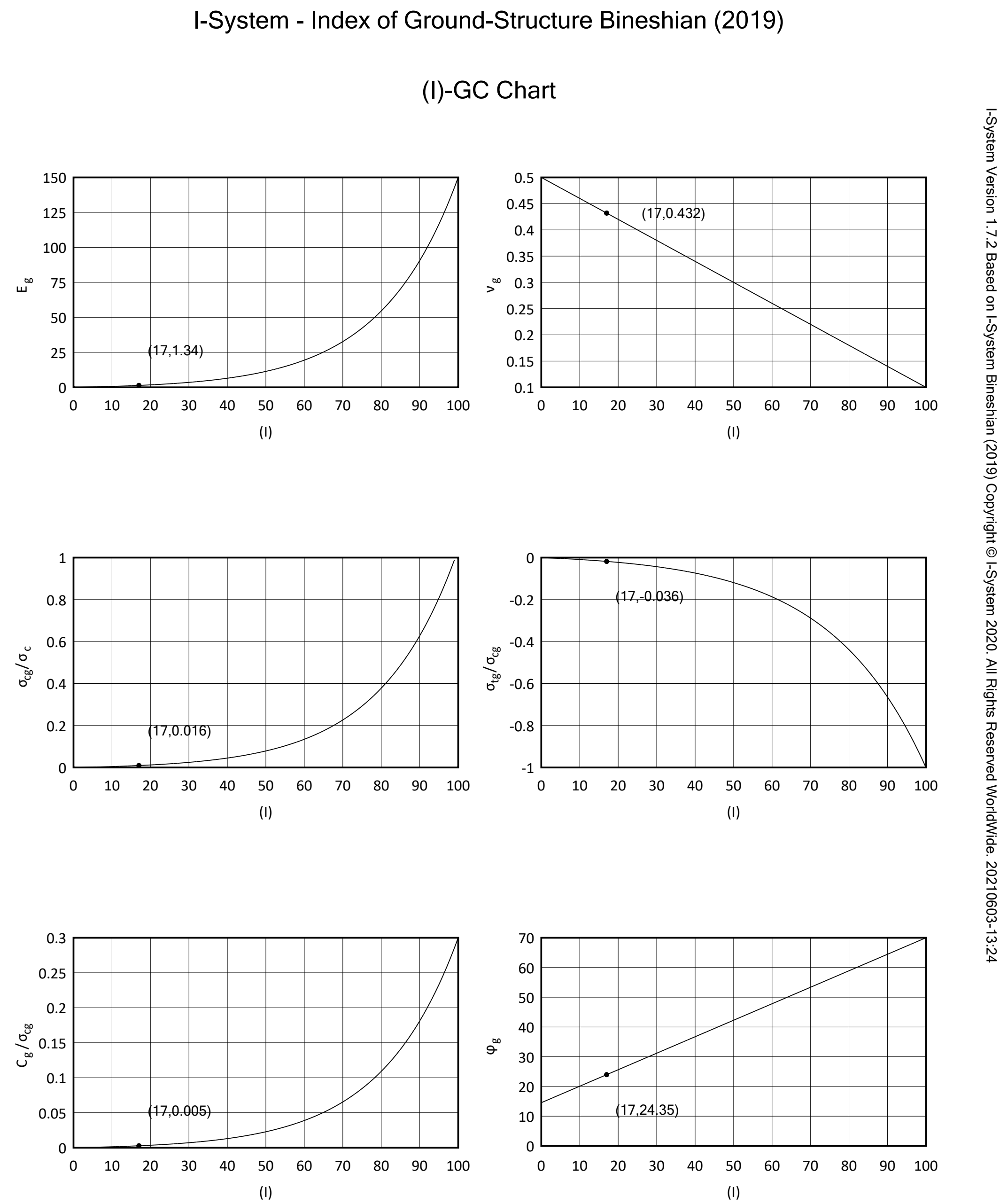

Figure 2d. I-System Software output – USBRL – T02 Tunnel

4. Surface Rock and Soil Works – USBRL Project – Tunnel Portal of T13

Portal works of both main and escape tunnels of T13 (one of the longest twin tunnels in USBRL with 9 km length in young Himalaya's terrain) is designed using I-System. Following case represents the output for I-System evaluation on portal of the escape tunnel of T13. The slope of this portal is located in a ground with mix of sandstone fragments in soil matrix. (I)-Class output obtained from I-System for the slope of the T13's portal is being applied. The portal is designed using (I)-GC output of I-System as design parameters.

