

K. SHAHRIAR*, E. BAKHTAVAR**, A. MOEINIZADEH***

Some experiments *in-situ* and in laboratory to determine the physico-mechanical properties of coal

Introduction

Coal is a concentrated form of invaluable natural energy. Its proper exploitation is important not only for economical development but also for environmental, ecological and conservation points of view (Singh et al. 1999). The increasing demand for energy is being met mainly by coal in some Asian countries. As such, the coal mining trend of the countries is different from that of many developed countries. The coal producing target is being increased every year and, to achieve it, the coal mining industry is moving fast towards mechanization (Singh et al. 1995). It means, one of the most important factors affecting the production rates in mining or civil engineering projects is the performance of the mechanical excavators such as road headers, continuous miners, shearers etc. The prediction of the machine performance plays a major role in decision making for the practicing engineer and the cuttability of rock is the key factor in performance prediction (Rostami et al. 1994). A large amount of research work has been done to visualize the cutting characteristics of coal seams in different countries, and a number of testing procedures has been suggested for the selection of coaling machines (Singh et al. 1995). Rock cuttability is usually determined with the aid of laboratory cutting rigs which need highly sophisticated instrumentation (Bilgin et al. 1997 a, b) and research engineers are always interested in finding a method to predict rock cuttability on the basis of the simple rock properties. Unfortunately, no such detailed investigation has been conducted for the Iranian coal seams and a wide variation of geo-mining conditions

* Department of Mining & Metallurgical Engineering, Amirkabir University of Technology, Tehran, Iran.

** Division of Mining Engineering, Urmia University of Technology, Urmia, Iran.

*** Science & Research Branch, Islamic Azad University, Tehran, Iran.

restricts direct adoption of the foreign norms and procedures. Therefore an extensive field and laboratory study in this paper was undertaken as a basis for cuttability assessment which is related to the selection of the proper coaling machines and of the most effective and fitness bits for the coal winning machine for the C1 coal seam of Parvadel mine of Tabas located in east of Iran. The field and laboratory data of coal cuttability was estimated due to comparing the results of uni-axial strength, in-situ shear strength tests, and also cuttability, strength index, expanding bolt and M.R.E. penetration tests on C1 coal seam with lab results gained in other countries.

1. Literature review

Although the first coal retrieval machine was developed and used in a British coal mine more than 130 years ago (Walker 1902), but most of the studies on coal cutting were done only within the last five decades. The effect of cutting tool and machine parameters, geo-mining conditions and physico-mechanical properties of coal over cutting force was studied by a number of authors and, theoretical aspects of coal cutting were detailed in the late 1950s (Evans 1958). Merchant's theory (Merchant 1944) of basic mechanics of the metal cutting process was applied to give an analytical equation of the cutting force for coal/rock cutting (Roxborough, Rispin 1973). Widely accepted rock cuttability assessment for the performance estimation of road header is the specific energy measured from core cutting tests (McFeat-Smith, Fowell 1977, 1979). Detailed laboratory and *in-situ* investigations carried out by Fowell and McFeat-Smith showed that there is a close relationship between specific energy values and the performance of medium and heavy weight "road headers" (McFeat-Smith, Fowell 1977; Fowell, Johson 1982, 1991; Johson, Fowell 1984). In 1972, Hughes represented an equation for calculating the specific energy (Hughes 1972). Farmer, Garritty and Poole (1987) showed that excavation rate in m³/h might be predicted correctly for a given power of road header, using specific energy values as the represented equation by Hughes in 1972, (Farmer, Garritty 1987; Poole 1987). Further research led to construction of a full scale boom tunneling research rig in a laboratory (Speight, Fowell 1987) to obtain accurate cutting data. The influence of thermo-contact transformation of coal mass (Jhama formation) by the igneous intrusion over its physico-mechanical properties (Singh, Singh 1989) is not well reported. Presence of large number of ball coal (Chandra 1992) and frequent bands of igneous intrusions in some of the Indian coal seams makes it very difficult to be worked by a coal-cutting machine. Sekula et al. (1991) and Krupa et al. (1993a,b, 1994) stated that the advance rate of a tunnel-boring machine for a given power is directly related to specific energy values according to Hughes equation in 1972 (Sekula et al. 1991; Krupa et al. 1993a, b, 1994). Specific energy is correctly obtained by carrying out full scale cutting experiments in laboratory and the cutting rate of mechanical excavators, which are road headers, continuous miners, TBM's etc., may be predicted from the equation that was suggested (Rostami et al. 1994). Experimental results of the tool-rock interaction have been

