A GENERAL EVALUATION OF THE PERFORMANCE OF ROADHEADERS USED IN COAL MINES

KÖMÜR OCAKLARINDA KULLANILAN KOLLU GALERİ AÇMA MAKİNELERİ PERFORMANSININ GENEL DEĞERLENDİRMESİ

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ÖZET

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Kollu galeri açma makineleri madencilik ve inşaat mühendisliği projelerinde yumuşak ve orta dayanımlı kayaçlarda galeri veya tünel kazısı için yaygın olarak kullanılmaktadır. Kollu galeri açma makinelerinin performansının doğru tahmini, özellikle proje süresinin belirlenmesi ve maliyet tahmini için önemlidir. Mevcut performans tahmin modelleri kaya kütlesi özelliklerini içermediğinden, galeri açma makineleri için kaya kütlesi özelliklerini içeren performans tahmin modellerinin geliştirilmesi çok faydalı olabilir. Bu çalışmanın temel amacı, kömür madenlerinde kullanılan galeri açma makineleri için kesici kafa gücü ve yeni kaya kütlesi kesilebilirlik sınıflandırma (RMCC) indeksi içeren genelleştirilmiş performans tahmin modellerinin geliştirilip geliştirilemeyeceğini araştırmaktır. Önerilen yeni RMCC sistemi kaya malzemesi dayanımını, süreksizlik özellikleri gibi kaya kütlesi özelliklerini, kaya aşındırıcılığını ve yeraltı suyu parametrelerini içerir. Türkiye' deki kömür madenlerinde galeri açma makinesi performans ölçümleri yapılmıştır. RMCC sistemi için ölçümler, performans ölçümleri ile birlikte gerçekleştirilmiş ve laboratuvar testleri için blok numuneler toplanmıştır. Performans ölçümlerinden Net Kesme Hızı (NCR) ve Makine Kullanım Oranı (MUT) değerleri hesaplanmıştır. RMCC indeks değerleri ise saha ölçümleri ve laboratuvar testlerinden hesaplanmıştır. Benzer durumlar için NCR ile RMCC indeksi arasında yüksek korelasyon olması, RMCC sisteminin geçerliliğini göstermiştir. MUT değerlerinin %20 ile %30 arasında değiştiği gözlenmiştir. Galeri açma makinelerinin Net Kesme Hızlarının tahmini için aksiyal ve transvers tip makineler için kesici kafa gücü, RMCC değeri ve diğer parametreleri içeren çoklu regresyon modelleri geliştirilmiştir. Türetilmiş modellerin geçerliliği F ve t testleri ile kontrol edilmiştir. Özellikle, geliştirilen lineer olmayan modellerin kömür madenlerinde kullanılan galeri açma makinelerinin performans tahmininde güvenilir bir şekilde kullanılabileceği sonucuna varılmıştır.

Anahtar Kelimeler: Kollu galeri açma makineleri, Net kesme hızı, Kaya kütlesi kesilebilirlik sınıflandırma sistemi.

ABSTRACT

A GENERAL EVALUATION OF THE PERFORMANCE OF ROADHEADERS USED IN COAL MINES

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Roadheaders have been widely used in mining and civil engineering projects for the excavation of roadway or tunnel in soft and medium strength rocks. The correct estimation of roadheader performance is important especially for determining project duration and cost estimation. Since the available models for the performance prediction of roadheaders do not include rock mass properties, the development of the performance prediction models including rock mass properties can be very useful. The main objective of this study is to investigate whether generalized performance prediction models including cutter head power and a new rock mass cuttability classification (RMCC) index can be developed for roadheaders used in coal mines. The suggested RMCC system includes intact rock strength, rock mass properties such as discontinuity properties, rock abrasivity, and ground water parameters. The performance measurements of roadheaders were carried out in coal mines in Türkiye. The measurements for RMCC system were performed in conjunction with performance measurements, and block samples were collected for the laboratory tests. The Net Cutting Rate (NCR) and the Machine Utilization Time (MUT) values were calculated from the performance measurements. The RMCC index values were calculated from the field measurements and the laboratory tests. That there were the high correlations between NCR and RMCC index for similar conditions indicated the validity of the RMCC system. It was observed that MUT values varied between 20% and 30%. For the prediction of Net Cutting Rates of roadheaders, multiple regression models including cutter head power, RMCC value, and other parameters were developed for axial and transverse type machines. The validity of the derived models was checked by F- and T-tests. Concluding remark is that especially nonlinear developed models can be reliably used for the performance prediction of roadheaders used in coal mines.

Keywords: Roadheaders, Net cutting rate, Rock mass cuttability classification system.

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SYMBOLS AND ABBREVIATIONS

Symbols

F_C	Cutting force
F_N	Normal force
Fs	Side force
Q	Volume of the excavated rock
Q	Tunneling rate index
d	Depth of Cut
d_{opt}	Optimum depth of cut
S	Cutter spacing
J_V	Volumetric Joint Count
σ_c	Uniaxial Compressive Strength
σ_{ci}	Uniaxial Compressive Strength of Intact Rock
P	Cutter head power
W	Weight of machine
K	Power transfer coefficient
W_Z	Specific destruction work
SH	Shore Hardness
I_S	Point Load Index
A_W	Water absorption by weight
α	Angel between discontinuity planes and tunnel axis
F	Force
D	Depth of penetration
A	Cross section

Abbreviations

TBM	Tunnel Boring Machine
SE	Specific Energy
NCR	Net Cutting Rate
MUT	Machine Utilization Time
TCR	Tool Consumption Rate

AR	Advanced Rate
DAR	Daily Advance Rate
AAR	Average Advance Rate
ICR	Instantaneous Cutting Rate
CAI	Cerchar Abrasivity Index
RMCC	Rock Mass Cuttability Classification
UCS	Uniaxial Compressive Strength
EPB-TBM	Earth Pressure Balance Tunnel Boring Machine
SPB-TBM	Slurry Pressure Balance Tunnel Boring Machine
RPM	Revolution Per Minute
PR	Penetration Rate
RQD	Rock Quality Designation
RMCI	Rock Mass Cuttability Index
RPI	Roadheader Penetration Index
RMBI	Rock Mass Brittleness Index
BTS	Brazilian Tensile Strength
NPI	Needle Penetration Index
NPR	Needle Penetration Resistance
RME	Rock Mass Excavatability Index
DRI	Drilling Rate Index
PLI	Point Load Index
HCR	Rockwell hardness
BI	Brittleness Index
OP	Operator Experience

1. INTRODUCTION

Extracting precious minerals from mineral sources is one of the goals of mechanized excavation. To do so, many operations must be performed consecutively or simultaneously, and excavation of the ground/rock can be considered one of the basic stages in this process during which host rocks are also excavated. Underground mining first started based on manpower, and then, drilling-blasting and mechanical excavation methods were developed along with technological advancements. Due to the various advantages of mechanized excavation over drilling and blasting, the development of mechanical excavation technology has accelerated, and the application of this method in opening of mine galleries and drilling wells has increased. Some of the advantages of mechanical excavation are less labor requirement, less cost, and better conditions. Moreover, using no explosives prevents disturbance of rock mass around an underground opening, which reduces support and ventilation costs. In spite of the fact that mechanized excavation requires more initial investment comparing to drilling and blasting method, for example, in the mechanized excavation with Tunnel Boring Machines (TBMs), the unit cost decreases as the tunnel length increases, as seen in Figure 1.1.

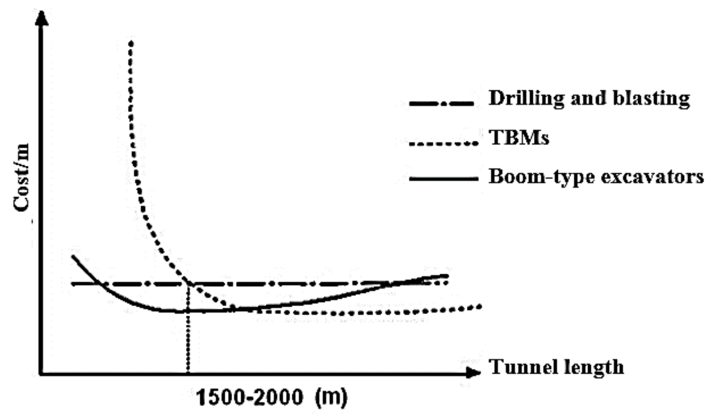


Figure 1.1. Variation of excavation cost depending on tunnel length (Pakes, 1991).

The mechanical excavation or rock-cutting approach in mining industry was born in the early 1950s (Bilgin, Copur and Balci, 2013), and since then, enormous developments have been achieved in this field, and this method has become unavoidable in every phase of mining industry to reach the ideal level of effectiveness and to reduce the operation costs.

There are also new excavation methods that are still being researched. These methods include techniques such as laser, plasma jets, spark erosion, and thermal excavation (Bilgin, Copur and Balci, 2013). However, mechanical excavation is considered the most common excavation method in mining and civil engineering.

With the industrial revolution at the beginning of the 20th century, the need for coal in the world increased. Along with the development of longwall mining method, to increase the productivity in coal industry, mechanical excavators such as shearers, coal ploughs, and roadheaders were developed, too (Bilim, 2007). Roadheaders, which were first produced with a single drum, started to be produced with double drums, and the engine power and dimensions of these excavators increased. Today, roadheaders are one of the frequently preferred machines in longwall coal mining method, and the manufacturers of these machines are countries such as Germany, England, USA, Australia, Japan, Switzerland, Russia, Italy, and others.

Any excavation project's efficiency and ultimate costs are heavily influenced by the selected mechanical excavator and organization of a systematic plan that takes all the relevant factors into account. For example, a wrong machine selection results in low production rates and high costs. In addition to the chosen mechanical excavator, there are several factors influencing the productivity of the excavation project, the most important of which can be considered the geological condition of the excavated ground. Therefore, an accurate performance prediction model, including the determining factors in the excavation, for the selected machine is required when examining the viability of employing a mechanical excavator for operation in a certain type of rock or ground. It is worth mentioning that while some of the factors like cutter head power do not change during the operation, some are highly variable such as geological characteristics of the excavated ground.

To obtain an appropriate performance prediction model for a mechanical excavator requires carefully monitored in-situ observations during which essential parameters influencing the excavation process are determined. In general, to assess the performance of a mechanical excavator parameters such as Net Cutting Rate (NCR), Tool Consumption Rate (TCR), Daily Advanced Rate (DAR), or Machine Utilization Time (MUT) are determined, and the overall performance of the excavator is evaluated based on those parameters. In the following paragraphs, the typical terminology used in performance evaluation of mechanical miners are introduced

Net Cutting Rate (NCR) or Instantaneous Cutting Rate (ICR) is the rate at which rock is excavated (volume of the excavated rock/cutting time), which is expressed in units of m^3/h (Rostami, Ozdemir, and Neil, 1995). NCR must be calculated based on actual time spent on cutting during operation, so when determining NCR, it is vital to take into account and subtract delays such as time spent on adjusting the boom position on the excavation face, breaking large pieces of rock block, or final profiling of the cutting face from total time (Hartman et al., 1992).

Machine Utilization Time (MUT) is the ratio of excavation time, considering the planned and unplanned stoppages, spent on real excavation action to a working shift's whole length or the overall time of project (%) (Rostami, Ozdemir and Neil, 1995). The stoppages during the excavation can occur due to muck removal, support installation, cutter replacement, electrical or mechanical problems, shift changes, or any other delay that interferes with the excavation. It is worth noting that MUT is mainly controlled by the operational system, whereas NCR is largely dependent on geological condition and the machine properties. However, NCR and MUT along with daily working hours and the cross-sectional area of excavation face identify advance rate.

Advance Rate is the ratio of excavation distance in meters to the time of excavation in hours, expressed in (m/day or m/h) (Hartman et al., 1992). Multiplying MUT by NCR yields daily production rate.

Specific Energy is defined as the energy needed to excavate a unite volume of rock, expressed in units of kW/m^3 or MJ/m^3 (Rostami, Ozdemir and Neil, 1995). It is a function of multiple parameters such as the physico-mechanical characteristics of excavated rock, cutter type and geometry, and interaction between rock and cutters (Hartman et al., 1992).

Tool Consumption Rate is expressed as the number of cutters changed per unit volume of the excavated ground/rock (cutters/m^3 or ton) (Bilgin, Copur and Balci, 2013). Rock abrasivity is the determining factor in Cutter Consumption Rate and is measured by identifying the volume percent of hard minerals or Cerchar Abrasivity Index (CAI).

The largest portion of the coal used to produce power is provided by underground mining, so the productivity level of coal mines is of great significance. There is a wide range of parameters determining the productivity rate of coal mines; however, because mechanical excavation has become a widespread and frequently accepted method in this sector, the anticipated progress relies on technological advancements, integrity, and accurate implementations of mechanical excavators to a high degree. In this regard, excavation methods and the general aspects of mechanical excavation in coal and coal host rocks must be examined. Roadheaders are partial-face mechanical excavators widely used for roadway excavation in coal mines. Especially large and medium-sized companies in coal industry make mechanized production and use roadheaders extensively. The use of roadheaders is expected to become more widespread in the coming years. There are many studies in the literature on roadheader performance estimation. However, the suggested models include either machine characteristic (cutter head power) or rock properties, and there is not a comprehensive model including both rock features and machine parameters to present an accurate performance prediction model for roadheaders. Furthermore, the suggested models do not take the discontinuity properties of the excavated rock mass into account. Another shortcoming of the current models, with the exception for a few models, is that they have been developed based on a single machine.

In this regard, the main aim of this thesis is to derive performance estimation equations for axial and transvers type roadheaders, including both rock mass and machine parameters. A new Rock Mass Cuttability Classification (RMCC) system was developed and used for the development of performance prediction of roadheaders used in coal mines.

For this purpose, performance measurements of roadheaders were carried out in seven coal mines, located in Çayırhan, Soma, Dodurga, Amasra, and Bergama, in Türkiye. Performance measurements on both axial and transverse type machines with different cutter head powers were made, and the operational and technical factors were recorded. In-situ tests and experimental works were also carried out to determine the discontinuity and rock strength properties.

The RMCC system was developed based on laboratory and field measurement data. The validity of the RMCC system was evaluated, and then, generalized performance prediction models, based on historical performance measurements, discontinuity measurements, and operational parameters were established for both axial and transverse type machines by multiple regression analyses.

It was shown that multiple regression models including RMCC index values, cutter head power, and operator experience factors yield the highest correlation coefficients and are useful in terms of practicality.

In the second chapter of the present thesis, general information on mechanical excavation, rock cutting tools and cutters, rock-cutting tests, and various mechanical excavators are presented, and details about roadheaders are provided.

In the third chapter, various parameters influencing mechanical excavators' performance are presented. These parameters are composed of geological characteristics, operational variables, and machine specifications.

In the fourth chapter, the literature review is given. In this section, firstly, the existing models on roadheader performance prediction are listed in detail. Then, the usability of these models is studied.

In the fifth chapter, a new Rock Mass Cuttability Classification System (RMCC) is introduced. The structure and the parameters of the RMCC are presented and each parameter is explained.

The sixth chapter presents a thorough analysis of the geological characteristics of coal mines where the performance measurements of roadheaders and the other investigations were performed.

In the seventh chapter of the present thesis, the studies carried out in the coal mines are summarized. After giving information about the investigated coal companies and the operating roadheaders, the performance measurements, observations, and explanations of the experiments carried out in the roadways are presented.

In the next chapters, the findings were evaluated and comments were made. The validity of the RMCC system was conducted in the eighth chapter. The results of the field investigations and laboratory measurements were evaluated with simple and multiple regression analyses in the ninth chapter, and the validity of the developed performance prediction models was tested statistically. Evaluating Machine Utilization Time was realized in the tenth chapter.

In the last chapter of the present thesis, the results of the present work are summarized, and the potential future research topics are suggested.

2. MECHANICAL EXCAVATION

In mechanical excavation, various types of machines with various types of cutters are used to cut and break up soil/rock mass/rock. In this method, cutters transfer forces to soil /rock and generate concentrated stress to overcome the strength of soil/rock and make progress. Technological advancements have provided such excavation tools with the ability to excavate in most of geological formations. In this regard, a new scientific field was born to determine and investigate the crucial factors influencing the rock-cutting process, named rock-cutting mechanics. In this field, the excavation process is evaluated based on cutter-rock interaction, machine specifications, and operational factors. Additionally, this field provides scientists with a broad horizon on the most appropriate excavator based on the relevant parameters.

2.1. Rock Cutting Mechanics

In order that the efficiency of mechanical excavation can be upgraded and the capability of the excavator be harnessed to a satisfactory level, it is of great importance to have a comprehensive understanding of rock-cutting mechanism, which is a complicated issue. To gain a realistic perspective on this subject requires numerous theoretical and experimental studies. Nevertheless, in hard rock cutting, two major parameters determine operation efficiency: system rigidity and the response of the cutters to induced forces. It is essential that the forces be within the machine's torque and thrust capacities; otherwise, the cutting tools and, even, the components of the machine body can be damaged. Hence, unwanted events can be prevented by accurately understanding the basic characteristics of the rock-cutting procedure.

As mentioned earlier, in mechanized excavation systems, the excavation process is accomplished by transmitting the thrust and rotation forces from cutters to the rock. According to the hypothesis suggested by Hurt and Evans (1980), cutters penetrate the rock in two stages:

1. First, the rock under the cutter tip begins to break, so cracks are formed. The formed cracks cause the rock pieces to break off from both sides and in front of the cutter.
2. The second step is to clean the broken pieces.

Despite the fact that the abovementioned stages are considered the main principles of rock cutting mechanism, there are different views on cutting theory for different types of cutters. As indicated in Figure 2.1, a cutter is affected by three main force components while cutting the rock (Yasar and Yilmaz, 2018; Bilgin, Copur and Balci, 2013):

1. Cutting force acting in the direction of cutting action (F_C)
2. Normal force acting perpendicular to the cutting direction (F_N)
3. Side force acting perpendicular to the plane of F_C and F_N (F_S)

Regardless of the geometry of cutters, the rock breakage is a result of shear or tensile stress. Because of the compressional stresses that cutting tools impose on rock surface, a crushed zone is produced beneath the cutter tip. In the perimeter of the crushed zone, tensile hoop stresses are initiated and cause tensile fractures (Mishnaevsky, 1995; Potts and Shuttleworth, 1958; Reichmuth, 1963; Evans, 1962, 1984). Following the above-mentioned process, a crack occurs in the rock, and when the tensile strain at the tip of the crack falls under the required tensile strain for crack propagation, radial tensile cracks develop and make their way toward the rock surface and cause rock breakage. However, shearing, rather than fracturing, is the primary cause of the rock breakage when the rock failure happens in ductile mode.

Various types of cutters such as chisel cutters, conical cutters, or disk cutters are employed in mechanical excavators, which will be explained in the next section. In chisel cutters, F_C is the most effective and energy-consuming component, while the side force (Fs) is usually small. The brittle and fragile nature of rock makes the forces on cutters be of variable nature. In sharp cutting tools, the cutting force is as twice as normal force, although the F_N increases dramatically with tool flattening.

The rock properties and cutter configurations are determining parameters in the failure mode of the rock (Copur et al., 2003). For instance, sharp cutters cut the rock in pure shearing mode, and the amount of small particles generated during the excavation decreases. Since normal force is the determinative parameter in penetration depth, cutting efficiency is specified by the normal force for chisel and point attack cutters. Additionally, the rolling/drag/cutting force is in direct relation with the torque capacity of the mechanical excavator, while normal force is correlated to thrust force.

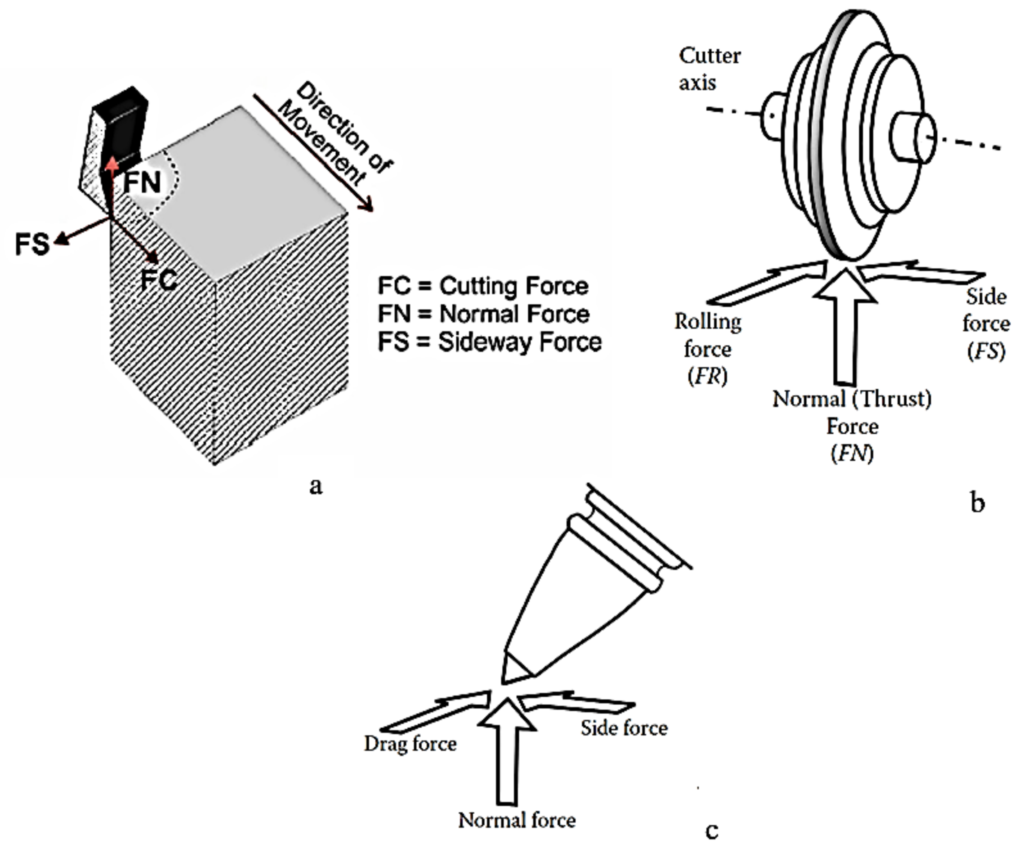


Figure 2.1. Forces acting on: a) simple chisel cutter, b) disk cutter, c) conical cutter during excavation (Yasar and Yilmaz, 2018; Bilgin, Copur and Balci, 2013).

2.2. Cutting Tools

2.2.1. Drag Picks

Different types of drag picks are illustrated in Figure 2.2. These cutters, made of tungsten carbide and cobalt, are preferred due to their economical aspect and ability to excavate effectively under certain conditions. Drag picks are generally used to excavate coal and soft formations. Chisel (wedge) cutters are suitable for soft formations, whereas point attack (conical) picks are suitable for harder and more abrasive formations. Radial picks are less effective than other cutters, and they become significantly less effective as they get blunt. Hence, point attack picks are typically chosen over radial picks (Bilgin, Copur and Balci 2013). Additionally, point attack picks are self-sharpening since they can rotate freely in their holders (Hartman et al., 1992), so they become less blunt over time and have a longer life time. Point attack picks are employed in machines such as coal ploughs, roadheaders, continuous miners, and shearers. The forward-leaning shape of chisel and point attack picks increases their durability during the cutting. The moving direction of drag picks during the excavation is parallel to the cutting face, and the cutting action is almost similar for all of them. The moving direction of drag picks cause them to cut off a large piece of rock when the cutter is first pushed into the rock surface, creating a crushed zone beneath the cutter tip. This phenomenon coincides with chip generation stemmed from crack propagation in the crushed zone. However, the major part of the energy required for excavation by drag picks is consumed to cut the large rock piece in the beginning stage, not for producing the secondary small crushed particles (Yasar and Yilmaz, 2018).

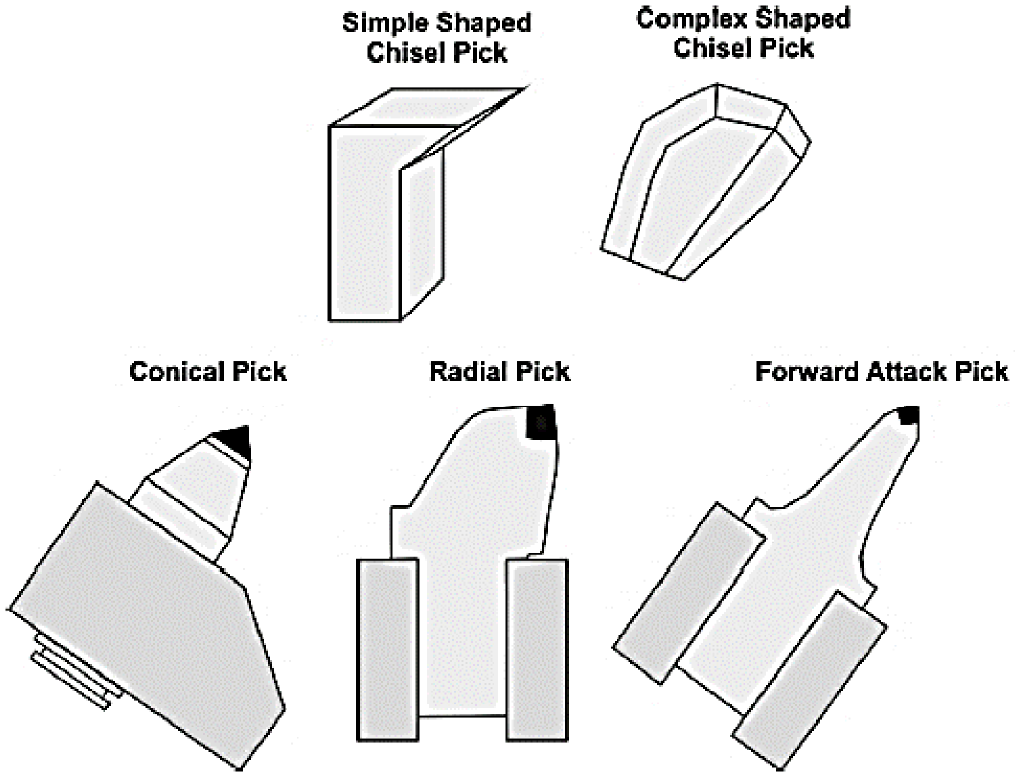
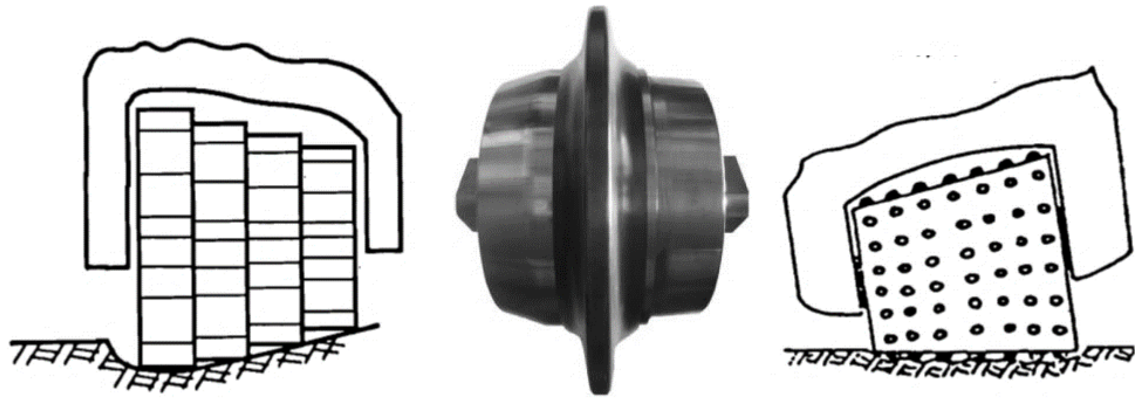


Figure 2.2. Various types of drag pick (Yasar and Yilmaz, 2018).

2.2.2. Roller Type Cutters

Roller cutters are used in Tunnel Boring Machines (TBMs) and raise boring machines. Disc cutters are the most common type of roller cutters. They are used for excavating medium-strength to very hard and abrasive rocks. Various types of disk cutters are shown in Figure 2.3. Simple disk cutters are generally employed in TBMs, while the multi-row disk cutters are used in raise boring machines (Hartman et al., 1992).



a b c

Figure 2.3. a) Multiple disk cutter b) single V-shaped disk cutter c) button cutter (Bilgin, Copur and Balci, 2013).

Rolling type cutters are made up of a series of disks with circumferential teeth that gradually get narrower along the bearing on which they are placed. In button cutters, buttons are placed on the cylindrical body. Each button has a very small influence area, which results in high stress concentration rates and the production of fine-grained particles.

In all types of disk cutters, the normal forces acting on disks make the cutters penetrate the excavation face and cause the rock surface to break. In simple disk cutters, with increasing penetration depth, the contact surface between rock and cutters also increases. Rolling forces, analogous to cutting forces in drag picks, act parallel to rock surface and cut rock as moving forward, and this cycle continues during the operation (Hartman et al., 1992). The major part of the energy transferred from cutters to the cutting face is used for producing small rock pieces (Bao et al., 2011; Entacher et al., 2015).

In hard and abrasive formations, disk cutters present far more effective performance than drag picks. However, in the case of clayey soft formations, disk cutters face difficulties in excavation process due to lack of enough independency of cutters to rotate freely in all directions, which results in lack of friction between rock and cutter, and this makes them prone to local abrasion. This is the main reason why drag picks are preferred over roller cutters in soft grounds. In addition, the required torque and thrust force for cutting a unit depth per cutter head revolution for chisel cutters are less than disk cutters in soft formations (Roxborough and Rispin, 1973b). On the whole, it could be stated that less thrust force and torque requirements are the advantages that drag cutters show in soft formation, while their disadvantages in comparison with disk cutters are their lack of resistance to high forces and having a limited life time due to wearing.

2.2.3. Application Limits of Cutters

Although there are several major factors, unconfined compressive strength is the most important parameter in the selection of cutters. Table 2.1 presents the application limits of cutters based on compressive strength. Another important thing to consider is that, in addition to rock strength, cutter wear is a crucial factor in terms of excavation efficiency. As the cutters wear out, the cut depth decreases, so the cutter forces and specific energy increase. Therefore, selecting cutters suitable for the rock type, considering both strength and abrasivity features, is of great significance. Table 2.2 summarizes some of the parameters involved in wear of cutters.

2.3. Rock Cutting Theories

2.3.1. Merchant-Potts-Shuttleworth Cutting Theory

The first theory of radial and point attack cutting tools was developed by Merchant (1945). It is based on metal cutting theory. Potts and Shuttleworth (1958) changed this theory for coal and mentioned that cutting velocity has no influence on cutting forces in rock cutting. Roxborough and Rispin (1973b), on the other hand, claimed that this approach gave more accurate results in rocks showing plastic properties when exposed to water, such as chalk stone.

Table 2.1. Application limits of cutters (Bilgin, Copur and Balci, 2013).

<table>
<tr><th>Formation</th><th>UCS (MPa)</th><th>Typical rock</th><th colspan="4">Cutter type</th></tr>
<tr><td>Soft</td><td><50</td><td>Shale, sandstone, coal</td><td>Wedge and chisel cutters</td><td rowspan="2">Conical cutters</td><td></td><td></td></tr>
<tr><td>Medium-strength</td><td>50-100</td><td>Limestone</td><td></td><td rowspan="2">Disk</td><td rowspan="3">Button cutters</td></tr>
<tr><td>Hard</td><td>100-200</td><td>Granit, quartz</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Very hard</td><td>>200</td><td>Hornblende</td><td></td></tr>
</table>

Table 2.2. Some of the parameters affecting wear of cutters.

Rock properties (Deketh, 1995)	Compressive and tensile strength of rock
	Hard mineral content
	Grain size and shape
	Filling material and the way they are connected to each other
Machine and operational features	Cutter head design
	Structural and metallurgical properties of cutters
	Cooling system
	Cutter head revolution
	Depth of cut
	Distance the cutters travel during excavation

2.3.2. Nishimatsu Cutting Theory

The theory of Nishimatsu (1972) is based on Mohr failure principle and is similar to that of the metal cutting theory of Merchand (1945). With respect to this theory, the shear strength of rocks is the main parameter in rock breakage process. In addition, this theory gives better results in high-strength rock condition.

2.3.3. Evans Cutting Theory

The rock breakage occurs when its tensile strength is exceeded while cutting with chisel cutters (Evans, 1962, 1972a, 1972b, 1984a, 1984b; Evans and Pomeroy, 1966). This result was derived from experiments conducted on coal. Evans stated that by overcoming tensile strength, cutter causes a circular crushed zone to form where the tip of the tool and rock come into contact. Due to the stresses formed around the cutter tip, the fractures are initiated from the moment the cutting tip starts to advance in the rock. Later studies have shown that this theory yields realistic results in coal and medium hard rocks when friction coefficient between rock and cutters is not considered.

Evans (1962) investigated the effect of the orientation of crack system relative to the cutter on the ploughbility of coal. It was seen that tractive forces were developed as a function of wedge position; that is, increasing the wedge angle caused tractive forces to raise, and this condition was valid for deeper cuts. Moreover, it was concluded that in low cut depths, the main controlling factor for the failure pattern would be the physical condition of the crack system around the cutter and not the position of the wedge relative to the discontinuities. Additionally, it was observed that tensile failure mode is proceeded by radiating crack propagation, and when coal tensile strength is less than the shear strength, tensile cracks develop in coal; nonetheless, the failure behavior of coal is an intermediate stage between tensile and shear failure. It is worth mentioning that the cleats were not well defined in most of the cases, and the determination of the direction of discontinuities was not possible, so the discontinuities had a random orientation relative to the cutters. Evans (1984) examined the cutting forces in conical picks and observed that when these cutters attack the rock, a hole is created on the rock surface. Due to the induced forces, outward radial compressive stresses are formed around the hole and, coincidently, tensile hoop stresses develop. Once the tensile stress reaches that of the rock, tensile cracks are initiated and make their way toward the unstressed parts of the rock. It was observed that point attack picks create V-shaped grooves.

2.4. Specific Energy (SE)

Specific Energy is a commonly used concept in determining the cuttability of rocks, and is considered a simple procedure for providing insights into the performance of all types of mechanical excavators (McFeat and Fowell, 1979). The applicability of an excavator can be interpreted based on Specific Energy (SE), and this parameter can be considered an indicator of the maximum production and advance rate of machine.

SE can be gained through rock cutting experiments. It is well-documented that the lower the Specific Energy, the higher the production rate achieved by a certain type of excavator, so SE is inversely corresponded to the excavation rate of roadheaders (Rostami, Ozdemir, and Neil, 1995).

In general, the operational parameters influencing SE can be classified as: cutting depth, cutting geometry, cutter spacing, and wear rate of cutters. However, based on the work done on numerous rock types (McFeat and Fowell, 1979), it was proved that rock cutting characteristic is the determinative factor in SE for any type of rock. McFeat and Fowell

(1979) examined the cuttability of various rocks and represented SE as a useful measure for obtaining cutting productivity, provided that a standardized rock cutting condition is employed. There are two types of laboratory cutting tests for SE: Full-scale and Small-scale liner cutting tests.

2.5. Rock Cutting Tests

2.5.1. Full-Scale Cutting Test

Real-life cutters are used in full-scale cutting tests to measure actual forces generated by cutters during the cutting of large rock blocks. This procedure can be employed for any type of cutting tool and yields relatively precise results for all machines and cutters. The data obtained from cutting tests can be used in choosing and designing excavators and cutter heads, evaluating the performance of mechanical miners, and estimating the project costs (Çopur et al., 2001).

Figure 2.4 depicts a view of a full-scale linear rock cutting machine. In this test, a rock block of a maximum 60×80×100 cm^3 dimension is cast in concrete in a heavy box and is subjected to cutting with a real-life cutter. The sample could be adjusted to different angles with respect to the present discontinuities, joint sets, or bedding planes to reflect the real condition of the investigated formation. The cutting speed and the cut depth and spacing are adjusted prior to cutting, and the process is repeated at various intervals to incorporate the effect of multiple cutters. The cutting, normal, and side forces imposed on the cutters during the cutting process are measured by a dynamometer. The collected data from the dynamometer is used to identify the SE as follows:

$$\text{Specific Energy} = F_C/Q \tag{1}$$

Where F_C is the cutting force in the direction of cutting action (kN) and Q is the volume of the excavated rock in a unit cutting length (m^3/km) (Pomeroy, 1963; Roxborough, 1973).

Cut material, collected to determine the cut volume, can be sieved to specify the productivity of the cutting. It was proven that as the size of the generated particles decreases, the power requirements increase, as represented in Figure 2.5. In other words, higher SE is needed to generate smaller rock pieces, and less SE is required as the particle size increases. This fact must be taken into consideration when designing cutter heads to achieve optimum SE. In general, cutter head design of a mechanical miner must be oriented in order to get the greatest penetration depth through the smallest number of cutting tools. Providing that the power, torque, and thrust are sufficient, SE leads engineers toward the most efficient cutter head designs (Rostami, Ozdemir, and Neil, 1995).

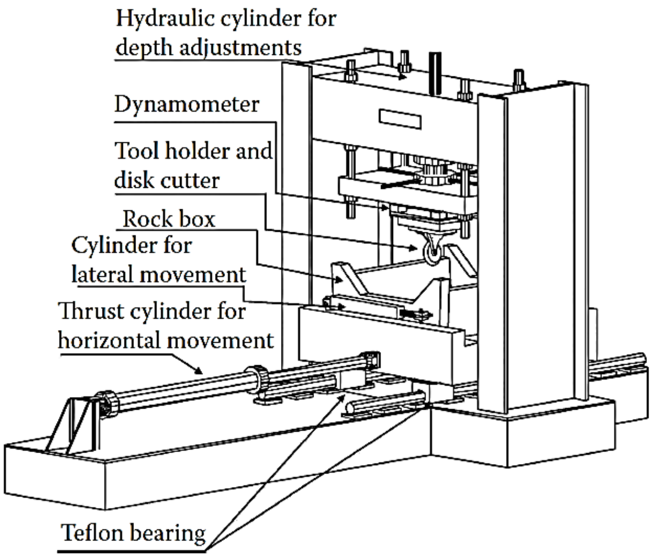


Figure 2.4. Schematic illustration of full-scale cutting machine (Çopur et al. 2001).

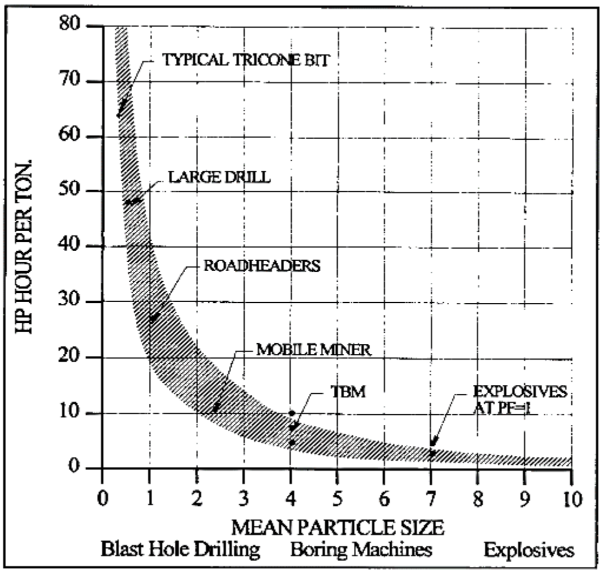


Figure 2.5. Specific Energy in relation to the particle size of muck (Rostami, Ozdemir and Neil, 1995).

In order that the optimum SE can be determined, the optimum ratio of cutter spacing to the cutting depth must be specified (Roxborough, 1973; Roxborough and Rispin, 1973a, 1973b). In this regard, two common types of cutting mode are considered: unrelieved (non-interactive) cutting mode and relieved (interactive) cutting mode, as shown in Figure 2.6. Unrelieved cutting mode refers to the mode in which the effect of rock grooves, generated by nearby cutters, are not considered, whereas, in relieved cutting mode, SE is measured with respect to the effect of nearby grooves on each other through tensile fractures.

Three main states were introduced for relived cutting mode, which are shown with a, b, and c in Figure 2.6 (right). In the cutting mode a, the cutter spacing is too close. This cause the rock to be overcrushed, which means that more energy is consumed to produce fine particles and dust, and the tool wear increases dramatically. In the cutting mode c, the cutter spacing is too wide that causes the cutting action to be not effective enough since the cracks generated by adjacent grooves cannot reach each other. As a result, chipping of the rock material does not occur, and the excavation process is inefficient. In the cutting mode b, which yields the most energy-efficient state, the cutters are placed in a reasonable distance from each other with respect to cutting depth. In this case, generated fragments are neither too small to waste energy nor too large to make the cutting process inefficient. Additionally, the cutter forces decrease in this mode in comparison with the unrelieved cutting mode (Çopur et al. 2001).

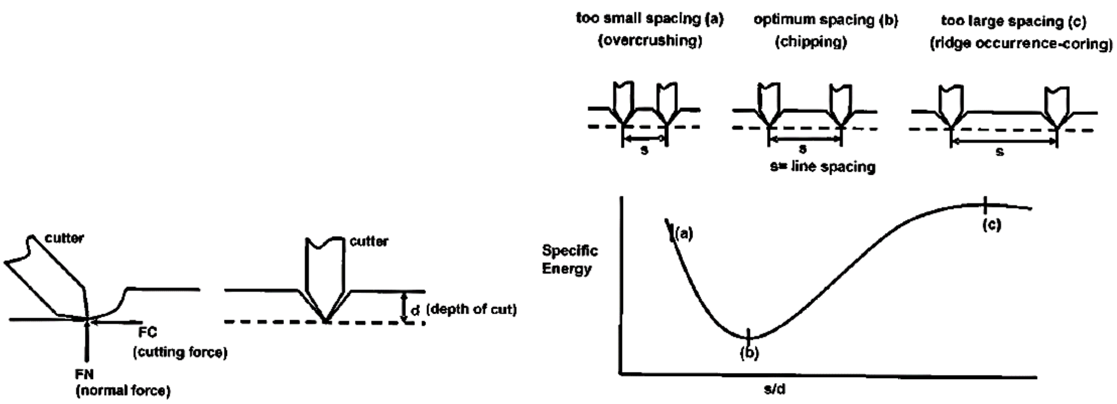


Figure 2.6. Unrelieved (left) and relieved (right) cutting modes (Çopur et al. 2001).

Figure 2.7 depicts overall relation between the depth of cut and SE. The ideal cutting condition, in which SE is at the lowest rate, can be specified in unrelieved cutting mode. Then, the optimal depth of cut attained is used in relieved cutting mode.

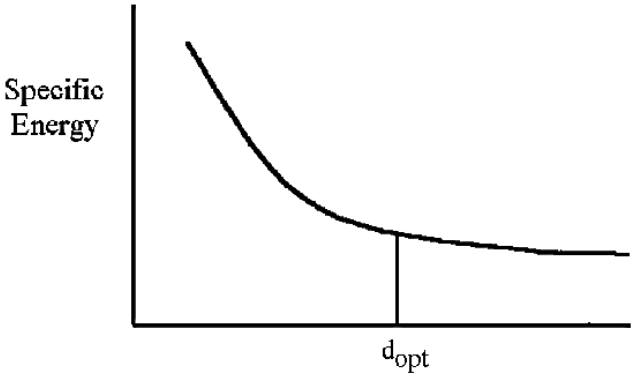


Figure 2.7. The relation between SE and cutting depth cut (Çopur et al. 2001).

2.5.2. Small-Scale Cutting Test

Small-scale rock cutting test was first developed at the Mining Research Establishment of the National Coal Board (Pomeroy, 1958; Evans and Murrell, 1958). In this method, a small-scale core or cubic rock sample is fixed in a cutting machine and is cut in certain intervals and cut depths. A force dynamometer can be used to identify the cutting and normal force values, and the SE is measured. The position of the present discontinuities can be adjusted with respect to the cutting direction. This method was employed to evaluate roadheaders’ performances (McFeat and Fowell, 1977, 1979). A small-scale cutting device is exhibited in Figure 2.8.

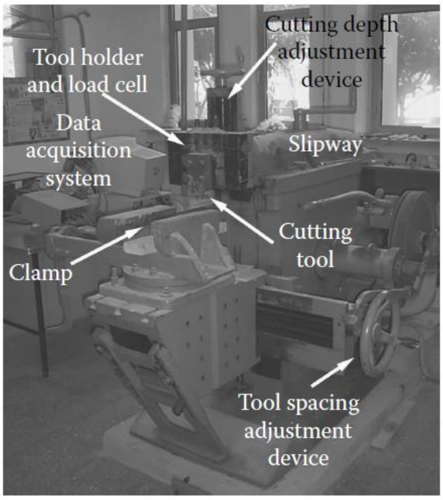


Figure 2.8. Small-scale rock cutting machine (Bilgin, Copur and Balci, 2013).

2.6. Mechanical Excavators

2.6.1. Underground Coal Mining

The excavation methods for underground coal mining fall into two main groups:

- Longwall mining method (shearers and ploughs)
- Room and pillar method (continuous miners)

Longwall mining method accounts for approximately 50% of the world's coal production, and shearers and ploughs are the main mechanical excavators used in longwall mining method (Bilgin, Copur and Balci, 2013). Shearer loaders may operate at inclinations of up to 20° and can cut coal layers ranging in thickness from 1.5 to 7.0 meters, from very weak to hard formations. The overall Machine Utilization Time of these excavators ranges from 40% to 60%. Shearers can cut coal from one end of the face or could be used bi-directionally. Figure 2.9 shows a typical shearer used in underground coal mining.

Figure 2.9. Shearer Loader (with the courtesy of Eickhoff).

Coal ploughs can work in faces with a longitudinal inclination of up to 45° and are employed in medium-strength coal seams the height of which can range between 0.6 to 2.3 m. Ploughs always cut coal in both directions, and their MUT is less than shearers (Myszkowski and Paschedag, 2013). In Figure 2.10, a typical coal plough is shown. On the other hand, continuous miners are widely used machines in room-and-pillar mining, and about 45% of coal produced through this method is excavated by continuous miners (Bilgin, Copur and Balci, 2013). In room-and-pillar mining, mine is divided into a series of rooms that are 6.0-10.0 meters long and up to 30.0 meters wide. Coal seams between

0.8 and 6.0 meters high can be excavated by continuous miners. A typical continuous miner is illustrated in Figure 2.11.

Figure 2.10. Coal plough (with the courtesy of CAT).

Figure 2.11. Continuous miner (with the courtesy of Eickhoff).

2.6.2. Tunnel Boring Machines (TBMs)

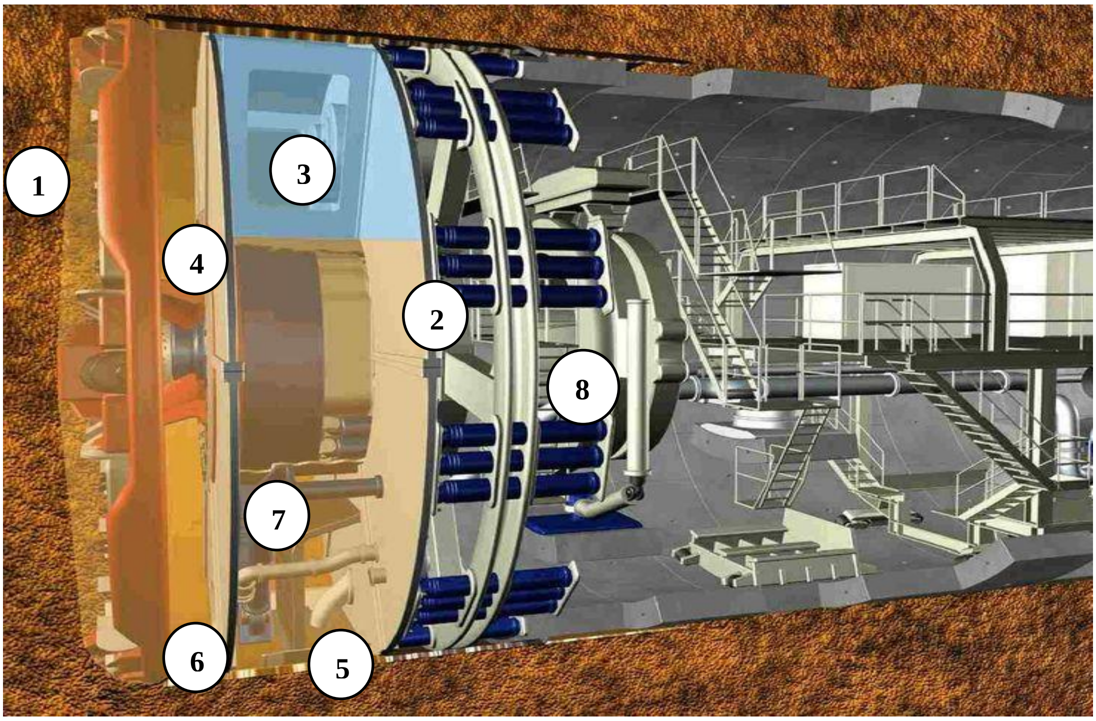
Tunnel Boring Machines (TBMs) are full-face excavators with a circular cutter head and are divided into two major groups as soft ground TBMs and hard rock TBMs.

a) Soft ground TBMs

Soft ground TBMs are generally used in excavation of underground tunnels in urban areas. Prior to the beginning of the excavation process, a thorough analysis of the ground's geological characteristics is required when tunneling through soft grounds where soil and weak material constitute the excavated tunnel route. In such areas, there is a high probability that the ground undergoes noticeable deformations. In the main, surface settlement and stability problems are the major issues in soft ground tunneling (Maidl et al., 2013). To overcome such problems, soft ground tunnel boring achines are employed for excavation in urban areas. Slurry Pressure Balance (SPB-TBM) and Earth Pressure Balance (EPB-TBM) machines are two significant varieties of soft ground TBMs.

b) SPB-TBM

A typical type of Slurry-TBM is depicted in Figure 2.12. In order that the excavation face can be stabilized while excavating with Slurry-TBM, pressurized bentonite slurry mixed with muck is applied on the tunnel face during the operation. Air pressure is used to adjust the necessary pressure on the tunnel face, and a hydraulic transportation system removes the mixture. Sand, gravel, and clayey/silty sand are examples of poor soil types that lack self-supporting ability and can be excavated by SPB-TBMs.

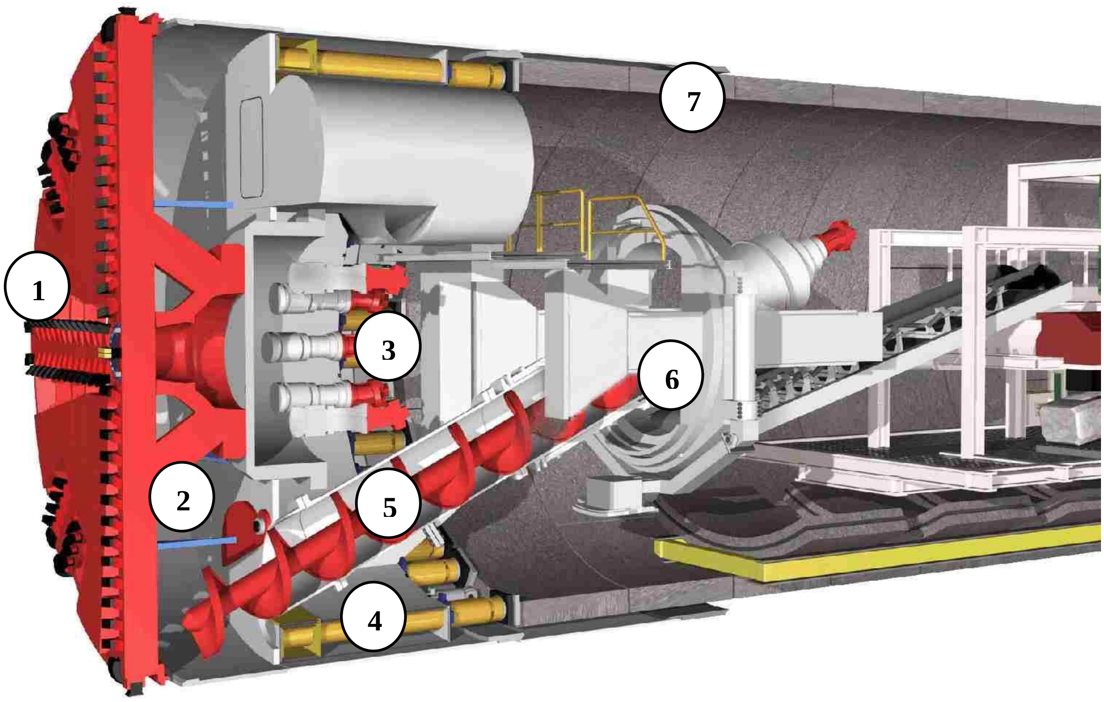


1. Cutting wheel 2. Pressure bulkhead 3. Compressed air 4. Submerged wall 5. Slurry line 6. Stone crusher 7. Feed line 8. Segment erector

Figure 2.12. Schematic cross section of SPB-TBM (with the courtesy of Herrenknecht).

c) EPB-TBM

Figure 2.13 illustrates various parts of an Earth Pressure Balance machine. In EPB-TBMs, hydraulic cylinders are used to pressurize the excavated soil, which enters excavation chamber, against tunnel face to balance the pressure of surrounding ground. It is obvious that in EPB-Tunneling the ground itself is the main component employed to prevent surface settlements and provides the tunnel face with required stability. However, to obtain intended condition from stability point of view and better operation, when required, the cut material in the excavation chamber can be mixed with various types of conditioning agents including foam, water, polymer, or air (Copur, 2012). To maintain a balance between the pressures applied by the machine on the excavation face and ground pressure, tunnel face pressure must be continuously controlled. To avoid stability issues on the excavation face, the screw conveyor's speed and the rate at which the excavated soil is transported must be regulated in accordance with the expected advance rate of the machine. Sand, clay, and silt are considered the soil types suitable for excavation with EPB-TBMs.



1. Cutting wheel 2. Excavation chamber 3. Pressure bulkhead 4. Thrust cylinders 5. Screw conveyor 6. Segment erector 7. Segment lining

Figure 2.13. Schematic cross section of EPB-TBM (with the courtesy of Herrenknecht).

d) Hard rock TBMs

In general, hard rock TBMs are categorized into three main groups: single-shield, double-shield, and open-type. The suitable machine is selected based on the ground to be excavated. Where the excavated ground is composed of hard rock, and there is a high number of rock discontinuity, single-shield TBMs can be employed. Double-shield TBMs are used in more extreme condition where there are fault and/or shear zones along the tunnel route. Open-type TBMs are suitable for excavation in grounds without major stability problems stemming from a high number of discontinuities or high rates of water ingress.

It must be mentioned that extreme geological condition such as extremely poor or hard rock mass, high ground pressure, or high rates of subsurface water diminish the performance of tunnel boring machines to a large extent, which can result in the machine being abandoned in the excavation site. This is because TBMs lack flexibility in terms of mobility due to high dimensions.

2.7. Roadheaders

Roadheaders are partial-face excavation machines, first developed for coal mining in Europe (Kogelmann and Schenck, 1983), and are widely used in underground mining for opening pilot tunnels, drafts, access tunnels, or for production/development purposes. These mechanical excavators can be used for excavating medium-strength rocks with UCS of up to 120 MPa. In Türkiye, roadheaders are commonly-used machines in underground coal mining.

2.7.1. Different Parts of a Roadheader

The constitutive parts of a roadheader are illustrated in Figure 2.14 and are considered as:

- Cutter head and extension arm or boom
- Muck loading unit
- Travelling unit
- Dust suppression unit
- Muck transfer unit
- Hydraulic and electrical units

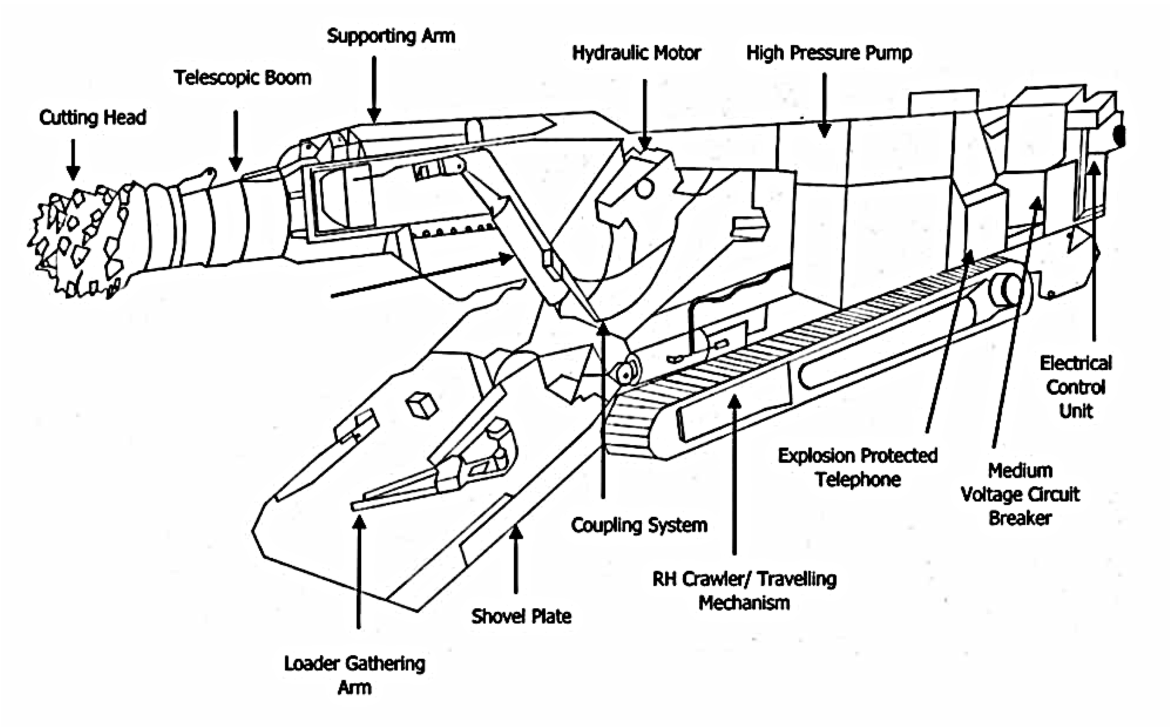


Figure 2.14. Different parts of a roadheader (with the courtesy of rotarypower).

a) Boom

The boom or arm carries cutter head, and cutter head engine is located inside it. In most roadheaders, the cutter head works by electrically driven motors, and the booms are hydraulically driven. The power obtained from the electric motor is transmitted to the gearbox and then to the cutter drum by means of a shaft. Cutter head plays the most critical role in any excavation process since the forces required for rock breakage are transmitted from cutters to the rock. The boom is connected to a platform on the main body, which is placed on the travelling unit, and can be moved in up-down and left-right directions with hydraulic cylinders. The boom is the part that meets the movements of the cutter head and the forces arising from these movements. The length of the boom is in direct relation to the strength of the rock; that is, shorter booms must be chosen for harder rocks to avoid unusual machine vibrations. Besides, the arrangement of the arm units varies according to the hardness of the rock. All units are in contact with each other in the arm body designed for soft rock application. Therefore, while the forces generated during the excavation are transferred to the machine body, the arm units and the electric motor are directly influenced by such forces.

b) Muck loading unit

The muck loading unit consists of an apron and gathering components and is located in the front part of the machine. Excavated material (muck) falls onto the loading apron and is gathered and loaded into a muck transfer unit placed in the center of the loading apron. Muck gathering systems are available in four different types: gathering arm loader, star wheel loader, spinner disk loader, and scraper conveyor loader, as presented in Figure 2.15.

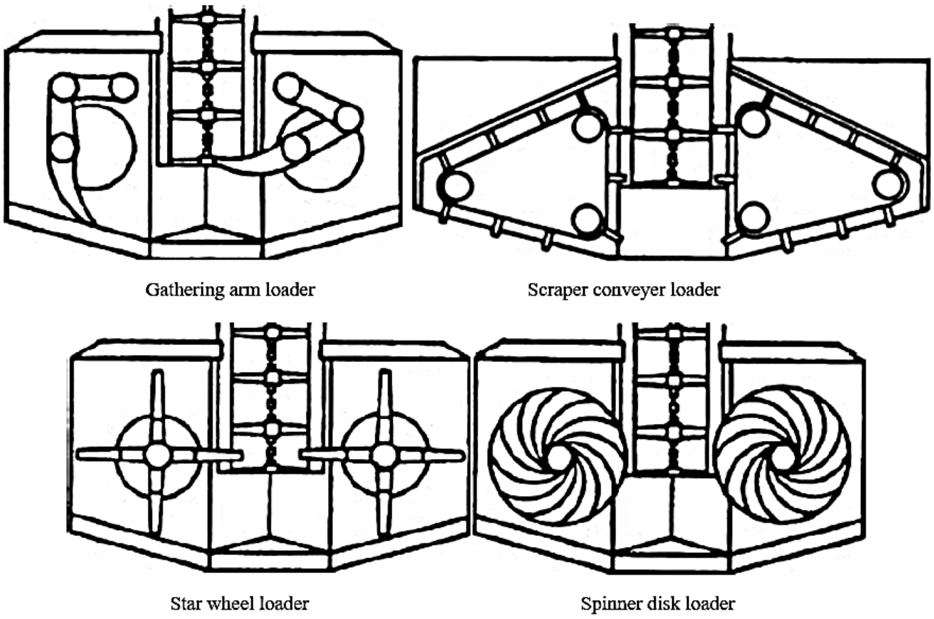


Figure 2.15. Various types of muck gathering system (Adopted from Kogelmann, 1988 as quoted by Breeds and Conway, 1992).

c) Muck transfer unit

The muck transfer system includes a chain conveyor and bridge conveyor. The excavated material loaded with a muck gathering unit is transmitted into the conveyor, and from there, is loaded into the main transport system. The main haulage system could be a belt conveyor, rail, or shuttle car. If the main conveyor is a belt conveyor, the bridge conveyor is designed in such a way to move on the belt conveyor.

d) Traveling unit

The travelling unit of roadheaders is the part where the machine body is located and moves on. In general, crawler-mounted roadheaders are very common in mining industry.

e) Hydraulic and electrical units

The cutter head is driven by electric power and the boom is driven by hydraulic power. Since a large portion of the power is spent on cutting, the motor power of the cutter head is chosen as the largest. Muck gathering and transferring units are hydraulic or electrically driven.

The working cycle of a roadheaders is shown in Figure 2.16. It is clear that the working cycle of a roadheader consists of three main stages: cutting, mucking, and support, all of which are influenced by various parameters during the excavation. Some mechanical features of roadheaders result in certain operational conditions that are valid in nearly all situations. The conditions can be categorized as follows:

- The higher the cutter head power, the higher the torque capacity and production rate.
- The heavier the machine, the less the vibrations during the excavation.
- The more stable the machine during the excavation, the higher the production rate.

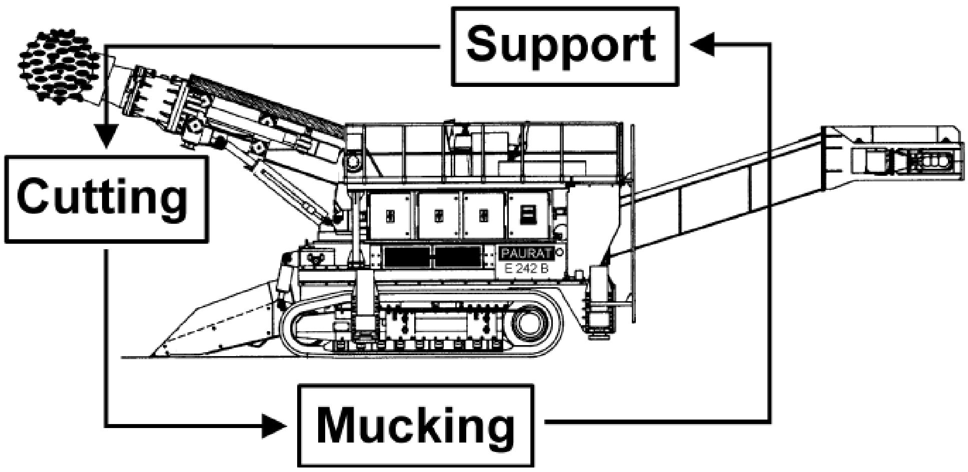


Figure 2.16. Working cycle of a Roadheader (Thuro and Plinninger 1999).

It is worth noticing that heavier machines provide the excavation process with fewer maintenance requirements. On the other hand, the more the machine's weight is, the less mobility it has during the operation. In case of unexpected geological conditions such as heavy water ingress, especially where there is clay, roadheaders could face serious problems due to large size and less mobility. However, machine stability issue is faced in case of lighter machines. Lighter machines, suitable for soft rocks, encounter great difficulty when hard rock bands happen to exist on the excavation face. In such cases, machine stability decreases to a high degree, and severe vibrations could induce irreversible damages to the excavator.

Considering the above mentioned points, it is obvious that roadheaders must be selected based on specific criteria to meet the excavated ground condition; otherwise, a wrongly chosen roadheader could result in lower advance and production rates, higher bit consumption rate and support requirements, and expanded project time, all of which increase the total costs of a project. In this regard, the preliminary parameters that must be considered in roadheader selection are rock/rock mass parameters, geological-geotechnical condition, and geometrical features of the excavated tunnel.

Rock parameters include properties such as rock cuttability, strength, abrasiveness, and texture. Geological-geotechnical parameters consist of parameters such as tunnel inclination, underground water situation, and discontinuity features and faults. Geometrical factor refers to size and shape of the opening. However, rock properties and tunnel size can be considered the major factors in determining the cutter head power and machine weight.

Roadheaders are divided into 3 groups in terms of excavation potential: light, medium, and heavy. In addition, they could be categorized based on weight and cutter head power, as summarized in Table 2.3.

Table 2.3. General classification of roadheaders based on weight and cutter head power (Heiniö, 1999).

Roadheader class	Roadheader weight (ton)	Cutter head power (kW)	Maximum Cross-section area (m^2)	Maximum UCS(MPa)
Light	8-40	50-170	~25 (~40)	60-80 (20-40)
Medium	40-70	160-230	~30 (~60)	80-100 (40-60)
Heavy	70-110	250-300	~40 (~70)	100-120 (50-70)
Extra heavy	>100	350-400	~45 (~80)	120-140 (80-100)

2.7.2. Axial and Transverse Type Roadheaders

Based on the type of cutter head, roadheaders are classified into two major categories: axial type and transverse type. Figure 2.17 shows an axial type roadheader. As can be seen, in axial type roadheaders, the cutter head has an axis placed along the axis of the boom that it is placed on. These excavators are useful in excavating non-abrasive rocks with UCS of up to 60-80 MPa. Nevertheless, it is possible to excavate rocks with UCS as high as 80-100 MPa with axial type roadheaders due to structural characteristics such as bedding planes in sedimentary rocks, discontinuities, or foliations that improve the performance of roadheaders.

Figure 2.17. An axial type roadheader (with the courtesy of MITSUIMIKE).

Figure 2.18 illustrates a transverse type roadheader. As can be seen, in these excavators, there are two cutting drums, the axes of which are placed perpendicularly to the axis of the boom they are placed on. These machine are capable of performing in rocks with the UCS of up to 100-120 MPa with non- or medium-abrasivity. The forces acting on the cutter head of axial type roadheaders are transmitted to the sides of the machine, causing the roadheader to slide on the floor. If there are clay and water in roadway, this situation is exacerbated. Transverse type roadheaders bear the same forces easier than axial type roadheaders since the acting forces tend to move the machine upward, and this movement is controlled by the machine weight in most of the cases. As a result, transverse type roadheaders are more stable than axial type roadheaders (Kogelmann and Schenck, 1983). Nonetheless, axial type cutter heads generate more even and smooth excavation surfaces, whereas transverse type cutter heads develop ragged (uneven) surfaces.

Figure 2.18. Transverse-type roadheader (with the courtesy of Sandvik).

2.7.3. Cutting Tools Used in Roadheaders

The performance of any excavator depends on the ability of its cutters to withstand the imposed forces (Mellor, 1975). In other words, the impact resistance of individual cutters is one of the determinative factors for the efficiency of the cutting process (McFeat and Fowell, 1979). In formations consisting of different rock formations with varying strength characteristics, one of the fundamental requirements of partial-face mechanical miners, is the capability to cut abrasive and hard rocks with an acceptable level of production and cutter consumption rates. Hence, in any excavation process, in order to identify the appropriate excavator and cutter type, the formation subjected to excavation must be examined in terms of physico-mechanical characteristics. Concordantly, every formation is divided into two main groups from a rock mechanics point of view: Intact rock and rock mass. The key qualities of intact rock can be classified according to their dominating characteristics, which include strength, abrasiveness, cuttability, and texture. The degree of abrasiveness is in direct relation to hard mineral content, dominantly quartz. Rock texture is defined by shape, dimension, and arrangement of minerals. In other respects, rock mass characteristics are mainly determined by discontinuities, joints, foliations, or bedding planes. Formations consisting of frequent weakness planes provide the excavator with such a condition that it would be able to pull or rip out the rock formations instead of cutting them; nonetheless, it must be noticed that the weaker formations need more and stronger support requirements (Çopur et al., 2001).

Roadheaders use drag and point attack bits almost exclusively (Hartman et al., 1992). In general, drag picks, forward attack, and point attack tools are the usual type of cutters used in roadheaders (McFeat and Fowell, 1979). Drag picks are generally employed in lighter machines, point attack picks on heavier machines, and both of them could be used in medium weight machines.

It is proven that, chisel or radial cutters consume less energy for excavation in sharp conditions, which results in less Specific Energy; however, when these cutters become blunt, they lose their efficiency rapidly, and the SE value increases drastically. This is the main reason why chisel and radial cutters are employed in soft formations. On the other hand, conical cutters wear evenly and represent more durability in the case of hard and abrasive rocks (Bilgin, Copur and Balci, 2013).

2.7.4. Rock Cutting Mechanism in Roadheaders

Rock-cutting mechanism is a very complex issue due to the variable nature of rock. Moreover, in partial-face excavators such as roadheaders. The effectiveness of the excavating mechanism is influenced greatly by the operator skill. For example, depending on the operator experience and skill and organization of the project MUT for roadheaders can increase up to 60% (Bilgin, Yazici and Eskikaya, 1996).

In general, two excavation modes are defined for roadheaders: sumping (penetration) into the excavation face and shearing (traversing or arcing) across the face. Sumping is the preliminary stage in breaking the rock on the excavation face and provides the cutter head with required free surface for shearing mode. In order that the excavation face gets ready, the cutter head is pushed into the face, and a hole is generated. The normal forces are applied in the thrust direction of the cutter head, and then, the cutting forces act parallel to the direction of the cutter head rotation. Sumping is a relatively challenging phase since there is no free surfaces on the excavation face prior to this stage. Sumping depth is basically arranged in accordance with the excavated rock features, such as hardness and the structural properties of the formation. It is obvious that the softer rocks provide the cutter head with more penetration depth possibilities. In the case of axial cutter heads, the sumping depth varies between a few centimeters to the whole size of cutter head, depending on operator preference and the encountered geological condition. During the sharing stage, the boom is moved in various directions in order to cut the rock in the most convenient way. The shearing direction of the transverse cutter heads could be vertical, horizontal, or diagonal.

In the case of hard rock bands, the performance of roadheaders could be decreased to a high degree, so it is of great significance to obtain a comprehensive perspective on the geological condition of the excavated ground prior to machine and cutter head selection. Moreover, rock mass is heterogeneous in nature, and its breakage pattern varies during the excavation course. In other words, the cracks and discontinuities in the rock structure determine the breakage pattern and the cutter forces. These forces fluctuate highly during the excavation process according to the relative position of the picks to joins, discontinuities, hard minerals, or other effective structural features.

It is worth noticing that the cutters on the cutter head of a roadheader do not experience the same forces during the excavation since the penetration depth does not remain the same for all cutters and changes based on the moving direction of the boom. In such excavators, unlike full-face excavators, while some of the picks are subjected to serious forces and wear, some of them are not in contact with the rock. This fact makes the performance prediction of roadheaders a more complicated issue.

2.7.5. Advantages and Disadvantages of Roadheaders

Roadheaders are very beneficial in mining industry since they make it possible to avoid excavating unnecessary materials; express differently, mineral/ore and waste can be excavated separately by roadheaders, resulting in less ore dilution and cost. Roadheaders are lighter than other underground mechanical excavators, so they could be relocated easily from one face to another. The excavation face is accessible during the operation, so the cutters can be inspected and changed without much difficulty. Roadheaders have a modular structure that makes it possible to assemble or dissemble them conveniently. These machines are able to excavate openings that are not circular in shape, such as rectangular, horseshoe, or any other shape. Such abilities make roadheaders be considered a flexible type of machine in mining industry. They are adaptable to different geological condition and are able to operate in gradients up to 15°. With the help of roadheaders, sharp turns, as much as 90°, could be excavated, and it is possible to employ roadheaders in gradients up to 20°-25° easily. In general, it could be stated that roadheaders have taken a specific place in mining due to unique features, such as mobility, flexibility, and selective excavation. In addition, roadheaders require lower initial and operational costs than other excavation methods such as full-face excavation machines or drill and blasting and cause minimal ground disturbance.

The main advantage of roadheaders is gained in heavily faulted grounds where it is possible to install the support system immediately after excavation. Shotcrete can be applied immediately after excavation in order to prevent difficult situation in terms of support requirements. Besides, in grounds where it is likely to encounter excessively variable condition in terms of geology, roadheaders can be used more effectively than full-face machines due to their adaptability to various changes in cross section, gradient, and turns. Finally, the most important advantages of roadheaders can be classified as:

- high maneuverability
- easy adaptability to working conditions
- assembly-disassembly and operational facilities

The main disadvantage of roadheaders in comparison with other excavation methods is their incapability of excavating hard rocks. The application of these excavators is limited mainly to formation having the UCS values of maximum 100-120 MPa. Furthermore, roadheaders cannot be employed in excavating abrasive rocks due to their cutter types. These machines are less rigorous than full-face machines, and sometimes, water affects the performance of roadheaders adversely, especially when there is clayey formation. Unlike full-face excavators, roadheader performance is highly dependent on the operator skill.

3. FACTORS AFFECTING THE PERFORMANCE OF MECHANICAL EXCAVATORS

The excavation performance of an excavator is an expression used to define the influence of some variables on excavation rate and tool wear (Thuro and Plinninger, 1999). Generally, the efficiency of roadheaders is determined by three main factors (Rostami, Ozdemir and Neil, 1995):

- machine parameters
- operational parameters
- geological–geotechnical parameters

The performance of machine must be estimated considering all of the abovementioned factors to gain an accurate prediction model. It should be noticed that the geological condition is not a flexible parameter and cannot be changed during the project, so the suitable machine must be chosen in accordance with the geotechnical and geological characteristics in the first stage. It should be tried to predict the performance of the mechanical excavator from the earliest phase of the project. However, the numerous number of factors influencing the performance of partial-face machines makes it a difficult task to estimate the performance of roadheaders precisely.

3.1. Machine Parameters

Machine parameters influencing the performance of roadheaders are summarized in Table 3.1. It is apparent that the machine-related parameters affecting the excavation performance are very diverse. It can be said that the most important factors are cutter head power and machine weight. However, many machine-related parameters such as machine type, arm type, and cutter head design affect the excavation efficiency.

3.2. Operational Parameters

Operational factors are very crucial in terms of MUT and are categorized into two groups: technical and mining parameters. Size and shape of the tunnel cross-section are considered technical parameters. Parameters such as support type, for instance, steel sets, shotcrete, rock bolt, muck haulage system, ground conditioning methods, and the number of workers are taken into account as mining parameters. Table 3.2 presents the technical and mining parameters influencing the performance of roadheaders.

Table 3.1. Machine-related factors influencing the performance of roadheaders (Bilgin, Copur and Balci, 2013).

Machine parameters	Machine type
	Machine age
	Dimensions and weight of the machine
	Force capacities of te boom
Cutterhed parameters	Cutter head Type
	Cutter head power
	RPM (Revolution Per Minute)
	Dimensions and type of the bits
	Lacing design
	Metallurgical properties of tip

Table 3.2. Operational parameters affecting the performance of roadheaders (Bilgin, Copur, and Balci, 2013).

Technical parameters	Size of the tunnel
	Shape of the tunnel
Mining parameters	Support type
	Muck transportation
	Utility lines
	Ground conditioning method
	Number of the workers at the excavation face

3.3. Geological Parameters

Geological parameters influencing the performance of roadheaders are investigated under two main categories as rock mass and intact rock properties. Table 3.3 presents the geological factors influencing the performance of roadheaders. As can be seen, intact rock characteristics involve strength features, while the rock mass properties concern mainly discontinuity characteristics. The quality of the rock mass is vital in terms of MUT that is directly related to daily advance rate of the machine; for instance, more time is required for setting support elements if rock mass has a poor quality due to high number of discontinuities, and as a result, the MUT will drop.

Table 3.3. Geological parameters influencing the performance of roadheaders (Bilgin, Copur, and Balci, 2013).

Rock mass properties	Discontinuities
	Hydrogeology
	Adverse geology
Physical and Mechanical properties (intact Rock)	Cuttability
	Strength carachteristics
	Texture and abrasivity
	Others such as brittleness, water content, swelling, etc.

Other unfavorable geological factors such as high water inflow and tunnel inclination can reduce MUT as much as 30% for roadheaders. Nonetheless, this general rule can change in specific circumstances. For example, NCR and MUT can be differently affected by tunnel inclination with respect to the advance rate. Where the advance direction of tunnel is against the tunnel inclination, it is possible that NCR increases since the function of the muck haulage system improves, on the contrary, MUT decreases because of mobility problems of the machine (Bilgin et al., 2004). Additionally, NCR of roadheaders can be positively influenced when there is a low amount of water ingress in tunnel since water weakens soft rocks and makes excavation easier. However, if there is clay, sticky muck could be a major problem. The negative impact of clay and silt on performance of a roadheader is shown in Figure 3.1. The muck transportation system was reported to be ineffective to remove the excavated material due to a mixture of silt, clay, and water; as a result, DAR decreased noticeably.

Another important issue in a successful excavation performance with roadheaders is tool consumption rate. Even though the excavation performance of the machine is significantly affected by macroscopic features of rock mass, such as discontinuity properties, tool wear is a function of equivalent quartz content that is considered a microscopic aspect of the geological features of rock mass.

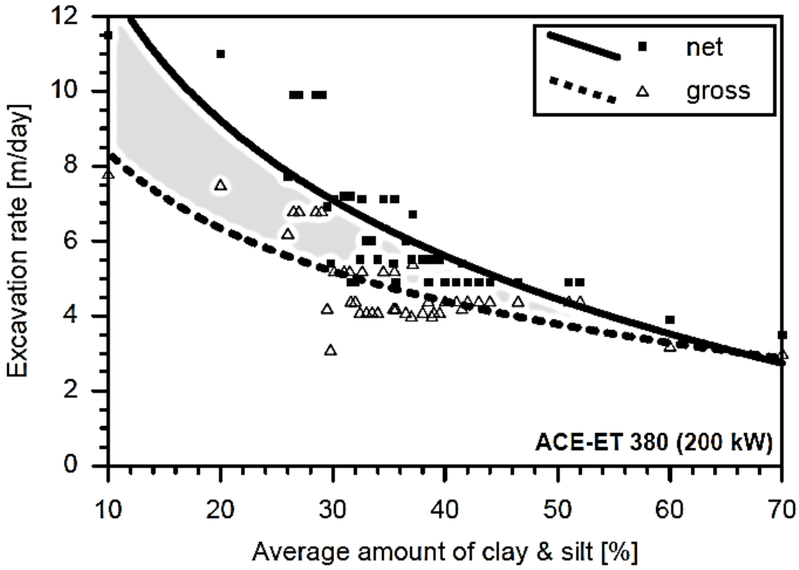


Figure 3.1. DAR of a roadheader against clay and silt percentage (Thuro and Plinninger, 1998).