Input as well as output of the analysis conducted using I-System Software is presented in Figure 3.

(I) = (Ai + Ci + Hi + Pi + Si) × DFi × ETi Bineshian (2019)

Calculation Sheet: ET Portal	Location: JnK
Project: USBRL - T13	Type of Structure: Surface
Country: IN	Date: 2021/06/03

Ai - ARMATURE INDEX: 5.48

dn Discontinuity Number/s - per m	15 - 19
ds Discontinuity Set/s	3
di Discontinuity Inclination - °	11 - 30
da Discontinuity Aperture	Semi-Tight
dd Discontinuity Disintegration	Weathered/Altered
df Discontinuity Friction	Moderate Friction - Nonsmooth
dp Discontinuity Persistency	≥ 0.90 x D

Ci - CONFIGURATION INDEX: 9.00

pc Problematical Configuration	Fractured - Highly
sc Structural Configuration	Layered (100 - 10 cm)

Hi - HYDRO INDEX: 12.00

gc Ground Conductivity (GCD) || [Wetness]	(≤ 0.99) || [Dry]
gs Ground Softness - Mohs	6

Pi - PROPERTIES INDEX: 16.00

cc Cohesiveness Consistency	Indurated
dc Denseness Consistency	Never Indented by Thumbnail
ps Particle Size	N/A (e.g. Grainless)
pm Particle Morphology	N/A (e.g. Grainless)
bw Body Wave Velocity - m/sec (Vp) || [Vs]	(4999 - 4500) || [2899 - 2600]

Si - STRENGTH INDEX: 12.60

cs UCS	74 - 50 MPa
se Scale Effect	B/H = 1.20 - 0.80

DFi - DYNAMIC FORCES IMPACT: 0.85

(PGASD) || [ERZ] || {MSK}	(0.36g - 0.50g) || [VH] || {IX-X}

ETi - EXCAVATION TECHNIQUE IMPACT: 0.99

(ET) || [PPV mm/sec]	(ME/NonExBreak) || [< 2]

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Figure 3a. I-System Software output – USBRL – T13 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

46%

(I)-Class

(I)-06

Recommended Measure/s

SS - Support System

Scng, SysA25.L.S, FRS150, DH54.L

ET - Excavation Technique/s

(PreS, DD6000-), (ProdBlast, PD2000-)

IT - Instrumentation Technique/s

3DMS@75m, IncM@500m

PT - Prevention Technique/s

Cover Slope Crest with WPM & FRS at a Width Equal to Height to Help Prevention of Tension Crack Generation, Avoid: ProdBlast/UnCtldBlast, Surcharge at Crest, & Toe Lightening

FT - Forecast Technique/s

ERT/VPH54.L

Design Remark/s

Check against plain/wedge/toppling failure & rock fall criteria

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Figure 3b. I-System Software output – USBRL – T13 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

(I)-GC; I-System's Ground Characterization

(I) = 46

Selected UCS range is 74 - 50 MPa.

Specified σ_c Value = 50 MPa

Modulus of Deformation

E_g = 8.974 GPa

Poisson's Ratio

ν_g = 0.316

Unconfined Compressive Strength

σ_{cg} = 3.491 MPa

Uniaxial Tensile Strength

σ_{tg} = -0.403 MPa

Cohesion

C_g = 69.639 KPa

Internal Friction Angle

φ_g = 40.300°

(I)-GC characterizes the ground based on (I); however, it is recommended to scrutinise it by deriving the mechanical properties of ground by standardised in-situ testing methods.