used for the improvement in cutting efficiency with the pick cutting machines (Hekimoglu 1995; Bilgin 1996). An empirical model of in situ cuttability of hard coal seams was developed (Singh et al. 1995) to estimate the power of a coal-cutting machine considering the geo-mining domain of the field in totality. Bilgin and co-workers developed a performance prediction equation based on rock compressive strength and rock quality designation (Bilgin et al. 1996, 1997a, b). Dunn et al. (1997) made a comparison between the models described by Bilgin (1996, 1997b) and McFeat-Smith and Fowel (1977, 1979) using the data obtained from Kambalda Mine where Voest Alpine AM75 road header was used (Dunn et al. 1997). The influence of geological disturbances over the physico-mechanical properties of a coal mass is well known. Matsui et al. (1998) attempted to visualize the influence of geological disturbances over the performance of a road header during drivage of a coal mine drivages (Matsui et al. 1998). However, this study was limited up to the affect of faults only. Thuro and Plinninger (1998, 1999) defined the area of stress-strain curve as destruction work, which has the unit of specific energy, and they reported that there is a good statistical relationship between destruction work and cutting rate of excavating machines and drilling rate of drill rigs (Thuro, Plinninger 1998, 1999). However, some practicing engineers and research workers strongly emphasized that the rock cuttability is directly related to some basic rock properties for massive rock formations such as rock compressive strength and that instantaneous cutting rate of mechanical excavators may be predicted from compressive strength (Uehigashietal 1987; Schneider 1998; Gehring 1989, 1997). The nature and amount of influence of the igneous intrusions seems to be quite complex but it has substantially altered the physico-mechanical properties of the surrounding coal mass. Strength and cuttability across the band of an igneous intrusion were found to be highly dependent upon the proximity and extent of the intrusion (Singh et al. 2002). Kahraman et al. (2003) also showed that the specific energy values calculated with Hughes equation (1972) might be used in estimating penetration rates of percussive drills (Kahraman et al. 2003). Specific energy is defined as the energy to a rock unit volume and it is an important indicator of rock cuttability (Copuretal 2001; Balci et al. 2004). The tests and subsequent analyses revealed that the texture coefficient and feldspar content of sandstones affected rock cuttability, evidenced by significant correlations between these parameters and specific cutting energy (SE) at a 90% confidence level. Felsic and mafic mineral contents of sandstones did not exhibit any statistically significant correlation against SE. Cementation coefficient, effective porosity, and pore volume had good correlations against SE, as well as, Poisson's ratio exhibited the highest correlation with SE and seemed to be the most reliable SE prediction tool in sandstones (Tiryaki et al. 2005).

Due to a study based on the Shore hardness which was differed from previous studies, it is concluded that there is a relationship between Shore hardness values, optimum specific energy and compressive strength, which may be used to estimate the rock cuttability and the instantaneous cutting rates of road headers within certain limits of reliability (Tumac et al. 2006).

Recently, during a valuable research; a new rippability classification system for coal measure rock based on specific energy is developed. The main results were conducted by

using some extensive field and laboratory studies and highlighting the physico-mechanical characteristics at six different lignite open pit mines and rock mechanics laboratory (Basarir et al. 2008).

Regarding to lack of standard procedures for characterization of coal reservoirs and determination of in-situ physical coal properties and the related problems, a new approach has been developed proposing the usage of relationships between coal rank and physical coal properties in 2008. In this approach, effects of shrinkage and swelling on total methane recovery at CO₂ breakthrough have been investigated by using rank-dependent coal properties (Bilim, Özkan 2008).

On the basis of a number of simple field and laboratory investigations, an attempt is made in this paper to identify some effective physical and mechanical properties required for cuttability assessment of the C1 coal seam which is noted above.

2. Site description

2.1. General investigation

The investigated coal seam and mine are situated in the Parvadeh coalfield near the Tabas city in east of Iran, which is a basin between two major North-South trending fault systems, the Kalmard Fault and the Hidden Fault to the West and the Nayband Fault to the East. Stratigraphically the coal bearing sequence is of Triassic age. The rocks are mostly mudstone with prominent coarsening up siltstone/sandstone sequences. Locally developed, thin marine limestones occur. The main coal horizons in the mine are seams B1, B2 and C1 that occur within 50 m of strata. Other seams C2, D and possibly E will affect mining principally because of their methane content. The seam thickness of C1 varies from approximately 2.2 m in the northeast to 1.5 m in the South West. The initial panels are located where the thickness is mostly between 1.8 m and 2.0 m. The seam thins rapidly near the 1.8 m contour to the South West where the thickness is from 1.5 m to 1.7 m. Due to low core recoveries and the friable/crushed nature of the core it is difficult to establish an accurate relationship between whole seam ash and the clean coal yield. The data on sulphur in this seam is very sparse, due mostly to a lack of complete analyses. There is a very general indication of an increase in sulphur content from the North to the South. In the initial mining area sulphur content varies from 1.75 to 2.0%. The C1 data for volatiles is similarly constrained by a lack of data, largely due to poor core recovery (IRITEC 2003).

2.2. Mineral analysis

One of the most important parameters affecting coal cuttability is the coal components such as: moisture, volatile material, ash, and a number of minerals that they directly or indirectly affect on coal cuttability. Increasing of 27% and 22% for moisture and volatile

material respectively in coal content can be cause of coal strength decreasing, but less than these values, coal strength may increase. The remained ash due to geochemical process stage is caused to a decreasing in coal strength but also increasing in coal brittleness. There are different minerals with various percents within coal content. Some of them such as Quartz can play a major negative role on erosion of cutter of coal winning machines, it means in presence of this mineral within coal seams, the cutter life seriously decrease. In Table 1, type and magnitude of other mineral components within C1 coal seam (target coal seam) is summarized (NISCOIR 1996).