The effect of UCS on NCR in a sewage tunnel is illustrated in Figure 3.2. It is clear that the cutting performance is inversely affected by UCS. Two separate curves can be distinguished in this figure as high performance and low performance curves indicating the influence of joint properties on cutting performance.

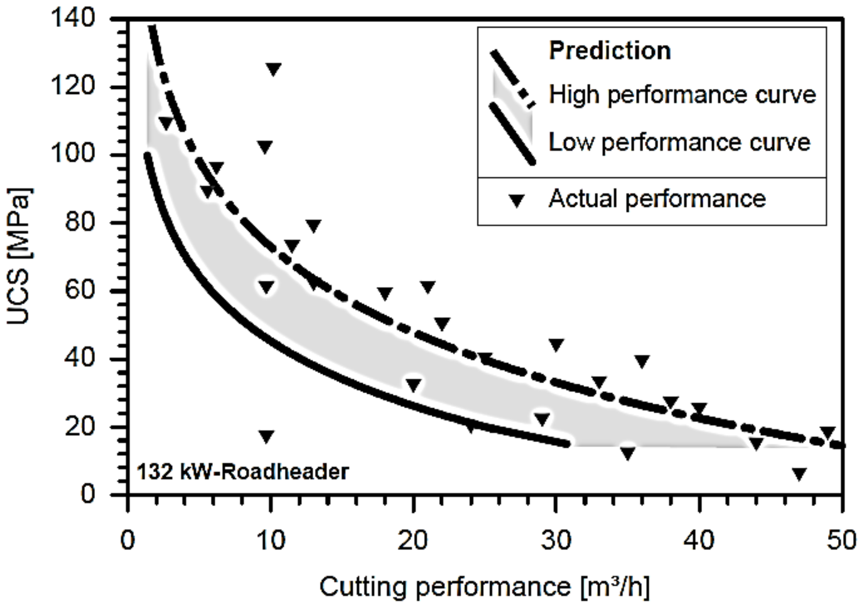


Figure 3.2. UCS versus NCR, (Thuro and Plinninger, 1999).

3.3.1. Discontinuities

Discontinuities in rocks include all types of weak zones, such as bedding planes, faults, fractures, schistosity planes, foliations, joints, fissures, and cleavages. In general, rock mass includes various types of discontinuities, which regardless of their origin, have the same characteristics in terms of tensile and shear strength (Priest, 1993). These geological features play a vital role in controlling and determining the behavior of rock mass as an engineering material, and it is stated that the role of geological properties in identifying rock mass engineering properties is more significant than the strength of the rock itself (Palmström, Sharma and Saxena, 2001). There are some reasons for this. The rock blocks can move along the discontinuity surfaces during the excavation, so the degree of movement of each block is highly dependent on discontinuity characteristics. In addition, the position of each rock block on the tunnel route is determined by the present discontinuities, and the type of rock block failure is defined by discontinuities. Besides, discontinuities provide paths for underground water, which causes operational problems, especially in the case of clayey faces.

The position and quantity of discontinuities influence the NCR. For example, excavation rate decreases where there are jointless and massive rock masses on the tunnel face, so it can be claimed that discontinuities affect the rock mass behavior during the excavation. Consequently, every underground excavation needs information on discontinuities in terms of support design and project duration.

Discontinuities in any jointed rock can be divided into two groups as primary and secondary discontinuities. The primary discontinuities are those of high persistency highly influencing rock mass mechanical behavior. The secondary discontinuities are small-scale and randomly oriented discontinuities not having a noticeable effect on large-scale mechanical behavior of rock mass. To assess how discontinuities affect cutting rate, it is essential to distinguish between rock mass and intact rock, as well as various types of discontinuities.

Intact rock refers to rock material between discontinuities that does not contain structural defects such as joints, bedding planes, faults, foliations, or any other type of discontinuities. Rock mass is a discontinuous medium including both rock material and abovementioned structural characteristics. From an engineering point of view, in most of the cases, rock mass is an anisotropic and heterogeneous environment (Brady and Brown, 1985).

All in all, rock discontinuities are determining factors in any mining operation since they affect opening stability, specify support requirements, and influence excavation method and rock cutting rate.

3.2.1.1. Various types of discontinuities in rocks

Figure 3.3 shows some randomly oriented discontinuities that can be seen in a rock layer. In the next section various types of discontinuities will be described in detail.

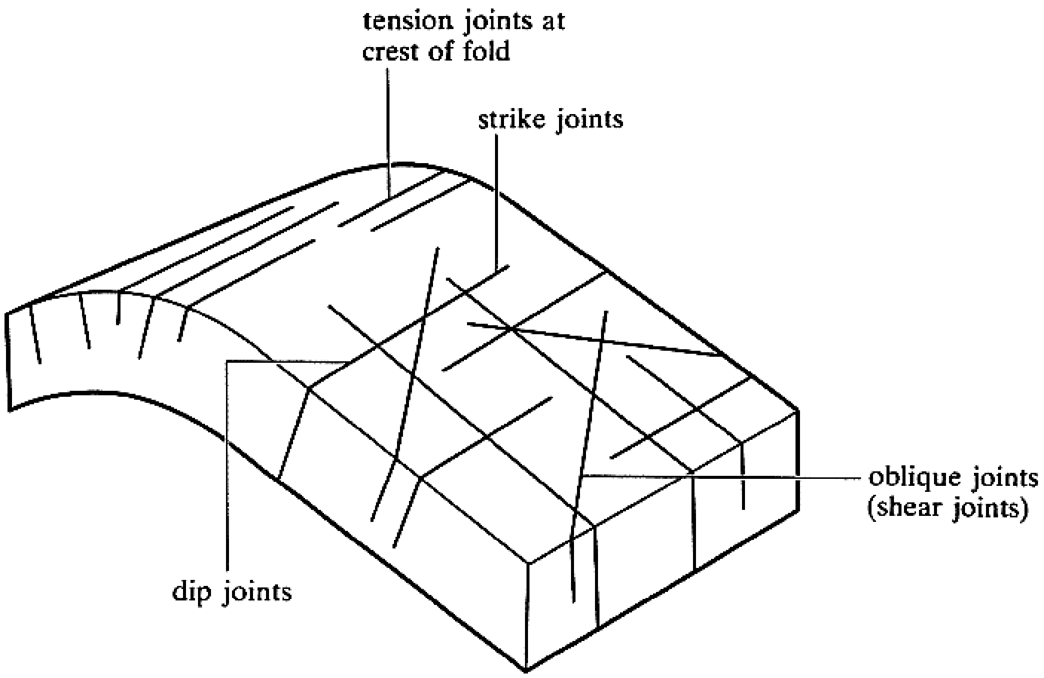


Figure 3.3. Some randomly oriented joints in a stratum (Brady and Brown, 1985).

a) **Joint**

Joints are considered the most prevalent and important type of discontinuities in rocks and form as a result of breakage in geological origins and do not include shear displacements. In general, sedimentary rocks include two joint sets that are perpendicular to bedding planes and to each other.

b) Bedding planes

During the course of the formation of sedimentary rocks, the rock mass is divided into several strata as a result of the depositional process of constitutive materials. The intersection between these strata is known as bedding planes, along which the shear strength is highly dependent on friction between the rock layers.

c) Fold

Folds are another structural feature of rock that form as a result of tectonic forces in post-depositional stages, which create flexures in the rock bed.

d) Fault

Fault zones are considered discontinuous environment on which detectable shear displacements have occurred. The relative displacement of rock on the opposite sides of the fault plane is a major factor in recognizing such discontinuities that have a low shear strength. The extension of faults could vary from several kilometers to meters. The thickness of faults, which changes from millimeters to several meters, encompasses different materials.

e) Foliation

Foliation is the repetitive layering in metamorphic rocks; in addition, the sedimentary bedding is considered foliation.

f) Cleavage

Cleavage is a type of secondary foliation which takes place in fine grained metamorphic rocks.

In terms of discontinuity density and condition, rock mass is divided into several groups which is illustrated in Figure 3.4. The definition of each rock mass group is presented in the following section.

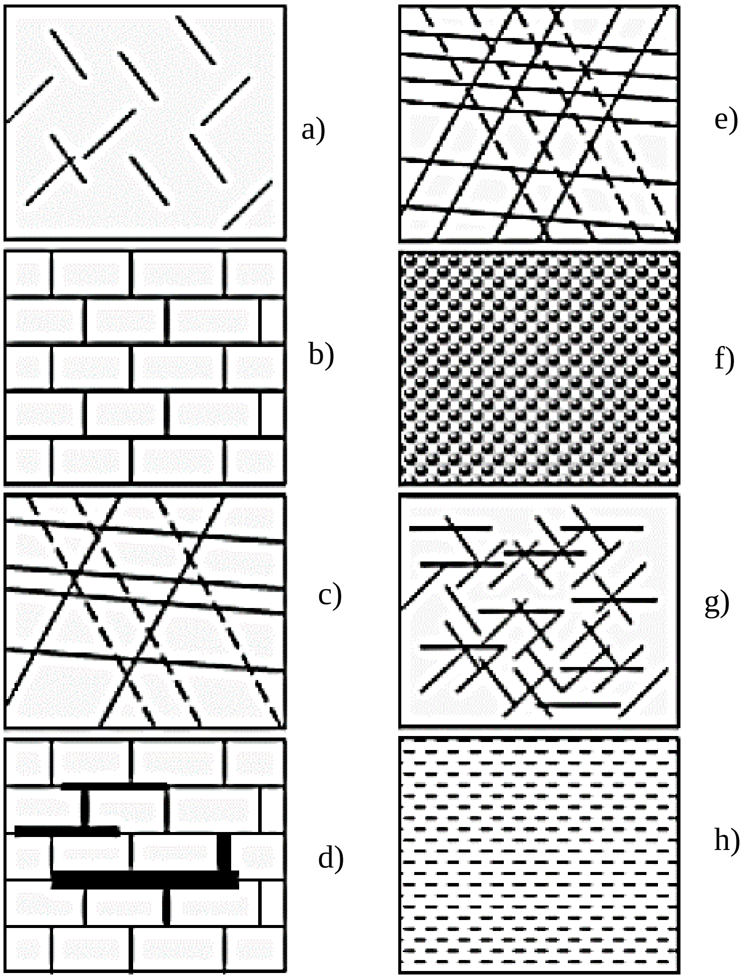


Figure 3.4. Various rock masses based on discontinuity condition, (Kürşat, 2019).

a) Massive Rock Mass: This group includes non-foliated rock masses, such as granite and massive sandstone, which is located below the weathering zone. Massive rock mass is considered isotropic, continuous, and homogeneous.
b) Partially Jointed Rock Mass: This group contains less than three discontinuities with low persistence, and when excavated, individual blocks cannot be obtained.
c) Partially Blocky Rock Mass: This rock mass group includes rocks having less than three discontinuity sets filled with soft materials, and secondary closed discontinuities. If one of the closed joint sets is opened due to deformation, blocking develops.
d) Voided Rock Mass: This group of rock mass includes soluble limestone, dolomite, gypsum, rock salt, and clastic sedimentary rocks bounded with a soluble cement.
e) Blocky Rock Mass: This rock mass group includes more than three well-developed discontinuity sets of high persistency. Discontinuities are filled with soft material or are open. It is easy to obtain rock blocks from such rock masses during the excavation.

f) Very Porous Rock Mass: In this rock mass, the significant amount of pores affects the mechanical behavior of the rock.
g) Highly Fissured Rock Mass: Fissured rock masses contain closely spaced small discontinuities, which cause significant brittleness and anisotropy and influence mechanical behavior of rock mass.
h) Compacted Swelling Rock Mass: This group contains active clay minerals, and when exposed to water, a sudden or delayed cracking occurs, and the volume of rock mass changes. The basic principles of soil mechanics can be applied to this group.

3.2.1.2. Quantitative aspects of rock mass discontinuities

Barton (1978) suggested several basic features to describe quantitative characteristics of discontinuities. Figure 3.5 depicts the fundamental characteristics of rock mass discontinuities, and in the following section, every aspect is explained in detail.

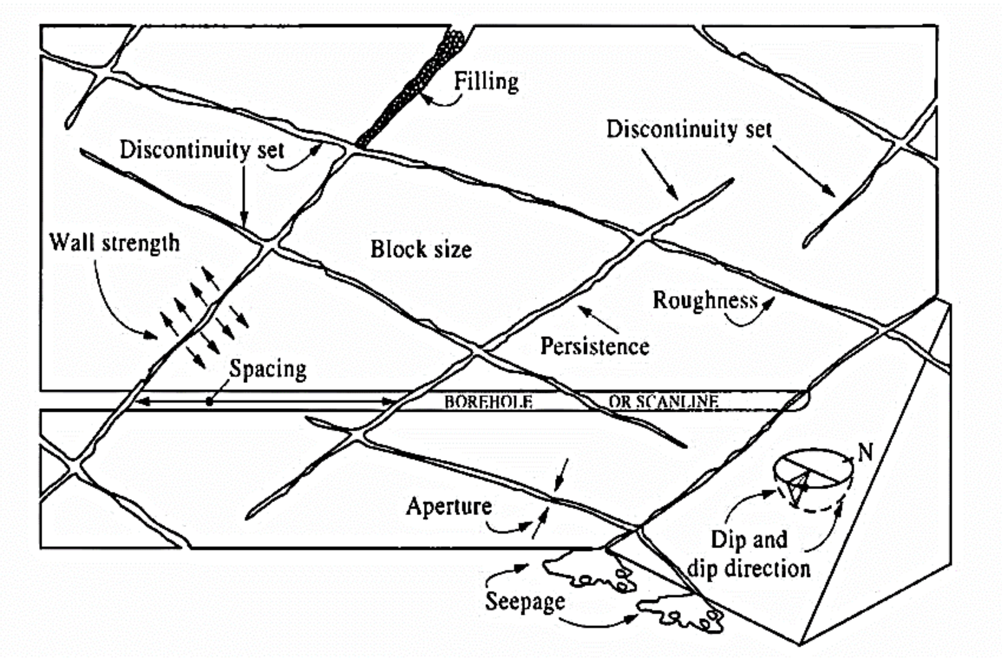


Figure 3.5. Basic features of rock mass discontinuities (Hudson, 1989).

a) Orientation

The orientation of a discontinuity equals the position of the discontinuity in space and is determined by the azimuth and dip of the line with the steepest declination in the discontinuity plane. Orientation of discontinuities with reference to tunnel axis is a crucial subject in excavation projects and is one of the parameters determining stability of the tunnel face. The importance of discontinuity orientation increases in excavations conducted by partial-face machines since the cutting action on the tunnel face could take a longer time due to an insufficient orientation of discontinuities with respect to the excavation direction and large rock blocks.

b) Spacing

The perpendicular distance between adjacent discontinuities is referred to as spacing, on which the block size is dependent to a large extent. In field measurements, the sampling length for determining the spacing value must not be less than 3 m, or it must be considered 10 times the anticipated spacing between discontinuities. Table 3.4 represents classification for discontinuities based on spacing.

Table 3.4. Discontinuity classification based on discontinuity spacing (Barton, 1978).

Description	Spacing (mm)
Extremely close spacing	< 20
Very close spacing	20 - 60
Close spacing	60- 200
Moderate spacing	200 - 600
Wide spacing	600- 2000
Very wide spacing	2000 - 6000
Extremely wide spacing	> 6000

c) Block size

Under a certain stress condition, the mechanical behavior of rock mass is closely related to the shear strength of present discontinuities and block size. Block size is controlled by the discontinuity set number, the persistence of discontinuities delineating the rock blocks, and the discontinuity spacing. In addition, block shape is specified by discontinuity set number and the orientation of discontinuities. Figure 3.6 shows different types of possible rock block shape.

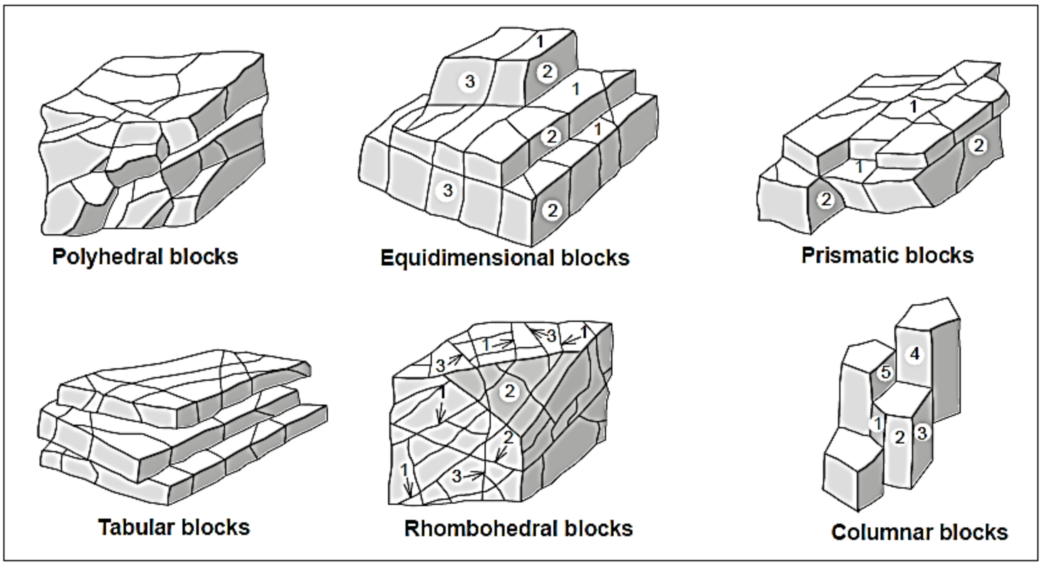


Figure 3.6. Various block shapes (Dearman, 1991).

d) Persistence

The extension of discontinuities on rock surface is defined as discontinuity persistence. This parameter is considered one of the vital rock mass properties, and can be determined by measuring the discontinuity trace length on rock surface; however, it is very difficult to measure this parameter since measuring the persistence of discontinuities is limited to the field of observation. Discontinuity orientation with respect to rock surface is important in discontinuity exposure. In addition, the length and size of discontinuity influence the probability of discontinuity exposure on rock surfaces. In most of cases, there is one particular discontinuity set whose persistence is the greatest. The classification of discontinuity persistence according to ISRM (1978) is presented in Table 3.5. Based on persistence, discontinuities fell into three major groups: persistent, sub-persistent, and non-persistent that is illustrated in Figure 3.7.

Table 3.5. Classification of discontinuity persistence (Barton, 1978).

Description	Model trace length (m)
Very low persistence	<1
Low persistence	1-3
Medium persistence	10-20
High persistence	>20

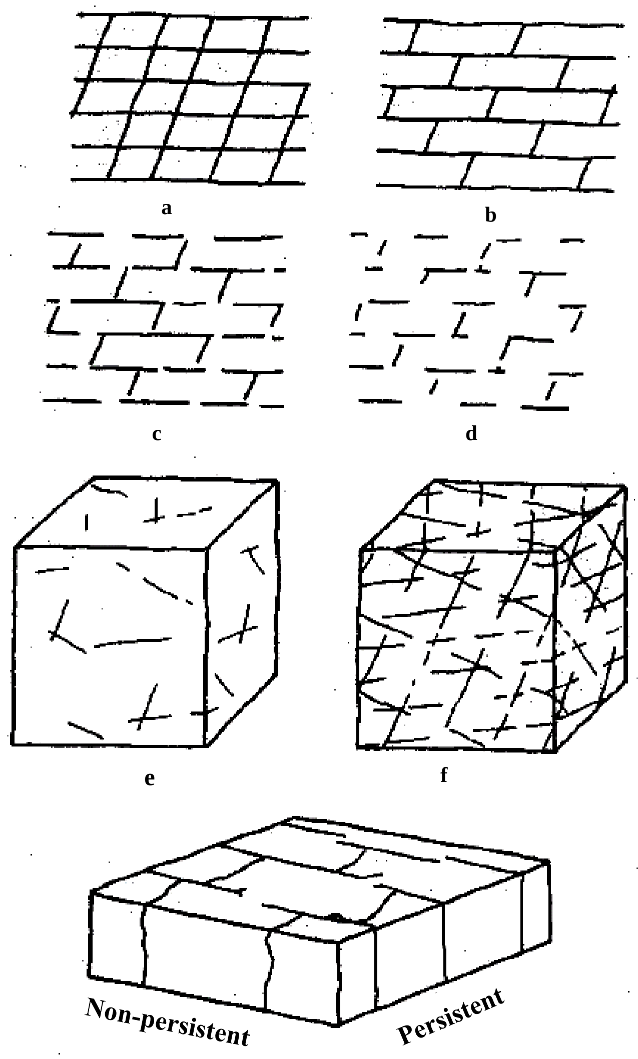


Figure 3.7. Persistence of discontinuities (Barton, 1978).

e) Aperture

If the perpendicular distance between adjacent rock walls of an open discontinuity is filled with air or water, the distance is called aperture. This rock mass characteristic has crucial impacts in terms of hydraulic conductivity and shear strength of discontinuities. Figure 3.8 shows three different modes of possible discontinuity spacing, in which the discontinuity walls could be in direct contact with each other (closed discontinuity), separated by air or water (aperture), or filled with various materials (filled discontinuity). Apertures can be created as a result of shear displacement of discontinuities with high roughness or solution and/or outwashing of the filling material. Table 3.6 presents the expressions suggested by ISRM (1978) to describe various types of aperture based on dimension.

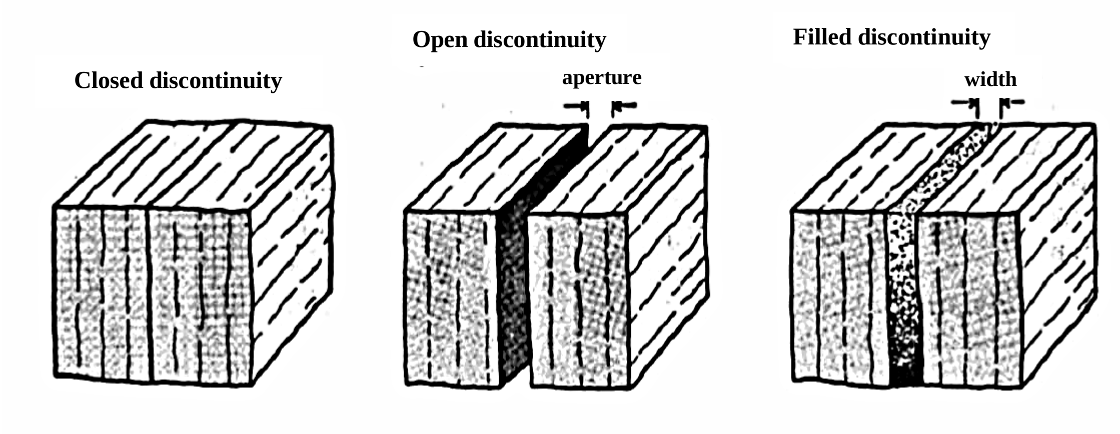


Figure 3.8. Discontinuity aperture (Barton, 1978).

Table 3.6. Discontinuity aperture classification (Barton, 1978).

Description		Aperture (mm)
Closed features	Very tight	< 0.1
	Tight	0.1 - 0.25
	Partly open	0.25 - 0.5
Gapped features	Open	0.5 - 2.5
	Moderately wide	2.5 - 10
	Wide	> 10
Open features	Very wide	10 - 100
	Extremely wide	100 - 1000
	Cavernous	1000

f) Seepage

Seepage is referred to as the water flow through discontinuities in a rock mass, which is directly related to the secondary permeability of discontinuities; however, it is possible that water follows through rock pores in some sedimentary rocks (primary permeability).

g) Roughness

Roughness of discontinuities is characterized by waviness and unevenness of discontinuity walls, and is in direct relation with the shear strength of it. The influence of this parameter increases for undisplaced discontinuities that are free of filling materials. It is vital to distinguish between the scales on which the roughness appears to exist. The descriptive terms for this parameter are presented in Table 3.7, and the following profiles in Figure 3.9 are suggested to classify the roughness of discontinuities in both small- and large-scales.

Table 3.7. Discontinuity roughness classification (Barton, 1978).

Class	Description
I	Rough or irregular, stepped
II	Smooth, stepped
III	Slickensided, stepped
IV	Rough or irregular, undulating
V	Smooth, undulating
VI	Slickensided, undulating
VII	Rough or irregular, planar
VIII	Smooth, planar
IX	Slickensided, planar

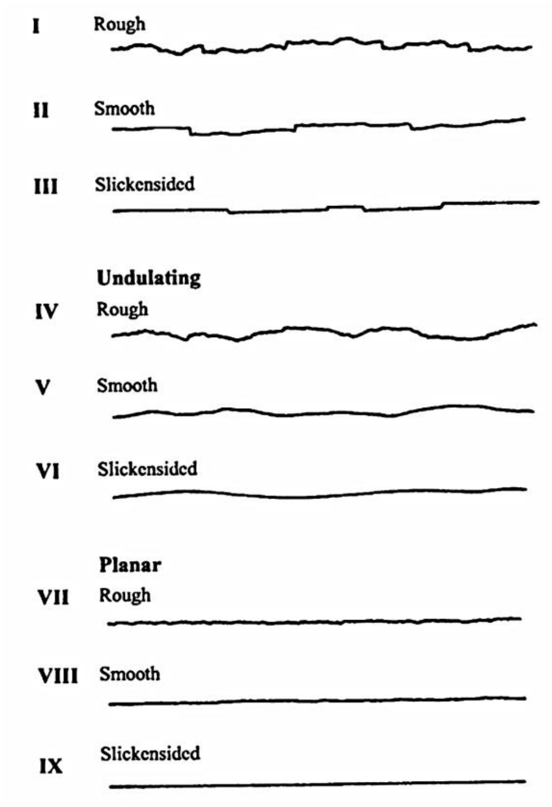


Figure 3.9. Roughness profiles of discontinuities (Barton, 1978).

h) Filling

Material occupying the distance between discontinuity walls is referred to as filling. The most common types of filling material include clay, calcite, silt, breccia, chlorite, and quartz. Filling material is one of the factors controlling discontinuity shear strength, deformability, and permeability and, generally, is weaker than the rock itself. Consequently, the shear strength of filled discontinuities is lower than those that do not contain such materials.

i) Wall strength

The UCS of adjacent discontinuity walls is known as wall strength, which is of considerable importance in terms of deformability and shear strength of discontinuities, especially when discontinuity walls are in direct contact with each other.

j) Number of joint sets

This characteristic determines whether the rock failure and deformation develop into the intact rock or not. In terms of tunnel stability, the set number is of primary importance. For instance, if the number of present discontinuity sets is three or more, it will provide the rock mass with more degree of freedom; that in turn, cause the rock mass to be more prone to deformability that results in tunnel instability.

3.2.1.3. Volumetric Joint Count (J_V)

Volumetric Joint Count (J_v) is described as the number of discontinuities per unit volume of rock mass. This parameter represents discontinuity intensity, which is a paramount factor influencing rock mass characteristics and is used for determining the block size. It is essential that J_v can be measured in regions bigger than the maximum discontinuity size. The volumetric discontinuity frequency is calculated as follows (Palmström, 1982):

$$Jv=\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}+\ldots+\frac{1}{S_N} \qquad (3)$$

Where, S_1, S_2, S_3, S_N are the mean spacing values for each discontinuity set in a unit volume of rock. Table 3.8 describes the block size according to J_V.

Table 3.8. Block size description based on J_V (Barton, 1978).

Block size description	J_v (joints/m^3)
Very large blocks	<1
Large blocks	1-3
Medium-sized blocks	3-10
Small blocks	10-30
Very small blocks	>30

3.2.1.4. Rock Quality Designation (RQD)

Rock Quality Designation was introduced by Deere and Miller (1966) as a criterion for evaluation of quality of borehole cores and is defined as the following equation:

$$RQD=\frac{\text{total length of core pieces whose length is 0.1 m or higher}}{\text{the length of the whole core (\%)}} \qquad (4)$$

It is obvious that RQD is dependent on coring direction. The following equation was suggested by Plamström (1982) to obtain RQD from J_V.

$$RQD=115-3.3J_V \qquad (5)$$

Here, if $J_V < 4.5$, RQD would be 100,

If $J_V > 35$, RQD would be 0.

Where, RQD is Rock Quality Designation, and J_V is Volumetric Joint Count.

In Figure 3.10, the effect of joint spacing is plotted against NCR of a roadheader excavating in argillaceous slates and quartzites in a sewage tunnel. It is evident that rock joints influence the NCR to a large extent. The roadheader shows a poor performance where joints are extensively distributed, but as the number of small cracks and fractures in rock mass increases, the performance of the roadheader improves. According to this figure, two cutting forms can be recognized: ripping and scrapping (cutting). In massive rock masses with low number of discontinuities, the cutting head must scrap the rock in order to make progress, which requires high amounts of energy and time. In contrast, when discontinuities are closer, the ripping mechanism is dominant, which requires less energy and time, resulting in higher NCR.

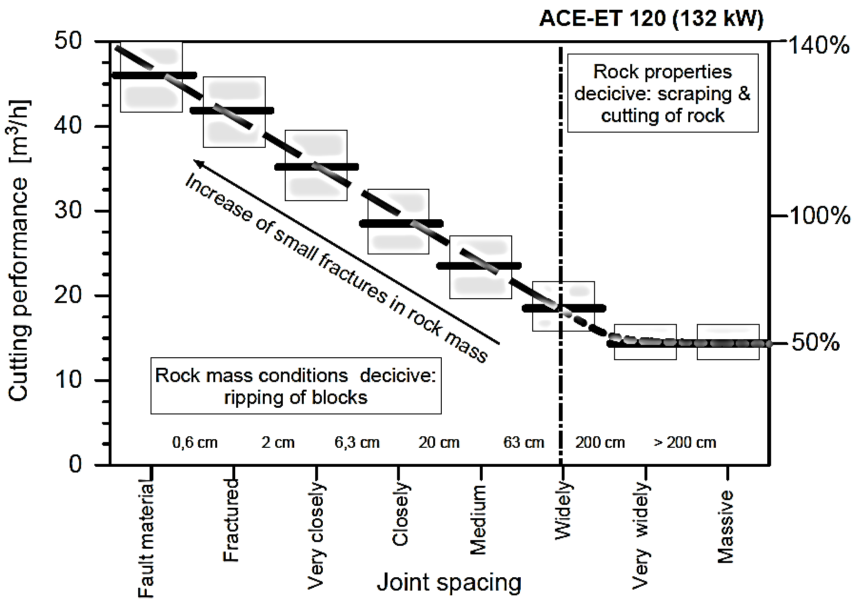


Figure 3.10. NCR of a roadheader against joint spacing (Thuro and Plinninger, 1999).

3.4. TBM-Tunneling (Adverse Geological Condition)

Generally, unfavorable geological conditions significantly reduce the efficiency of both TBMs and roadheaders. TBMs may not be able to perform under certain circumstances, such as extremely high or extremely low quality rock masses (Barla and Pelizza 2000; Laughton 2005). Some unfavorable geological conditions can be identified in TBM-Tunneling as follows (Gong et al. 2016):

- Highly fractured and fault zones
- Mixed ground
- High stressed rock mass
- Low boreable rock

- **Highly fractured and fault zone**

Extreme deformability and instability of highly fractured and fault zones are the major problems encountered in such formations. Generally, there is high amount of water ingress in such zones, and gripper issues are faced frequently, both of which have negative effects on MUT and DAR of TBMs. Furthermore, it is possible that a gap is created around the tunnel opened in fault zones, so a need for an early support installation arises (Barton, 2000).

- **Mixed ground condition**

The distribution of rock mass characteristics on tunnel face would be unequal in the mixed ground condition. The cutters are under variable levels of pressure during the excavation because, for instance, abrasivity and hardness of the excavated rock mass would vary in the various areas of the excavation face, which results in instability of the excavation face and uneven cutter wear (Gong et al. 2016). The other major problems in TBM-Tunneling in mixed ground condition are steering and blockage of the machine (Osborne et al., 2008).

Mixed ground condition can be investigated in terms of discontinuity distribution on the excavation face; that is, discontinuity number and persistence determine the rock block size on the tunnel face, so where the degree of fracturing changes widely on the excavation face, there would be rock blocks of various sizes, that can influence the performance of TBM negatively. Additionally, discontinuity orientation determines block shape, which is important for TBM performance. Two types of unfavorable discontinuity orientation, resulting in blocky structure on the excavation face, are illustrated in Figure 3.11. The cutter head is subject to excessive cutter wear, and the machine undergoes high amounts of vibration due to irregular shape of the rock blocks on excavation face (Delisio, Zhao, and Einstein, 2013). In tunnel faces composed of sliding rock blocks, blockage and damage of the cutting head is expected (Barton, 2000).

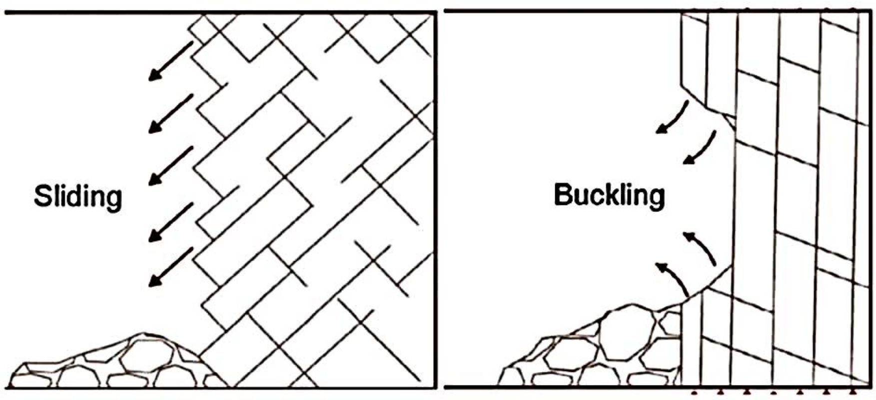


Figure 3.11. Blocky rock structure on tunnel face (Delisio et al., 2013).

- **High stressed rock mass**

As confining pressure in rock mass increases, more thrust is necessary to penetrate rock, which results in lower penetration rates. In addition, DAR of TBM decreases in rock mass with high level of in-situ stress leading to rock burst, which results in stoppages brought on by cutting head damage, muck haulage problems, or gripper problems (Gong et al., 2016). It is worth mentioning that Revolution Per Minute (RPM) of the machine may increase if high in-situ stress results in rock failure; however, problems associated with muck haulage and maintenance will decrease DAR of the machine.

- **Limited boreability condition**

When a TBM cannot penetrate the excavation face at a suitable rate, and/or the cutter wear exceeds an acceptable limit, this condition indicates limited boreability of the rock. In order to categorize rocks based on boreability, when the RPM of a TBM drops below 2-2.5 mm/rev the rock is considered low boreable (Barla and Pelizza, 2000). The boreability of rock is mostly determined through its abrasivity and strength features. This rock property diminishes with increasing abrasivity resulting in low RPM. Furthermore, due to cutter replacements in highly abrasive rocks, longer stoppages occur during the operation, and SE rises. Additionally, in rocks of limited boreability, to compensate low DARs, cutter head is pushed against the tunnel face as hard as possible, which can impose excessive vibration and damage on various parts of the machine (Gong et al., 2016).

3.5. Effect of Joint Spacing and Orientation on TBM Performance

In hard rock tunneling, the rock mass fracturing factor, consisting of two parameters as joint spacing and the angle between the tunnel axis and weakness planes, is considered the main parameter specifying the performance of TBM (Bruland, 1998). There are two main issues affecting the performance of TBM when it comes to the rock mass properties in mechanical excavation with TBMs:

1. Hard rocks with widely spaced discontinuities
2. Weak rocks with closely spaced discontinuities

TBMs show a poor performance in hard rocks with widely spaced discontinuities which results in low penetration rates; on the other hand, stability problems are faced in weak rocks containing closely spaced discontinuities. The Advance Rate of TBMs depends substantially on rock mass features, and increasing thrust force does not increase the AR of the machine while performing in competent rocks. One of these features is the petrographic composition of the excavated rock. For instance, it is observed that RPM of TBM can be lower in metamorphic rocks than sedimentary rocks with the approximately same discontinuity and strength specifications.

The discontinuity orientation with reference to the tunnel face can be considered an important factor in TBM-Tunneling. It was found that when this angel is 90°, higher energy is needed to penetrate the rock than when the angle is 0° in gneiss (Ribacchi and Fazio, 2005). Table 3.9 describes the parameter r_s as a factor representing the joint spacing. Figure 3.12 shows the influence of joint spacing based on r_s on AR of the TBM excavating in the abovementioned gneiss formation. It is evident that as joint spacing increases, AR rate decreases.

Table 3.9. Classification of joint spacing (Ribacchi and Fazio, 2005).

Spacing (m)	r_s
0.06-0.2	8
0.2-0.6	10
0.6-2.0	15
>2.0	20

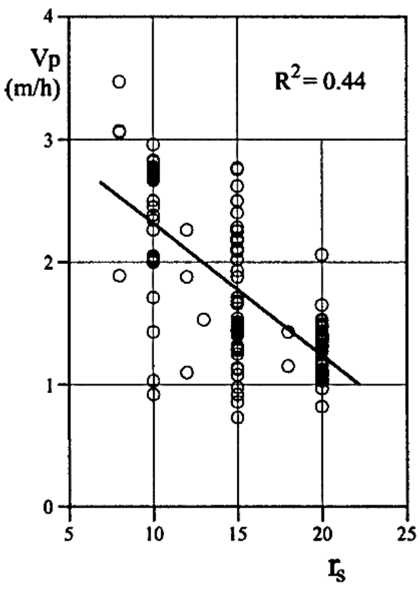


Figure 3.12. Joint spacing versus AR of a TBM (Ribacchi and Fazio, 2005).

Table 3.10 presents the influence of jointing degree on Penetration Rate (PR) of a TBM in granodiorite with 300-400 MPa UCS. It is evident that in hard rock tunneling, as the joint frequency increases the PR increases, too.

Table 3.10. Effect of degree of jointing on PR of a TBM excavating in granodiorite (Klein, Schmoll and Avery, 1995).

Degree of jointing	mm/rev
Low	5
moderate	15
Highly jointed	30

Penetration rate of TBM can be affected by joint spacing in sedimentary rocks, too. For example, Figure 3.13 illustrates the effect of this parameter on performance of a TBM in limestone. However, it was observed that whereas discontinuities with filling result in higher PR, tight joints have no effect on it (Wanner and Aeberli, 1979).

Figure 3.14 illustrates a ground excavated by TBM and divided into four sections based on discontinuity frequency, rock strength, and Tunneling Rate Index (Q) values. It was concluded that PR is inversely influenced by UCS and tunneling rate index values and directly by joint frequency (Barton, 2000).

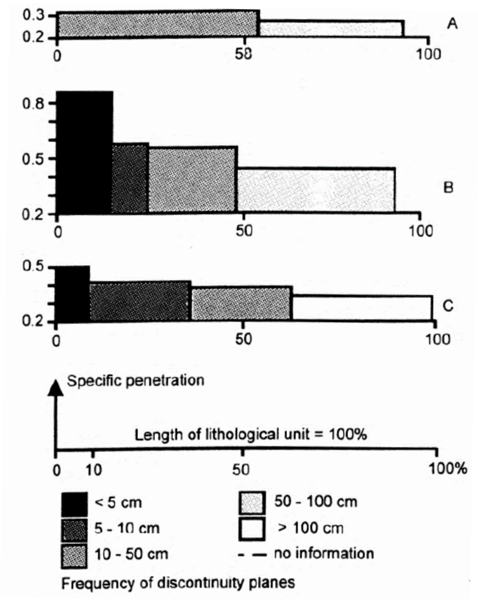


Figure 3.13. Influence of joint spacing on PR of a TBM in limestone (Wanner and Aeberli, 1979).

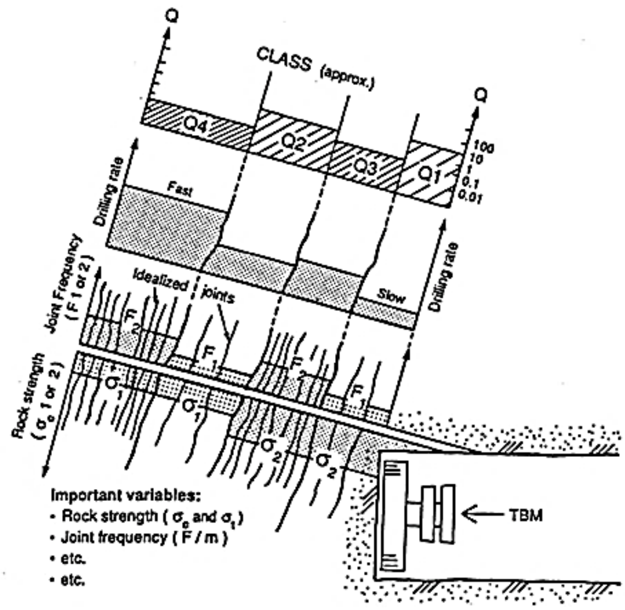


Figure 3.14. PR of TBM as a function of discontinuity frequency, rock strength, and Tunneling Rate Index (Barton, 2000).

If the tunnel route is divided based on the hardness degree of the excavated rock into two groups as hard and soft, generally, PR is higher in softer rocks; however, there are instability problems in such formation, and a need for temporary support system arises due to low stand-up time of the tunnel span. Moreover, it is possible that to encounter problems such as rock jam and cutter head damage during the operation (Barton, 2000). Although harder rocks may not require temporary support, the Bit Consumption Rate (BCR) will be increased due to the high abrasivity of the excavated rock (Fawcett, 1993).

3.6. Effect of Intact Rock Properties on TBM Performance

The maximum values of UCS and BTS must be considered when establishing rock mass strength qualities concerning machine performance when discontinuities have the least advantageous orientation (Barton, 2000). Porosity and abrasivity are the other effective variables in PR of TBMs since PR can be different in rocks with approximately same BTS and UCS (Korbin, 1998).

In the evaluation of intact rock characteristics concerning TBM performance, in addition to BTS, UCS, and abrasivity, Brittleness Index (BI) and Drilling Rate Index (DRI) can be considered important factors. DRI can be taken into account as a parameter representing the boreability of rocks. This parameter can be useful for defining the boreability of various rock types with the same strength; that is, an igneous rock can be more boreable than a metamorphic rock with the same strength features.

Furthermore, the effect of rock strength measured in terms of drilling rate index on penetration rate is less significant in jointed rocks than in intact rock (Movinkel and Johannessen, 1986). Figure 3.15 indicates UCS of various rock types versus DRI. It is obvious that UCS and DRI are inversely related to each other.

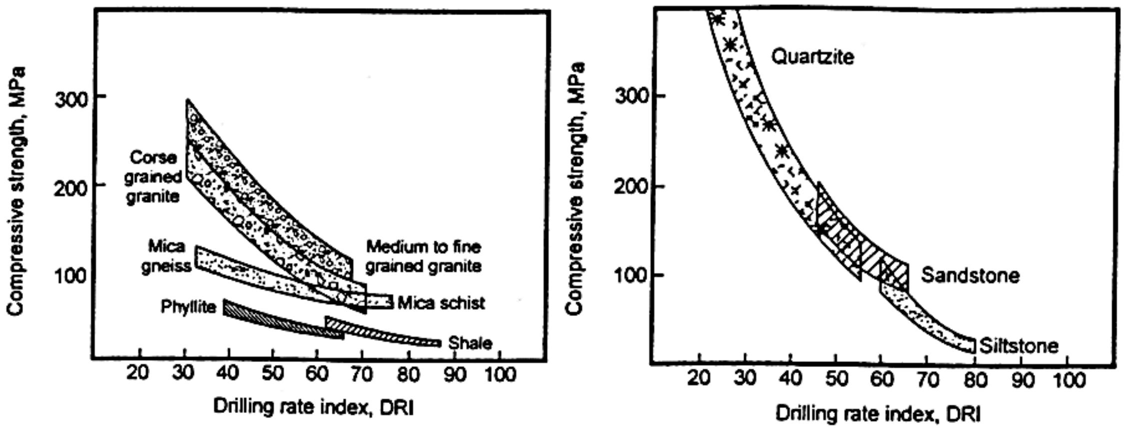


Figure 3.15. UCS versus DRI in various rock types (Movinkel and Johannessen, 1986).

4. PREVIOUS STUDIES

As explained in the preceding chapters, when properly planned, mechanized excavation results in higher production rates; however, an inappropriate project planning leads to low productivity levels and higher costs. Therefore, the parameters influencing mechanical excavators performance should be carefully examined prior to any excavation project.

Sandbak (1985) and Douglas (1985) developed a rock classification system for explaining changes in roadheader advance rates at San Manuel Copper Mine.

Gehring (1989) suggested performance prediction models by examining the performance of two roadheaders with 250 kW transverse type cutter head and 230 kW axial type cutter head, respectively.

$$ICR=\frac{719}{\sigma_C^{0.78}} \tag{6}$$

Where, ICR is the Instantaneous Cutting Rate of a transverse type roadheader (m^3/h) and σ_c is the Uniaxial Compressive Strength of rock (MPa).

$$ICR=\frac{1739}{\sigma_C^{1.13}} \tag{7}$$

Where, ICR is the Instantaneous Cutting Rate of an axial type roadheader (m^3/h) and σ_c is the Uniaxial Compressive Strength of rock (MPa).

Bilgin et al. (1990) presented a performance prediction model for axial type roadheaders based on observations in tunneling projects conducted in Istanbul Metro Tunnels. The following equations were suggested for performance prediction of roadheaders.

$$RMCI=\sigma_c\left(\frac{RQD}{100}\right)^{2/3} \tag{8}$$

$$ICR=0.34.\ P.0.976^{RMCI} \tag{9}$$

Where, RMCI is the Rock Mass Cuttability Index (MPa), σ_c is Uniaxial Compressive Strength (MPa), ICR is the Instantaneous Cutting Rate (m^3/h), and P is cutter head power (kW).

Copur, Ozdemir, and Rostami (1998) developed distinct performance prediction models based on the machine type and the geological formation. They applied this procedure to a wide range of historical data obtained from various excavation projects in different geological formations and presented a performance prediction model for transverse type roadheaders excavating evaporitic rocks as follows:

$$ICR=27.511e^{0.0023(RPI)} \quad (10)$$

$$RPI=\frac{P.W}{UCS} \quad (11)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), RPI is Roadheader Penetration Index, P is cutter head power (kW), W is machine weight (ton), UCS is Uniaxial Compressive Strength (MPa).

Rostami, Ozdemir, and Neil (1995) used Specific Energy to specify the Instantaneous Cutting Rate of mechanical excavators as follows:

$$ICR=K\frac{P}{SE_{opt}} \quad (12)$$

Where ICR is the Instantaneous Cutting Rate of the mechanical miner (m^3/h), P is the cutter head power (kW), SE_{opt} is the Optimum Specific Energy obtained from full-scale linear cutting test (kWh/m^3), and k is the power transfer coefficient. K depends on the machine type and is determined to be 0.85-0.9 for TBMs and 0.45- 0.55 for roadheaders.

Thuro and Plinninger (1999) investigated the effect of geological-mineralogical and geotechnical parameters on cutting performance and Bit Consumption Rate of a 132 kW transverse type roadheader operating in a sewage tunnel in Thuringia, Germany. They suggested the following equation for estimating the performance of the roadheader.

$$ICR = 75.7 - 14.3 \times \ln(UCS) \quad (13)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), UCS is Uniaxial Compressive Strength (MPa). However, they found UCS of the rock to be insufficient in determining ICR and introduced a new parameter as specific destruction work, which is defined as the work required for destruction of the rock sample; in other words, this parameter determines the energy needed to generate new surfaces or cracks in the rock. The following equation was established for the performance estimation:

$$ICR = 107.6 - 19.5 \ln (W_Z) \quad (14)$$

Where, W_z is the specific destruction work (kJ/m^3).

Tumac et al. (2007) investigated the predictability of rock cuttability based on shore hardness and performance of an axial type roadheader having a cutter head power of 90 (kW). They suggested the following equations to predict the performance of roadheaders:

$$ICR = 81.21 SH^{-0.78} \quad (15)$$

$$ICR = 109.25 \sigma_C^{-0.72} \quad (16)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), SH is Shore Hardness value, σ_c is Uniaxial Compressive Strength of rock (MPa).

Ocak and Bilgin (2010) compared the performance of an axial type roadheader and impact hammers with conventional drilling and blasting method in excavation of station tunnels of Istanbul Metro. According to this study, roadheaders yield higher NCR and MUT than impact hammers. Nonetheless, difficulties in displacing and high pick consumption rates were reported as common problems of roadheaders. They presented the following relation for prediction of roadheader performance:

$$ICR = 510588 \sigma_C^{-2.1779} \quad (17)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), and σ_c is Uniaxial Compressive Strength of rock (MPa). They recommended that the dip and dip direction of joints must be taken into account while developing a performance prediction model for roadheaders.

Ebrahimabadi et al. (2011a) investigated performance of an axial type roadheader with 82 kW cutter head power in coal measure rocks in Tabas Coal Mine in Iran. They introduced a new parameter as Rock Mass Brittleness Index (RMBI) to correlate the brittleness of rock, which could be considered as a cuttability feature for rocks, with cutting performance of roadheaders and engaged this parameter and RQD into the performance prediction models and obtained the Instantaneous Cutting Rate as follows:

$$ICR=30.75RMBI^{0.23} \quad (18)$$

$$RMBI=e^{\frac{\sigma_c}{\sigma_t}}\left(\frac{RQD}{100}\right)^3 \quad (19)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), RMBI is Rock Mass Brittleness Index, UCS is Uniaxial Compressive Strength of the rock (MPa), BTS is the Brazilian Tensile Strength of the rock (MPa), RQD is the Rock Quality Designation of the rock mass (%). Eq. (18) was modified into Eq. (20) with increasing the number of cutting cases from 42 to 62.

$$ICR=9.07\ln(RMBI)+29.93 \quad (20)$$

Later in their work, Ebrahimabadi et al. (2011b) examined the effect of orientation of present discontinuities and Specific Energy on performance of roadheaders in the same formation. To do so, they considered the angle between the weakness planes and the tunnel axis (alpha angle) and studied the influence of this parameter on ICR, which showed to have a good correlation coefficient. In addition, the Specific Energy values gained from core cutting experiments were used to evaluate ICR. The prediction models were developed as follows:

$$ICR=5.56\,RMBI+0.6\alpha-8.17 \quad (21)$$

$$ICR=-0.18SE^3+28.75SE-92.82 \quad (22)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), RMBI is the Rock Mass Brittleness Index, α is the angle between tunnel axis and the planes of weakness (°), and SE is Specific Energy (MJ/m^3).

Based on data obtained from previous experimental studies in Tabas Coal Mine excavation process, Abdolreza and Siamak (2013) investigated the statistical relation between mechanical and geological factors with instantaneous cutting rate of roadheaders. They found UCS as the most effective parameter and RQD as the parameter showing the least effect on performance of roadheaders and derived the following equation:

$$ICR=1.759UCS + 0.501\alpha + 0.636RQD - 4.839BTS- 22.127 \quad (23)$$

Where, ICR is Instantaneous Cutting Rate (m^3/h), UCS is Uniaxial Compressive Strength of the rock, α is the angle between tunnel axis and the planes of weakness in degrees, RQD is the Rock Quality Designation of the rock mass (%), and BTS is Brazilian Tensile Strength (MPa).

Kahraman and Kahraman (2016) used a series of easy testing methods to develop a performance prediction model for an axial type roadheader with 112 kW cutter head power operating in Çayırhan Lignite Mine in Ankara, Türkiye. They tried to estimate ICR based on Point Load Index (PLI), density, water absorption rate, ultrasonic velocity, Brazilian Tensile Strength (BTS), and porosity. To achieve this purpose, multiple regression analyses were employed and the best fitted model was presented as:

$$NCR=-2.92I_S-0.79A_W+22.95 \quad (24)$$

Where ICR is Instantaneous Cutting Rate (m^3/h), I_s is Point Load Index, and A_W is water absorption by weight (%). Additionally, they showed that several features of the cut rock control the performance of a mechanical excavator. Among these features, strength parameters, such as BTS and I_s, were determined to be the main controlling parameters.

Besides, clay content of the excavated rock was considered to be a function of water absorption ratio; that is, in formations including high amounts of clay, the water absorption rate increases and the resulting sticky mud acts as a barrier in front of the excavation process.

Kahraman et al. (2019) investigated the predictability of the performance of a 112 kW axial type roadheader from Needle Penetration Index (NPI) test in coal measure rocks in Çayırhan Lignite Mine in Ankara, Türkiye. In weak rocks, such as coal, sample disintegration makes it difficult to obtain appropriate core samples to conduct UCS tests in the laboratory. However, Needle Penetration Index test, suggested by Ulusay et al., 2013, is a simple test providing a quick and easy evaluation of the rock strength. The equation was found as:

$$NCR=-8.58 \ln NPI+55.06 \quad (25)$$

Where ICR is Instantaneous Cutting Rate (m^3/h), and NPI is Needle Penetration Index.

Performance estimation models could determine the excavation rates and the economic and technical viability of the excavation process. There are different methods for determining the performance of mechanical excavators. Nevertheless, performance prediction of partial-face machines is more difficult than full-face machines for two main reasons. First, in partial face machines the cutter head is mounted on a boom that transfers power to cutters. This causes partial face machines to be less rigid than full-face machines. Second, such machines do not cut the whole excavation face at the same time, and the cutter head removes the face part by part. Considering the overall condition of the face and present discontinuities, several cutting modes could occur during the excavation with a roadheader. Depending on the operator preference, the cutter head could be moved in any direction on the cutting face, or it could be sumped into the face. As a result, the performance of roadheaders depends on the operator choice to a large extent, and the production rate could vary, due to the operator skill. Additionally, while excavating, not all parts of the cutter head would be in contact with the rock, and even the penetration depth would be different for the picks that are in contact with rock, so the forces acting on various cutters will differ.

Rock Mass Excavatability Index (RME) was introduced by Bieniawski and Grandori (2007) in order to predict the performance of TBMs. This index value is obtained using a quantification of TBM performance and rock mass properties. The data based on which the RME system has been established was obtained from tunnels opened by open-type and double-shield TBMs. RME classification system is presented in Table 4.1. This classification system includes five main parameters as:

- Uniaxial compressive strength
- Drilling Rate Index (DRI)
- Discontinuity condition on the excavation face
- Stand-up time of the tunnel
- Ground water condition

RME index is obtained by summation of values rated for each parameter in Table 4.1. The total value for RME index could reach 100, which shows the most favorable condition for excavation by tunnel boring machines. RME index value can be employed to assess the applicability of TBMs for operation in a particular geological setting. In this method, the tunnel route can be divided into sections based on RME index value calculated for each zone separately, and the machine applicability can be evaluated for each section. The TBM applicability classification based on RME index is given in Table 4.2.

In RME classification system, as UCS increases, the excavatability of rock decreases. In this classification system, abrasivity of rock mass is represented by drilling rate index. Figure 4.1 shows the concept of drillability and the most effective factors on this parameter. DRI is directly related to the excavatability. It can be seen that homogeneous discontinuities have a positive impact on excavatability of rocks in RME system, and when the layers are parallel to the tunnel axis, the highest energy is needed to cut rock.

As the water inflow increases, the RME index decreases, since high amounts of water inflow is considered in this classification system. The stand-up time of tunnel is determined based on RMR system, represented in Figure 4.2, and is directly related to the RME index; put differently, as the stand-up time of the tunnel increases, the geological formation is more suitable to be excavated by TBMs.

Table 4.1. Input parameters for RME Index (Bieniawski and Grandori, 2007).

<table>
<tr><th colspan="11">Uniaxial compressive strength of intact rock [0 –25 points]</th></tr>
<tr><td colspan="2">σ_{cir} (MPa)</td><td colspan="2">< 5</td><td colspan="2">5 - 30</td><td colspan="2">30 - 90</td><td colspan="2">90 – 180</td><td>> 180</td></tr>
<tr><td colspan="2">Ratings</td><td colspan="2">4</td><td colspan="2">14</td><td colspan="2">25</td><td colspan="2">14</td><td>0</td></tr>
<tr><th colspan="11">Abrasivity – Drilling Rate Index [0 – 15 points]</th></tr>
<tr><td colspan="2">DRI</td><td colspan="2">> 80</td><td colspan="2">80 - 65</td><td colspan="2">65 - 50</td><td colspan="2">50 – 40</td><td>< 40</td></tr>
<tr><td colspan="2">Ratings</td><td colspan="2">15</td><td colspan="2">10</td><td colspan="2">7</td><td colspan="2">3</td><td>0</td></tr>
<tr><th colspan="11">Discontinuities at excavation front [0 – 30 point]</th></tr>
<tr><td colspan="3">Homogeneity</td><td colspan="5">Number of joints per meter</td><td colspan="3">Orientation w.r.t. tunnel axis</td></tr>
<tr><td colspan="2">Homogeneous</td><td>Mixed</td><td>0 - 4</td><td>4 - 8</td><td>8 - 15</td><td>15 - 30</td><td>> 30</td><td>Parallel</td><td>Oblique</td><td>Perpendicular</td></tr>
<tr><td>Ratings</td><td>10</td><td>0</td><td>2</td><td>7</td><td>15</td><td>10</td><td>0</td><td>0</td><td>3</td><td>5</td></tr>
<tr><th colspan="11">Stand-up time [0 – 25 point]</th></tr>
<tr><td colspan="2">Hours</td><td colspan="2">< 5</td><td colspan="2">5 - 24</td><td colspan="2">24 - 96</td><td colspan="2">96 - 192</td><td>> 192</td></tr>
<tr><td colspan="2">Ratings</td><td colspan="2">0</td><td colspan="2">2</td><td colspan="2">10</td><td colspan="2">15</td><td>25</td></tr>
<tr><th colspan="11">Ground water inflow [0 – 5 point]</th></tr>
<tr><td colspan="2">Liters / sec</td><td colspan="2">> 100</td><td colspan="2">70 - 100</td><td colspan="2">30 - 70</td><td colspan="2">10 – 30</td><td>< 10</td></tr>
<tr><td colspan="2">Ratings</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">4</td><td>5</td></tr>
</table>

Table 4.2. TBM applicability classification based on RME index (Bieniawski et al., 2006).

RME index	Classification	AAR (m/day)
>75	Very high suitability	>16
50-75	Good suitibility	10-16
25-50	Moderate suitibility	5-10
<25	TBM is not suggested	<5

The average advance rate of TBMs versus RME index is illustrated in Figures 4.3 and 4.4. RME Index is suggested as a rock mass excavatability system to estimate DAR of TBMs, and this is the only excavatability system; however, this classification system does not apply to roadheaders for several reasons. For instance, strike and dip of the discontinuities on the excavation face influence the performance of TBMs and roadheaders differently. In addition, there is a big difference between the rock strength that can be excavated by TBMs and roadheaders. Whereas TBMs are capable of excavating rocks with UCS of up to 300-400 MPa, roadheaders show relatively poor performance in rocks with UCS higher than 50-60 MPa. As a result, a need for a rock mass cuttability classification system for roadheaders arises.

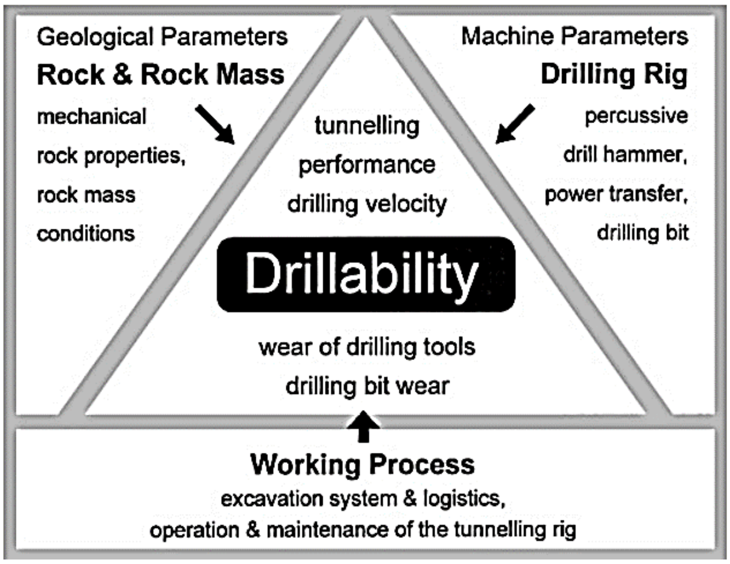


Figure 4.1. Drillability and influential parameters (Thuro, 1997).

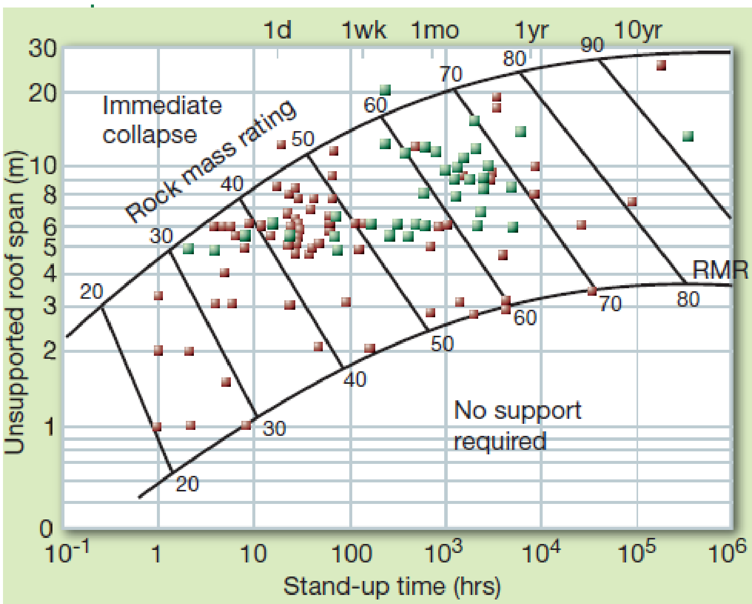


Figure 4.2. Stand-up time as a function unsupported tunnel span and RMR (Bieniawski, 1989).

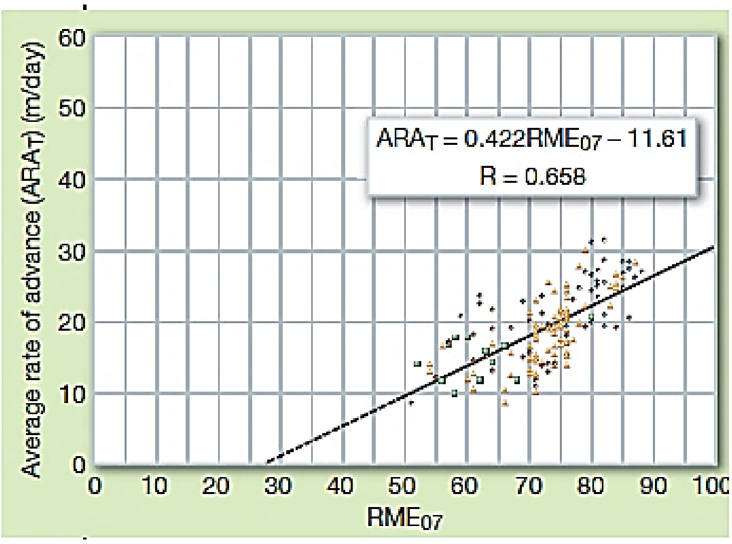


Figure 4.3. RME Index versus advance rate of a double shield TBM (Bieniawski et al., 2006).

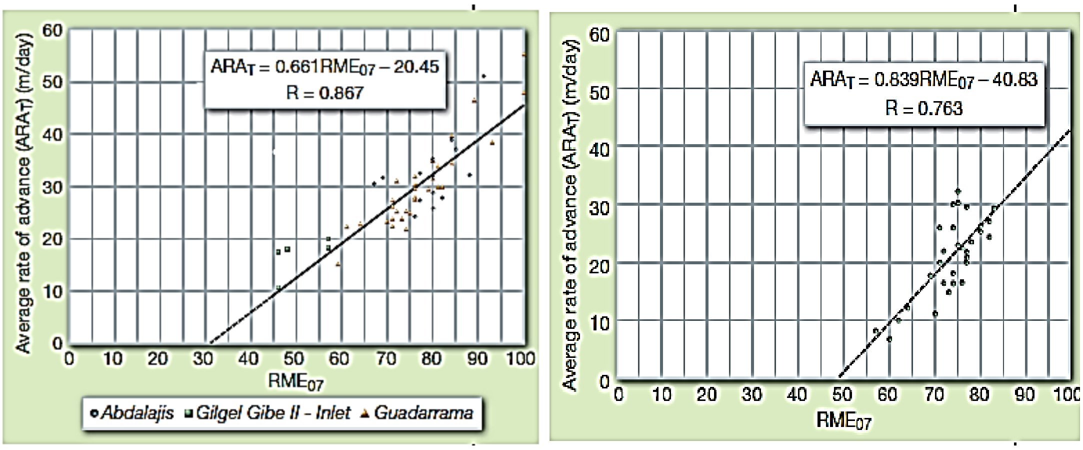


Figure 4.4. RME Index against advance rate for tunnels excavated by double-shield TBMs (left) and Open-type TBM (right) (Bieniawski and Grandori, 2007).

5. A NEW ROCK MASS CUTTABILITY CLASSIFICATION FOR ROADHEADERS

In this thesis, a new Rock Mass Cuttability Classification (RMCC) is introduced to predict the cuttability of rocks excavated by roadheaders. RMCC system is presented in Table 5.1 and employs six parameters specifically regarding rock mass characteristics and ground condition as follows:

- Uniaxial compressive strength (MPa) with the maximum value of 30
- Volumetric joint count (joint number/m^3) with the maximum value of 20
- Strike and dip of discontinuities with respect to the tunnel axis with the maximum value of 20
- Joint spacing (mm) with the maximum value of 10
- Cerchar Abrasivity Index with the maximum value of 10
- Groundwater condition with the maximum value of 10

There are five ranges for the UCS parameter : >120.0 MPa, 60.0–120.0 MPa, 40.0–60.0 MPa, 20.0–40.0 MPa, and < 20.0 MPa. The ranges have been determined considering the application limit of roadheaders, experience, and literature. As mentioned earlier, roadheaders do not show an acceptable performance in rocks having UCS more than 60 MPa, so closer intervals were considered for UCS less than 60 MPa. For a UCS value less than 20.0 MPa, the maximum rating of 30.0 is rated. The rating is designated as zero for UCS>120.0 MPa since rock cutting by roadheaders is either impossible or extremely wasteful for this range of rock strength.

The strike and dip of joints in relation to the tunnel axis, the joint aperture, and the volumetric joint count (J_v) are the three joint properties included in the RMCC system. The assessment of discontinuities in the rock mass is performed with J_v. In coal mines, for the excavation of roadways in coal or coal measure rocks, roadheaders are the frequently employed machines. Coal seams have very high J_v values due to their cleavage systems. The majority of the block samples gathered from different mines could not be cored for performing rock strength tests since high J_v values are also present in coal measure rocks. According to Chapter 7, the majority of the J_v values of the investigated coal measure rocks ranged between 50 and 100 joints/m^3. There are more than 150 joints/m^3 in coal seams. In light of this, five categories were considered for the J_v value: <50 joints/m^3, 75–50 joints/m^3, 100–75 joints/m^3, 150–100 joints/m^3, and >150 joints/m^3. For J_v more than 150 joint/m^3, the J_v parameter's maximum rating considered 20.0. When J_v values are less than 50 joints/m^3, the J_v parameter's lowest rating is 1.0. Coal seams always get a rating of 20.0, as their J_v values are greater than 150 joints/m^3. In the evaluation of the strike and dip of discontinuities with respect to the tunnel axis, three general modes were considered: strike parallel to tunnel axis, strike vertical to tunnel axis, and strike oblique to tunnel axis. Drive with dip and drive against dip are two subcategories considered where the strike is vertical to tunnel axis. The dip angle relative to tunnel axis is divided into three ranges for each category: 0°–30°, 30°–60°, and 60°–90°. Maximum and minimum ratings of 20.0 and 3.0 are assigned for the dip and strike of joints parameter.

Considering the fact that in underground excavations wide discontinuity aperture is uncommon, the joint aperture parameter is divided into five groups, starting from 0.1 mm: very tight (0.1 mm), tight (0.1–1.0 mm), open (1.0–5.0 mm), very open (>5.0 mm), and hard cemented filling. For apertures filled with hard cement, zero value is assigned in the RMCC table. Moreover, for very open joints, the maximum value of 10.0 is rated in RMCC table.

There are five categories for the Cerchar Abrasivity Index (CAI) values: >4.0, 2.0–4.0, 1.0–2.0, 0.5–1.0, and <0.5. The CAI parameter has maximum and minimum ratings of 10.0 and 0, respectively.

The five categories for the ground water parameter were defined as: dry, damp, wet, dripping, and flowing. The minimum rating, zero, denotes a dry situation, while the maximum rating, 10.0, denotes a flowing condition.

The excavatability index is gained through summation of the numerical ratings assigned for each of the abovementioned parameters. The RMCC index denotes that how much a roadheader is a suitable choice for excavating in a specific type of geological formation. The proposed classification system is based on the NCR of roadheaders; that is, it is expected that the higher values of RMCC index are associated with higher NCRs. RMCC index can reach the maximum value of 100, and the higher index values indicate the more suitability of the formation for excavation with roadheaders. Table 5.2 shows the cuttability classification for rock mass according to RMCC system.

RMCC has been checked with data obtained from various roadways excavated in various geological and operational conditions and with various roadheaders operating in active coal mines in Türkiye. Several statistical correlations were established between RMCC index and the relevant NCR values obtained from field investigations to validate the RMCC table.

The most important issue in evaluation of a roadheader performance is to gain a comprehensive understanding of the factors affecting the interaction between rock mass and the excavator during the excavation in a specific ground condition. In order that the interaction between the machine performance and the rock mass condition can be correctly evaluated, the excavatability of the rock mass must be considered, so the RMCC index is of high significance.

Table 5.1. Input parameters for RMCC system.

<table>
<tr><th>Parameters</th><th colspan="12">Ranges of Parameters</th></tr>
<tr><td>Uniaxial Compressive Strength (MPa)</td><td colspan="2">< 20</td><td colspan="3">20 – 40</td><td colspan="2">40 – 60</td><td colspan="3">60 – 120</td><td colspan="2">> 120</td></tr>
<tr><td>Rating</td><td colspan="2">30</td><td colspan="3">20</td><td colspan="2">10</td><td colspan="3">5</td><td colspan="2">0</td></tr>
<tr><td>Volumetric Joint Count (Joints/m³)</td><td colspan="2">> 150</td><td colspan="3">150 – 100</td><td colspan="2">100 – 75</td><td colspan="3">75 – 50</td><td colspan="2">< 50</td></tr>
<tr><td>Rating</td><td colspan="2">20*</td><td colspan="3">15</td><td colspan="2">10</td><td colspan="3">5</td><td colspan="2">1</td></tr>
<tr><td rowspan="4">Strike and dip of joints with reference to the tunnel axis</td><td colspan="6">Strike ⊥ to tunnel axis</td><td colspan="3" rowspan="2">Strike ‖ to tunnel axis</td><td colspan="3" rowspan="2">Strike Oblique to tunnel axis</td></tr>
<tr><td colspan="3">Drive with dip</td><td colspan="3">Drive against dip</td></tr>
<tr><td colspan="3">Dip (°)</td><td colspan="3">Dip (°)</td><td colspan="3">Dip (°)</td><td colspan="3">Dip (°)</td></tr>
<tr><td>0-30</td><td>30-60</td><td>60-90</td><td>0-30</td><td>30-60</td><td>60-90</td><td>0-30</td><td>30-60</td><td>60-90</td><td>0-30</td><td>30-60</td><td>60-90</td></tr>
<tr><td>Rating</td><td>3</td><td>10</td><td>5</td><td>7</td><td>20</td><td>3</td><td>5</td><td>20</td><td>10</td><td>5</td><td>20</td><td>10</td></tr>
<tr><td>Joint aperture</td><td colspan="2">Very open (>5 mm)</td><td colspan="3">Open (1 – 5 mm)</td><td colspan="2">Moderately open (0.1– 1 mm)</td><td colspan="3">Tight (< 0.1 mm)</td><td colspan="2">Hard cemented filling</td></tr>
<tr><td>Rating</td><td colspan="2">10</td><td colspan="3">8</td><td colspan="2">5</td><td colspan="3">2</td><td colspan="2">0</td></tr>
<tr><td>Cerchar Abrasivity Index</td><td colspan="2">< 0.5</td><td colspan="3">0.5 – 1</td><td colspan="2">1 – 2</td><td colspan="3">2 – 4</td><td colspan="2">> 4</td></tr>
<tr><td>Rating</td><td colspan="2">10</td><td colspan="3">8</td><td colspan="2">4</td><td colspan="3">1</td><td colspan="2">0</td></tr>
<tr><td>Ground water</td><td colspan="2">Flowing</td><td colspan="3">Dripping</td><td colspan="2">Wet</td><td colspan="3">Damp</td><td colspan="2">Dry</td></tr>
<tr><td>Rating</td><td colspan="2">10</td><td colspan="3">7</td><td colspan="2">5</td><td colspan="3">2</td><td colspan="2">0</td></tr>
</table>

* Always 20 points is rated for coal due to cleavage.

* The effect of clay is not applied.

Table 5.2. Rock Mass Cuttability Classification System for roadheaders.

Class	Rating	Cuttability
I	100 – 90	Very good
II	90 – 70	Good
III	70 – 40	Fair
IV	40 – 20	Poor
V	< 20	Very poor

In any excavation process, the strength of the excavated material is the most important feature affecting the function of the machine. It is obvious that the harder the rock, the more difficult the excavation. Uniaxial Compressive Strength (UCS) and Needle Penetration Index (NPI) tests were used to determine the strength of the rock to be excavated. Additionally, discontinuity effect is obvious in the case of host rocks having a higher UCS than coal since it takes more time and energy to overcome the large pieces of rock blocks. The number of the joins per cubic meter of the excavated rock as well as the strength of the excavated rock are considered paramount factors.

Furthermore, the shape of the rock block and its orientation with respect to the tunnel axis could be evaluated by the strike and dip of discontinuities. This parameter determines the effort needed to penetrate the rock. The excavation of rock blocks in the direction of joint dipping is easier than those dipping against it. Besides, the degree of abrasivity of the cut rock is in direct relation with the pick consumption rate and the cutting time. When the percentage of abrasive minerals is high, the excavator needs to pulverize the rock rather than cutting it. CAI was considered to evaluate the effect of abrasivity. Groundwater is another critical factor affecting the advance rate of roadheaders, especially when there is clay in the excavation route.

The classification system proposed in this study allows an index for coal and coal measure rocks excavated by roadheaders and provides a realistic insight into the effects of geological condition on performance of roadheaders. The cuttability classification system was applied over the proposed cuttability system gained in various geological conditions. The rapid application of the system can be achieved by empirical evaluation of the parameters.

Since the current performance prediction models include either the machine specification or rock mass properties, it is of high value to introduce a comprehensive prediction model that engages both the rock mass properties and roadheader specification (cutter head power).

6. STUDY AREAS AND GEOLOGY

Within the scope of the present dissertation, field studies were performed in seven coal mines in Türkiye. The name and the location of the investigated basins are presented in Figure 6.1 and Table 6.1. The aims of the study are to investigate and evaluate the performance of both transverse and axial type roadheaders.

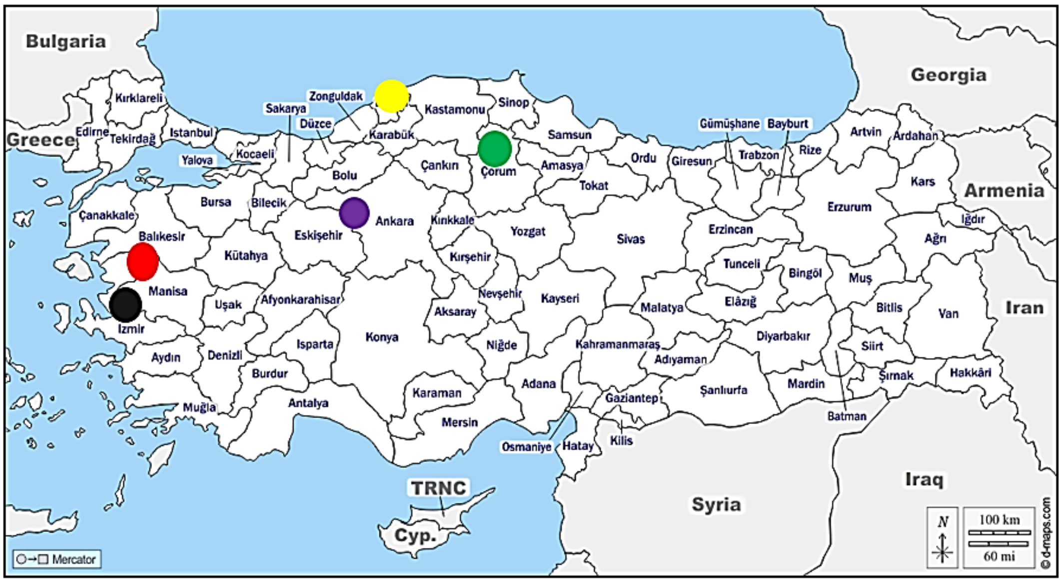


Figure 6.1. Studied coal basins.

Table 6.1. Study areas and the corresponding companies.

Mining Company	**Location**
İmbat and Demir Export	● (red) Soma/Manisa
Hattat	● (yellow) Amasra/Bartın
Park Termik and KİAŞ	● (purple) Çayırhan/ Ankara
YS	● (green) Dodurga/Çorum
Polyak	● (black) Kınık/Bergama

6.1. Soma Basin

The field studies in the Soma Basin were carried out in İmbat Mining, Demir Export Mining, and Polyak Mining Companies. The underground facilities and plants of the İmbat and Demir Export Mining Companies are located in the Eynez Village, Soma District. The underground facilities of Polyak Mining are established near Elmadere village, Kınık District.

In the Soma Basin, in a designated area with approximately 50 million ton reserve, İmbat Incorporated Company with a loyalty agreement, and, in an area with approximately 37 million ton reserve, Demir Export Incorporated Company with a service purchase contract are still operating.

Soma-Eynez Basin is located approximately 25 km from the Soma District of Manisa Province, 100 km northeast of İzmir and 50 km from the Aegean Coast. It is neighboring Eynez village in the southwest. The basin is reached by an 11 km asphalt road from the town of Cenkyeri located on the 16th km of the Soma-Bergama highway. This formation has gotten its name from the Soma District, where it can be best observed.