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Figure 3c. I-System Software output – USBRL – T13 Tunnel

I-System - Index of Ground-Structure Bineshian (2019)

(I)-GC Chart

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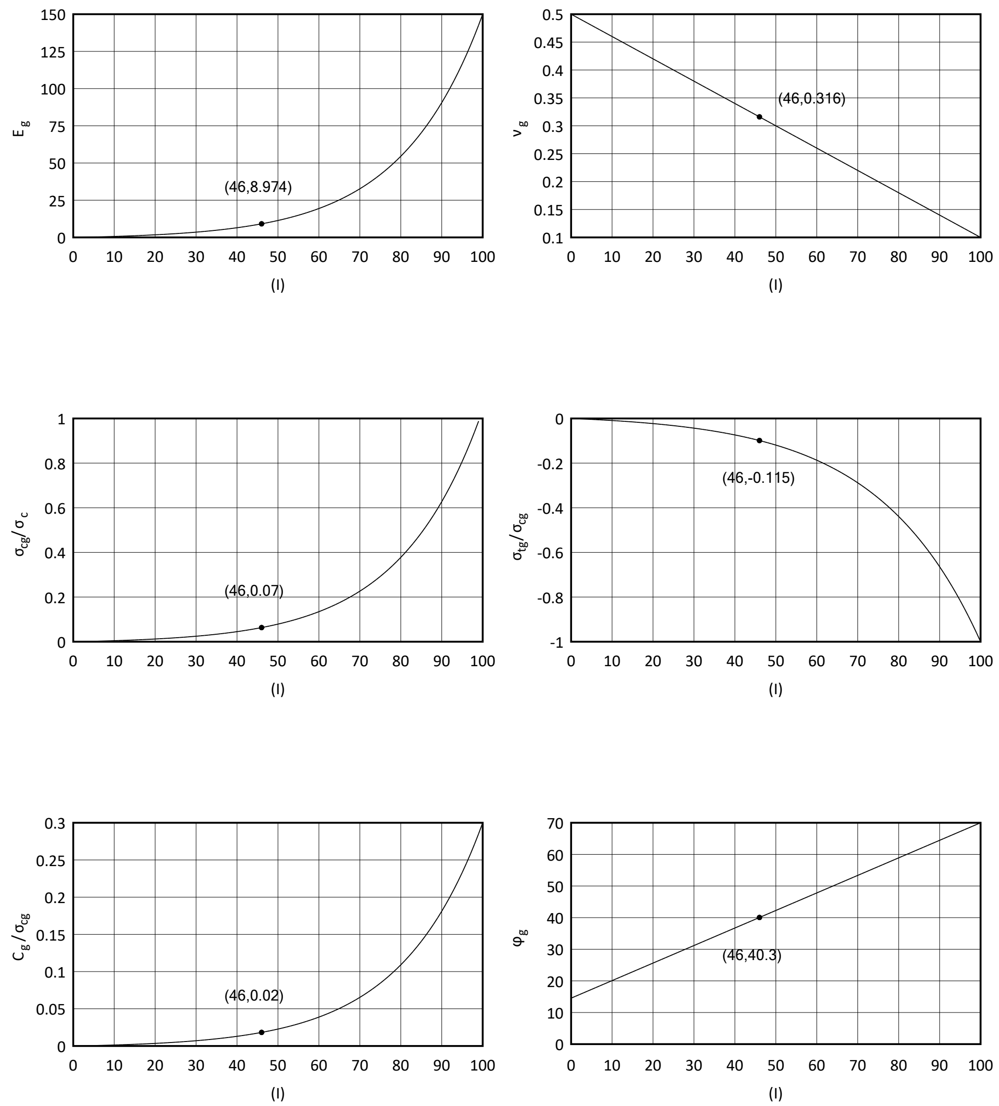

Figure 3d. I-System Software output – USBRL – T13 Tunnel

5. Semi-surface Unweathered Rock Works – Teesta HEP (Stage VI)

NHPC is the client of the project. Work is being executed by LTHPL. Subject work is the characterisation of ground for slope stabilisation design for barrage and power intake pile wall and the desilting basin. I-System is used for derivation of ground parameters as well as prediction for required measures for stabilisation of the subject structures.

Six parameters including E_g, σ_{cg}, σ_{cg}, C_g, and φ_g for the fresh rock mass for the semi-surface structure is estimated using (I)-GC.