TABLE 1

Characteristic of other C1 coal seam

TABELA 1

Charakterystyka pokładu węgla C1

Composition	Carbon [%]	Volatile material [%]	Ash [%]	Quartz [%]	Pyrite [%]	Moisture [%]	Clay [%]	Calcite [%]
Maximum	96	23	36	6	8	18	30	20
Minimum	68	19	30	0	1	5	1	1
Average	84	21	32	1	3	8	9	3

According to Russian classification of coal seams, the C1 coal seam of Tabas Parvadehl is taken in the class of Low Volatile Coking Coal or Low Volatile Bituminous Coal, and due to National Coal Board (NCB) classification, its class is 301, as well as based on American Society for Testing Materials (ASTM) classification, it is taken place in class I of Bituminous Coals.

2.3. Cleat investigation

As is well established, the direction of the natural inherent fracture systems of coal seams, such as cleats, plays an important role in establishing a preferred direction for the mine development. The strength of coal is influenced by the frequency and orientation of the cleats. The application of an external force on a coal seam tends to break it along these natural weak planes of the main cleats or the bord cleats (Singh et al. 1995). The orientations of cleats were identified at the site of study for C1 coal seam. According to cleat observations were taken at the site along the exposed coal surface of the galleries. In general, one major set and two sub sets of cleats were found in the C1 seam. Orientation of major cleat set in respect to the C1 coal seam direction (with dip "between" 11 to 22 degree) was almost vertical. The direction of one of the sub set of cleat in relation to C1 seam direction was approximately parallel but with a plan plunge difference of 35 degree relating to horizon. Direction of the other was entirely parallel in relation of C1 coal seam direction (see Fig. 1).

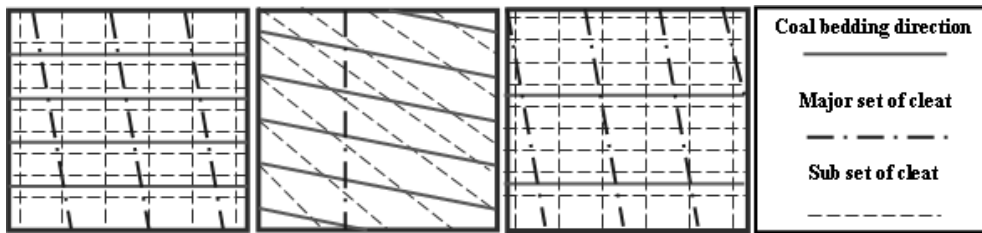


Fig. 1. Orientation of cleats and C1 coal seam in three sections

Rys. 1. Orientacja płaszczyzn osłabienia w pokładzie C1 w trzech przekrojach

3. Laboratory and *in-situ* studies

The testing procedure and sample preparation adopted were in accordance with the norms of the International Society of Rock Mechanics (ISRM) (Brown 1981). A number of indexing systems such as impact strength index (ISI) and Protodyakonov strength index values (PSI) were also determined to furnish information on the overall response of the mass. Coal strength directly affect on the cuttability. There are several tests procedure in laboratory and field for strength and cuttability measurements. Often there considerably were differences between obtained results of laboratory tests of coal specimens and the *in-situ* coal characteristics. According to Protodyakonov researches, difference between coal strength values in laboratory and *in-situ* actual values is approximately 30 percent and obviously it is considerable. Unfortunately, recovery of core type samples of coal for laboratory testing was rather difficult except in some cases and hence due to the poor number of samples, the reliability of the measurements remained poor. Because of these reasons, in the present study frequently *in-situ* tests were done.

3.1. Impact Strength Index (ISI)

Impact Strength Index (ISI) is a way of characterizing coal strength, which has immense possibility for practical implementation in coal cutting and drilling. There are various methods and equipments (such as; Hardgrove device, Pomeroy mortar) for determination of ISI. Due to actual results, simplicity and quick tend of the Pomeroy mortar test performance, as well as its propagation, in the present study this test was carried out. The mean value of ISI for different coal samples which were collected from two parts of the C1 coal seam of Tabas Parvadeh1 colliery (Material Drift and Conveyer Drift) was measured. The observed mean value of the ISI varied from 35 to 46. The obtained results of ISI test (Table 2) demonstrate a poor strength of the coal in the Tabas region. It is notable that moisture content within the collected coal samples not constant and with its increasing; the strength of coal may decrease (Fig. 2).