The Soma Basin containing economic lignite deposits in western Anatolia is a basin formed by tectonic events from Miocene to Quaternary Eras (Brinkmann and Feist, 1970; Nebert, 1978; İnci, 1998, 2002; Arpalıyiğit and İnci, 2000; İnci et al., 2003). In this basin, various geological units from Paleozoic to Recent are exposed. Generalized stratigraphic column section of the Soma Basin is illustrated in Figure 6.2.

In general, the basement of this basin is composed of Paleozoic graywacke and Mesozoic crystallized limestone, while the Neogene system includes different sedimentary rocks containing economic lignite levels that discordantly overlie the older basement. The stratigraphic sequence of rocks forming the Soma-Eynez Coal Basin from bottom to top can be divided as follows: (1) Pre-Neogene Units, (2) Neogene Units, and (3) Post-Neogene Units.

6.1.1. Pre-Neogene Rock Units

The basement, the oldest rock units of the region, consists of Paleozoic-aged graywacke, metamorphosed sandstone, schist, and conglomerates. There is lenticular and banded limestone among the Paleozoic rocks. Furthermore, Mesozoic units are represented by thick layered or massive limestone with a thickness of up to 400 m.

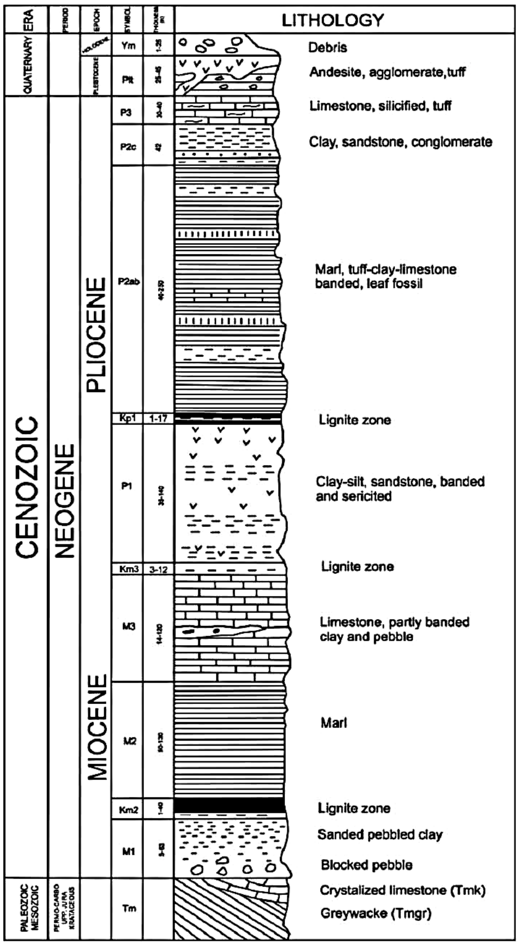


Figure 6.2. Generalized stratigraphic column section of the Soma Basin, Nebert (1978) modified by Gürsoy (1990).

6.1.2. Neogene Rock Units

The Neogene deposits containing lignite are divided into two series, lower series belonging to Miocene Era represented by M symbol and upper series belonging to Pliocene Era represented by P symbol in the Figure 6.2 (Nebert, 1978). The Neogene Units in the Soma Region are composed of two formations as the Soma Formation and Deniş Formation.

- **Soma Formation**

Considering the dominant sedimentary rock components, this formation is divided into three sub-units. The lower part of this formation is named basal series, which is predominantly composed of medium to well-hardened conglomerate and accompanies mudstone and sandstone alternations (Tekin, 2011), the middle part is greenish marl, and the upper part is composed of limestone. There are two separate economic coal veins in the formation. The lower vein is approximately 25-30 m thick and is located just above the basal series. The second vein is called the "middle vein". The thickness of the middle vein is between 10-12 meters and is located on top of the lacustrine limestone. Nebert (1978) classified the rock layers of the Soma Formation from bottom to top as:

1. Conglomerate-sandstone-claystone (M1)
2. Lower Lignite Level (KM2)
3. Marl (M2)
4. Limestone (M3)
5. Middle Lignite Level (KM3)

The operability in Lower Lignite Level (KM2) is limited to the upper half, most appropriately the upper two-thirds of the lignite horizon. The Lower Lignite Level is the vertical stretch of lignite veins from its subunit, M1. Therefore, there is no clear boundary between KM2 and M1 layers. Lignite veins are dominant in the middle and upper parts of the KM2 Layer. This level consists of thick and/or massive, mostly shiny and high-calorie, average 4000-5000 kcal, lignite. The quality of lignite declines, and the amount of clay increases in the lower parts of the KM2 Layer. At this level, there are bands of clay, lignite-stained clay, and marl in sizes from a few centimeters to meters (Gürsoy, 1990).

The Middle Lignite Level (KM3) is located in the upper part of the limestone levels. The lateral continuity of this level is limited. This situation indicates a discordance between the Pliocene and Miocene Periods and the interruptions due to the development of the marsh environment, albeit from time to time, during the formation of the coal. This unit is extremely low in quality and thickness compared to KM2 Coal Layer and has a very low calorie value.

- **Deniş Formation**

The Deniş Formation takes its name from the village of Deniş, located in the northern part of the Soma Neogene Region. As indicated in Figure 6.2, this unit, overlying the Soma Formation, is represented by the lithostratigraphic symbol of “P” (Pliocene) (Gürsoy, 1990). The Deniş Formation is exposed widely around the Soma Area and is represented by a volcano-sedimentary succession that was probably formed concurrently with the late Miocene volcanism. The total thickness of the unit is more than 600 m. While the Soma and Deniş Formations are separated from each other by deposition unconformity, the Deniş Formation spreads over a much wider area than the Soma Formation. According to recent studies, the Soma and Deniş Formations are Miocene in age (İnci, 1998a, 1998b, 2002).

The rock units of this formation are divided into 6 series from bottom to top as (Nebert, 1978):

1. Sandstone-Siltstone- Clay Unit (P1)
2. Upper Lignite Horizon (KP1)
3. Clay-Tuff-Marl Unit (P2ab)
4. Clay-Sandstone-Conglomerate Unit (P2c)
5. Fine gravel (silica) limestone series (P3)
6. Tuff-agglomerate series (P4)

6.1.3. Post-Neogene Rock Units

Plio-Quaternary Rock Units and Alluviums can be considered three different units: Late Pliocene Kumköy Formation, Pleistocene Alluvial Fan Deposits, and Holocene Colluvial Apron and current fluvial deposits (İnci et al., 2003).

The Kumköy Formation consists of reddish conglomerate-sandstone, greenish mudstone, and pisolitic limestone. The unit is well observed on the Soma-Savaştepe road. Red conglomerate and sandstones are deposited in alluvial fan and fluvial channels, greenish mudstones are deposited in flood plains, and pisolitic limestone is deposited in very shallow carbonate lakes in the floodplain (Arpalıyiğit, 2004).

6.1.4. Kınık Basin

The Kınık Lignite Mine is located near Elmadere Village and is operated by Polyak Mining Company since 2014. The mine site is located in the Aegean Region, approximately 150 kilometers north of İzmir Province and approximately 9 kilometers southeast of Kınık. Consisting of one main roadway and two shafts, the facility is the deepest underground lignite mine in Türkiye.

Within the license area no 201100458, the preparation works for opening the entrance shaft with a length of approximately 3500 m and a useful cross section of 24 m² was started in 2014; furthermore, the preparation works for two wells of 800 m deep and 8 m net diameter have been started within the license area no 82015.

The Kınık Sequence is predominantly composed of lacustrine sediments at the bottom and volcanic rock units at the top. Figure 6.3 shows the geological map of the Kınık Area, and Figure 6.4 depicts a generalized stratigraphic column section of the rock units for the Kınık Basin.

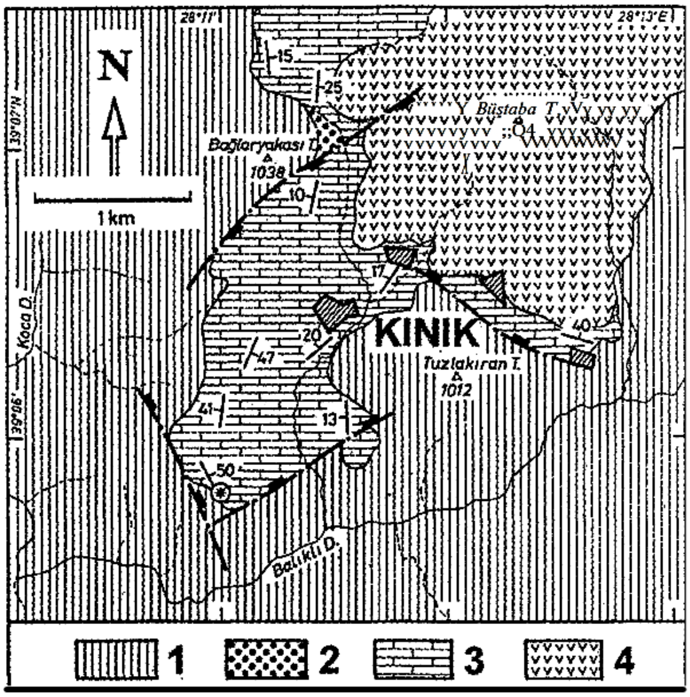


Figure 6.3. Geological map of the Kınık Region, 1: basement of Upper Cretaceaus, 2: basal conglomerate, 3: Küçükderbent Formation, 4: Sıdan Formation (Ünay and Göktaş, 2000).

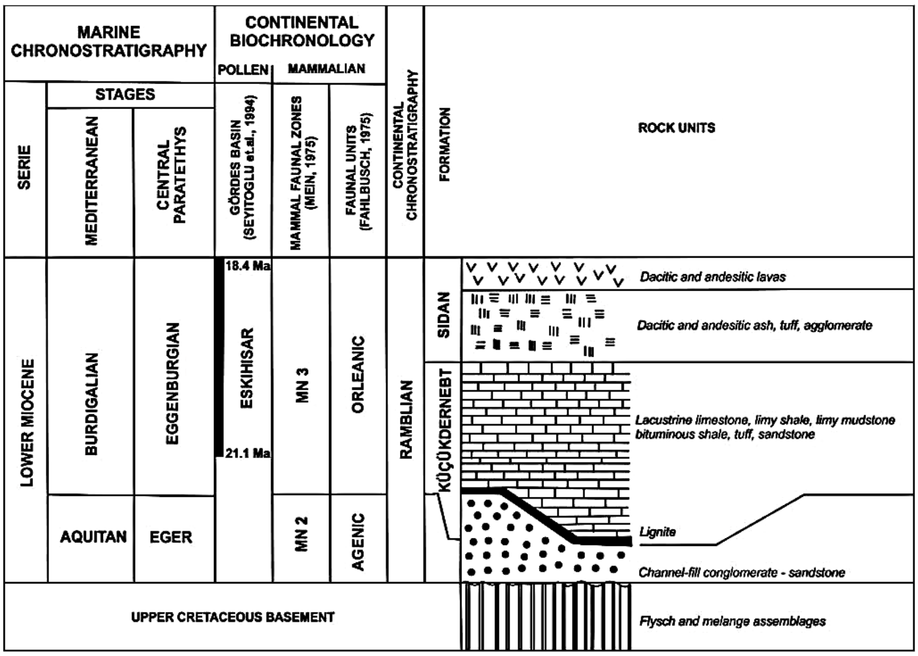


Figure 6.4. Generalized stratigraphic column section of the rock units of the Kınık Region (Ünay and Göktaş, 2000).

6.3. Çayırhan Basin

The Çayırhan Lignite Mine is located in Çayırhan town of Nallıhan district of Ankara province. The establishment is located on Ankara-Nallıhan road and is 122 km away from Ankara. A contract granting Park Termik Company the right to produce in this area for 20 years was signed on July 1th, 2000. Coal is now produced in this area by KİAŞ, Kömür şletmeleri Anonim Şirket, to which the exploitation right was given in 2020.

The Neogene Basin, extending from Beypazarı to Nallıhan, is surrounded on the north by a mountain belt forming the Western Pontides. The Neogene Sediments, formed in the middle-upper Miocene Era with a total thickness of 1200 m, expose widely between Nallıhan and Beypazarı (Yağmurlu, Helvacı, and İnci, 1988). In this region, two main coal seams can be distinguished. A third coal seam was found during the underground preparations in 1982. This seam is located 140–160 m below the existing seams. The generalized stratigraphic section of the Çayırhan Basin is presented in Figure 6.5.

The formation represented by M1 in Figure 6.5 includes the coal layers. In the upper part of the M1 formation, there is a silicified chalk layer with a thickness of approximately 5-6 m, under which there are two coal veins separated from each other by silty claystone. There is a layer of green claystone with a thickness of 7-8 m under the coal layer (Yağmurlu, Helvacı, and İnci, 1988).

The coal seam, which is in the shape of a bowl, is exposed on a slope created by the northern fault. The vein slope on the sides of the bowl ranges from 8º to 24º.The thickness of the coal seams in the basin varies between 1.0 and 2.25 m. The coal seam is roughly 1.52 m thick in the upper and 1.72 m thick in the lower part.

Furthermore, in the west of the field, the siltstone is 1.3 to 2.0 m thick while in the east part, the thickness of siltstone ranges from 0.5 to 0.8 m. In this basin, the color of coal is usually dark brown or black. It is of semi-bright and bright type, and its hardness is considered medium (Bilim, 2007).

Layer M2, the thickness of which ranges from 80 to 120 m, consists of clay, marl, and bituminous schist. Two layers of the thick bituminous shale are located in the upper and lower parts of the formation which are 20 m thick.

Formation M3 consists of two separate silicified limestone levels and layered cherts in the top and bottom and greenish claystone-chert alternations in the middle. The thickness of M3, which is the hardest formation, is between 30 to 35 m. Formation M4 is approximately 800 m thick and consists of red, green, beige, and gray colored tuffs.

The basin is tectonically under the influence of normal and reverse faults. When the region is considered as a whole, the results of effective tectonism and epeirogenic movements are evident. The region is characterized by faults and fold axes extending in the NE-SW direction (Kahraman, 2012).

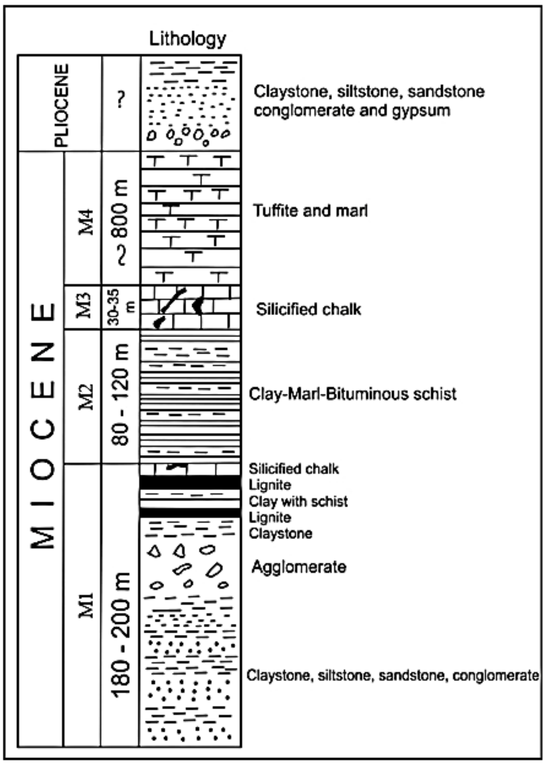


Figure 6.5. Stratigraphic column section of the Çayırhan basin (Aydın and Funfstuck, 1988).

6.4. Dodurga Basin

The investigated coal mine is located in Alpagut village of Dodurga district, 45 km north of Çorum province, and is operated by YS Mining Company. The general geology and the location of the area are presented in Figure 6.6.

Neogene-aged marine and lacustrine sedimentary coal basins have a wide distribution in Türkiye. One of those basins is the Miocene-aged lacustrine basin observed in different parts of Dodurga Region. Dodurga Formation representing the coal-bearing Neogene units in the area outcrops in seven regions stretched from the northeast to the southwest, namely Evlik, Kargı, İncesu, İkizler, Kumbaba, Alpagut, and Ayvaköy, respectively, where the coal mines are located. It is worth mentioning that İncesu is a continuation of Kargi region, and İkizler is a small field comparing to the other fields (Toprak, 1996). Figure 6.7 shows the reference sections for these regions. Dodurga formation consists of marl-clay alternation, and the economic coal seams are located at the base of the unit. The unit containing the coal sequence consists of an alternation of light green, cream colored marl and claystone. There is limestone sporadically emplaced in the intermediate layers.

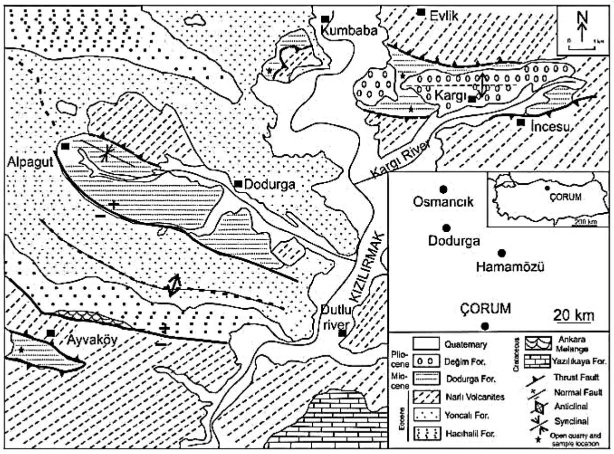


Figure 6.6. Geological map of the Dodurga Basin (Yalçın and Karslı, 1998).

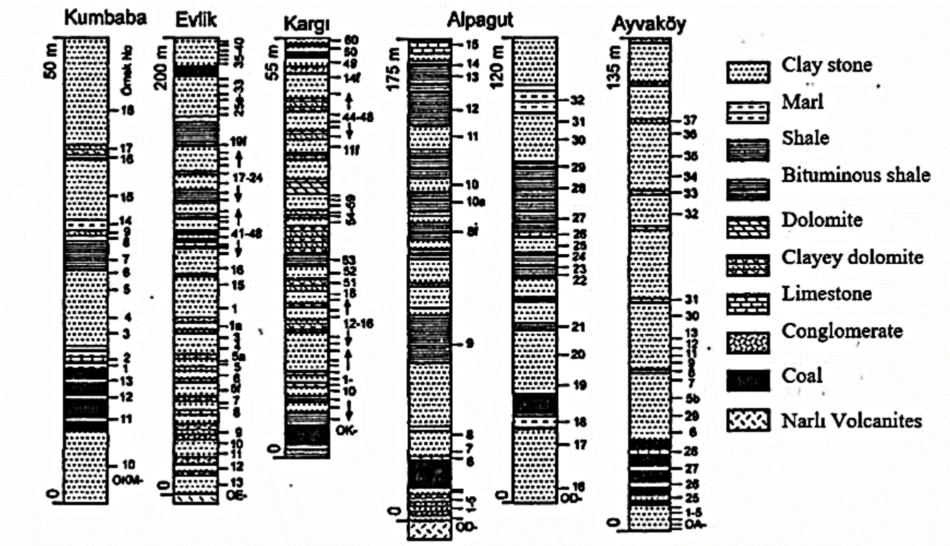


Figure 6.7. Reference sections of the Dodurga Formation (Yalçın and Karslı, 1998).

Alpagut-Dodurga Coal field is the most important coal basin in the area. The thickness of the Miocene-aged coal seams is around 13-15 m, and, generally, intense tectonic deformation effects are evident. Dodurga Formation has the widest spread in this region which contains the hardest and the best quality coal. In the coal seams, in conformity with the general characteristics of the basin, overturned folds, intra-layer folds and distortions, and synclines of varying scales are observed (Erik, Aslan and Büyüksaraç, 2018).

In the northeastern part of the coal mine, there is alternations of red-colored conglomerate and red-blue colored claystone. This layer, which is 1.5 m thick, consists of angular, poorly graded volcanic rock pebbles reaching a maximum diameter of 30 cm. This level is overlain by a coal-bearing zone with a thickness of 8.5 m, varying between less clayey lignite-lignite claystone. The layers starting with white dolomite over the coal zone continue with green, gray and black claystone with vegetation traces and Molluscan shells. In the upper parts, there is a level consisting of alternations of gray, green, black claystone, marl, shale, and bituminous shale, and it ends with yellowish, brown colored carbonate cherts of about 3 m thickness (Yalçın and Karslı, 1998).

6.5. Amasra Basin

The Amasra district is located within the borders of Bartın province and has an area of 50 km^2. The coal production area in the region is divided into two fields named A and B. The coal reserve in the field B and below the level of -400 m in the field A is operated by Hattat Mining Company. The generalized stratigraphic section of the area is presented in Figure 6.8. Coal bearing units in the area are covered by thick sediments developed in the Permian-Triassic-Eocene period range. The carbonate succession, which is very thick and widely distributed in the basin, gradually passes into fine-coarse-grained clastic in upper parts containing coal seams at various levels. This thick succession, which lasts until the Late Carboniferous period, includes coal-bearing formations in the region. In this basin, the units formed in Paleozoic Era belong to Carboniferous and Permian periods.

Yılanlı Formation is generally composed of dolomite, limestone and dolomitic limestone. Hydrocarbon traces are observed in this formation. The age of the formation, whose thickness can reach up to 1500 meters, is middle Devonian-Visean (Ünalan, 2010).

Clastic deposits containing coal overlie consistently the Yılanlı Formation at various levels. This clastic succession, which is defined and distinguished as coal-bearing formations in the region, consists of fine and coarse-grained clastic units which are lithologically alike. In the Western Black Sea Hard Coal Basin, the Carboniferous sequence containing coal is represented from bottom to top by the Alacaağzı, Kozlu, and Karadon Formation, respectively.

The Alacaağzı Formation generally consists of alternations of shale, siltstone, claystone, sandstone, and fine coal. Fine-grained clastic (shale, siltstone claystone) are the dominant lithology in the lower parts of the formation. These levels alternate with fine-grained sandstone layers. The grain size and ratio and the layer thickness of the sandstone increase towards the upper parts of the formation. In the uppermost part of the unit, there are coal seams alternating with relatively coarse-grained clastic (coarse grained sandstone and pebbly sandstone).

Kozlu Formation consists of conglomerate, sandstone, siltstone, claystone, and coal alteration. The bottom part of the Kozlu Formation, is represented by lacustrine deposits. The upper part, containing thick and laterally widespread coal seams, is represented by floodplain deposits. The Kozlu Formation is mainly composed of sandstone, gravel, conglomerate, and, to a lesser extent, coal, siltstone, claystone, and mudstone.

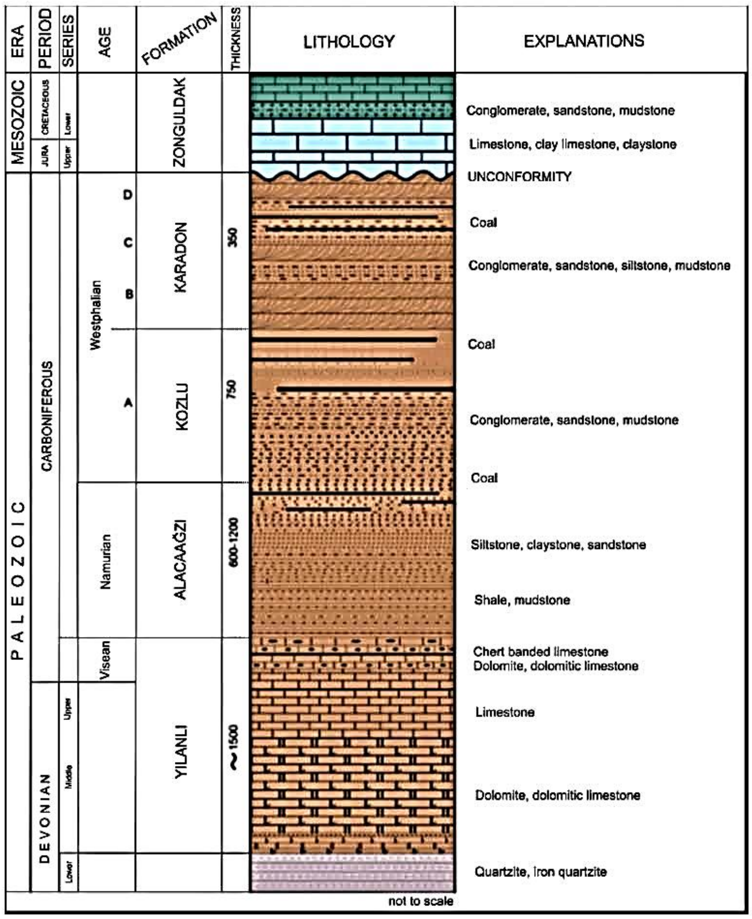


Figure 6.8. Generalized stratigraphic section of the Bartın Area (KANAR et al., 2019).

7. FIELD AND LABORATORY STUDIES

In-situ rock tests provide a realistic viewpoint on excavation condition and geological features of the excavated ground. Over a hundred number of field works were performed to specify roadheaders performance operating under various geological and operational conditions. The NCR of roadheaders was determined according to the actual time spent on excavation. Where it was possible and formation was hard enough, large rock blocks were sampled from excavation face to conduct basic rock mechanics tests. The uniaxial compressive strength of rock samples was determined in the laboratory. Smaller rock samples were collected to conduct Point Load Index (PLI) test, (Broch and Franklin, 1972), where the appropriate rock blocks were not available due to the brittleness of the rocks.

Moreover, because of the soft nature of coal measure rocks, the needle penetration index test, (Ulusay et al., 2013), was employed in-situ to determine the UCS of coal and surrounding soft rocks. This test is applicable to smooth rock surface in laboratory and on roadway face (Kahraman et al., 2019). The abrasivity of rocks was determined by the Cerchar Abrasivity Index test (ISRM, 2014). Data collected from performance measurements and laboratory tests were used to validate the RMCC index and to develop performance prediction models.

7.1. Field Studies

Field measurements mainly include evaluation of machine performance based on NCR and rock mass properties. In this dissertation, the following information was collected from each roadway:

- Rock mass data: Intact rock strength, abrasivity, discontinuity characteristics, and water condition.
- Machine related data: Machine characteristics and performance measurements.
- Operational data: Roadway inclination, operator experience, mucking system, and roadway cross-section.

7.1.1. Performance Measurements

Performance measurements for 52 axial type and 49 transverse type roadheaders were carried out in underground coal mines belonging to seven mining companies. Most of the measurements were carried out by attending the roadways before the machines start excavation, and the time spent on excavation, support installation, muck haulage, and delays due to various reasons were measured with the help of a chronometer and recorded on performance forms presented in Appendix 1. In addition to machine performance measurements made in the various mine galleries, some of the corresponding calculations of the measurements are presented in the performance forms. These forms contain data on excavation performances and Machine Utilization Time (MUT). The company names and the number of observations are given in Table 7.1.

Table 7.1. Company names and the number of measurements.

Roadheader type	Company name and location	Measurement number
Axial	Park Termik Mining, Çayırhan	15
	KİAŞ Mining, Çayırhan	17
	İmbat Mining, Soma	7
	YS Mining, Dodurga	7
	Polyak Mining, Bergama	6
Transverse	İmbat Mining, Soma	24
	Demir Export Mining, Soma	3
	Polyak Mining, Bergama	19
	Hattat Mining, Amasra	3

The Net Cutting Rates (NCR) were determined during the excavations. When the excavation was completed, the total volume of the excavated rock was found by multiplying the roadway cross sectional area by the length of the progress. NCR values in (m^3/h) were obtained by dividing the calculated excavation volume by the excavation time.

During the performance measurements, it was observed that the large blocks of rock had to be broken to be gathered by loaders and transported by the conveyor. In most cases, to obviate the blockage of conveyor and stoppage in process, big rock blocks were broken with the help of hydraulic hammers. The stoppages due to rock block breakage were subtracted from the total excavation time.

7.1.2. Sampling

During the excavation of the formations that were expected to be cored, block samples were taken to conduct UCS and CAI tests. Some samples with high clay content taken for getting cores were broken down during the coring. It is worth mentioning that the samples were not taken in a systematic manner, for in most of the cases, the formation along the roadway route was not changed during the field investigation, and taking samples representing the strength and discontinuity properties of the excavated formation was thought to be enough.

7.1.3. Discontinuity Measurements

During the performance measurements, discontinuity measurements were made on the roadway faces. Joint measurements were performed to determine the strike and dip of discontinuities and the volumetric joint counts. In addition, block samples were taken to measure joint aperture in the laboratory. The number of main joint sets was specified with a steel tapeline. Despite being irregular in pattern or geometry, due to the sedimentary nature of the excavated rocks, the dominant discontinuity pattern and the gradient of the layers remained stable during the operations in most of the cases. In general, the roadway faces were divided by more than one set of joins, and the overall gradient of the discontinuities was determined based on the most dominant ones.

Here, it is worth mentioning the determination of J_v classes. Coal measure rocks often have weak or very weak strength. Although high-strength formations are encountered in some mines, it has been observed that they are mostly very fractured-cracked. As seen in Figure 7.1, more than half of the J_v values are below 150; these values belong to the measurements made during rock excavation. Due to the cleavage system in coal formations, the J_v value is more than 150 in coal and formations consisting of coal and clay/claystone. Even in faces made entirely of coal, the J_v value is around 1000 or greater. According to the experience, it can be said that there is not a major change in excavation performance when the J_v value is greater than 150. This point has been taken into account when determining the J_v classes. Since the J_v value is always more than 150, the J_v rating for excavation faces made entirely of coal is always considered to be 20 in RMCC system. Since the previously calculated J_v values for coal were always more than 150, the J_v values were not calculated for the later measurements.

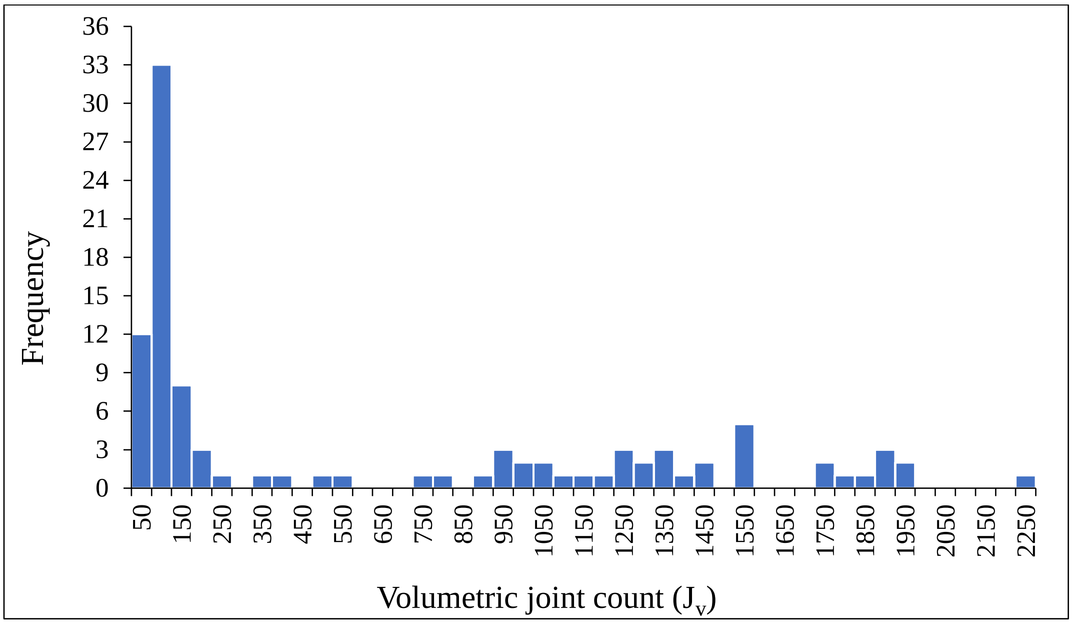


Figure 7.1. Histogram of volumetric joint count values.

By measuring the perpendicular distance between discontinuities in the main discontinuity sets, the joint spacing of the main discontinuity sets was determined on the roadway faces.

Coal typically has three primary cleavage planes that are aligned in three perpendicular orientations, as seen in Figure 7.2. The measurements of cleavage planes were conducted in the laboratory and under a microscope. It was observed that there is a very high number of discontinuities in coal due to the cleavage system. The red and green lines and the blue circles show three main discontinuity planes perpendicular to each other. The discontinuity planes perpendicular to the viewing direction of the photograph are shown by blue circles. As mentioned earlier, due to the soft nature of coal, and since there is a high number of discontinuities in micro scale, the complete value of 20 is assigned to coal formations in the RMCC table.

Nevertheless, host rocks of coal, mainly sandstone, claystone, and marl, have noticeable strength, and joint spacing of the main discontinuity sets in such rocks had found to have a great influence on NCR. Consequently, when the formation was composed of coal and other rock types, the effect of discontinuity spacing is considered in macro scale for both formations in order to involve the effect of this parameter in a realistic way. To do so, before the performance measurements were made, the main joint sets were determined on the tunnel face, and the number of joints for each joint set was measured at a certain distance in order to calculate the volumetric joint count (J_{v}). Then, the dip and strike of the determined joint sets were specified with the help of a compass.

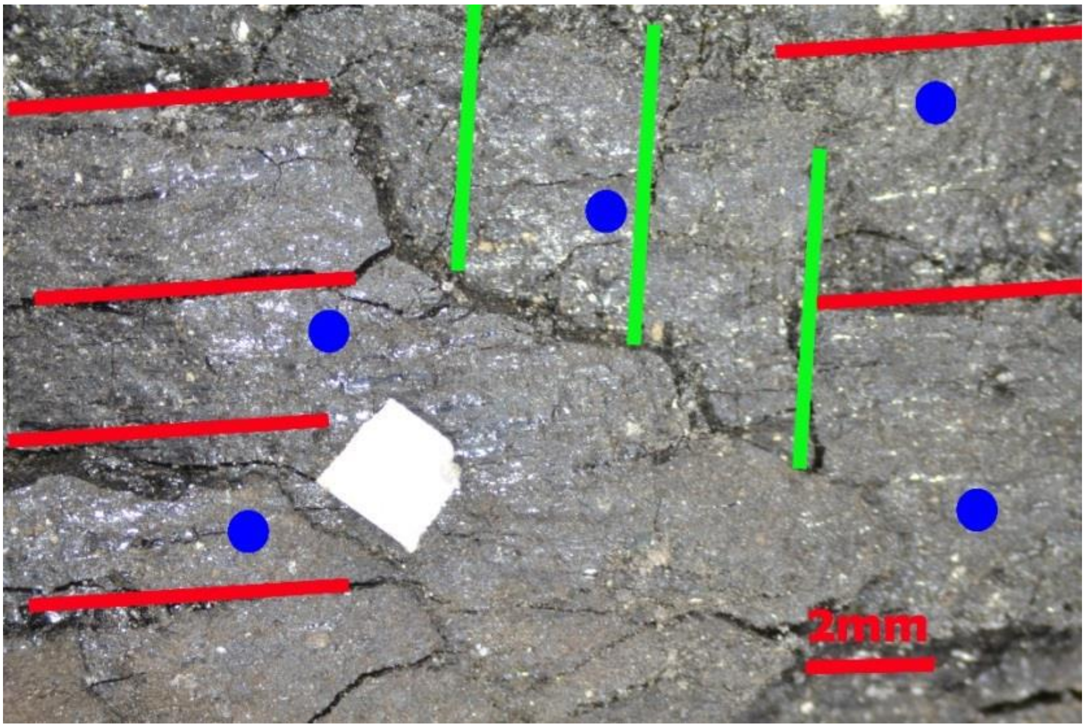


Figure 7.2. Cleavage planes in a coal sample.

The joint apertures were measured under a microscope, and it was tried to repeat the readings for at least three times at different intervals. The average value of the readings conducted on each coal and rock sample was considered as the final value. One of the scaled photographs taken from a rock samples and the associated aperture measurements are depicted in Figure 7.3.

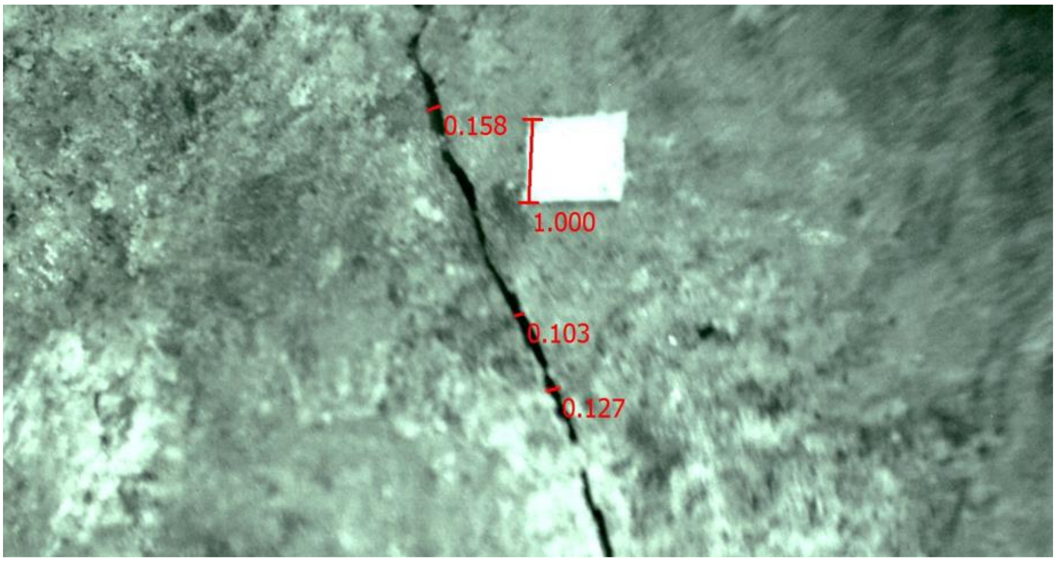


Figure 7.3. Aperture measurement.

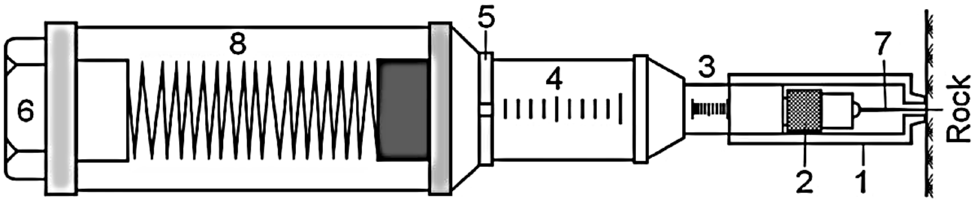
7.1.4. Needle Penetration Test

It is of great significance to specify the mechanical features of rocks prior to any excavation project. High-standard field studies and laboratory tests are necessary to provide an accurate assessment of the strength characteristics of rocks. The quality of the core samples prepared for the laboratory tests are really important in obtaining accurate strength features of the excavated rock. In this regard, two major challenges can be distinguished. First of all, high-quality and expensive equipment is needed to conduct such demanding tests in both the laboratory and field. Secondly, it is either very hard or impossible to gain suitable core samples to carry out laboratory tests. Hereof, some indirect test methods have been suggested to obtain strength properties of intact rock in which there is no need to conduct laboratory tests on rock samples of a certain size (ISRM, 2007). Needle penetration test is an indirect test suggested by the Rock Mechanics Committee of the Japan Society of Civil Engineers (JSCE-RMC, 1980). In this test, the UCS of rocks having a soft nature and the clay-bearing rocks can be indirectly predicted without a need for rock specimens of certain dimension. Needle Penetration Index (NPI) test can be conducted on both rock samples in the laboratory or rock exposures in the field. Figure 7.4 indicates the needle penetrometer. Needle penetrometer is manually pushed against the rock surface with a force up to 100 N. The needle must penetrate the rock surface perpendicularly. The maximum penetration depth is 10 mm. When either the maximum penetration load, 100 N, or maximum penetration depth, 10 mm, is achieved, the penetrometer must be slowly removed. The penetration depth and force are recorded. The result of the test is not influenced by the rate at which the needle penetrates the rock surface, so this test is a reliable indirect test to obtain the UCS of weak rocks. For each rock sample or surface being tested, the test must be performed three to five times. If the outcomes are unsatisfactory, test numbers should be increased. The penetration points must be spaced apart by at least 10 mm. The average values of readings are taken, and the NPI is calculated according to Eq. (26) and Eq. (27):

For D=10 mm and F $\leq$ 100 N, NPI=F/10 (26)

For F=100 N and D $\leq$ 10 mm, NPI=100/D (27)

Where, NPI is Needle Penetration Index (N/mm), F is the penetration force (N), and D is the penetration depth (mm).



Needle penetrometer: 1-presser, 2-chuck, 3-scale for penetration, 4-scale for load, 5-load indicator, 6-cap, 7-needle, and 8-spring

Figure 7.4. Needle penetration test device (Ulusay et al., 2013).

The UCS and NPI have a high correlation in weak rocks, according to studies conducted by several researchers (Ulusay and Ergurler, 2012; Erguler and Ulusay, 2007; Takahashi, Noto and Yokokawa, 1998; Yamaguchi et al., 1997).

The following formula was recommended to estimate the UCS of weak rocks from NPI value:

$UCS=0.402NPI^{0.929}$ (28)

Where, UCS is Uniaxial Compressive Strength (MPa) and NPI is Needle Penetration Index (N/mm).

To estimate the UCS of coal from NPI, Kahraman et al. (2021) derived the following formula:

$$UCS=0.35NPI \tag{29}$$

In this thesis, Eqs. (28) and (29) were employed for predicting the UCS of soft rocks and coal, respectively.

The Needle Penetration Test conducted in Çayırhan Basin is indicated in Figure 7.5. Special attention must be paid to the measurement point. If the needle penetration causes the rock surface to break and generate radial fractures around the tip of the device, as shown in Figure 7.6, the test results must be considered invalid; similarly, when the needle penetration occurs along weakness planes, the test results must be ignored. However, if such conditions are faced during the needle withdrawal, the test is considered valid (Ulusay and Erguler, 2012).

Figure 7.5. Needle penetration test.

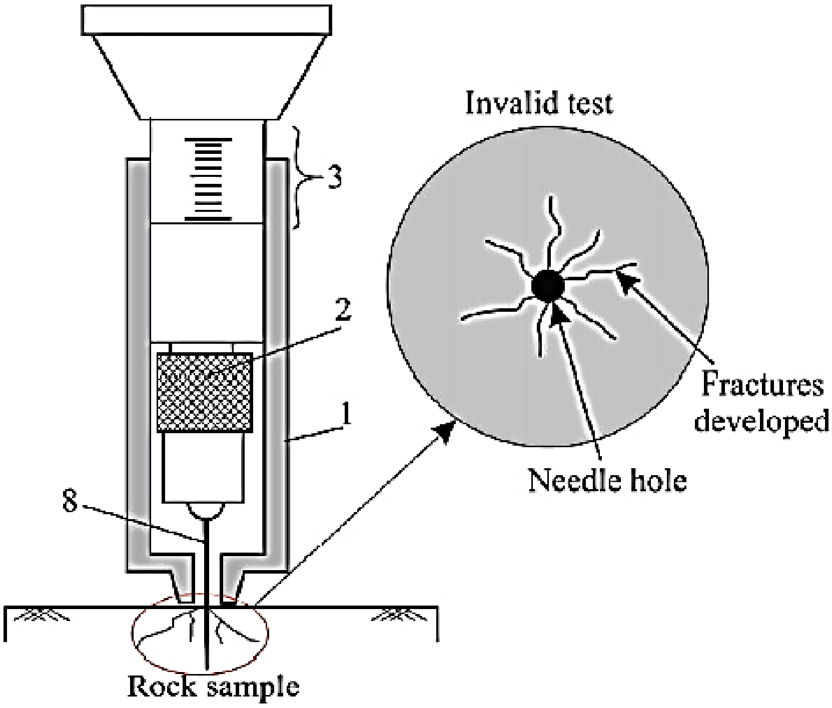


Figure 7.6. An unacceptable needle penetration index test (Ulusay and Erguler, 2012).

Needle penetration test is applicable to rocks with a UCS of up to 9.8 MPa (JSCE, 1991; JGS, 2012); however, Ulusay and Erguler (2012) suggested that this test can be used for rocks with a UCS of up to 20 MPa. In this study, the model SH-70 Needle Penetration Device, manufactured by Maruto Co. Ltd was employed. The main reasons why needle penetration test is practical and useful could be considered as follows:

- There is no need for sample preparation
- It is a non-destructive test
- It is easy and quick
- It could be conducted in both field and the laboratory
- The device is portable and light-weight

7.2. Laboratory Experiments

7.2.1. Uniaxial Compressive Strength Test

The UCS tests were conducted on NX-size core rock samples in accordance with ISRM (2007) standard test methods. Core samples were prepared with a length to diameter ratio of 2.5-3.0. The lower and upper ends of the specimens were cut and grounded. The side surfaces of the specimens were smooth, flat and free of any fractures and cracks. The experiments were carried out in the Rock Mechanics Laboratory of the Mining Engineering Department of Hacettepe University. It was tried to conduct at least five tests for each rock type. The UCS test device and core drilling machine are illustrated in Figure 7.7. The Uniaxial Compressive Strength (σ_c) is calculated from the following equation.

$$\sigma_c = \frac{F_{max}}{A} \tag{30}$$

Where, σ_c is the Uniaxial Compressive Strength of rock (MPa), F_{max} is the force at the failure (N), and A is the sample cross section (m^2). Some samples with high clay content were broken down during the process. In addition, samples with standard size could not be taken from some rocks, so size correction was applied to the UCS values of these samples.

Figure 7.7. Coring machine (a), core samples (b), hydraulic press (c), and the samples after the UCS test (d).

7.2.2. Point Load Strength Test

Point Load Index (PLI) tests were carried out on samples close to approximately prismatic in shape in rocks that were too hard to perform a needle penetration test and could not be cored due to discontinuities. The test was carried out in accordance with the suggested ISRM (1985) method. The tests were repeated at least twelve to thirteen times for each sample due to the high variability of the PLI results. Numerous empirical formulas are available to estimate the UCS value from the PLI. ISRM (1985) proposes to convert the PLI to the UCS value by multiplying it by 22. In the study conducted by Kahraman (2001), a value close to 22 was found between PLI and UCS for coal measure rocks. For this reason, the PLI values were multiplied by 22 and converted to the UCS values. Figure 7.8 illustrates some of the samples prepared for the Point Load Test. The UCS values obtained from the tests and estimated from the PLI values are given in Table 7.2.

Figure 7.8. Prepared samples for point load test.

Table 7.2. Results of Uniaxial Compressive Strength Test.

Company	Location	Date	Rock type	UCS (MPa)	Average UCS (MPa)
İmbat	Soma	13.07.2018	Marl	67.5, 60.6, 63.4, 57.2, 51.4	59.2
Hattat	Amasra	19.02.2019	Sandstone	44.8, 34.4, 56.2	44.8
Hattat	Amasra	19.02.2019	Schist	54.4, 52.2*, 55.6*, 53.2*	53.9
Hattat	Amasra	20.02.2019	Schist	56.6, 68.4	62.5
Hattat	Amasra	21.02.2019	Sandstone	46.5, 41.0, 27.8, 25.8	35.3
Park Termik	Çayırhan	28.02.2019	Silex	124.8*, 116.6*, 131.5*, 158.5*	132.8
Park Termik	Çayırhan	01.03.2019	Silex	143.9, 114.5, 101.7, 125.6, 153.26*, 142.29*,118.7*	128.6
Polyak	Soma	10.06.2021	Marl	23.6*, 26.4*, 28.6*, 30.1*, 26.2*, 17,1*	25.3
Polyak	Soma	11.06.2021	Marl	19.2*, 21.3*, 22.6*, 26.3*, 22.2*,16.3*	21.3
İmbat	Soma	03.10.2021	Marl	55.1, 58.3, 50.4, 58.3, 54.9, 57 55.1	55.6
İmbat	Soma	03.10.2021	Marl	62.2, 62.3, 54.7, 54.5, 58.2 58.63, 59.1, 59.4	58.6
İmbat	Soma	03.10.2021	Marl	59.2, 60.7, 63.6, 63.1, 66.3, 63.4 65.6, 61.7	62.9
İmbat	Soma	04.10.2021	Marl	60.2, 59.2, 65.3, 62.5, 65.8, 64.1, 63.4, 60.7	62.6
İmbat	Soma	04.10.2021	Marl	68.2, 65.2, 65.3, 60.4, 68.6, 67.8, 63.1, 62.8	65.2
İmbat	Soma	05.10.2021	Marl	65.3, 65.2, 69.8, 63.7, 63.6, 67.2, 61.2	65.1
İmbat	Soma	06.10.2021	Marl	69.7, 67.1, 68.2, 63.6, 67.5, 71.2 69.1, 66.4, 65.9	67.6
İmbat	Soma	18.10.2021	Marl	44.7, 42.5, 40.1, 41.3, 43.2, 45.1, 41.3, 42.8	42.6
İmbat	Soma	20.10.2021	Marl	49.2, 50.7, 42.3, 44.1, 45.9, 47.3 43.5, 48.3	46.4
İmbat	Soma	22.10.2021	Marl	34.8, 36.6, 39.6, 42.1, 39.3, 36.1 37.2, 40.2	38.2

* Estimated from point load strength.

7.2.3. Cerchar Abrasivity Index Test

When excavating abrasive and hard rocks, cutter wear is a main problem affecting the cost and time of the project. Predicting and evaluating the abrasiveness of the excavated rock contributes to any excavation project to a large extent. When the abrasive minerals in hard rocks get in contact with cutters, the cutters are worn or torn away. The quantity and type of constitutive minerals and the degree of bond strength between them are determinant in hardness and abrasiveness of any rock type. In order to specify the cutter wear in excavation as a result of cutter and rock contact, abrasion tests have been developed. Cerchar Abrasivity Index (CAI) test is one of the common tests for identifying the wear of cutters developed for coal mining applications in France. The CAI tests were performed in accordance with accepted test procedures suggested by ISRM (2014). Figure 7.9 shows Cerchar Abrasivity Test setup in the Laboratory of the Mining Engineering Department of Hacettepe University. Cerchar Abrasivity test results are presented in Table 7.3. The freshly fractured rock surfaces were prepared. To do so, with the help of a hammer various rock samples were prepared from rock blocks taken from investigated galleries. Then, a water-cooled diamond saw blade was used to cut block samples. The tests were performed by scratching pins of HRC 54-56 loaded with 70 N over a distance of 10 mm. A least five tests were carried out on each rock sample, using a new re-sharpened stylus for each test. No wear was observed in the coal and very soft samples with high clay content. The mean value of the measured wear diameters is calculated according to Eq. (31).

$$d=\frac{1}{10}\sum_{i=1}^{10} di \text{ (mm)} \tag{31}$$

Where, d is the mean pin wear (mm), and d_i is the wear flat diameter of the stylus in (1/10) mm. CAI value is attained by multiplying the measured wear flat value by 10.

$$CAI = d \times 10 \tag{32}$$

When the experiment is executed on saw-cut surface of the rock sample, the following correction is applied to the d parameter:

$$d= 1.14d_s \tag{33}$$

Figure 7.9. Cerchar Abrasivity Test setup.

Table 7.3. Cerchar Abrasivity Test results.

Company	Location	Date	Rock type	CAI	Average CAI
Hattat Mining	Amasra	19.02.2019	Sandstone	2.26, 1.87, 1.71, 1.87, 1.67	1.88
Hattat Mining	Amasra	20.02.2019	Sandstone	1.49, 1.52, 1.56, 1.51, 1.28, 1.41	1.46
Hattat Mining	Amasra	21.02.2019	Sandstone	1.23, 1.02, .98, 1.25, 1.12	1.12
Hattat Mining	Amasra	18.02.2019	Schist	0.71, 0.53, 0.67, 0.40, 0.94, 0.70	0.66
Hattat Mining	Amasra	19.02.2019	Schist	0.43, 1.00, 0.88, 0.67, 0.6	0.72
Hattat Mining	Amasra	20.02.2019	Schist	0.67, 0.57, 0.56, 0.74, 0.63	0.63
İmbat Mining	Soma	13.07.2018	Marl	0.75, 0.72, 0.63, 0.57, 0.80	0.69
Park Termik	Çayırhan	27.02.2019	Silex	1.32, 1.65, 1.23, 1.42, 1.62	1.45
Park Termik	Çayırhan	28.02.2019	Silex	1.36, 1.40, 1.39, 1.26, 1.40, 1.28, 1.19	1.33
Park Termik	Çayırhan	01.03.2019	Silex	2.43, 2.05, 1.96, 2.14, 2.53, 2.14, 2.0	2.18
Polyak	Bergama	25.11.2019	Marl	0.61, 1.01, 1.01, 0.75, 0.70, 0.52	0.77
Polyak	Bergama	25.11.2019	Marl	1.24, 0.84, 0.96, 0.82, 1.21, 1.16	1.04
Polyak	Bergama	26.11.2019	Marl	1.22, 0.75, 0.81, 1.68, 1.54, 0.92	1.15
Polyak	Bergama	26.11.2019	Marl	0.64, 1.00, 1.07, 0.86, 1.06, 0.71, 0.91, 0.68	0.87
Polyak	Bergama	27.11.2019	Marl	0.71, 1.40, 0.84, 0.96, 1.40, 0.72	1.01
Polyak	Bergama	27.11.2019	Marl	1.32, 2.98, 2.58, 1.88, 2.55, 1.29	2.16

7.3. Results of Field and Laboratory Measurements

NCR, cutter head power, RMCC index, and some other parameters obtained during the field investigations for axial type roadheaders are presented in Table 7.4. In this context, observations were made on machines with 75, 112, 160, and 200 kW cutting head powers. In these investigations, the NCR values varied between 5.5 and 50.4 m^3/h. RMCC index values vary between 26 and 98. Details of performance measurements for all fields are presented in Appendix 1. Appendix 2 contains NPI test results. Discontinuity measurements are presented in Appendix 3. RMCC tables and the associated rating values are included in Appendix 4 of the thesis.

Table 7.4. Performance data and other information on axial type machines.

No.	**Company**	**NCR (m^3/h)**	**P (kW)**	**RMCC index**	**OP (year)**	**Machine age (year)**	**Company Experience (year)**	**Gallery inclination (°)**	**Gallery cross section (m^2)**
1	Park Termik	24.0	112	74	4	30	20	-2	24.0
2	Park Termik	29.3	112	81	3	30	20	-2	22.0
3	Park Termik	13.5	112	62	3	30	20	-3	18.0
4	Park Termik	28.3	112	73	7	30	20	1	22.0
5	Park Termik	15.3	112	64	2	30	20	-7	20.4
6	Park Termik	19.6	112	66	3	30	20	-5	20.0
7	Park Termik	29.5	112	72	7	30	20	-15	20.0
8	Park Termik	24.0	112	72	3	30	20	-15	20.0
9	Park Termik	24.9	112	72	3	30	20	-15	20.0
10	Park Termik	14.5	112	49	4	30	20	-15	16.7
11	Park Termik	14.1	112	51	4	30	20	-15	16.7
12	Park Termik	19.6	112	47	4	30	20	-15	16.7
13	Park Termik	20.5	112	47	4	30	20	-15	16.7
14	Park Termik	15.5	112	51	3	30	20	-15	16.7
15	Park Termik	15.0	112	51	3	30	20	-15	16.7
16	KİAŞ	37.1	112	88	6	32	20	-1.5	23.5
17	KİAŞ	35.3	112	88	6	32	20	-1.5	23.5
18	KİAŞ	38.1	112	88	6	32	20	-1.5	23.5

Continuing from Table 7.4.

19	KİAŞ	35.3	112	88	6	32	20	-1.5	23.5
20	KİAŞ	35.3	112	88	6	32	20	-1.5	23.5
21	KİAŞ	36.2	112	88	6	32	20	-1.5	23.5
22	KİAŞ	47.0	112	95	7	32	20	-2.5	23.5
23	KİAŞ	40.3	112	95	7	32	20	-2.5	23.5
24	KİAŞ	47.0	112	95	7	32	20	-2.5	23.5
25	KİAŞ	48.6	112	95	7	32	20	-2.5	23.5
26	KİAŞ	47.0	112	98	7	32	20	-2.5	23.5
27	KİAŞ	44.1	112	98	7	32	20	-2.5	23.5
28	KİAŞ	50.4	112	98	7	32	20	-2.5	23.5
29	KİAŞ	50.4	112	98	7	32	20	-2.5	23.5
30	KİAŞ	28.2	112	80	6	32	20	-1.5	23.5
31	KİAŞ	27.1	112	80	6	32	20	-1.5	23.5
32	KİAŞ	27.1	112	80	6	32	20	-1.5	23.5
33	YS Mining	6.4	75	65	0.5	5	2	-18	12.0
34	YS Mining	6.4	75	67	0.5	5	2	-18	12.0
35	YS Mining	7.2	75	62	0.5	5	2	-14	12.0
36	YS Mining	8.2	75	67	0.5	5	2	-14	12.0
37	YS Mining	8.0	75	62	0.5	5	2	-17	12.0
38	YS Mining	6.1	75	57	0.5	5	2	-17	12.0
39	YS Mining	7.8	75	57	0.5	5	2	0	12.0
40	Polyak	13.3	160	35	23	5	3	4	23.0
41	Polyak	10.2	160	26	23	5	3	4	23.0
42	Polyak	16.3	160	46	23	5	3	4	23.0
43	Polyak	14.4	160	40	23	5	3	4	23.0
44	Polyak	12.1	160	33	23	5	3	4	23.0
45	Polyak	14.7	160	39	23	5	3	4	23.0
46	İmbat	5.5	200	33	3	1	15	4	22.0
47	İmbat	5.8	200	33	5	1	15	4	22.0
48	İmbat	5.7	200	28	3	1	15	4	22.0
49	İmbat	6.3	200	28	5	1	15	4	22.0
50	İmbat	5.5	200	28	3	1	15	4	22.0
51	İmbat	5.6	200	30	3	1	15	4	22.0
52	İmbat	5.7	200	30	3	1	15	4	22.0

Data belonging to transverse type roadheaders are given in Table 7.5. As it is evident, measurements were made on machines with cutting head powers of 100, 132, and 160 kW. In these measurements, NCR values were observed to vary between 4.0 and 44.8 m^3/h. RMCC index values vary between 27 and 90.

Table 7.5. Performance data and other information on transverse type machines.

No.	Company	NCR (m^3/h)	P (kW)	RMCC index	OP (year)	Machine age (year)	Company Experience (year)	Gallery inclination (°)	Gallery cross section (m^2)
1	İmbat	22.3	100	86	3	39	15	1	16.4
2	İmbat	13.6	100	73	2	39	15	3	16.4
3	İmbat	16.8	100	75	6	39	15	-2	16.4
4	İmbat	11.8	100	63	3	39	15	19	16.4
5	İmbat	9.2	100	38	3	39	15	3	24.0
6	İmbat	15.4	132	73	3	39	15	15	16.4
7	İmbat	15.4	100	75	2	39	15	1	16.4
8	İmbat	13.6	132	73	3	39	15	15	16.4
9	Demir Export	15.3	100	87	5	12	5	2	19.9
10	Demir Export	12.0	100	87	5	12	5	2	19.9
11	Demir Export	18.0	100	90	5	12	5	2	19.9
12	Hattat	44.8	160	46	5	5	4	-8	28.0
13	Hattat	12.0	160	32	5	5	4	-8	28.0
14	Hattat	9.9	160	27	5	5	4	-8	28.0
15	İmbat	13.4	132	74	6	39	15	-12	16.0
16	İmbat	12.9	132	74	6	39	15	-12	16.0
17	İmbat	14.0	100	72	6	39	15	-6	14.0
18	İmbat	14.7	100	72	6	39	15	-6	14.0
19	İmbat	16.8	100	69	6	39	15	-6	14.0
20	İmbat	15.3	132	74	6	39	15	-12	16.0
21	İmbat	13.2	132	77	6	39	15	-12	16.0
22	İmbat	12.0	132	74	6	39	15	-12	16.0
23	İmbat	15.1	100	69	6	39	15	-6	14.0
24	İmbat	15.9	100	72	6	39	15	0	14.0
25	İmbat	15.5	100	69	6	39	15	0	14.0
26	İmbat	13.4	100	69	6	39	15	0	14.0

Continuing from Table 7.5

27	İmbat	13.1	100	72	6	39	15	0	14.0
28	İmbat	5.5	100	33	3	39	15	4	22.0
29	İmbat	4.4	100	36	3	39	15	4	22.0
30	İmbat	4.0	100	42	3	39	15	4	22.0
31	Polyak	17.8	132	65	15	5	1	3.5	23.0
32	Polyak	19.2	132	69	15	5	1	3.5	23.0
33	Polyak	16.9	132	68	15	5	1	3.5	23.0
34	Polyak	23.0	132	77	15	5	1	3.5	23.0
35	Polyak	20.8	132	79	3	7	3	10	24.0
36	Polyak	28.2	132	84	3	7	3	7	24.0
37	Polyak	27.0	132	84	4	7	3	7	24.0
38	Polyak	36.0	132	90	4	7	3	7	24.0
39	Polyak	33.2	132	90	3	7	3	7	24.0
40	Polyak	28.2	132	84	4	7	3	7	24.0
41	Polyak	36.0	132	90	4	7	3	7	24.0
42	Polyak	32.7	132	90	2	7	3	7	24.0
43	Polyak	24.0	132	76	2	7	3	10	24.0
44	Polyak	22.5	132	77	4	7	3	10	24.0
45	Polyak	25.1	132	74	2	7	3	10	24.0
46	Polyak	20.8	132	72	15	5	1	3.5	23.0
47	Polyak	17.1	132	65	3	7	3	10	24.0
48	Polyak	18.0	132	66	2	7	3	10	24.0
49	Polyak	19.6	132	71	3	7	3	10	24.0

7.3.1. Field Investigation in Çayırhan Basin

Field investigations in the Çayırhan Basin were carried out in two fields, namely H and J. Technical characteristics of roadheaders operating in the Çayırhan region is presented in Table 7.6. The performance of axial type roadheaders with 112 kW cutter head power was measured in 32 different locations under different geological conditions. Seventeen numbers of the measurements were conducted in coal, nine numbers were made during rock excavation, and six numbers were carried out in formations composed of coal and the host rocks. Before starting the excavation, the NPI tests were conducted at a minimum 10 different points on the excavation face. It was tried to conduct the NPI tests in such a way that the obtained values represent the whole formation as much as possible. The measurements for the inaccessible parts of the tunnel face were performed on rock block samples. In addition, the final values for RMCC index were calculated considering the percentage of the each formation on the excavated tunnel face. For example, in faces consisting of 40% coal and 60% hard rock, the final value for RMCC index is obtained by applying the corresponding percentage on the RMCC index value for each formation and summation of the results.

Table 7.6. Machine specifications in Park Termik and KİAŞ Mining Companies.

Machine specification	Roadheader type		
	Dosco MK2a	Dosco MK2b	Modified machine
Weight (ton)	23.4	44	35
Cutter type	Axial	Axial	Axial
Cutter head power (kW)	67	112	112
Cutter number	24	24	24
Excavation section (m^2)	23.5	31	24.2
Total power of the electric units (kW)	150	224	-
Power of hydraulic motor (kW)	56	112	15
Power of loading motors (kW)	55	-	-

It is a hard task to detect and measure joint sets in underground conditions. Various factors such as lack of illumination, irregular shape of the tunnel face, safety issues, and support system on the roadway face make the measurement process difficult. However, a big effort was made to determine the number of the main joint sets as accurate as possible on each roadway face. Then, the dip and strike of the main joint sets were determined. The number of joints in a certain distance for each joint set was measured with the help of a steel tapeline. Where the tunnel face consisted of coal and other rock types, the measurements were carried out separately for each formation. The joint measurement values were used to calculate the J_v parameter.

The first fifteen measurements were carried out in Park Termik Mining Company. For this set of data, the NCR changes between 13.5 and 29.5 (m^3/h), which was mainly measured in coal+clay and clay formations. It can be seen that despite the soft nature of coal and clay, the lowest NCR value was observed in this formation, which shows the importance of the other operational and technical parameters in the excavation process. On the other hand, the highest value for NCR belongs to clay with 29.5 m^3/h. NPI values change between 7.6 and 29.8 (N/mm). Due to the cleavage system in coal and the high number of discontinuities, J_v parameter was not measured for coal, and a total value of 20 was assigned for tunnel faces consisting of coal. J_v was determined for other formations, and a weighted value was calculated for formations composed of coal and other rock types.

Seventeen numbers of measurements in Çayırhan Basin were conducted after the coal mine operational right was taken by KİAŞ Company. The excavated formation during the field investigations consisted of coal. Due to the favorable condition of the investigated roadways, from operational and geological point of view, the highest values of NCR were obtained during these inspections. NCR changed between 27.1 and 50.4 m^3/h. Since the tunnel face was completely composed of coal, discontinuity measurements were not conducted. NPI values showed a relatively constant trend with the highest value of 7.3 N/mm.

RMCC index values for the first fifteen measurements, conducted in Park Termik Company, vary between 47 and 81, which were made in clay+silex and coal+clay formations, respectively. In the second set of data, related to the investigations conducted in KİAŞ Company, NCR changed between 35.3 and 50.4 m^3/h. RMCC index values are high and have a minimum value of 80 and a maximum value of 98.

7.3.2. Field Investigation in Dodurga Basin

The performance measurements and field investigations were carried out in the Dodurga Mine operated by YS Mining around Alpagut village of Dodurga district of Çorum province. The roadheader employed in this region was produced by XCMG Company for use in coal mines and has the ability to excavate in rocks with the strength of up to 50 MPa. The technical characteristics of this machine are presented in Table 7.7.

In the Dodurga Basin, seven measurements were conducted in a roadway composed of clay excavated by an axial type roadheader. Due to the soft formation of clay, there was no need to obtain block samples to perform the UCS test. NPI values showed a wide range, changing from 38.5 to 89.7 N/mm. Volumetric joint count varies from 117.0 to 192.5 Joints/m^3.

For this field, NCR values changes from 6.4 m^3/h to 7.8 m^3/h. The low values of NCR can be due to the loose nature of clay, high inclination of the roadway, low cutter head power, and low experience of the operator. High amount of dust was generated since the excavation was performed in a completely dry condition. RMCC index value ranges between 57 and 67 m^3/h.

Table 7.7. Machine specifications in YS Mining Company.

Machine specification	Roadheader-EBZ75
Weight (ton)	23
Cuter type	Axial
Cutter head power (kW)	75
Cutter number	36
Excavation section (m^2)	17
Maximum conveyor capacity (m^3/h)	60
Total power of electric units (kW)	132
Power of hydraulic motor (kW)	55

7.3.3. Field Investigation in Soma Basin (İmbat Mining Company)

Performance measurements were conducted in roadways excavated by transverse type roadheaders (ATM50, AM 65P) having cutter head powers of 100 and 132 kW and an axial type roadheader (EBZ 200H) with 200 kW cutter head power. Alpine Tunnel Miner ATM50 is a very robust and versatile roadheader and is categorized in the small-light roadheader class. This machine can be used in a variety of applications in the mining and tunneling industries, such as water tunnel, road tunnel, and special underground storage openings. The technical features of ATM50 roadheader employed by İmbat Mining Company have been changed, and the cutter head power was reduced from 132 kW to 100 kW in some roadways.

Alpine Miner AM65 P is classified in the medium class roadheader group. This excavator shows good performance due to its weight and high engine capacity. However, the cutting head power of this machine in İmbat Mining has changed to 132 kW in some roadways. Technical characteristics of the roadheaders employed by İmbat Mining is given in Table 7.8.

Table 7.8. Machine specifications in İmbat Mining Company.

Machine specification	Roadheader type		
	ATM50	EBZ 200H	AM 65P
Weight (ton)	32	86 (including dust and suppression units)	40
Cutter head power (kW)	100/132	200	175
Cutter type	Transverse	Axial	Transverse
Cutter number	90	90	90
Excavation section (m^2)	21.4	32	32
Maximum conveyor capacity (m^3/h)	250	300	300
Total power of electric units (kW)	216.5	384	300
Power of hydraulic motor (kW)	22	132 (including dust and suppression units)	70
Power of loading motors (kW)	44	-	55

A total number of 23 field measurements were performed in the Soma Basin, İmbat Mining Company. Seven numbers of the field measurements were carried out in roadways excavated by an axial type roadheader with 200 kW cutter head power. The excavations were performed in hard rock formation mainly composed of marl. NPI test could not be performed due to the hardness of the roadway face, so rock block samples were collected and UCS tests were carried out in the laboratory. For this field, NCR changes from 5.5 m^3/h to 6.3 m^3/h. The low NCR value is due to high UCS of the excavated rock varying between 58 MPa and 67 MPa. Volumetric joint count changes between 8.3 joint/m^3 and 15.33 joint/m^3. RMCC index value for this part of the tunnel ranges from 28 to 33, indicating that the roadheader had difficulty in excavating the hard rock. It can be seen that the low number of J_v and the hard rock formation resulted in low RMCC index values.

In İmbat Mining Company, 16 number of the measurements were conducted in the roadways that were being excavated by transverse type roadheaders. Thirteen numbers of the measurements were performed in coal formation, and three numbers in the roadways consisting of hard rock, mainly marl. UCS of coal and hard rock formations were determined by NPI and UCS tests, respectively. The minimum value of the NCR is 4.0 m^3/h specified in marl, and the maximum value is 16.8 m^3/h specified in coal. RMCC index values for coal change between 69 and 77 and for marl are 33, 36, and 42. NPI value ranges from 4.3 N/mm to 40.2 N/mm in coal. The volumetric joint count for the hard rock formation ranges from 8.3 joint/m^3 to 15.5 joint/m^3.

7.3.4. Field Investigation in Soma Basin (Demir Export Mining Company)

Field investigations in the Soma Basin (Demir Export Mining Company) were carried out in 4109 roadway. A transverse type roadheader (AM50) with 100 kW cutter head power was operating in this roadway. The technical characteristics of the roadheader AM50 are presented in Table 7.9. The formation consisted of coal, and three measurements were carried out in this field. Since the measurements were conducted in coal, J_v values have not been included in the calculations, and a total value of 20 is assigned for this formation in RMCC tables.

Table 7.9. Machine specifications in Demir Export Mining Company.

Machine specification	Roadheader type
	AM50
Weight (ton)	30
Cuter type	Transverse
Cutter head power (kW)	100
Cutter number	84
Excavation section (m^2)	19-20
Total power of electric units (kW)	166
Power of hydraulic motor (kW)	22
Power of conveyor motors (kW)	2×11
Power of crawler motors (kW)	2×11

7.3.5. Field Investigation in Amasra Basin

Field measurements in the Amasra Basin were conducted in 147.Connection roadway. Technical features of DH R60T roadheader employed in Hattat Mining Company are given in Table 7.10. The DH R60T roadheader is capable of excavating rocks with UCS of up to 100 MPa. Three measurements were conducted in this field. In the first two days, the formation consisted of clay, silt, and schist. As the excavation progressed, the formation got harder, and on the third day, 80% of the tunnel face was composed of hard formation, mainly sandstone. The roadheader was not able to make further progress in such condition due to high amounts of dust and vibration, and it was decided to change the excavation method to drill and blasting method. The highest value for NCR was obtained on the first day, and as the excavation continued, NCR and RMCC values decreased due to the hard formation. As mentioned earlier, the final values for the data were calculated considering the percentage of the formations on the roadway face. For instance, where the excavation face is composed of 60% coal and 40% sandstone, measurements are conducted separately for each formation, and the final value for each parameter is gained by multiplying the measured value by the corresponding percentage of the formation on the tunnel face.

Table 7.10. Roadheader specification used in Hattat Mining Company.

Machine specification	Roadheader- DH R60T
Weight (ton)	69
Cuter type	Transvers
Cutter head power (kW)	160
Cutter number	2×42
Excavation section (m^2)	14 -31 m^2
Maximum conveyor capacity (m^3/h)	350
Total power of electric units (kW)	305
Power of hydraulic motor (kW)	100

7.3.6. Field Investigation in Soma Basin (Polyak Mining Company)

Field investigations in Polyak-Eynez Mining Company were conducted in four roadways, namely 3305, CK1110, and 2304. Connection roadway, where transverse type roadheaders with 132 kW cutter head power were performing, and 2302-2 Roadway, where an axial type roadheader with 160 kW cutter head power was excavating. The technical characteristics of the machines employed in Polyak Mining Company are given in Tables 7.11 and 7.12. In this basin, 25 measurements were conducted, six of which were performed in a roadway excavated by an axial type roadheader and 19 of which in roadways excavated by transverse type roadheaders. Six measurements were conducted in the 2302-2 Roadway. The formation consisted of marl, which is considered a hard rock, with UCS of up to approximately 100 MPa. NCR changes between 10.2 and 16.3 m^3/h for this formation. RMCC index values are 26 and 46 for abovementioned NCR values. Volumetric joint count ranges between 55.6 and 307.5 joint/m^3 for this formation.

Table 7.11. Machine specification in Polyak Mining Company, transverse type roadheader.

Machine specification	Roadheader- IBS-SM130
Weight (ton)	35
Cutter head power (kW)	132
Cutter type	Transverse
Cutter number	2×45
Excavation section (m^2)	19.4
Maximum conveyor capacity (m^3/h)	110
Total power of electric units (kW)	207
Operating pressure (max.) (bar)	220
Power of conveyor motors (kW)	2×15

Table 7.12. Machine specification in Polyak Mining Company, axial type roadheader.

Machine specification	Roadheader- EBZ-160A
Weight (ton)	45
Cutter head power (kW)	160
Cutter type	Axial
Cutter number	42
Excavation section (m^2)	25-26
Maximum conveyor capacity (m^3/h)	204
Total power of electric units (kW)	235
Power of hydraulic motor (kW)	75

The measurements for transverse type roadheaders were carried out in three different roadways and formations. The formations were composed of soft rocks, schist, and coal in the 3305 Roadway, coal in CK1110 Roadway, and claystone and coal in the 2304 Connection Roadway. The highest NCR value was observed in coal, 36 m^3/h, and the lowest rate was recorded in formation consisting of schist and coal, 16.9 m^3/h. RMCC indices were found to be 90 and 60 for the highest and lowest NCRs, respectively. J_v measurements were carried out in schist and claystone. In order that the UCS can be determined, UCS and PLI tests were carried out in hard rock samples, and NPI tests were performed in soft formations.

8. VALIDATION OF THE NEW ROCK MASS CUTTABILITY CLASSIFICATION SYSTEM

An indication of the RMCC system's correctness will be a strong correlation between the NCR and RMCC index in the excavation of various formations for the same machine type. Therefore, the relationships between NCR and RMCC index are examined separately for axial and transverse type roadheaders.

Since the data obtained from galleries excavated by 75 and 200 kW axial type machines are very close to each other, a meaningful correlation was not found between the NCR and RMCC index values of these machines. However, exponential relationships with very strong correlation coefficients (R^2=0.88 and 0.97) were found for 112 and 160 kW axial type machines, Figures 8.1 and 8.2.

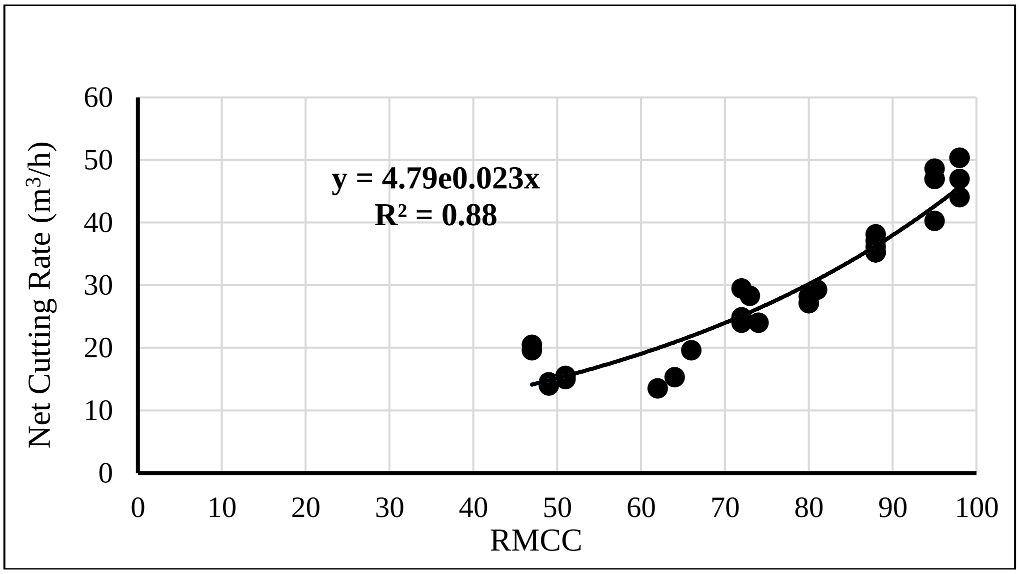


Figure 8.1. NCR versus RMCC index for 112kW axial roadheaders.

The extension and comparison of the curves in Figures 8.1 and 8.2 by extrapolation can be seen in Figure 8.3. As can be seen here, the trends of the two curves are similar. As it should be, the 160 kW machine has higher NCR values than the 112 kW machine at the same RMCC ratings. The equations and the correlation coefficients for axial type machines are as follows:

For 112 kW axial type roadheader $\quad NCR=4.79e^{0.023RMCC} \quad r = 0.94 \quad (34)$

For 160 kW axial type roadheader $\quad NCR=5.53e^{0.024RMCC} \quad r = 0.99 \quad (35)$

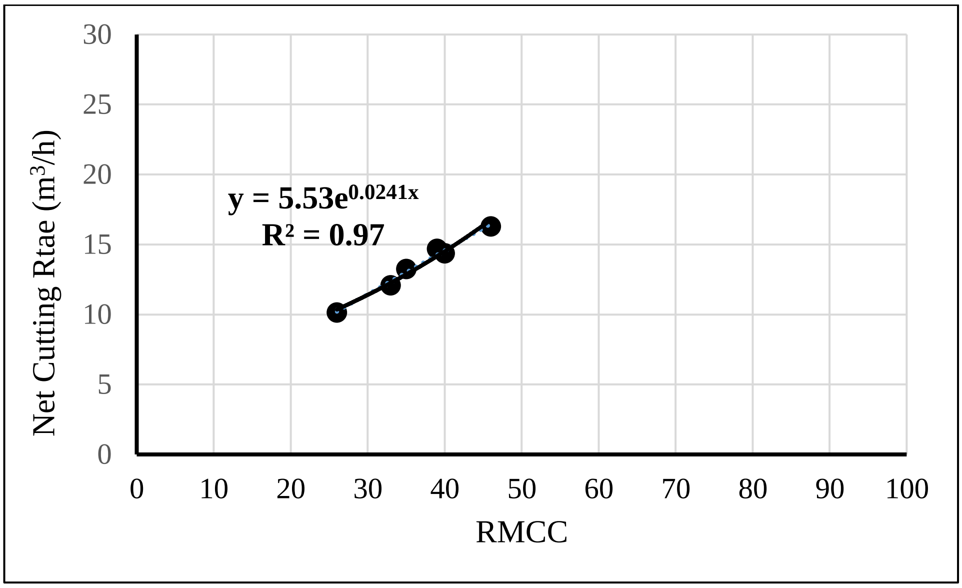


Figure 8.2. NCR against and RMCC index for 160kW axial type roadheaders.