Analysis input and output of I-System Software is presented in Figure 4.

(I) = (Ai + Ci + Hi + Pi + Si) × DFi × ETi Bineshian (2019)

Calculation Sheet: Fresh	Location: Sikkim
Project: TeestaHEP	Type of Structure: Semi-Surface
Country: IN	Date: 2021/05/22

Ai - ARMATURE INDEX: 9.50

dn Discontinuity Number/s - per m	10 - 14
ds Discontinuity Set/s	3
di Discontinuity Inclination - °	31 - 60
da Discontinuity Aperture	Tight
dd Discontinuity Disintegration	Unweathered/Unaltered
df Discontinuity Friction	High Friction - Rough/Uneven
dp Discontinuity Persistency	< 0.90 x D

Ci - CONFIGURATION INDEX: 12.75

pc Problematical Configuration	Fractured - Moderately
sc Structural Configuration	Layered (> 100 cm)

Hi - HYDRO INDEX: 16.00

gc Ground Conductivity (GCD) || [Wetness]	(3 - 4.99) || [Moist]
gs Ground Softness - Mohs	≥ 7

Pi - PROPERTIES INDEX: 12.00

cc Cohesiveness Consistency	Indurated
dc Denseness Consistency	Never Indented by Thumbnail
ps Particle Size	N/A (e.g. Grainless)
pm Particle Morphology	N/A (e.g. Grainless)
bw Body Wave Velocity - m/sec (Vp) || [Vs]	(3499 - 3000) || [1999 - 1500]

Si - STRENGTH INDEX: 12.60

cs UCS	74 - 50 MPa
se Scale Effect	B/H = 1.20 - 0.80

DFi - DYNAMIC FORCES IMPACT: 0.90

(PGASD) || [ERZ] || {MSK}	(0.26g - 0.35g) || [H] || {VII-VIII}

ETi - EXCAVATION TECHNIQUE IMPACT: 0.99

(ET) || [PPV mm/sec]	(ME/NonExBreak) || [< 2]

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Figure 4a. I-System Software output – Teesta HEP – Barrage

I-System - Index of Ground-Structure Bineshian (2019)

56%

(I)-Class

(I)-05

Recommended Measure/s

SS - Support System

Scng, SpotB32/SpotA32, HEAM/WeldM, DH54.L

ET - Excavation Technique/s

(PreS, DD6000-), (ProdBlast, PD3000-)

IT - Instrumentation Technique/s

3DMS@150m

PT - Prevention Technique/s

Protect Crest with FRS to Prevent Increment in Pore Water Pressure, Avoid: ProdBlast/UnCtldBlast, & Bulk Removal of Toe

FT - Forecast Technique/s

ERT/VPH54.L

Design Remark/s

Check against plain/wedge/toppling failure & rock fall criteria, SFL not required

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Figure 4b. I-System Software output – Teesta HEP – Barrage

I-System - Index of Ground-Structure Bineshian (2019)

(I)-GC; I-System's Ground Characterization

(I) = 56

Selected UCS range is 74 - 50 MPa.

Specified σ_c Value = 50 MPa

Modulus of Deformation

E_g = 15.445 GPa

Poisson's Ratio

ν_g = 0.276

Unconfined Compressive Strength

σ_{cg} = 5.756 MPa

Uniaxial Tensile Strength

σ_{tg} = -0.990 MPa

Cohesion

C_g = 189.298 KPa

Internal Friction Angle

φ_g = 45.800°

(I)-GC characterizes the ground based on (I); however, it is recommended to scrutinise it by deriving the mechanical properties of ground by standardised in-situ testing methods.