TABLE 2

Obtained results of ISI test for C1 coal seam

TABELA 2

Uzyskane wyniki testu wytrzymałościowego ISI w pokładzie C1

Place	C.D	C.D	C.D	C.D	C.D	C.D	C.D	M.D	M.D	M.D	M.D	Average
Moisture [%]	5.2	5.5	5.5	5.4	5.3	5.4	5.8	7.8	8	8.2	8	6.375
ISI	41	46	43	42	41	41	39	35	36	38	37	39.91
C.D = Conveyer Drift							M.D = Material Drift					

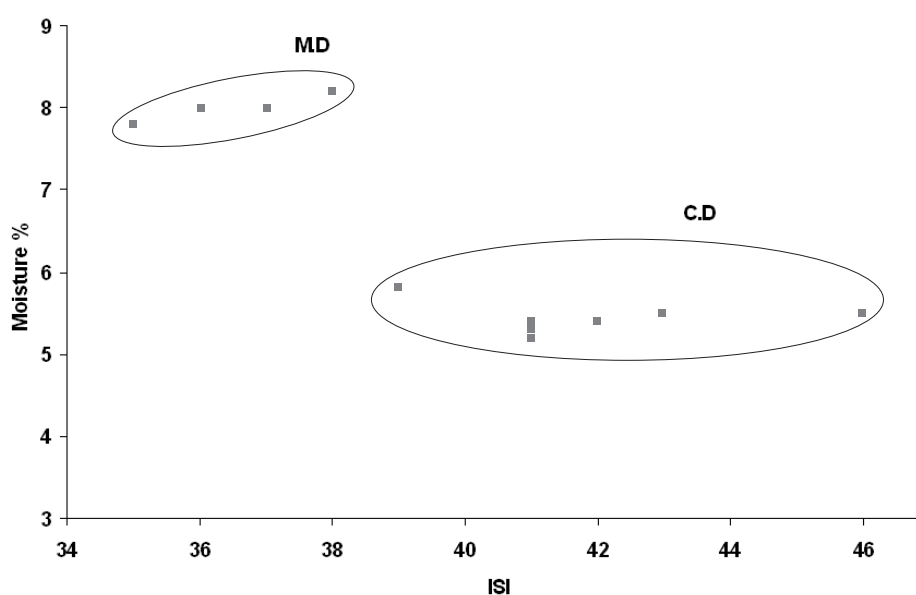


Fig. 2. The relationship between moisture and ISI

Rys. 2. Zależność pomiędzy zawartością wilgoci a wskaźnikiem ISI

3.2. M.R.E. Penetrometer

In the M.R.E. Penetrometer which is performed as an in-situ test in the different parts through the C1 coal seam thickness from the roof to floor for coal cuttability assessment, a cylindrical rod (with a smooth head) with a length of 12.7 cm, a radius of 1.43 cm and a sectional area of $2.54 \cdot 2.54$ cm perpendicularly using a hydraulically jack was penetrated (Fig. 3). Then, its penetration measure per each inch of penetration was recorded and its consequent was calculated. The M.R.E. Penetrometer test in the Material Drift (M.D) and Conveyer Drift (C.D) on C1 seam was done. Table 3 demonstrates the obtained results of the test in the mentioned two parts and the penetration trend of the rod in the C1 coal seam. Due to evaluating the obtained results from the two test station (C.D and M.D), it is clear that the

TABLE 3

Obtained results the M.R.E. Penetrometer test for C1 coal seam

TABELA 3

Uzyskane wyniki testu penetracyjnego MRE w pokładzie C1

Place	Situation	Imposed force value in each penetration stage [ton]					Average force [ton]	Maximum force [ton]
		Step1	Step2	Step3	Step4	Step5		
M.D	Roof	0.147	0.221	0.368	0.735	0.882	0.47	0.882
	Seam upward	0.176	0.221	0.368	0.47	0.735	0.394	0.735
	Meddle of seam	0.074	0.147	0.176	0.074	0.074	0.109	0.176
	Downward	0.147	0.397	0.588	0.809	1.029	0.594	1.029
	Floor	0.617	0.779	0.956	1.206	1.544	1.02	1.544
	Foot wall	0.147	0.265	0.323	0.412	0.662	0.362	0.662
C.D	Roof	0.397	0.441	0.706	0.853	0.956	0.67	0.956
	Upward seam	0.338	0.412	0.515	0.706	0.912	0.493	0.912
	Meddle of seam	0.221	0.265	0.441	0.544	0.853	0.465	0.853
	Downward seam	0.47	0.838	1.206	1.911	—	1.106	1.911
	Floor	0.706	0.794	0.926	1.5	2.073	0.809	2.073
	Foot wall	0.132	0.323	0.662	0.794	0.97	0.577	0.97

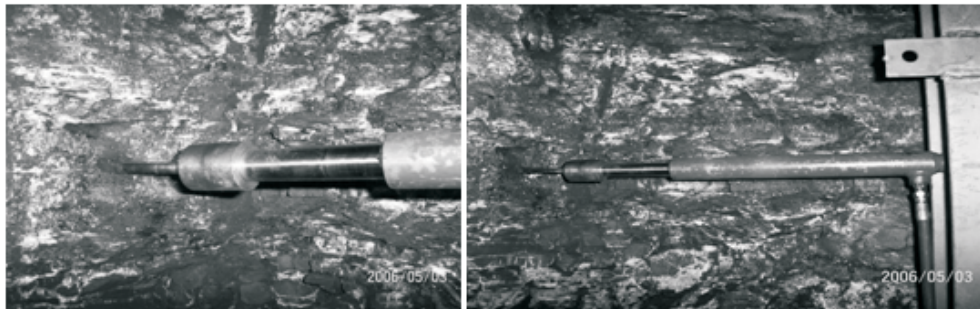


Fig. 3. Work manner of the M.R.E. Penetrometer test machinery

Rys. 3. Sposób pracy penetrometru MRE

coal strength inverse of the rod penetration is relatively high in the C1 coal seam bottom but on top of the seam (see Figures 4 and 5). As it shown in Figure 6, the penetration trend of the rod in the whole performed M.R.E. Penetrometer tests is ascendant.