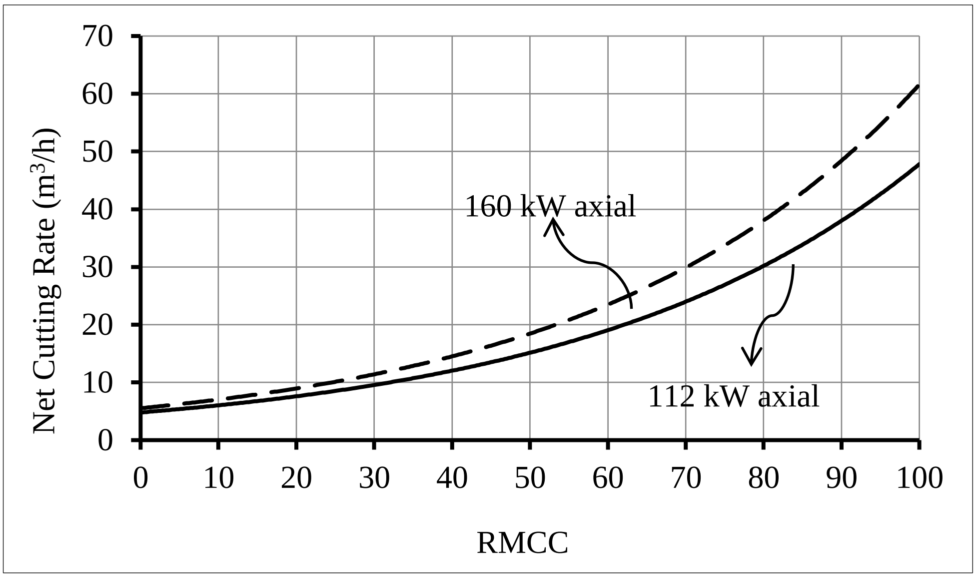


Figure 8.3. Comparison of NCR and RMCC index relations of 112 kW and 160 kW axial type roadheaders.

The correlation between NCR and RMCC index values for transverse type machine with 100 kW cutter head power is shown in Figure 8.4. Here, the data related to measurements obtained during the investigations in Demir Export Mining Company show a contradiction. The reason behind this could be the operator ability and different machine brands. Machines manufactured by different companies have different force transferring systems that can influence the performance of machines. However, it must be considered that the number of measurements in Demir Export Mining Company is low, and a realistic conclusion needs a higher number of measurements. When only the data related to İmbat Mining is taken into account, it is seen that there is a very strong exponential relationship between the two parameters.

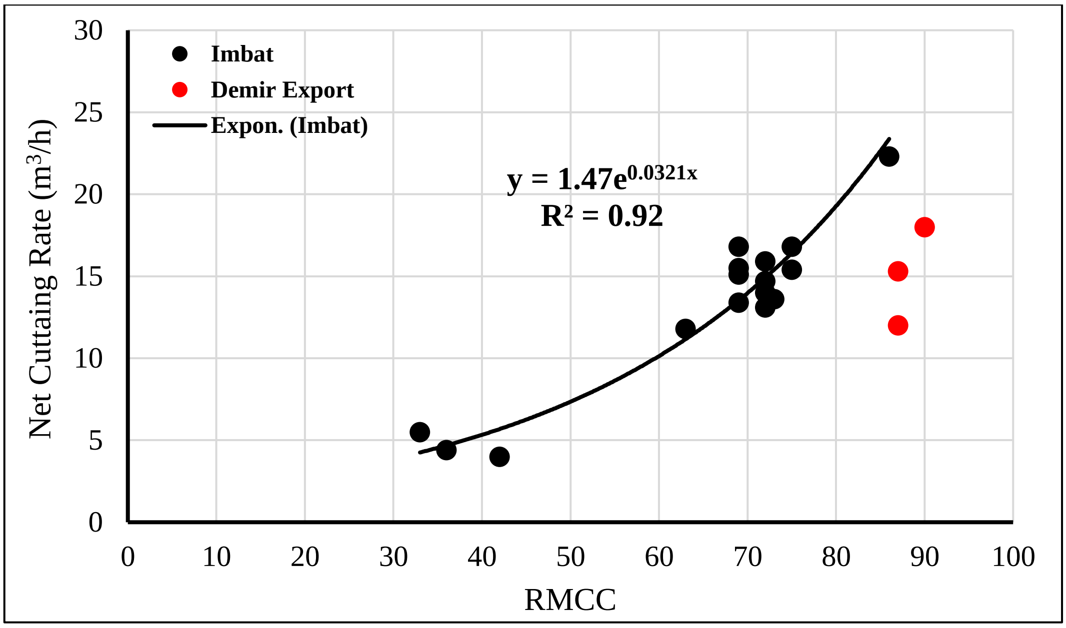


Figure 8.4. NCR against RMCC index for 100 kW transverse type roadheaders (Data marked in red show the outliers).

The correlation between NCR and RMCC index values for 132 kW transvers type machines is given in Figure 8.5. Here, İmbat data show contradiction. When İmbat data are not included, there is an exponential relationship with a very high correlation coefficient between the two parameters. The outlier data seen in Figures 8.4 and 8.5 are the data related to machines with different brands than the machines to which the compatible data belongs. Aforementioned, even if the machines of different companies have the same cutter head power, they may perform differently due to different power transmission systems. It is thought that the reason for the outliers stem from this reason. The highly correlated graphs of axial machines given in Figures 8.1 and 8.2 also belong to machines of the same brand.

In addition, during the last visit to İmbat Company, it was revealed that changes were made in the power transmission systems of very old (approximately 40 years old) 132 kW machines, to which the data showing contradictory in Figure 8.5 belong. The cutterhead power of 165 kW roadheaders were decreased to 132 kW in some roadways, and this makes the machines unable to show their real performance during the excavation. These changes can also have an impact on the appearance of the outliers.

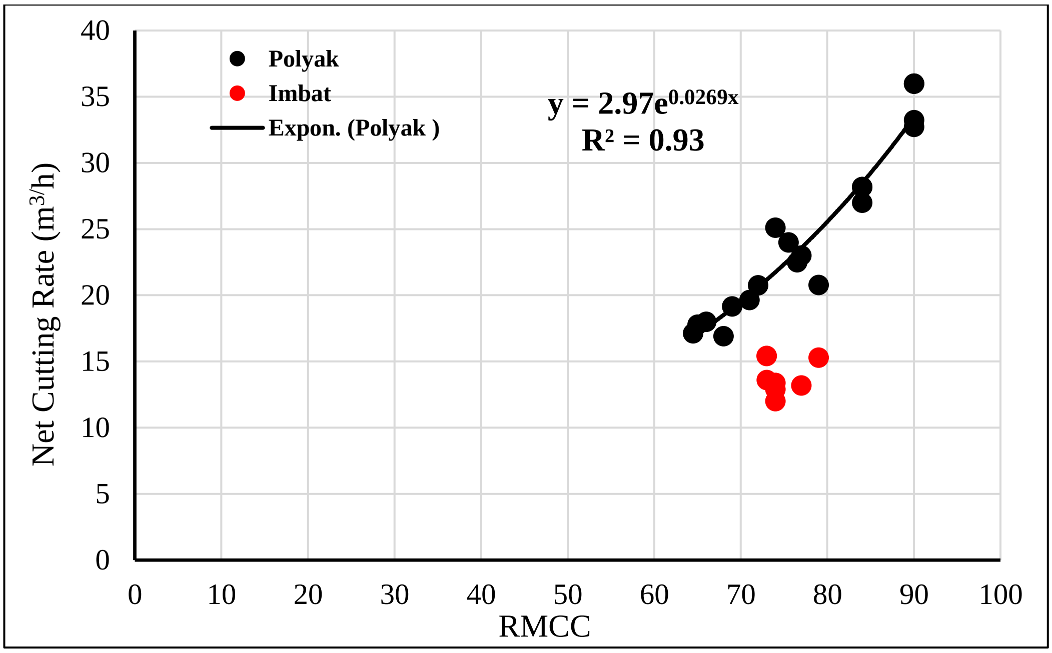


Figure 8.5. Relationship between NCR and RMCC index for 132 kW transverse type roadheader (Data marked in red show the outliers).

The extrapolation and comparison of the curves in Figures 8.4 and 8.5 are given in Figure 8.6. As the graph shows, both curves show similar trends. As expected, the 132 kW machine has higher NCR values than the 100 kW machine at the same RMCC ratings. The validity of the suggested RMCC system can be proved by establishing highly correlated relationships between RMCC index and NCR for both axial and transverse type roadheaders. However, the RMCC system may not be applicable to the excavatability classification of other rocks since it is based on measurements and observations of coal and coal bearing rocks. The equations and the correlation coefficients for transverse type machines are as follows:

For 100 kW transverse type roadheader $NCR=1.47e^{0.032RMCC}$ $r=0.96$ (36)

For 132 kW transverse type roadheader $NCR=2.97e^{0.027RMCC}$ $r = 0.96$ (37)

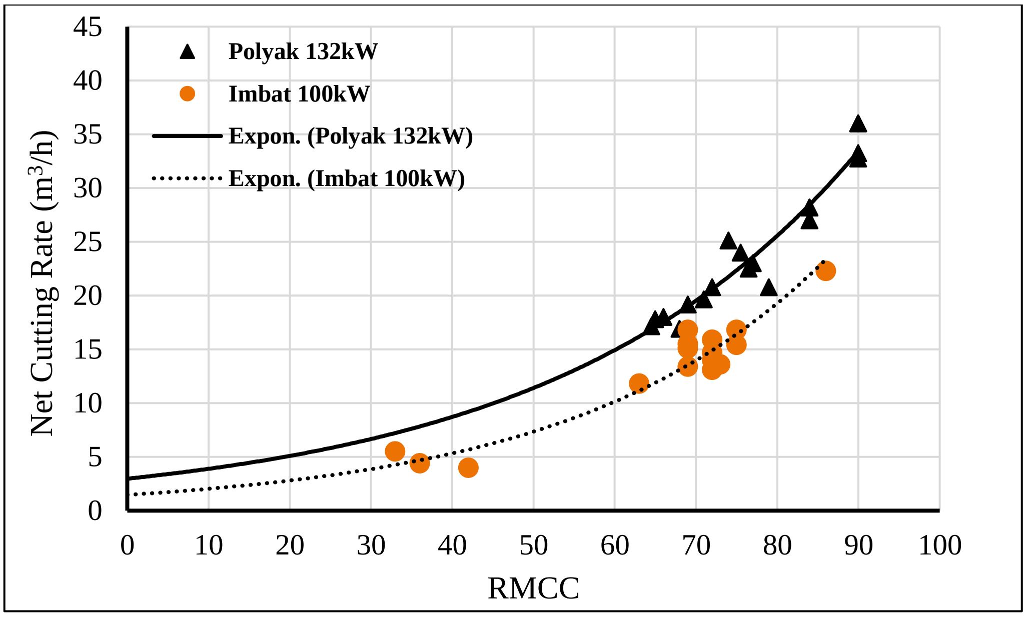


Figure 8.6. Comparison of NCR and RMCC index relations of 100 kW and 132 kW transverses type roadheaders.

The analyses show that the correlation coefficients between the NCR and the RMCC are higher than 0.94 for both axial and transverse type roadheaders with different cutter head power values. Therefore, it can be stated that the RMCC system is valid for different roadheaders and different rock mass conditions in the excavation of coal and coal measure rocks.

9. DEVELOPMENT OF PERFORMANCE PREDICTION MODELS

9.1. Performance Evaluation for Axial Type Roadheaders

Multiple regression models were developed to predict the NCR of roadheaders. First of all, the multicollinearity problem should be determined prior to doing multiple regression analyses. A high correlation between independent variables results in multiple dependency problem. In this case, one of the two variables with high correlation between them must be excluded from the analysis.

Some researchers accept a correlation coefficient higher than 0.80 while some take values higher than 0.70. In the analyses conducted in this thesis, values greater than 0.70 will be taken as the basis.

Table 9.1 shows the correlation matrix of axial type machine data, and the high correlation values are indicated in bold. Even if some correlations are coincidental, they will affect the regression analyses negatively. As can be seen, there is a high correlation between machine age and RMCC index. Furthermore, there is a high correlation between machine age and company experience.

It is not possible to eliminate RMCC index. During the field studies, it was observed that machine age does not influence NCR noticeably, and the cutterhead power is the determinant factor for NCR, so the machine age was eliminated. Due to the elimination of the machine age, the company experience may not be eliminated.

However, during the field studies, it was observed that the company experience, considered in years, did not have a noticeable effect on NCR and could be excluded. As in the case of the transfer of the operation rights of the Çayırhan coal mine from Park Termik to KİAŞ Mining Company, the personnel do not change significantly during the operational transfer. There are also experienced team transfers from other mining companies to the newly established company.

Moreover, there is a high correlation between galley cross section and gallery inclination. It was decided to eliminate the gallery cross-section since gallery inclination was observed to have a much more effect in terms of MUT and NCR. As a result, four independent variables were included in the regression analysis, namely cutter head power, RMCC index, operator experience, and gallery inclination.

The histogram and scatter plots of the data for axial and transverse type machines are shown in Figure 9.1 and Figure 9.2, respectively. The data mostly show non-normal distribution. It can be also said that there is no heavy-tailed data.

Table 9.1. Correlation matrix for axial type roadheaders.

	RMCC index	**Cutter head power (kW)**	**Operator experience (year)**	**Machine age (year)**	**Company experience (year)**	**Gallery inclination (°)**	**Gallery cross section (m^2)**
RMCC index	1.00						
Cutterhead power (kW)	-0.65	1.00					
Operator experience (year)	-0.24	0.38	1.00				
Machine age (year)	**0.76**	-0.49	-0.20	1.00			
Company experience (year)	0.48	0.00	-0.35	**0.82**	1.00		
Gallery inclination (°)	-0.17	0.70	0.52	-0.23	0.01	1.00	
Gallery cross section (m^2)	0.23	0.51	0.49	0.31	0.49	**0.76**	1.00

Another issue in regression analyses is deciding to use parametric or non-parametric tests. If the data has a normal distribution, parametric tests are used; otherwise, non-parametric tests are employed. In addition, if the number of data is more than 30, parametric tests can be used, assuming that the data have a normal distribution, and the variances are homogeneous. Here, parametric tests will be used since the number of data is more than 30.

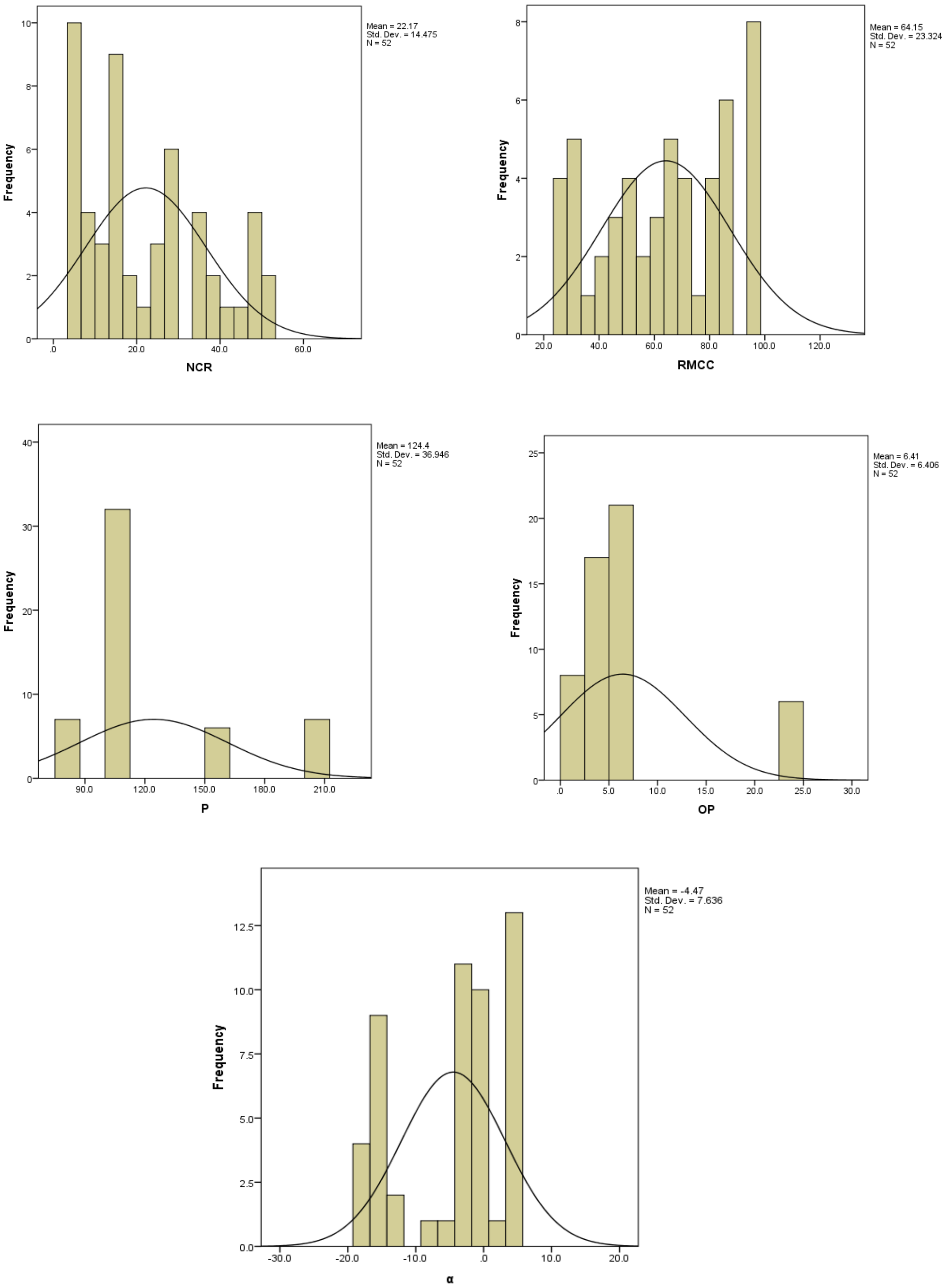


Figure 9.1. Histogram plots for axial type machine data.

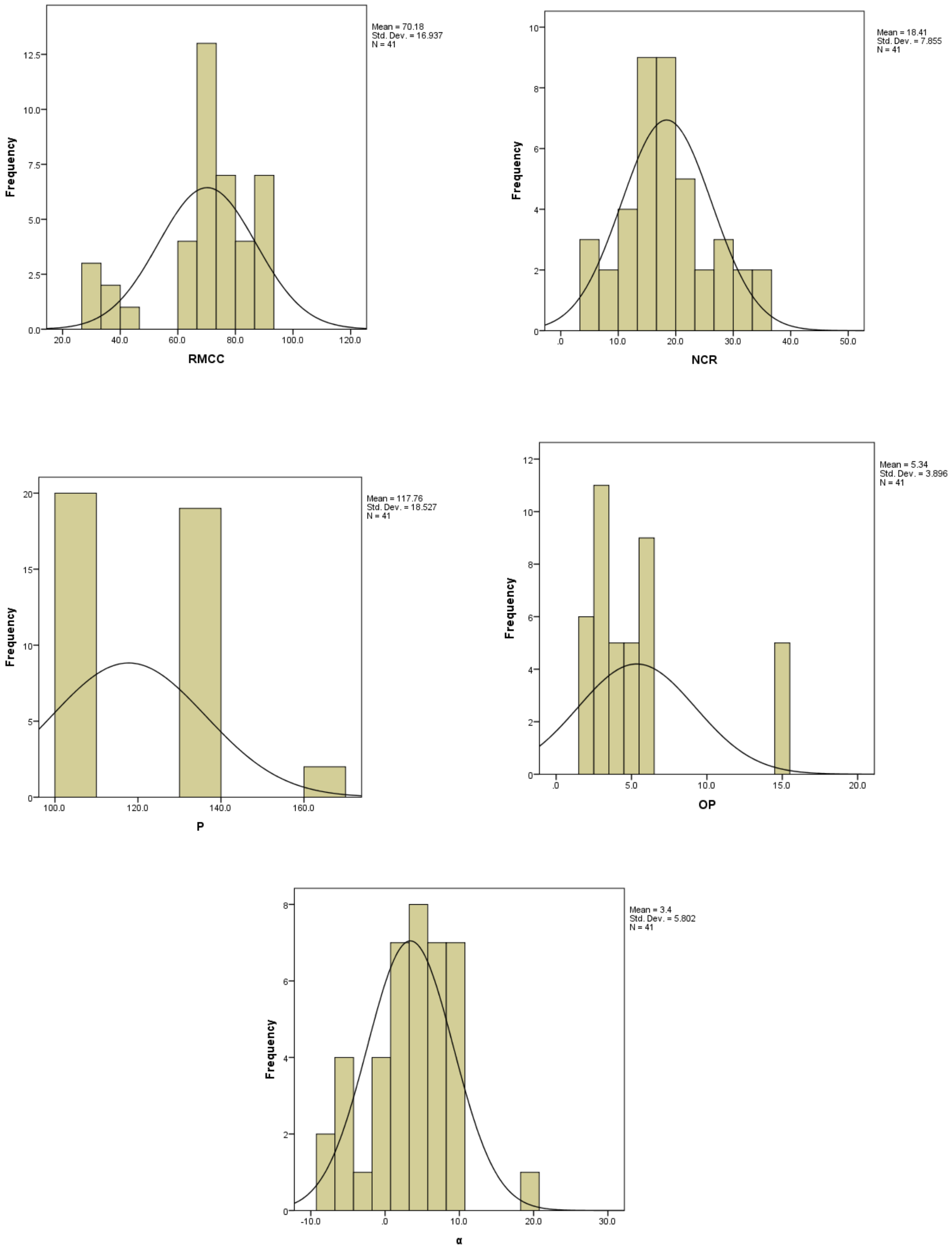


Figure 9.2. Histogram plots for transverse type machine data.

By identifying the outliers with residual analyses and eliminating them from the regression analysis, the predictive power of the dependent variable can be improved in regression analyses. The critical value for standard residuals is 2.0 or 3.0 in the residual analyses. Here, critical value is considered 2.0. It is evident in Figure 9.3 that in the residual analysis for axial type machine data the residual value of three data is higher than the critical value 2.0. These values correspond to measurements no. 14, 15, and 34. These measurements were not included in the regression analyses.

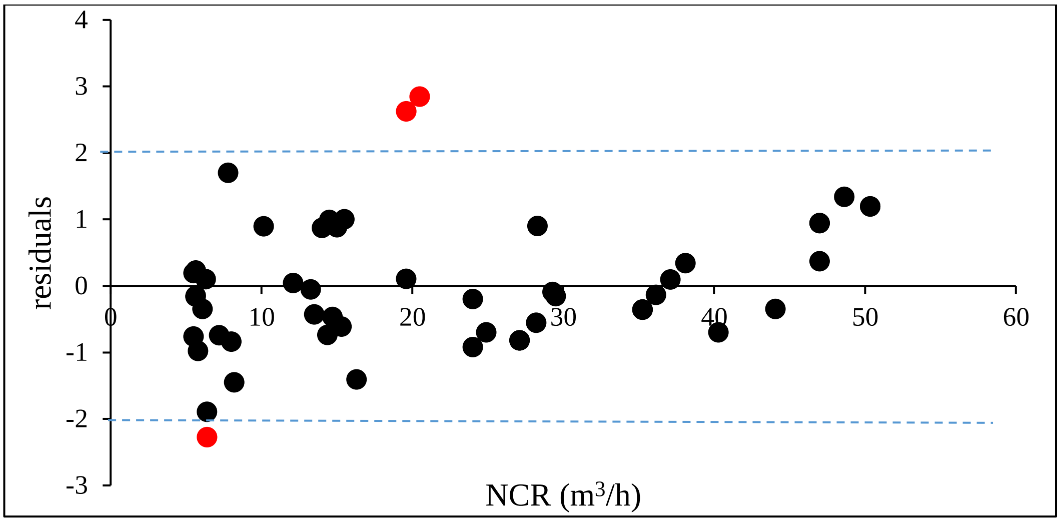


Figure 9.3. Standard residual values for axial type machine data (Data marked in red show the outliers).

The results of stepwise multiple regression analyses for axial type machine data with the help of SPSS program are shown in Tables 9.2-9.4. The dependent and independent variables in the tables are, in order, as:

1. Net Cutting Rate (NCR)
2. Cutter head power (P)
3. RMCC index
4. Operator experience (OP)
5. Gallery inclination (α)

Table 9.2. Model summary of regression analysis of axial type machine data.

Model Summary[e]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.894[a]	.800	.795	6.66546
2	.954[b]	.909	.905	4.53431
3	.973[c]	.947	.943	3.51993
4	.976[d]	.953	.948	3.35321
a. Predictors: (Constant), RMCC				
b. Predictors: (Constant), P, RMCC				
c. Predictors: (Constant), α, RMCC, P				
d. Predictors: (Constant), OP, α, RMCC, P				
e. Dependent Variable: NCR				

Table 9.3. Result of variance analysis of axial type machine data.

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig
1	Regression	8337.607	1	8337.607	187.664	.000[b]
	Residual	2088.133	47	44.428		
	Total	10425.740	48			
2	Regression	9479.980	2	4739.990	230.544	.000[c]
	Residual	945.760	46	20.560		
	Total	10425.740	48			
3	Regression	9868.194	3	3289.398	265.490	.000[d]
	Residual	557.546	45	12.390		
	Total	10425.740	48			
4	Regression	9931.004	4	2482.751	220.807	.000[e]
	Residual	494.736	44	11.244		
	Total	10425.740	48			

a. Dependent Variable: NCR
b. Predictors: (Constant), RMCC
c. Predictors: (Constant), P, RMCC
d. Predictors: (Constant), OP, RMCC, P
e. Predictors: (Constant), α, OP, RMCC, P

It is evident in Table 9.4 that four models with very high correlation coefficients can be developed as a result of stepwise regression. The formulated versions of the models are given as:

$$NCR=0.55RMCC-13.34 \qquad R = 0.89 \qquad (38)$$

$$NCR=0.18P+0.74RMCC-48.06 \qquad R = 0.95 \qquad (39)$$

$$NCR=0.15P+0.75RMCC+0.47OP-47.71 \qquad R = 0.97 \qquad (40)$$

$$NCR=0.2P+0.79RMCC+0.56OP-0.28\alpha-58.43 \qquad R = 0.98 \qquad (41)$$

Here, NCR is the Net Cutting Rate of axial type roadheader (m^3/h), RMCC is Rock Mass Cuttability Classification Index, P is the cutter head power of the roadheader (kW), OP is Operator Experience (year), and α is the gallery inclination (°). Equation 38 is not a useful model since it does not include cutter head power. Equation 39 is considered to be the most powerful model. Equations 40 and 41 can be preferred for a more precise estimation. However, it should be noted that the correlation is less linear if the correlation coefficient approaches 1.0. For this reason, nonlinear regression analyzes were performed in the following sections.

Table 9.4. Coefficients of regression analysis of axial type machine data.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-13.336	2.790		-4.780	.000
	VAR00003	.554	.040	.894	13.699	.000
2	(Constant)	-48.064	5.031		-9.554	.000
	VAR00003	.744	.037	1.200	19.847	.000
	VAR00002	.178	.024	.451	7.454	.000
3	(Constant)	-47.713	3.906		-12.216	.000
	VAR00003	.746	.029	1.204	25.634	.000
	VAR00002	.150	.019	.379	7.784	.000
	VAR00004	.467	.083	.207	5.598	.000
4	(Constant)	-58.433	5.867		-9.960	.000
	VAR00003	.787	.033	1.270	24.052	.000
	VAR00002	.200	.028	.507	7.113	.000
	VAR00004	.562	.089	.249	6.310	.000
	VAR00005	-.283	.120	-.140	-2.363	.023
a. Dependent Variable: NCR						

9.2. Performance Evaluation for Transverse Type Roadheaders

The correlation matrix of transverse type machine data is given in Table 9.5, and high correlation values are indicated in bold. As can be seen, there is a high correlation between machine age and company experience, and there is the high correlation between machine age and galley cross-section. Additionally, there is a high correlation between company experience and gallery cross-section. The elimination was done similarly to the axial type machine data, and four independent variables were included in the regression analyses for the transverse type machines as cutter head power, RMCC index, operator experience, and gallery inclination.

Table 9.5. Correlation matrix of transverse type machine data.

	RMCC index	**Cutter head power (kW)**	**Operator experience (year)**	**Machine age (year)**	**Company experience (year)**	**Gallery inclination (°)**	**Gallery cross section (m^2)**
RMCC index	1.00						
Cutter head power (kW)	-0.08	1.00					
Operator experience (year)	0.14	0.04	1.00				
Machine age (year)	-0.65	-0.17	-0.21	1.00			
Company experience (year)	-0.62	-0.21	-0.27	**1.00**	1.00		
Gallery inclination (°)	-0.02	0.19	-0.24	-0.35	-0.37	1.00	
Gallery cross section (m^2)	0.66	-0.25	0.00	**-0.84**	**-0.82**	0.33	1.00

As it is clear in Figure 9.4, the residual value of one datum is higher than the critical value 2.0 in the residual analysis of transverse type machine data. This value corresponds to the measurement no. 12; this measurement was not included in the regression analyses. The model summary of stepwise multiple regression analysis for transverse type machines is shown in Table 9.6. It is thought that the reason why the models here are not as powerful as the models developed for axial type machines is due to seven data belonging to 132 kW machine in İmbat Mining Company. These data show also contradiction in Figure 8.5. As already mentioned, the power transmission systems of the 132 kW machines, which are very old (about 40 years old), have been modified, and it is thought that these machines cannot reveal their true power during excavation. In addition, when the data belonging to the transverse type machines are examined, it will be seen that the NCR values of these machines excavating in the same roadway or in formations with close RMCC index values are the same or lower than the NCR of a transverse type machine with 100 kW cutter head power. For this reason, the data in question was removed from the data set, and the regression analysis was repeated.

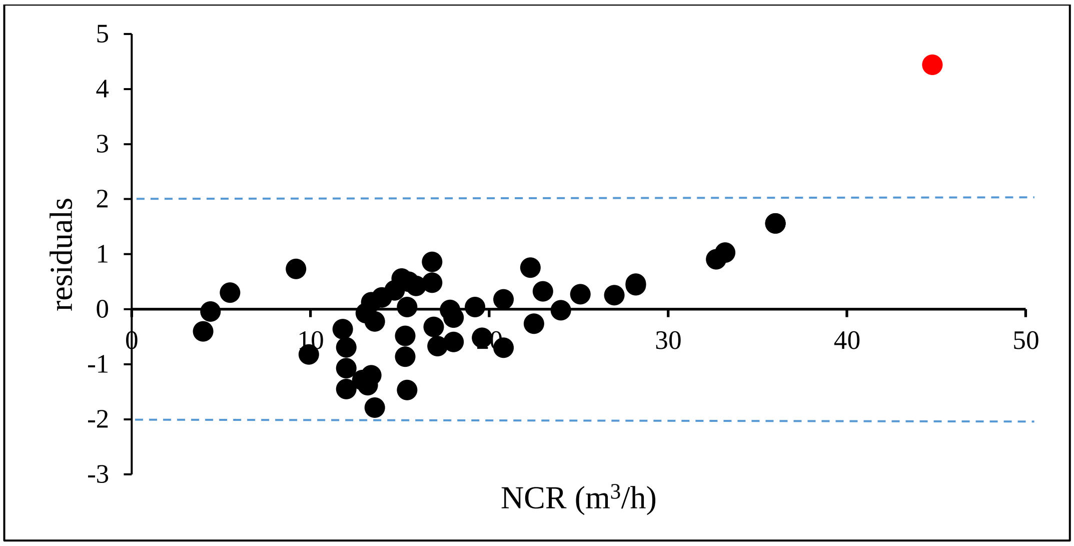


Figure 9.4. Standard residual values for transverse type machine data (Data marked in red shows the outlier).

Table 9.6. Model summary of regression analysis of transverse type machine data.

Model Summary[d]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.704[a]	.496	.485	5.34936
2	.809[b]	.654	.638	4.48153
3	.842[c]	.710	.690	4.15048
a. Predictors: (Constant), VAR00003				
b. Predictors: (Constant), VAR00003, VAR00002				
c. Predictors: (Constant), VAR00003, VAR00002, VAR00005				
d. Dependent Variable: VAR00001				

The model summary of the stepwise multiple regression analyses obtained after removing the contradictory data, belonging to the 132 kW machines in İmbat Mining Company, are given in Tables 9.7-9.9. Compared to the models presented in Table 9.6, it is evident that the models in Table 9.7 have much higher correlation coefficients and much lower standard errors. Therefore, these models are recommended. The dependent and independent variables in the tables are, respectively, as:

1. Net Cutting Rate (NCR)
2. Cutter head power (P)
3. RMCC index
4. Operator experience (OP)

Table 9.7. Model summary of regression analysis of transverse type machine data excluding 132 kW machine data belonging to İmbat Mining Company.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.749a	.561	.549	5.27213
2	.910b	.827	.818	3.34836
3	.921c	.848	.835	3.18635
a. Predictors: (Constant), RMCC				
b. Predictors: (Constant), P, RMCC				
c. Predictors: (Constant), OP, P, RMCC				
d. Dependent Variable: NCR				

Table 9.8. Result of variance analysis of transverse type machine data excluding 132 kW machine data belonging to İmabt Mining Company.

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1383.319	1	1383.319	49.768	.000[b]
	Residual	1084.017	39	27.795		
	Total	2467.336	40			
2	Regression	2041.298	2	1020.649	91.036	.000[c]
	Residual	426.038	38	11.212		
	Total	2467.336	40			
3	Regression	2091.682	3	697.227	68.673	.000[d]
	Residual	375.654	37	10.153		
	Total	2467.336	40			
a. Dependent Variable: NCR						
b. Predictors: (Constant), RMCC						
c. Predictors: (Constant), P, RMCC						
d. Predictors: (Constant), OP, P, RMCC						

Table 9.9. Coefficients of regression analysis of transverse type machine data excluding 132 kW machine data belonging to İmbat Mining Company.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-5.964	3.552		-1.679	.101
	VAR00003	.347	.049	.749	7.055	.000
2	(Constant)	-32.445	4.128		-7.861	.000
	VAR00003	.357	.031	.770	11.409	.000
	VAR00002	.219	.029	.517	7.661	.000
3	(Constant)	-32.309	3.928		-8.225	.000
	VAR00003	.360	.030	.776	12.070	.000
	VAR00002	.230	.028	.542	8.312	.000
	VAR00004	-.292	.131	-.145	-2.228	.032
a. Dependent Variable: NCR						

The formulated versions of the models developed for transverse type machines are given below:

$$NCR=0.35RMCC-5.96 \qquad R = 0.75 \qquad (42)$$

$$NCR=0.22P+0.36RMCC-32.44 \qquad R = 0.91 \qquad (43)$$

$$NCR=0.23P+0.36RMCC+0.29OP-32.31 \qquad R = 0.92 \qquad (44)$$

Where, NCR is the Net Cutting Rate (m^3/h), RMCC is Rock Mass Cuttability Classification Index, P is cutter head power (kW), and OP is operator experience (year). Since the cutter head power is not included in Equation 42, it is not a practical model. There is no significant difference between the correlation coefficients and standard errors of Equations 43 and 44. Equation 43 is recommended since it contains two variables and is simpler to use.

9.3. Evaluation of Axial and Transverse Type Roadheaders' Performance by Nonlinear Regression Method

Nonlinear regression analyses were carried out to determine whether the NCR equations to be developed would be more reliable than those developed by the linear regression method. In this section, the nonlinear regression analyses are only performed for equations 43 and 39 developed by linear regression analyses and proposed accordingly. Double logarithmic method (Standard Cobb-Douglas Production Function) was used to form nonlinear methods. This method, in which both dependent and independent variables are logarithmic, can be expressed as follows:

$$Y=aX_1^{b_1}X_2^{b_2}, \ldots, X_n^{b_n} \quad (45)$$

Here, Y is dependent variable, a is constant, X_1, X_2, X_n are independent variables, and b_1, b_2, b_n are coefficients of X_1, X_2, X_n. Equation 46 is obtained, if the logarithm of both sides in equation 45 is taken as follows:

$$\log Y=\log a+b_1 \log X_1 +b_2\log X_2+\ldots +b_n\log X_n \quad (46)$$

Equation 46 can be written as a linear regression function as follows:

$$Y=a+b_1X_1+b_2X_2+\ldots +b_nX_n \quad (47)$$

The residual analysis graph of the nonlinear regression method for axial type roadheaders is given in Figure 9.5. In the residual analysis, the residual value of three data is higher than the critical value 2.0. These data will not be included in the regression analysis.

The results of nonlinear regression analysis for axial type machine data are shown in Tables 9.10–9.12. The dependent and independent variables in the tables are, in order, as:

1. NCR (Net Cutting Rate)
2. P (Cutter head power)
3. RMCC (RMCC index)

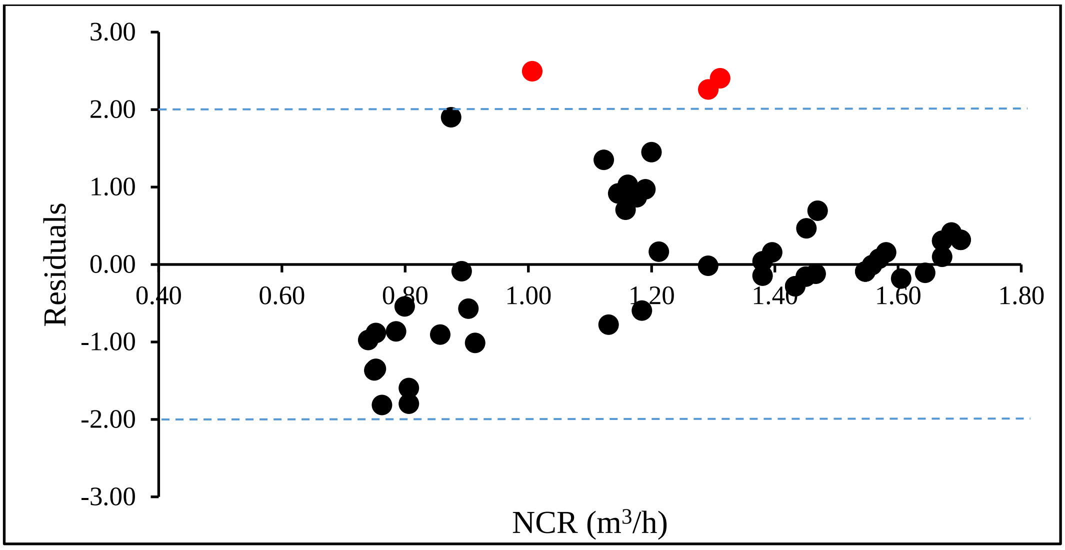


Figure 9.5. Standard residual values in the nonlinear regression method of axial type machine data (Data marked in red show the outliers).

Table 9.10. Model summary of nonlinear regression analysis of axial type machine.

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.947[a]	.896	.891	0.10742
a. Predictors: (Constant), P, RMCC				
b. Dependent Variable: NCR				

Table 9.11. Result of variance analysis of nonlinear regression analysis of axial type machine data.

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	4.572	2	2.286	198.114	.000[b]
	Residual	.531	46	.012		
	Total	5.103	48			
a. Dependent Variable: NCR						
b. Predictors: (Constant), P, RMCC						

Table 9.12. Coefficients of nonlinear regression analysis of axial type machine data.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-6.393	.524		-12.200	.000
	P	1.673	.170	.638	9.831	.000
	RMCC	2.332	.120	1.257	19.375	.000
a. Dependent Variable: NCR						

The model developed for axial type machines, formulated as a result of logarithmic transformation method, is given below:

$$NCR=4.1x10^{-7}(\frac{P^{1.67}}{RMCC^{-2.33}}) \qquad R=0.95 \qquad (48)$$

Equation 48 has the same correlation coefficient as Equation 39 developed by the linear regression method. However, while the standard error of Equation 39 is 4.53, this value is 0.11 for Equation 48, so Equation 48 is recommended for application. Due to the very low standard error of equation 48, the predictive power will be higher.

The residual analysis graph of the nonlinear regression method for transverse type roadheaders is given in Figure 9.6.

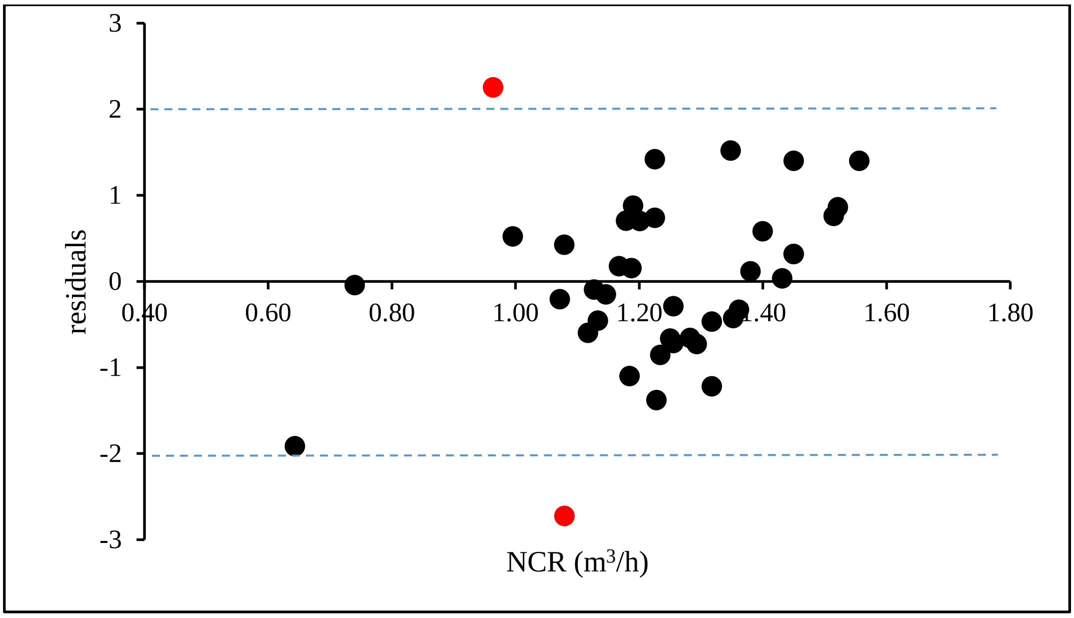


Figure 9.6. Standard residuals in nonlinear regression of transverse type machine (Data marked in red show the outliers).

The results of nonlinear regression analyses for transverse type machine data are shown in Tables 9.13–9.15. The dependent and independent variables in the tables are, in order, as:

1. Net Cutting Rate (NCR)
2. Cutter head power (P)
3. RMCC index (RMCC)

Table 9.13. Model summary of nonlinear regression analysis of transverse type machine data, excluding 132 kW machine data belonging to İmbat Mining Company.

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.941[a]	.886	.880	0.06605
a. Predictors: (Constant), P, RMCC				
b. Dependent Variable: NCR				

Table 9.14. Result of variance analysis of transverse type machine data obtained from nonlinear regression analysis.

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1.252	2	0.626	143.494	.000[b]
	Residual	.161	37	.004		
	Total	1.414	39			
a. Dependent Variable: NCR						
b. Predictors: (Constant), P, RMCC						

Table 9.15. Coefficients of transverse type machine data obtained from nonlinear regression analysis.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-4.240	.375		-11.311	.000
	P	1.582	.159	.555	9.945	.000
	RMCC	1.201	.082	0.815	14.609	.000
a. Dependent Variable: NCR						

The model developed for transverse type machines, formulated as a result of logarithmic transformation, is given below:

$$NCR=5.7x10^{-5}\left(\frac{P^{1.58}}{RMCC^{-1.2}}\right) \qquad R=0.94 \qquad (49)$$

Equation 49 has a higher correlation coefficient than Equation 43 developed with the linear method. Furthermore, while the standard error of Equation 43 is 3.35, this value is 0.07 for Equation 49. Due to high correlation coefficient and low standard error, the predictive power of Equation 49 will be higher and is recommended for application.

10. EVALUATION OF MACHINE UTILIZATION TIME

The Machine Utilization Time (MUT) values of the companies that were observed and measured are given in Table 10.1. This parameter was measured in each working shift for all of the investigated roadways. The maintenance records of companies for all operational years couldn’t be considered due to some limitations such as Covid-19 pandemic. The overall performances of roadheaders are also presented in Figure 10.1. MUT values vary between approximately 20% and 30%. The standard deviations of the mean values are quite high. In general, while high MUT is reached in appropriate situations, adverse geological conditions or technical failures result in quite low rates of MUT.

Table 10.1. Machine Utilization Time (%) of companies.

Company	Machine Utilization Time (%)	Average (%)	Standard deviation
(A) İmbat Mining	6.4, 21.0, 10.1, 2.3, 12.8, 7.6, 11.0, 21.0, 20.8, 21.7, 9.0, 26.1, 14.4, 25.4, 20.8, 34.4, 10.2, 15.7, 23.8, 18.3, 18.8, 27.9, 34.4, 37.9, 33.3, 65.6, 36.5, 32.7, 37.5, 36.7, 36.5	23.6	13.1
(B) Demir Export	36.5, 15.6, 41.6	31.5	13.3
(C) Park Termik	56.2, 37.5, 24.0, 21.9, 25.0, 28.1, 37.5, 50.0, 21.9, 17.7, 30.2, 30.2, 32.2, 32.2, 23.9	31.2	11.4
(D) Hattat Mining	9.3, 29.2, 35.4	24.6	13.6
(E) YS Mining	26.0, 25.0, 20.9, 30.2, 20.9, 9.8, 31.9	23.5	7.4
(F) Polyak Mining	12.1, 11.2, 12.7, 18.7, 10.5, 9.4, 10.0, 9.0, 21,7, 13.1, 25.0, 22.9, 16.2, 33.3, 18.7, 13.5, 26.0, 12,5, 6.9, 16.2, 21.2, 26.5, 15.0, 17.9, 29.4,	17.8	6.4
(G) KİAŞ	23.8, 25.0, 23.1, 25.0, 25.0, 24.3, 25.0, 29.2, 25.0, 24.2, 25.0, 26.7, 23.3, 23.3, 31.2, 32.5, 32.5	26.1	3.2

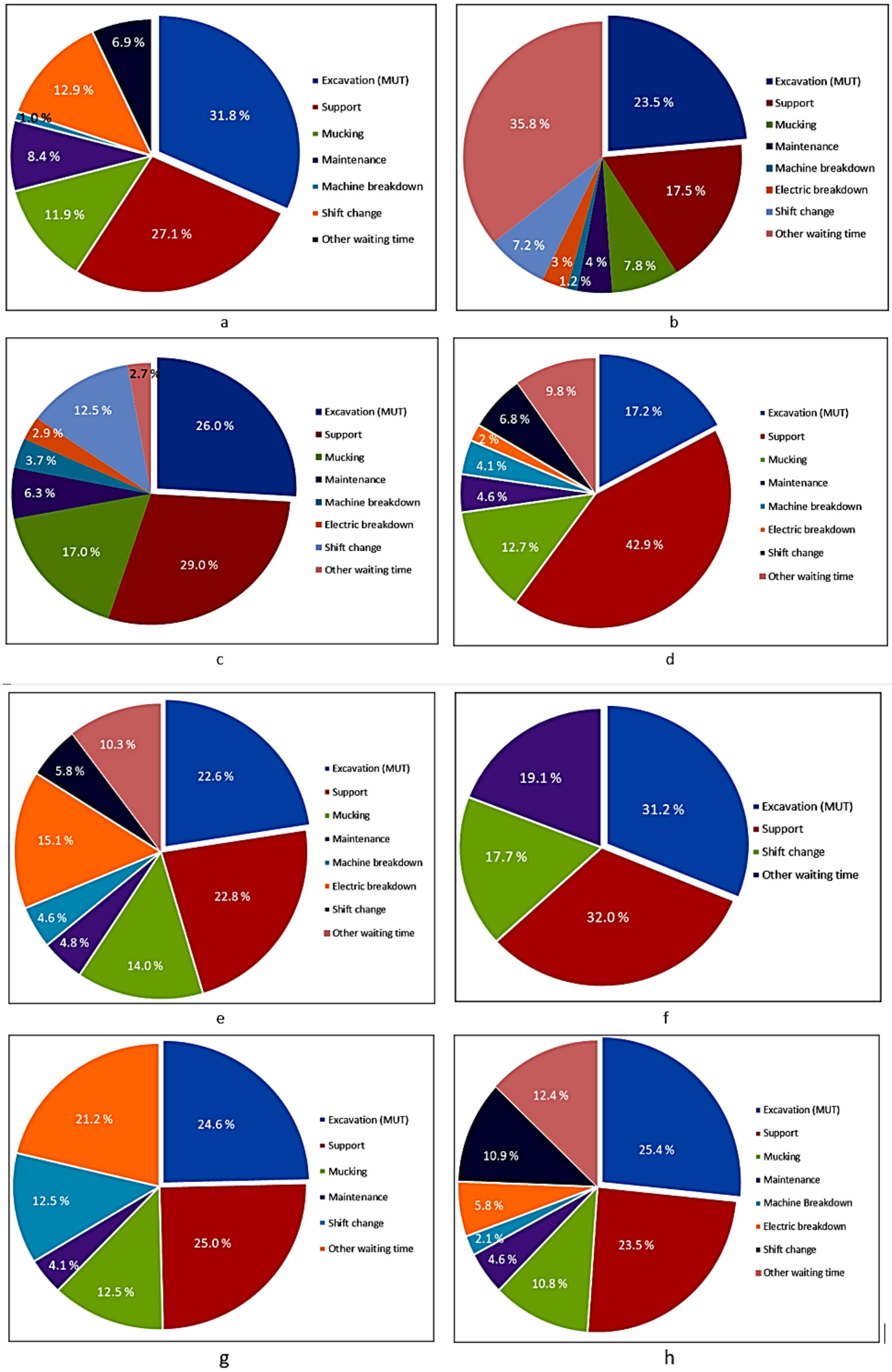


Figure 10.1. The overall performances of roadheaders for coal mine A (a), coal mine B (b), coal mine C (c), coal mine D (d), coal mine E (e), coal mine F (f), coal mine G (g), and all coal mines (h).

In İmbat Mining (A), the excavated material by roadheaders was transported to the belt conveyor by the chain conveyor, and it takes at least 1.5 hours to extend the chain conveyor depending on the overall condition of the roadway. On the other hand, the belt conveyor consists of three to five transfers, and the excavation stops when one of the belts fails. In addition, since the number of panels and developing galleries is high in the company, the main transport band is overloaded from time to time, and in such condition, the gallery excavation process is stopped or slowed down.

For the above-mentioned reasons, when the last measurements are not taken into account, the MUT is the lowest with 17.7% in İmbat Mining Company. The MUT of the most recent measurements in this company is over 30% since there are no stoppages due to transportation problems during the measurements. As can be seen in the performance forms of the previous investigations, there are always stoppages due to the mucking and loading problems. The average MUT for İmbat Mining is determined to be 23.6%.

Three measurements were carried out in Demir Export Mining Company (B). While the MUT values were quite high in the first two measurements, the value decreased in the third measurement due to the breakage of the main band. It is thought that the high (31.5%) MUT in this company is due to the fact that the measurements were carried out during coal excavation, and there were no problems related to clay and other rock types. Moreover, the machines are not old and the periodic maintenance of the machines was conducted every two weeks, which can lead to low number of failures.

The MUT value in Park Termik Company (C), (31.2%), is almost the same as Demir Export. Overall rates are high, although there are some lower values due to delays because of support and loading. It is thought that the application of mechanical excavation for about forty years has a share in the high rates.

In Hattat Mining (D), the average MUT is 24.6%; two out of three measurements are high. The lower value is due to variable geological formation and the excavation planning. Normally, the hard formation was being excavated, so the planning was based on a daily progress of 1 m. Contrary to what was expected, the excavation work was completed in a short time, as soft formations were encountered in the roadway of the aforementioned measurement, and a significant amount of time was spent waiting in idle.

In YS Mining (E), the average MUT value, which usually varies between 20% and 30%, is 23.5%. The rather low 9.8% value was due to a failure in the main belt conveyor system. Although there is a high clay formation in the excavated roadway, no problems arising from the clay were encountered since the excavation was carried out in a dry condition during the observations.

The lowest MUT rate (17.8%) belongs to Polyak Mining Company (F). The reason is that the excavations were conducted at a depth of about 1000 m, in a very fractured-cracked formation and under a lot of water flow. It will help to understand the working condition that the workers mostly worked in raincoats during the performance measurements. Due to the multi-fractured-cracked formation, support problems, and related waiting periods, the MUT decreased. Except for the low MUT values due to mechanical failure, low MUT values between 9%-10% are due to delays caused by support installation.

Average MUT value of 26.1% was recorded in KİAŞ Company (G). KİAŞ, which took over the Çayirhan colliery from Park Termik, continues to work with almost the same personnel. MUT values of KİAŞ Company are very close to the values determined in Park Termik Company.

The performance measurements were also evaluated for the development of the estimation models for MUT. MUT is influenced by a variety of factors; hence, it cannot be studied using simple regression models. The analysis must therefore be performed using multiple regression techniques. The experience of operators, the age of machines, the experience of companies, the inclination of roadways, and the cross-sectional area of roadways were all added to the regression analysis as independent variables. It should be noted that difficult ground conditions may decrease the MUT value. However, it would not be appropriate to add it as a parameter to the MUT formula, since difficult ground conditions generally increase the support time. The derived equations and the correlation coefficients are as follows:

$$MUT_a=-0.21OP-0.31A_m+0.8E_c+0.4\alpha-0.85A+41.92 \qquad R = 0.78 \qquad (50)$$

$$MUT_t=0.26OP-0.12A_m+1.95E_c-0.43\alpha+2.38A-44.61 \qquad R = 0.76 \qquad (51)$$

Where, MUT_a is the machine utilization time of axial roadheaders (%), MUT_t is the machine utilization time of transvers roadheaders (%), OP is the experience of operator (years), A_m is the age of machine (years), E_c is the experience of company (years), α is the inclination of roadway (°), A is the cross-sectional area of roadway (m^2). It can be said that the correlation coefficients of Equations 50 and 51 are strong. Therefore, they can be used reliably for the estimation of MUT values of roadheaders. However, it should be kept in mind that the operator ability is not taken into account in the operator experience parameter, and only the number of the working years is taken as the operator experience parameter. In addition, it should be taken into account that these equations do not cover difficult ground conditions such as high water inflow and high clay content.

11. DISCUSSIONS

In this section, the reliability analyses of the developed multiple regression models are performed with the help of statistical tests. In addition, it has been discussed whether the models can be compared with the existing roadheaders' performance models in the literature.

Although a high correlation coefficient is an important measure, it is not always sufficient for determining the reliability of a model. To overcome this problem, t- and F- tests were applied in order to test the reliability of the obtained equations. The significance of the correlation coefficient values is measured with the t-test. In this test, the t value found in the table is compared with the calculated t values. Whether the model is valid as a result of the comparison is decided with the help of the hypothesis testing. The hypothesis to be tested is the null hypothesis, denoted by H_0. Another hypothesis is the alternative hypothesis expressed by H_1:

- H_0: If $b = 0$, the null hypothesis is accepted; means this model is invalid.
- H_1: If $b \neq 0$, the null hypothesis is rejected; means this model is valid.

As a result, if the calculated t value is equal to or less than the t value found in the table, the null hypothesis is accepted. Otherwise, the null hypothesis is rejected; in this case, the model is valid. As it is clear in Table 11.1, t values of all models except Equation 42 are greater than the t value found in the table, so these models are valid according to the t test. The significance of the regression models can be determined by analyses of variance.

Analyses of variance are based on the F distribution, also, known as the F test. The F test is similar to t test. Comparison of the calculated F value with the F value found in the table is performed. Whether the model is valid as a result of the comparison is decided with the help of hypothesis testing. The hypotheses to be tested are the null hypothesis (H_0) and the alternative hypothesis (H_1), and can be expressed as follows:

- H_0: If $b1 = b2 = b3 = 0$, the null hypothesis is accepted; indicates that this model is invalid.

- H_1: If b1≠ b2 ≠ b3 ≠ 0, the null hypothesis is rejected; indicates that this model is valid.

In other words, if the calculated F value is equal to or less than the F value found in the table, the null hypothesis is accepted. Otherwise, the null hypothesis is rejected; meaning that the model is valid. As seen in Table 11.1, the F values of all models are greater than the F value found in the table; the models are valid according to the F test.

Table 11.1. Results of F and t tests.

Eq. no.	Independent variable	Coefficient	t value	Table t value	F value	Table F value
38	Constant RMCC index	-13.336 0.554	-4.780 13.699	±1.96	187.66	1.66
39	Constant RMCC index Cutter head power	-48.064 0.744 0.178	-9.554 19.847 7.454	±1.96	230.54	4.04
40	Constant RMCC index Cutter head power Operator's experience	-47.713 0.746 0.150 0.467	-12.216 25.634 7.784 5.598	±1.96	265.49	3.18
41	Constant RMCC index Cutter head power Operator's experience Gallery inclination	-58.433 0.787 0.200 0.562 -0.283	-9.960 24.052 7.113 6.310 -2.363	±1.96	220.81	2.76
42	Constant RMCC index	-5.964 0.347	-1.679 7.055	±1.96	49.768	1.64
43	Constant RMCC index Cutter head power	-32.445 0.357 0.219	-7.861 11.409 7.661	±1.96	91.036	4.02
44	Constant RMCC index Cutter head power Operator's experience	-32.309 0.360 0.230 -0.292	-8.225 12.070 8.312 -2.228	±1.96	68.673	3.20
48	Constant Cutter head power RMCC index	-6.393 1.673 2.332	-12.200 9.831 19.375	±1.96	198.114	4.04
49	Constant Cutter head power RMCC index	-4.240 1.582 1.201	-11.311 9.945 14.609	±1.96	143.494	4.08

11.1. Comparison of Developed Models with Previous Models

It is not meaningful to compare formulas containing a single rock feature with newly developed formulas. The only comparable model is the one developed by Bilgin et al. (1990). To use this model, it can be considered to estimate the RQD values from the Eq. (5).

For Eq. (5), as mentioned earlier, RQD = 0 if $J_v > 35$, and RQD = 100 if and $J_v < 4.5$. Within the scope of this thesis, except for seven measurements, J_v values are greater than 35, so the RDQ values are zero. In this case, according to the model provided by Bilgin et al. (1990), the RMCI value in the model becomes zero, and Eq. (9) turns into Eq. (52) given below, and it is obvious that NCR depends only on cutter head power. Hence, the models developed in this study are not comparable to the models developed by Bilgin et al. (1990).

$$NCR=0.28\ P \tag{52}$$

It is not possible to make comparisons for seven measurements with J_v values greater than 35; that is, since these seven measurements belong to the excavations conducted in the same formation with the same machine, the NCR values, (5.5-6.3 m^3/h), and UCS values, (58.0-67.0 MPa), do not change very much and stay almost the same. Additionally, it must be taken into account that the excavated formation is mainly composed of marl with high clay content, and it is stated that Eq. (5) is not valid for clayey rocks (Hoek 2007).

The comparisons of the models developed in this study and the models developed by other researchers in the previous studies are given in Figures 11.1-11.4.

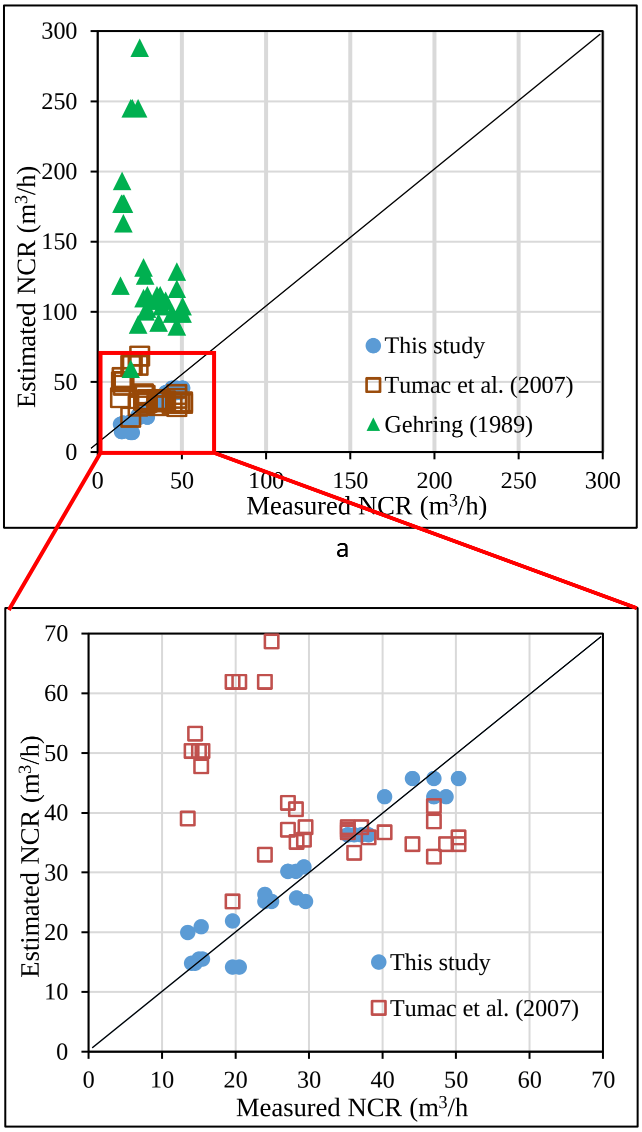


Figure 11.1. The comparison between Eq. (34) and previous studies for all data (a) and for the NCR value of below 70 m^3/h (b).

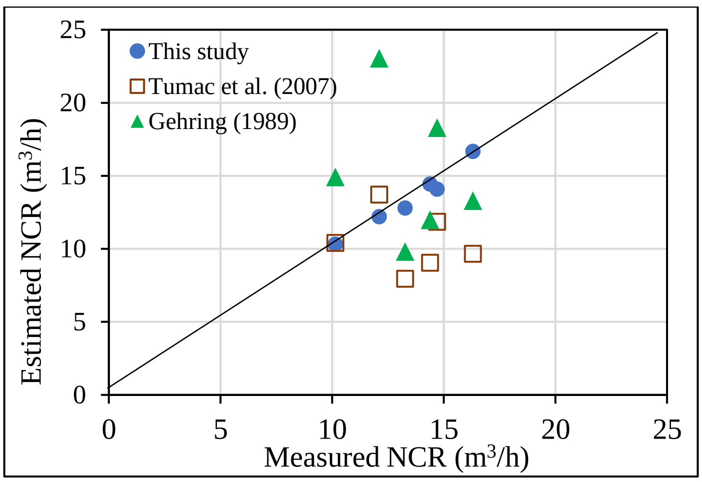


Figure 11.2. Comparison between Eq. (35) and previous studies.

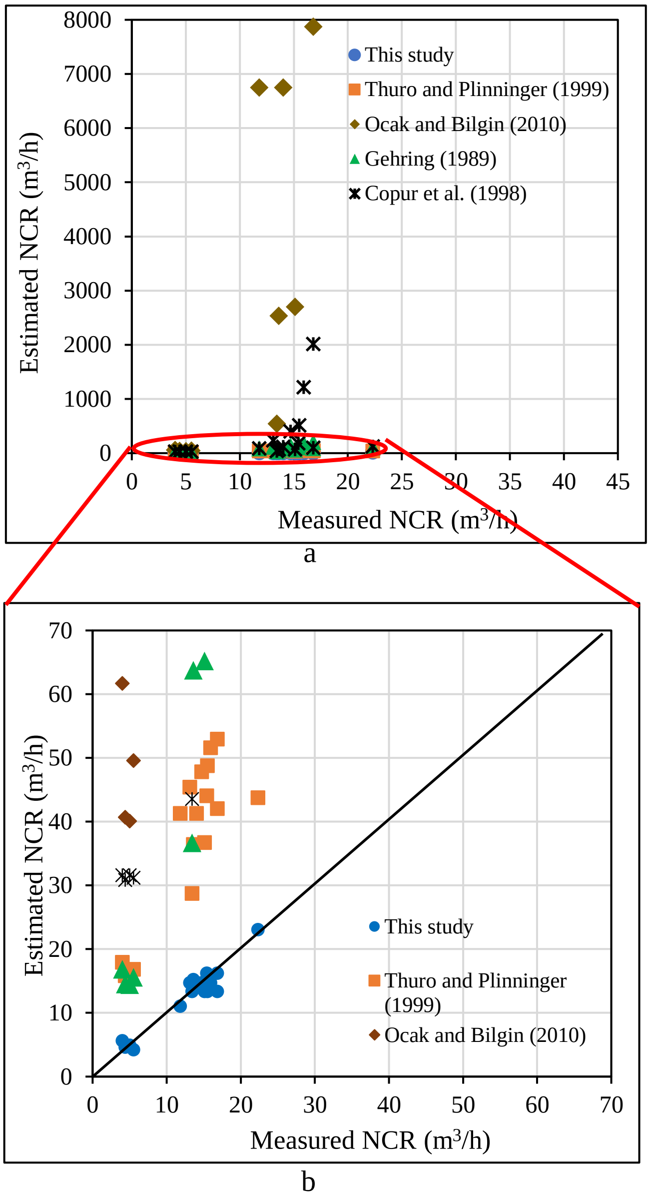


Figure 11.3. The comparison between Eq. (36) and previous studies for all data (a) and for the NCR value of below 70 m^3/h (b).

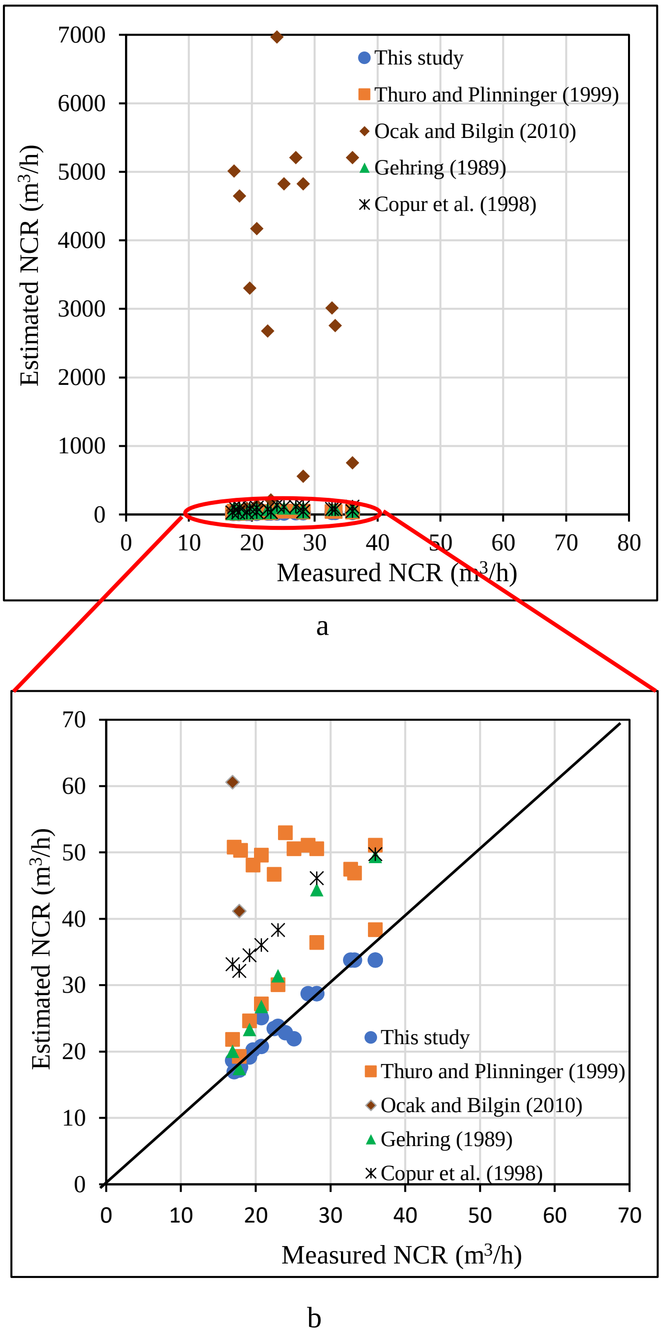


Figure 11.4. The comparison between Eq. (37) and previous studies for all data (a) and for the NCR value of below 70 m^3/h (b).

12. CONCLUSIONS

In this dissertation, a new Rock Mass Cuttability Classification (RMCC) system was established, the reliability of the system was investigated, and the development of the models was aimed to predict the Net Cutting Rate (NCR) of roadheaders used in coal mines based on the RMCC index. Moreover, the Machine Utilization Time (MUT) values for the roadheaders were measured and analyzed. Based on the analyses and evaluations, the following results were obtained:

- The validity of the suggested RMCC system was revealed by finding very high correlations between RMCC index and NCR according to the measurement data obtained under different geological conditions and from different machines. However, the RMCC system may not be applicable to the cuttability classification of other rock types since it is developed based on excavations conducted in coal and coal measure rocks.
- Alternative multiple regression models with very high correlation coefficients have been developed to predict NCR for both axial and transverse type roadheaders. Among these models, nonlinear models including cutter head power and RMCC index are suggested for practical usage. Again, it should be noted that the developed models may not be valid for the excavation of rocks other than coal and coal measure rocks.
- According to the observations made in seven different coal mines, MUT values vary between approximately 20% and 30%; 25% can be used as the average value.

Concluding remark is that the developed RMCC system can be reliably used for the cuttability classification of coal and coal measure rocks when excavating by roadheaders and for the performance prediction of both axial and transverse type roadheaders that are used in coal mines.

This thesis is based on the measurements and observations performed during the excavations of coal and coal measure rocks since there is no other use of roadheaders in our country during the project proposal and realization stages. It is worth mentioning that the classes of volumetric joint count in the proposed RMCC system, may not be appropriate for other rock types (particularly those other than sedimentary rocks). For this reason, it should be investigated whether the proposed cuttability classification system is valid for the rocks out of the scope of this study. Similarly, whether the developed performance prediction models are valid for the excavation of rocks other than coal and coal measure rocks is another issue that needs to be investigated. Moreover, a future research may be the use of ANFIS to define the ranges for the UCS parameter in the RMCC system with membership functions instead of constant values.

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APPENDICES

APPX 1: PERFORMANCE FORMS

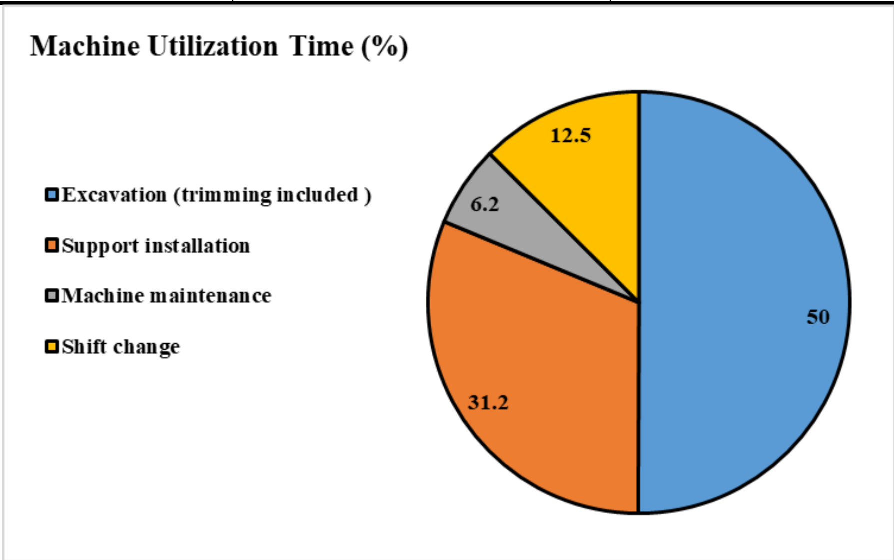
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 07.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J Field, West main road **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** -2° **Formation**: Clay-coal **General condition of the formation**: Mostly consists of coal. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 4 h **Net production**: 96 m^3 **Net cutting rate**: 24 m^3/h **Length of advance**: 1 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	240	50
Support installation	150	31.2
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



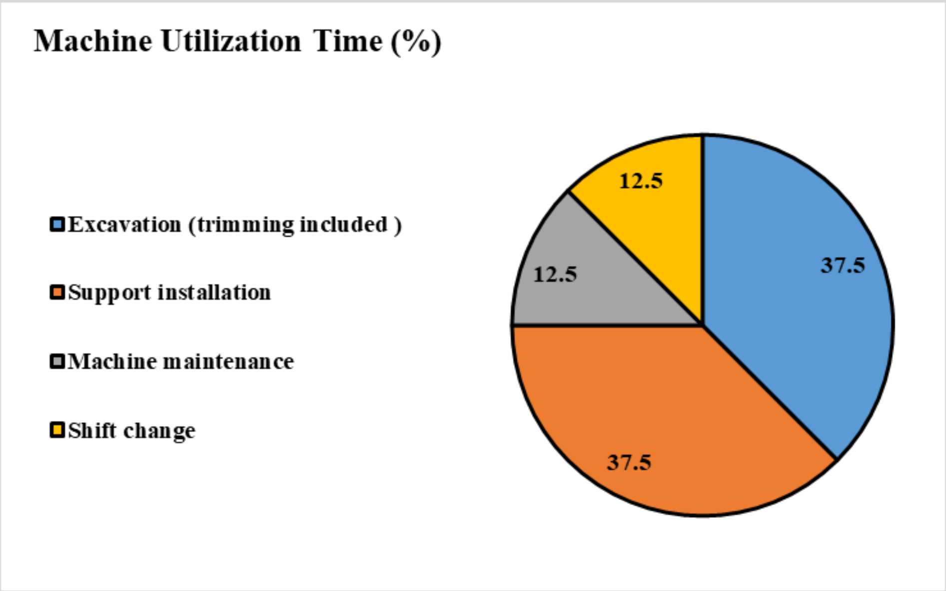
Other information:
Number of workers: 7
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 07.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J 710 Sub-tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** -2° **Formation**: Clay-coal **General condition of the formation**: 80% of the excavation face consists of coal. **Water condition**: Dripping **Support system**: Steel sets **Muck transportation system:** Belt conveyor
Net cutting rate: 3 h **Net production:** 88 m^3 **Net cutting rate:** 29.33 m^3/h **Length of advance:** 1.33 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	180	37.5
Support installation	180	37.5
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	60	12.5
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	---	---

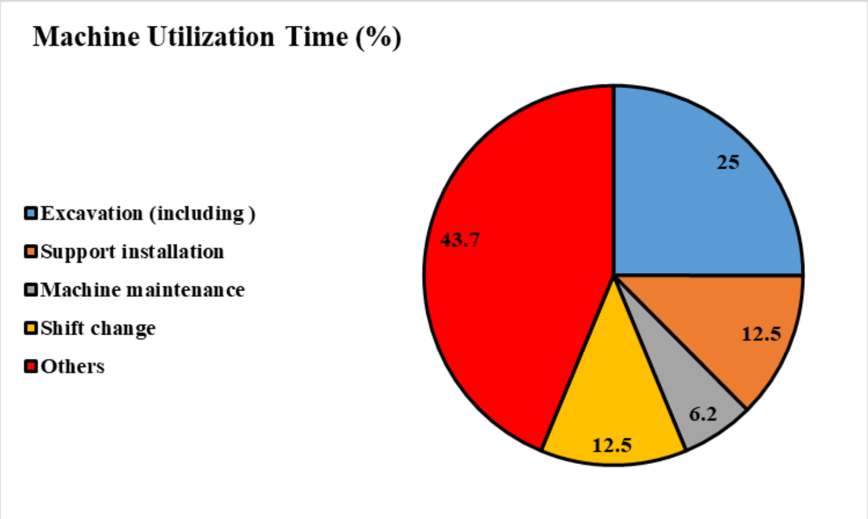


Other information:
Number of workers: 5
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 08.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H209 Tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**:18 m^2 **Gallery Inclination:** -3° **Formation**: Clay-coal **General condition of the formation**: 50% of the face consisted of clay. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2 h **Net production:** 27m^3 **Net cutting rate:** 13.5 m^3/h **Length of advance:** 0.75 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	

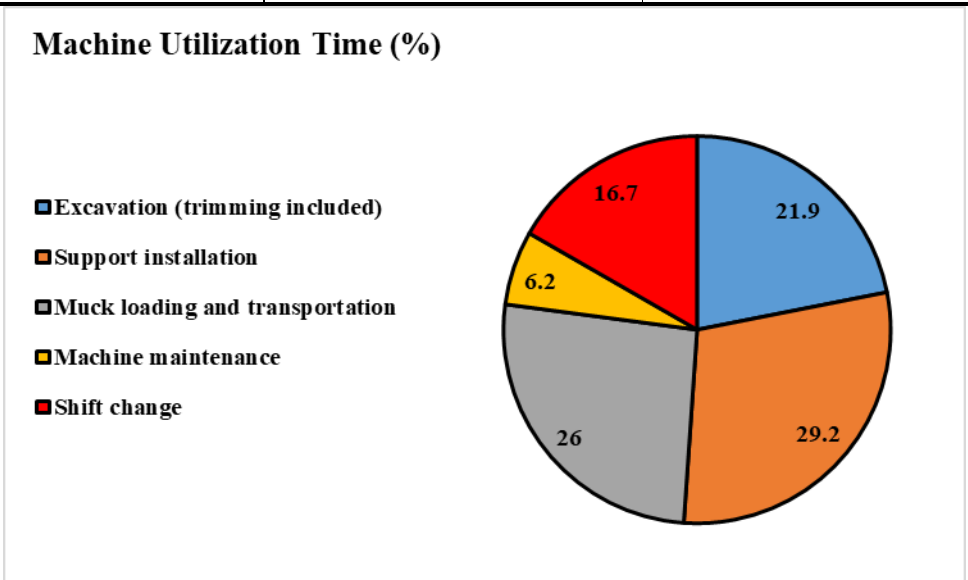
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	120	25
Support installation	60	12.5
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	210	43.7



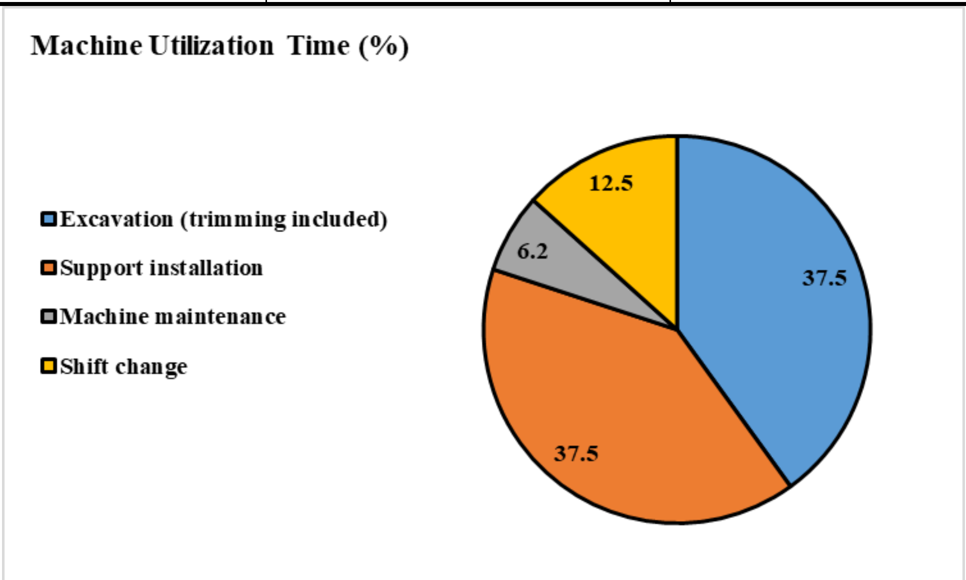
Other information:
Number of workers: 5
Horizontal distance between steel sets: 75 cm
The middle part of the tunnel face was composed of loose material, and the excavation took long time.

