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Laboratory Investigation on the Strength Property of Field Collected Coal Samples

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Abstract - *The compressive strength of coal is a most troublesome property to examine by exploratory methods. This comes about not only because of coal's variability laterally as well as vertically in the seam but also because invariably it will have one set of cracks or planes of weakness and often three sets of cracks or planes of weakness approximately normal to each other, namely, face cleavage, butt cleavage and bedding planes. The knowledge of compressive strength of coal helps in the efficient extraction of coal. Since, coal belongs to the family of hard rock therefore its impact strength can be determined by the* Protodyaknov Strength Index *test. In order to perform this test in the laboratory the coal samples were collected from the field and its compressive strength was determined. In this experimental investigation it was observed that the coal having maximum compressive strength of 0.24 MPa and minimum of 0.12 MPa for the number of blows of 25 and 5 in* Protodyaknov Strength Index test set-up.

Key Words: Coal, Protodyaknov Strength Index, Compressive strength, Hard rock

1. INTRODUCTION

Rock is an aggregate of various minerals constituents which are naturally occurring. Every rock constituent having a fixed chemical composition and molecular structure. In general, the rock is composed of grains of varied polycrystalline and non-crystalline materials which are connected together either by some kind of glue or mechanical bonding [1]. Thus, we can say that rock is a firm and coherent substance which is having a non-homogenous property and it cannot be extracted by manual operation. Therefore, there is a need of an appropriate engineering principle which can help in the proper extraction of the rock mass. The principle which involves in rock engineering is called as rock mechanics.

The term rock mechanic can be described as the theoretical and applied science of the behaviour of rock. It is the that branch of mechanics which deals with the response of the rock under the force field of its environment [2-3]. In rock mechanics, the rock is not only considered as the engineering material but also the rock mechanics deals with changes in mechanical behaviour of rocks which occurred due to the engineering activities. The problems of rock mechanics are also associated with the design and stability of the rocks by determining the strength property of the rock samples. The strength property of the rock sample is called as the mechanical property of the rock sample. The strength of the rock is one of the most important mechanical property which helps in deciding the failure criteria of the rock mass during the any excavation operation.

The determination of rock mechanical property such as strength will helps the rock mechanics engineers to design the appropriate structure. There is various method available to determine the strength property of the rock. These methods may capable for measuring the different types of rock strength such as impact strength, uniaxial compressive strength (UCS), tensile strength, shear strength, point load strength etc. In the mining scenario, rock suffers mostly under the action of compressive load [4]. Due to this, the determination of compressive strength in mining scenario becomes the necessary task designing any underground or surface mines project. In this paper, an attempt has been made to study the strength of the rock samples by indirect approach. In order to determine the strength of rock by indirect approach the Protodyakonov strength index apparatus was used. In this method, the impact strength of the rock samples was determined under the laboratory environment condition [5].

Moreover, due to the impact loading on the structure the stain rate increases under the same amount of applied strength. This phenomenon affects the strength, stiffness, ductility and failure mode of the rock sample. Further, under this condition the inertia is also activated which influences the resistance and failure mode of the supporting and parent structures. The impact strength of the rock mass is the capability of the rock to withstand against the sudden applied load. The impact strength of the rock can be considered as an energy, which defines the amount of energy required to break the fracture the rock [6-7]. The impact strength of the rock depends on the type of the rock mass and it varies based on the rock type. The harder rock type having the higher amount of strain energy and vice versa. In order to determine the strength of the rock against its fracture the impact strength analysis of the rock samples becomes much necessary.

In the present study, the coal as a type of rock sample was considered for impact strength analysis. Coal is a hard rock which is the family of sedimentary rock formed from peat by the pressure of rock laid down later on top. In this paper, the impact strength analysis of both the selected rock was carried out by Protodyakonov strength index test apparatus.