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Figure 4c. I-System Software output – Teesta HEP – Barrage

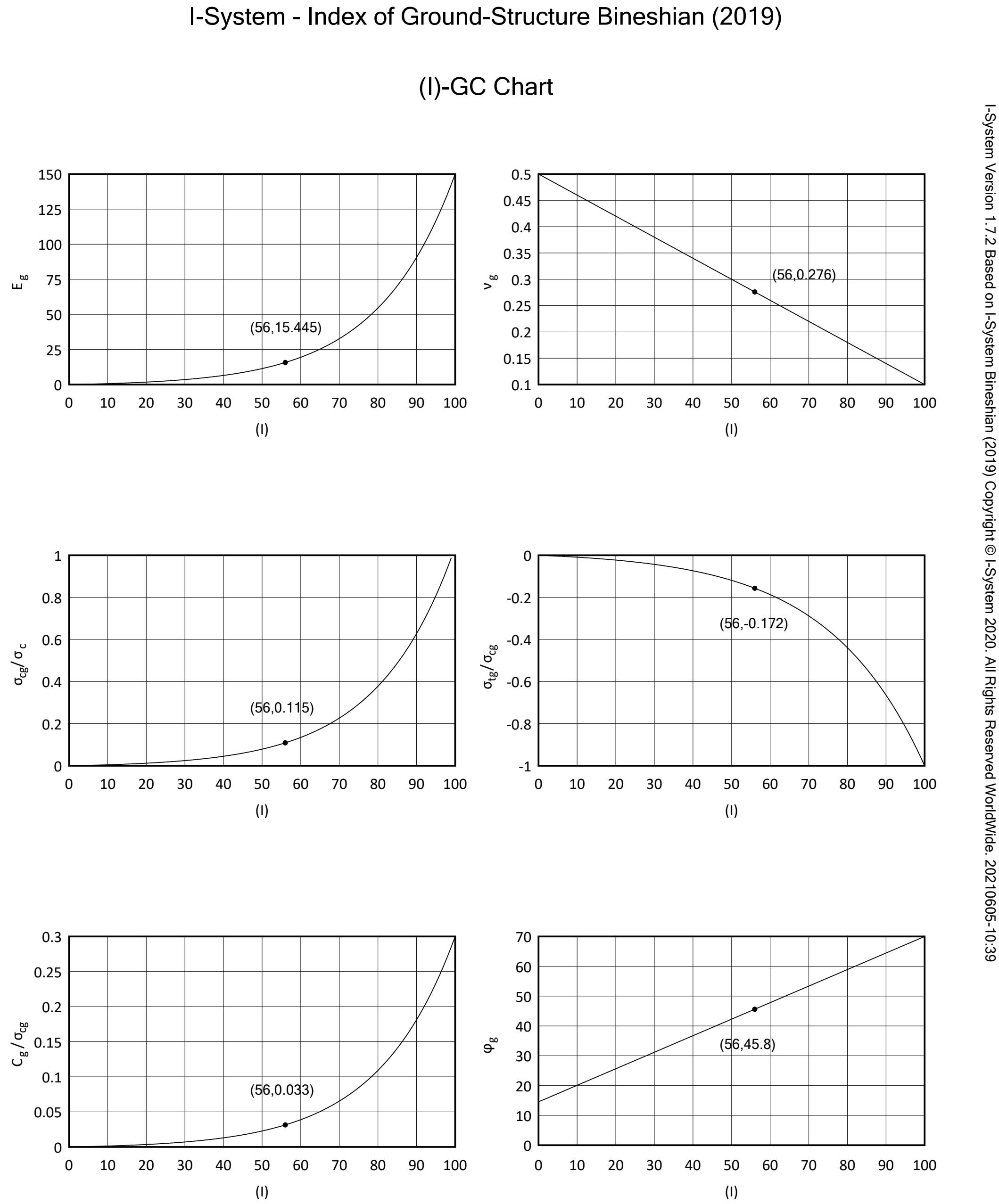

Figure 4d. I-System Software output – Teesta HEP – Barrage

6. Surface Highly Weathered Rock Work – Teesta HEP (Stage VI)

Subject work is the characterisation of ground for slope stabilisation design for barrage and power intake pile wall and the desilting basin in a highly weathered rock mass as a surface structure. I-System is used for derivation of ground parameters as well as prediction for required measures for stabilisation of the subject structures.

Similar to the Section 5, six parameters including E_g, σ_{cg}, σ_{cg}, C_g, and φ_g for the highly weathered rock mass for the surface structure is estimated using (I)-GC.