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 09.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H610 **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 1° **Formation**: Clay-coal **General condition of the formation**: Formation gets softer upwards. **Water condition**: Dripping-Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.75 h **Net production**: 49.5 m^3 **Net cutting rate:** 28.28 m^3/h **Length of advance:** 1.28 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	105	21.9
Support installation	140	29.2
Muck loading and transportation	125	26.0
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	80	16.7
Others	---	---



Other information:
Number of workers: 4
Horizontal distance between steel sets: 75 cm
The middle part of the face collapsed and trimming was difficult.
The needle penetrometer penetrated more into the right side of the mirror than the left side.

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 14.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H210 Head tail **Shift:** 8-16 **Operator experience:** 2 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**:20.4 m^2 **Gallery Inclination:** -7° **Formation**: Clay-Coal **General condition of the formation**: 50% of the excavation face composed of coal and 50% of clay. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 3 h **Net production**: 45.9 m^3 **Net cutting rate:** 15.3 m^3/h **Length of advance:** 0.75 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	180	37.5
Support installation	180	37.5
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



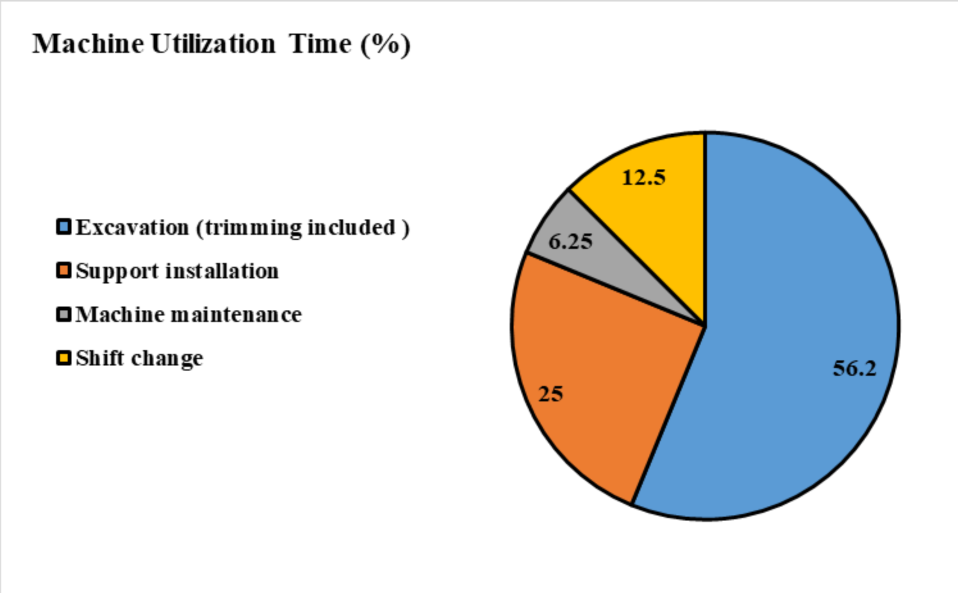
Other information:
Number of workers: 7
Horizontal distance between steel sets: 75 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 15.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J710 **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 20 m^2 **Gallery Inclination:** -5° **Formation**: Clay-Coal **General condition of the formation**: 80% of the excavation face composed of coal. **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 4.5 h **Net production**: 88 m^3 **Net cutting rate:** 19.55 m^3/h **Length of advance:** 0.88 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	

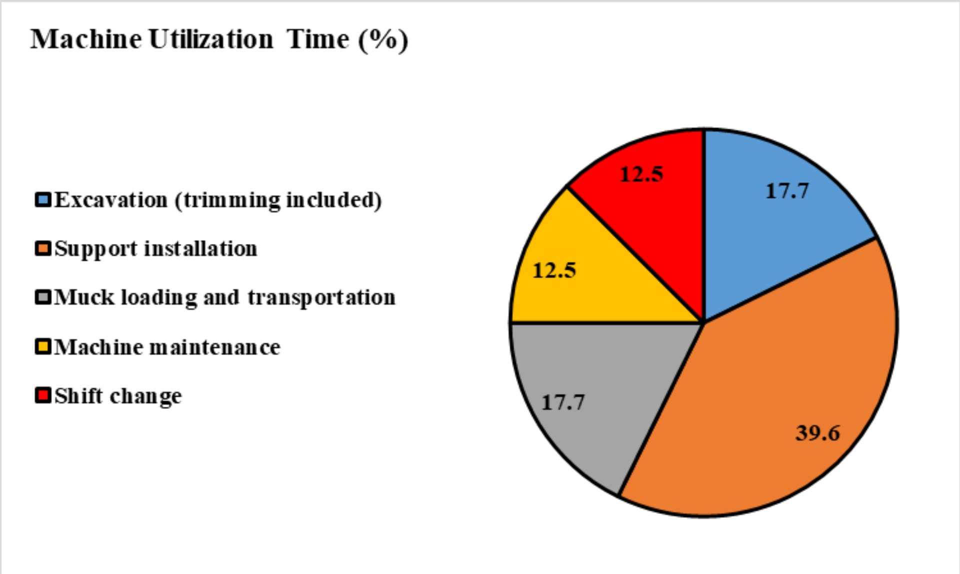
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	270	56.2
Support installation	120	25.0
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



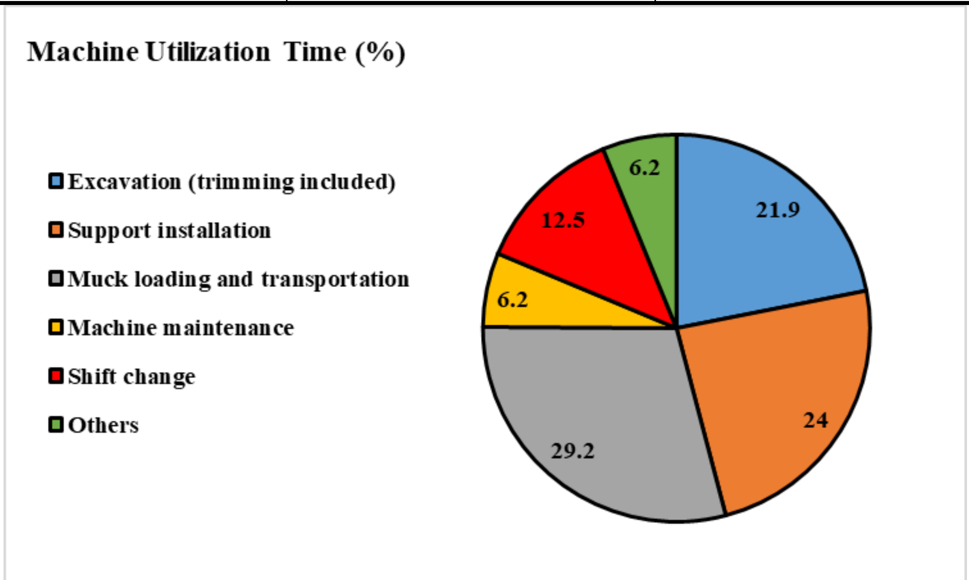
Other information:
Number of workers: 6
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 04.09.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**:20 m^2 **Gallery Inclination:** -15° **Formation**: Clay **General condition of the formation**: 100% loose clay. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.42 h **Net production**: 42 m^3 **Net cutting rate:** 29.5 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	85	17.7
Support installation	190	39.6
Muck loading and transportation	85	17.7
Cutter change	---	---
Machine maintenance	60	12.5
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



Other information:
Number of workers: 5
Horizontal distance between steel sets: 100 cm

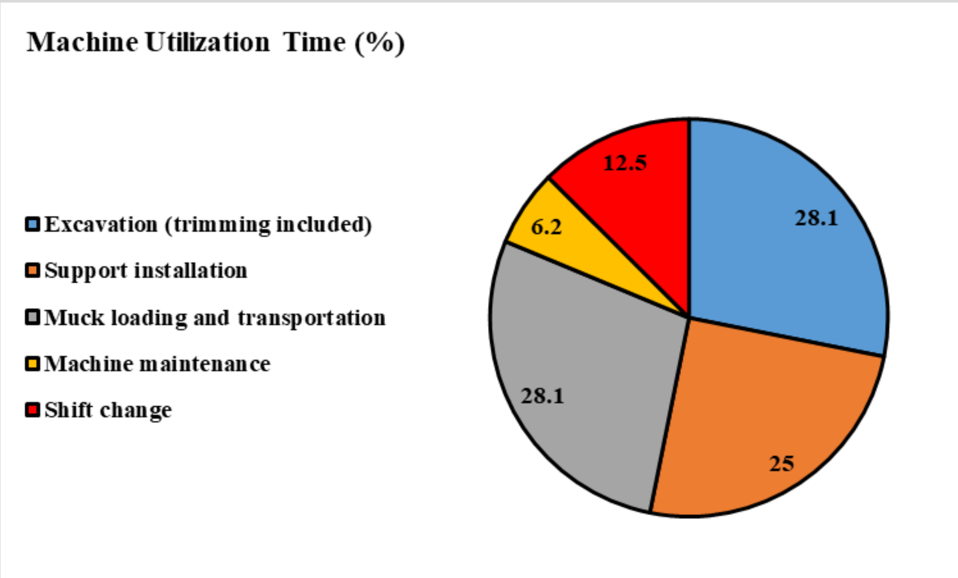
ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 06.09.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 20 m^2 **Gallery Inclination:** -15º **Formation**: Clay **General condition of the formation**: 100% loose clay. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.75 h **Net production:** 42 m^3 **Net cutting rate:** 24 m^3.h **Length of advance:** 1.2 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the side corners of the gallery face and continued upwards.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	105	21.9
Support installation	115	24.0
Muck loading and transportation	140	29.2
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	30	6.2



Other information:
Number of workers: 5
Horizontal distance between steel sets: 100 cm

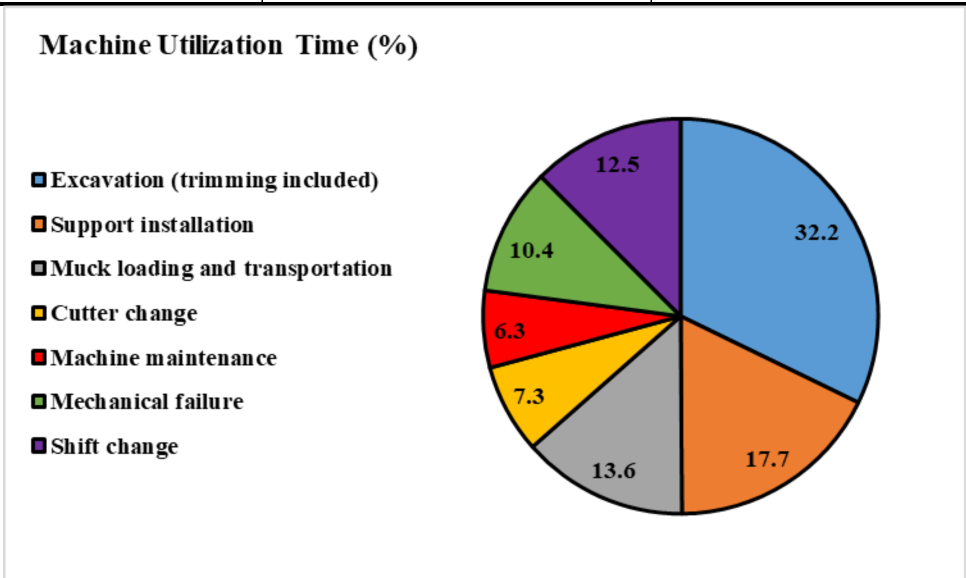
ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 07.09.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 20 m^2 **Gallery Inclination:** -15° **Formation**: Clay **General condition of the formation**: 100% loose clay. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate : 2.25 h **Net production**: 56 m^3 **Net cutting rate:** 24.9 m^3/h **Length of advance:** 1.24 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation started from the lower part of the side corners of the gallery face and continued upwards.	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	135	28.1
Support installation	120	25.0
Muck loading and transportation	135	28.1
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



Other information:
Number of workers: 5
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number** : 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 16.7 m^2 **Gallery Inclination:** -15° **Formation**: Clay and silex **General condition of the formation**: There were 2 narrow bands of hard silex in the face consisting of clay. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.58h **Net production**: 37.4 m^3 **Net cutting rate:** 14.49 m^3/h **Length of advance:** 0.77 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** In addition to the excavation of the gallery face, 2m^3 of the lower part of the face was excavated for the support installation for the next round.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	155	32.2
Support installation	85	17.7
Muck loading and transportation	65	13.6
Cutter change	35	7.3
Machine maintenance	30	6.3
Mechanical failure	50	10.4
Electrical failure	-	-
Shift change	60	12.5
Others	-	-



Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm

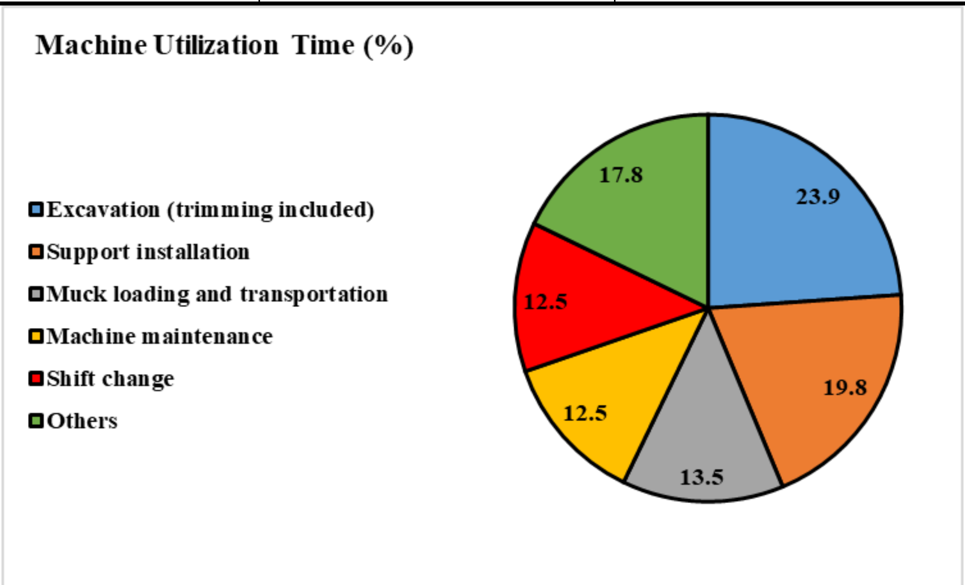
<table>
<tr><th colspan="3">ROADHEADER’S PERFORMANCE FORM</th></tr>
<tr><th>General Information</th><th>Machine Specification</th><th>Gallery information</th></tr>
<tr><td>Date: 27.02.2019
Company: Park Termik
Location: Çayırhan
Gallery: H North preparation
Shift: 8-16
Operator experience: 4 years
Company experience: 20 years</td><td>Type: Axial
Brand: DOSCO
Age: 30 years
Cutter type: Conic
Cutter number: 24
Cutter head power: 112 kW
Cutter head revolution: 58 rev/min
Weight: 35 ton</td><td>Gallery cross section: 16.7 m^2
Gallery Inclination: -15^o
Formation: Clay and silex
General condition of the formation: There were 2 narrow bands of hard silex in the face consisting of clay.
Water condition: Damp
Support system: Steel sets
Muck transportation system: Belt conveyor</td></tr>
<tr><td>Net cutting rate: 1.33 h
Net production: 18.7 m^3
Net cutting rate: 14.06 m^3/h
Length of advance: 0.56 m/h</td><td colspan="2">The starting point of the excavation on the face and the way of continuing the excavation:
In addition to the excavation of the gallery face, 2m^3 of the lower part of the face was excavated for the support installation for the next round.</td></tr>
<tr><th colspan="3">Measurements of Machine Utilization Time</th></tr>
<tr><th>Activities</th><th>Time (min)</th><th>Ratio to the total time (8 hours) (%)</th></tr>
<tr><td>Excavation (trimming included)</td><td>---</td><td>---</td></tr>
<tr><td>Support installation</td><td>---</td><td>---</td></tr>
<tr><td>Muck loading and transportation</td><td>---</td><td>---</td></tr>
<tr><td>Cutter change</td><td>---</td><td>---</td></tr>
<tr><td>Machine maintenance</td><td>---</td><td>---</td></tr>
<tr><td>Mechanical failure</td><td>---</td><td>---</td></tr>
<tr><td>Electrical failure</td><td>---</td><td>---</td></tr>
<tr><td>Shift change</td><td>---</td><td>---</td></tr>
<tr><td>Others</td><td>---</td><td>---</td></tr>
<tr><td colspan="3">NOTE: Since this form is the performance form of the second excavation round of the first form dated 27.02.2019, MUT measurements were calculated in the first form.</td></tr>
<tr><td colspan="3">Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm</td></tr>
</table>

ROADHEADER’S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 28.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 16.7 m^2 **Gallery Inclination:** -15º **Formation**: Clay and silex **General condition of the formation**: There were 2 narrow bands of hard silex in the face consisting of clay. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.91 h **Net production:** 37.4 m^3 **Net cutting rate:** 19.58 m^3/h **Length of advance:** 1.04 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** In addition to the excavation of the gallery face, 2m^3 of the lower part of the face was excavated for the support installation for the next round.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	115	23.9
Support installation	95	19.8
Muck loading and transportation	65	13.5
Cutter change	---	---
Machine maintenance	60	12.5
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	85	17.8



Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 28.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number** : 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 16.7 m^2 **Gallery Inclination:** -15^o **Formation**: Clay and silex **General condition of the formation**: There were 2 narrow bands of hard silex in the face consisting of clay. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 0.91 h **Net production:** 18.7 m^3 **Net cutting rate:** 20.54 m^3/h **Length of advance:** 1.09 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** In addition to the excavation of the gallery face, 2m^3 of the lower part of the face was excavated for the support installation for the next round.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	---	---
Support installation	---	---
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	---	---
Others	---	---
NOTE: Since this form is the performance form of the second excavation round of the first form dated 28.02.2019, MUT measurements were calculated in the first form.		
Other information: Number of workers: 4 Horizontal distance between steel sets: 100 cm		

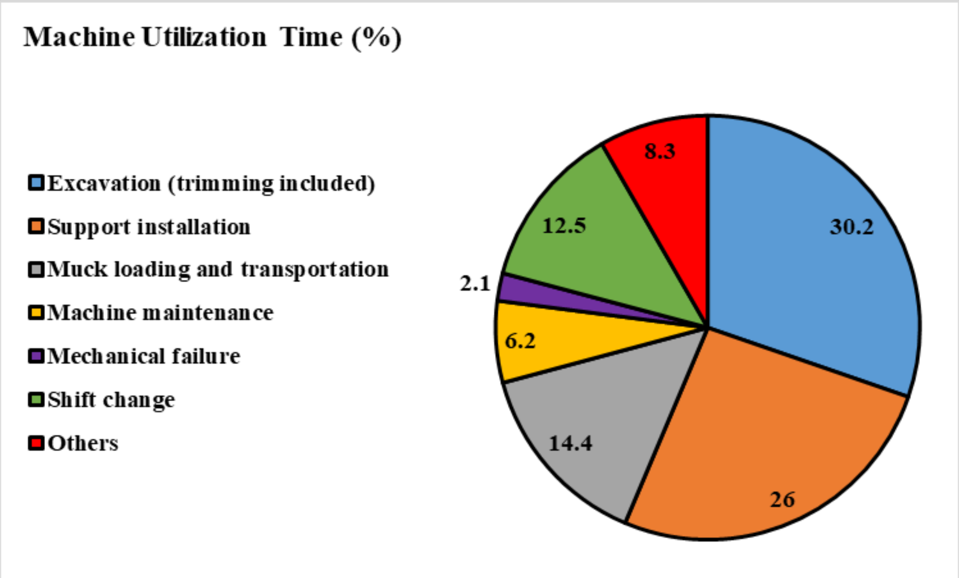
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H North preparation **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 20 years	**Type**: Axial **Brand**: DOSCO **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 16.7 m^2 **Gallery Inclination:** -15º **Formation**: Clay and silex **General condition of the formation**: There were 2 narrow bands of hard silex in the face consisting of clay. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor

Net cutting rate: 2.41 h **Net production:** 37.4 m^3 **Net cutting rate:** 15.5 m^3.h **Length of advance:** 0.82 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** In addition to the excavation of the gallery face, 2m^3 of the lower part of the face was excavated for the support installation for the next round.

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	145	30.2
Support installation	125	26.0
Muck loading and transportation	70	14.4
Cutter change	---	---
Machine maintenance	30	6.2
Mechanical failure	10	2.1
Electrical failure	---	---
Shift change	60	12.5
Others	40	8.3



Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm

<table>
<tr><th colspan="3">ROADHEADER'S PERFORMANCE FORM</th></tr>
<tr><th>General Information</th><th>Machine Specification</th><th>Gallery information</th></tr>
<tr><td>Date: 01.03.2019
Company: Park Termik
Location: Çayırhan
Gallery: H North preparation
Shift: 8-16
Operator experience: 3 years
Company experience: 20 years</td><td>Type: Axial
Brand: DOSCO
Age: 30 years
Cutter type: Conic
Cutter number: 24
Cutter head power: 112 kW
Cutter head revolution: 58 rev/min
Weight: 35 ton</td><td>Gallery cross section: 16.7 m^2
Gallery Inclination: -15º
Formation: Clay and silex
General condition of the formation: There were 2 narrow bands of hard silex in the face consisting of clay.
Water condition: Damp
Support system: Steel sets
Muck transportation system: Belt conveyor</td></tr>
<tr><td>Net cutting rate: 1.25 h
Net production: 18.7 m^3
Net cutting rate: 14.96 m^3/h
Length of advance: 0.80 m/h</td><td colspan="2">The starting point of the excavation on the face and the way of continuing the excavation:
In addition to the excavation of the gallery face, 2m^3 of the lower part of the face was excavated for the support installation for the next round.</td></tr>
<tr><th colspan="3">Measurements of Machine Utilization Time</th></tr>
<tr><th>Activities</th><th>Time (min)</th><th>Ratio to the total time (8 hours) (%)</th></tr>
<tr><td>Excavation (trimming included)</td><td>---</td><td>---</td></tr>
<tr><td>Support installation</td><td>---</td><td>---</td></tr>
<tr><td>Muck loading and transportation</td><td>---</td><td>---</td></tr>
<tr><td>Cutter change</td><td>---</td><td>---</td></tr>
<tr><td>Machine maintenance</td><td>---</td><td>---</td></tr>
<tr><td>Mechanical failure</td><td>---</td><td>---</td></tr>
<tr><td>Electrical failure</td><td>---</td><td>---</td></tr>
<tr><td>Shift change</td><td>---</td><td>---</td></tr>
<tr><td>Others</td><td>---</td><td>---</td></tr>
<tr><td colspan="3">NOTE: Since this form is the performance form of the second excavation round of the first form dated 01.03.2019, MUT measurements were calculated in the first form.</td></tr>
<tr><td colspan="3">Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm</td></tr>
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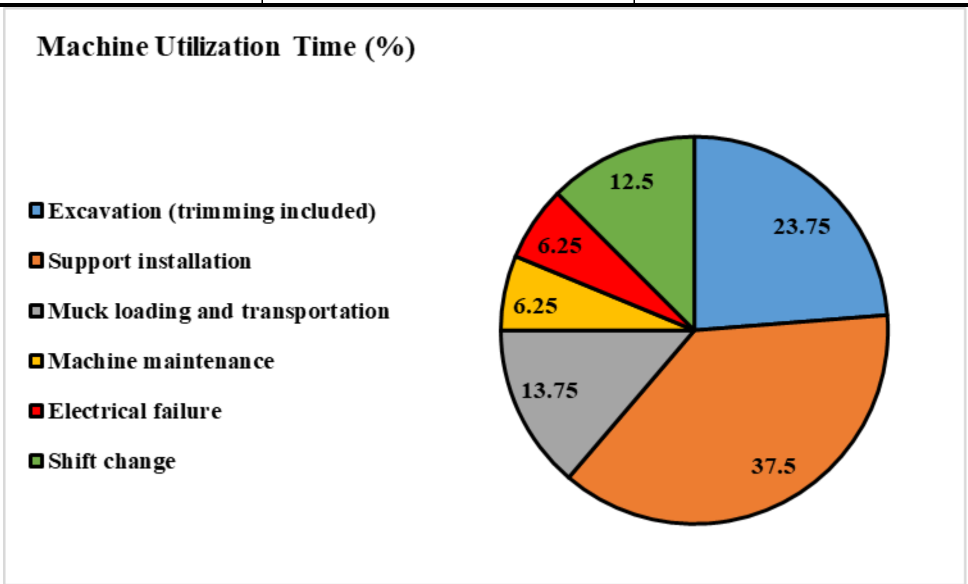
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.9 h **Net production:** 70.5 m^3 **Net cutting rate:** 37.1 m^3/h **Length of advance:** 1.6 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	114	23.75
Support installation	180	37.50
Muck loading and transportation	66	13.75
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.5
Others	---	---



Other information:
Number of workers : 7
Horizontal distance between steel sets: 100 cm

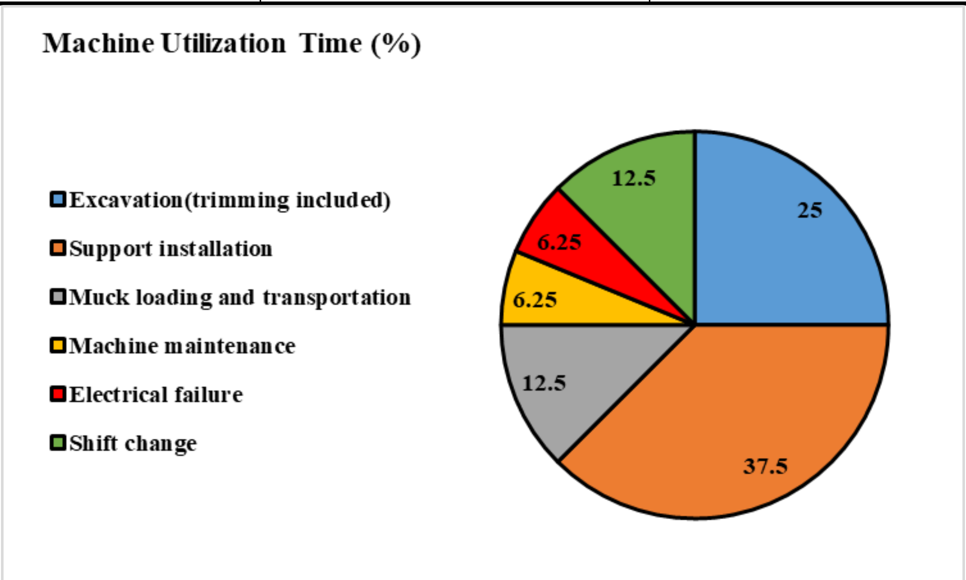
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.0 h **Net production:** 70.5 m^3 **Net cutting rate:** 35.3 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.

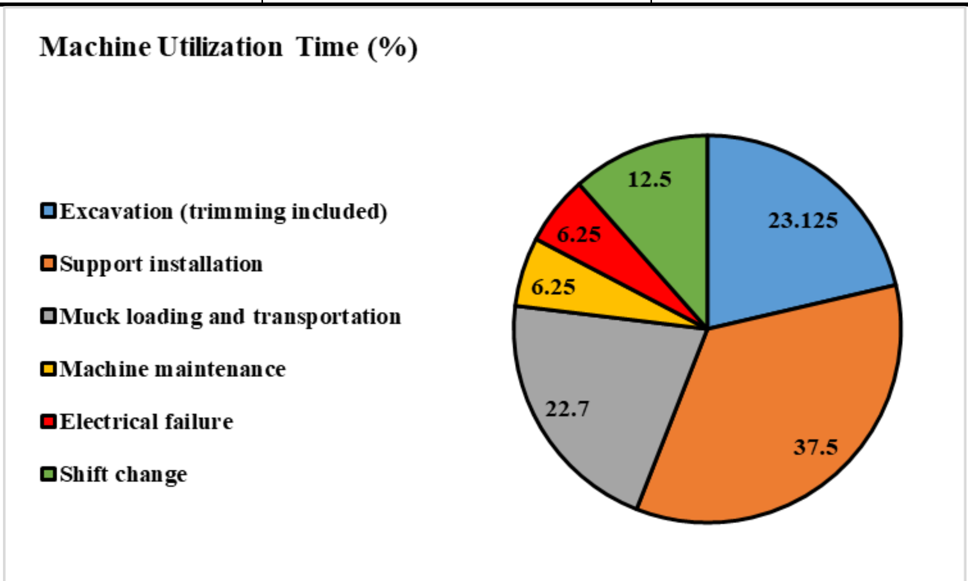
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	120	25.0
Support installation	180	37.5
Muck loading and transportation	60	12.5
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.5
Others	---	---



Other information:
Number of workers: 7
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.85 h **Net production:** 70.5 m^3 **Net cutting rate:** 38.1 m^3/h **Length of advance:** 1.6 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	111	23.125
Support installation	180	37.50
Muck loading and transportation	109	22.70
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.50
Others	---	---



Other information:
Number of workers: 7
Horizontal distance between steel sets: 100 cm

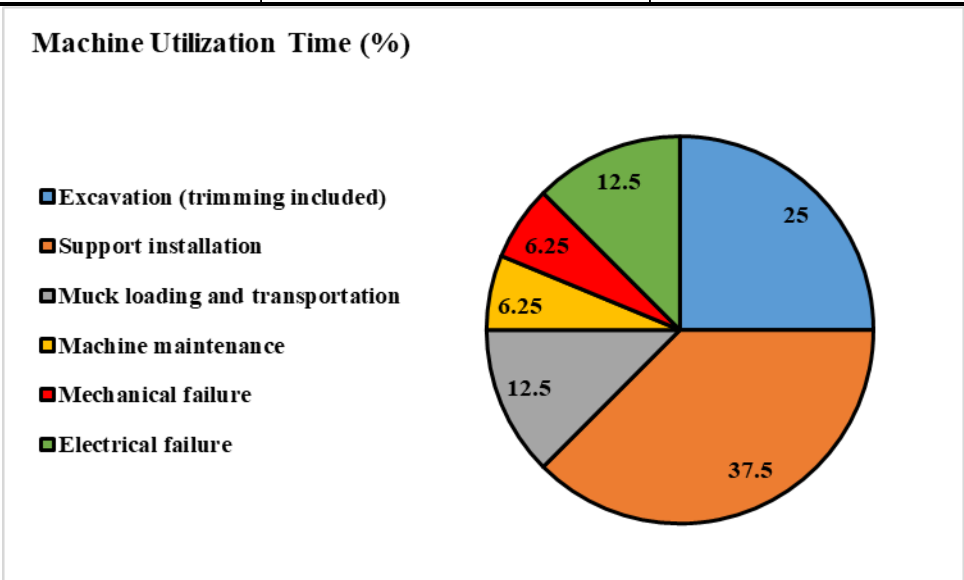
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.0 h **Net production:** 70.5 m^3 **Net cutting rate:** 35.3 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	120	25.0
Support installation	180	37.5
Muck loading and transportation	60	12.5
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.5
Others	---	---



Other information:
Number of workers : 7
Horizontal distance between steel sets: 100 cm

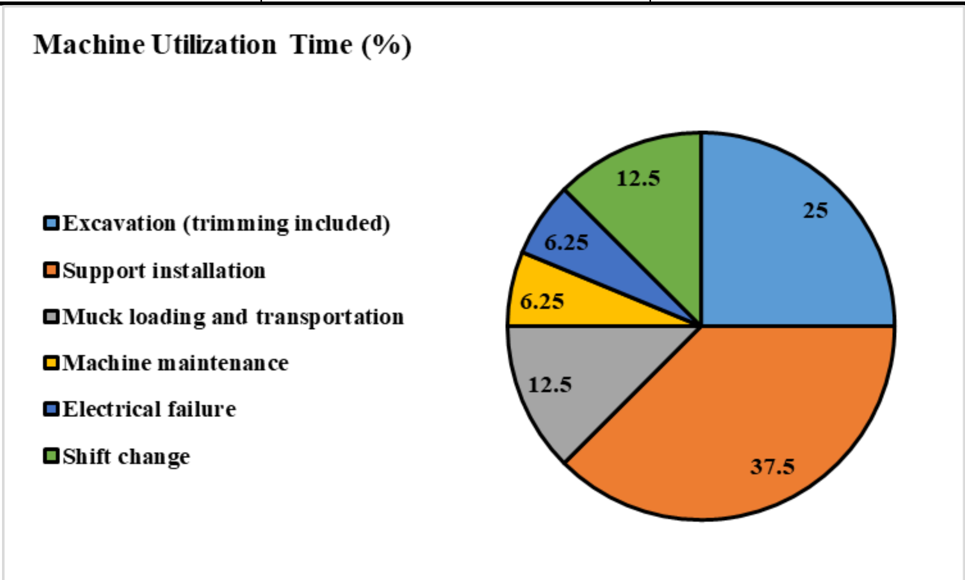
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.0 h **Net production**: 70.5 m^3 **Net cutting rate:** 35.3 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.

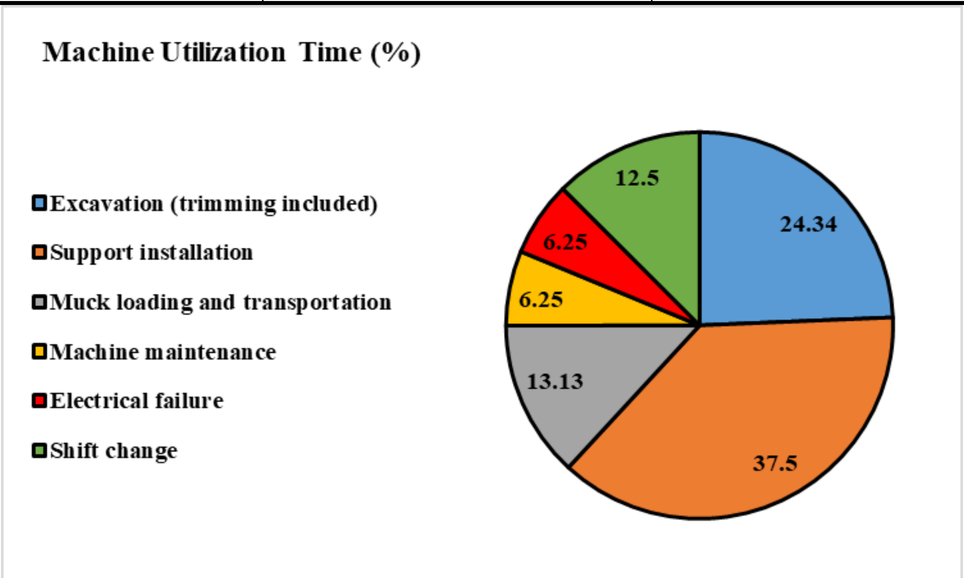
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	120	25.0
Support installation	180	37.5
Muck loading and transportation	60	12.5
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.5
Others	---	---



Other information:
Number of workers : 7
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number** : 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.95 h **Net production:** 70.5 m^3 **Net cutting rate:** 36.2 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	117	24.34
Support installation	180	37.50
Muck loading and transportation	63	13.13
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.50
Others	---	---



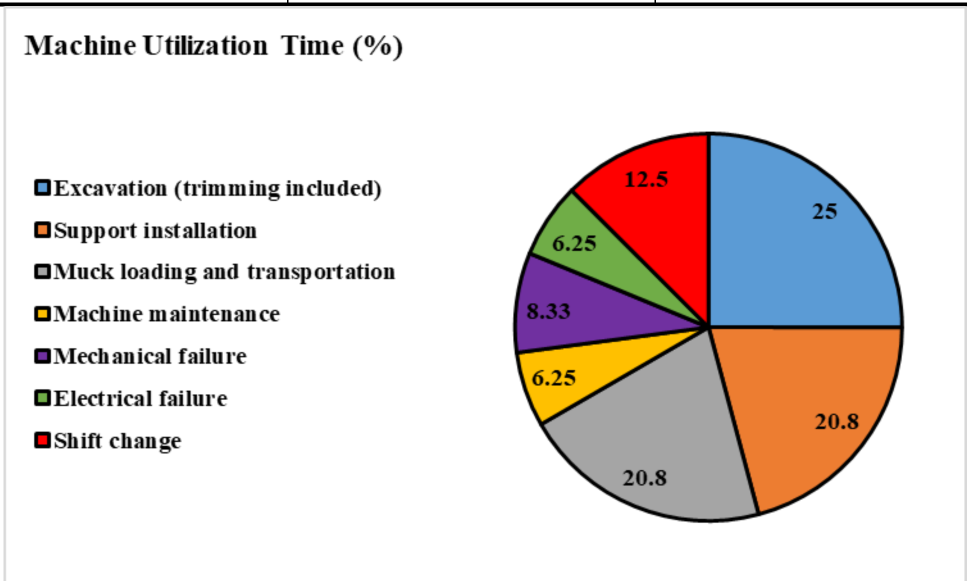
Other information:
Number of workers : 7
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.0 h **Net production**: 94.0 m^3 **Net cutting rate:** 47.0 m^3/h **Length of advance:** 2.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	120	25.0
Support installation	100	20.8
Muck loading and transportation	100	20.8
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	40	8.33
Electrical failure	30	6.25
Shift change	60	12.5
Others	---	---



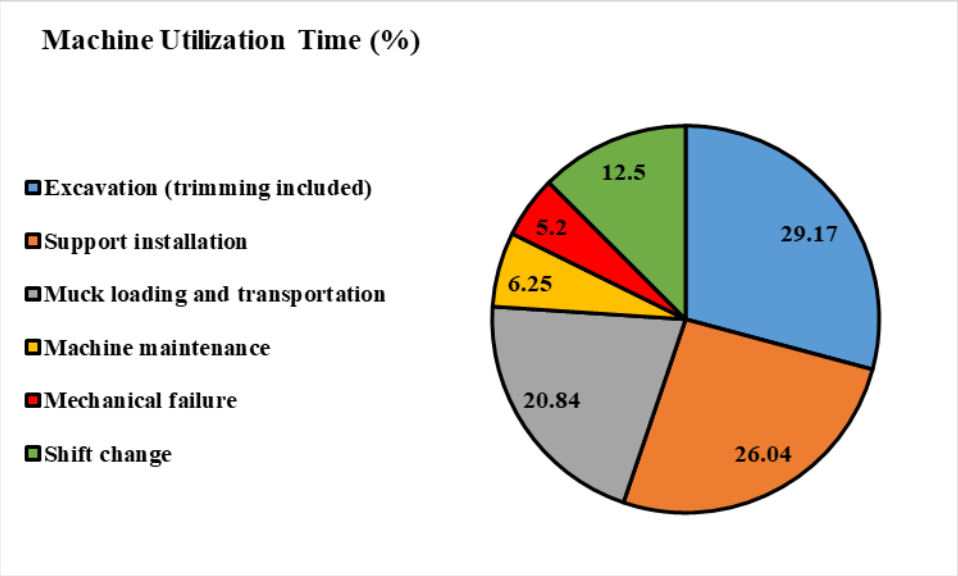
Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.33 h **Net production:** 94.0 m^3 **Net cutting rate:** 40.3 m^3/h **Length of advance:** 1.71 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	140	29.17
Support installation	125	26.04
Muck loading and transportation	100	20.84
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

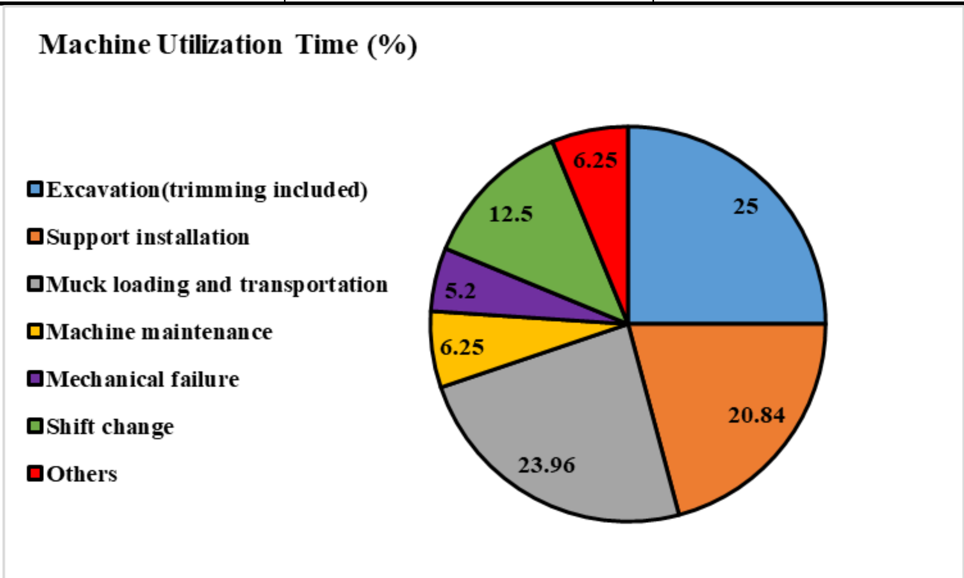
ROADHEADER’S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.0 h **Net production:** 94.0 m^3 **Net cutting rate:** 47.0 m^3/h **Length of advance:** 2.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.

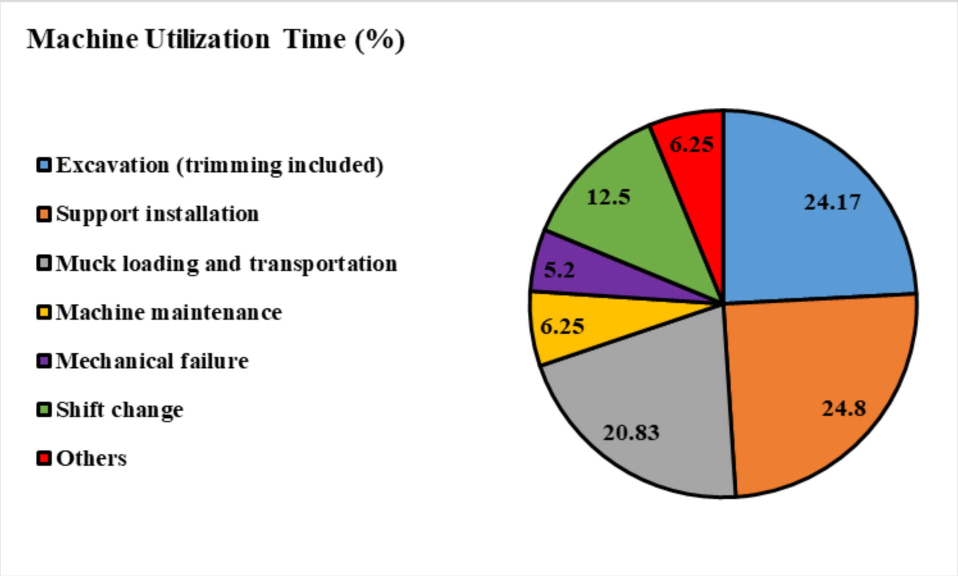
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	120	25.0
Support installation	100	20.84
Muck loading and transportation	115	23.96
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	---	---
Shift change	60	12.5
Others	30	6.25



Other information:
Number of workers: 8
Horizontal distance between steel sets : 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.93 h **Net production:** 94.0 m^3 **Net cutting rate:** 48.6 m^3/h **Length of advance:** 2.07 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	116	24.17
Support installation	119	24.80
Muck loading and transportation	100	20.83
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	---	---
Shift change	60	12.5
Others	30	6.25



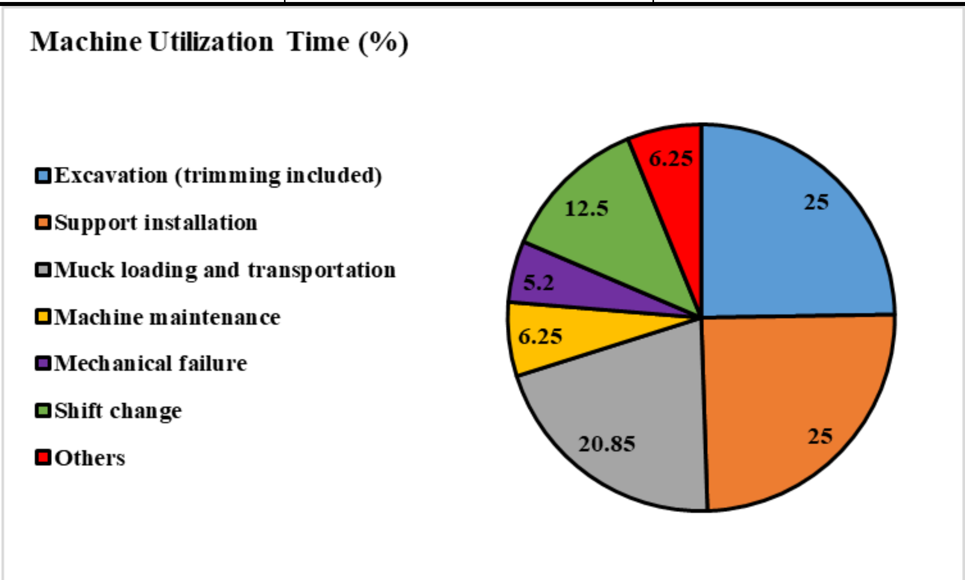
Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

ROADHEADER’S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.0 h **Net production:** 94.0 m^3 **Net cutting rate:** 47.0 m^3/h **Length of advance:** 2.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

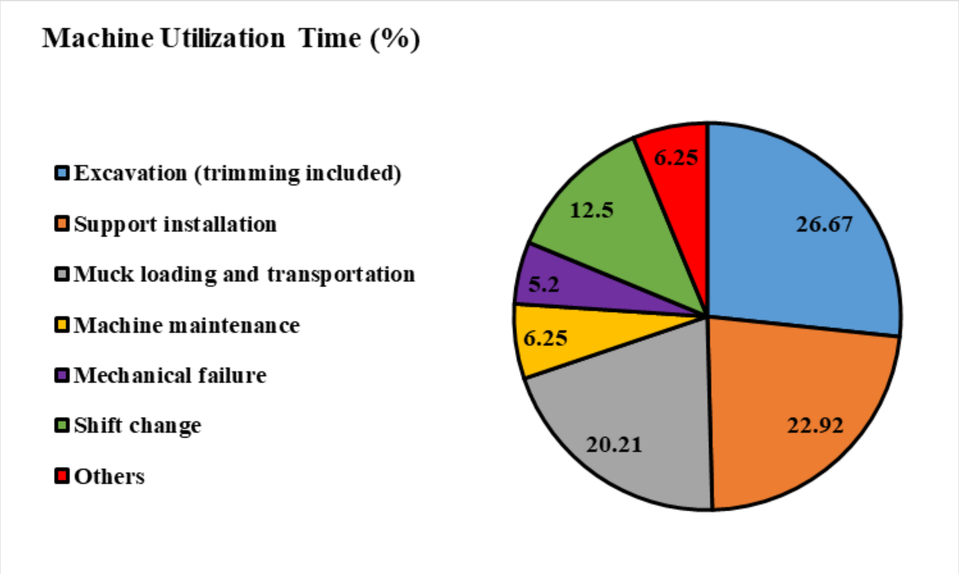
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	120	25.0
Support installation	120	25.0
Muck loading and transportation	100	20.85
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	---	---
Shift change	60	12.5
Others	25	5.20



Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.13 h **Net production:** 94.0 m^3 **Net cutting rate:** 44.1 m^3/h **Length of advance:** 1.87 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	128	26.67
Support installation	110	22.92
Muck loading and transportation	97	20.21
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	---	---
Shift change	60	12.5
Others	30	6.25



Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

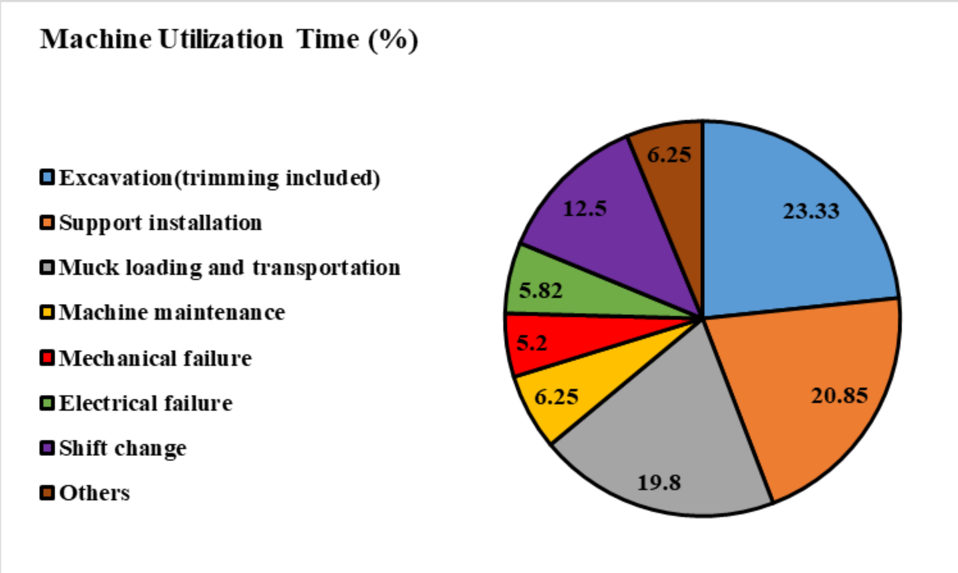
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.87 h **Net production:** 94.0 m^3 **Net cutting rate:** 50.4 m^3/h **Length of advance:** 2.14 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.

Measurements of Machine Utilization Time

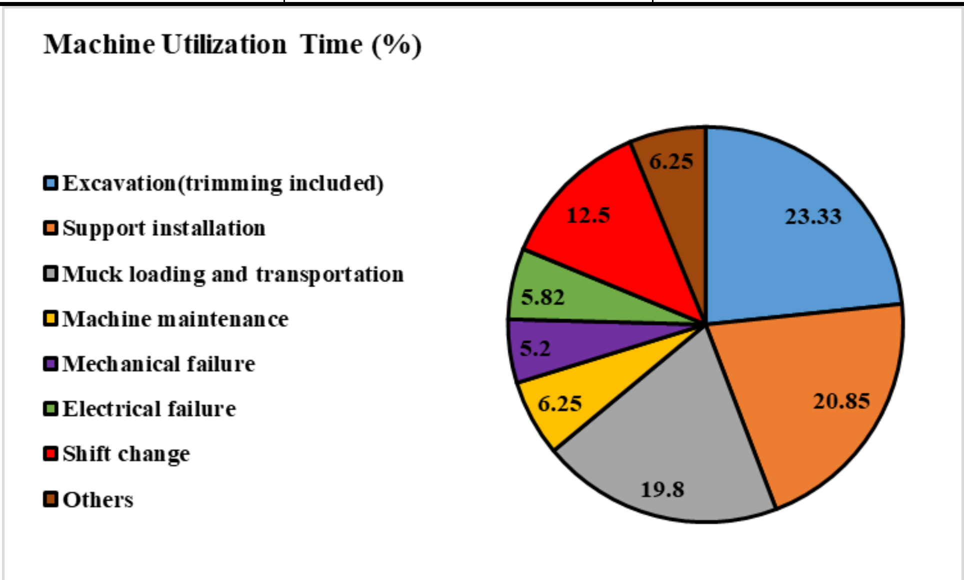
Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	112	23.33
Support installation	100	20.85
Muck loading and transportation	95	19.80
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	28	5.82
Shift change	60	12.5
Others	30	6.25



Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 Preparation **Shift:** 8-16 **Operator experience:** 7 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -2.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.87 h **Net production:** 94.0 m^3 **Net cutting rate:** 50.4 m^3/h **Length of advance:** 2.14 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	112	23.33
Support installation	100	20.85
Muck loading and transportation	95	19.80
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	25	5.20
Electrical failure	28	5.82
Shift change	60	12.5
Others	30	6.25



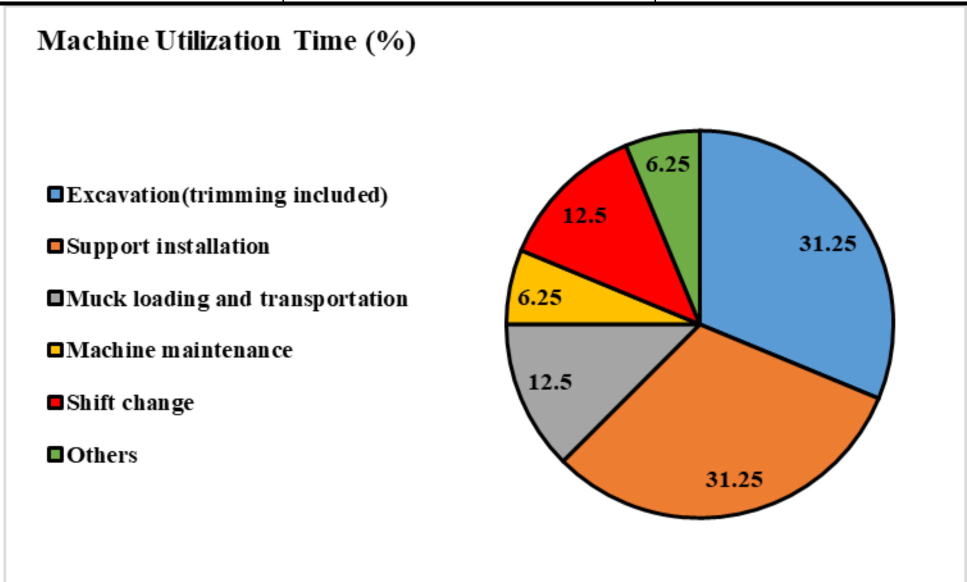
Other information:
Number of workers: 8
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number** : 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.5 h **Net production**: 70.5 m^3 **Net cutting rate:** 28.2 m^3/h **Length of advance:** 1.2 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	150	31.25
Support installation	150	31.25
Muck loading and transportation	60	12.5
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.5
Others	30	6.25

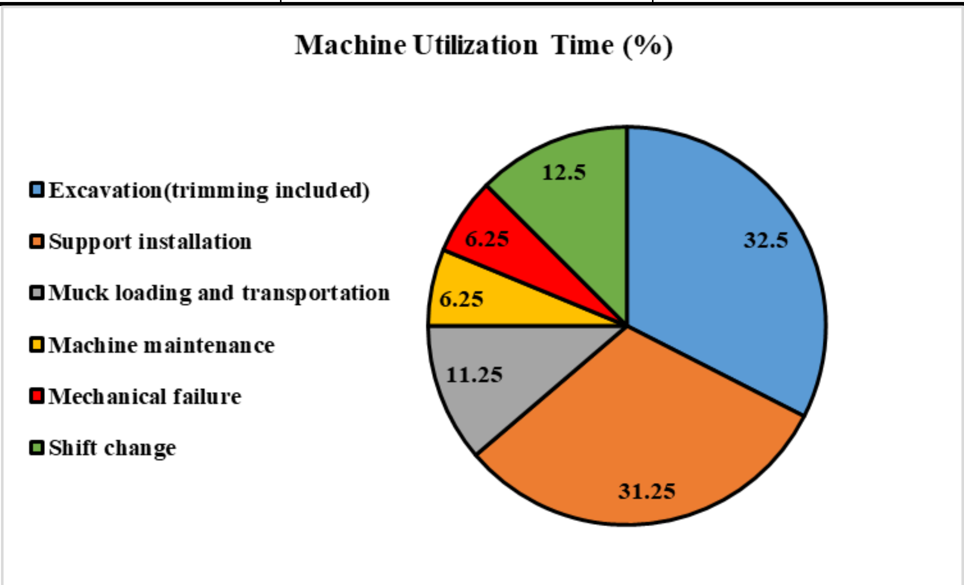


Other information:
Number of workers: 7
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.6 h **Net production:** 70.5 m^3 **Net cutting rate:** 27.1 m^3/h **Length of advance:** 1.15 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	156	32.5
Support installation	150	31.25
Muck loading and transportation	54	11.25
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	30	6.25
Electrical failure	---	---
Shift change	60	12.5
Others	---	---



Other information:
Number of workers: 7
Horizontal distance between steel sets: 100 cm

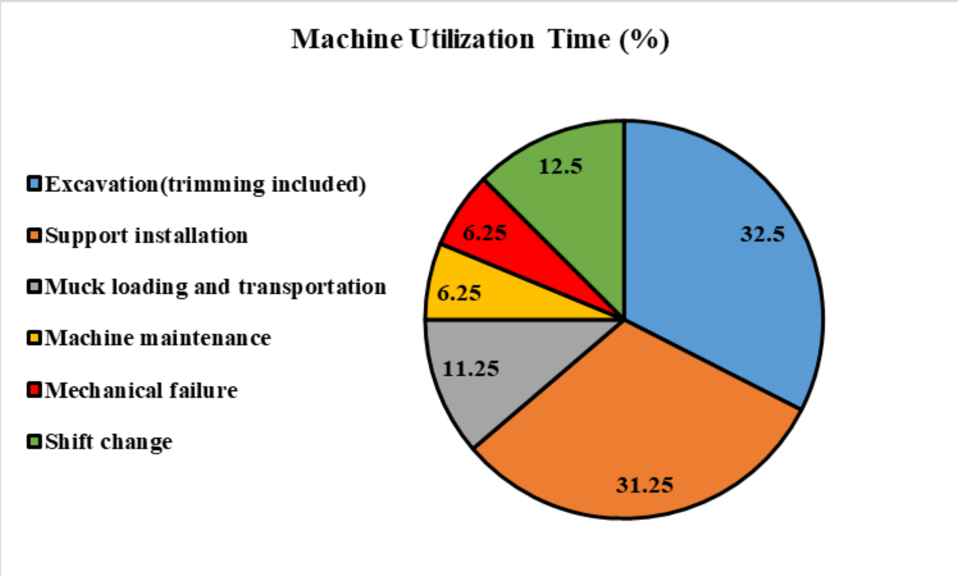
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** J Main road **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 1.5 years	**Type**: Axial **Brand**: Dosco **Age**: 30 years **Cutter type**: Conic **Cutter number**: 24 **Cutter head power**: 112 kW **Cutter head revolution**: 58 rev/min **Weight**: 35 ton	**Gallery cross section**: 23.5 m^2 **Gallery Inclination:** -1.5° **Formation**: Coal **General condition of the formation**: 100% soft coal **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.6 h **Net production:** 70.5 m^3 **Net cutting rate:** 27.1 m^3/h **Length of advance:** 1.15 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower side corners of the face and continued upwards. In the next stage, the middle and upper parts of the excavation face were removed, and finally, the lower part was excavated.

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	156	32.5
Support installation	150	31.25
Muck loading and transportation	54	11.25
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	30	6.25
Shift change	60	12.5
Others	---	---



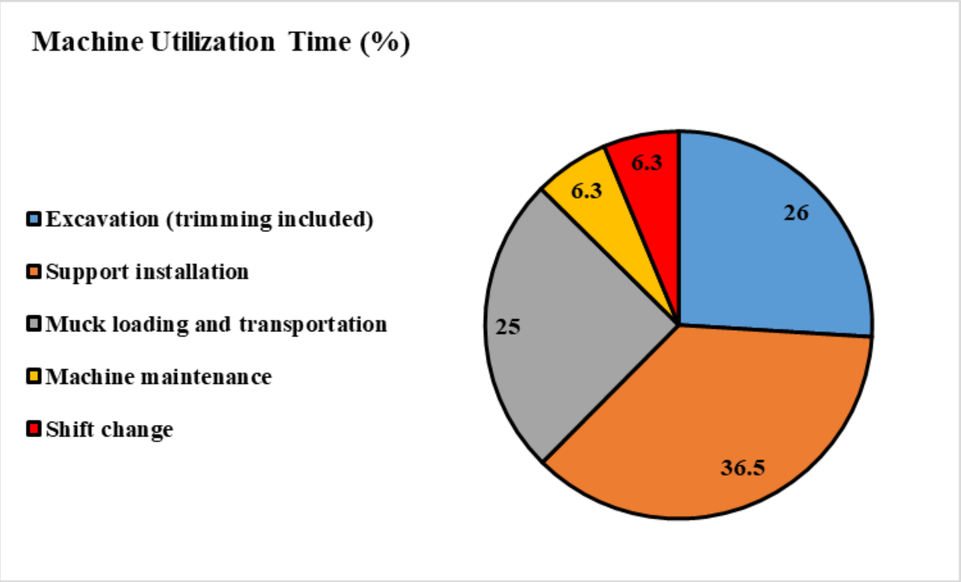
Other information:
Number of workers: 7
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 20.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** Ventilation **Shift:** 8-16 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** -18° **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.1 h **Net production:** 13.4 m^3 **Net cutting rate:** 6.4 m^3/h **Length of advance:** 0.8 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	125	26.0
Support installation	175	36.5
Muck loading and transportation	120	25.0
Cutter change	---	---
Machine maintenance	30	6.3
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.3
Others	---	---



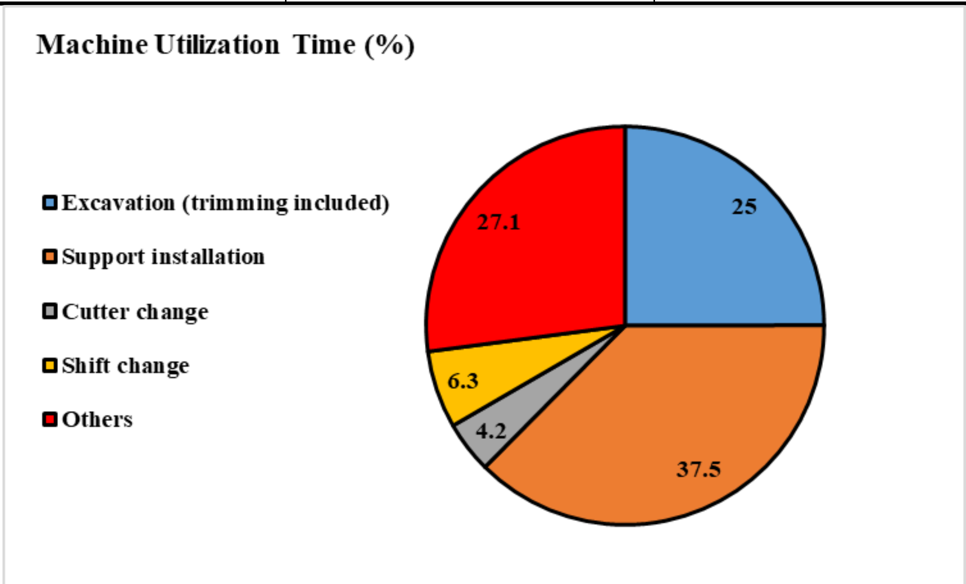
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 21.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** Ventilation **Shift:** 8-16 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** -18^o **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2 h **Net production:** 12.8 m^3 **Net cutting rate:** 6.4 m^3/h **Length of advance:** 0.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	

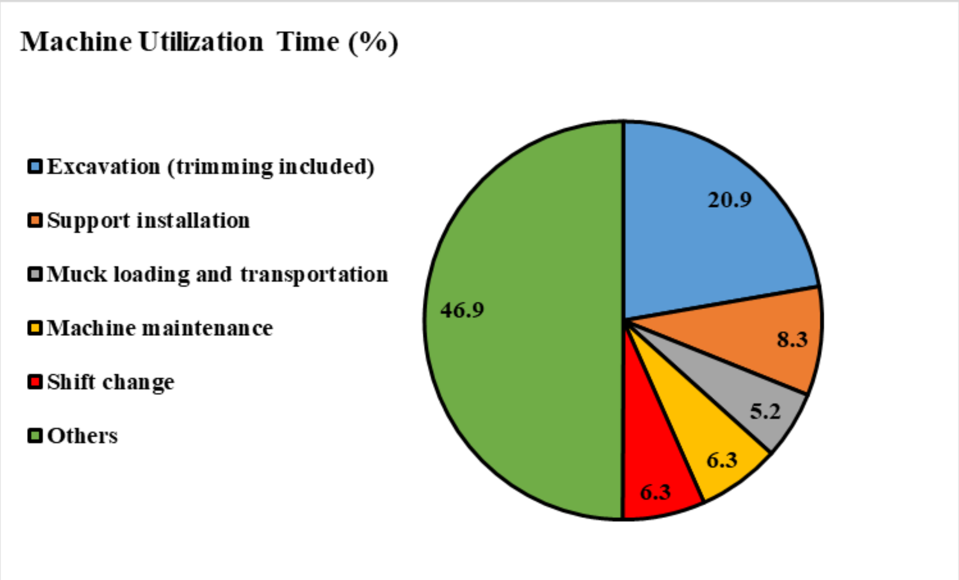
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	120	25.0
Support installation	180	37.5
Muck loading and transportation	---	---
Cutter change	20	4.2
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.3
Others	130	27.1



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 22.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** Ventilation **Shift:** 16-24 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** -14º **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.66 h **Net production**: 11.95 m^3 **Net cutting rate:** 7.2 m^3/h **Length of advance:** 0.85 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	100	20.9
Support installation	40	8.3
Muck loading and transportation	25	5.2
Cutter change	---	---
Machine maintenance	30	6.3
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.3
Others	255	46.9



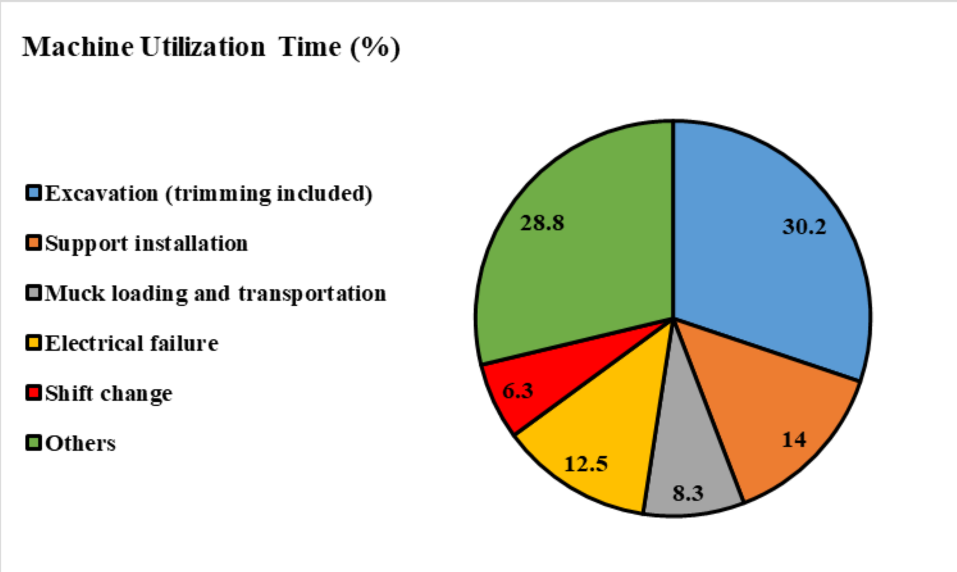
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 22.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** Ventilation **Shift:** 8-16 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** -14° **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.41 h **Net production**: 19.8 m^3 **Net cutting rate:** 8.2 m^3/h **Length of advance:** 0.95 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	

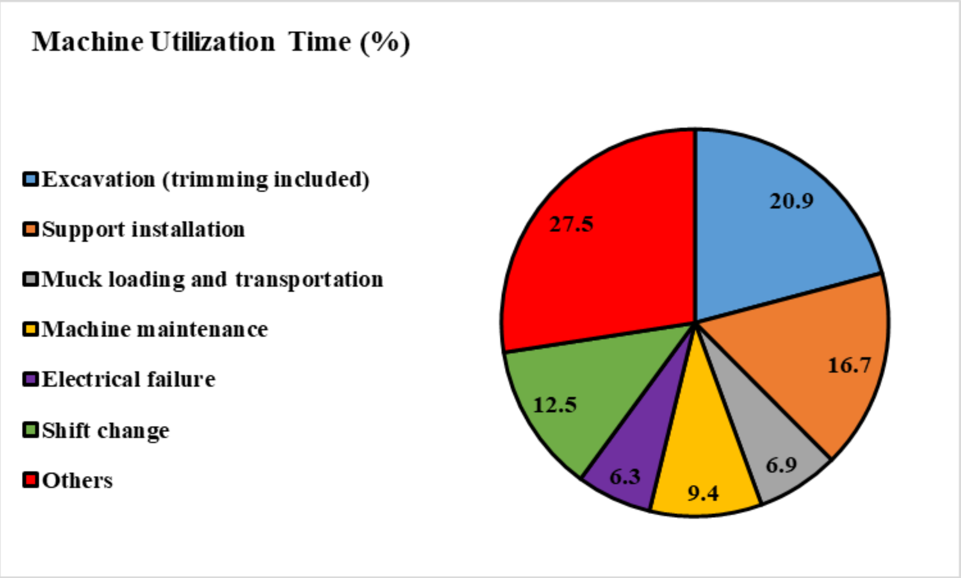
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	145	30.2
Support installation	67	14.0
Muck loading and transportation	40	8.3
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	60	12.5
Shift change	30	6.3
Others	138	28.8



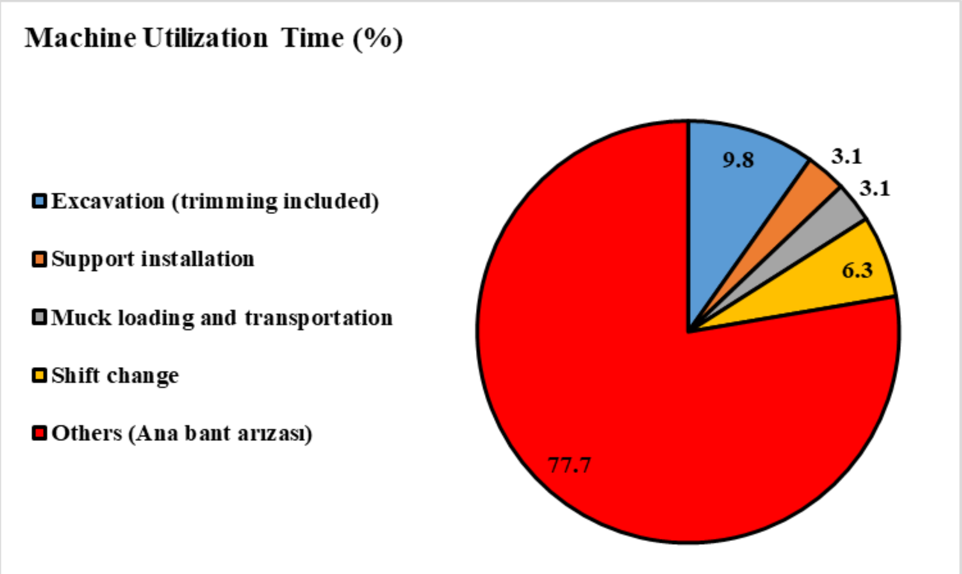
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 23.05.2019 **Company:** YS Mining **Location:** Dodurga.Çorum **Gallery:** Ventilation **Shift:** 8-16 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** -17° **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.7 h **Net production:** 13.4 m^3 **Net cutting rate:** 8.0 m^3/h **Length of advance:** 6.7 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	100	20.9
Support installation	80	16.7
Muck loading and transportation	33	6.9
Cutter change	---	---
Machine maintenance	45	9.4
Mechanical failure	---	---
Electrical failure	30	6.3
Shift change	60	12.5
Others	132	27.5



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

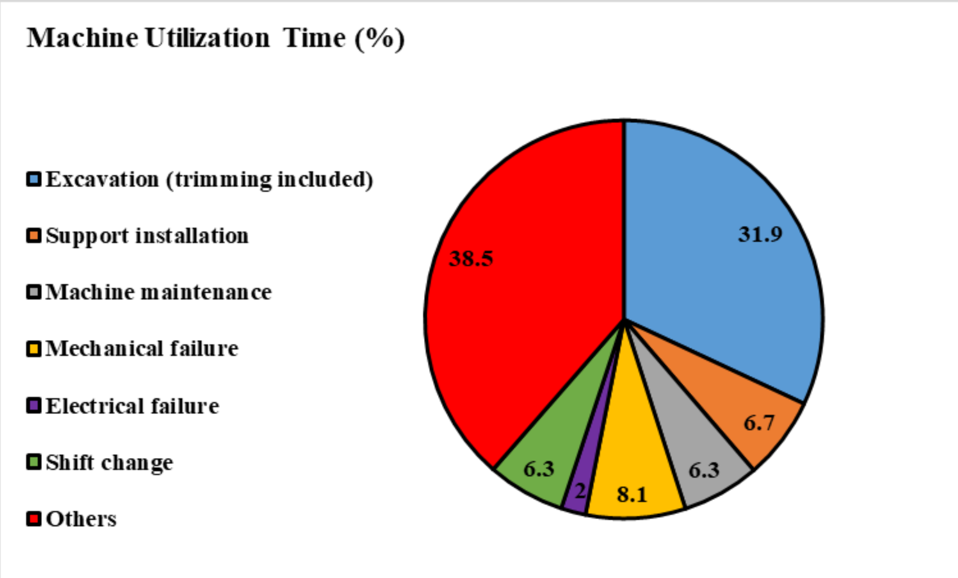
ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 23.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** Ventilation **Shift:** 16-24 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** -17° **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.78 h **Net production**: 4.8 m^3 **Net cutting rate:** 6.1 m^3/h **Length of advance:** 0.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	47	9.8
Support installation	15	3.1
Muck loading and transportation	15	3.1
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.3
Others (Ana bant arızası)	373	77.7



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 24.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** Ventilation **Shift:** 8-16 **Operator experience:** 6 months **Company experience:** 2 years	**Type**: Axial **Brand**: EBZ75 **Age**: 5 years **Cutter type**: Conic **Cutter number**: 36 **Cutter head power**: 75 kW **Cutter head revolution**: 49 rev/min **Weight**: 24 ton	**Gallery cross section**: 12 m^2 **Gallery Inclination:** 0° **Formation**: Claystone **General condition of the formation**: 100% hard claystone **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.55 h **Net production:** 19.8 m^3 **Net cutting rate:** 7.8 m^3/h **Length of advance:** 0.95 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	153	31.9
Support installation	32	6.7
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	30	6.3
Mechanical failure	39	8.1
Electrical failure	10	2.0
Shift change	30	6.3
Others	185	38.5



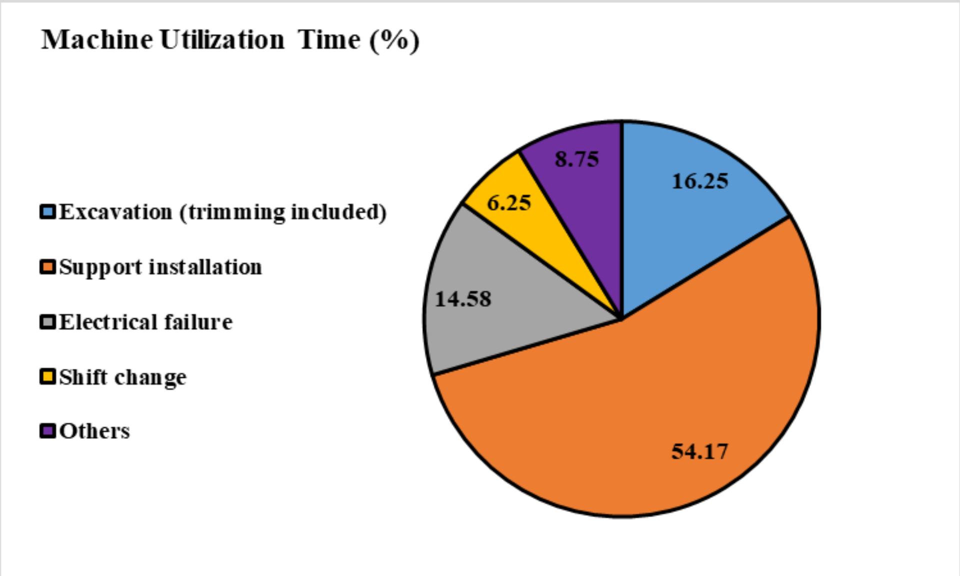
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 8-16 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Axial **Brand**: EBZ-160A **Age**: 5 years **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 160 kW **Cutter head revolution**: --- **Weight**: 45 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: hard formation- marl with hard filling **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.30 h **Net production**: 17.25 m^3 **Net cutting rate:** 13.27 m^3/h **Length of advance:** 0.57 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after the support installation, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	78	16.25
Support installation	260	54.17
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	70	14.58
Shift change	30	6.25
Others	42	8.75

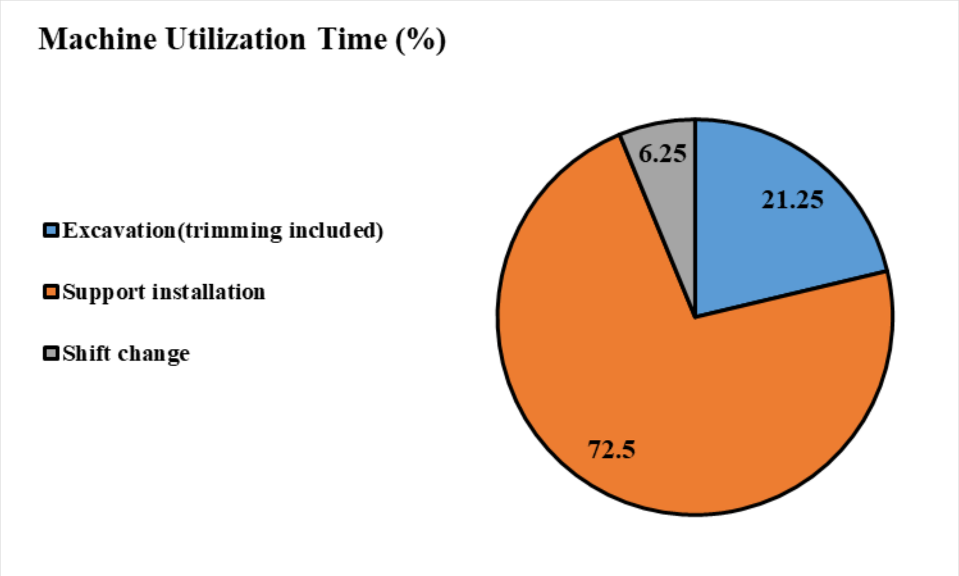


Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 16-24 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Axial **Brand**: EBZ-160A **Age**: 5 years **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 160 kW **Cutter head revolution**: --- **Weight**: 45 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: hard formation- marl with hard filling **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.70 h **Net production:** 17.25 m^3 **Net cutting rate:** 10.15 m^3/h **Length of advance:** 0.44 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after after the support installation, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time

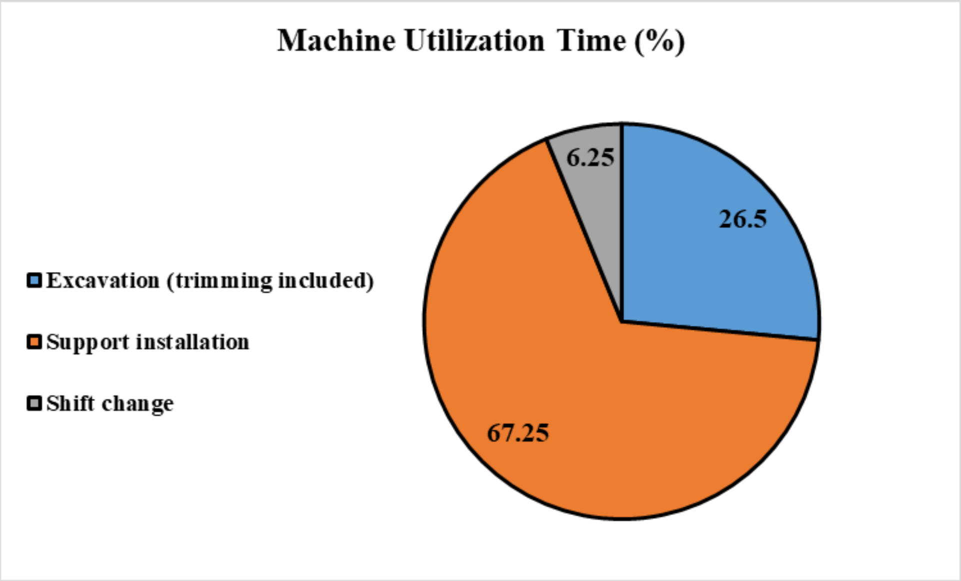
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	102	21.25
Support installation	348	72.50
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	---	---



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 8-16 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Axial **Brand**: EBZ-160A **Age**: 5 years **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 160 kW **Cutter head revolution**: --- **Weight**: 45 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Hard formation- marl with hard filling **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.12 h **Net production:** 34.50 m^3 **Net cutting rate:** 16.3 m^3/h **Length of advance:** 0.71 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after the support installation, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	127.2	26.50
Support installation	322.8	67.25
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	---	---



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5 m

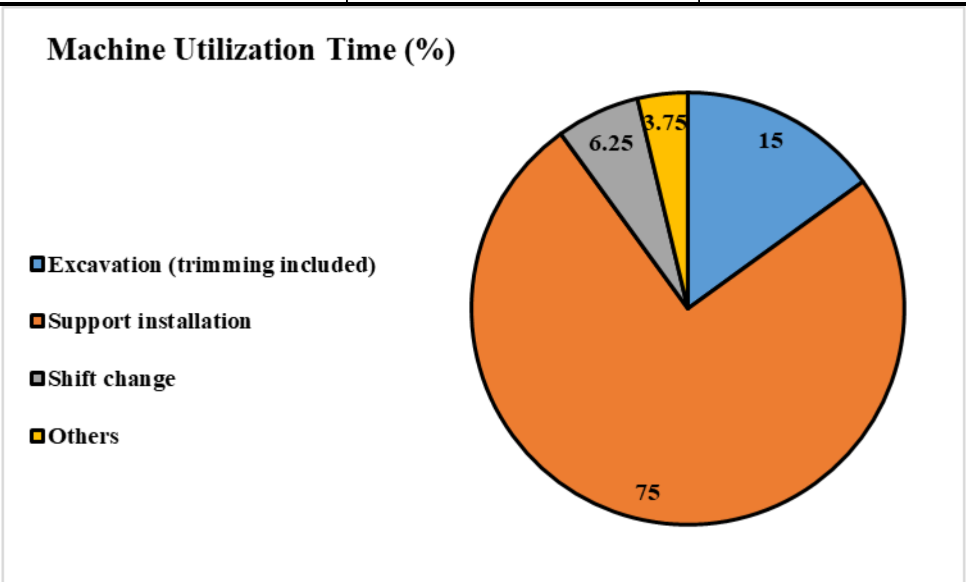
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 24-8 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Axial **Brand**: EBZ-160A **Age**: 5 years **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 160 kW **Cutter head revolution**: --- **Weight**: 45 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Hard formation- marl with hard filling **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Belt conveyor

Net cutting rate: 1.20 h **Net production:** 17.25 m^3 **Net cutting rate:** 14.38 m^3/h **Length of advance:** 0.62 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after the support installation, the other parts of the tunnel face were removed.