Fig. 4. The required force for penetration in C1 coal seam of M.D

Rys. 4. Wymagana siła dla penetracji pokładu C1 w wyrobisku transportowym

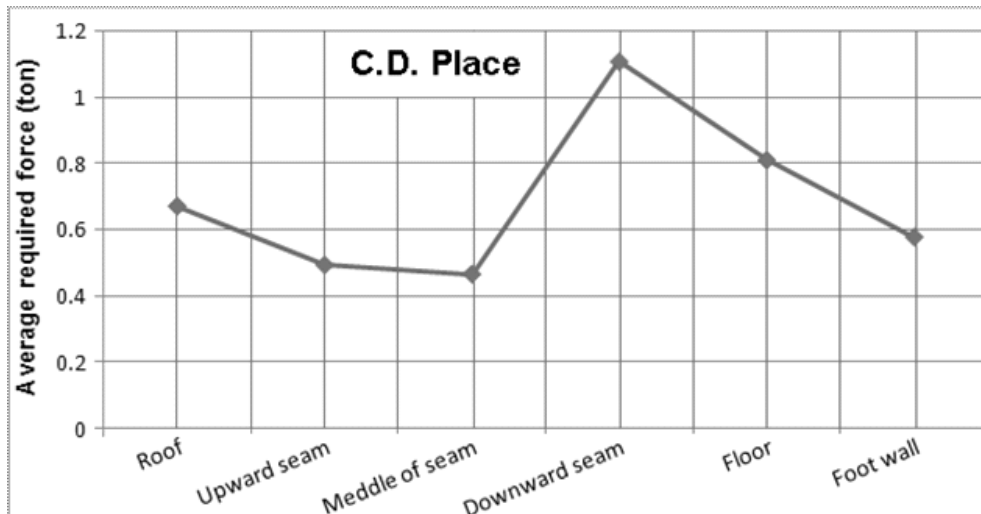


Fig. 5. The required force for penetration in C1 coal seam of C.D

Rys. 5. Wymagana siła dla penetracji pokładu C1 w wyrobisku odstawczym

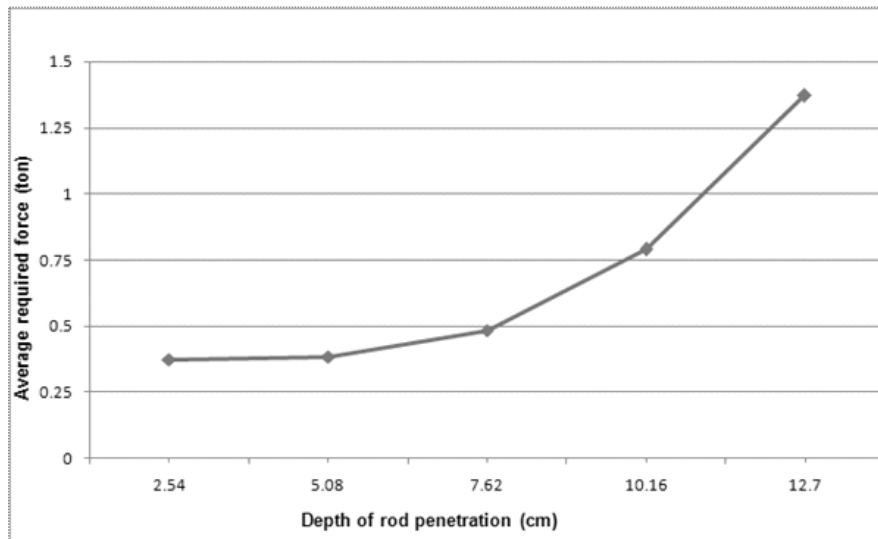


Fig. 6. Variation trend of force for penetration of a rod with length of 5in

Rys. 6. Trend zmiany siły penetracji dla penetrometru o długości 5 cali

3.3. Expanding bolt

This test can be performing in laboratory and field. In the laboratory scale, for modeling imposed pressure to specimen a pressure cell is necessitated. In this case, a specimen with size of 17.8 cm · 17.8 cm · 10.2 cm must be supply (Fig. 7). In the present study, an in-situ test was done. Initially, a hole with a diameter of 1in and depth of 15.2 cm within the C1 coal work face was drilled and a bolt in diameter of 2.1 cm with expandable value up to 3.5 cm in the hole was placed and activated. Then, by a special system including three hydraulically jacks, the mentioned bolt under tension was taken away (Fig. 8). Due to the bolt tension process, a coal content of face in the form of a cone was emitted. Finally, required force for bolt withdraws was recorded.