Figure 5 provides the input and output of the analysis conducted using I-System Software.

(I) = (Ai + Ci + Hi + Pi + Si) × DFi × ETi Bineshian (2019)

Calculation Sheet: Weathered	Location: Sikkim
Project: TeestaHEP	Type of Structure: Surface
Country: IN	Date: 2021/05/22

Ai - ARMATURE INDEX: 2.03

dn Discontinuity Number/s - per m	20 - 24
ds Discontinuity Set/s	≥ 4
di Discontinuity Inclination - °	31 - 60
da Discontinuity Aperture	Semi-Tight
dd Discontinuity Disintegration	Weathered/Altered
df Discontinuity Friction	Moderate Friction - Nonsmooth
dp Discontinuity Persistency	< 0.90 x D

Ci - CONFIGURATION INDEX: 9.00

pc Problematical Configuration	Fractured - Highly
sc Structural Configuration	Layered (100 - 10 cm)

Hi - HYDRO INDEX: 9.00

gc Ground Conductivity (GCD) || [Wetness]	(5 - 6.99) || [Leak]
gs Ground Softness - Mohs	6

Pi - PROPERTIES INDEX: 10.00

cc Cohesiveness Consistency	Indurated
dc Denseness Consistency	Never Indented by Thumbnail
ps Particle Size	N/A (e.g. Grainless)
pm Particle Morphology	N/A (e.g. Grainless)
bw Body Wave Velocity - m/sec (Vp) || [Vs]	(2499 - 2000) || [999 - 750]

Si - STRENGTH INDEX: 9.00

cs UCS	29 - 20 MPa
se Scale Effect	B/H = 1.20 - 0.80

DFi - DYNAMIC FORCES IMPACT: 0.90

(PGASD) || [ERZ] || {MSK}	(0.26g - 0.35g) || [H] || {VII-VIII}

ETi - EXCAVATION TECHNIQUE IMPACT: 0.99

(ET) || [PPV mm/sec]	(ME/NonExBreak) || [< 2]

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Figure 5a. I-System Software output – Teesta HEP – Desilting basin

I-System - Index of Ground-Structure Bineshian (2019)

35%

(I)-Class

(I)-07

Recommended Measure/s

SS - Support System

Scng, SysA32.L.S, FRS250, PostG/I, DH54.L

ET - Excavation Technique/s

ME/NonExBreak

IT - Instrumentation Technique/s

3DMS@25m, IncM@400m

PT - Prevention Technique/s

Cover Slope Crest with WPM & FRS at a Width Equal to Height to Help Prevention of Tension Crack Generation, Avoid: ProdBlast/UnCtldBlast, Sharp/Tall Slope, Short Berm, Surcharge at Crest, & Toe Lightening

FT - Forecast Technique/s

ERT/SRT/VPH54.L

Design Remark/s

Check against plain/wedge/toppling failure & rock fall criteria

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Figure 5b. I-System Software output – Teesta HEP – Desilting basin

I-System - Index of Ground-Structure Bineshian (2019)

(I)-GC; I-System's Ground Characterization

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(I) = 35

Selected UCS range is 29 - 20 MPa.

Specified σ_c Value = 25 MPa

Modulus of Deformation

E_g = 4.755 GPa

Poisson's Ratio

ν_g = 0.360

Unconfined Compressive Strength

σ_{cg} = 1.007 MPa

Uniaxial Tensile Strength

σ_{tg} = -0.075 MPa

Cohesion

C_g = 11.590 KPa

Internal Friction Angle

φ_g = 34.250°

(I)-GC characterizes the ground based on (I); however, it is recommended to scrutinise it by deriving the mechanical properties of ground by standardised in-situ testing methods.