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	72	15.0
Support installation	360	75.0
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	18	3.75

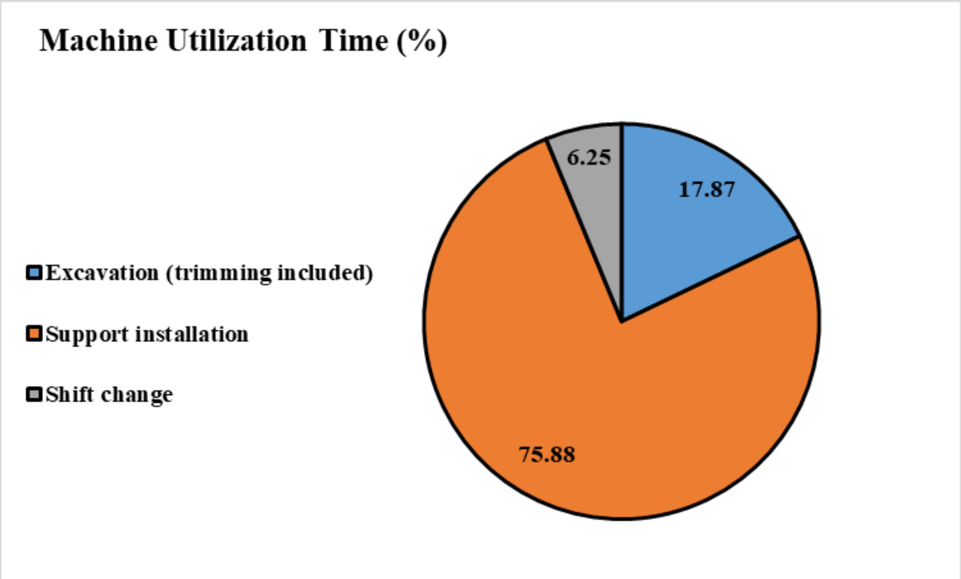


Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 8-16 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Axial **Brand**: EBZ-160A **Age**: 5 years **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 160 kW **Cutter head revolution**: --- **Weight**: 45 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Hard formation- marl with hard filling **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.43 h **Net production:** 17.25 m^3 **Net cutting rate:** 12.1 m^3/h **Length of advance:** 0.53 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after the support installation, the other parts of the tunnel face were removed.	

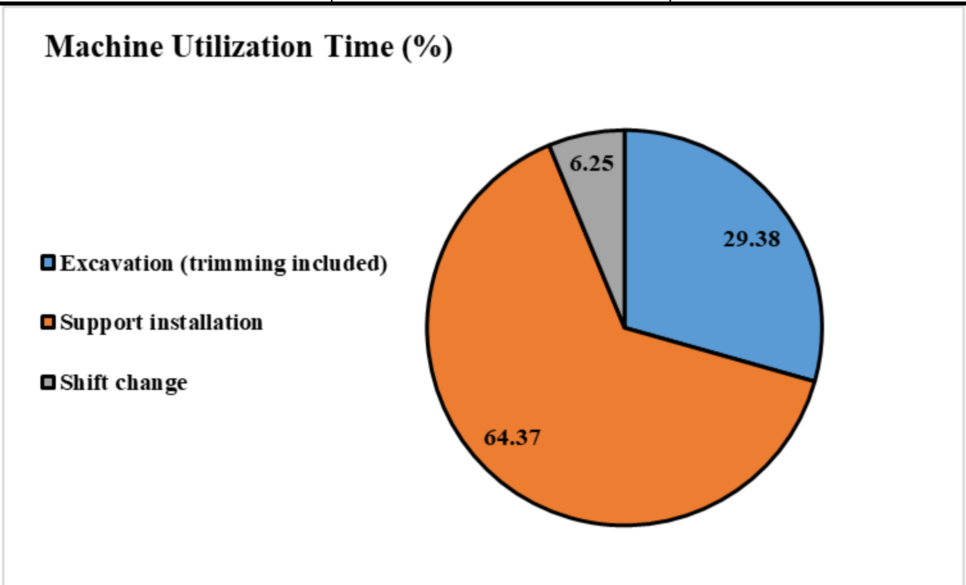
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	85.8	17.87
Support installation	364.2	75.88
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	---	---



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

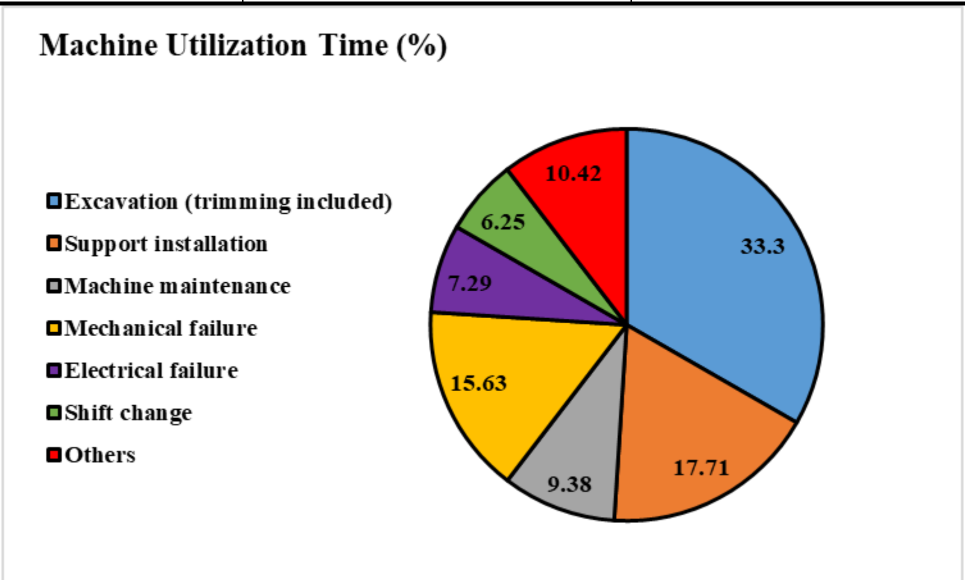
ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 16-24 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Axial **Brand**: EBZ-160A **Age**: 5 years **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 160 kW **Cutter head revolution**: --- **Weight**: 45 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Hard formation-marl with hard filling **Water condition**: Flowing **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.35 h **Net production:** 34.50 m^3 **Net cutting rate:** 14.7 m^3/h **Length of advance:** 0.64 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after the support installation, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	141	29.38
Support installation	309	64.37
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	---	---



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 03.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 26.6 h **Net production:** 16.5 m^3 **Net cutting rate:** 6.19 m^3/h **Length of advance:** 0.28 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	160	33.30
Support installation	85	17.71
Muck loading and transportation	--	--
Cutter change	--	--
Machine maintenance	45	9.38
Mechanical failure	75	15.63
Electrical failure	35	7.29
Shift change	30	6.25
Others	50	10.42



Other information:
Number of workers: 9
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

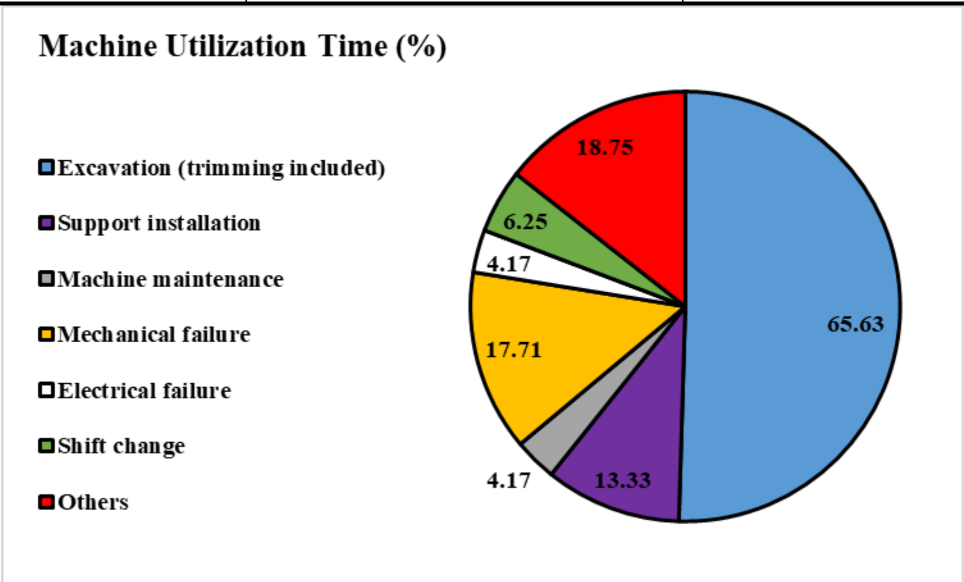
ROADHEADER’S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 03.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4 ° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor

Net cutting rate: 2.85 h **Net production:** 16.5 m^3 **Net cutting rate:** 5.79 m^3/h **Length of advance:** 0.26 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after installation of the support system, the other parts of the tunnel face were removed.

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	171	65.63
Support installation	64	13.33
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	20	4.17
Mechanical failure	85	17.71
Electrical failure	20	4.17
Shift change	30	6.25
Others	90	18.75



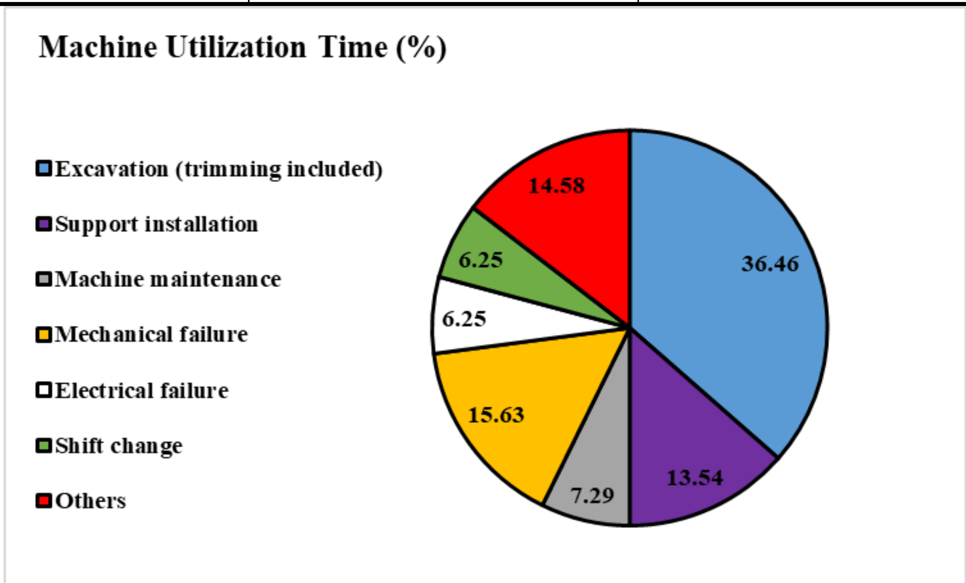
Other information:
Number of workers: 9
Horizontal distance between Steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 03.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 16-24 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4 ° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.91 h **Net production:** 16.5 m^3 **Net cutting rate:** 5.66 m^3/h **Length of advance:** 0.25 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceilıng, and after installation of the support system, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	175	36.46
Support installation	65	13.54
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	35	7.29
Mechanical failure	75	15.63
Electrical failure	30	6.25
Shift change	30	6.25
Others	70	14.58



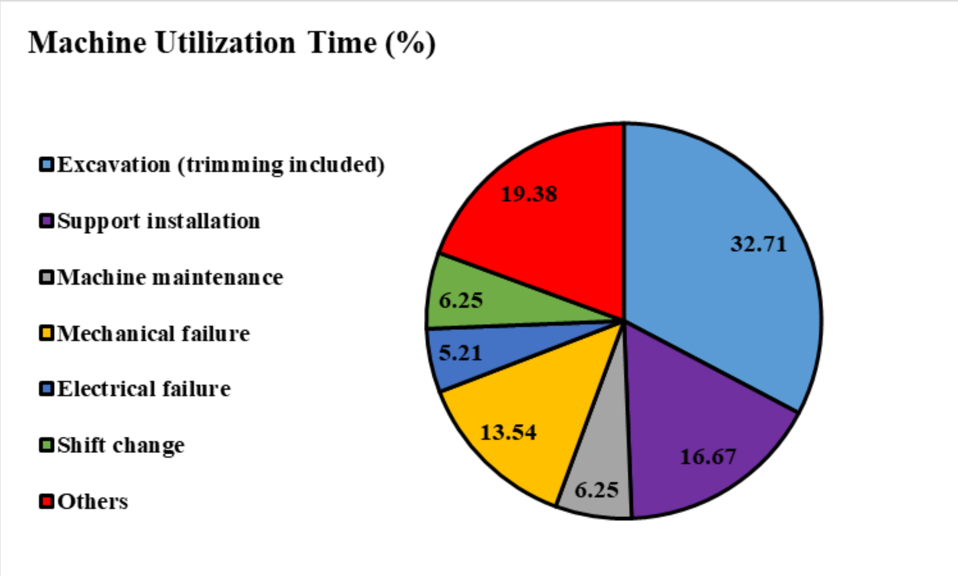
Other information:
Number of workers: 9
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 04.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 24-8 **Operator experience:** 5 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4 ° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.61 h **Net production:** 16.5 m^3 **Net cutting rate:** 6.31 m^3/h **Length of advance:** 0.28 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	157	32.71
Support installation	80	16.67
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	65	13.54
Electrical failure	25	5.21
Shift change	30	6.25
Others	93	19.38



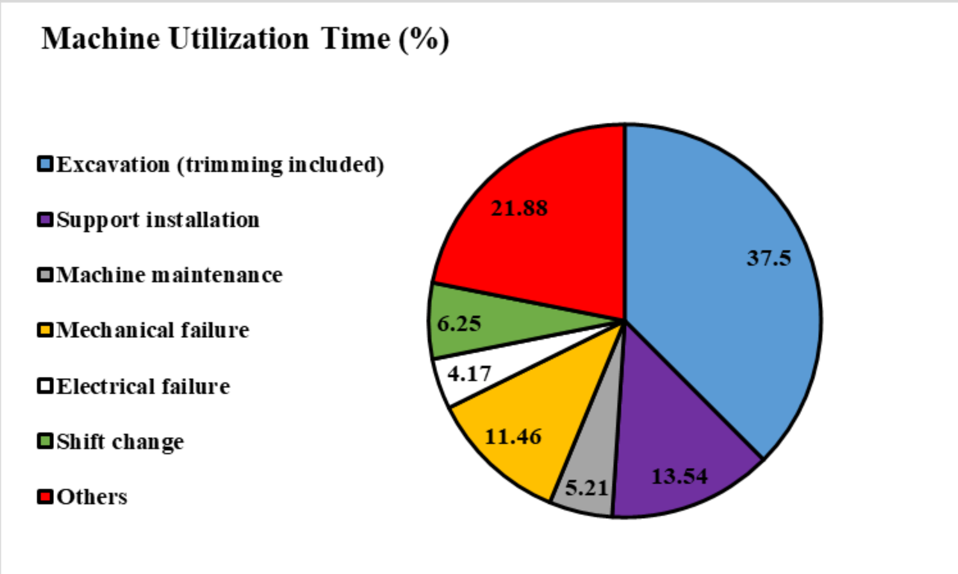
Other information:
Number of workers: 9
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 04.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 3.0 h **Net production:** 16.5 m^3 **Net cutting rate:** 5.50 m^3/h **Length of advance:** 0.25 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

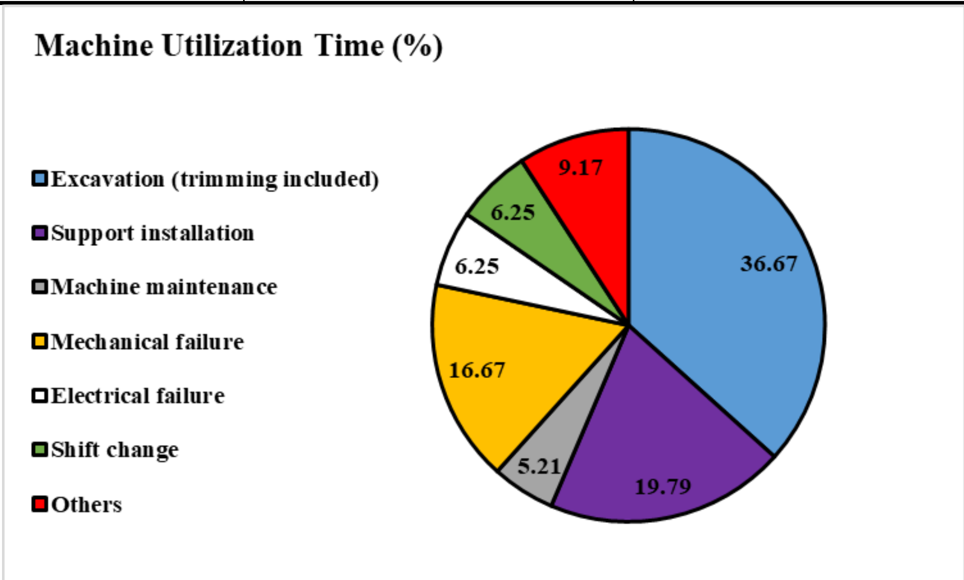
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	180	37.50
Support installation	65	13.54
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	25	5.21
Mechanical failure	55	11.46
Electrical failure	20	4.17
Shift change	30	6.25
Others	105	21.88



Other information:
Number of workers: 9
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 05.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type:** Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4 ° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.93 h **Net production:** 16.5 m^3 **Net cutting rate:** 5.63 m^3/h **Length of advance:** 0.25 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	176	36.67
Support installation	95	19.79
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	25	5.21
Mechanical failure	80	16.67
Electrical failure	30	6.25
Shift change	30	6.25
Others	44	9.17



Other information:
Number of workers: 9
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

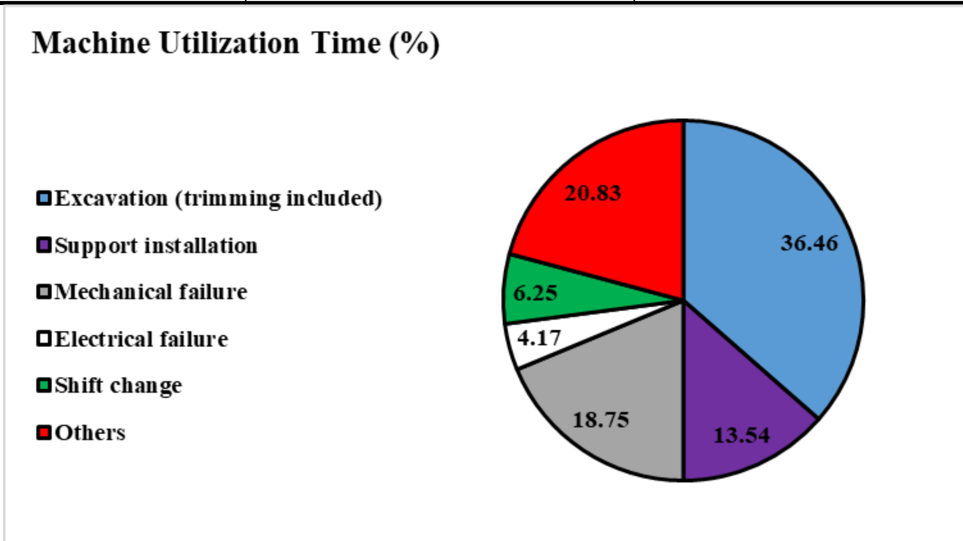
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 06.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** +21 Sub-tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Axial **Brand**: EBZ200H **Age**: 1 year **Cutter type**: Conic **Cutter number** : --- **Cutter head power**: 200 kW **Cutter head revolution**: 36.7 rev/min **Weight**: 40 ton	**Gallery cross section**: 22 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor

Net cutting rate: 2.91h **Net production**: 16.5 m^3 **Net cutting rate:** 5.66 m^3/h **Length of advance:** 0.25 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the ceiling, and after installation of the support system, the other parts of the tunnel face were removed.

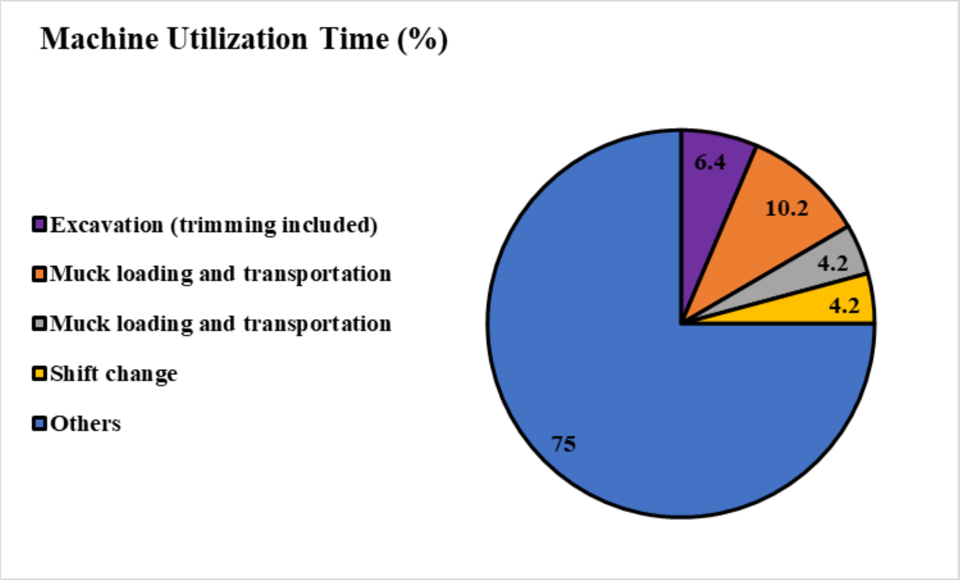
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	175	36.46
Support installation	65	13.54
Muck loading and transportation	---	---
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	90	18.75
Electrical failure	20	4.17
Shift change	30	6.25
Others	100	20.83



Other information:
Number of workers: 9
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 09.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D7 Upper head gate, 1.floor **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 32 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 1° **Formation**: Clay-Coal **General condition of the formation**: mostly composed of coal **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.5 h **Net production**: 11.5 m^3 **Net cutting rate:** 22.3 m^3/h **Length of advance:** 1.3 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, coal is excavated from the lower part of the tunnel face, and then, clay is removed from the upper part.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	31	6.4
Support installation	---	---
Muck loading and transportation	49	10.2
Cutter change	---	---
Muck loading and transportation	20	4.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	20	4.2
Others	360	75



Other information:
Number of workers:
Horizontal distance between Steel sets: 70 cm
In order to prevent the oxidation on the ceiling of the gallery, water was pumped out and the conveyor was broken.
Length of advance: 0.7 m

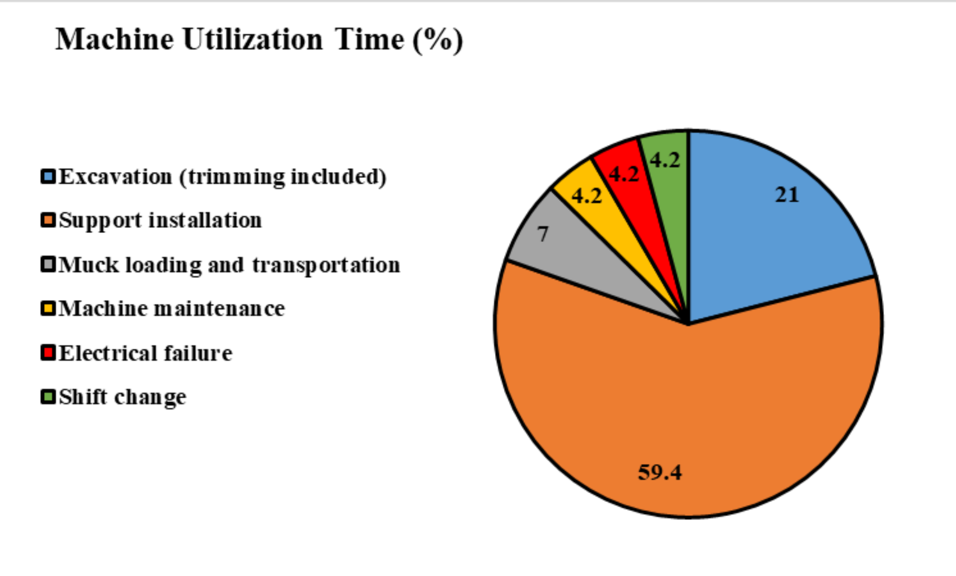
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date:10.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D10 Sub-tail gate **Shift:** 8-16 **Operator experience:** 2 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 32 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 3° **Formation**: Coal-Marl **General condition of the formation**: mostly composed of coal. **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 1.7 h **Net production**: 23 m^3 **Net cutting rate:** 13.6 m^3/h **Length of advance:** 0.82 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** After the upper part of the tunnel face is excavated, first the right lower side and then the left lower side of the face were removed. Face supporting is applied at every stage.

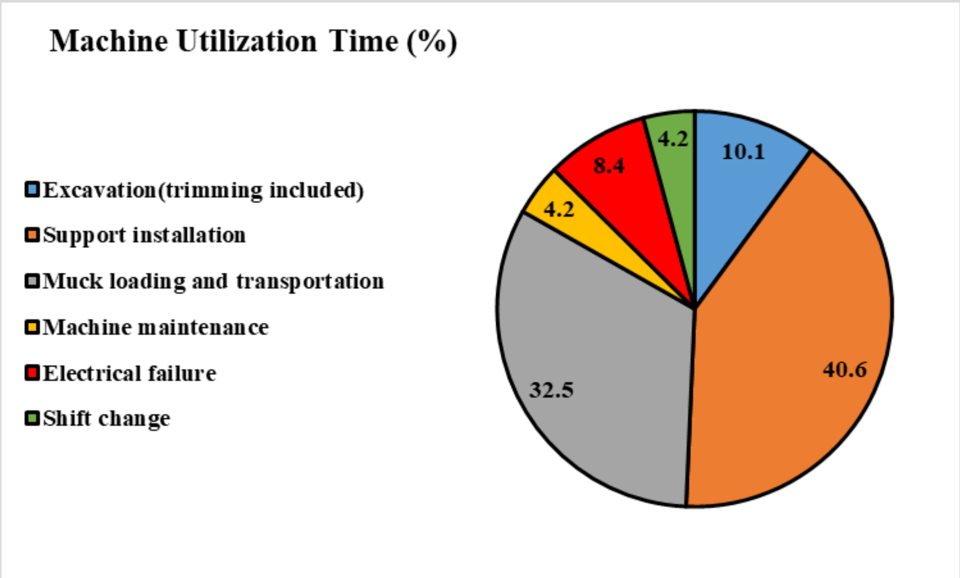
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	102	21.0
Support installation	285	59.4
Muck loading and transportation	33	7.0
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	---	---
Electrical failure	20	4.2
Shift change	20	4.2
Others	---	---



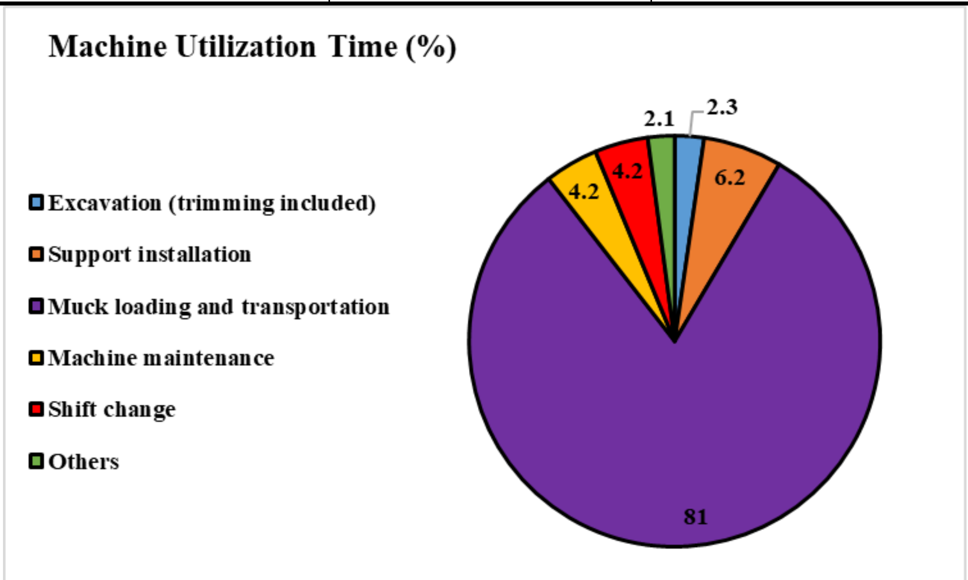
Other information:
Number of workers:
Horizontal distance between steel sets: 70 cm
Length of advance: 1.4 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 11.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D7 Upper head gate, 1.floor **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 32 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** -2° **Formation**: Coal **General condition of the formation**: mostly composed of coal **Water condition:** Dripping **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.8 h **Net production**:13.6 m^3 **Net cutting rate:** 16.8 m^3/h **Length of advance:** 0.87 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** 1-The crown of the tunnel was excavated. 2- The support installation was performed. 3-The side parts of the tunnel face were excavated and support system was installed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	49	10.1
Support installation	195	40.6
Muck loading and transportation	156	32.5
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	---	---
Electrical failure	40	8.4
Shift change	20	4.2
Others	---	---



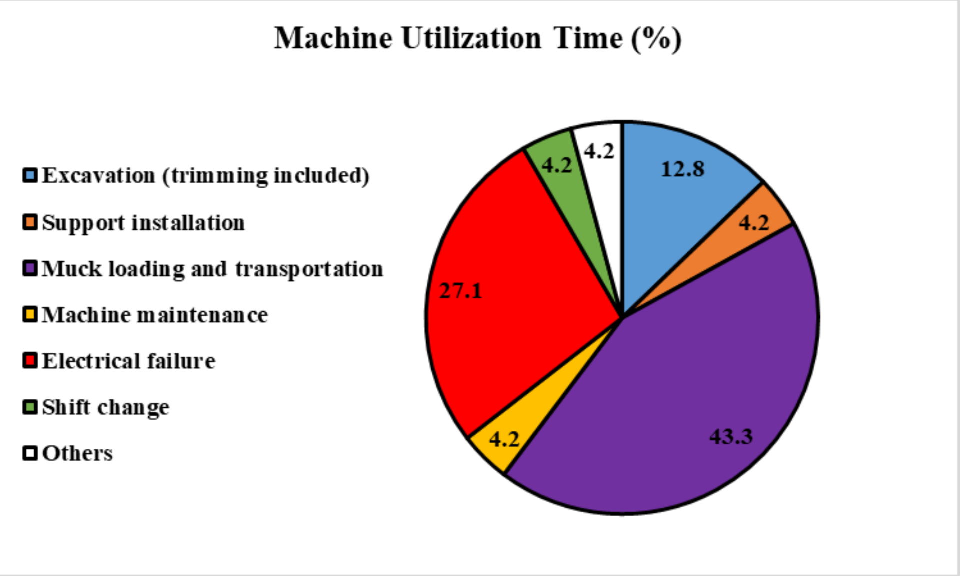
Other information:
Number of workers:
Horizontal distance between steel sets: 70 cm
Length of advance: 0.7 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 12.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D7 Sub-tail gate 2.floor **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 32 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 19° **Formation**: Clay-Coal **General condition of the formation**: mostly composed of clay and there were coal seams on the face. **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.18 h **Net production**: 2.1 m^3 **Net cutting rate:** 11.8 m^3/h **Length of advance:** 0.72 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Only the crown of the tunnel face was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	11	2.3
Support installation	30	6.2
Muck loading and transportation	389	81.0
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	---	---
Electrical failure	---	---
Shift change	20	4.2
Others	10	2.1



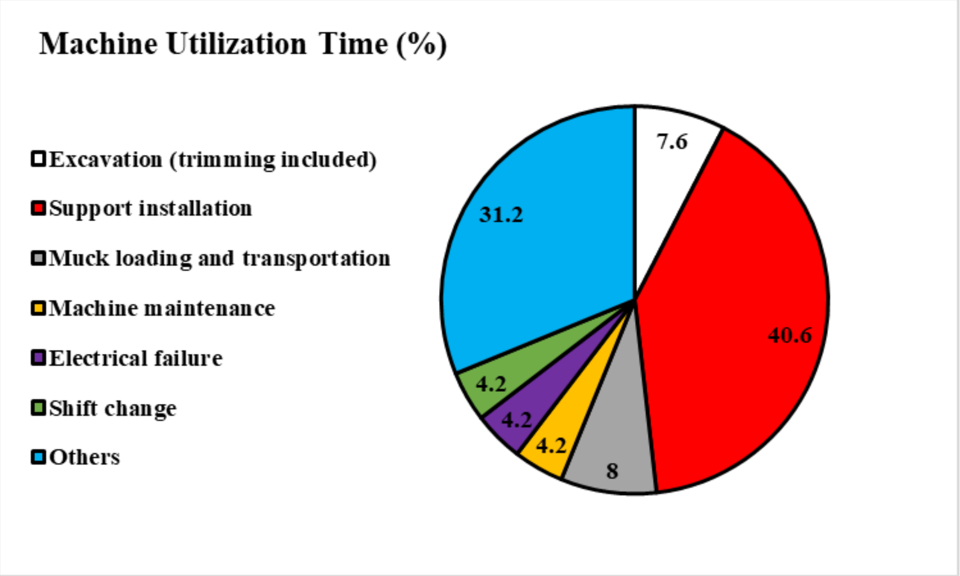
Other information:
Number of workers:
Horizontal distance between steel sets: 70 cm
Due to muck density on the main loading band, the loading time was long.

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Galeri Bilgiler**
Date: 13.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Upper tail gate 1.floor **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**:--- **Weight**: 32 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 3° **Formation**: Marl-Coal **General condition of the formation**: mostly composed of marl. **Water condition**: Dripping **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.02 h **Net production**: 9.4 m^3 **Net cutting rate:** 9.2 m^3/h **Length of advance:** 0.58 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** The crown of the tunnel was excavated in the last shift. Only the lower sides of the tunnel face were excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	61	12.8
Support installation	20	4.2
Muck loading and transportation	209	43.3
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	---	---
Electrical failure	130	27.1
Shift change	20	4.2
Others	20	4.2



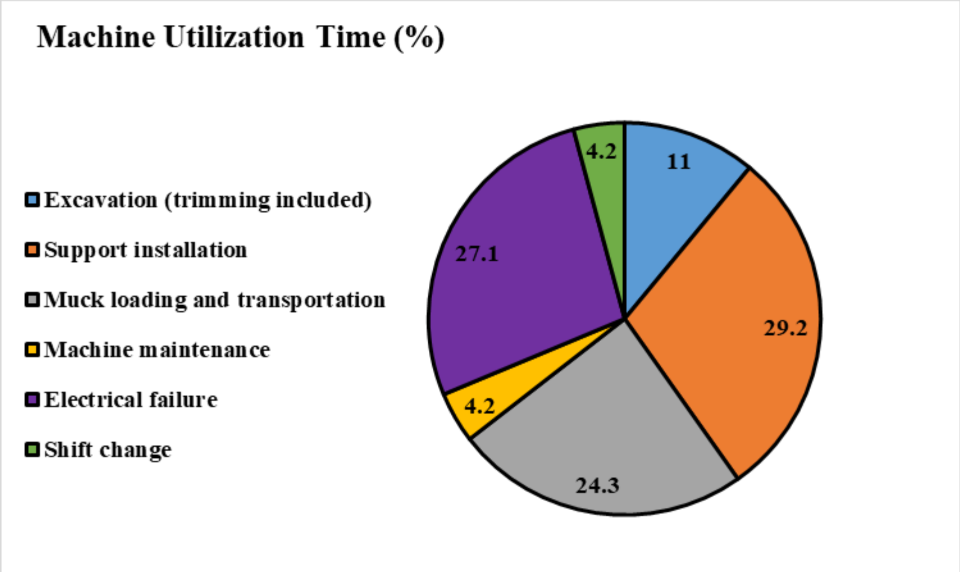
Other information:
Number of workers:
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 16.07.2018 **Company:** Imabt **Location:** Soma **Gallery:** G7 Sub tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 p **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 132 kW **Cutter head revolution**:--- **Weight**: 40 ton	**Gallery cross section**:16.4 m^2 **Gallery Inclination:** 15° **Formation**: Clay-Coal **General condition of the formation**: very weak and flowing, the excavation face composed of 50% coal bands and 50% clay. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.61 h **Net production**: 9.4 m^3 **Net cutting rate:** 15.4 m^3/h **Length of advance:** 1.2 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** The tunnel crown was excavated by hand. Only one side of the tunnel face was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	37	7.6
Support installation	195	40.6
Muck loading and transportation	38	8.0
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	---	---
Electrical failure	20	4.2
Shift change	20	4.2
Others	150	31.2



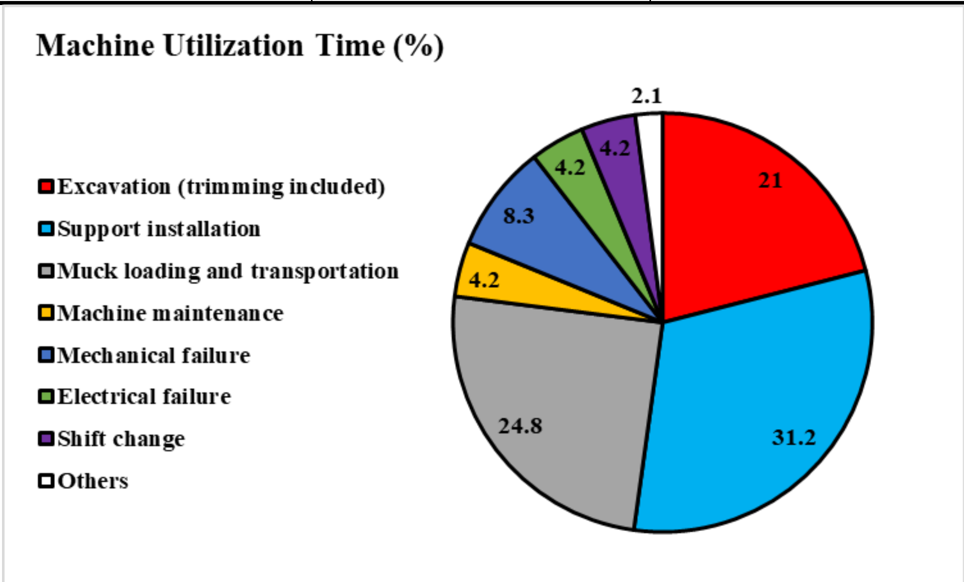
Other information:
Number of workers:
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 17.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D10 Sub-tail gate **Shift:** 8-16 **Operator experience:** 2 years **Company experience:** 20 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**:--- **Weight**: 30 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 1° **Formation**: Clay-coal **General condition of the formation**: There were two narrow band of coal on the face. **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.88 h **Net production**: 13.6 m^3 **Net cutting rate:** 15.4 m^3/h **Length of advance:** 1.2 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** In addition to 1.2 m progress, a crown was excavated.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	53	11.0
Support installation	140	29.2
Muck loading and transportation	115	24.3
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	---	---
Electrical failure	130	27.1
Shift change	20	4.2
Others	---	---



Other information:
Number of workers:
Horizontal distance between Steel sets: 70 cm
There was a large rock jam in the conveyor.

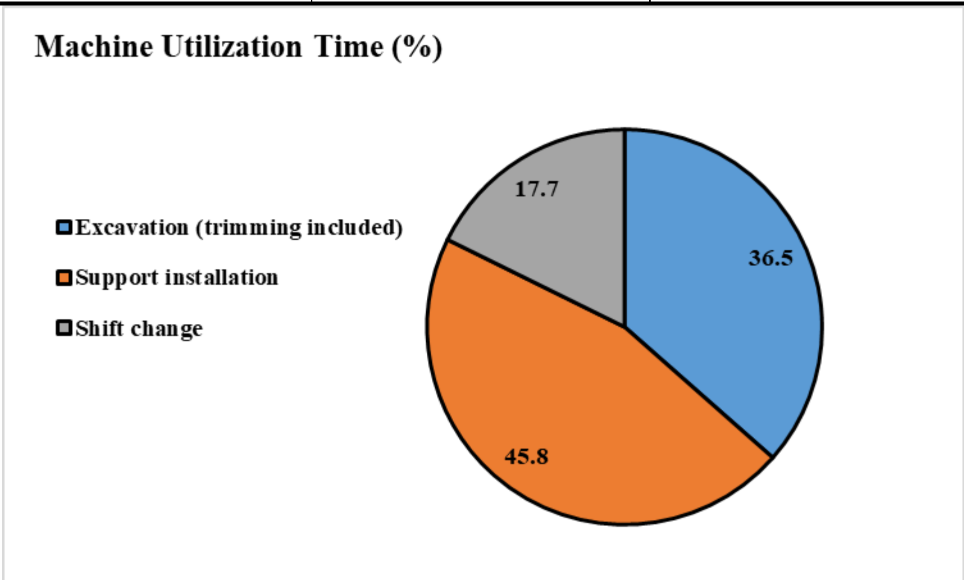
ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 18.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** G7 Sub tail gate **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 P **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 132 kW **Cutter head revolution**:--- **Weight**: 40 ton	**Gallery cross section**:16.4 m^2 **Gallery Inclination:** 15° **Formation**: Clay-Coal **General condition of the formation**: Very weak and flowing, the excavation face composed of 50% coal bands and 50% clay. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.69 h **Net production:** 23 m^3 **Net cutting rate:** 13.6 m^3/h **Length of advance:** 0.88 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:**	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	101	21.0
Support installation	150	31.2
Muck loading and transportation	119	24.8
Cutter change	---	---
Machine maintenance	20	4.2
Mechanical failure	40	8.3
Electrical failure	20	4.2
Shift change	20	4.2
Others	10	2.1



Other information:
Number of workers:
Horizontal distance between steel sets: 70 cm
Length of advance: 1.4 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 19.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109 **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 5 years	**Type**: Transverse **Brand**: AM50 **Age**: 12 years **Cutter type**: Conic **Cutter number**: 84 **Cutter head power**: 100 kW **Cutter head revolution**: - **Weight**: 30 ton	**Gallery cross section**: 19.9 m^2 **Gallery Inclination:** 2º **Formation**: Coal **General condition of the formation**: composed of 100% coal **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.91 h **Net production**: 44.77 m^3 **Net cutting rate:** 15.34 m^3/h **Length of advance:** 0.77 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the tunnel face and continued upwards.	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	175	36.5
Support installation	220	45.8
Muck loading and transportation	-	-
Cutter change	-	-
Machine maintenance	-	-
Mechanical failure	-	-
Electrical failure	-	-
Shift change	85	17.7
Others	-	-

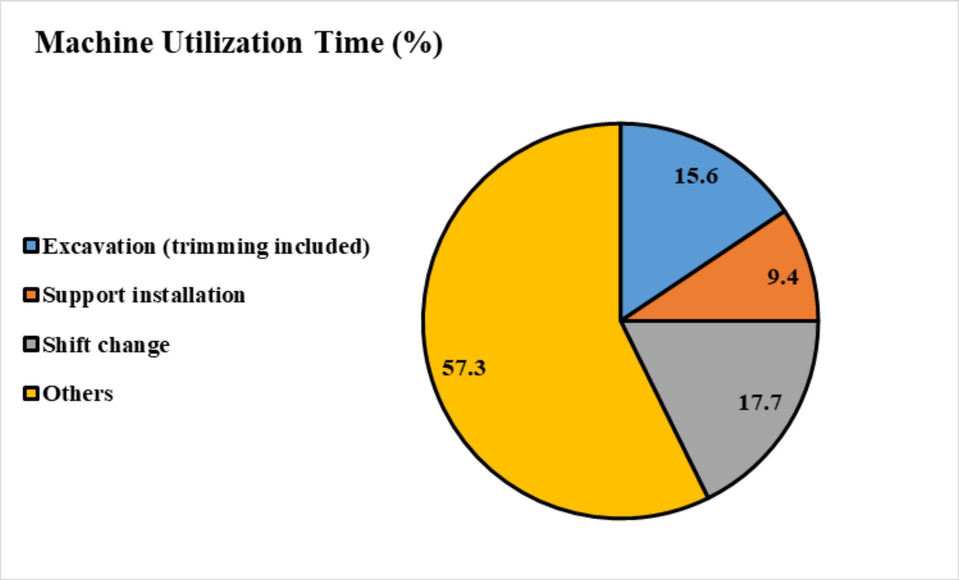


Other information:
Number of workers: 4
Horizontal distance between steel sets: 75 cm
Length of advance: 4 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 20.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109 **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 5 years	**Type**: Transverse **Brand**: AM50 **Age**: 12 years **Cutter type**: Conic **Cutter number**: 84 **Cutter head power**: 100 kW **Cutter head revolution**: - **Weight**: 30 ton	**Gallery cross section**: 19.9 m^2 **Gallery Inclination:** 2º **Formation**: Coal **General condition of the formation**: composed of 100% coal **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.25 h **Net production**: 14.92 m^3 **Net cutting rate:** 11.95 m^3/h **Length of advance:** 0.6 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the tunnel face and continued upwards.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	75	15.6
Support installation	45	9.4
Muck loading and transportation	-	-
Cutter change	-	-
Machine maintenance	-	-
Mechanical failure	-	-
Electrical failure	-	-
Shift change	85	17.7
Others	275	57.3

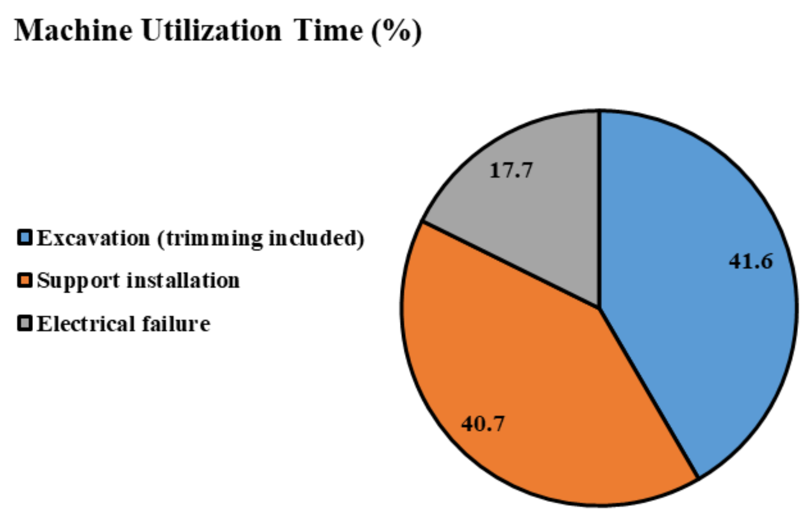


Other information:
Number of workers: 4
Horizontal distance between steel sets: 75 cm
The main conveyor band was broken, and it was waited until the end of the shift.

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 21.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109 **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 5 years	**Type**: Transverse **Brand**: AM50 **Age**: 12 years **Cutter type**: Conic **Cutter number**: 84 **Cutter head power**: 100 kW **Cutter head revolution**: - **Weight**: 30 ton	**Gallery cross section**:19.9 m^2 **Gallery Inclination:** 2º **Formation**: Coal **General condition of the formation**: composed of 100% coal **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 3.33 h **Net production**: 59.70 m^3 **Net cutting rate:** 17.93 m^3/h **Length of advance:** 0.90 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the tunnel face and continued upwards.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	200	41.6
Support installation	195	40.7
Muck loading and transportation	-	-
Cutter change	-	-
Machine maintenance	-	-
Mechanical failure	-	-
Electrical failure	-	-
Shift change	85	17.7
Others	-	-

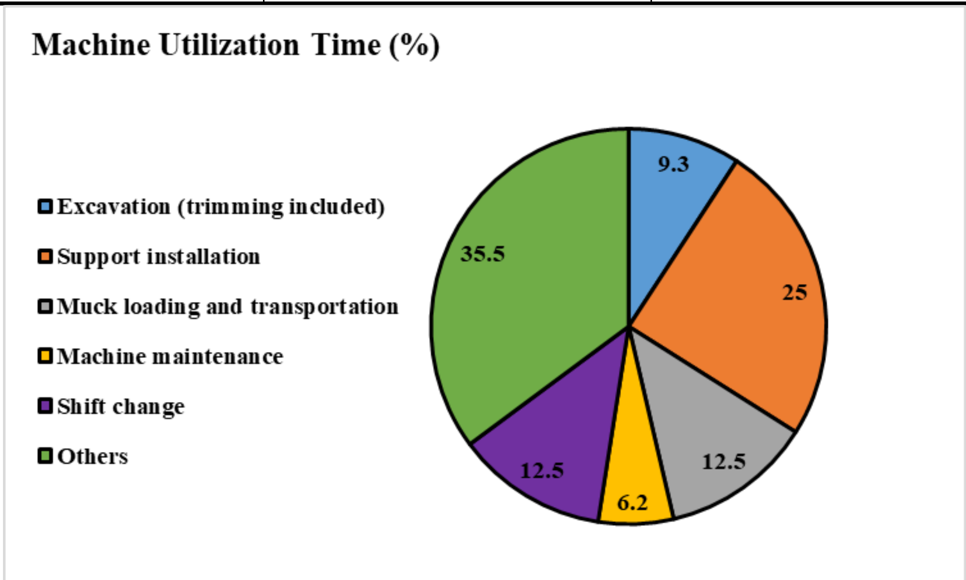


Other information:
Number of workers: 4
Horizontal distance between steel sets: 75 cm
Length of advance: 4 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 18.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 4 years	**Type**: Transverse **Brand**: DH R60T **Age**: 5 years **Cutter type**: Conic **Cutter number**: 84 **Cutter head power**: 160 kW **Cutter head revolution**: 64.9 rev/min **Weight**: 69 ton	**Gallery cross section**: 28 m^2 **Gallery Inclination:** -8° **Formation**: sandstone and a mixture of clay-silt-schist **General condition of the formation**: There was %20 very hard sandstone on the face. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: truck
Net cutting rate: 0.75 h **Net production:** 33.6 m^3 **Net cutting rate:** 44.8 m^3/h **Length of advance:** 1.60 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the tunnel face and continued upwards.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	45	9.3
Support installation	120	25.0
Muck loading and transportation	60	12.5
Cutter change	-	-
Machine maintenance	30	6.2
Mechanical failure	-	-
Electrical failure	-	-
Shift change	60	12.5
Others	165	35.5



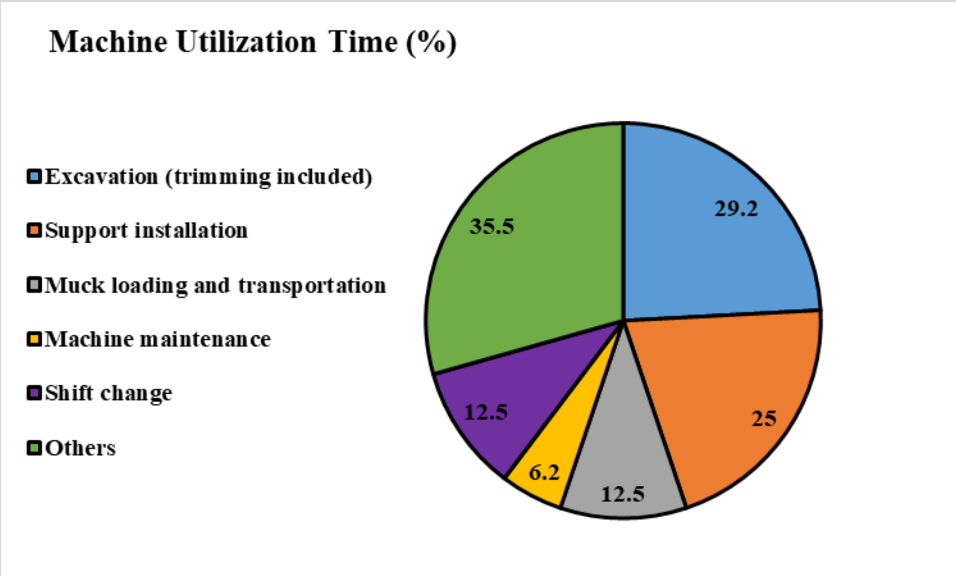
Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 19.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 4 years	**Type**: Transverse **Brand**: DH R60T **Age**: 5 years **Cutter type**: Conic **Cutter number**: 84 **Cutter head power**: 160 kW **Cutter head revolution:** 64.9 rev/min **Weight**: 69 ton	**Gallery cross section**: 28 m^2 **Gallery Inclination:** -8° **Formation**: sandstone and a mixture of clay-silt-schist **General condition of the formation**: There was % 40 very hard sandstone on the face. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: truck
Net cutting rate: 2.33 h **Net production**: 28 m^3 **Net cutting rate:** 12.01 m^3/h **Length of advance:** 0.42 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the tunnel face and continued upwards.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	140	29.2
Support installation	120	25.0
Muck loading and transportation	60	12.5
Cutter change	-	-
Machine maintenance	30	6.2
Mechanical failure	-	-
Electrical failure	-	-
Shift change	60	12.5
Others	70	14.6



Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm
Length of distance: 1 m

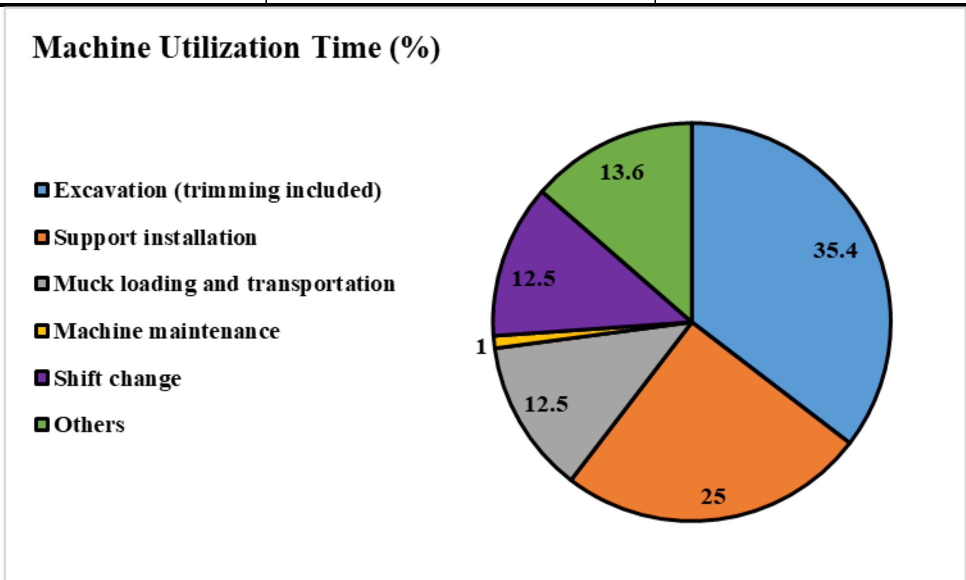
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 20.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection **Shift:** 8-16 **Operator experience:** 5 years **Company experience:** 4 years	**Type**: Transverse **Brand**: DH R60T **Age**: 5 years **Cutter type**: Conic **Cutter number**: 84 **Cutter head power**: 160 kW **Cutter head revolution**: 64.9 rev/min **Weight**: 69 ton	**Gallery cross section**: 28 m^2 **Gallery Inclination:** -8° **Formation**: sandstone and a mixture of clay-silt-schist **General condition of the formation**: There was %60 very hard sandstone on the face. **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: truck

Net cutting rate: 2.83 h **Net production:** 28 m^3 **Net cutting rate:** 9.89 m^3/h **Length of advance:** 0.35 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the lower part of the tunnel face and continued upwards.

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	170	35.4
Support installation	120	25.0
Muck loading and transportation	60	12.5
Cutter change	-	-
Machine maintenance	-	-
Mechanical failure	5	1.0
Electrical failure	-	-
Shift change	60	12.5
Others	65	13.6

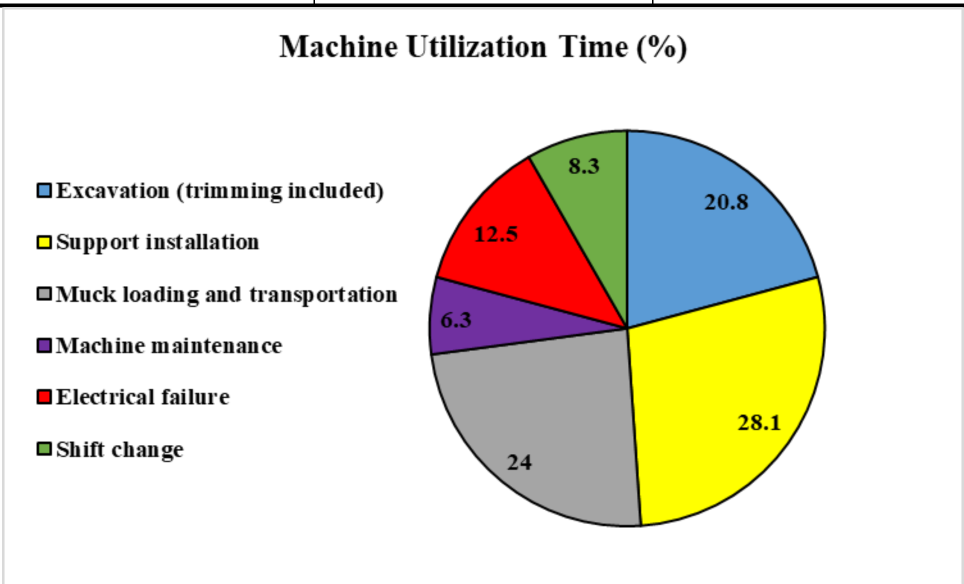


Other information:
Number of workers: 4
Horizontal distance between steel sets: 100 cm
Length of advance: 1 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 01.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 P **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 132 kW **Cutter head revolution**:--- **Weight**: 40 ton	**Gallery cross section**: 16 m^2 **Gallery Inclination:** -12° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.67 h **Net production:** 22.4 m^3 **Net cutting rate:** 13.4 m^3/h **Length of advance:** 0.83 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	

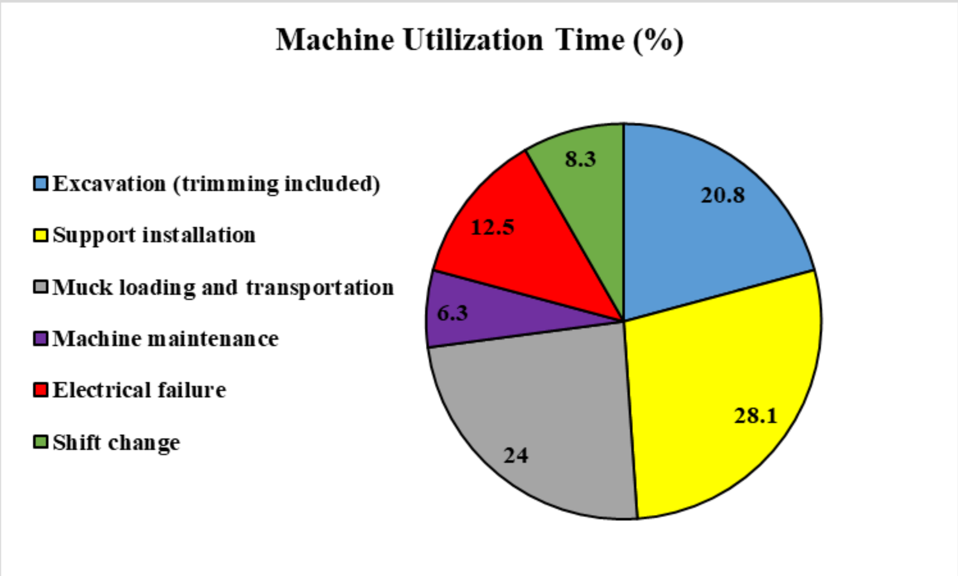
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	100	20.8
Support installation	135	28.1
Muck loading and transportation	115	24.0
Cutter change	---	---
Machine maintenance	30	6.3
Mechanical failure	----	---
Electrical failure	60	12.5
Shift change	40	8.3
Others	----	---



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 01.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 16-24 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 P **Age**: 39 years **Cutter type**: Conic **Cutter number** : 90 **Cutter head power**: 132 kW **Cutter head revolution**: **Weight**: 40 ton	**Gallery cross section**: 16 m^2 **Gallery Inclination:** -12° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.73 h **Net production**: 22.4 m^3 **Net cutting rate:** 12.9 m^3/h **Length of advance:** 0.8 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	104	21.7
Support installation	130	27.1
Muck loading and transportation	46	9.6
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	125	26.0
Shift change	30	6.3
Others	45	9.4

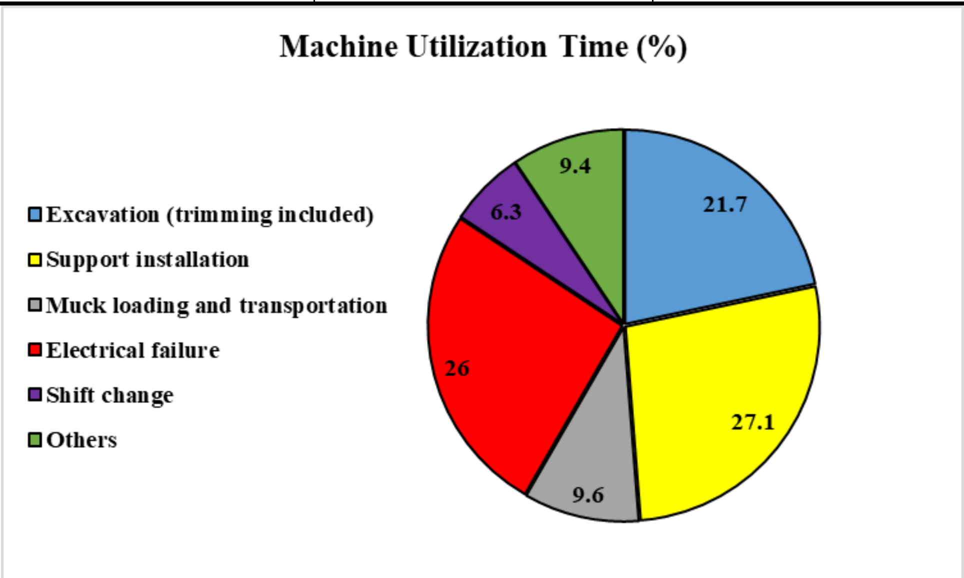


Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 01.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 Middle floor **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: **Weight**: 32 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** -6° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.70 h **Net production:** 9.8 m^3 **Net cutting rate:** 14.0 m^3/h **Length of advance:** 0.9 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	42	9.0
Support installation	65	13.5
Muck loading and transportation	27	5.5
Cutter change	---	---
Machine maintenance	60	12.5
Mechanical failure	---	---
Electrical failure	255	53.3
Shift change	---	---
Others	30	6.3



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

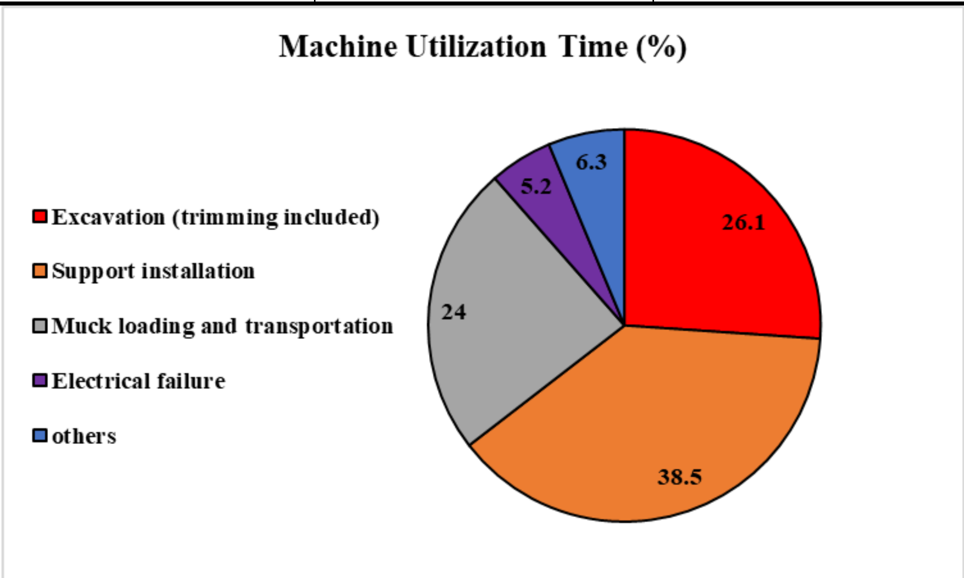
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 02.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 Middle floor **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: **Weight**: 32 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** -6° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.0 h **Net production:** 29.4 m^3 **Net cutting rate:** 14.7 m^3/h **Length of advance:** 1.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.

