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Prediction of abrasiveness index of some Indian rocks using soft computing methods

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ABSTRACT

The present paper mainly describes the prediction methodology to determine the Cerchar Abrasiveness Index and Penetration Rate related to rock excavation using simple geomechanical parameters as predictors. As abrasiveness of rocks is influenced by many geomechanical parameters, an attempt is made to use these parameters for its prediction using Multivariate Regression Analysis and Artificial Neural Networking. Abrasiveness Index as well as Penetration Rate are very vital in deciding the economics of the excavations as they directly govern the wear and tear of drill bit. It was observed that ANN shows a better prediction capability than MVRA using UCS, Point load index, P wave velocity and Young's modulus as predictors.

1. Introduction

Many good quality rocks like granite, basalt, kotastone, sandstone and marble are abundantly used by infrastructural agencies across India since ages. The desired size of block to be cut and polished for use needs appropriate drilling, cutting and facing of the rock mass it is being derived from. The economics of these operations makes the building stones more relevant to use for different purposes like flooring, cladding, pillars, partitions, etc. The rock properties as well as its appearance often control the decision making of the end user but drilling, cutting, polishing and finishing costs which are governed by the abrasiveness of the rock decides the price and other market parameters.

Abrasivity of rock plays a very dominant and crucial role while selecting the cutting material. It has been reported that abrasivity of rock mass is influenced by many geomechanical and mineralogical parameters like compressive strength, shear strength, Young's modulus, quartz percentage, grain size, etc. Abrasivity can be determined by various tools and techniques described by various researchers as well as international standards. Among them Cerchar Abrasivity Index (CAI) is one of the easiest and convenient techniques used. CAI of rocks indicates the life of drill bit for a particular rock mass. It is routinely used to understand the performance of tunnel boring machines as well as to help the planners and designers to visualize the drillability and blastability index of rocks in order to decide the economics of the project. A small improvement in the performance of drill/cutter can shift the economics of the excavation from a negative to positive direction. CAI is used by many researchers to decide the life of drill/cutter, blades of turbines, runnage of drill length, etc. [1–4].

2. Review of previous work

CAI is widely used as an acceptable tool to decide the machine performance in civil, infrastructural and mining industry. Abrasion, wear and tear are very important parameters to decipher the life span of drilling rods/bits.

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Table 1
Rock types and the determined Geomechanical parameters.

Rock type	Cohesion (MPa)	E (GPa)	Penetration rate (m/min)	CAI	Tensile strength (MPa)	UCS (MPa)	PLI (MPa)	P-wave velocity (m/s)
Limestone	21.50	18.00	0.66	1.99	14.28	128.34	5.68	4619.28
Carbonaceous phyllite	12.20	9.00	0.94	1.09	9.06	92.13	4.86	3865.33
Quartzite (partially weathered)	37.00	24.00	0.75	4.90	21.93	201.96	9.48	5112.81
Augen gneiss	21.75	21.00	0.65	3.90	14.33	129.34	5.78	4019.99
Slate	22.25	22.00	0.55	2.04	15.59	142.32	7.11	4732.76
Limestone (impure)	17.50	18.25	0.76	1.87	11.77	115.39	5.01	4170.28
Quartzite (impure)	35.25	23.00	0.13	4.70	22.83	211.73	9.02	5256.37
Quartzite	39.00	26.00	0.13	5.10	23.01	227.89	8.73	5992.80
Shale	11.50	16.24	1.45	1.12	3.12	27.36	5.21	1480.36
Phyllite	19.50	10.25	0.84	1.19	11.58	105.36	4.26	1910.37

Table 2
Standards for determination of different geo-mechanical parameters.

Parameter	Standard	Formula
UCS, Young's modulus	ASTM D7012 [28], ISRM 1979 [29]	$UCS = \frac{P}{A}$
Brazilian tensile strength	ASTM D3967 [30], ISRM 1978b [31]	$\sigma_t = \frac{2P}{\pi dt}$
Point load index	ASTM D5731 [32], ISRM 1985 [33]	$I_s = \frac{P}{D_e^2}$
P wave velocity	ASTM D2845 [34], ISRM 1978c [35]	$V_P = \frac{D}{t}$

It was long back estimated that the huge loss of economy in these operations was resulting from abrasion [5]. Previously, the influence of various strength parameters with mineral content on CAI have been studied [6]. The scratch bit also has impact on abrasivity of rock mass. The suggested specifications some time mislead the result and do not reflect accuracy in measurement due to inability in procurement of appropriate material [7,8]. Some researchers have advised to perform the test on fresh broken rock samples in order to minimize evaluation errors [9], but sometimes few stratified or poorly consolidated rocks do not provide such surface and show erroneous results while testing [7]. There has been skepticism regarding the reliability of the method for accessing the CAI [10], due to lack of any international standard except laboratory testing guidelines for CAI [11]. However, now with the availability of better quality of pin, more reliable results are produced which are most consistent and accurate.

Some researchers explained that the higher the crushing strength or hardness of the rock, more energy is required to break or cut it [12]. It is also well established fact that the micro hardness of the rock grains mostly controls the abrasivity. Some of the researchers found it appropriate to do petrographic study of the rocks and calculate the free and equivalent quartz content to estimate the CAI values of different rocks, but also appreciated the influence of other Geomechanical parameters [13,14]. Porosity and cementing material of rock have adverse effect on CAI value. Higher the porosity and amount of cementing material lower is the CAI values [13,15,16]. A correlation between CAI and LCPC (Laboratoire Central des Ponts et Chaussees) values has been proposed based on the experimental work on Olivine and Tholeiitic Basalt as well as data collected from literature available [17]. LCPC is an abrasion testing method developed in France which provides rock abrasion values like that of CAI.

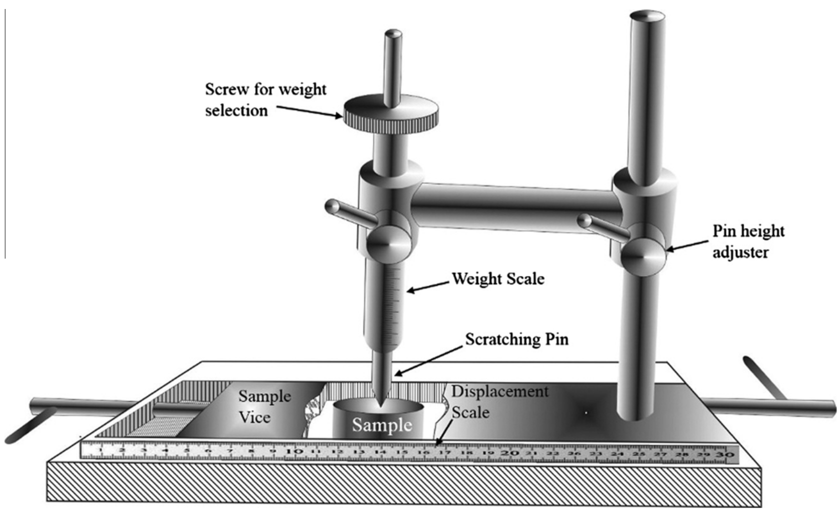

Fig. 1. Schematic of instrument used for determination of CAI.