Figure 5c. I-System Software output – Teesta HEP – Desilting basin

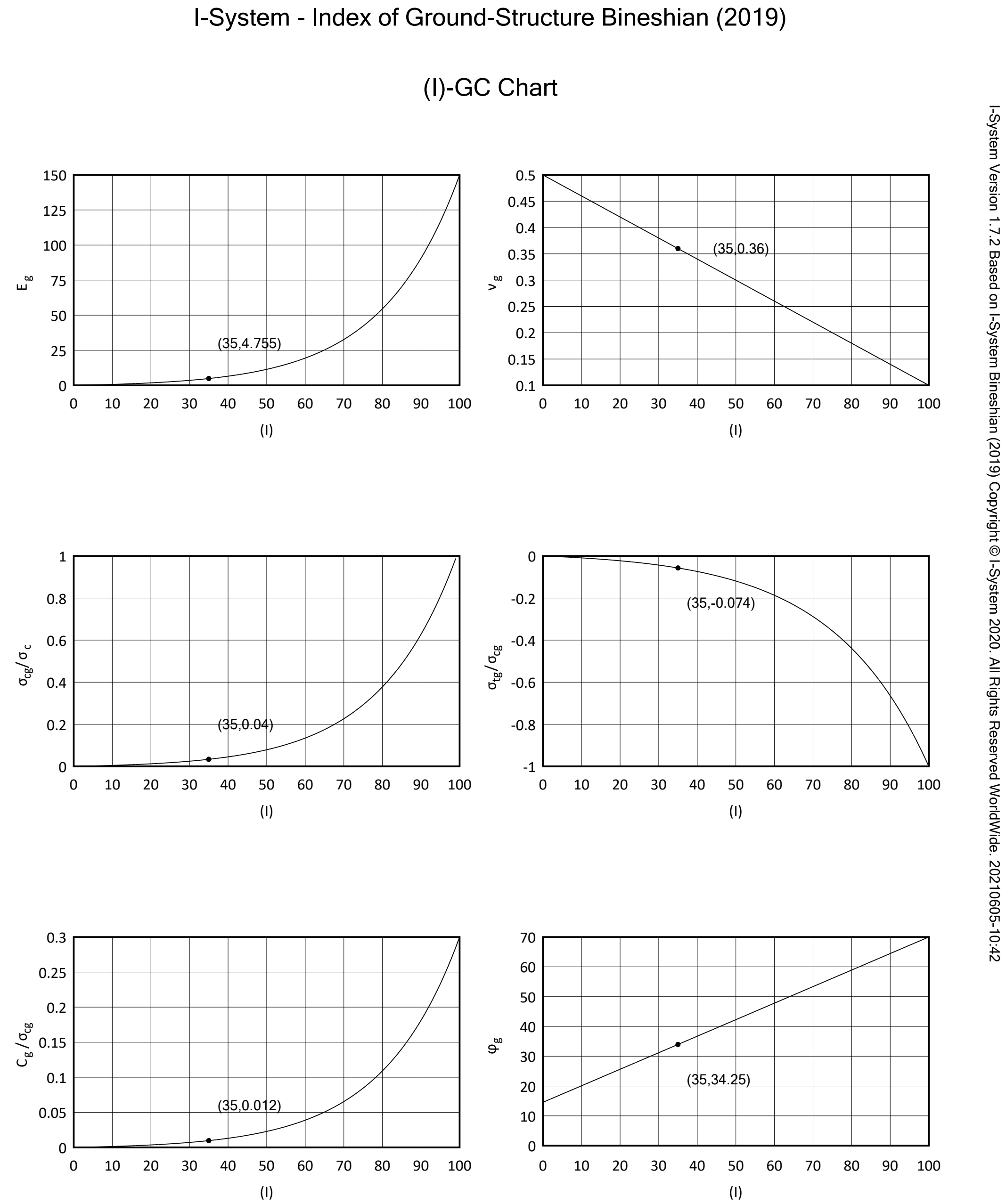

Figure 5d. I-System Software output – Teesta HEP – Desilting basin

7. Conclusions

I-System is used for classification as well as characterisation of ground in several projects before it is first ever published in 2019 and after that till now. Five case studies are presented here in this paper for the above-stated purpose in underground structures (T02, and T05, USBRL), semi-surface structure (Teesta barrage and distilling basin), and surface structures (T13 portal and Teesta barrage).

The results as output of I-System in both (I)-Class and (I)-GC is applied in both design as well as practice. Execution of some of these projects are already completed and some are being executed.

8. References

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