Now on the basis of the achieved consequences and the coal cone characterization, as well as, employing the following formula (Evans et al. 1966), coal strength index (CSI) of the C1 coal seam was calculated. It is noteworthy that there is a direct relationship between the CSI value and coal tensile strength (CTS). Table 4 is summarized the acquired results of the Expanding bolt and CSI for the C1 coal seam in Tabas Parvadeh1 mine.

$$\sigma_b = \frac{3F_b}{\pi h_b (R_b + 2r_b)}$$

Where, σ_b is coal strength index (CSI) in Pa, F_b is required force for bolt tension in N, h_b is height of the coal cone in m, R_b is maximum diameter of the coal cone in m, and r_b is hole diameter in m (Evans et al. 1966).

TABLE 4

The achieved results of the Expanding bolt test and calculated CSI

TABELA 4

Uzyskane wyniki testu kotwi rozprężnej i obliczone wartości wskaźnika wytrzymałości węgla (CSI)

Number	Pressure [bar]	Required force [ton]	Cutting depth [cm]	Cutting width [cm]	Cutting length [cm]	CSI [MPa]
1	40	0.94	12.7	15	22	0.308
2	74	1.74	12.7	11	23	0.612
3	100	2.35	12.7	12	20	0.867
4	50	1.18	11.5	10	25	0.447
5	70	1.65	12	15	24	0.548
6	45	1.06	11.5	10	18	0.48
7	30	0.71	10	12	21	0.325

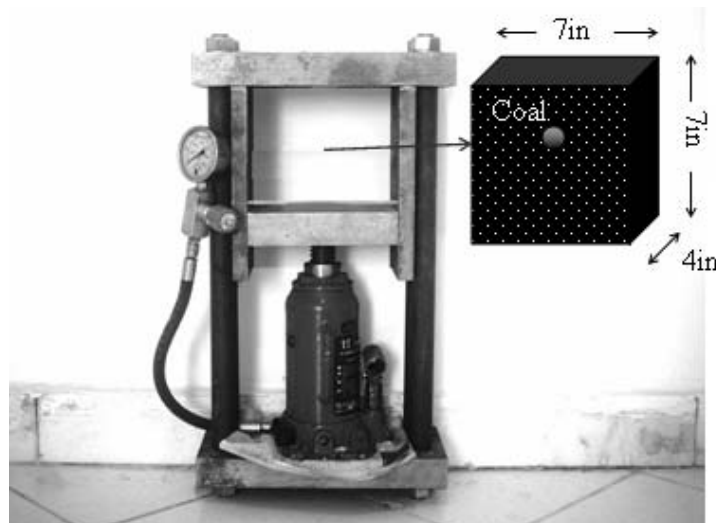


Fig. 7. The pressure cell and the specimen size for the Expanding bolt test in laboratory

Rys. 7. Komora ciśnieniowa i rozmiary próbki do testu kotwi rozprężnej w laboratorium

3.4. Uniaxial Compressive Strength

Due to high brittleness of the coal, as well as, cleat and coal bedding arrangement in the target site (Tabas Parvadeh1 Coal Mine), furnishing the cubic and cylindrical specimens with large dimensions was not possible; hence uniaxial compressive strength (UCS) tests were conducted on the small pieces of specimens $2.54 \text{ cm} \cdot 2.54 \text{ cm} \cdot 2.54 \text{ cm}$ in size for each coal sample. Number of coal samples for this test were 20, but 10 samples were suitable for the



Fig. 8. The Expanding bolt system for *in-situ* test on C1 coal seam

Rys. 8. System kotwi rozprężnej do testów *in-situ* w pokładzie węgla C1

test. The results of the others were not substantial and reliable because of weathering surface of coal and exist of attendance of discontinues. Table 5 is summarized the results of UCS tests for C1 coal seam.

TABLE 5

Results of UCS test of C1 coal seam

TABELA 5

Wyniki testu jednoosiowego ściskania (USC) dla pokładu węgla C1

Test number	1	2	3	4	5	6	7	8	9	10	Average
F [N]	4350	4050	4258	4570	3950	4558	3564	4252	4300	5050	4290.2
UCS [MPa]	6.74	6.28	6.6	7.08	6.12	7.06	5.52	6.59	6.67	7.83	6.6549

Regarding the obtained results of UCS tests (Table 5), the mean of UCS of C1 coal seam was approximately measured 6.65 MPa. It is remarkable that the moisture of coal samples in all mechanical tests was nearly 6 percent.