2. METHODOLOGY

The impact strength analysis of considered rock samples were performed by Protodyakonov strength index test apparatus which is based on the principle of crushability of rock under the standard experimental test condition. First of all, the rock samples namely Khondalite and Coal were collected from the field so that their strength property can be determined. Both the rock samples were collected from the eastern part of the Andhra Pradesh and Telangana state of India. Thereafter, these samples were processed in the rock mechanics laboratory of Aditya Engineering College, Surampalem, Andhra Pradesh. In this experimental test the mild steel (MS) cylinder of 76 mm internal diameter having height of 750 mm and weight of the hammer of 2.4 Kg (24N) was used. The external diameter of the cylinder was 66 mm. With the aim of crushing the rock samples the hammer is to be dropped from 600 mm height on the rock samples.

The rock samples of mass 250 g and size of the samples in between 20 mm to 40 mm were selected for the study. Further, these samples were divided in five different portions is subjected to 5 to 25 droppings. Thereafter, the materials is sieved and fines less than 0.5 mm is collected in a volumeter which is having internal diameter of 23 mm and height (h) of the fines materials are measured. At last, the Protodyakonov strength index (PSI) of the samples are calculated using Equation (1). On the basis of calculated Protodyaknov strength index the compressive strength of the coal was determined which is given by Equation (2).

$$PSI = \frac{20\,n}{h} \quad (1)$$

where, PSI=Protodyaknov Strength Index

n= Number of droppings

h= Height of crushed coal in volumeter

$$\sigma_c = \sqrt{1.06 \times E \times PSI} \quad (2)$$

where, PSI=Protodyaknov Strength Index

σ_c= Compressive strength in Kgf/cm^2

E= Modulus of elasticity in compression in GPa

In general, the modulus of elasticity of coal is 2 GPa which is only considered in order to determine the compressive strength of the rock mass. The used MS cylinder with rope wounded hammer is shown in Figure 1.

For measuring the height of the crushed rock, a volumeter is required which is shown in Figure 2. Similarly, the sieved coal after required blows and weighting machine are shown in Figure 3 and Figure 4. In order to obtain the required size of crushed coal sample, which is defined in above paragraph, the sieve analysis was carried out.

Fig-1: MS cylinder with rope wound hammer

Fig-2: Volume meter device for measuring the height of the sample

Fig-3: Obtained sieved coal sample after crushing by hammer

Fig-4: Weighting machine for measuring the weight of the coal sample

3. RESULTS AND DISCUSSION

The selected 250 g coal sample is divided into five portions with each carry 50 g of coal sample. Each 50 g samples were designated as S_1, S_2, S_3, S_4 and S_5. These samples were crushed by hammer in the MS cylinder. The samples in MS cylinder were crushed by the number of blows ranging from 5 to 25. The reading after each 5 blows were noted and tabulated in Table 1, Table 2 and Table 3.

Table -1: Obtained readings from different droppings for S_1 and S_2

Sample	No. of blows	Height of sample in volume meter in mm
S_1	15	31
	20	28.5
	25	19
S_2	5	10
	10	20
	15	29
	20	27
	25	24

Table -2: Obtained readings from different droppings for S_3 and S_4

Sample	No. of blows	Height of sample in volume meter in mm
S_3	5	13
	10	24
	15	33
	20	23
	25	22
S_4	5	9
	10	20
	15	29
	20	27
	25	24

Table -3: Obtained readings from different droppings for S_5

Sample	No. of blows	Height of sample in volume meter in mm
S_5	5	12
	10	22
	15	30
	20	27
	25	25

Based on the readings obtained from Table 1, Table 2, and Table 3, the Protodyaknov Strength Index is calculated by using Equation (1). This PSI value for each sample was calculated and presented in Table 4, Table 5, and Table 6.