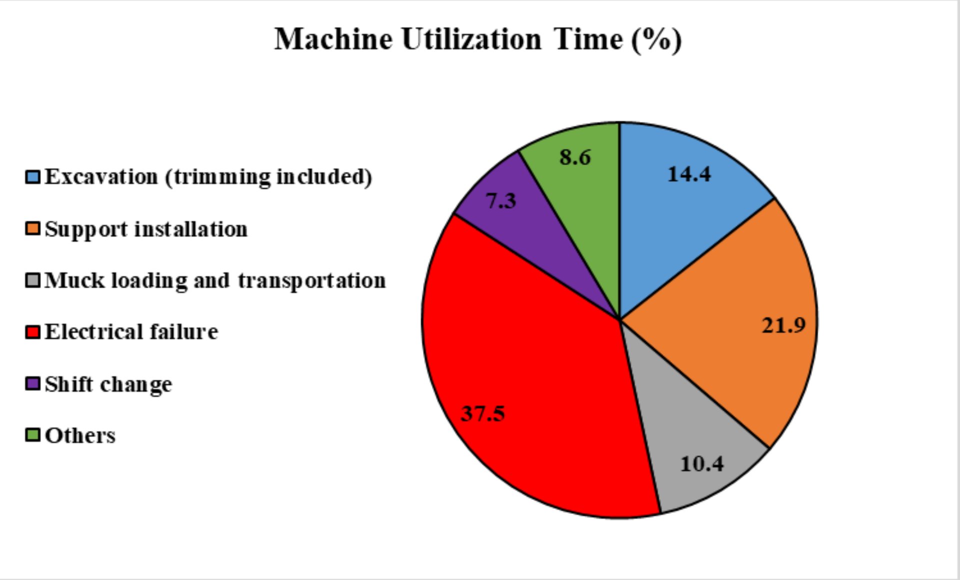
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	120	26.1
Support installation	185	38.5
Muck loading and transportation	115	24.0
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	25	5.2
Shift change	---	---
Others	30	6.3



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 02.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 Middle floor **Shift:** 16-24 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: **Weight**: 32 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** -6° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.17 h **Net production:** 19.6 m^3 **Net cutting rate:** 16.8 m^3/h **Length of advance:** 1.2 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	70	14.4
Support installation	105	21.9
Muck loading and transportation	50	10.4
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	180	37.5
Shift change	35	7.3
Others	40	8.6



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

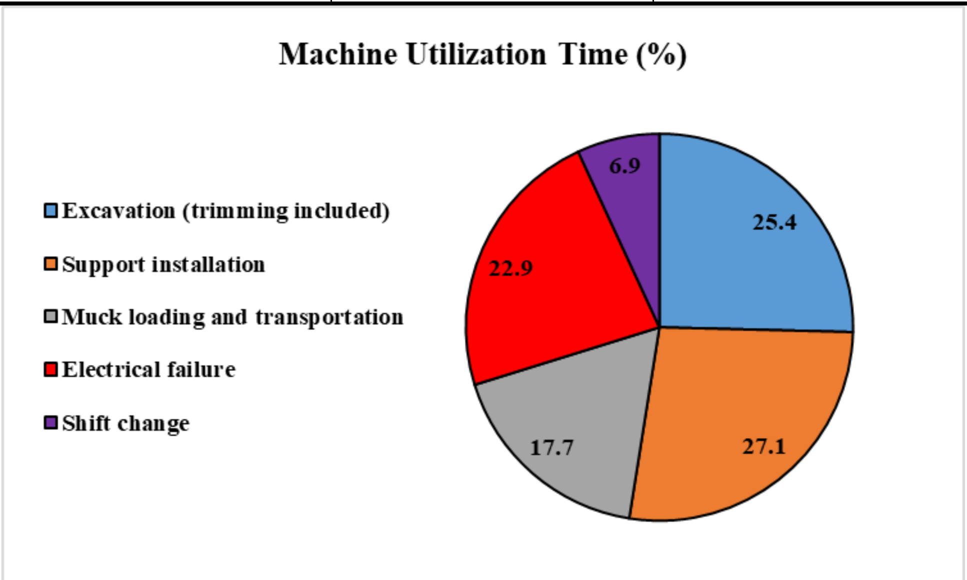
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 02.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 P **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 132 kW **Cutter head revolution**:--- **Weight**: 40 ton	**Gallery cross section**: 16 m^2 **Gallery Inclination:** -12° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor

Net cutting rate: 2.2 h **Net production:** 33.6 m^3 **Net cutting rate:** 15.3 m^3/h **Length of advance:** 1.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	132	25.4
Support installation	130	27.1
Muck loading and transportation	85	17.7
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	100	22.9
Shift change	33	6.9
Others	---	---



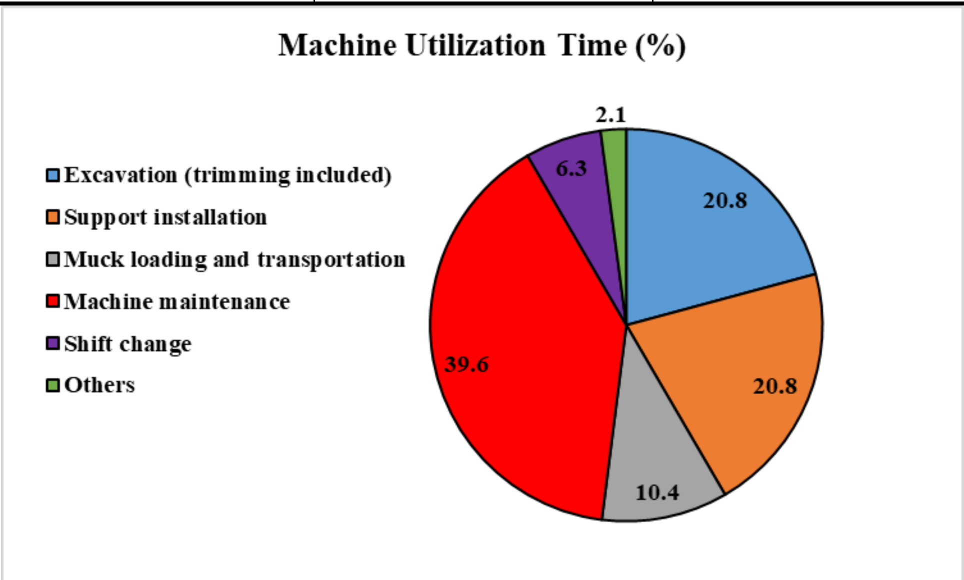
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 03.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 P **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 132 kW **Cutter head revolution**: **Weight**: 40 ton	**Gallery cross section**: 16 m^2 **Gallery Inclination:** -12° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.70 h **Net production:** 22.4 m^3 **Net cutting rate:** 13.2 m^3/h **Length of advance:** 0.9 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	

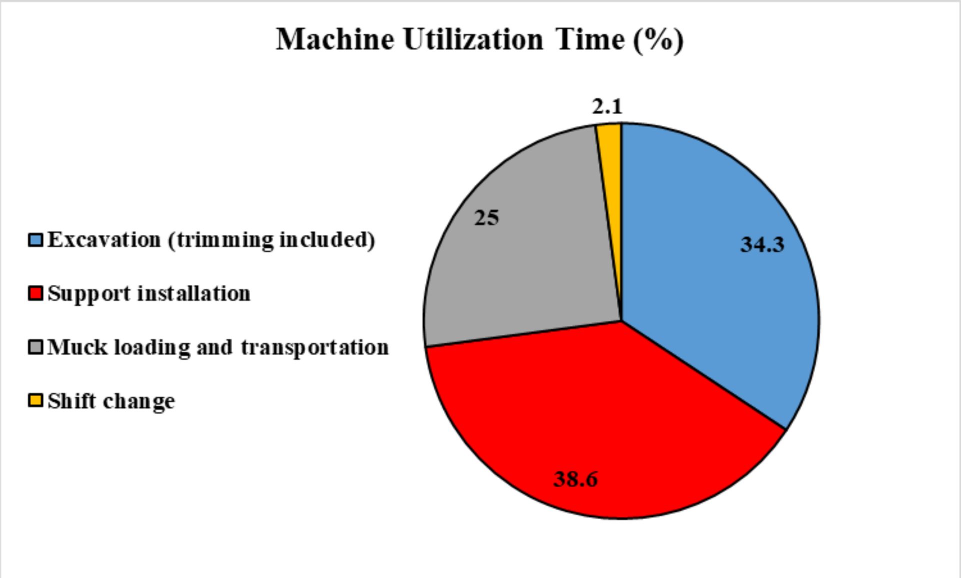
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	100	20.8
Support installation	100	20.8
Muck loading and transportation	50	10.4
Cutter change	---	---
Machine maintenance	190	39.6
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.3
Others	10	2.1



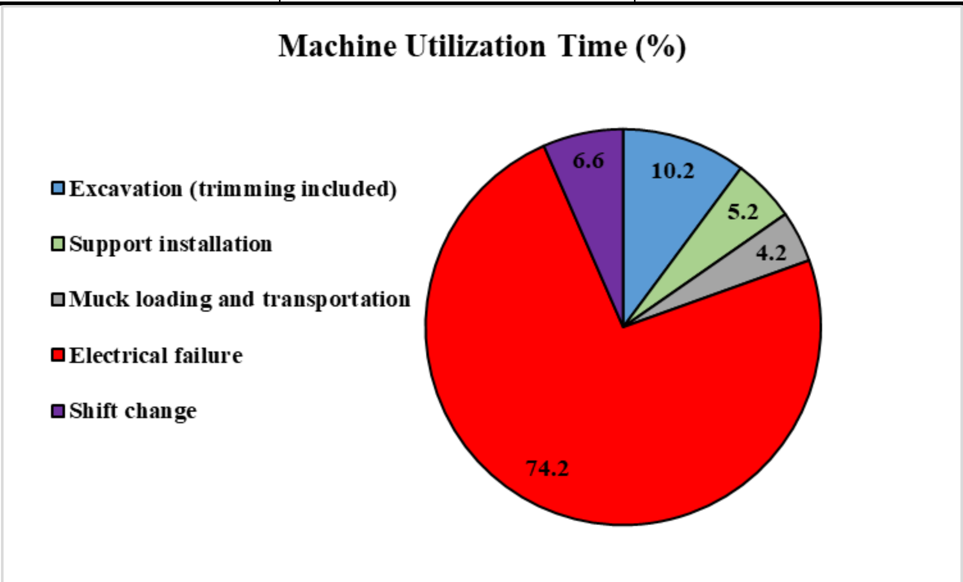
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 03.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 16-24 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 65 P **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 132 kW **Cutter head revolution**:--- **Weight**: 40 ton	**Gallery cross section**: 16 m^2 **Gallery Inclination:** -12° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 2.8 h **Net production:** 33.6 m^3 **Net cutting rate:** 12.0 m^3/h **Length of advance:** 0.8 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	165	34.3
Support installation	185	38.6
Muck loading and transportation	120	25.0
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	10	2.1
Others	---	---



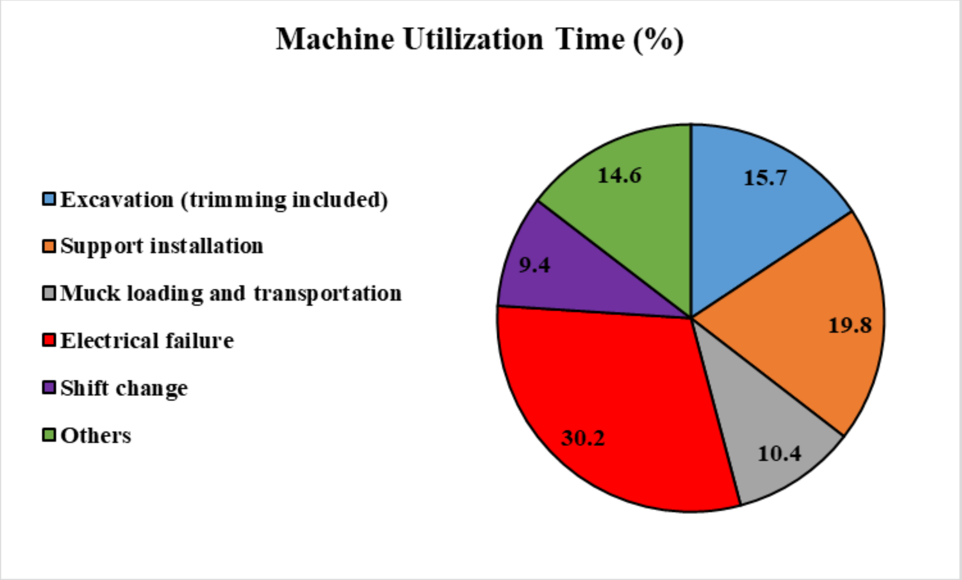
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 03.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 Middle floor **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**:--- **Weight**: 30 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** -6° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 0.65 h **Net production**: 9.8 m^3 **Net cutting rate:** 15.1 m^3/h **Length of advance:** 0.9 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	39	10.2
Support installation	25	5.2
Muck loading and transportation	20	4.2
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	366	74.2
Shift change	30	6.6
Others	---	---



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 04.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**:--- **Weight**: 30 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** 0° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.23 h **Net production**: 19.6 m^3 **Net cutting rate:** 15.9 m^3/h **Length of advance:** 1.1 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	74	15.7
Support installation	95	19.8
Muck loading and transportation	50	10.4
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	145	30.2
Shift change	45	9.4
Others	71	14.6

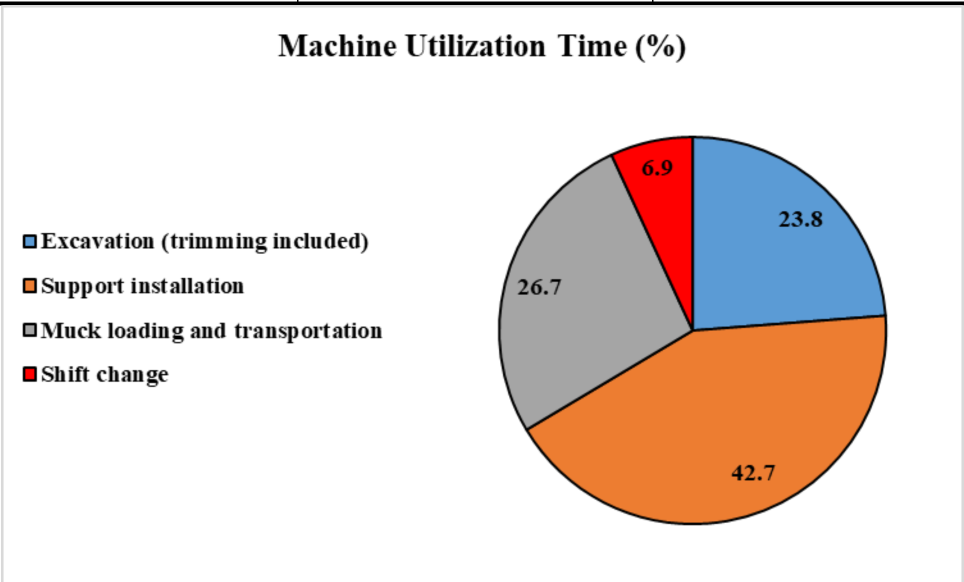


Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 04.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 **Shift:** 16-24 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: **Weight**: 30 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** 0° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.9 h **Net production:** 29.4 m^3 **Net cutting rate:** 15.5 m^3/h **Length of advance:** 1.1 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	

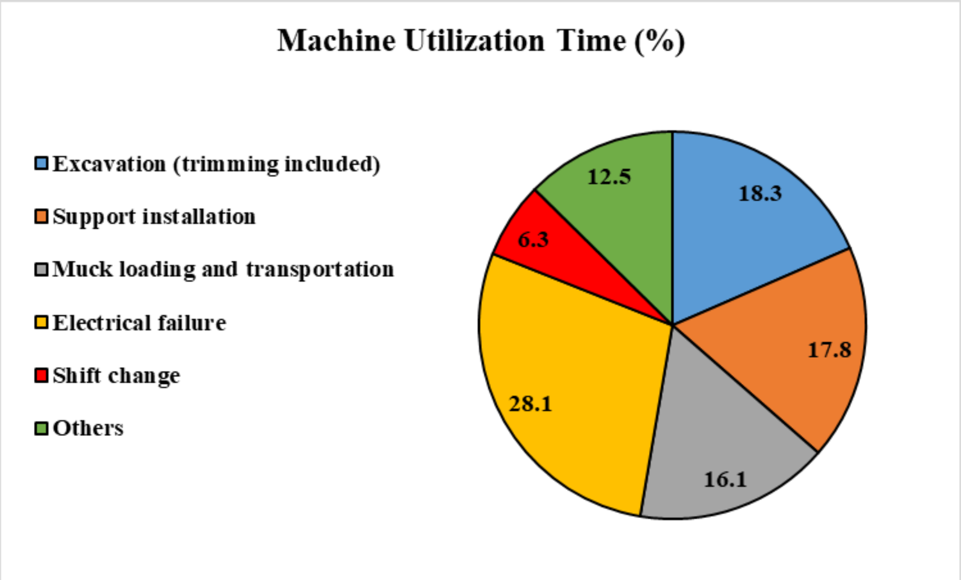
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	114	23.8
Support installation	205	42.7
Muck loading and transportation	128	26.7
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	33	6.9
Others	---	---



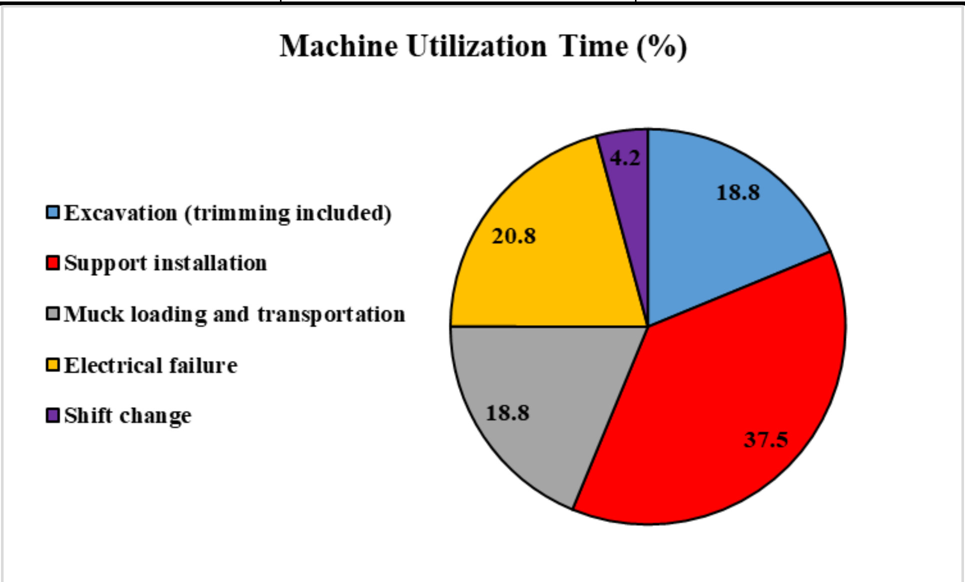
Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER’S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 05.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 **Shift:** 8-16 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**:--- **Weight**: 30 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** 0° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor
Net cutting rate: 1.46 h **Net production:** 19.6 m^3 **Net cutting rate:** 13.4 m^3/h **Length of advance:** 1.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	88	18.3
Support installation	90	17.8
Muck loading and transportation	77	16.1
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	135	28.1
Shift change	30	6.3
Others	60	12.5



Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 05.07.2019 **Company:** İmbat **Location:** Soma **Gallery:** D10 **Shift:** 16-24 **Operator experience:** 6 years **Company experience:** 15 years	**Type**: Transverse **Brand**: ATM 50 **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: **Weight**: 30 ton	**Gallery cross section**: 14 m^2 **Gallery Inclination:** 0° **Formation**: Coal **General condition of the formation**: Composed of 100% coal **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Chain conveyor **Strike of the face**: 350°
Net cutting rate: 1.5 h **Net production**: 19.6 m^3 **Net cutting rate:** 13.1 m^3/h **Length of advance:** 1.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** First, the crown of the tunnel was excavated and supported. Then, the right and left sides of the tunnel face were excavated and supported.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	90	18.8
Support installation	180	37.5
Muck loading and transportation	90	18.8
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	100	20.8
Shift change	20	4.2
Others	---	---

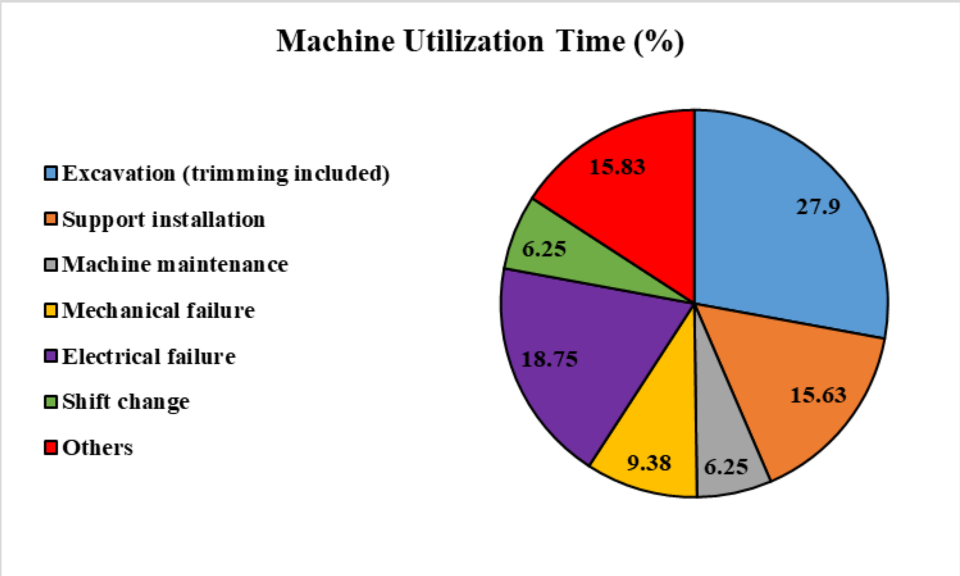


Other information:
Number of workers: 5
Horizontal distance between steel sets: 70 cm

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 18.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** Sub-tail gate **Shift:** 8-16 **Operator experience:** 4 **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 45 EX **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 23 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.23 h **Net production**: 12.3 m^3 **Net cutting rate:** 5.51 m^3/h **Length of advance:** 0.33 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

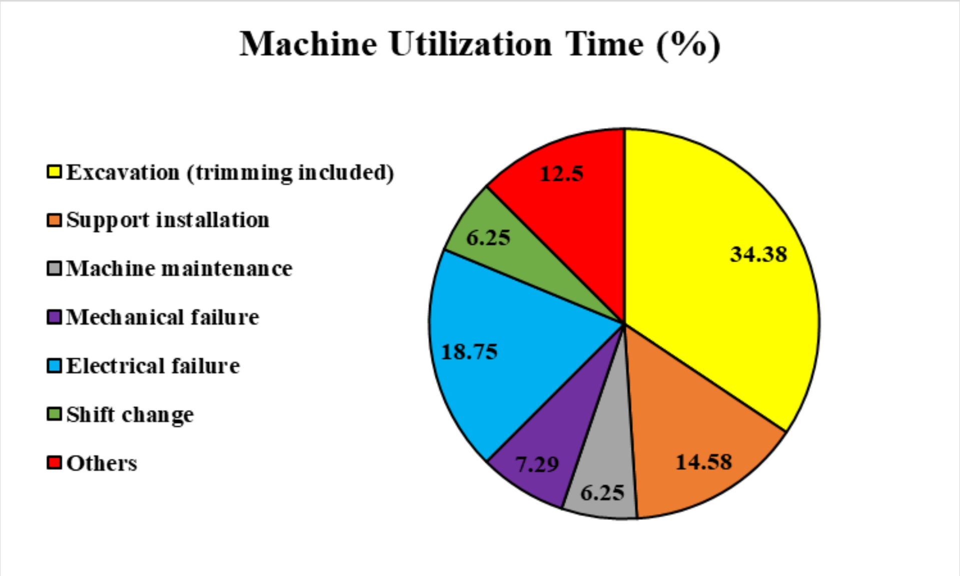
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	134	27.9
Support installation	75	15.63
Muck loading and transportation	--	--
Cutter change	--	--
Machine maintenance	30	6.25
Mechanical failure	45	9.38
Electrical failure	90	18.75
Shift change	30	6.25
Others	76	15.83



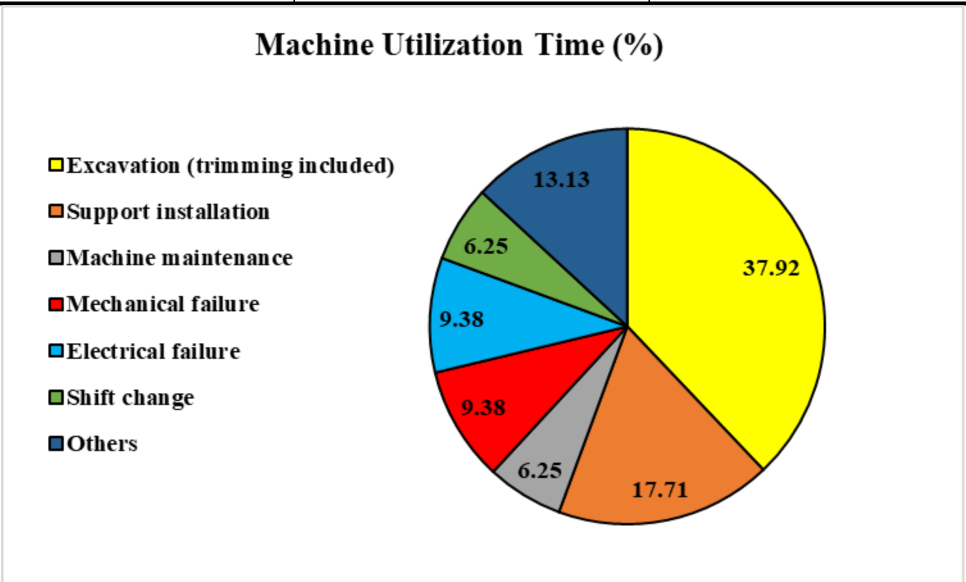
Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 20.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** Sub-tail gate **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 45 EX **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 23 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.75 h **Net production**: 12.3 m^3 **Net cutting rate:** 4.4 m^3/h **Length of advance:** 0.28 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	165	34.38
Support installation	70	14.58
Muck loading and transportation	--	--
Cutter change	--	--
Machine maintenance	30	6.25
Mechanical failure	35	7.29
Electrical failure	90	18.75
Shift change	30	6.25
Others	60	12.50



Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 22.10.2021 **Company:** İmbat **Location:** Soma **Gallery:** Sub-tail gate **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 15 years	**Type**: Transverse **Brand**: AM 45 EX **Age**: 39 years **Cutter type**: Conic **Cutter number**: 90 **Cutter head power**: 100 kW **Cutter head revolution**: --- **Weight**: 23 ton	**Gallery cross section**: 16.4 m^2 **Gallery Inclination:** 4° **Formation**: Marl **General condition of the formation**: Medium hard and moderately jointed **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 3.03 h **Net production**: 12.3 m^3 **Net cutting rate:** 4 m^3/h **Length of advance:** 0.25 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	182	37.92
Support installation	85	17.71
Muck loading and transportation	--	--
Cutter change	--	--
Machine maintenance	30	6.25
Mechanical failure	45	9.38
Electrical failure	45	9.38
Shift change	30	6.25
Others	63	13.13



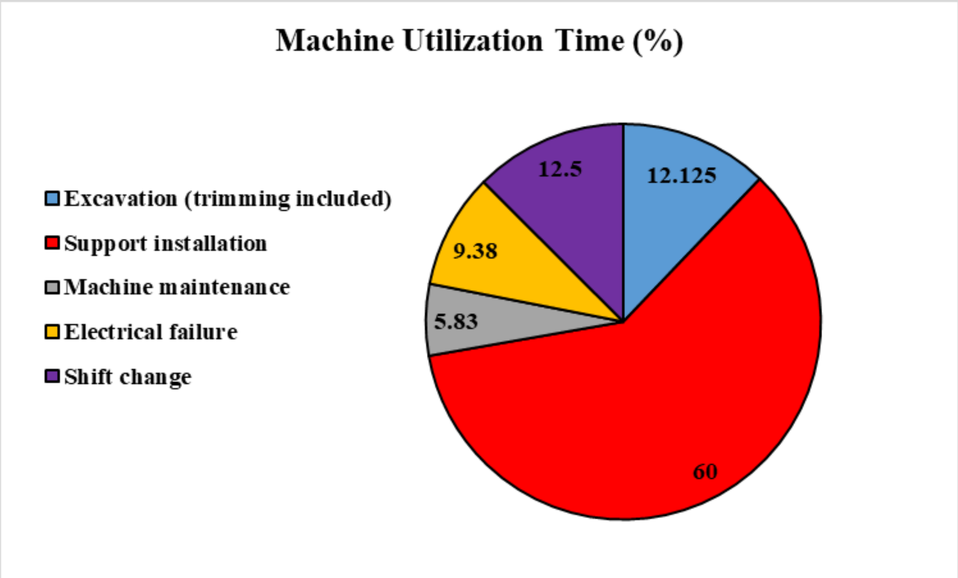
Other information:
Number of workers: 8
Horizontal distance between steel sets : 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 **Shift:** 8-16 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Transverse **Brand**: İBS-SM130 **Age**: 5 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 3.5° **Formation**: Schist and coal **General condition of the formation**: soft formation **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 0.97 h **Net production**: 17.25 m^3 **Net cutting rate:** 17.8 m^3/h **Length of advance:** 0.77 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	58.2	12.125
Support installation	288.8	60.0
Muck loading and transportation	28	5.83
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	45	9.38
Shift change	60	12.50
Others	---	---



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

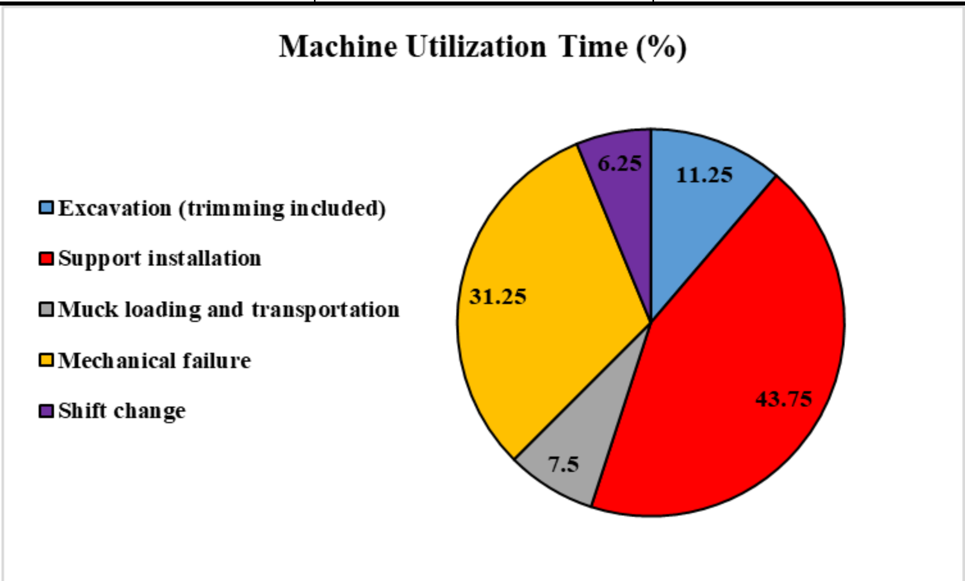
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 **Shift:** 24-8 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Transverse **Brand**: İBS-SM130 **Age**: 5 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 3.5° **Formation**: Schist and coal **General condition of the formation**: soft formation **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor

Net cutting rate: 0.9 h **Net production:** 17.25 m^3 **Net cutting rate:** 19.17 m^3/h **Length of advance:** 0.83 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.

Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	54	11.25
Support installation	210	43.75
Muck loading and transportation	36	7.50
Cutter change	---	---
Machine maintenance		
Mechanical failure	150	31.25
Electrical failure	---	---
Shift change	30	6.25
Others	---	---

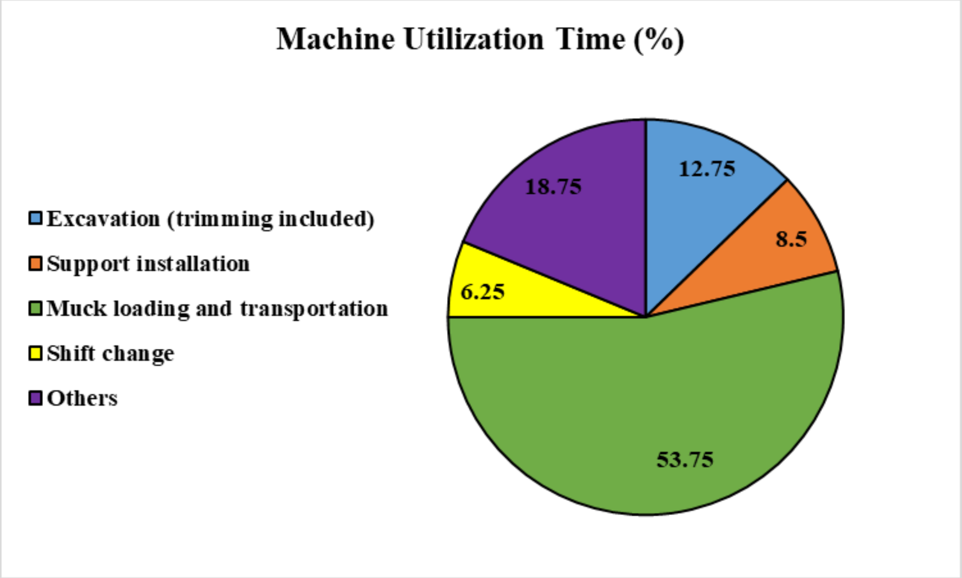


Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 **Shift:** 8-16 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Transverse **Brand**: İBS-SM130 **Age**: 5 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 3.5° **Formation**: Schist and coal **General condition of the formation**: soft formation **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.02 h **Net production:** 17.25 m^3 **Net cutting rate:** 16.91 m^3/h **Length of advance:** 0.74 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

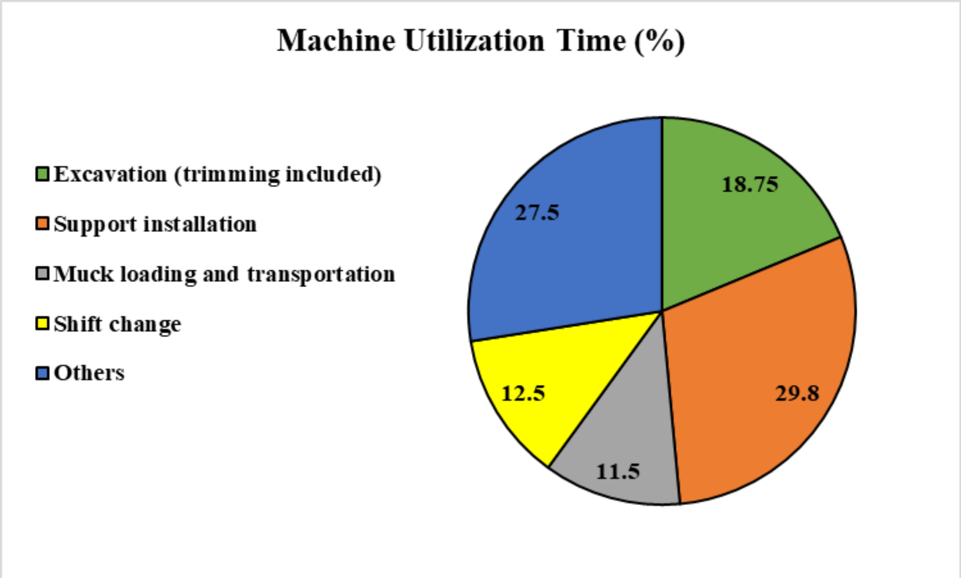
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	61	12.75
Support installation	41	8.50
Muck loading and transportation	258	53.75
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	90	18.75



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 **Shift:** 8-16 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Transverse **Brand**: İBS-SM130 **Age**: 5 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 3.5° **Formation**: Schist and coal **General condition of the formation**: soft formation **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.5 h **Net production:** 34.5 m^3 **Net cutting rate:** 23 m^3/h **Length of advance:** 1.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	90	18.75
Support installation	143	29.8
Muck loading and transportation	55	11.50
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	60	12.50
Others	132	27.50



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5 m

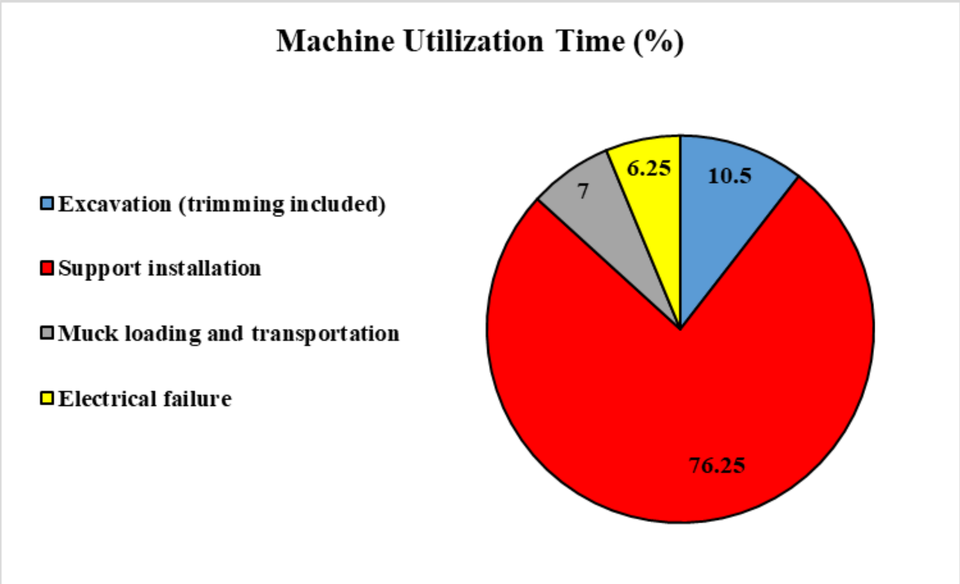
ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 **Shift:** 16-24 **Operator experience:** 23 years **Company experience:** 1 year	**Type**: Transverse **Brand**: İBS-SM130 **Age**: 5 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 23 m^2 **Gallery Inclination:** 3.5° **Formation**: Schist and coal **General condition of the formation**: soft formation **Water condition**: Dry **Support system**: Steel sets **Muck transportation system**: Belt conveyor

Net cutting rate: 0.83 h **Net production:** 17.25 m^3 **Net cutting rate:** 20.78 m^3/h **Length of advance:** 0.9 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.

Measurements of Machine Utilization Time

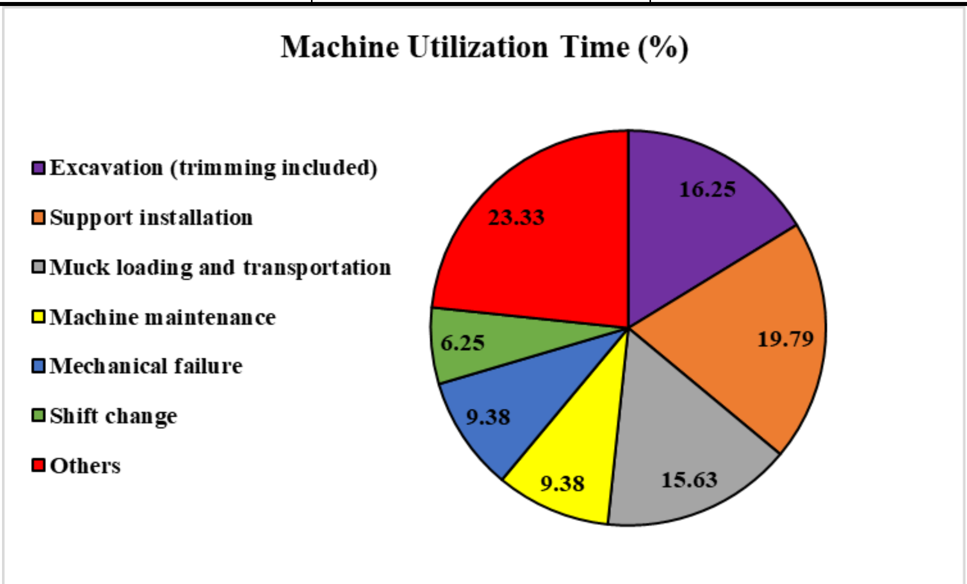
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	50	10.50
Support installation	366	76.25
Muck loading and transportation	34	7.00
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	---	---



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75 m

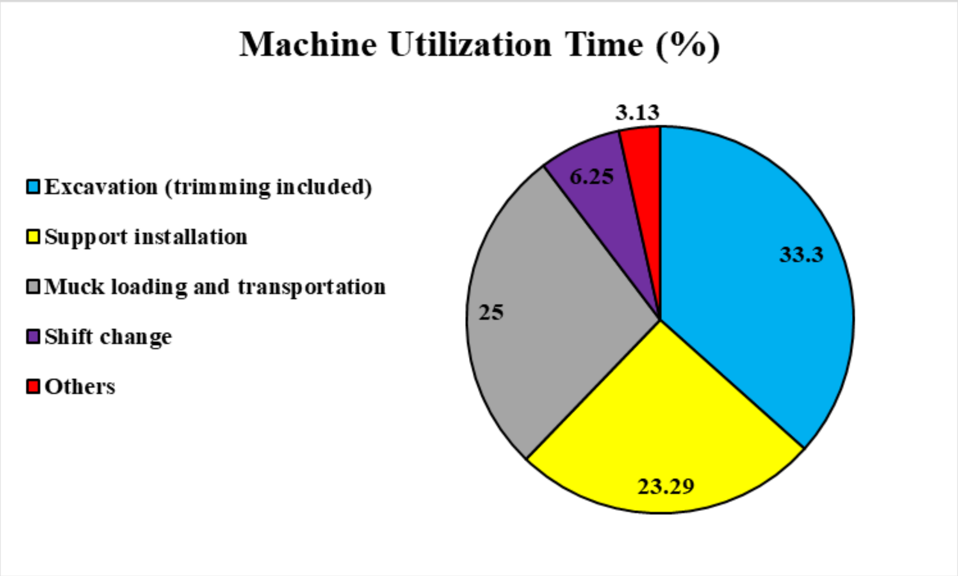
ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 8.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Damp **Support system**: Steel sets **Muck transportation system:** Belt conveyor
Net cutting rate: 1.3 h **Net production:** 36 m^3 **Net cutting rate:** 28.16 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	78	16.25
Support installation	95	19.79
Muck loading and transportation	75	15.63
Cutter change	--	--
Machine maintenance	45	9.38
Mechanical failure	45	9.38
Electrical failure	--	--
Shift change	30	6.25
Others	112	23.33



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 9.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 24-8 **Operator experience:** 4 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.67 h **Net production:** 72 m^3 **Net cutting rate:** 27m^3/h **Length of advance:** 1.12 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (t rimming included)	160	33.3
Support installation	155	23.29
Muck loading and transportation	120	25
Cutter change	---	---
Machine maintenance	---	---
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	15	3.13



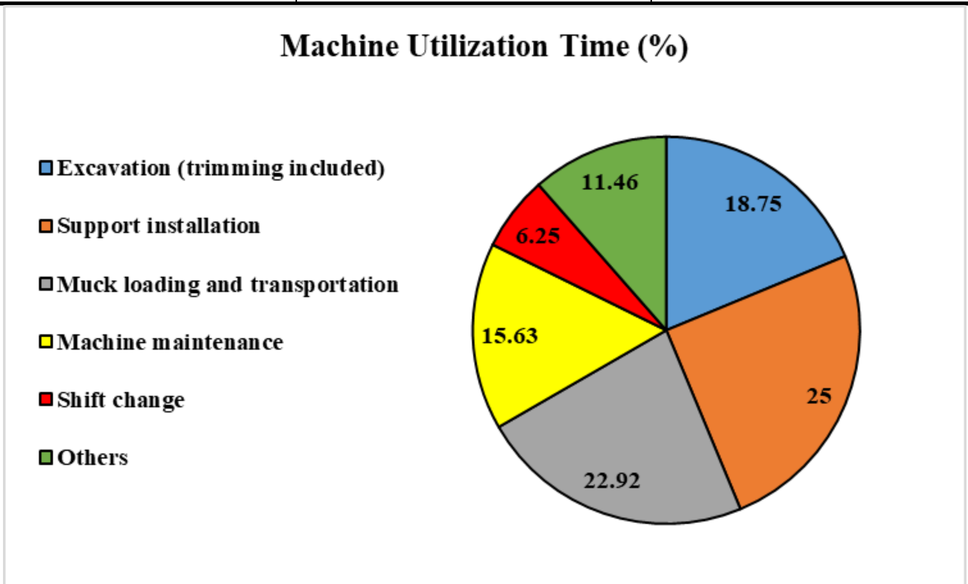
Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 2.25

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 9.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 **Operator experience:** 4 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.5 h **Net production:** 54 m^3 **Net cutting rate:** 36 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

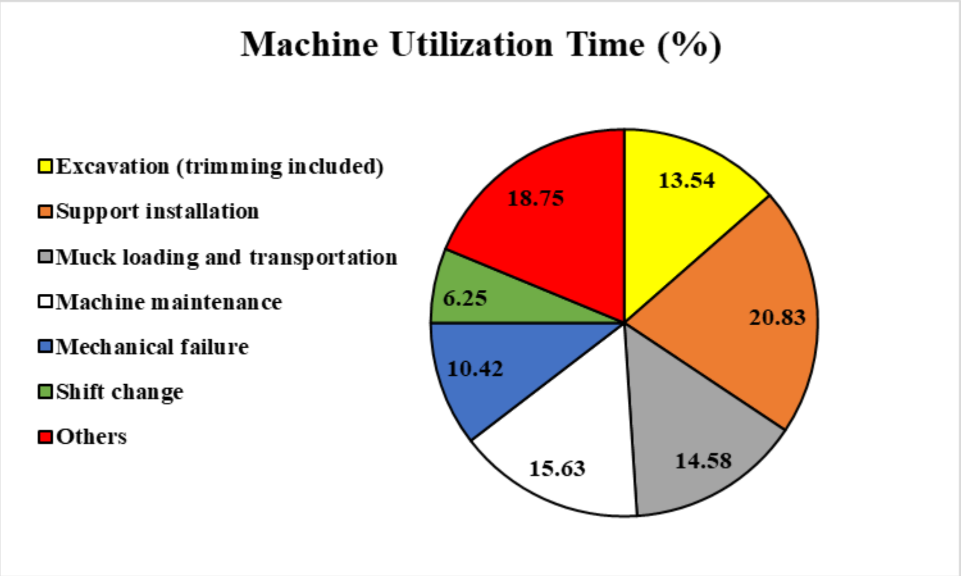
Measurements of Machine Utilization Time

Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	90	18.75
Support installation	120	25
Muck loading and transportation	110	22.92
Cutter change	--	--
Machine maintenance	75	15.63
Mechanical failure	--	--
Electrical failure	--	--
Shift change	30	6.25
Others	55	11.46



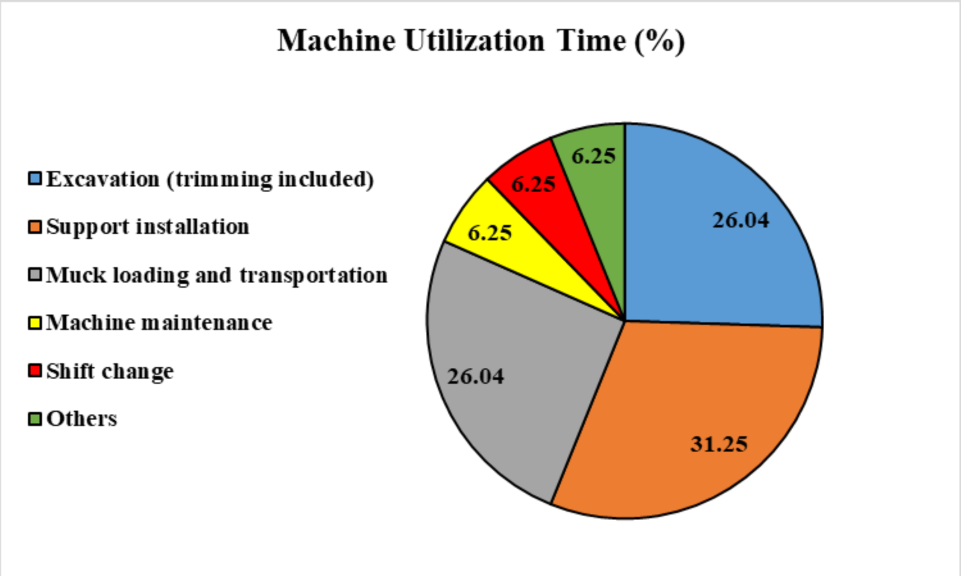
Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 2.25 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 10.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.08 h **Net production:** 36 m^3 **Net cutting rate:** 33.23 m3/h **Length of advance:** 1.38 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	65	13.54
Support installation	100	20.83
Muck loading and transportation	70	14.58
Cutter change	---	---
Machine maintenance	75	15.63
Mechanical failure	50	10.42
Electrical failure	---	---
Shift change	30	6.25
Others	90	18.75



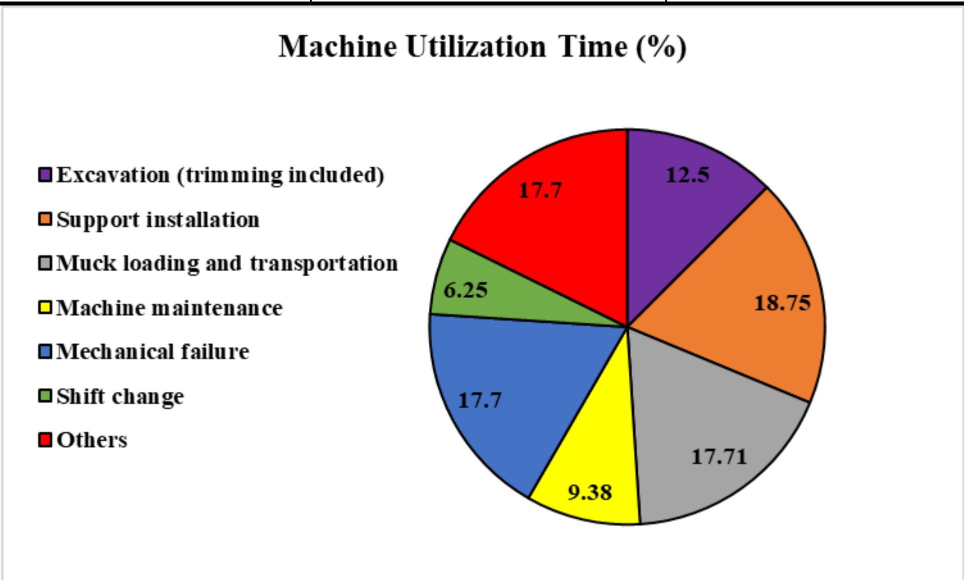
Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 10.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 16-24 **Operator experience:** 4 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.92 h **Net production:** 54 m^3 **Net cutting rate:** 28.17m^3/h **Length of advance:** 1.17 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	115	26.04
Support installation	150	31.25
Muck loading and transportation	125	26.04
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	---	---
Shift change	30	6.25
Others	30	6.25



Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 2.25m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 11.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 24-8 **Operator experience:** 4 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.0 h **Net production:** 36 m^3 **Net cutting rate:** 36 m^3/h **Length of advance:** 1.5 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	60	12.5
Support installation	90	18.75
Muck loading and transportation	85	17.71
Cutter change	--	--
Machine maintenance	45	9.38
Mechanical failure	85	17.7
Electrical failure	--	--
Shift change	30	6.25
Others	85	17.7



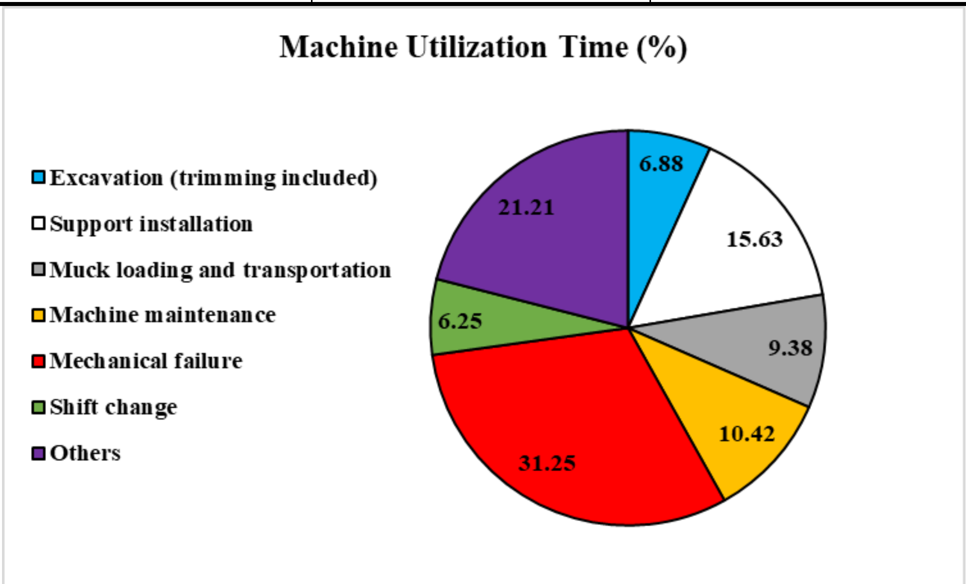
Other information:
Number of workers:
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5 m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 11.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 **Operator experience:** 2 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 7° **Formation**: Coal **General condition of the formation**: Composed of coal containing narrow clay bands **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 0.55 h **Net production**: 18 m^3 **Net cutting rate:** 32.73 m^3/h **Length of advance:** 1.36 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

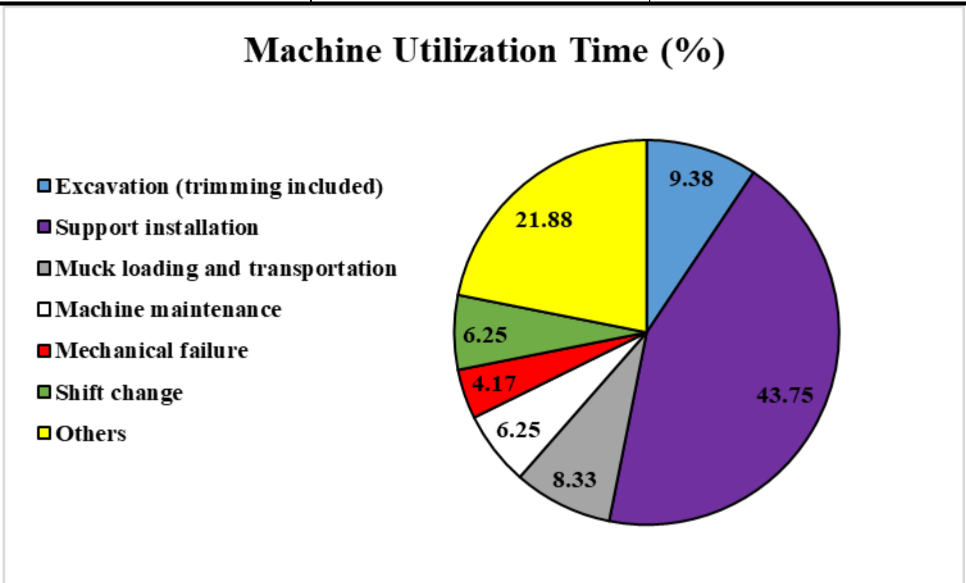
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	33	6.88
Support installation	75	15.63
Muck loading and transportation	45	9.38
Cutter change	---	---
Machine maintenance	50	10.42
Mechanical failure	150	31.25
Electrical failure	---	---
Shift change	30	6.25
Others	97	21.21



Other information:
Number of workers:
Horizontal distance between steel sets: 0.75 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 8.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery 2304 **Shift:** 8-16 **Operator experience:** 2 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 10° **Formation**: Coal and clay **General condition of the formation**: composed of 50% coal and 50% clay **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 0.75 h **Net production**: 18 m^3 **Net cutting rate:** 24 m^3/h **Length of advance:** 1.0 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	45	9.38
Support installation	210	43.75
Muck loading and transportation	40	8.33
Cutter change	--	--
Machine maintenance	30	6.25
Mechanical failure	20	4.17
Electrical failure	--	--
Shift change	30	6.25
Others	105	21.88



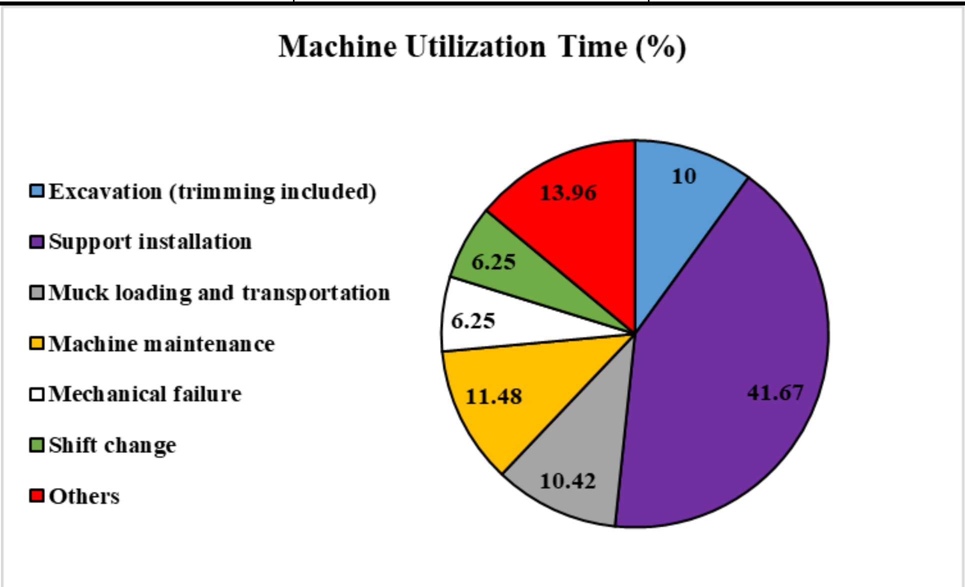
Other information:
Number of workers: 8
Horizontal distance between steel sets : 75 cm
Length of advance: 0.75 m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 9.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery 2304 **Shift:** 12-8 **Operator experience:** 4 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 10° **Formation**: Coal and clay **General condition of the formation**: composed of 50% coal and 50% clay **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 0.8 h **Net production:** 18 m^3 **Net cutting rate:** 22.5 m^3/h **Length of advance:** 0.93 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

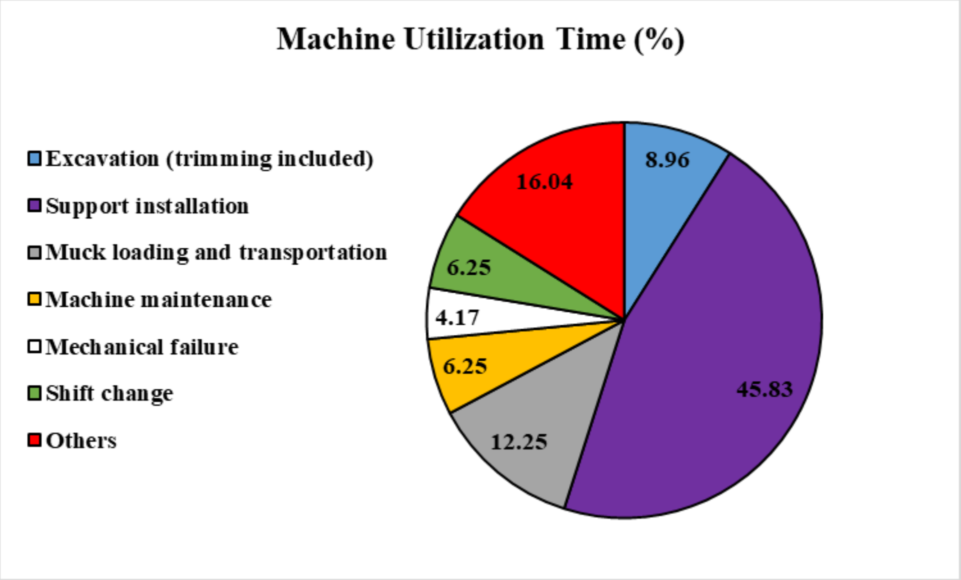
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	48	10
Support installation	200	41.67
Muck loading and transportation	50	10.42
Cutter change	---	--
Machine maintenance	55	11.48
Mechanical failure	---	--
Electrical failure	30	6.25
Shift change	30	6.25
Others	67	13.96



Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 9.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery 2304 **Shift:** 8-16 **Operator experience:** 2 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 10° **Formation**: Coal and clay **General condition of the formation:** composed of 50% coal and 50% clay **Water condition**: Wet **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 0.72 h **Net production**: 18 m^3 **Net cutting rate:** 25.12 m^3/h **Length of advance:** 1.04 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	43	8.96
Support installation	220	45.83
Muck loading and transportation	60	12.25
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	20	4.17
Shift change	30	6.25
Others	77	16.04



Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75m

<table>
<tr><th colspan="3">ROADHEADER’S PERFORMANCE FORM</th></tr>
<tr><th>General Information</th><th>Machine Specification</th><th>Gallery information</th></tr>
<tr><td>Date: 10.6.2021
Company: Polyak
Location: Bergama
Gallery: 2. Connection gallery 2304
Shift: 8-16
Operator experience: 3 years
Company experience: 3 years</td><td>Type: Transverse
Brand: IBS-SM130
Age: 7 years
Cutter type: Conic
Cutter number: ---
Cutter head power: 132 kW
Cutter head revolution: ---
Weight: 35 ton</td><td>Gallery cross section: 24 m^2
Gallery Inclination: 10°
Formation: Coal and clay
General condition of the formation: composed of 50% coal and 50% clay
Water condition: Wet
Support system: Steel sets
Muck transportation system: Belt conveyor</td></tr>
<tr><td>Net cutting rate: 1.73 h
Net production: 36 m^3
Net cutting rate: 20.77 m^3/h
Length of advance: 0.86 m/h</td><td colspan="2">The starting point of the excavation on the face and the way of continuing the excavation:
Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.</td></tr>
<tr><th colspan="3">Measurements of Machine Utilization Time</th></tr>
<tr><th>Activities</th><th>Time (min)</th><th>Ratio to the total time (8 hours) (%)</th></tr>
<tr><td>Excavation (trimming included)</td><td>104</td><td>21.67</td></tr>
<tr><td>Support installation</td><td>210</td><td>43.75</td></tr>
<tr><td>Muck loading and transportation</td><td>100</td><td>20.83</td></tr>
<tr><td>Cutter change</td><td>--</td><td>--</td></tr>
<tr><td>Machine maintenance</td><td>36</td><td>7.5</td></tr>
<tr><td>Mechanical failure</td><td>--</td><td>--</td></tr>
<tr><td>Electrical failure</td><td>--</td><td>--</td></tr>
<tr><td>Shift change</td><td>30</td><td>6.25</td></tr>
<tr><td>Others</td><td>0</td><td>---</td></tr>
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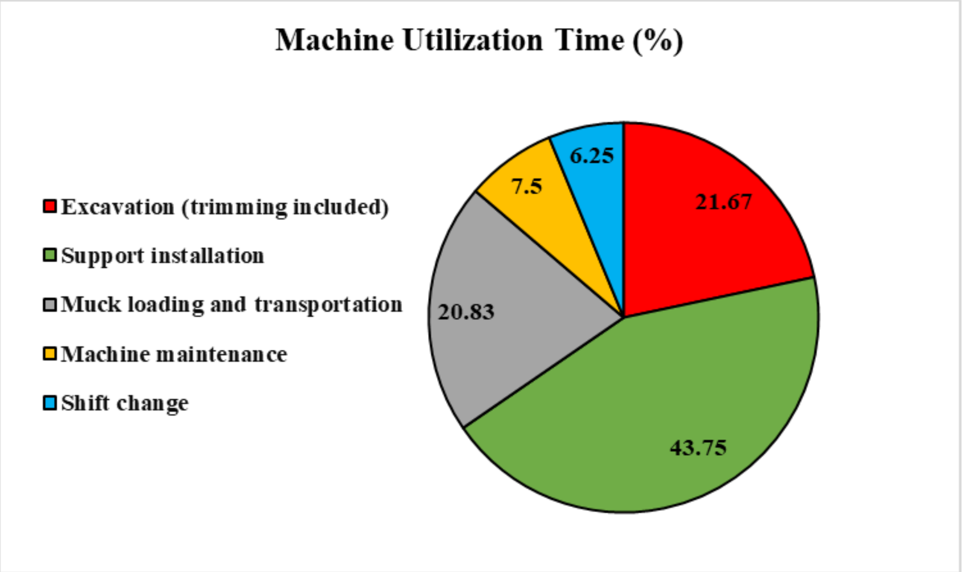


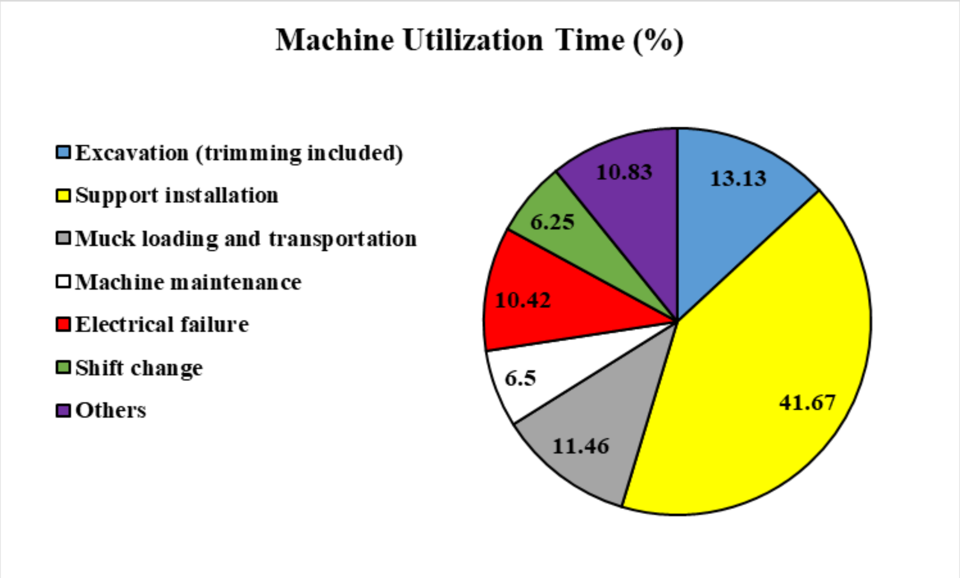
Other information:
Number of workers: 8
Horizontal distance between Steel sets: 75 cm
Length of advance: 1.5m

ROADHEADER'S PERFORMANCE FORM

General Information	Machine Specification	Gallery information
Date: 10.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery 2304 **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 10° **Formation**: Coal and clay **General condition of the formation**: composed of 50% coal and 50% clay **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.05 h **Net production:** 18 m^3 **Net cutting rate:** 17.14 m^3/h **Length of advance:** 0.86 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	

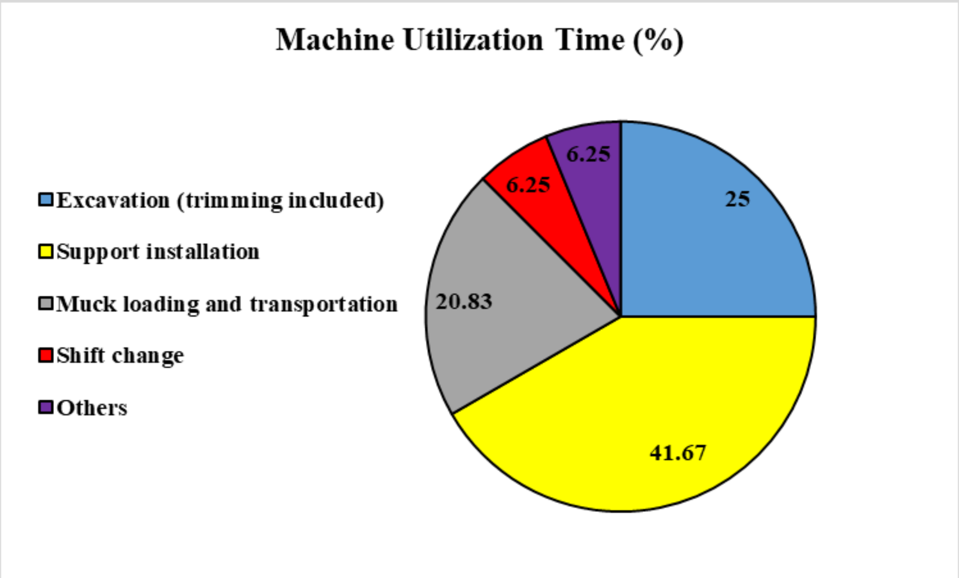
Measurements of Machine Utilization Time

Activities	Time (min)	Ratio to the total time (8 hours) (%)
Excavation (trimming included)	63	13.13
Support installation	200	41.67
Muck loading and transportation	55	11.46
Cutter change	---	---
Machine maintenance	30	6.25
Mechanical failure	---	---
Electrical failure	50	10.42
Shift change	30	6.25
Others	52	10.83



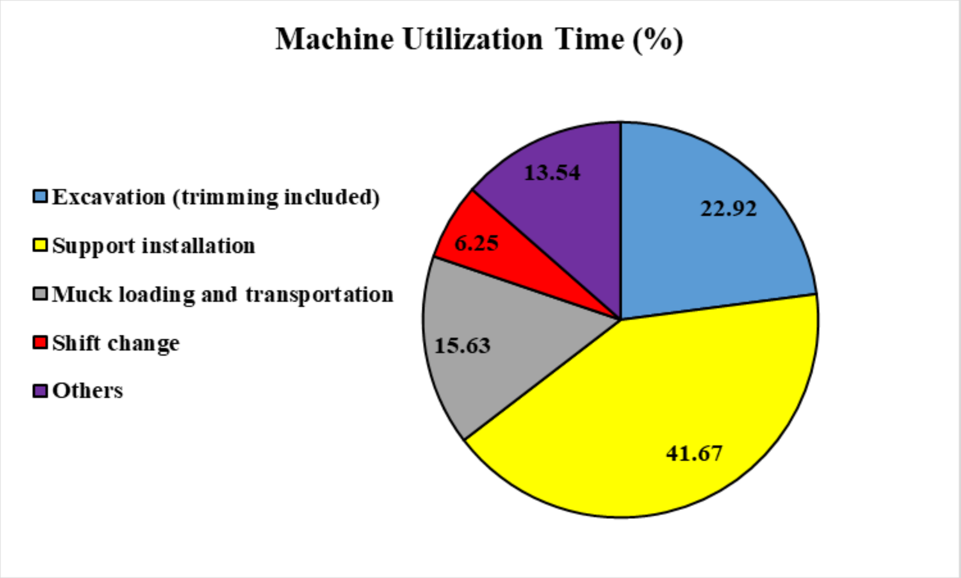
Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 0.75m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 11.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery 2304 **Shift:** 24-8 **Operator experience:** 2 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 10° **Formation**: Coal and clay **General condition of the formation**: composed of 50% coal and 50% clay **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 2.0 h **Net production:** 36 m^3 **Net cutting rate:** 18 m^3/h **Length of advance:** 0.75 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	120	25.0
Support installation	200	41.67
Muck loading and transportation	100	20.83
Cutter change	--	--
Machine maintenance	--	--
Mechanical failure	--	--
Electrical failure	--	--
Shift change	30	6.25
Others	30	6.25



Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5 m

ROADHEADER'S PERFORMANCE FORM		
General Information	**Machine Specification**	**Gallery information**
Date: 11.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery 2304 **Shift:** 8-16 **Operator experience:** 3 years **Company experience:** 3 years	**Type**: Transverse **Brand**: IBS-SM130 **Age**: 7 years **Cutter type**: Conic **Cutter number**: --- **Cutter head power**: 132 kW **Cutter head revolution**: --- **Weight**: 35 ton	**Gallery cross section**: 24 m^2 **Gallery Inclination:** 10° **Formation**: Coal and clay **General condition of the formation**: composed of 50% coal and 50% clay **Water condition**: Damp **Support system**: Steel sets **Muck transportation system**: Belt conveyor
Net cutting rate: 1.83 h **Net production**: 36 m^3 **Net cutting rate:** 19.64 m^3/h **Length of advance:** 0.81 m/h	**The starting point of the excavation on the face and the way of continuing the excavation:** Excavation was started from the tunnel ceiling, and after installation of the support system, the other parts of the tunnel face were removed.	
Measurements of Machine Utilization Time		
Activities	**Time (min)**	**Ratio to the total time (8 hours) (%)**
Excavation (trimming included)	110	22.92
Support installation	200	41.67
Muck loading and transportation	75	15.63
Cutter change	--	--
Machine maintenance	--	--
Mechanical failure	--	--
Electrical failure	--	--
Shift change	30	6.25
Others	65	13.54



Other information:
Number of workers: 8
Horizontal distance between steel sets: 75 cm
Length of advance: 1.5 m

APPX 2: NEEDLE PENETRATION TESTS

Date: 07.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J 710 Lower tailgate			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.0
2	100	3.0	33.3
3	90	10.0	9.0
4	100	5.0	20.0
5	100	3.0	33.3
6	100	6.0	16.7
7	100	8.0	12.5
8	100	4.0	25.0
9	100	7.0	14.3
10	100	4.0	25.0
		Average	21.4
UCS (MPa)			7.5

Date: 07.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J 710 Lower tailgate			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.0	33.3
2	100	5.0	20.0
3	100	4.0	25.0
4	100	5.0	20.0
5	100	3.0	33.3
6	90	10.0	9.0
7	100	4.0	25.0
8	100	8.0	12.5
9	90	10.0	9.0
10	100	4.0	25.0
11	100	4.0	25.0
		Average	21.5
UCS (MPa)			6.9

Date: 07.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** West J main road			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	80	10.0	10.0
2	90	10.0	33.3
3	60	10.0	50.0
4	40	10.0	28.6
5	50	10.0	50.0
6	100	8.0	9.0
7	50	10.0	9.0
8	60	10.0	5.0
9	40	10.0	12.5
10	60	10.0	33.3
		Average	24.0
UCS (MPa)			7.7

Date: 08.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H209 head gate			
Formation: Coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	7.0	14.3
2	100	9.0	11.1
3	100	6.0	16.7
4	90	10.0	9.0
5	60	10.0	6.0
6	90	10.0	9.0
7	100	6.0	16.7
8	40	10.0	4.0
9	90	10.0	9.0
10	100	6.0	16.7
		Average	11.2
UCS (MPa)			3.9

Date: 09.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H610			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.0
2	50	10.0	5.0
3	100	3.0	33.3
4	100	5.0	20.0
5	100	4.0	25.0
6	100	4.0	25.0
7	100	5.0	20.0
8	100	4.0	25.0
9	100	3.0	33.3
10	70	10.0	7.0
11	40	10.0	4.0
12	60	10.0	6.0
13	80	10.0	8.0
		Average	18.2
UCS (MPa)			6.37

Date: 09.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H610			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	6.0	16.7
2	100	5.0	20.0
3	100	7.0	14.3
4	50	10.0	5.0
5	100	7.0	14.3
6	40	10.0	4.0
7	30	10.0	3.0
8	80	10.0	8.0
9	100	7.0	14.3
10	100	8.0	12.5
		Average	11.2
UCS (MPa)			3.8

Date: 08.08.2018
Company: Park Termik
Location: Çayırhan
Gallery: H209 head gate

Formation: Claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.0	33.3
2	100	3.0	33.3
3	100	2.0	50.0
4	100	3.5	28.6
5	100	2.0	50.0
6	90	10.0	9.0
7	90	10.0	9.0
8	50	10.0	5.0
9	100	8.0	12.5
10	100	3.0	33.3
11	60	10.0	6.0
12	50	10.0	5.0
		Average	22.9
UCS (MPa)			7.3

Date: 07.08.2018
Company: Park Termik
Location: Çayırhan
Gallery: West J main road

Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	100	8.0	12.5
3	100	7.0	14.3
4	70	10.0	7.0
5	100	7.0	14.3
6	100	5.0	20.0
7	100	6.0	16.7
8	100	6.0	16.7
9	90	10.0	9.0
10	100	5.0	20.0
		Average	15.0
UCS (MPa)			5.2

Date: 14.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H210 Head gate			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.0
2	100	6.0	16.7
3	100	4.0	25.0
4	70	10.0	7.0
5	90	10.0	9.0
6	100	3.0	33.3
7	100	7.0	14.3
8	80	10.0	8.0
9	100	6.0	16.7
10	100	9.0	11.1
		Average	16.6
UCS (MPa)			5.8

Date: 14.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H210 Head gate			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	70	10.0	7.0
2	100	5.0	20.0
3	60	10.0	6.0
4	100	6.0	16.7
5	70	10.0	7.0
6	40	10.0	4.0
7	50	10.0	5.0
8	50	10.0	5.0
9	70	10.0	7.0
10	60	10.0	6.0
		Average	8.4
UCS (MPa)			2.9

Date: 15.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J710			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	100	4.0	25.0
3	100	3.0	33.3
4	100	4.0	25.0
5	100	3.0	33.3
6	100	4.0	25.0
7	100	4.0	25.0
8	100	5.0	20.0
9	100	3.0	33.3
10	100	6.0	16.7
		Average	25.7
UCS (MPa)			9.0

Date: 15.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J710			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	2.0	50.0
2	100	2.0	50.0
3	100	3.0	33.3
4	100	5.0	20.0
5	100	2.0	50.0
6	100	2.0	50.0
7	100	3.0	33.3
8	100	3.0	33.3
9	100	4.0	25.0
10	100	2.0	50.0
11	100	3.0	33.3
		Average	38.9
UCS (MPa)			12.0

Date: 04.09.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	80	10.0	8.0
2	90	10.0	9.0
3	90	10.0	9.0
4	70	10.0	7.0
5	50	10.0	5.0
6	60	10.0	6.0
7	90	10.0	9.0
8	70	10.0	7.0
9	100	8.0	12.5
10	100	7.0	14.3
		Average	8.7
UCS (MPa)			3.0

Date: 06.09.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	6.0	16.7
2	70	10.0	7.0
3	90	10.0	9.0
4	100	4.0	25.0
5	100	3.0	33.3
6	60	10.0	6.0
7	100	4.0	25.0
8	80	10.0	8.0
9	100	5.0	20.0
10	100	3.0	33.3
		Average	18.3
UCS (MPa)			6.0

Date: 07.09.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	80	10.0	8.0
2	60	10.0	6.0
3	90	10.0	9.0
4	70	10.0	7.0
5	80	10.0	8.0
6	100	7.0	14.3
7	60	10.0	6.0
8	70	10.0	7.0
9	50	10.0	5.0
10	60	10.0	6.0
		Average	7.6
UCS (MPa)			2.6

Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	80	10	8.0
2	60	10	6.0
3	70	10	7.0
4	40	10	4.0
5	80	10	8.0
6	100	9	11.1
7	40	10	4.0
8	100	8	12.5
9	90	10	9.0
10	100	5	20.0
11	100	3	33.3
		Average	11.1
UCS (MPa)			3.7

Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	6	16.6
2	100	7	14.2
3	100	9	11.1
4	100	5	20.0
5	100	8	12.5
6	90	10	9.0
7	100	8	12.5
8	100	7	14.2
9	80	10	8.0
10	70	10	7.0
11	60	10	6.0
		Average	11.9
UCS (MPa)			4.0

Date: 28.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5	20.0
2	70	10	7.0
3	60	10	6.0
4	100	6	13.3
5	70	10	7.0
6	75	10	7.5
7	50	10	5.0
8	80	10	8.0
9	80	10	8.0
10	80	10	8.0
		Average	9.0
UCS (MPa)			3.0

Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	8	12.5
2	100	7	14.3
3	50	10	5.0
4	100	9	11.1
5	100	7	14.3
6	90	10	9.0
7	100	7	14.3
8	100	7	14.3
9	100	8	12.5
10	100	8	12.5
		Average	11.9
UCS (MPa)			4.0

Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H north ventilation			
Formation: Claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	8	12.5
2	100	7	14.2
3	100	6	16.6
4	100	9	11.1
5	100	8	12.5
6	90	10	9.0
7	100	7	14.2
8	50	10	5.0
9	100	8	12.5
10	100	7	14.2
		Average	12.2
UCS (MPa)			4.0

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main road **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	6.0	16.7
2	100	7.0	14.3
3	100	6.0	16.7
4	100	5.0	20.0
5	100	6.0	16.7
6	100	4.0	25.0
7	100	5.0	20.0
8	100	6.0	16.7
9	100	8.0	12.5
10	100	8.0	12.5
		Average	17.1
UCS (MPa)			6.0

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main road **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	8.0	12.5
2	100	5.0	20.0
3	100	6.0	16.7
4	100	6.0	16.7
5	100	6.0	16.7
6	100	4.0	25.0
7	100	4.0	25.0
8	100	6.0	16.7
9	100	9.0	11.1
10	100	8.0	12.5
		Average	17.3
UCS (MPa)			6.0

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	7.0	14.3
2	100	6.0	16.7
3	100	8.0	12.5
4	100	5.0	20.0
5	100	7.0	14.3
6	100	4.0	25.0
7	100	3.0	33.3
8	100	8.0	12.5
9	100	7.0	14.3
10	100	5.0	20.0
		Average	18.3
UCS (MPa)			6.4

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	100	4.0	25.0
3	100	8.0	12.5
4	100	6.0	16.7
5	100	9.0	11.1
6	100	5.0	20.0
7	100	4.0	25.0
8	100	8.0	12.5
9	100	8.0	12.5
10	100	5.0	20.0
		Average	17.5
UCS (MPa)			6.1

Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	8.0	12.5
2	100	8.0	12.5
3	100	5.0	20.0
4	100	4.0	25.0
5	100	9.0	11.1
6	100	6.0	16.7
7	100	4.0	25.0
8	100	7.0	14.3
9	100	5.0	20.0
10	100	5.0	20.0
		Average	17.7
UCS (MPa)			6.2

Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	6.0	16.7
2	100	4.0	25.0
3	100	5.0	20.0
4	100	3.0	33.3
5	100	5.0	20.0
6	100	6.0	16.7
7	100	7.0	14.3
8	100	8.0	12.5
9	100	4.0	25.0
10	100	5.0	20.0
		Average	20.35
UCS (MPa)			7.1

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: 1210 **Shift:** 8-16			
Formation: Coal			
Mea. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	8.0	12.5
2	100	7.0	14.3
3	100	4.0	25.0
4	70	10.0	7.0
5	100	9.0	11.1
6	80	10.0	8.0
7	100	8.0	12.5
8	100	5.0	20.0
9	100	4.0	25.0
10	100	6.0	16.7
		Average	15.2
UCS (MPa)			5.3

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: 1210 **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	6.0	16.7
2	100	5.0	20.0
3	100	7.0	14.3
4	100	8.0	12.5
5	100	7.0	14.3
6	100	6.0	16.7
7	100	4.0	25.0
8	100	5.0	20.0
9	100	5.0	20.0
10	100	6.0	16.7
		Average	17.6
UCS (MPa)			6.2

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: 1210 **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	80	10.0	8.0
2	100	5.0	20.0
3	70	10.0	7.0
4	100	5.0	20.0
5	100	6.0	16.7
6	100	4.0	25.0
7	100	5.0	20.0
8	60	10.0	6.0
9	100	4.0	25.0
10	100	6.0	16.7
		Average	16.4
UCS (MPa)			5.8

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: 1210 **Shift:** 8-16			
Formation: Coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.0
2	100	6.0	16.7
3	100	7.0	14.3
4	100	5.0	20.0
5	70	10.0	7.0
6	100	6.0	16.7
7	100	4.0	25.0
8	100	3.0	33.3
9	100	6.0	16.7
10	100	6.0	16.7
		Average	19.1
UCS (MPa)			6.7

Date: 26.08.2021
Company: KİAŞ
Location: Çayırhan
Gallery: 1210 Preparation Gallery
Shift: 8-16

Formation: coal

Meas. no.	Force (N)	Penetration (mm)	NPI (N/mm)
1	100	3.0	33.3
2	100	4.0	25.0
3	100	5.0	20.0
4	100	5.0	20.0
5	100	8.0	12.5
6	100	6.0	16.7
7	100	5.0	20.0
8	100	3.0	33.3
9	100	7.0	14.3
10	100	7.0	14.3
		Average	20.9
UCS (MPa)			7.3

Date: 26.08.2021
Company: KİAŞ
Location: Çayırhan
Gallery: 1210 Preparation Gallery
Shift: 8-16

Formation: coal

Meas. no.	Force (N)	Penetration (mm)	NPI (N/mm)
1	100	5.0	20.0
2	100	4.0	25.0
3	100	6.0	16.7
4	100	5.0	20.0
5	100	7.0	14.3
6	100	5.0	20.0
7	100	4.0	25.0
8	100	8.0	12.5
9	100	5.0	20.0
10	100	6.0	16.7
		Average	19.0
UCS (MPa)			6.7

Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: 1210 Preparation Gallery **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	80	10.0	8.0
3	100	4.0	25.0
4	100	3.0	33.3
5	100	8.0	12.5
6	100	5.0	20.0
7	100	6.0	16.7
8	100	8.0	12.5
9	100	5.0	20.0
10	100	4.0	25.0
		Average	19.3
UCS (MPa)			6.7

Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: 1210 Preparation Gallery **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	100	4.0	25.0
3	100	6.0	16.7
4	100	3.0	33.3
5	70	10.0	7.0
6	70	10.0	7.0
7	100	3.0	33.3
8	100	5.0	20.0
9	100	6.0	16.7
10	100	3.0	33.3
		Average	18.2
UCS (MPa)			6.4

Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	7.0	14.3
2	100	8.0	12.5
3	100	9.0	11.1
4	100	5.0	20.0
5	100	6.0	16.7
6	100	8.0	12.5
7	100	9.0	11.1
8	100	5.0	20.0
9	100	8.0	12.5
10	100	4.0	25.0
		Average	15.6
UCS (MPa)			5.4

Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.0	33.3
2	100	5.0	20.0
3	100	7.0	14.3
4	100	8.0	12.5
5	100	4.0	25.0
6	100	8.0	12.5
7	100	7.0	14.3
8	100	9.0	11.1
9	100	5.0	20.0
10	100	8.0	12.5
		Average	17.5
UCS (MPa)			6.1

Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery**: YJ Main Road **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	8.0	12.5
2	100	9.0	11.1
3	100	5.0	20.0
4	100	9.0	11.1
5	100	7.0	14.3
6	100	8.0	12.5
7	100	8.0	12.5
8	100	7.0	14.3
9	100	5.0	20.0
10	100	5.0	20.0
		Average	14.8
UCS (MPa)			5.2

Date: 20.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 8-16			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.0
2	100	3.0	33.3
3	100	3.0	33.3
4	100	2.5	40.0
5	100	2.0	50.0
6	100	3.0	33.3
7	100	2.0	50.0
8	100	3.0	33.3
9	100	2.0	50.0
10	100	2.5	40.0
		Average	38.8
UCS (MPa)			13.6

Date: 21.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 8-16			
Formation: claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	1.5	66.7
2	100	2.5	40.0
3	100	2.0	50.0
4	100	2.0	2.0
5	100	2.0	2.0
6	100	3.0	33.3
7	100	4.0	25.0
8	100	3.0	33.3
9	100	2.0	50.0
10	100	2.0	50.0
11	100	1.5	66.7
12	100	1.5	66.7
		Average	48.5
UCS (MPa)			17.0

Date: 22.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 16-24			
Formation: claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	2.0	50.0
2	100	1.5	66.7
3	100	3.0	33.3
4	100	2.0	50.0
5	100	2.0	50.0
6	100	2.5	40.0
7	100	5.0	20.0
8	100	3.0	33.3
9	100	4.0	25.0
10	100	2.5	40.0
11	100	3.0	33.3
		Average	40.20
UCS (MPa)			14.1

Date: 22.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 8-16			
Formation: claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	2.0	50.0
2	100	3.0	33.3
3	100	1.5	66.7
4	100	2.0	50.0
5	100	3.0	33.3
6	100	2.0	50.0
7	100	2.0	50.0
8	100	3.0	33.3
9	100	3.0	33.3
10	100	1.5	66.7
		Average	46.7
UCS (MPa)			16.3

Date: 23.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 8-16			
Formation: claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N.mm)**
1	100	1.5	66.7
2	100	1.0	100.0
3	100	2.0	50.0
4	100	2.0	50.0
5	100	3.0	33.3
6	100	2.0	50.0
7	100	2.5	40.0
8	100	4.0	25.0
9	100	1.0	100.0
10	100	2.5	40.0
11	100	2.0	50.0
12	100	2.0	50.0
		Average	54.6
UCS (MPa)			19.1

Date: 23.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 16-24			
Formation: claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.0	33.3
2	100	3.0	33.3
3	100	2.0	50.0
4	100	3.5	28.6
5	100	3.0	33.3
6	100	2.5	40.0
7	100	3.0	33.3
8	100	2.0	50.0
9	100	2.0	50.0
10	100	3.0	33.3
		Average	38.5
UCS (MPa)			13.5