3.5. Shear Strength

Considering the importance of shear strength in coal cuttability assessment and the useful results of Protodyakonov studies, in this paper *in-situ* test for measuring coal shear strength was performed. For this objective, firstly for preparation of the testing place, almost a thick of

TABLE 6

Results of Shear Strength *in-situ* test of C1 coal seam

TABELA 6

Wyniki testu wytrzymałości na ścinanie *in-situ* dla pokładu węgla C1

Test number	Imposed pressure [bar]	Cutting surface area [m ²]	Cutting force [kN]	Shear strength [MPa]
1	25	0.0375	1 766.25	0.471
2	33	0.0412	2 331.45	0.566
3	30	0.0392	2 119.5	0.540
5	26	0.0395	1 836.9	0.465
6	31	0.04035	2 190.15	0.5428
7	28	0.036	1 978.2	0.5495
8	27	0.0348	1 907.55	0.548
Average	28.57	0.038	2 018.57	0.52615

40 cm of weathered coal surface on work face, was removed. Subsequently, a rectangular cubic hole (Fig. 9) with dimensions of 10 cm · 50 cm · 3 cm tending the bedding and within the coal was created. After misplace a length of 15cm of coal in one side of the mentioned hole, the other rectangular cubic hole at the same orientation with dimensions of 12 cm · 20 cm · 3 cm was generated. In the other side of first hole, jack backrest plane with

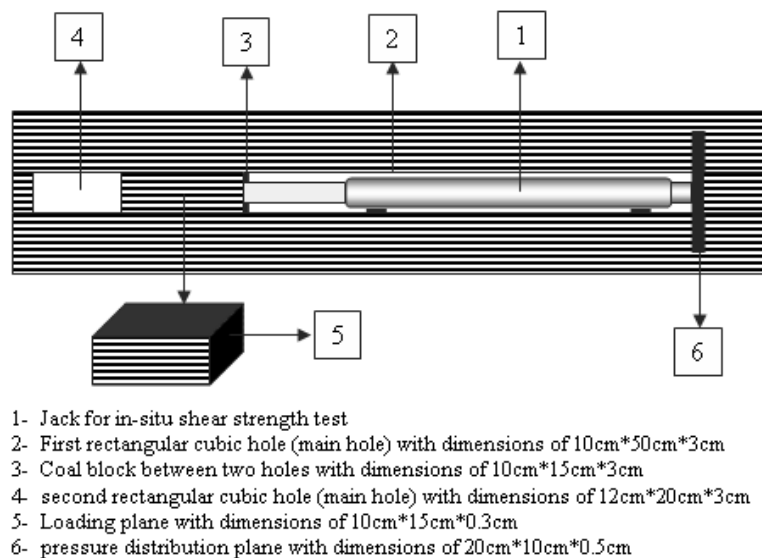


Fig. 9. Procedure and requirements of in-situ test for coal shear strength measurement

Rys. 9. Procedura i wymagania do wykonania testu wytrzymałości na ścinanie

the dimensions of 20 cm · 10 cm · 0.5 cm titled pressure distribution plane was manufactured. Eventually, jack for the target was placed in the first hole (main hole) and by manual pump a loading rate of 10 bar/min to the jack was imposed. In the coal in the direction of the bedding, shear deformation was occurred. The entire process and requirements is illustrated in Figure 9.

The obtained results of the filed test for determination of coal shear strength of C1 seam were summarized in Table 6. Based upon numerous tests and the results (Table 6), the approximate average coal shear strength of 0.53 MPa for the C1 seam in the Tabas Parvadeh1 Mine was achieved.

3.6. Tensile Strength

In general, preparation of coal specimen (sample) for tensile strength measurement is very extremely difficult and laborious. For this reason tensile strength test performance is not very feasible and it only is done in particular cases. On account of coal weak strength in the C1 seam, hence, experimental specimen preparation of the coal seam not practicable. Accordingly in the study for determination of C1 coal seam tensile stress, the Evans graph (1966) which explains the relation between tensile strength and Impact Strength Index (ISI) was employed. The graph was obtained due to an extensive study on a number of coal seams in England (Evans et al. 1966). According to the ISI average of 40 approximately for C1 coal seam (Table 2) and using the Evans graph (Fig. 10), the maximum tensile strength of the target coal is nearly 0.38 MPa. This tensile strength value is utilized for the design.

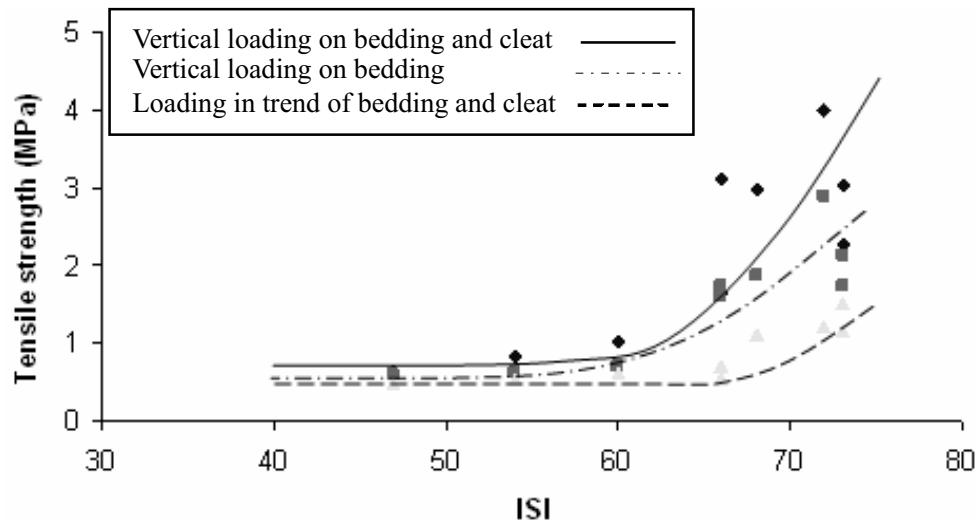


Fig. 10. Relationship between ISI and tensile strength (Evans et al. 1966)