Table -4: Calculated PSI and σ_c for S_1 and S_2

Sample	PSI	Compressive strength (σc) in MPa
S1	9.09	0.139
	9.524	0.142
	9.677	0.143

	14.035	0.172
	26.316	0.236
S2	10	0.1456
	10	0.1456
	10.34	0.148
	14.815	0.177
	20.83	0.210

Table -5: Calculated PSI and σ_c for S_3 and S_4

Sample	PSI	Compressive strength (σc) in MPa
S3	7.692308	0.127702
	8.333333	0.132916
	9.090909	0.138826
	1.73913	0.06072
	22.72727	0.219504
S4	11.111	0.138
	10	0.206
	10.345	0.248
	14.814	0.239
	20.833	0.226

Table -6: Calculated PSI and σ_c for S_5

Sample	PSI	Compressive strength (σc) in MPa
S5	8.333	0.159
	9.090	0.216
	10	0.252
	14.814	0.239
	20	0.230

The obtained values of PSI and compressive strength of coal depicts that these values increase with the increase number of blows. The compressive strength of coal varies from 0.12 MPa to 0.24 MPa for all blow rate. It can be concluded from the obtained results that the compressive strength of the coal increases as the blow rate increases. The relationship between number of blow and compressive strength of coal is presented in Figure 5. As shown in Figure 5, the one data point of the calculated compressive strength is not following the trends. This is because of the environmental problems such as presence of moisture in the coal sample and observational error.

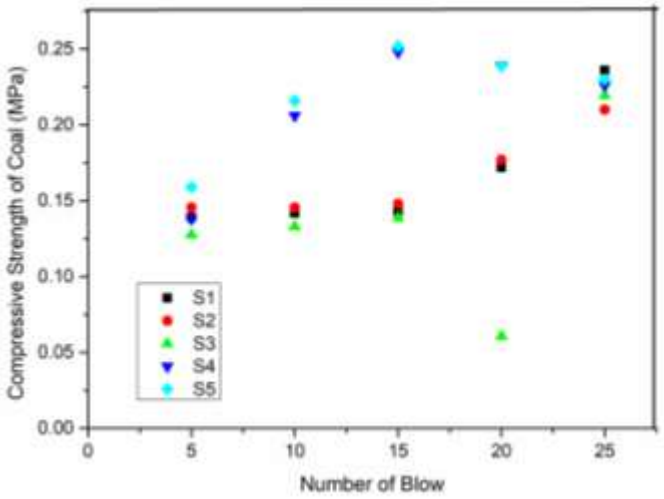

Fig -1: Graphical representation of compressive strength of coal against number of blows

4. CONCLUSIONS

Coal is one of the important minerals in the family of hard rock which can be burned as solid fossil fuel. The coal has many advantages in worldwide. The most vital uses of coal are in electricity generation, steel production, cement manufacturing industry and as a liquid fuel. Thus, the proper and efficient extraction of coal is becoming very necessary. The knowledge of compressive strength of coal helps in efficient extraction of coal. In this paper a laboratory investigation on the compressive strength of field collected coal was carried out. The compressive strength of coal is a most difficult property to examine by experimental means. The maximum compressive strength of 0.24 MPa and minimum of 0.12 MPa was recorded for the number of blows of 25 and 5 in the Protodyaknov Strength Index test.

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BIOGRAPHIES

Dr. Abhishek Kumar Tripathi received his degree in Mining Engineering in the year 2014 from National Institute of Technology Rourkela, India. He earned his Ph.D. degree from National Institute of Technology Karnataka, Surathkal in the year of 2019. He has published 31 research articles in reputed journals and conferences. He is also a member of several professional bodies. He awarded as a Best Research Paper Award in 2nd International Conference on Paradigm in Engineering & Technology (ICPET-2018) during 28th and 29th December 2018. He recognized and honored as a Fellow of Engineering Research Council (FERC) by Global Journals, a society Accredited ISO Certified and United State Corporation Under Open Association of Research Society (USA). Recently, he awarded as the excellent researcher award by International Academic and Research Excellence Award 2019 in association with GISR foundation Team. Currently, he is working as an Assistant Professor in Aditya Engineering College (Autonomous), Surampalem, Andhra Pradesh, India. His research interests include Rock Mechanics, Renewable Energy Sources, Mines Power System, Mine Environment.

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