Date: 24.05.2019 **Company:** YS Mining **Location:** Çorum **Gallery:** Ventilation Gallery, 30-50 m **Shift:** 8-16			
Formation: claystone			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	1.5	66.7
2	100	1.5	66.7
3	100	1.0	100.0
4	100	1.0	100.0
5	100	1.0	100.0
6	100	0.5	200.0
7	100	1.0	100.0
8	100	1.0	100.0
9	100	1.5	66.7
10	100	2.0	50.0
11	100	1.0	100.0
12	100	1.5	66.7
13	100	2.0	50.0
		Average	89.8
UCS (MPa)			31.4

Date: 09.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D7 Upper head gate, 1.floor			
Formation: coal			
Meas. No.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	17	10.0	1.7
2	20	10.0	2.0
3	20	10.0	2.0
4	35	10.0	3.5
5	20	10.0	2.0
6	30	10.0	3.0
7	20	10.0	2.0
8	25	10.0	2.5
9	25	10.0	2.5
10	40	10.0	4.0
11	40	10.0	4.0
12	30	10.0	3.0
		Average	2.7
UCS (MPa)			0.95

Date: 09.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D7 Upper head gate, 1.floor			
Formation: claystone			
Meas. no	**Force (N)**	**penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	100	9.0	11.1
3	100	3.0	33.3
4	100	7.0	14.3
5	100	8.0	12.5
6	100	2.0	50.0
7	100	4.0	25.0
8	100	8.0	12.5
9	100	7.0	14.3
10	100	8.0	12.5
11	100	8.0	12.5
		Average	19.8
UCS (MPa)			6.4

Date: 10.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D10 Sub-tail Gate			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	60	10.0	6.0
2	30	10.0	3.0
3	40	10.0	4.0
4	40	10.0	4.0
5	30	10.0	3.0
6	30	10.0	3.0
7	40	10.0	4.0
8	50	10.0	5.0
9	60	10.0	6.0
10	40	10.0	4.0
		Average	4.2
UCS (MPa)			1.5

Date: 10.07.2018 **Company:** İmbat **Location:** Soma **Gallery:** D10 Sub-tail Gate			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.0	33.3
2	100	3.0	33.3
3	100	2.0	50.0
4	100	2.0	50.0
5	100	4.0	25.0
6	100	2.0	50.0
7	100	3.0	33.3
8	100	2.0	50.0
9	100	4.0	25.0
10	100	3.0	33.3
		Average	38.3
UCS (MPa)			11.8

Date: 11.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D7 Upper head gate, 1.floor			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	45	10.0	4.5
2	100	4.0	25.0
3	60	10.0	6.0
4	100	7.0	14.3
5	100	4.0	25.0
6	70	10.0	7.0
7	80	10.0	8.0
8	60	10.0	6.0
9	80	10.0	8.0
10	100	7.0	14.3
11	100	4.0	25.0
12	30	10.0	3.0
13	100	6.0	16.7
		Average	12.5
UCS (MPa)			4.4

Date: 12.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D7 Sub-tail gate 2.floor			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	30	10.0	3.0
2	70	10.0	7.0
3	50	10.0	5.0
4	60	10.0	6.0
5	70	10.0	7.0
6	70	10.0	7.0
7	60	10.0	6.0
8	70	10.0	7.0
9	70	10.0	7.0
10	100	2.0	50.0
11	80	10.0	8.0
12	100	3.0	33.3
13	100	8.0	12.5
		Average	12.2
UCS (MPa)			4.3

Date: 12.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D7 Sub-tail gate 2.floor			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	7.0	14.3
2	100	4.0	25.0
3	100	5.0	20.0
4	70	10.0	7.0
5	100	4.0	25.0
6	100	7.0	14.3
7	80	10.0	8.0
8	100	6.0	16.7
9	60	10.0	6.0
10	40	10.0	4.0
11	90	10.0	9.0
		Average	13.6
UCS (MPa)			4.5

Date: 13.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Sub-tail Gate			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5.0	20.0
2	100	4.0	25.0
3	100	5.0	20.0
4	70	10.0	7.0
5	100	4.0	25.0
6	100	4.0	25.0
7	100	4.0	25.0
8	100	5.0	20.0
9	100	3.0	33.3
10	100	6.0	16.7
		Average	21.7
UCS (MPa)			7.6

Date: 16.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Sub tail Gate			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	70	10.0	7.0
2	100	8.0	12.5
3	100	5.0	20.0
4	60	10.0	6.0
5	30	10.0	3.0
6	40	10.0	4.0
7	100	4.0	25.0
8	30	10.0	3.0
9	40	10.0	4.0
10	50	10.0	5.0
11	40	10.0	4.0
		Average	8.5
UCS (MPa)			3.0

Date: 16.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Sub tail Gate			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	60	10.0	6.0
2	20	10.0	2.0
3	30	10.0	3.0
4	40	10.0	4.0
5	100	4.0	25.0
6	90	10.0	9.0
7	100	6.0	16.7
8	100	4.0	25.0
9	90	10.0	9.0
10	100	5.0	20.0
		Average	12.0
UCS (MPa)			4.0

Date: 17.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Sub-tail Gate			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	80	10.0	8.0
2	60	10.0	6.0
3	70	10.0	7.0
4	80	10.0	8.0
5	60	10.0	6.0
6	90	10.0	9.0
7	50	10.0	5.0
8	100	8.0	12.5
9	40	10.0	4.0
10	80	10.0	8.0
11			
		Average	7.3
UCS (MPa)			2.5

Date: 17.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Sub-tail Gate			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	9.0	11.1
2	80	10.0	8.0
3	70	10.0	7.0
4	100	7.0	14.3
5	70	10.0	7.0
6	90	10.0	9.0
7	90	10.0	9.0
8	75	10.0	7.5
9	100	7.0	14.3
10	100	8.0	12.5
11	100	8.0	12.5
12	100	9.0	11.1
		Average	12.3
UCS (MPa)			4.3

Date: 18.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Sub tail Gate			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	70	10.0	7.0
2	100	4.0	25.0
3	100	4.0	25.0
4	90	10.0	9.0
5	100	5.0	20.0
6	100	6.0	16.7
7	100	6.0	16.7
8	100	3.0	33.3
9	100	5.0	20.0
10	100	7.0	14.3
11	100	4.0	25.0
		Average	19.3
UCS (MPa)			5.8

Date: 18.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Sub tail Gate			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.0	33.3
2	100	2.0	50.0
3	100	5.0	20.0
4	100	4.0	25.0
5	100	2.0	50.0
6	100	3.0	33.3
7	100	1.0	100.0
8	100	2.0	50.0
9	100	3.0	33.3
10	100	4.0	25.0
		Average	42.0
UCS (MPa)			13.0

Date: 20.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	1.5	66.6
2	100	3.0	33.3
3	100	5.0	20.0
4	100	3.0	33.3
5	100	3.0	33.3
6	100	4.0	25.0
7	100	2.0	50.0
8	100	4.0	25.0
9	100	3.0	33.3
10	100	3.0	33.3
		Average	35.3
UCS (MPa)			12.3

Date: 19.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4	25.0
2	100	3	33.3
3	100	4	25.0
4	100	5	20.0
5	100	2	50.0
6	100	7	14.2
7	100	3	33.3
8	100	4	25.0
9	100	5	20.0
10	100	4	25.0
		Average	27.1
UCS (MPa)			9.5

Date: 21.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3	33.3
2	100	4	25.0
3	100	4	25.0
4	100	5	20.0
5	100	3	33.3
6	100	6	16.6
7	100	3	33.3
8	100	2	50.0
9	100	3	33.3
10	100	4	25.0
		Average	29.5
UCS (MPa)			10.3

Date: 18.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147. Connection Gallery			
Formation: mixed			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4	25.0
2	70	10	7.0
3	100	3	33.3
4	100	3	33.3
5	70	10	7.0
6	70	10	7.0
7	80	10	8.0
8	100	2	50.0
9	100	4	25.0
10	100	6	16.6
11	100	4	25.0
12	100	3	33.3
13	100	8	12.5
		Average	22.1
UCS (MPa)			7.0

Date: 19.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147. Connection Gallery			
Formation: mixed			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	1	100.0
2	100	1	100.0
3	100	2	50.0
4	100	1	100.0
5	100	1	100.0
6	100	2	50.0
7	100	1	100.0
8	100	3	33.3
9	100	3	33.3
10	100	3	33.3
		Average	70.0
UCS (MPa)			20.7

Date: 01.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	7	14.3
2	100	4	25.0
3	100	6	16.7
4	100	5	20.0
5	100	5	20.0
6	100	6	16.7
7	100	4	25.0
8	80	10	8.0
9	100	8	12.5
10	100	6	16.7
		Average	17.5
UCS (MPa)			6.1

Date: 02.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	30	10	3.0
2	100	8	12.5
3	40	10	4.0
4	60	10	6.0
5	80	10	8.0
6	50	10	5.0
7	70	10	7.0
8	50	10	5.0
9	50	10	5.0
10	100	8	12.5
		Average	6.8
UCS (MPa)			2.4

Date: 02.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 16-24			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	20	10	2.0
2	25	10	2.5
3	60	10	6.0
4	70	10	7.0
5	50	10	5.0
6	20	10	2.0
7	30	10	3.0
8	40	10	4.0
9	50	10	5.0
10	60	10	6.0
		Average	4.3
UCS (MPa)			1.5

Date: 03.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	40	10	4
2	70	10	7
3	50	10	5
4	60	10	6
5	40	10	4
6	60	10	6
7	70	10	7
8	50	10	5
9	40	10	4
10	40	10	4
		Average	5.3
UCS (MPa)			1.9

Date: 01.07.2019 **Company:** Imbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	30	10	3.0
2	40	10	4.0
3	20	10	2.0
4	40	10	4.0
5	100	7	14.3
6	100	4	25.0
7	100	3	33.3
8	100	3	33.3
9	30	10	3.0
10	40	10	4.0
		Average	12.6
UCS (MPa)			4.4

Date: 01.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 16-24			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5	20.0
2	100	5	20.0
3	100	4	25.0
4	100	3	33.3
5	100	4	25.0
6	100	7	14.3
7	100	6	16.7
8	100	8	12.5
9	100	6	16.7
10	100	4	25.0
		Average	20.6
UCS (MPa)			7.2

Date: 03.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4	25.0
2	100	6	16.7
3	100	7	14.3
4	100	6	16.7
5	100	5	20.0
6	100	6	16.7
7	100	4	25.0
8	100	8	12.5
9	100	4	25.0
10	100	5	20.0
		Average	19.2
UCS (MPa)			6.7

Date: 02.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13 Upper tail gate **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	5	20.0
2	100	3	33.3
3	100	6	16.7
4	100	6	16.7
5	90	10	9.0
6	80	10	8.0
7	100	4	25.0
8	100	5	20.0
9	100	9	11.1
10	100	6	16.7
		Average	17.6
UCS (MPa)			6.2

Date: 04.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 8-16			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	60	10	6
2	20	10	2
3	50	10	5
4	30	10	3
5	30	10	3
6	70	10	7
7	80	10	8
8	60	10	6
9	40	10	4
10	40	10	4
		Average	4.8
UCS (MPa)			1.7

Date: 04.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 16-24			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	90	10	9
2	70	10	7
3	70	10	7
4	60	10	6
5	40	10	4
6	50	10	5
7	50	10	5
8	60	10	6
9	60	10	6
10	70	10	7
		Average	6.2
UCS (MPa)			2.2

Date: 05.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 8-16			
Formation: coal			
Meas .no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	2.0	50.0
2	100	1.5	66.7
3	100	3.0	33.3
4	100	2.0	50.0
5	100	2.0	50.0
6	100	2.5	40.0
7	100	5.0	20.0
8	100	3.0	33.3
9	100	4.0	25.0
10	100	2.5	40.0
11	100	3.0	33.3
		Average	40.2
UCS (MPa)			14.1

Date: 05.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Middle Floor **Shift:** 16-24			
Formation: coal			
Meas. no	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	7	14.3
2	100	8	12.5
3	70	10	7.0
4	80	10	8.0
5	90	10	9.0
6	60	10	6.0
7	50	10	5.0
8	70	10	7.0
9	100	7	14.3
10	40	10	4.0
		Average	8.7
UCS (MPa)			3.0

Date: 25.11.2019 **Shift:** 8-16 **Company:** Polyak **Location:** Bergama **Gallery:** 3305			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.0
2	100	3.0	33.3
3	100	3.0	33.3
4	100	4.0	25.0
5	100	3.0	33.3
6	100	3.0	33.3
7	100	3.0	33.3
8	100	3.5	28.6
9	100	3.5	25.0
10	100	4.0	33.3
		Average	30.4
UCS (MPa)			10.6

Date: 26.11.2019 **Shift :** 24-8 **Company:** Polyak **Location:** Bergama **Gallery:** 3305			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	3.5	28.8
2	100	4	25.0
3	100	4	25.0
4	100	3	33.3
5	100	3	33.3
6	100	4	25.0
7	100	3	33.3
8	100	5	20.0
9	100	3	33.3
10	100	4	25.0
		Average	28.2
UCS (MPa)			9.9

Date: 26.11.2019 **Shift :** 8-16 **Company:** Polyak **Location:** Bergama **Gallery:** 3305			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	10	4.0	25.0
2	100	3.0	33.3
3	100	4.0	25.0
4	100	3.0	33.3
5	100	3.5	28.8
6	100	3.5	28.8
7	100	4.0	25.0
8	100	4.0	25.0
9	100	3.5	28.8
10	100	4.0	25.0
		Average	27.7
UCS (MPa)			9.7

Date: 27.11.2019 **Shift :** 8-16 **Company:** Polyak **Location:** Bergama **Gallery:** 3305			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	4.0	25.00
2	100	3.5	28.57
3	100	3.0	33.33
4	100	2.5	40.00
5	100	4.0	25.00
6	100	3.0	33.33
7	100	4.0	25.00
8	100	3.5	28.57
9	100	3.0	33.33
10	100	2.5	40.00
		Average	31.21
UCS (MPa)			10.93

Date: 27.11.2019 **Shift :**16-24 **Company:** Polyak **Location:** Bergama` **Gallery:** 3305			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	100	2.5	40.0
2	100	3.5	28.8
3	100	3.0	33.3
4	100	3.0	33.3
5	100	4.0	25.0
6	100	3.0	33.3
7	100	3.0	33.3
8	100	3.5	28.8
9	100	4.0	25.0
10	100	3.5	28.8
		Average	30.9
UCS (MPa)			10.82

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	7	100	14.3
2	8	100	12.5
3	4	100	25.0
4	6	100	16.7
5	5	100	20.0
6	4	100	25.0
7	4	100	25.0
8	7	100	14.3
9	10	90	9.0
10	6	100	16.7
		Average	17.6
UCS (MPa)			6.1

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	4	100	25.0
2	4	100	25.0
3	6	100	16.7
4	8	100	12.5
5	7	100	14.3
6	7	100	14.3
7	8	100	12.5
8	6	100	16.7
9	7	100	14.3
10	5	100	20.0
		Average	17.1
UCS (MPa)			5.6

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 24-8			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	8	100	12.5
2	6	100	16.7
3	5	100	20.0
4	6	100	16.7
5	8	100	12.5
6	8	100	12.5
7	9	100	11.1
8	6	100	16.7
9	5	100	20.0
10	5	100	20.0
		Average	15.9
UCS (MPa)			5.5

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 24-8			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	5	100	20.0
2	6	100	16.7
3	5	100	20.0
4	5	100	20.0
5	6	100	16.7
6	5	100	20.0
7	6	100	16.7
8	7	100	14.3
9	6	100	16.7
10	6	100	16.7
		Average	17.8
UCS (MPa)			5.8

Date: 09.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	5	100	20.0
2	7	100	14.3
3	4	100	25.0
4	6	100	16.7
5	6	100	16.7
6	6	100	16.7
7	7	100	14.3
8	7	100	14.3
9	8	100	12.5
10	6	100	16.7
		Average	16.7
UCS (MPa)			5.6

Date: 09.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	4	100	25.0
2	3	100	33.3
3	4	100	25.0
4	2	100	50.0
5	3	100	33.3
6	4	100	25.0
7	4	100	25.0
8	3	100	33.3
9	6	100	16.7
10	5	100	20.0
		Average	28.7
UCS (MPa)			9.04

Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	7	100	14.3
2	4	100	25.0
3	4	100	25.0
4	7	100	14.3
5	6	100	16.7
6	6	100	16.7
7	7	100	14.3
8	7	100	14.3
9	5	100	20.0
10	8	100	12.5
		Average	17.3
UCS (MPa)			6.1

Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	4	100	25.0
2	3	100	33.3
3	4	100	25.0
4	2	100	50.0
5	3	100	33.3
6	4	100	25.0
7	4	100	25.0
8	3	100	33.3
9	6	100	16.7
10	5	100	20.0
		Average	28.7
UCS (MPa)			9.04

Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 16-24			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	6	100	16.7
2	8	100	12.5
3	7	100	14.3
4	5	100	20.0
5	7	100	14.3
6	4	100	25.0
7	5	100	20.0
8	9	100	11.1
9	6	100	16.7
10	7	100	14.3
		Average	16.5
UCS (MPa)			5.8

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	5	100	20.0
2	9	100	11.1
3	7	100	14.3
4	8	100	12.5
5	8	100	12.5
6	8	100	12.5
7	9	100	11.1
8	6	100	16.7
9	6	100	16.7
10	7	100	14.3
		Average	14.2
UCS (MPa)			5.0

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection Gallery 2304 **Shift:** 24-8			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	8	100	12.5
2	6	100	16.7
3	6	100	16.7
4	4	100	25.0
5	6	100	16.7
6	7	100	14.3
7	5	100	20.0
8	6	100	16.7
9	9	100	11.1
10	5	100	20.0
11	6	100	16.7
		Average	16.9
UCS (MPa)			5.9

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery: :** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	8	100	12.5
2	4	100	25.0
3	5	100	20.0
4	7	100	14.3
5	6	100	16.7
6	4	100	25.0
7	3	100	33.3
8	5	100	20.0
9	7	100	14.3
10	7	100	14.3
		Average	19.5
UCS (MPa)			6.8

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery: :** 2. Connection Gallery 2304 **Shift:** 8-16			
Formation: claystone			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	3	100	33.3
2	4	100	25.0
3	7	100	14.3
4	8	100	12.5
5	5	100	20.0
6	4	100	25.0
7	3	100	33.3
8	4	100	25.0
9	4	100	25.0
10	5	100	20.0
		Average	23.6
UCS (MPa)			7.8

Date: 09.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 24-8			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	4	100	25.0
2	4	100	25.0
3	3	100	33.3
4	3	100	33.3
5	4	100	25.0
6	5	100	20.0
7	6	100	16.7
8	7	100	14.3
9	8	100	12.5
10	8	100	12.5
		Average	21.8
UCS (MPa)			7.6

Date: 09.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	9	100	11.1
2	6	100	16.7
3	5	100	20.0
4	4	100	25.0
5	6	100	16.7
6	7	100	14.3
7	8	100	12.5
8	5	100	20.0
9	6	100	16.7
10	8	100	12.5
		Average	16.5
UCS (MPa)			5.8

Date: 10.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	5	100	20.0
2	6	100	16.7
3	5	100	20.0
4	4	100	25.0
5	6	100	16.7
6	7	100	14.3
7	6	100	16.7
8	6	100	16.7
9	6	100	16.7
10	7	100	14.3
		Average	17.7
UCS (MPa)			6.2

Date: 10.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 16-24			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	6	100	16.7
2	5	100	20.0
3	5	100	20.0
4	7	100	14.3
5	6	100	16.7
6	4	100	25.0
7	8	100	12.5
8	6	100	16.7
9	7	100	14.3
10	8	100	12.5
11	9	100	11.1
		Average	16.3
UCS (MPa)			5.7

Date: 11.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 24-8			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	7	100	14.3
2	5	100	20.0
3	7	100	14.3
4	4	100	25.0
5	8	100	12.5
6	6	100	16.7
7	5	100	20.0
8	7	100	14.3
9	6	100	16.7
10	7	100	14.3
		Average	16.8
UCS (MPa)			5.9

Date: 11.6.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16			
Formation: coal			
Meas. no.	**Force (N)**	**Penetration (mm)**	**NPI (N/mm)**
1	4	100	25.0
2	5	100	20.0
3	5	100	20.0
4	4	100	25.0
5	7	100	14.3
6	5	100	20.0
7	4	100	25.0
8	5	100	20.0
9	7	100	14.3
10	7	100	14.3
		Average	19.8
UCS (MPa)			7.0

APPX 3: DISCONTINUITY MEASUREMENTS

Date: 07.08.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements											
	Dip	Dip direction	Number	Measurement length(cm)	Formation		Dip	Dip direction	Number	Measurement length(cm)	Formation
1	06	145	4	50	Clay	4	38	323	3	40	Coal
2	33	323	3	50	Clay	5	74	201	3	40	Coal
3	88	220	13	60	Coal	6	40	100	4	50	Coal
4	34	175	7	50	Coal	7					

	Formation (%)	**Strike and dip of discontinuities**	**J_v**
	Clay-15%	Strike || to tunnel axis, dip 0-30	14.0
	Coal-85%		58.7

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	6	70
Joint Set 2	6	34
Joint Set 3	6	34
Joint Set 4	-	-
Joint Set 5	-	-
J_v	363	

Date: 07.08.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	17 / 040	3	50	Clay	4				
2	87 / 108	5	40	Coal	5				
3	74 / 270	21	50	Coal	6				
4	35 / 340	10	40	Coal	7				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Clay-15%	Strike ⊥ to tunnel axis, Drive against dip, dip 30-60	6.0
	Coal-85%		79.0

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length (mm)
Joint Set 1	14	80
Joint Set 2	11	44
Joint Set 3	4	43
Joint Set 4	-	-
Joint Set 5	-	-
J_v	518	

Date: 08.08.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	69 / 216	4	200	Clay	4	82 / 035	5	100	Coal
2	05 / 320	8	100	Clay	5	30 / 260	11	100	Coal
3	18 / 225	5	150	Clay	6				
4	84 / 180	6	100	Coal	7				

Formation (%)	**Strike and dip of discontinuities**	**J_v**
Clay-55%	Strike || to tunnel axis, dip 0-30	13.3
Coal-45%		22.0

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	9	100
Joint Set 2	8	67
Joint Set 3	5	36
Joint Set 4	-	-
Joint Set 5	-	-
J_v	348	

Date: 09.08.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	29 / 229	4	40	Clay	4	14 / 201	10	100	Coal
2	83 / 023	4	50	Coal	5	29 / 292	4	40	Coal
3	67 / 270	4	40	Coal	6	49 / 055	5	50	Coal
4	85 / 190	6	50	Coal	7				

Formation (%)	**Strike and dip of discontinuities**	**J_v**
Clay-30%	Strike ⊥ to tunnel axis, Drive with dip dip 30-60	10.0
Coal-70%		65.0

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	6	51
Joint Set 2	5	52
Joint Set 3	4	92
Joint Set 4	-	-
Joint Set 5	-	-
J_v	257	

Date: 14.08.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	06 / 253	11	40	Clay	4	83 / 322	15	70	Coal
2	79 / 335	8	30	Clay	5	80 / 057	26	50	Coal
3	89 / 100	6	30	Clay	6	11 / 191	7	25	Coal
4	67 / 290	3	30	Clay	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-60%	Strike || to tunnel axis, dip 0-30	84.2
	Coal-40%		101.4

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	13	53
Joint Set 2	7	60
Joint Set 3	4	100
Joint Set 4	-	-
Joint Set 5	-	-
J_v	383	

Date: 15.08.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	73 / 220	6	20	Clay	4	80 / 090	40	30	Coal
2	16 / 014	20	100	Clay	5	83 / 290	20	50	Coal
3	82 / 270	6	30	Clay	6	4 / 293	20	**30**	Coal
4	83 / 150	14	30	Coal	7	40 / **018**	6	**30**	Coal

	Formation (%)	**Strike and dip of discontinuities**	**J_v**
	Clay-30%	Strike || to tunnel axis, dip 0-30	70.0
	Coal-70%		306.7

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	15	39
Joint Set 2	9	23
Joint Set 3	4	50
Joint Set 4	-	-
Joint Set 5	-	-
J_v	856	

Date: 04.09.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	38 / 065	6	100	Clay	4				
2	54 / 335	8	30	Clay	5				
3	87 / 320	6	30	Clay	6				
4	70 / 300	14	40	Clay	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-100%	Strike Oblique to tunnel axis, dip 30-60	87.7

Date: 06.09.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	58 / 245	11	50	Clay	4	87 / 143	6	30	Clay
2	64 / 120	8	40	Clay	5				
3	87 / 357	10	50	Clay	6				
4	58 / 093	6	50	Clay	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-100%	Strike Oblique to tunnel axis, dip 30-60	94

Date: 07.09.2018

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	41 / 115	6	40	Clay	4	17 / 050	7	40	Clay
2	76 / 326	10	70	Clay	5	57 / 110	12	90	Clay
3	85 / 060	4	50	Clay	6				
4	77 / 260	10	100	Clay	7				

Formation (%)	**Strike and dip of discontinuities**	**J_v**
Clay-100%	Strike Oblique to tunnel axis, dip 30-60	78

Date: 27.02.2019

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	17 / 279	7	30	Clay	4				
2	30 / 280	10	40	Clay	5				
3	80 / 160	4	40	Clay	6				
4	20 / 270	5	30	Silex	7				

Formation (%)	**Strike and dip of discontinuities**	**J_v**
Clay-75%	Strike ⊥ to tunnel axis, Drive against dip, dip 0-30	88.4
Silex-25%		16.6

Date: 270.2.2019

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	45 / 137	4	30	Clay	4				
2	54 / 013	6	30	Clay	5				
3	80 / 225	4	20	Clay	6				
4	27 / 240	7	30	Silex	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-80%	Strike ⊥ to tunnel axis, Drive against dip, dip 0-30	83.3
	Silex-20%		23.3

Date: 28.02.2019

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	15 / 234	9	40	Clay	4	29 / 274	8	30	Silex
2	79 / 058	7	40	Clay	5				
3	59 / 220	5	30	Clay	6				
4	53 / 121	4	30	Silex	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-80%	Strike ⊥ to tunnel axis, Drive against dip, dip 0-30	56.6
	Silex-20%		40.0

Date: 28.02.2019

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	20 / 240	10	35	Clay	4	35 / 260	7	45	Silex
2	85 / 055	5	40	Clay	5				
3	65 / 225	6	30	Clay	6				
4	45 / 115	5	35	Silex	7				

Formation (%)	Strike and dip of discontinuities	J_v
Clay-80%	Strike ⊥ to tunnel axis, Drive against dip, dip 0-30	61.0
Silex-20%		29.8

Date: 01.03.2019

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	62 / 290	14	30	Clay	4	83 / 06 3	4	30	Silex
2	56 / 042	9	30	Clay	5				
3	80 / 250	5	30	Clay	6				
4	35 / 010	9	30	Silex	7				

Formation (%)	Strike and dip of discontinuities	J_v
Clay-80%	Strike ⊥ to tunnel axis, Drive against dip, dip 0-30	93.2
Silex-20%		43.3

Date: 01.03.2019

Company: Park Termik

Location: Çayırhan

Main Discontinuity Measurements

	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1	60 288	15	40	Clay	4	88 055	5	40	Silex
2	45 030	8	30	Clay	5				
3	85 245	6	35	Clay	6				
4	30 015	4	30	Silex	7				

Formation (%)	**Strike and dip of discontinuities**	**J_v**
Clay-80%	Strike ⊥ to tunnel axis, Drive against dip, Dip 0-30	81.2
Silex-20%		25.9

Date: 20.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements

	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1	66 037	15	30	Claystone	5				
2	60 164	6	20	Claystone	6				
3	23 048	22	30	Claystone	7				
4	48 139	14	20	Claystone	8				

Formation (%)	**Strike and dip of discontinuities**	J_v
Claystone-100%	Strike || to tunnel axis, Dip 30-60	117

Date: 21.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	76 / 237	10	20	Claystone	5				
2	44 / 176	10	30	Claystone	6				
3	52 / 350	6	20	Claystone	7				
4	04 / 300	6	20	Claystone	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Claystone-100%	Strike || to tunnel axis, Dip 30-60	143.3

Date: 22.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	73 / 353	17	40	Claystone	5				
2	60 / 024	9	20	Claystone	6				
3	57 / 110	10	30	Claystone	7				
4	77 / 070	10	20	Claystone	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Claystone-100%	Strike || to tunnel axis, Dip 30-60	187.5

Date: 22.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	44 / 120	10	20	Claystone	5	14 / 340	6	30	
2	48 / 308	7	40	Claystone	6				
3	80 / 220	14	20	Claystone	7				
4	57 / 100	7	20	Claystone	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Claystone-100%	Strike || to tunnel axis, Dip 30-60	192.5

Date: 23.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	83 / 067	10	30	Claystone	5				
2	42 / 171	14	20	Claystone	6				
3	88 / 010	10	40	Claystone	7				
4	76 / 305	6	40	Claystone	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Claystone-100%	Strike || to tunnel axis, Dip 30-60	143.3

Date: 23.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	76 / 237	10	20	Claystone	5				
2	44 / 176	10	30	Claystone	6				
3	52 / 350	6	20	Claystone	7				
4	04 / 300	6	20	Claystone	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Claystone-100%	Strike || to tunnel axis, Dip 30-60	143.3

Date: 24.05.2019

Company: YS Mining

Location: Dodurga

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	89 / 067	7	70	Claystone	5	23 / 220	5	40	Claystone
2	65 / 140	11	30	Claystone	6				
3	89 / 216	10	30	Claystone	7				
4	08 / 120	6	20	Claystone	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Claystone-100%	Strike || to tunnel axis, Dip 30-60	147.5

Date: 25.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		90	100	Marl	5				
2					6				
3					7				
4					8				
			Formation	**Strike and dip of discontinuities**				**J_v**	
			Marl	Strike ⊥ to tunnel axis Drive against dip, Dip 60-90				90	

Date: 25.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		60	108	Marl	4				
2					5				
3					6				
4					7				
			Formation	**Strike and dip of discontinuities**				**J_v**	
			Marl	Strike ⊥ to tunnel axis Drive against dip, Dip 60-90				55.6	

Date: 26.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1		105	120	Marl	4				
2		220	100	Marl	5				
3					6				
4					7				
			Formation	**Strike and dip of discontinuities**				**J_v**	
			Marl	Strike ⊥ to tunnel axis Drive against dip, Dip 60-90				307.5	

Date: 26.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1		60	130	Marl	4				
2		44	132	Marl	5				
3		35	112	Marl	6				
4					7				
			Formation	**Strike and dip of discontinuities**				**J_v**	
			Marl	Strike ⊥ to tunnel axis, Drive against dip, Dip 60-90				110.74	

Date: 27.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		90	140	Marl	4				
2		50	110	Marl	5				
3					6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike ⊥ to tunnel axis Drive against dip, Dip 60-90	109.74

Date: 27.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		80	100	Marl	4				
2		55	110	Marl	5				
3		48	120	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike ⊥ to tunnel axis Drive against dip, Dip 60-90	170

Date: 03.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		8	150	Marl	4				
2		5	200	Marl	5				
3		6	150	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	11.83

Date: 03.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		7	200	Marl	4				
2		4	100	Marl	5				
3		2	130	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	8.3

Date: 03.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		6	200	Marl	4				
2		3	140	Marl	5				
3		6	110	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	10.5

Date: 04.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		6	150	Marl	4				
2		8	100	Marl	5				
3		4	150	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	14.66

Date: 04.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		7	200	Marl	4				
2		8	150	Marl	5				
3		4	250	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	10.4

Date: 05.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		3	100	Marl	4				
2		4	200	Marl	5				
3		5	150	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	8.33

Date: 06.10.2021

Company: Imbat

Location: Soma

Main Discontinuity Measurements

	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1		10	100	Marl	4				
2		5	150	Marl	5				
3		4	200	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	15.33

Date: 09/07/2018

Company: İmbat

Location: Soma

Main Discontinuity Measurements

	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1	353 76	5	60	Clay	4	100 70	40	147	Coal
2	348 87	7	100	Clay	5	230 56	10	70	Coal
3	340 79	22	150	Clay	6				
4	45 15	24	86	Coal	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-80%	Strike Oblique to tunnel axis, Dip 30-60	30
	Coal-20%		69.4

Date: 10/07/2018

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	230 / 23	3	75	Clay	4	136 / 32	7	80	Coal
2	210 / 83	4	82	Clay	5	087 / 70	5	70	Coal
3	351 / 66	3	80	Clay	6				
4	273 / 52	12	80	Coal	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-10%	Strike Oblique to tunnel axis, Dip 0-30	12.6
	Coal-90%		31.0

Date: 11/07/2018

Company: İmbat Mining

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	207 / 83	5	90	Clay	4	348 / 74	18	70	Coal
2	87 / 85	4	100	Clay	5				
3	320 / 25	30	160	Coal	6				
4	060 / 43	28	180	Coal	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-20%	Strike || to tunnel axis, Dip 90-60	9.6
	Coal-80%		54.3

Date: 12.07.2018

Company: İmbat Mining

Location: Soma

Main Discontinuity Measurements											
	Dip	Dip direction	Number	Measurement length(cm)	Formation		Dip	Dip direction	Number	Measurement length(cm)	Formation
1	263	14	4	96	Clay	4	239	11	20	76	Coal
2	258	48	7	100	Clay	5	145	55	4	80	Coal
3	200	36	3	65	Clay	6					
4	260	14	23	85	Coal	7					

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-35%	Strike ⊥ to tunnel axis, Drive with dip, Dip 0-30	15.8
	Coal-65%		58.4

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	12	22
Joint Set 2	12	34
Joint Set 3	11	23
Joint Set 4	-	-
Joint Set 5	-	-
Jv	983	

Date: 13.07.2018

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	296 / 82	22	220	Marl	4	200 / 88	7	90	Coal
2	066 / 75	40	400	Marl	5	234 / 03	15	100	Coal
3	071 / 10	12	120	Marl	6	124 / 24	4	80	
4	300 / 48	11	135	Marl	7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Marl-75%	Strike ⊥ to tunnel axis, Drive against dip, Dip 90-60	38
	Coal-25%		27.7

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	15	55
Joint Set 2	13	54
Joint Set 3	14	65
Joint Set 4	-	-
Joint Set 5	-	-
Jv	729	

Date: 16.07.2018

Company: İmbat Mining

Location: Soma

Main Discontinuity Measurements

	Dip Dip direction	Number	Measurement length(cm)	Formation		Dip Dip direction	Number	Measurement length(cm)	Formation
1	335 27	4	30	Coal	4				
2	027 26	14	100	Coal	5				
3	283 80	6	80	Coal	6				
4					7				

	Formation (%)	**Strike and dip of discontinuities**	**J_v**
	Clay-50%	Strike || to tunnel axis, Dip 60-30	34.8
	Coal-50%		41.5

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	12	40
Joint Set 2	18	53
Joint Set 3	8	14
Joint Set 4	-	-
Joint Set 5	-	-
Jv	1211	

Date: 17.07.2018

Company: İmbat Mining

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	310 / 05	30	150	Coal	4				
2	268 / 30	17	100	Coal	5				
3	148 / 59	12	100	Coal	6				
4					7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Soft Clay-20%	Strike ǁ to tunnel axis, Dip 0-30	---
	Coal-80%		49

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	20	39
Joint Set 2	17	24
Joint Set 3	13	13
Joint Set 4	-	-
Joint Set 5	-	-
Jv	2221	

Date: 18.07.2018

Company: İmbat Mining

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	306 / 09	46	200	Clay	4	027 / 72	16	150	Coal
2	027 / 72	16	150	Clay	5	352 / 40	9	150	Coal
3	352 / 40	9	150	Clay	6				
4	306 / 09	46	200	Coal	7				

	Formation (%)	**Strike and dip of discontinuities**	**J_v**
	Clay-50%	Strike || to tunnel axis, Dip 60-30	39.7
	Coal-50%		39.7

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	21	33
Joint Set 2	14	16
Joint Set 3	22	53
Joint Set 4	-	-
Joint Set 5	-	-
Jv	1926	

Date: 19.07.2018

Company: Demir Export

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	79 / 191	19	90	Coal	4				
2	82 / 099	8	160	Coal	5				
3	13 / 105	30	250	Coal	6				
4					7				

	Formation (%)	**Strike and dip of discontinuities**	**J_v**
	Coal-100%	Strike ⊥ to tunnel axis, Drive with dip, Dip 30-60	38.1

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	19	81
Joint Set 2	12	45
Joint Set 3	16	34
Joint Set 4	-	-
Joint Set 5	-	-
J_v	972	

Date: 20.07.2018

Company: Demir Export

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	57 / 160	6	150	Coal	4				
2	08 / 110	10	150	Coal	5				
3	37 / 090	13	40	Coal	6				
4					7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike ⊥ to tunnel axis, Drive with dip, Dip 30-60	43.1

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	8	46
Joint Set 2	8	39
Joint Set 3	8	49
Joint Set 4	-	-
Joint Set 5	-	-
J_v	542	

Date: 21.07.2018

Company: Demir Export

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	69 / 125	8	150	Coal	4				
2	04 / 152	10	150	Coal	5				
3	19 / 114	4	100	Coal	6				
4					7				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike ⊥ to tunnel axis, Drive with dip, Dip 30-60	16.0

DISCONTINUITY ASSESSMENTS FOR COAL

Discontinuity (Cleavage) Measurement in the Laboratory		
Joint Sets	Joint number	Measurement Length(mm)
Joint Set 1	12	73
Joint Set 2	14	33
Joint Set 3	14	41
Joint Set 4	-	-
Joint Set 5	-	-
J_v	930	

Date: 18.02.2019

Company: Hattat Mining

Location: Amasra

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	19 / 136	5	66	Clay-Silt-Schist	5	44 / 322	14	40	Clay-Silt-Schist
2	57 / 097	7	47	Clay-Silt-Schist	6				
3	57 / 160	7	34	Clay-Silt-Schist	7				
4	29 / 076	15	54	Clay-Silt-Schist	8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-Silt-Schist-65%	Strike ⊥ to tunnel axis, Drive against dip, Dip 0-30	130.5
	Sandstone-35%		0

Date: 19.02.2019

Company: Hattat Mining

Location: Amasra

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	38 / 246	8	80	Clay-Silt-Schist	5	44 / 322	14	40	Clay-Silt-Schist
2	22 / 142	10	25	Clay-Silt-Schist	6				
3	37 / 179	11	42	Clay-Silt-Schist	7				
4	60 / 230	7	36	Clay-Silt-Schist	8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-Silt-Schist-60%	Strike ⊥ to tunnel axis, Drive against dip, Dip 0-30	130.5
	Sandstone-40%		0

Date: 20.02.2019

Company: Hattat Mining

Location: Amasra

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	28 / 150	12	35	Clay-Silt-Schist	5	72 / 311	7	30	Sandstone
2	44 / 045	8	40	Clay-Silt-Schist	6	78 / 033	8	50	Sandstone
3	63 / 317	6	40	Clay-Silt-Schist	7				
4	58 / 340	4	40	Sandstone	8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Clay-Silt-Schist-40%	Strike ⊥ to tunnel axis, Drive against dip, Dip 0-30	69.2
	Sandstone-60%		49.3

Date: 01.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	23 / 250	7	30	Coal	5				
2	12 / 045	9	20	Coal	6				
3	65 / 147	12	30	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike ‖ to tunnel axis, Dip 60-90	98.3

Date: 01.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	75 / 145	6	20	Coal	5				
2	23 / 265	7	30	Coal	6				
3	55 / 1470 35	10	40	Coal	7				
4	53 / 230	5	30	Coal	8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Coal-100%	Strike || to tunnel axis, Dip 60-90	78.3

Date: 01.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	65 / 154	5	20	Coal	5				
2	16 / 254	7	40	Coal	6				
3	84 / 075	10	30	Coal	7				
4					8				

	Formation (%)	**Strike and dip of discontinuities**	J_v
	Coal-100%	Strike || to tunnel axis, Dip 0-30	75.8

Date: 02.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	24 / 230	6	40	Coal	5				
2	80 / 110	4	20	Coal	6				
3	65 / 045	3	10	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike || to tunnel axis, Dip 0-30	65.0

Date: 02.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	77 / 320	4	15	Coal	5				
2	45 / 154	8	40	Coal	6				
3	15 / 055	9	30	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike || to tunnel axis, Dip 0-30	76.7

Date: 02.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	24 / 145	5	15	Coal	5				
2	80 / 054	9	20	Coal	6				
3	65 / 250	14	40	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike || to tunnel axis, Dip 60-90	113.3

Date: 03.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	65 / 156	5	20	Coal	5				
2	15 / 240	12	30	Coal	6				
3	85 / 055	15	40	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike || to tunnel axis, Dip 60-90	102.5

Date: 03.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	65 / 145	9	20	Coal	5				
2	25 / 260	8	30	Coal	6				
3	12 / 095	12	40	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike || to tunnel axis, Dip 60-90	101.7

Date: 03.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	80 / 250	9	20	Coal	5				
2	32 / 095	8	30	Coal	6				
3	45 / 175	12	40	Coal	7				
4					8				

	Formation (%)	Strike and dip of discontinuities	J_v
	Coal-100%	Strike || to tunnel axis, Dip 0-30	52.5

Date: 04.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	15	4	25	Coal	5				
	251								
2	50	12	40	Coal	6				
	045								
3	35	8	30	Coal	7				
	190								
4					8				
			Coal-100%	Strike and dip of discontinuities				72.7	
			-	Strike || to tunnel axis, Dip 0-30				---	

Date: 04.07.2019

Company: İmbat

Location: Soma

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1	23	4	20	Coal	5				
	142								
2	55	8	30	Coal	6				
	263								
3	85	7	20	Coal	7				
	055								
4					8				
			Formation (%)	**Strike and dip of discontinuities**				J_v	
			Coal-100%	Strike || to tunnel axis, Dip 0-30				81.7	

Date: 05.07.2019

Company: İmbat

Location: Soma

<table>
<tr><th colspan="10">Main Discontinuity Measurements</th></tr>
<tr><td rowspan="2"></td><td>Dip</td><td rowspan="2">Number</td><td rowspan="2">Measurement length(cm)</td><td rowspan="2">Formation</td><td rowspan="2"></td><td>Dip</td><td rowspan="2">Number</td><td rowspan="2">Measurement length(cm)</td><td rowspan="2">Formation</td></tr>
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<tr><td rowspan="2">4</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">8</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="3" rowspan="3"></td><td>Formation (%)</td><td colspan="4">Strike and dip of discontinuities</td><td colspan="2">J_v</td></tr>
<tr><td>Coal-100%</td><td colspan="4" rowspan="2">Strike || to tunnel axis, Dip 0-30</td><td colspan="2">108.3</td></tr>
<tr><td>-</td><td colspan="2">---</td></tr>
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Date: 05.07.2019

Company: İmbat

Location: Soma

<table>
<tr><th colspan="10">Main Discontinuity Measurements</th></tr>
<tr><td rowspan="2"></td><td>Dip</td><td rowspan="2">Number</td><td rowspan="2">Measurement length(cm)</td><td rowspan="2">Formation</td><td rowspan="2"></td><td>Dip</td><td rowspan="2">Number</td><td rowspan="2">Measurement length(cm)</td><td rowspan="2">Formation</td></tr>
<tr><td>Dip direction</td><td>Dip direction</td></tr>
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<tr><td rowspan="2">2</td><td>15</td><td rowspan="2">6</td><td rowspan="2">20</td><td rowspan="2">Coal</td><td rowspan="2">6</td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
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<tr><td colspan="3" rowspan="2"></td><td>Formation (%)</td><td colspan="4">Strike and dip of discontinuities</td><td colspan="2">J_v</td></tr>
<tr><td>Coal-100%</td><td colspan="4">Strike || to tunnel axis, Dip 0-30</td><td colspan="2">103.3</td></tr>
</table>

Date: 18.10.2021

Company: İmbat

Location: Soma

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		7	100	Marl	4				
2		9	200	Marl	5				
3		6	150	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	15.5

Date: 22.10.2021

Company: İmbat

Location: Soma

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		5	100	Marl	4				
2		3	150	Marl	5				
3		2	200	Marl	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Marl	Strike || to tunnel axis, Dip 60-90	8.3

Date: 22.10.2021

Company: İmbat

Location: Soma

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		9	200	Marl	4				
2		3	150	Marl	5				
3		6	150	Marl	6				
4					7				

Formation	Strike and dip of discontinuities	J_v
Marl	Strike || to tunnel axis, Dip 60-90	10.6

Date: 25.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		550	125	Coal	4		150	105	Schist
2		600	100	Coal	5		140	100	Schist
3		150	105	Coal	6		80	120	Schist
4					7				

Formation	Strike and dip of discontinuities	J_v
Schist	Strike Oblique to tunnel axis, Dip 30-60	350

Date: 26.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		420	120	Coal	4		120	105	Schist
2		260	100	Coal	5		60	90	Schist
3		220	120	Coal	6				
4					7				

Formation	Strike and dip of discontinuities	J_v
Schist	Strike Oblique to tunnel axis, Dip 30-60	187.6

Date: 26.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		200	120	Coal	4		120	105	Schist
2		100	100	Coal	5		80	120	Schist
3		140	150	Coal	6				
4					7				

Formation	Strike and dip of discontinuities	J_v
Schist	Strike Oblique to tunnel axis, Dip 30-60	181

Date: 27.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		280	120	Coal	4		60	100	Schist
2		80	100	Coal	5		60	100	Schist
3		180	100	Coal	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Schist	Strike Oblique to tunnel axis, Dip 30-60	194.6

Date: 27.11.2019

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		330	105	Coal	4		160	200	Schist
2		380	110	Coal	5		180	120	Schist
3		200	100	Coal	6		95	100	
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Schist	Strike Oblique to tunnel axis, Dip30-60	325

Date: 08.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		15	70	Claystone	4				
2		30	100	Claystone	5				
3		15	90	Claystone	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis, Drive with dip, dip 60-90	68.09

Date: 09.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		22	55	Claystone	4				
2		15	60	Claystone	5				
3		10	70	Claystone	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis, Drive against dip, dip 60-90	79.3

Date: 09.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		9	60	Claystone	4				
2		20	80	Claystone	5				
3		13	90	Claystone	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis Drive against dip, dip 60-90	54.4

Date: 10.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		22	110	Claystone	4				
2		14	70	Claystone	5				
3		6	70	Claystone	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis, Drive against dip, dip 60-90	48.6

Date: 10.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		10	60	Claystone	4				
2		10	80	Claystone	5				
3		20	80	Claystone	6				
4					7				

G	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis. Drive against dip, dip 60-90	54.16

Date: 11.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements

	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		14	70	Claystone	4				
2		15	60	Claystone	5				
3		12	100	Claystone	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis, Drive against dip, dip 60-90	57

Date: 11.06.2021

Company: Polyak

Location: Bergama

Main Discontinuity Measurements									
	Dip / Dip direction	Number	Measurement length(cm)	Formation		Dip / Dip direction	Number	Measurement length(cm)	Formation
1		20	80	Claystone	4				
2		12	60	Claystone	5				
3		14	70	Claystone	6				
4					7				

	Formation	Strike and dip of discontinuities	J_v
	Claystone+ Coal	Strike ⊥ to tunnel axis, Drive against dip, dip 60-90	65

APPX 4: RMCC INDEX TABLES

Date: 07.08.2018
Company: Park Termik
Location: Çayırhan
Gallery: J 710, lower tailgate (Coal 85%)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	<20	7.4	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to Axis, dip 0-30	15	5
Joint aperture (mm)	Moderately open	0.29	5
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dripping	-	7
		Total Rating	77

Date: 07.08.2018
Company: Park Termik
Location: Çayırhan
Gallery: J 710, lower tailgate (Claystone 15%)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	<20	6.9	30
Volumetric joint count (Joint/m^3)	<50	14	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to Axis, dip 0-30	15	5
Joint aperture (mm)	Moderately open	0.18	5
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dripping	-	7
		Total Rating	58
		RMCC	74

Date: 07.08.2018 Company: Park Termik Location: Çayırhan Gallery: J, main gallery (Coal 85%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	5.2	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 30°-60°	50	20
Joint aperture (mm)	Tight	< 0.1	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Damp	-	2
		Total Rating	84

Date: 07.08.2018 Company: Park Termik Location: Çayırhan Gallery: J, main gallery (Claystone 15%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	7.7	30
Volumetric joint count (Joint/m^3)	<50	6	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 30°-60°	50	20
Joint aperture (mm)	Tight	< 0.1	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Damp	-	2
		Total Rating	65
		RMCC	81

Date: 08.08.2018 Company: Park Termik Location: Çayırhan Gallery: H209, tailgate (Coal 45%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	3.9	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 0°-30°	0	5
Joint aperture (mm)	Moderately open	0.3	5
Cerchar Abrasivity index	<0.5	0	10
Water condition	Damp	-	2
		Total Rating	72

Date: 08.08.2018 Company: Park Termik Location: Çayırhan Gallery: H209, tailgate (Claystone 55%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	7.3	30
Volumetric joint count (Joint/m^3)	<50	13.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 0°-30°	0	5
Joint aperture (mm)	Moderately open	0.28	5
Cerchar Abrasivity index	<0.5	0	10
Water condition	Damp	-	2
		Total Rating	53
		RMCC	62

Date: 09.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H610 (Coal 70%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	6.4	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ⊥ to tunnel axis, Drive with dip, dip 30°-60°	40	10
Joint aperture (mm)	Tight	0.071	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dripping	-	7
		Total Rating	79

Date: 09.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H610 (Claystone 30%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	3.8	30
Volumetric joint count (Joint/m^3)	<50	10	1
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ⊥ to tunnel axis, Drive with dip, dip 30°-60°	40	10
Joint aperture (mm)	Tight	0.088	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dripping	-	7
		Total Rating	60
		RMCC	73

Date: 14.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H210, head gate (Coal 40%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	5.8	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to Axis, dip 0°-30°	0	5
Joint aperture (mm)	Moderately open	0.12	5
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dry	-	0
		Total Rating	70
Date: 14.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H210, head gate (Claystone 60%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength(MPa)	<20	2.9	30
Volumetric joint count (Joint/m^3)	75-100	84.2	10
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to Axis, dip 0°-30°	0	5
Joint aperture (mm)	Moderately open	0.12	5
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dry	-	0
		Total Rating	60
		RMCC	64

Date: 15.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J710 (Coal 70%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	9.0	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 0°-30°	15	4
Joint aperture (mm)	Tight	0.097	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Wet	-	5
		Total Rating	71

Date: 15.08.2018 **Company:** Park Termik **Location:** Çayırhan **Gallery:** J710 (Clay30%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	12.0	30
Volumetric joint count (Joint/m^3)	75 ─ 50	70.0	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 0°-30°	15	4
Joint aperture (mm)	Tight	0.061	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Wet	-	5
		Total Rating	56
		RMCC	66

Date: 04.09.2018 Company: Park Termik Location: Çayırhan Gallery: H, north ventilation (Clay 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	6.0	30
Volumetric joint count (Joint/m^3)	100 ─ 75	87.7	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	40	20
Joint aperture (mm)	Tight	0.062	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dry	-	0
		Total Rating	72

Date: 06.09.2018 Company: Park Termik Location: Çayırhan Gallery: H, north ventilation (Clay 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	3.0	30
Volumetric joint count (Joint/m^3)	75-100	94	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	40	20
Joint aperture (mm)	Tight	0.091	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dry	-	0
		Total Rating	72

Date: 07.09.2018 Company: Park Termik Location: Çayırhan Gallery: H, north ventilation (Clay 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	2.6	30
Volumetric joint count (Joint/m^3)	75-100	78	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	40	20
Joint aperture (mm)	Tight	0.077	2
Cerchar Abrasivity index	<0.5	0	10
Water condition	Dry	-	0
		Total Rating	72

Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Claystone 75%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	3.7	30
Volumetric joint count (Joint/m^3)	100 ─ 75	88.4	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Tight	0.067	2
Cerchar Abrasivity index	< 0.5	-	10
Water condition	Damp	-	2
		Total Rating	61

Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Silex 25%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	> 120	130.0	0
Volumetric joint count (Joint/m^3)	<50	16.6	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.45	3
Water condition	Damp	-	2
		Total Rating	13
		RMCC	49

Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Claystone 80%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	4.0	30
Volumetric joint count (Joint/m^3)	75-100	83.3	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Tight	0.059	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	61

Date: 27.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Silex 20%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	> 120	130	0
Volumetric joint count (Joint/m^3)	< 50	23.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.45	3
Water condition	Damp	-	2
		Total Rating	13
		RMCC	51

Date: 28.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Claystone 80%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	3.0	30
Volumetric joint count (Joint-/m^3)	50-75	56.6	5
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Tight	0.067	2
Cerchar Abrasivity index	< 0.5	-	10
Water condition	Damp	-	2
		Total Rating	56

Date: 28.02.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Silex 20%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	> 120	136	0
Volumetric joint count (Joint/m^3)	<50	40.0	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.33	3
Water condition	Damp	-	2
		Total Rating	13
		RMCC	47

Date: 28.02.2019
Company: Park Termik
Location: Çayırhan
Gallery: H, north ventilation (Claystone 80%)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	<20	3.0	30
Volumetric joint count (Joint/m^3)	50-75	61.0	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Tight	0.084	2
Cerchar Abrasivity index	< 0.5	-	10
Water condition	Damp	-	2
		Total Rating	56

Date: 28.02.2019
Company: Park Termik
Location: Çayırhan
Gallery: H, north ventilation (Silex 20%)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	> 120	136	0
Volumetric joint count (Joint/m^3)	<50	29.8	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.33	3
Water condition	Damp	-	2
		Total Rating	13
		RMCC	47

Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Claystone 80%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	4.0	30
Volumetric joint count (Joint/m^3)	100-75	93.2	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Tight	0.092	2
Cerchar Abrasivity index	< 0.5	-	10
Water condition	Damp	-	2
		Total Rating	61
Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Silex 20%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	> 120	130	0
Volumetric joint count (Joint/m^3)	<50	43.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	2-4	2.18	1
Water condition	Damp	-	2
		Total Rating	11
		RMCC	51

Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Claystone 80%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	4.0	30
Volumetric joint count (Joint/m^3)	75-100	81.2	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Tight	0.074	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	61

Date: 01.03.2019 **Company:** Park Termik **Location:** Çayırhan **Gallery:** H, north ventilation (Silex 20%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	> 120	130.7	0
Volumetric joint count (Joint/m^3)	<50	25.9	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	15	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	2-4	2.18	1
Water condition	Damp	-	2
		Total Rating	11
		RMCC	51

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.0	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60-90	70	10
Joint aperture (mm)	Open	1.1	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	88

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.0	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60-90	70	10
Joint aperture (mm)	Open	1.1	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	88

Date: 23.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.4	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60-90	80	10
Joint aperture (mm)	Open	1.1	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	88

Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.1	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60-90	80	10
Joint aperture (mm)	Open	1.106	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	88

Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.2	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60-90	75	10
Joint aperture (mm)	Open	1.04	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	88

Date: 24.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	7.1	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60-90	65	10
Joint aperture (mm)	Open	1.1	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	88

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.3	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30-60	45	20
Joint aperture (mm)	Moderately open	1.37	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	95

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.1	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30-60	39	20
Joint aperture (mm)	Moderately open	1.2	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	95

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.8	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30-60	53	20
Joint aperture (mm)	Moderately open	1.102	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	95

Date: 25.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.7	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30-60	49	20
Joint aperture (mm)	Moderately open	1.48	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	95

Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	7.3	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30-60	38	20
Joint aperture (mm)	Moderately open	1.23	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	98

Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.7	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30-60	52	20
Joint aperture (mm)	Open	1.33	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	98

Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.7	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30-60	35	20
Joint aperture (mm)	Open	1.2	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	98

Date: 26.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** 1210 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.4	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30-60	50	20
Joint aperture (mm)	Open	1.14	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Flowing	-	10
		Total Rating	98

Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.4	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, Dip 60°-90°	70	10
Joint aperture (mm)	Very open	1.2	10
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	80

Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.2	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, Dip 60°-90°	80	10
Joint aperture (mm)	Very open	5	10
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	80

Date: 27.08.2021 **Company:** KİAŞ **Location:** Çayırhan **Gallery:** YJ Main road **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.1	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, Dip 60°-90°	80	10
Joint aperture (mm)	Very open	5	10
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	80

Date: 20.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	20-40	36.2	20
Volumetric joint count (Joint/m^3)	100-150	117	15
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 30°-60°	55	20
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	65

Date: 21.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	20-40	38.8	20
Volumetric joint count (Joint/m^3)	100-150	143.3	15
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to Axis, dip 30°-60°	48	20
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	2
		Total Rating	67

Date: 22.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	46.4	10
Volumetric joint count (Joint/m^3)	> 150	187.5	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to Axis, dip 30°-60°	45	20
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	2
		Total Rating	62

Date: 22.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	46.4	10
Volumetric joint count (Joint/m^3)	> 30	192.5	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 30°-60°	42	20
Joint aperture (mm)	Moderately open	0.12	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	2
		Total Rating	67

Date: 23.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	46.4	10
Volumetric joint count (Joint/m^3)	100-150	143.3	15
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 30°-60°	38	20
Joint aperture (mm)	Moderately open	0.1	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	2
		Total Rating	62

Date: 23.05.2019 **Company:** YS Mining **Location:** Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	44.8	10
Volumetric joint count (Joint/m^3)	100-150	143.3	15
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 30°-60°	39	20
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	2
		Total Rating	57

Date: 24.05.2019 **Company**: YS Mining **Location**: Dodurga **Gallery:** ventilation **Shift:** 8-16 (Claystone 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	41.2	10
Volumetric joint count (Joint/m^3)	100-150	147.5	15
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to Axis, dip 30°-60°	40	20
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	2
		Total Rating	57

Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	120 ─ 60	83.6	5
Volumetric joint count (Joint/m^3)	75-100	90	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	82	3
Joint aperture (mm)	Tight	0.066	2
Cerchar Abrasivity index	0.5-1	0.77	5
Water condition	Flowing	-	10
		Total Rating	35

Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 16-24 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	104.5	5
Volumetric joint count (Joint/m^3)	50-75	55.6	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	79	3
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.04	3
Water condition	Flowing	-	10
		Total Rating	26

Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 24-8 16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	50.8	10
Volumetric joint count (Joint/m^3)	> 150	307.5	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	85	3
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.15	3
Water condition	Flowing	-	10
		Total Rating	46

Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60 ─ 120	68.7	5
Volumetric joint count (Joint/m^3)	100-150	110.7	15
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	70	3
Joint aperture (mm)	Tight	0.066	2
Cerchar Abrasivity index	0.5-1	0.87	2
Water condition	Flowing	-	10
		Total Rating	40

Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	64.4	5
Volumetric joint count (Joint/m^3)	100-150	109.7	10
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	63	3
Joint aperture (mm)	Tight	0.059	2
Cerchar Abrasivity index	1-2	1.01	3
Water condition	Flowing	-	10
		Total Rating	33

Date: 03.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 12-8 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	58	10
Volumetric joint count (Joint/m^3)	< 50	8.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike || to tunnel axis, dip 60°-90°	73	10
Joint aperture (mm)	Tight	0.065	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	33

Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 2302-2 **Shift:** 16-24 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	94.9	5
Volumetric joint count (Joint/m^3)	>150	170	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	74	3
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	2-4	2.10	1
Water condition	Flowing	-	10
		Total Rating	39

Date: 03.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 12-8 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40 ─ 60	58	10
Volumetric joint count (Joint/m^3)	< 50	11.8	1
Strike and dip of discontinuities w.r.t the tunnel axis (o)	Strike || to tunnel axis, dip 60°-90°	80	10
Joint aperture (mm)	Tight	0.078	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	33

Date: 03.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 16-24 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	62	5
Volumetric joint count (Joint/m^3)	< 50	10.5	1
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ‖ to tunnel axis, dip 60°-90°	75	10
Joint aperture (mm)	Tight	0.091	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	28

Date: 04.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 12-8 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	62	5
Volumetric joint count (Joint/m^3)	< 50	14.66	1
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ‖ to tunnel axis, dip 60°-90°	85	10
Joint aperture (mm)	Tight	0.086	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	28

Date: 03.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	65	5
Volumetric joint count (Joint/m^3)	< 50	10.4	1
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ‖ to tunnel axis, dip 60°-90°	65	10
Joint aperture (mm)	Tight	0.091	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	28

Date: 05.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	65	5
Volumetric joint count (Joint/m^3)	< 50	8.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 60°-90°	80	10
Joint aperture (mm)	Tight	0.086	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	30

Date: 06.10.2021 **Company:** İmbat Mining **Location:** soma **Gallery:** +21 Lower tail gate **Shift:** 12-8 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	67	5
Volumetric joint count (Joint/m^3)	< 50	15.33	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 60°-90°	72	10
Joint aperture (mm)	Tight	0.068	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	30

<table>
<tr><td colspan="4">Date: 09.07.2018
Company: İmbat Mining
Location: Soma
Gallery: D7 Upper head gate (Coal 80%)</td></tr>
<tr><th>Parameters</th><th>Class</th><th>Value</th><th>Rating</th></tr>
<tr><td>Uniaxial compressive Strength (MPa)</td><td>< 20</td><td>2.8</td><td>30</td></tr>
<tr><td>Volumetric joint count (Joint/m^3)</td><td>> 150</td><td>*</td><td>20</td></tr>
<tr><td>Strike and dip of discontinuities w.r.t the tunnel axis (^{o})</td><td>Oblique, dip 30°-60°</td><td>40</td><td>20</td></tr>
<tr><td>Joint aperture (mm)</td><td>Moderately open</td><td>0.3</td><td>5</td></tr>
<tr><td>Cerchar Abrasivity index</td><td>< 0.5</td><td>0</td><td>10</td></tr>
<tr><td>Water condition</td><td>Wet</td><td>-</td><td>5</td></tr>
<tr><td colspan="3">Total Rating</td><td>90</td></tr>
<tr><td colspan="4">Date: 09.07.2018
Company: İmbat Mining
Location: Soma
Gallery: D7 Upper head gate (Claystone 20%)</td></tr>
<tr><th>Parameters</th><th>Class</th><th>Value</th><th>Rating</th></tr>
<tr><td>Uniaxial compressive Strength (MPa)</td><td>< 20</td><td>6.4</td><td>30</td></tr>
<tr><td>Volumetric joint count (Joint/m^3)</td><td>50-75</td><td>30</td><td>1</td></tr>
<tr><td>Strike and dip of discontinuities w.r.t the tunnel axis (^{o})</td><td>Oblique, dip 30°-60°</td><td>40</td><td>20</td></tr>
<tr><td>Joint aperture (mm)</td><td>Moderately open</td><td>0.62</td><td>5</td></tr>
<tr><td>Cerchar Abrasivity index</td><td>< 0.5</td><td>0</td><td>10</td></tr>
<tr><td>Water condition</td><td>Wet</td><td>-</td><td>5</td></tr>
<tr><td colspan="3">Total Rating</td><td>71</td></tr>
<tr><td colspan="3">RMCC</td><td>86</td></tr>
</table>

Date: 10.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Lower tailgate (Coal 90%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	1.5	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, 0°-30°	25	5
Joint aperture (mm)	Moderately open	0.1	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	75
Date: 10.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Lower tailgate (Claystone 10%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	1.5	30
Volumetric joint count (Joint/m^3)	< 50	12.6	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, 0°-30°	25	5
Joint aperture (mm)	Moderately open	0.1	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	56
		RMCC	73

Date: 11.07.2018 Company: İmbat Mining Location: Soma Gallery: D7 Upper head gate (Coal 80%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	4.4	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike || to tunnel axis, dip 60°-90°	70	10
Joint aperture (mm)	Tight	0.064	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dripping	-	7
		Total Rating	79

Date: 11.07.2018 Company: İmbat Mining Location: Soma Gallery: D7 Upper head gate (Claystone 20%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	2.76	30
Volumetric joint count (Joint/m^3)	< 50	9.6	1
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike || to tunnel axis, dip 60°-90°	70	10
Joint aperture (mm)	Tight	0.059	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dripping	-	7
		Total Rating	60
		RMCC	75

Date: 12.07.2018 Company: İmbat Mining Location: Soma Gallery: D7 Lower tailgate (Coal 65%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	4.4	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive with dip, dip 0°-30°	25	3
Joint aperture (mm)	Moderately open	0.13	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	70

Date: 12.07.2018 Company: İmbat Mining Location: Soma Gallery: D7 Lower tailgate (Claystone 35%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	4.5	30
Volumetric joint count (Joint/m^3)	<50	15.8	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive with dip, dip 0°-30°	25	3
Joint aperture (mm)	Moderately open	0.13	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	51
		RMCC	63

Date:13.07.2018
Company: İmbat Mining
Location: Soma
Gallery: D10 Upper head gate (Coal 25%)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	< 20	7.6	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	75	3
Joint aperture (mm)	Tight	0.073	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dripping	-	7
		Total Rating	72

Date:13.07.2018
Company: İmbat Mining
Location: Soma
Gallery: D10 Upper head gate (Marl 75%)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	40-60	59.2	10
Volumetric joint count (Joint/m^3)	<50	38	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ⊥ to tunnel axis, Drive against dip, dip 60°-90°	75	3
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	0.5-1	0.69	5
Water condition	Dripping	-	7
		Total Rating	26
		RMCC	38

Date: 16.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Lower tailgate (Coal 50%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	3.0	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-30°	45	20
Joint aperture (mm)	Tight	0.092	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	82
Date: 16.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Lower tailgate (Claystone 50%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	4.0	30
Volumetric joint count (Joint/m^3)	<50	34.8	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-30°	45	20
Joint aperture (mm)	Tight	0.078	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	63
		RMCC	73

Date: 17.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10 Lower tail gate (100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	3.4	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ‖ to Axis, dip 0°-30°	9	5
Joint aperture (mm)	Moderately open	0.12	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	75
		RMCC	75

Date: 18.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Lower tailgate (Coal 50%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.8	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ‖ to Axis, dip 60°-30°	45	20
Joint aperture (mm)	Tight	0.088	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	82
Date: 18.07.2018 **Company:** İmbat Mining **Location:** Soma **Gallery:** G7 Lower tailgate (Claystone 50%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	13.0	30
Volumetric joint count (Joint/m^3)	<50	39.7	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike ‖ to Axis, dip 30°-60°	45	20
Joint aperture (mm)	Tight	0.095	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	63
		RMCC	73

Date: 19.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	9.45	30
Volumetric joint count (Joint/m^3)	>150	38.1	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive with dip, dip 30°-60°	50	20
Joint aperture (mm)	Tight	0.056	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	87

Date: 20.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	12.37	30
Volumetric joint count (Joint/m^3)	>150	43.1	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive with dip, dip 30°-60°	43	20
Joint aperture (mm)	Tight	0.069	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	87

Date: 21.07.2018 **Company:** Demir Export **Location:** Soma **Gallery:** 4109 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	10.5	30
Volumetric joint count (Joint/m^3)	>150	16	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive with dip, dip 30°-60°	40	20
Joint aperture (mm)	Moderately open	0.14	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	90

Date: 19.02.2019 Company: Hattat Mining Location: Amasra Gallery: 147.Connection gallery (Complex formation, 65%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	7.0	30
Volumetric joint count (Joint/m^3)	100-150	130.5	15
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	25	7
Joint aperture (mm)	Tight	0.087	2
Cerchar Abrasivity index	0.5-1	0.66	5
Water condition	Dry	-	0
		Total Rating	59

Date: 19.02.2019 Company: Hattat Mining Location: Amasra Gallery: 147.Connection gallery (Sandstone, 35%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	45.0	10
Volumetric joint count (Joint/m^3)	< 50	40	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	25	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.4	3
Water condition	Dry	-	0
		Total Rating	21
		RMCC	46

Date: 20.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection gallery (Complex formation, 60%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	54.8	10
Volumetric joint count (Joint/m^3)	100-150	110	15
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	30	7
Joint aperture (mm)	Tight	0.093	2
Cerchar Abrasivity index	0.5-1	0.72	5
Water condition	Dry	-	0
		Total Rating	39

Date: 20.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection gallery (Sandstone, 40%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	46.3	10
Volumetric joint count (Joint/m^3)	< 50	25	1
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	30	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1	3
Water condition	Dry	-	0
		Total Rating	21
		RMCC	32

Date: 21.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection gallery (Complex formation, 40%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	62.5	5
Volumetric joint count (Joint/m^3)	75-50	69.2	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	25	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	0.5-1	0.63	5
Water condition	Dry	-	0
		Total Rating	22

Date: 21.02.2019 **Company:** Hattat Mining **Location:** Amasra **Gallery:** 147.Connection gallery (Sandstone, 60%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	20-40	34.9	20
Volumetric joint count (Joint/m^3)	< 50	49.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike ⊥ to tunnel axis, Drive against dip, dip 0°-30°	25	7
Joint aperture (mm)	Hardly cemented	-	0
Cerchar Abrasivity index	1-2	1.12	3
Water condition	Dry	-	0
		Total Rating	31
		RMCC	27

Date: 01.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13, Upper tail gate **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.1	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-90°	75	10
Joint aperture (mm)	Tight	0.058	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	74

Date: 01.07.2019 **Company:** İmbat Mining Mining **Location:** Soma **Gallery:** G13, Upper tail gate **Shift:** 16-24 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	7.2	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-90°	75	10
Joint aperture (mm)	Tight	0.076	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	74

Date: 01.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	4.4	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 0°-30°	22	5
Joint aperture (mm)	Moderately open	0.23	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	72

Date: 02.07.2019 **Company:** İmbat Mining Mining **Location:** Soma **Gallery:** D13, middle level **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	2.4	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 0°-30°	25	5
Joint aperture (mm)	Moderately open	0.16	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	72

Date: 02.07.2019 **Company:** İmbat Mining Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 16-24 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength(MPa)	< 20	1.5	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 0°-°30	19	5
Joint aperture (mm)	Tight	0.085	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	69

Date: 02.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13, Upper tail gate **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.2	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-90°	70	10
Joint aperture (mm)	Tight	0.093	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	74

Date: 03.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13, Upper tail gate **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.7	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-90°	73	10
Joint aperture (mm)	Moderately open	0.17	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	77

Date: 03.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** G13, Upper tail gate **Shift:** 16-24 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	8.4	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 60°-90°	78	10
Joint aperture (mm)	Tight	-	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	74

Date: 03.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	1.9	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to Axis, dip 0°-30°	23	5
Joint aperture (mm)	Moderately open	0.1	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	69

Date: 04.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	1.7	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike || to Axis, dip 0°-30°	25	5
Joint aperture (mm)	Moderately open	0.15	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	72

Date: 04.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 16-24 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	2.2	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike || to Axis, dip 0°-30°	23	5
Joint aperture (mm)	Tight	-	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	69

Date: 05.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	14.1	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Strike || to Axis, dip 0°-30°	20	5
Joint aperture (mm)	Tight	0	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	69

Date: 05.07.2019 **Company:** İmbat Mining **Location:** Soma **Gallery:** D10, middle level **Shift:** 16-24 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	3.0	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike || to Axis, dip 0°-30°	21	5
Joint aperture (mm)	Moderately open	0.33	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	72

Date: 18.10.2021 **Company:** İmbat Mining **Location:** Soma **Gallery:** Lower tail gate **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40 ─ 60	42	10
Volumetric joint count (Joint/m^3)	< 50	15.5	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike || to Axis, dip 60°-90°	75	10
Joint aperture (mm)	Tight	0.069	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	33

Date: 20.10.2021 **Company:** İmbat Mining **Location:** Soma **Gallery:** Lower tail gate **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	46	10
Volumetric joint count (Joint/m^3)	< 50	8.3	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike || to Axis, dip 60°-90°	80	10
Joint aperture (mm)	Moderately open	0.21	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	36

Date: 22.10.2021 **Company:** İmbat Mining **Location:** Soma **Gallery:** Lower tail gat08.06.2021 **Shift:** 8-16 (Marl 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	20-40	38	20
Volumetric joint count (Joint/m^3)	< 50	10.57	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Strike || to Axis, dip 60°-90°	80	10
Joint aperture (mm)	Tight	0.078	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	42

Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Schist 80%) **Shift:** 8-16			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	60-120	62	5
Volumetric joint count (Joint/m^3)	> 150	350	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 30°-60°	45	20
Joint aperture (mm)	Moderately open	0.37	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	60
Date: 25.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Coal 20%) **Shift:** 8-16			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	10.63	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique,dip 30°-60°	45	20
5	Moderately open	----	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	85
		RMCC	65

Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Schist 80%) **Shift:** 24-8			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	42.2	10
Volumetric joint count (Joint/m^3)	> 150	188	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	53	20
Joint aperture (mm)	Moderately open	0.83	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	65
Date: 26.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Coal 20%) **Shift:** 24-8			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	9.87	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	50	20
Joint aperture (mm)	Moderately open	0.85	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	85
		RMCC	69

Date: 26.11.2019 Company: Polyak Location: Bergama Gallery: 3305 (Schist 80%) Shift: 8-16			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40-60	51.7	10
Volumetric joint count (Joint/m^3)	> 150	181	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	38	20
Joint aperture (mm)	Moderately open	0.35	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	65

Date: 26.11.2019 Company: Polyak Location: Bergama Gallery: 3305 (Coal 20%) Shift: 8-16			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	9.71	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	43	20
Joint aperture (mm)	Tight	0.043	2.0
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	82
		RMCC	68

Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Schist 80%) **Shift:** 8-16			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	20-40	27.7	20
Volumetric joint count (Joint/m^3)	>150	194.6	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	39	20
Joint aperture (mm)	Open	1.2	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	78
Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Coal 20%) **Shift:** 8-16			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	10.93	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 30°-60°	40	20
Joint aperture (mm)	Moderately open	0.18	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	75
			77

Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Schist 80%) **Shift:**16-24			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	20-40	34.5	20
Volumetric joint count (Joint/m^3)	> 150	325	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Oblique, dip 30°-60°	35	20
Joint aperture (mm)	Open	2.1	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	78

Date: 27.11.2019 **Company:** Polyak **Location:** Bergama **Gallery:** 3305 (Coal 20%) **Shift:**16-24			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	10.82	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Oblique, dip 30°-60°	35	20
Joint aperture (mm)	Moderately open	0.18	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Dry	-	0
		Total Rating	85
		RMCC	79

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	4.95	20
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°	40	20
Joint aperture (mm)	Tight	0.088	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	84

Date: 09.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 24-8 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	7.61	20
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°	48	20
Joint aperture (mm)	Tight	0.076	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	84

Date: 09.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.78	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°°	45	20
Joint aperture (mm)	Moderately open	1.21	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	90

Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.19	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°	55	20
Joint aperture (mm)	Moderately open	1.23	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	90

Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 16-24 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.71	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°	51	20
Joint aperture (mm)	Tight	0.78	2
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	84

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 24-8 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.87	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°	49	20
Joint aperture (mm)	Moderately open	1.53	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	90

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** CK 1110 **Shift:** 8-16 (Coal 100%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.95	30
Volumetric joint count (Joint/m^3)	>150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Strike || to tunnel axis, dip 30°-60°	35	20
Joint aperture (mm)	Moderately open	1.89	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	90

Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery, 2304 **Shift:** 8-16 (Claystone %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.59	30
Volumetric joint count (Joint/m^3)	50-75	68	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	75	10
Joint aperture (mm)	Open	1.02	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	68
Date: 08.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery, 2304 **Shift:** 8-16 (Coal %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.07	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel (°)	Oblique, dip 60°-90°	75	10
Joint aperture (mm)	Open	1.06	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	83
		RMCC	76

Date: 09.06.2021 Company: Polyak Location: Bergama Gallery: 2. Connection gallery, 2304 Shift: 24-8 (Claystone %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.79	30
Volumetric joint count (Joint/m^3)	75-100	79	10
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Oblique, dip 60°-90°	72	10
Joint aperture (mm)	Open	1.07	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	73

Date: 09.06.2021 Company: Polyak Location: Bergama Gallery: 2. Connection gallery, 2304 Shift: 24-8 (Coal %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.55	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (º)	Oblique, dip 60°-90°	70	10
Joint aperture (mm)	Moderately open	0.61	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	80
		RMCC	77

Date: 09.06.2021
Company: Polyak
Location: Bergama
Gallery: 2. Connection gallery, 2304
Shift: 8-16 (Claystone %50)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	< 20	5.79	30
Volumetric joint count (Joint/m^3)	50-75	54.4	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	75	10
Joint aperture (mm)	Open	1.12	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	68

Date: 9.6.2021
Company: Polyak
Location: Bergama
Gallery: 2. Connection gallery, 2304
Shift: 8-16 (Coal %50)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	< 20	5.55	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	75	10
Joint aperture (mm)	Moderately open	0.65	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	80
		RMCC	74

Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery, 2304 **Shift:** 8-16 (Claystone %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	9.03	30
Volumetric joint count (Joint/m^3)	<50	48.6	1
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60°-90°	75	10
Joint aperture (mm)	Open	3.57	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	64
Date: 10.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery, 2304 **Shift:** 8-16 (Coal %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.05	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60°-90°	80	10
Joint aperture (mm)	Moderately open	0.54	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Wet	-	5
		Total Rating	80
		RMCC	72

Date: 10.06.2021 Company: Polyak Location: Bergama Gallery: 2. Connection gallery, 2304 Shift: 16-24 (Claystone %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	40 ─ 20	25.3	20
Volumetric joint count (Join/.m^3)	50-75	54.16	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	81	10
Joint aperture (mm)	Moderately open	0.23	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	52

Date: 10.06.2021 Company: Polyak Location: Bergama Gallery: 2. Connection gallery, 2304 Shift: 16-24 (Coal %50)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	5.78	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	73	10
Joint aperture (mm)	Moderately open	0.27	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	77
		RMCC	65

Date: 11.06.2021
Company: Polyak
Location: Bergama
Gallery: 2. Connection gallery, 2304
Shift: 24-8 (Claystone %50)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	40 ─ 20	21.3	20
Volumetric joint count (Joint/m^3)	50-75	57	5
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60°-90°	82	10
Joint aperture (mm)	Open	1.2	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	55

Date: 11.06.2021
Company: Polyak
Location: Bergama
Gallery: 2. Connection gallery, 2304
Shift: 24-8 (Coal %50)

Parameters	Class	Value	Rating
Uniaxial compressive Strength (MPa)	< 20	5.92	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (^{o})	Oblique, dip 60°-90°	79	10
Joint aperture (mm)	Moderately open	0.30	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	77
		RMCC	66

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery, 2304 **Shift:** 8-16 (Claystone 50%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	<20	7.46	30
Volumetric joint count (Joint/m^3)	50-75	65	5
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	69	10
Joint aperture (mm)	Open	1.82	8
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	65

Date: 11.06.2021 **Company:** Polyak **Location:** Bergama **Gallery:** 2. Connection gallery, 2304 **Shift:** 8-16 (Coal 50%)			
Parameters	**Class**	**Value**	**Rating**
Uniaxial compressive Strength (MPa)	< 20	6.83	30
Volumetric joint count (Joint/m^3)	> 150	*	20
Strike and dip of discontinuities w.r.t the tunnel axis (°)	Oblique, dip 60°-90°	74	10
Joint aperture (mm)	Moderately open	0.24	5
Cerchar Abrasivity index	< 0.5	0	10
Water condition	Damp	-	2
		Total Rating	77
		RMCC	71

APPX 5: PUBLICATIONS DERIVED FROM THE THESIS

- A New Rock Mass Cuttability Classification for Roadheaders Used in Coal Mining