Rys. 10. Zależność pomiędzy wskaźnikiem ISI a wytrzymałością na rozciąganie

Discussion and conclusions

Coal samples taken from the C1 coal seam of Tabas Parvadeh1 mine, Iran were subjected to a comprehensive physico-mechanical properties analysis with emphasis on the coal cuttability assessment. On the basis of rigorous laboratory and field studies, as well as, considering relevant geo-mining parameters of the site, some expressions were derived to estimate the field cuttability of a C1 coal seam. Textural and mineralogical properties of coal were investigated, along with the cleats. The achieved results of all performed tests in the present study demonstrate an extremely low strength of coal in the C1 seam; hence, for high productivity and prevention of dust generation, coal cutting must be performed with low speed but high advance and penetration depth. Because of low coal strength and exist of very cleat sets in various alignments, influence of the cleats system on cutting mechanism and trend is negligible. The results of M.R.E. Penetrometer tests illustrate that the coal strength opposite of the rod penetration in the C1 coal seam bottom is relatively high but on top of the seam and the penetration trend of the rod in the whole performed M.R.E. Penetrometer tests is ascendant. The expanding bolt test was done as an in-situ and a mean required force for bolt tension of 1.38 ton, cutting depth of 11.87 cm, cutting width of 12.14 cm, cutting length of 21.86 cm, and CSI of 0.512 MPa, were estimated. Regarding the carried out UCS test, the mean of UCS of C1 coal seam was approximately measured 6.65 MPa. Considering the importance of shear strength in coal cuttability assessment, shear strength test was achieved and approximate average coal shear strength of 0.53 MPa was extracted. Finally, using the Evans graph, the maximum tensile strength of the target coal was obtained nearly 0.38 MPa.

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SOME EXPERIMENTS IN-SITU AND IN LABORATORY TO DETERMINE THE PHYSICO-MECHANICAL PROPERTIES
OF COAL

Key words

Physico-mechanical properties, field tests, cuttability, C1 coal seam, Tabas, Parvadel mine

Abstract

A number of simple field and laboratory studies and tests were carried out to visualize the nature and variation extent of mechanical properties with emphasis on cuttability across C1 coal seam in Parvadel mine of Tabas located in east of Iran. Selection of the suitable coal winning machines and of the most effective and fitness bits for it and their arrangement on cutter head have a special relation to reach maximum productivity with minimum energy consumption. The effect of physico-mechanical properties on cuttability were studied in the laboratory and field for the C1 coal seam to identify the relevant parameters affecting the specific energy of coal cuttability. Field studies were also *in-situ* cuttability along with conducted over a number of active mechanized coal faces to study the geo-mining conditions of the site. The field and the laboratory data of coal cuttability was estimated due to the achieved results of uni-axial, shear, and tensile strength tests, as well as, Impact strength index, expanding bolt, and M.R.E. penetration tests on C1 coal seam.

EKSPERYMENTY PRZEPROWADZANE IN-SITU I W LABORATORIUM DLA OKREŚLENIA FIZYKOMECHANICZNYCH
WŁAŚCIWOŚCI WĘGLA

Słowa kluczowe

Właściwości fizykomechaniczne, testy polowe, urabialność, pokład C1 węgla, Tabas, Kopalnia Parvadel

Streszczenie

Przeprowadzono szereg prostych badań i prób polowych oraz laboratoryjnych testów dla określenia mechanicznych właściwości, a w szczególności urabialności pokładu C1 węgla w kopalni Parvadel w miejscowości Tabas w południowym Iranie. Wybór odpowiednich maszyn urabiających oraz najbardziej efektywnych noży na głowicy urabiającej ma szczególne znaczenie dla uzyskania maksymalnej wydajności przy minimalizacji zużycia energii. Wpływ właściwości fizykomechanicznych na urabialność został zbadany w laboratorium i testach polowych w pokładzie C1 węgla, dla określenia jakie parametry wpływają na jednostkowe zużycie energii w trakcie urabiania. Badania polowe obejmowały testy urabialności *in-situ* prowadzone w szeregu działających przodkach zmechanizowanych i dotyczyły badania warunków geologiczno-górnictwowych w kopalni. Dane dotyczące urabialności otrzymano dzięki wykorzystaniu wyników testów wytrzymałościowych jednoosiowego ściskania, ścinania i rozciągania, jak również wykonanych bezpośrednio na pokładzie węgla C1: testu wytrzymałościowego (ISI), kotwii rozprężnej oraz testu peneracyjnego (MRE).